The role of BIM in retrofitting works within the UK social housing sector

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Abstract

The deadline for greenhouse gas emissions in the UK to be reduced by 80 per cent against the 1990 baseline is 2050. Over a quarter of these emissions are attributable to the 28m properties within the residential sector, with over 4m homes being maintained and managed by social housing registered providers. The UK Government advocates retrofitting of the existing housing stock to help meet the carbon reduction targets, with the UK social housing sector being ideally placed to deliver these types of energy-efficient retrofit projects on a large scale. The Government's industrial strategy also supports the acceleration of the adoption of Building Information Modelling (BIM) as an efficient and collaborative way of working throughout the UK construction supply chain. BIM is already used across the social housing sector with respect to new build projects and the aim of this research is to: 1) examine whether the social housing sector has accepted the implementation of BIM for retrofitting works; and 2) endeavour to identify new areas and roles where BIM may contribute in future. The findings indicate that if the diffusion of BIM within the social housing sector is to be successful with respect to retrofitting works, then BIM should not be adopted in isolation. Innovative developments in cloud technology, geomatics and the introduction of complementary software may also need to be accepted in conjunction with a change in the perception of BIM by actors within the sector.

Keywords: BIM, social housing, retrofit, carbon reduction

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INTRODUCTION

In the UK, 2050 is the deadline for greenhouse gas (GHG) emissions to be reduced by 80 per cent, with an intermediate target being set at a 26 per cent reduction by 2020 against the 1990 baseline.[1] This target could well be elevated in the foreseeable future to net zero emissions in light of the Paris Agreement.[2] Over a quarter of the current carbon dioxide emissions[3] are attributable to the 28m homes in the residential sector.[4] Given the slow turnover of the UK building stock, it has been projected that 90 per cent of current homes will still be in use in 2050.[5] From a societal and historical perspective, retrofit works seem to be more acceptable in the UK than demolition and rebuild,[6] with retrofit also being mooted as the most cost-effective way of achieving the required levels of carbon reduction.[7] If the UK is to meet its current carbon reduction targets, it has been estimated that one home will need to be retrofitted every minute until 2050.[8]

In the context of this paper, 'retrofit' will focus on the 'fabric first approach', which optimises the fabric design of dwellings to minimise energy consumption over the life of the building. The Institute for Sustainability opines that 'it is fairly well accepted that "fabric first" is the most effective strategy for retrofit'.[9] There are several definitions of fabric first principles, such as those put forward by the BRE[10] and Passivhaus,[11] which have the common features for meeting advanced energy efficiency requirements by using super high insulation, maximising airtightness, thermal bridging, optimising natural ventilation and using the thermal mass of the building fabric.

Prima facie, social housing registered providers (RPs) are ideally placed to deliver retrofit measures, as they offer: 1) volume scale of operations through an aggregated, community-based stock; and 2) efficiency via the effective use of their existing reinvestment programmes.[12] They also have the technical skill and customer-facing experience gained in delivering large-scale improvement programmes such as Decent Homes.[13] There are over 4m dwellings being maintained and managed in the UK social housing sector (SHS) and a significant number of these homes will need retrofit works to improve their thermal comfort and to replace building components at the end of their economic life.[14]

Nevertheless, the SHS is currently facing several financial challenges, such as: 1) welfare reforms, including rent cuts; 2) banks' withdrawal in some instances from long-term lending; and 3) cuts to development subsidies. To overcome these difficulties, RPs are seeking more streamlined and efficient ways of working.

One way of increasing efficiency could be to implement Building Information Modelling (BIM) — with, perhaps, one of BIM's most important contributions to sustainable development being its use in reducing waste throughout a building's lifecycle. The government-commissioned report into the current skills shortage in the UK construction industry 'Modernise or Die' places BIM at the heart of the road map to collaboration and high efficiency and states that 'the importance of BIM adoption cannot be overestimated'.[15]

As BIM is used globally, there are many definitions, but this inquiry has applied the UK Government's definition as detailed in the Industrial Strategy for BIM:[16]

> 'BIM is essentially value creating through the entire life cycle of an asset, underpinned by the creation, collation, and exchange of shared three-dimensional (3D) models and intelligent, structured data attached to them.'

BIM is a way of working in a collaborative team environment. The 3D model, the intelligent data that it contains and the simulations of the design, build, operate process facilitate informed decision making, which

results in reduction of risk and uncertainty, improved collaboration and communication with stakeholders in a common data environment (CDE) and, ultimately, increased efficiency.[17]

The use of BIM functions concentrates on preplanning, design, construction and integrated project delivery of buildings and infrastructure and includes techniques such as clash detection, visualisation, costing and data management.[18] Subsequently specialised tools, including scheduling, structural analysis and progress tracking, have been integrated into BIM alongside the basic functionalities.[19] These tools can provide a link between BIM and its implementation in fabric first retrofitting projects. There is a clear synergy between the principles of fabric first design and energy analysis tools such as whole building analysis, conceptual mass, climate analysis, sun/shadow studies[20] and specially designed environmental analysis software.[21] Organisations such as the Passivhaus Trust have recognised this connection and are in the process of developing tools so that BIM models of retrofit projects can be exported into the Passive House Planning Package using platform neutral open file format specifications, which enables the various stakeholders throughout the supply chain to be part of the design process.[22]

However, Bew[23] argues that BIM is not a 'silver bullet'. Strategic challenges have been encountered with the relatively poor response to the Government's mandate to make all centrally procured government contracts BIM level 2 compliant by 2016.[24] At the operational level, the application of BIM to existing building retrofit projects faces challenges due to the fragmented nature of information exchange.[25]

FRAMING THE PROBLEM

Although the UK Government construction industry strategy supports the adoption of BIM as a means of achieving the necessary efficiencies and cost savings through collaborative working, there is little, if any, evidence in literature or otherwise to suggest that the SHS has made any significant progress in adopting BIM for retrofit works.

Therefore, the overarching aim of this research was to provide a summary of the current position with respect to the adoption of BIM and identify new areas and roles where BIM could contribute to the sector achieving the 2050 carbon emissions targets.

RESULTS OF THE LITERATURE REVIEW

One of the traditional barriers to the implementation of BIM in retrofitting has been the lack of good quality data available to input into the pre-construction 3D BIM model, which has consequently led to design and construction inefficiencies within the retrofitting supply chain.[26] However, improvements to geomatic technologies such as laser scanning[27] and photogrammetry have enhanced the quality of BIM models, which begs the question as to whether this has created new opportunities with respect to the implementation of BIM.

The use of 4D BIM in retrofit, which links 3D components or assemblies with time or schedule-related information, has also been addressed by various researchers to determine whether the construction team can visually gain a deeper understanding of a project when compared to traditional approaches.[28] 4D simulation may reveal problems in the existing schedules, provide opportunities for improving construction sequencing, location of equipment and health and safety issues[29] and support early decision making.[30]

The energy efficiency retrofit works that have been carried out by RPs have not only led to a reduction in overall energy consumption but, unfortunately, have also introduced risks of unintended consequences, such as

poor indoor air quality, cold bridging, condensation dampness and mould growth.[31] Given the advent of energy analysis tools produced by BIM authoring software manufacturers such as Green Building Studio,[32] there was scope for further research to determine whether the use of such tools can eliminate or reduce the occurrence of unintended consequences.

One of the core learning points from social housing retrofit pilot schemes such as 'Retrofit for the Future'[33] was that the works produced better results, in terms of minimising energy consumption and reducing carbon emissions, when the residents were engaged and empowered throughout the process so that their expectations of the works were met. This appears to be a good fit with BIM, as the core of BIM is the use of technology and software applications to enhance people/stakeholder collaboration. This suggests that further exploratory investigation should be undertaken to ascertain whether it could prove beneficial to the retrofit process if residents are provided access to the pre-construction BIM model to gain a better understanding of the proposed retrofit works to their property.

The 'Retrofit for the Future' pilot project, using the whole house framework approach, was intended to kick-start volume retrofitting programmes in the SHS to address the GHG emissions issue. This has not materialised, however, so there was scope within this inquiry to explore and ascertain whether the carbon emissions reduction targets still form part of RPs' long-term asset management strategies.

RESEARCH QUESTIONS

The results of the literature review, together with the aim of providing an overall position statement with respect to the role of BIM in retrofit works in the SHS, resulted in the formulation of the following two main research questions and three sub-questions:

(1) What are the drivers/barriers for the adoption of BIM in the social housing sector with respect to retrofit works?;
(2) What new opportunities are there for BIM to play a useful role in retrofit projects?
    (a) Can BIM be used at the design stage to eliminate or reduce the unintended consequences associated with retrofitting dwellings?;
    (b) Can BIM visualisations assist residents in understanding or collaborating in the retrofit process to their properties?;
    (c) Do RPs allow for the reduction GHG emissions within their current asset management strategies?

RESEARCH APPROACH AND METHODOLOGY

The research methodology was an exploratory sequential mixed method comprising: 1) semi-structured interviews employing thematic analysis (TA) to identify ideas and patterns within the resulting datasets; and 2) an online questionnaire. Data was collected from senior professionals working within the social housing retrofit supply chain.

The two research methods were employed to facilitate a better understanding of the research findings. Methodological triangulation was used as a means of assessing the findings to provide a richer, more developed, and balanced picture of the situation[34] while still acknowledging the limited nature of the research.

It is acknowledged and accepted that BIM is an inherently collaborative process and that to be successfully implemented, it requires support and 'buy-in' from all stakeholders at all levels within the various supply chains over the whole life of the building. This research, however, took the position that if BIM is to be adopted as an industry standard within the SHS, then the first step is for it to be procured by organisations

within the SHS retrofitting supply chain. Consequently, the research focused on actors who, prima facie, could be influential in the decision-making process to procure BIM for use in retrofitting projects.

The interview frameworks focused around the research questions and ten interviewees were selected on a purposive sampling basis, using the criteria that they were representative of experienced senior professionals within the SHS supply chain acting as clients, consultants, developers or software specialists. All of them: 1) were decision makers within their own organisations, ie working at either board or executive management level; and 2) had the knowledge to supply perceptive and useful comments on some, or all, of the research topics.[35]

The interviewees had a broad range of experience and expertise and were members of independent bodies including the UK Government BIM Task Group, UK Housing Forum, Green Building Council and the AEC (UK) BIM Protocols Committee. Figure 1 sets out the list of the interviewees, giving each participant a descriptive name to preserve their anonymity.

Each interview took between 45–75 minutes to complete and all were audio recorded. Reflexive memos recording the researcher's initial thoughts were produced immediately following each interview. Transcripts of the interviews were typed up by the researcher and checked against the recording to ensure that they were verbatim accounts of the interviews.

THEMATIC ANALYSIS

There is a plethora of analytic methods that aim to characterise patterns throughout qualitative data, including discourse analysis,[36] content analysis[37] and TA,[38] with Grounded Theory[39] also being identified as a possible methodology for inductive theory building.

While all qualitative approaches can be considered disparate with varying degrees of complexity, TA can be used to obtain the core skills of examining themes and identifying ideas within and across datasets that can be applied to other forms of qualitative analysis. More pertinently, TA is not tied to any specific theoretical or epistemological position[40] and in this inquiry TA was treated as a realist method so that it reported the knowledge, meanings and truth of the interviewees. However, it is acknowledged that reliability can sometimes be a concern with this method, because of the wide variety of interpretations that can arise from the themes, and it may miss nuanced data.[41]

Name	*Organisation*	*Specialism*	*Operational Area*	*Interview Medium*
RP senior manager	Housing association	Retrofit	UK-wide	Face-to-face
Senior construction consultant	Multi-disciplinary practice	BIM & Retrofit	South East England	Face-to-face
Geomatics specialist	Multi-disciplinary practice	BIM & Retrofit	North England	Telephone
RP director	Housing association	Retrofit	North London	Skype
Chief engineer	Innovative developer	BIM & Retrofit	UK-wide	Telephone
RP manager	Housing association	Retrofit	UK-wide	Face-to-face
Energy analyst	Research consultancy	Retrofit	Scotland, Cambridge	Face-to-face
Expert witness	Chartered surveyors	Retrofit	Wales	Telephone
BIM specialist	BIM curriculum development	BIM	UK-wide	Skype
Software developer	Software consultancy	BIM & Retrofit	South East England	Face-to-face

Figure 1: List of interviewees
Source: Author

The transcripts and reflexive memos were analysed using Braun and Clarke's six-phase TA process, which comprises: 1) immersion in the data; 2) generating initial codes; 3) probing for themes; 4) reviewing themes; 5) naming themes; and 6) final analysis and production of a written report. NVivo 11 Pro was used to assist in the organisation of the data and identification of the trends within it.

Phase 1: the dataset was read through so that the researcher became immersed in its depth and breadth.

Phase 2: various patterns and ideas within the data were located, labelled and recorded as 'codes'. The data-reduction coding exercise was both theory-driven, relating to the research questions, and data-driven to identify as many potential interpretations, themes, and patterns as possible across the whole dataset. Analysis created 98 codes that were associated with 896 extracts of data, which included a portion of the surrounding data to preserve context.

Phase 3: the next stage was to search for themes. In this inquiry, a theme 'captured something important about the data in relation to the research question and represents some level of patterned response or meaning within the dataset'.[42] As a starting point, the codes were put into 'theme piles' to establish a tentative relationship between the codes, the themes and sub-themes.

However, the prevalence of a code was not the only factor considered, and relationships between codes and themes were also established by reading and interpreting the data extracts and reassessing the content of the reflexive memos that had been recorded during the research period. An initial thematic map was produced (see Figure 2) and comprised five candidate themes (green) that were directly related to the research questions and 19 sub-themes (white).

Phase 4: the candidate themes were reviewed and refined using Patton's dual criteria[43] that themes must be clear and distinct from each other and that data contained within the themes must be cohesive and meaningful. Where the data extracts for each candidate theme did not form a coherent pattern, they were either moved into a different theme or discarded entirely.

This process gave rise to the reformed thematic map (see Figure 3).

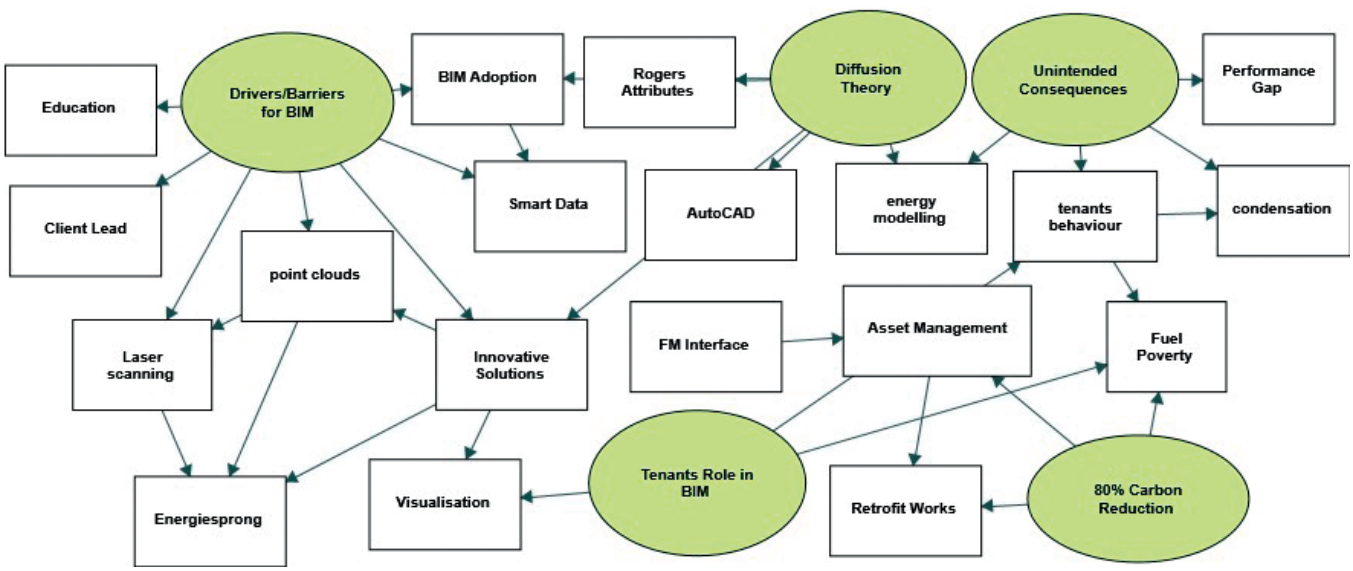

Figure 2: Initial thematic map

Source: Author

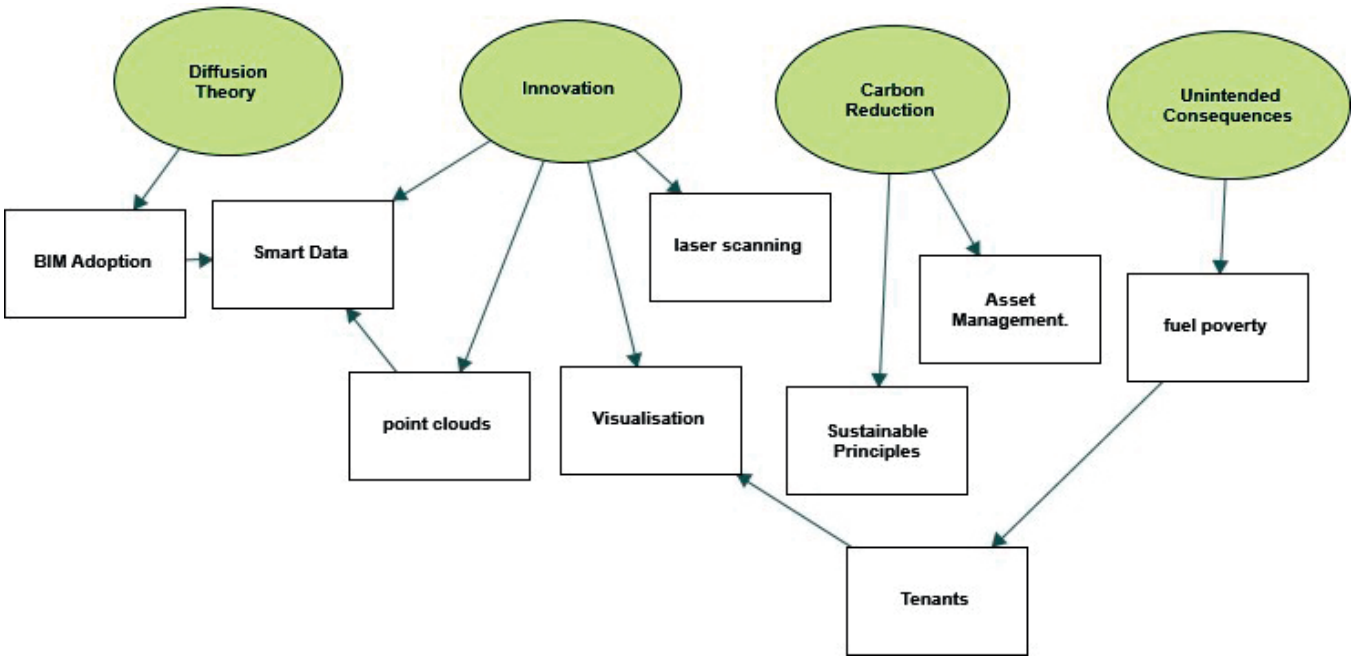

Figure 3: Developed thematic map
Source: Author

Phase 5: the candidate themes were redefined once again to establish: 1) the core elements of each theme; and 2) the data extracts that comprised each theme. This was completed by revisiting the extracts for each theme and assembling them into their respective narratives. An analysis for each theme was produced which reflected not only the content of the data but also how the theme related to the research questions.

The candidate themes were refined for the final time to reflect a sense of the composition of each theme and a final thematic map was produced (see Figure 4). The sub-themes were used to demonstrate the hierarchy of meaning within the data, which was established by the continuous refinement and reduction of the data.

QUESTIONNAIRE

Once the TA had been completed, several issues arose out of the interviews which had not been considered when the research

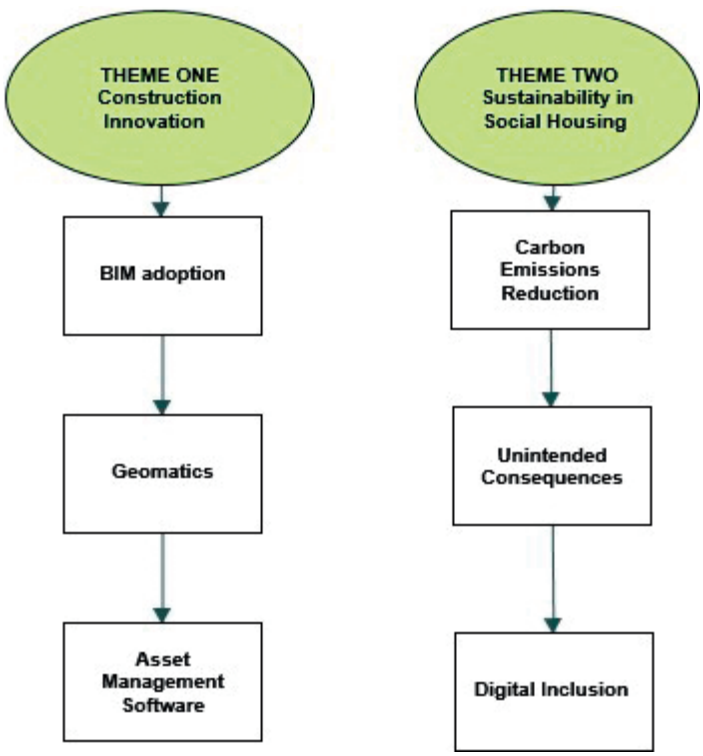

Figure 4: Final thematic map
Source: Author

questions were initially formulated. These issues were used to inform the questionnaire and included how BIM could be used: 1) in 'quick-win' retrofit works to improve Standard Assessment Procedure (SAP) ratings; and 2) in a variety of ways to add value to asset management strategies.

The same sampling criteria were used as for the interview process so that the two resulting datasets could be integrated. Due to the disparate geographical locations of the potential respondents, it was decided to use an online survey to allow the researcher to try and maximise the number of returns from the respondents. A link to the questionnaire site, together with a covering e-mail, was sent to 100 senior professionals within the SHS supply chain who were decision makers within their own organisation at either board or executive management level. A response rate of 31 per cent was achieved, which was acceptable.

RESEARCH FINDINGS
THEME 1: CONSTRUCTION INNOVATION

This theme suggests that, from the respondents' reported opinions, BIM may only realise its true potential if it is not implemented in isolation from other innovative technologies. The analysis indicates that if the diffusion of BIM within the SHS is to be successful, then not only will the perceptions of actors within the sector need to change, but innovative developments in geomatics and asset management software may also need to be utilised.

BIM adoption

The SHS is already using BIM for retrofit works, albeit in a limited way, although generally this research interpreted that the participants' perceptions of BIM were negative. Several of the interviewees believed that there was no or little relative advantage in implementing BIM at the current time. Some saw it mainly as a tool to be used in the development of new build social housing but failed to see how it could be helpful in a retrofit context. The RP director was very sceptical about the use of BIM, stating:

> 'I am not certain about BIM for retrofit works, I don't think it is going to happen anytime soon.'

These views were supported by the results of the questionnaire, in which 86 per cent of the respondents thought that BIM was not suitable for use on residential retrofitting projects. This response seemed to parallel the indication that over half the questionnaire respondents had used BIM during their career (see Figure 5) but only 16 per cent were currently using BIM on a residential retrofit project.

The three main reasons for not using BIM retrofit projects as indicated by the respondents were: 1) there is no client requirement for BIM; 2) the concept of BIM is not understood; and 3) the respondents were satisfied with their existing design software (see Figure 6).

If the diffusion of BIM is to be successful, then these negative perceptions may need to be changed so that BIM can be seen to: 1) have a relative advantage over other software; and 2) be compatible with social housing culture; further, 3) its benefits will need to be seen to be recognised. Education could play a key role in this change process, with the geomatics specialist commenting that:

> 'The kids that are coming through … they are brought up this way [to know] that collaboration works, when they hit the market and they become the decision makers that's when it will start to come together.'

The interviewees' reflections on their experiences were underpinned by the results of the questionnaire (see Figure 7), with the

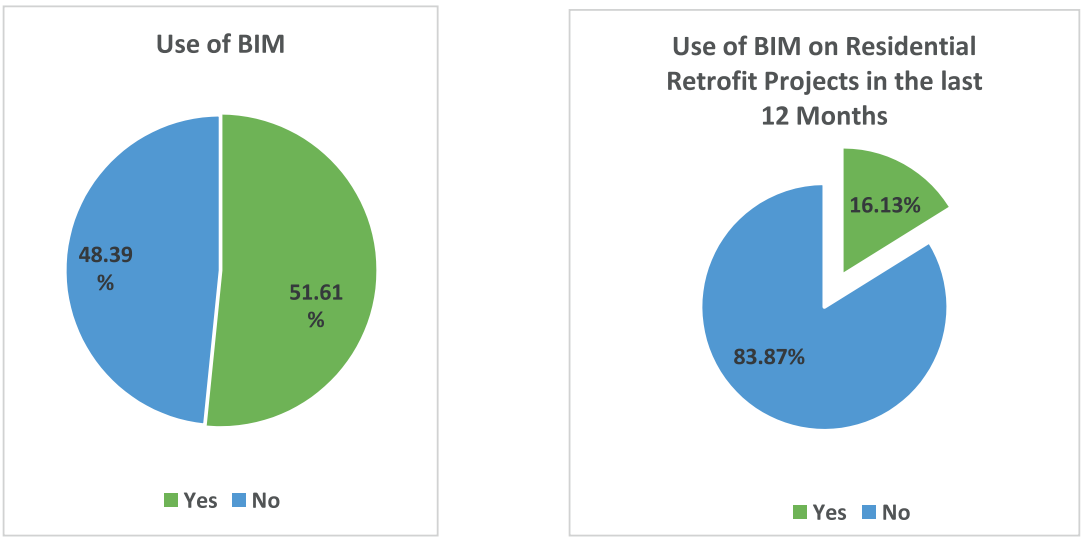

Figure 5: Use of BIM and current use of BIM on retrofit projects
Source: Author

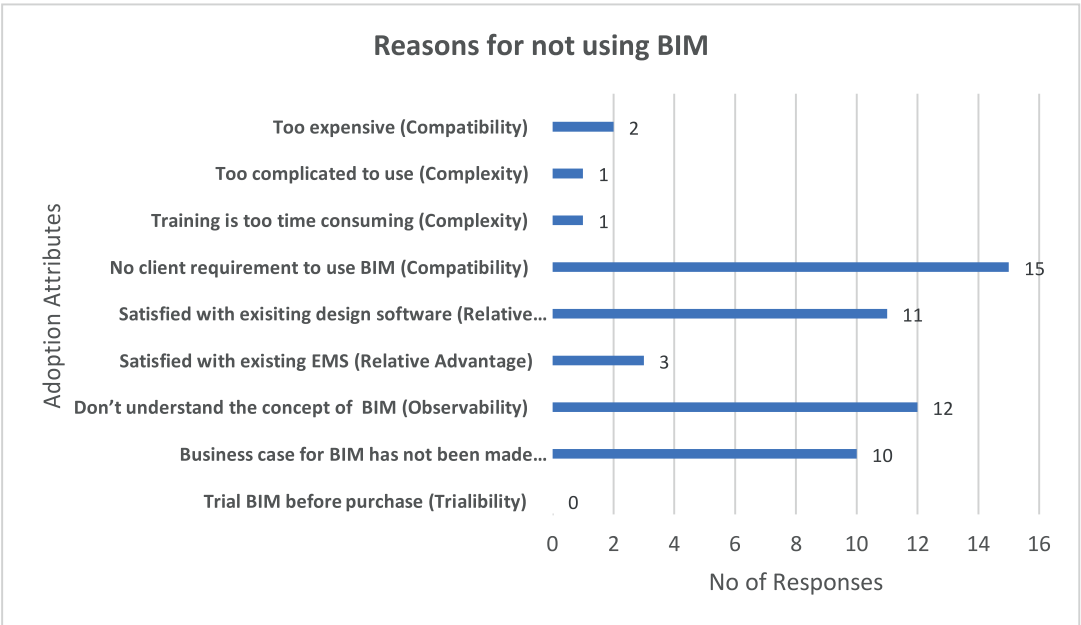

Figure 6: Reasons for not using BIM
Source: Author

two main benefits being improved efficiency and improved client relations.

Finally, the findings were ambivalent on the question of whether the use of BIM can reduce capital project costs; while the geomatics specialist reported that cost savings could be achieved by using BIM, the questionnaire results showed that only one respondent out of the 15 who had used BIM believed it would reduce costs. The results

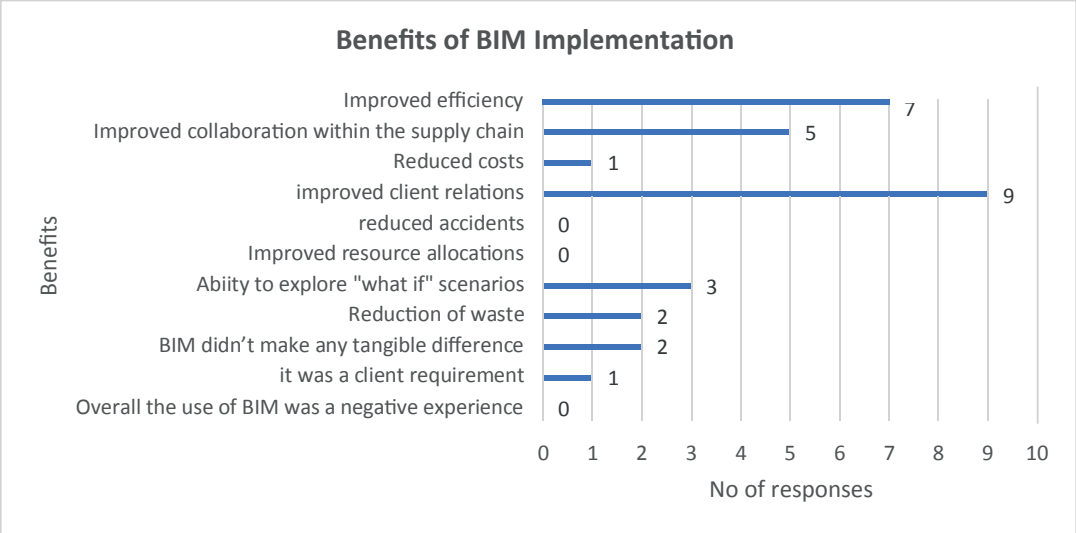

Figure 7: Benefits of BIM implementation
Source: Author

are inconclusive but, prima facie, they do not support the UK Government's aspiration that BIM can reduce capital project costs by 15–20 per cent.

GEOMATICS

One of the advantages for BIM's implementation could be the exploitation of its extensive database capabilities to store intelligent data. Potentially, it can then be used in tandem with complementary project management software and cloud construction platforms using a common data environment (CDE) for the sharing, storing and managing of data for the whole project team to foster collaboration.

To realise this goal, the role of geomatics and the need for dependable measuring techniques such as laser scanning and photogrammetry to produce accurate 3D BIM models is critical. Both these methods allow highly detailed survey information to be gathered over a greatly reduced time period compared to traditional methods.

The interview with the chief engineer revealed that the use of point clouds to store the spatial data generated by laser scanning of houses is not trouble-free; he stated that:

> 'There were some trials with the laser scanning but it kind of died a death because of some of the challenges and everything has gone back to being measured by hand now.'

These types of problem demonstrate the challenges presented by the lack of BIM knowledge throughout the supply chain, meaning the contractor may revert to using traditional methods if problems with BIM or associated new technologies arise. This was supported by the results of the questionnaire insofar as 85 per cent of the respondents agreed that the supply chain is currently not ready to use IBM.

ASSET MANAGEMENT SOFTWARE

Several of the interviewees stated that they believed BIM's most effective role in retrofitting works would be if it were to be used as part of an RP's asset management strategy because of BIM's wide-ranging

database capability. Among the questionnaire respondents, 67 per cent agreed with the statement that a future use of BIM could be to store asset management data and to realise the transition of the pre-retrofit 3D BIM model into an asset information model (AIM).

The barriers to the implementation of this type of strategy were mentioned by several of the interviewees, in that it is problematical for BIM authoring software to 'speak' to standard social housing asset management databases — not least because they cannot deal with 3D spatial geometry. The RP senior manager stated that her employer was installing a new asset management database and one of the requirements was that it was BIM compatible, but advised:

> 'Our new system won't have a direct interface, but it will be better than what we have now in terms of interacting with BIM.'

There was a partial agreement among the participants that there is a lack of motivation around writing a program that addresses the direct interface issue due to the perception that the requirements of BIM authoring software may change every few years, thereby rendering the bespoke system obsolete.

The software developer wished to widen the use of the BIM model so that it could be accessed by tenants who would be able to obtain information relating to their property by clicking on the model which, in effect, provides a three-dimensional version of existing tenants' portals.

Apart from the software developer, most of the interviewees were sceptical about tenants using BIM models with virtual reality (VR) and/or augmented reality (AR), describing them as 'gimmicky' and a 'novelty'; there was a possibility, therefore, that the software developer's answer included overstatement bias that needed to be cross-checked. The questionnaire respondents took a slightly different view, in that over 50 per cent agreed that residents could be allowed to interact with the BIM model in the future; this tentatively supports the view of the software industry and application developers, in that games engine technology now enables software to link to existing user-tracking interfaces to provide real- time refreshing of the users' views and allow users to interrogate data directly from BIM models.

Notwithstanding the acknowledged challenges cited by the respondents to utilising BIM as part of an asset management strategy and the interface issues with legacy databases, the development of innovative complementary software provides a potential pathway for BIM to be incorporated within an RP's asset management operation to become an authentic AIM.

THEME 2: SUSTAINABILITY IN SOCIAL HOUSING

This theme reflects the respondents' statements that the social housing sector is committed to the provision of sustainable development. Aspects of projects were identified in which the implementation of BIM could assist RPs in undertaking retrofitting works while working within a framework of sustainability principles.

Carbon emissions reduction

Within the feedback from the interviewees there was a common thread that climate change and the reduction of carbon emissions *per se* were not goals on many RPs' operational agendas.

The RP manager was very specific in his view:

> 'Reduction of emissions … fossil fuels? … they are not a massive driver for senior managers because in truth compliance, legislation and key stakeholders are not crying out for the senior executive team to be focusing on that … there

> is no requirement on a social landlord to do anything with respect to energy efficiency.'

Most of the interviewees thought that the 80 per cent reduction in emissions target would not be achieved and some thought that the targets would be revised prior to 2050. Fifty-eight per cent of the questionnaire respondents disagreed that BIM would help RPs achieve the carbon reduction targets, with 35 per cent being unsure. It was suggested by some of the interviewees that RPs will focus on the elimination of fuel poverty, as the well-being and comfort of their tenants is paramount. The lack of focus on reducing carbon emissions may have consequential effects on an RP's desire to undertake deep retrofitting works in the short to medium term. This may restrict the implementation of BIM as there is little or no relative advantage in using it for small-scale SAP upgrading works.

BIM and unintended consequences

While the respondents did think that BIM authoring software could possibly facilitate modelling analyses in retrofit projects to enable identification and elimination of the conditions that can cause unintended consequences, they also identified two main problems with these tools: 1) they are still in a basic format so cannot be relied upon; and 2) the difficulty of inputting accurate information. The geomatics specialist opined that:

> 'I don't think that the tools are there quite yet, the analysis tools are fairly new … the tools are pretty basic but getting better all the time.'

Digital inclusion

As the literature review concentrated on fabric first retrofitting, the use of smart data with respect to retrofitting works was not identified until the respondents highlighted that RPs are investigating new ways of utilising smart data, including installing smart meters. The RP senior manager was very supportive of the idea:

> 'I think the smart data thing is going to be huge … it is so powerful sharing with them in tracking their bills … information really is power.'

The advantages of real-time integrity are that energy consumption could be optimised, with a corresponding reduction in fuel bills, which would assist in mitigating fuel poverty.

The software developer advised that the nascent complementary software to be used with BIM is already being developed for district heating networks and RPs are making savings on fuel bills:

> 'They are using it diagnostically, but they have saved about £50,000 per year so we think the savings could be huge.'

> 'We do it iteratively, we have a full-time tester and we have a staging environment so for the London Council project we built it on the staging site and tested it there for a month and then transferred it over to the live system, so we have a good process for the software testing.'

DISCUSSION

The research discussion is split into five sections to reflect the two main research questions and the three sub-questions.

The drivers/barriers for the adoption of BIM

While BIM has been implemented for use in retrofitting projects by a number of the organisations included within this research, from this limited study there is little evidence to suggest that there will be a successful diffusion of BIM within the

SHS in the foreseeable future. This research indicates that BIM is not currently being meaningfully adopted on a full-time basis and, consequently, diffusion throughout the sector is limited.

A small number of RPs reporting in this research are beginning to understand the benefits of cloud-based BIM being used in conjunction with other developing technologies such as geomatics and complementary software platforms to produce an accurate pre-retrofit 3D BIM model. This model could subsequently be used to store intelligent data over the whole life of the subject building. Currently such data is being used to automatically generate transparent audit trails of retrofitting project costs; this is important in fulfilling the probity requirements of public sector expenditure.

The main barriers to adoption identified were: 1) a lack of understanding as to how BIM operates; 2) satisfaction with existing design software; and 3) no client requirement for BIM to be used. If the perceptions of the majority of RPs acting as client organisations do not change with respect to the benefits of BIM via education or perhaps with a change forced upon them due to the enactment of legislation, then the social housing supply chain may remain locked into using legacy processes for the foreseeable future, or at least until the current set of 'digital natives' become decision makers within the industry.

NEW OPPORTUNITIES FOR BIM

Previous research highlighted in the literature review suggests that the implementation of 4D BIM may improve working practices in retrofit projects, as BIM enables large amounts of intelligent data to be stored, and so could not only facilitate the design of retrofitting works but could also — perhaps more productively — be used in the whole life management of the asset. Although the implementation of 4D BIM was not specifically referred to by the participants in this research, they did identify that the ability of BIM to hold large quantities of data provides the potential to reduce costs by integrating retrofit work packages within an RP's planned maintenance and investment strategy.

The barrier to BIM being utilised as part of an asset management strategy identified in this research is the interface problem between a BIM database and an RP's existing asset management database, meaning the two cannot readily communicate with each other. The research suggested that two potential solutions to this problem are possibly emerging:

(1) Software developers can code bespoke programs so that 3D BIM models can integrate directly with an RP's existing asset management database;
(2) A consultant is iteratively building up a 3D BIM simulation model of an RP's housing stock portfolio where data is inputted as and when a dwelling is retrofitted. Ultimately over an extended period the BIM database will become a true AIM and supersede the legacy database.

As identified in the literature review, the use of laser scanning and photogrammetry for surveying and measuring individual dwellings can produce a 3D BIM model that is an accurate geometric representation of the subject property. The pre-construction retrofit model can be used to accurately estimate the quantities of materials that are required for site-based operations, which can lead to a reduction in waste with a resultant cost saving for RPs acting in the client role.

It is acknowledged that RPs are beginning to instal smart meters into their properties; another potential benefit of using BIM is that advances around interoperability of file formats could allow smart meters to interrogate the intelligent data held in BIM models and compare it with external smart city data.

This gives rise to the possibility that BIM could play a role in the real-time optimisation of internal temperature and humidity levels within retrofitted social housing dwellings, leading to a potential reduction in energy consumption and lower fuel bills.

USE OF BIM TO REDUCE UNINTENDED CONSEQUENCES

The literature review noted that BIM authoring software manufacturers have produced analytic tools that can address some of the issues that cause unintended consequences, but the common consensus among the participants was that, currently, the tools are not of sufficient quality to address the various problems satisfactorily and there is a lack of suitable quality data to model these issues with any degree of confidence in the result. This suggests that, regardless of whether BIM or alternative energy modelling software is used to undertake the pre-construction analysis, unintended consequences may still occur. This is compounded by the difficulty in accurately predicting and modelling tenants' behaviour, which can be a significant factor in whether or not the performance of a retrofitted property is satisfactory.

However, an accurate pre-retrofit BIM model can lead to the production of enhanced construction drawings, which can be printed out on-site to address specific tasks such as detailing at materials joints to eliminate or reduce the occurrence of thermal bridging within retrofit projects.

CAN BIM VISUALISATIONS ASSIST RESIDENTS IN COLLABORATING WITH THE RETROFIT PROCESS?

Although the literature review identified that the involvement of tenants and residents can improve the retrofitting process, the research demonstrated an ambivalent view of the proposition that the 3D BIM model could usefully be accessed by residents to provide feedback while retrofitting works were being carried out.

The software developer highlighted the potential for RPs' tenants using VR and AR technology in conjunction with a BIM model. Given the common usage of VR and AR outside the construction industry together with technical advancements in gaming technology, this type of visual collaboration using laptops, tablets or even smartphones to interact with the 3D BIM model could, potentially, become a standard method of engaging with residents in the foreseeable future. An industry VR expert and chartered surveyor, Nick Blenkarn, has advised that BIM models could be viewable using AR on phones or tablets and using Desktop VR with a standard PC.[44]

ARE REGISTERED PROVIDERS PLANNING FOR 2050 CARBON EMISSIONS REDUCTION?

RPs reporting in this research appear to be concentrating on 'quick wins' retrofitting by upgrading properties to improve SAP ratings for relatively modest expenditure, as opposed to specially undertaking works to address the 2050 targets.

Given the financial challenges that the SHS is currently facing, the findings of the research suggest that there seems no real prospect that this stance will change in the short term unless government policy changes and significant funding is provided specifically for energy-efficient retrofitting works or new funding mechanisms are introduced. However, this position could alter once the results of the Energy Company Obligation (ECO) 3 consultation process,[45] which is currently being carried out, are known.

CONCLUSIONS

The research indicated that, currently, the main barriers to the implementation of BIM

in the SHS are: 1) very little or no client requirement for BIM; 2) incomplete understanding of the concept of BIM; and 3) satisfaction among respondents with their existing design software. If the diffusion of BIM is to be successful, then these negative perceptions may need to be changed so that BIM can be seen to have a relative advantage over other software and be more compatible with social housing culture.

One possible route for the adoption of BIM in the SHS is through RPs taking a long-term view of BIM's effectiveness and using it to drive their asset management strategies. This would be advantageous, particularly as the ability of BIM to hold large quantities of data provides the potential to reduce costs by integrating retrofit work packages within an RP's planned maintenance and investment strategy. A slightly more radical route to adoption could be tenant or resident-driven, with RPs trying to improve consumer satisfaction by engaging residents in the retrofitting process — especially if they can interact with the BIM model using their smartphones or laptops.

If the rate of adoption within the SHS is to be increased, then it would appear that education would play a key role in this change process. Alternatively, the UK Government could underpin their industrial strategy to accelerate the use of BIM by enacting legislative changes to make its use mandatory in the SHS for certain types of retrofitting projects if funded (or partially funded) by government monies.

Finally, the findings indicate that if the diffusion of BIM within the SHS is to be successful with respect to retrofitting works, then BIM should not be adopted in isolation. Innovative developments in cloud technology, geomatics and the introduction of complementary software may also need to be accepted so that BIM can help RPs achieve the efficiencies they require to deliver successful retrofit programmes.

References

(1) Gov.UK (2008), 'Climate Change Act', available at https://www.legislation.gov.uk/ukpga/2008/27/contents (accessed 11th September, 2018).

(2) Committee on Climate Change (2016), 'UK Climate Action Following the Paris Agreement', available at https://www.theccc.org.uk/publication/uk-action-following-paris/ (accessed 11th September, 2018).

(3) Committee on Climate Change (2016), 'Meeting Carbon Budgets. Progress Report to Parliament', available at https://www.theccc.org.uk/publication/2017-report-to-parliament-meeting-carbon-budgets-closing-the-policy-gap/ (accessed 11th September, 2018).

(4) Gov.UK (2018), 'Live tables on dwelling stock', Ministry of Housing, Communities & Local Government, available at https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants (accessed 11th September, 2018).

(5) Maclean, K., Sansom, R., Watson, T. and Gross, R. (2016), 'Managing Heat System Decarbonisation', Centre for Energy Policy and Technology, Imperial College, London.

(6) Power, A. (2008), 'Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability?', *Energy Policy*, Vol. 36, No. 12, pp. 4487–4501.

(7) Brown, D., Kivimaa, P., Rosenow, J., Martiskainen, M. and Bird, J. (2018), 'Warm Homes for All — A Comprehensive policy approach for residential energy retrofit in the UK', Centre on Innovation and Energy Demand, University of Sussex.

(8) UK Green Building Council (2017), 'Building Places that Work for Everyone', available at https://www.ukgbc.org/wp-content/uploads/2017/09/08488-Places-for-Everyone-WEB-1.pdf (accessed 11th September, 2018).

(9) Institute for Sustainability (2012), 'Retrofit Strategies. Key Findings: Retrofit project team perspectives', available at www.

instituteforsustainability.co.uk/uploads/File/2236_KeySummary03.pdf (accessed 24th July, 2017).
(10) Stenlund, S. (2016), 'BRE: Applying Fabric First Principles. Complying with UK energy efficiency requirements', BRE, Bracknell.
(11) Passivhaus Trust (2018), 'Passivhaus Retrofit', available at http://www.passivhaustrust.org.uk/competitions_and_campaigns/passivhaus-retrofit/ (accessed 6th September, 2018).
(12) National Energy Foundation (2012), 'Social Housing Sub-Group: Output Report August 2012', available at http://www.nef.org.uk/themes/site_themes/agile_records/images/uploads/GDPG_SocialHousing_WorkGroup_WorkingDocument_Aug2012.pdf (accessed 25th July 2017).
(13) National Audit Office (2010), 'The Decent Homes Programme', HMSO, London.
(14) Itard, L., Meijer, F., Vrins, E. and Hoiting, H. (2008), 'Building renovation and modernisation in Europe: State of the art review', final report, OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, Netherlands.
(15) Farmer, M. (2016), 'Modernise or Die: The Farmer Review of the UK Construction Labour Model', Construction Leadership Council, p. 36.
(16) Gov.UK (2012) 'Building Information Modelling. Industrial Strategy: Government and industry in partnership', Department of Business, Innovation & Skills, available at https://www.gov.uk/government/publications/building-information-modelling (accessed 11th september, 2018).
(17) BiM Regions (2016), 'The UK BIM Alliance — cross industry alliance emerging to drive leadership around implementation of BIM Level 2', available at http://bimregions.co.uk/ukbimalliance/ (accessed 1st August, 2017).
(18) Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011), *BIM Handbook — A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers, and Contractors*, 2nd edn, Wiley, Hoboken, NJ.
(19) Becerik-Gerber, B., Jazizzadeh, F., Li, N. and Calis, G. (2012), 'Application Areas and Data Requirements for BIM-enabled Facilities Management', *Journal of Construction Engineering Management*, Vol. 138, No. 3, pp. 431–442.
(20) Autodesk (2018), 'Building Performance Analysis', available at http://help.autodesk.com/view/BUILDING_PERFORMANCE_ANALYSIS/ENU/?guid=GUID-39C1F9A7-AB5B-4186-B00E-4083CDBD7A73 (accessed 8th September, 2018).
(21) Integrated Environmental Solutions (2018), 'Revit: Overview', available at https://www.iesve.com/software/interoperability/revit (accessed 6th September, 2018).
(22) Passivhaus Trust (2018), 'Masterclass: BIM and PHPP', available at http://www.passivhaustrust.org.uk/event_detail.php?eId=605#.W5Oppc5KiUk (accessed 8th September, 2018)
(23) Bew, M. (2012) 'Why BIM is important to the UK', New Civil Engineer, available at https://www.newcivilengineer.com/future-tech/mark-bew-why-bim-is-important-to-the- uk/8625756.article_ (accessed 26th July, 2017).
(24) Chartered Institute of Building (CIOB) (April 2017), 'What happened to the BIM bang?', *Construction Manager,* pp. 28–32.
(25) Khaddaj, M. and Sour, I. (2016), 'Using BIM to Retrofit Existing Buildings', *Procedia Engineering*, Vol. 145, pp. 1526–1533.
(26) Gholami, E., Sharples, S., Kiviniemi, A., and Kocaturk, T. (2015), 'Exploiting BIM in energy efficient domestic retrofit: Evaluation of benefits and barriers', 2nd International Conference on Civil and Building Engineering Informatics ICCBEI, 22nd–24th April, 2015, Tokyo.
(27) Mahdjoubi, L., Moobela, C. and Laing, R. (2013), 'Providing real-estate services through the integration of 3D laser scanning and building information modelling', *Computers in Industry*, Vol. 64, pp. 1272–1281.

(28) Dave, B., Kiviniemi, A., Koskela, L. J., Owen, R. L. and Tzortzopoulos, P. (March 2013), *Implementing Lean in Construction: Lean Construction and BIM*, Ciria, London.
(29) *Ibid.*, note 18.
(30) Capeluto, I. G. and Ochoa, C. E. (2014), 'Simulation-based method to determine climatic energy strategies of an adaptable building retrofit façade system', *Energy*, Vol. 76, pp. 375–384.
(31) Forman, T. and Tweed, C. (2014), 'Solid Wall Insulation Retrofit in UK dwellings: Critical Factors Affecting Management and Quality', in Raiden, A. B. and Aboagye-Nimo, E. (eds) *Procs 30th Annual ARCOM Conference,* 1st–3rd September, 2014, Association of Researchers in Construction Management, Portsmouth, pp. 1367–1376.
(32) Autodesk (2017), 'Revit built for BIM', available at https://www.autodesk.co.uk/products/revit-family/overview (accessed 14th August, 2017).
(33) Technology Strategy Board (TSB) (2014), 'Retrofit for the Future', available at https://www.gov.uk/government/publications/retrofit-for-the-future-analysis-of-cost-data (accessed 11th September, 2018).
(34) Altrichter, H., Feldman, A., Posch, P. and Somekh, B. (2008), *Teachers Investigate their Work: An Introduction to Action Research across the Professions*, 2nd edn, Routledge, London, p. 147.
(35) Rowley, J. (2012), 'Conducting Research Interviews', *Management Research Review*, Vol. 35, Nos. 3/4, pp. 260–271.
(36) Willig, C. (2003), 'Discourse Analysis', in Smith, J. A. (ed.), *Qualitative Psychology: A Practical Guide to Research Methods*, Sage, London, pp. 159–183.
(37) Meehan, T., Vermeer, C. and Windsor, C. (2000), 'Patient's Perceptions of Seclusion: A qualitative investigation', *Journal of Advanced Nursing*, Vol. 31, No. 2, pp. 370–377.
(38) Braun, V. and Clarke, V. (2006), 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, Vol. 3, No. 2, pp. 77–101.
(39) Glaser, B. (1992), *Basics of Grounded Theory Analysis*, Sociology Press, Mill Valley.
(40) *Ibid.*, note 38.
(41) Guest, G. (2012), *Applied Thematic Analysis*, Sage, Thousand Oaks, CA.
(42) *Ibid.*, note 38.
(43) Patton, M. Q. (1990), *Qualitative Evaluation and Research Methods*, 2nd edn, Sage, Newbury Park, CA.
(44) Blenkarn, N. (2017), 'Convert BIM into a non-technical custom visualisation-how? Don't Panic', The BIM Hub, available at https://thebimhub.com/2016/06/14/convert-bim-into-non-technical-custom-how-dont/#.WY10ClGGPIU (accessed 11th August, 2017).
(45) Ofgem (2018), 'ECO3 Consultation: Environmental Programmes', available at https://www.ofgem.gov.uk/publications-and-updates/eco3-consultation (accessed 8th September, 2018).