HOW CAN DIGITAL TECHNOLOGY IMPROVE PRODUCTIVTY IN RETROFITTING WORKS WITHIN THE UK SOCIAL HOUSING SECTOR?

ABSTRACT

The UK Government advocates undertaking retrofitting works to the existing housing stock to assist in meeting the carbon reduction targets set out in the Climate Change Act 2008. Over 4 million dwellings within the current stock are managed and maintained by social housing registered providers and a significant number of these properties require retrofitting works in order for the registered providers to deliver low-carbon, energy-efficient dwellings. However, the social housing sector is facing a number of financial challenges which means that registered providers are seeking more streamlined and efficient ways of working to improve productivity in retrofitting contracts.

The Government's industrial strategy supports the adoption of Digital Technology [DT] to enable effective and collaborative ways of working throughout the construction supply chain This research sets out to establish whether the innovative use of DT has, to date, been accepted within the UK social housing sector with respect to retrofitting works and endeavours to identify new areas and roles where DT may contribute to improving the productivity of retrofitting works.

The research methodology collected data from senior professionals working within the social housing retrofit supply chain, using semi-structured interviews. Thematic analysis was used to identify ideas and patterns within the resulting datasets.

The findings indicate that DT could be employed throughout the whole-life of a retrofitted property, from the initial design and construction stages through to playing a pivotal role in the management of the asset. This could include the utilisation of smart data and encourage collaborative engagement with all stakeholders including end users. However, for the diffusion of DT within the social housing sector to be successful a change in the perception of DT by actors within the sector is required.

Keywords: carbon reduction, digital technology, retrofitting, social housing.

INTRODUCTION

Social Housing is the provision of accommodation let on a secure basis at affordable rents to people on low incomes. In the UK, Registered Providers [RPs] are bodies that own and manage social housing and are, predominantly, not-for-profit organisations such as local authorities and housing associations (Shelter 2017). Between 4 and 5 million dwellings are maintained and managed in the social housing sector (SHS) (Smith & Abbott 2017). A significant number of these homes will need retrofit works to improve the thermal comfort and to replace building components at the end of their economic life (Brown et al. 2018).

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. There are a number of definitions of fabric-first principles including those put forward by the BRE (Stenlund 2016) and Passivhaus (2018) which have the common features for meeting advanced energy efficiency requirements by using; the thermal mass of the building fabric, super high insulation, maximising airtightness, thermal bridging, and optimising natural ventilation.

Prima facie, RPs of social housing should be ideally placed to deliver retrofit contracts as they, together with their approved contractors, can (i) offer a volume scale of efficient operations via their existing reinvestment programmes (Loosemore 2016) and (ii) have the technical skill and customer-facing experience gained in delivering large scale improvement programmes (IET 2018). Nevertheless, the SHS is, currently, facing financial challenges such as cuts in development funding subsidies (Marsh 2018), reduction in rental income due to welfare reforms (MHCLG 2016) and the withdrawal of some banks from long-term lending resulting in more risk prone investments with other institutional lenders (PIC 2016). To overcome these difficulties, RPs are seeking more productive ways of working.

Intrinsic problems with productivity and how to improve value in the UK construction sector have been recognized over many decades, with the Chartered Institute of Building (CIOB) branding productivity as a "thorn in the side" of the industry in its report "Productivity in Construction" (CIOB 2016 p. 5). It is acknowledged that current productivity challenges in the UK construction sector focus around a mix of human, cultural and economic factors such as an ageing workforce, the poor image of construction, the ubiquitous Brexit issue, an inability to deliver projects on-time and within budget et al. Manifestly, there is no one panacea for these problems but the UK Government's 2018 Industrial Strategy "Building a Britain Fit for the Future " sets out to improve productivity by utilising digital technology with a focus on investment in digital skills, infrastructure and innovation. In addition to this the government has contributed £170 million to the "Transforming Construction" challenge which supports industry to adopt new technologies and help buildings to be constructed 50% faster, 33% cheaper and with half the lifetime carbon emissions (UK Research and Innovation 2019).

There have been several reports which suggest how digital technology will assist in improving productivity (ICE 2015, Mckinsey 2017, Accenture 2018). These reports have focused on the following digital technologies; (i) Building Information Modelling [BIM], (ii) Unmanned Ariel Vehicles (UAV's)/drones and associated technologies such as laser scanning and photogrammetry, (iii) Smart technology including artificial intelligence and algorithms and (iv) virtual and augmented reality. These areas are the core focus of the literature review which assesses how each technology is currently being used with respect to retrofitting works within the UK construction industry.

LITERATURE REVIEW

BIM is a way of working in a team environment. The 3D model, the intelligent data that it contains and the simulations of the 'design-build-operate' process facilitate informed decision-making. This results in the reduction of risk and uncertainty, improved collaboration and communication in a common data environment (CDE) and, ultimately, increased efficiency (UK BIM Task Group 2017). There are four dimensions of BIM which refer to the linkage of specific data to a shared 3D BIM model. 4D BIM connects associated time schedules including visualisations to the model. 5D BIM adds accurate cost information based on the 3D model. 6D BIM provides whole life cycle cost information and data to support the ongoing management of the asset using the Asset Information Model (AIM). 6D BIM is sometimes known as 'integrated BIM'or 'iBIM'. 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 “BIM should be embraced by industry-the private sector moving to BIM adoption as a business norm” (Farmer 2016, p.69).

In general, the academic literature around BIM addresses its use on new-build construction projects, though research with respect to retrofit projects has made a case for the implementation of BIM to minimise disruption to tenants in housing retrofits (Kemmer et al 2016) and improve stakeholders understanding of the retrofit process (Chaves et al 2016). However, the application of BIM to retrofit existing buildings raises challenges in the production of a 3D pre-retrofit model which may be due to the wide array of technological components that are required to ensure the optimal exchange of information during the collaborative design process (Khaddaj & Srour 2016).

A possible future role of BIM in improving productivity is provided by a Dutch concept known as “Energiesprong” (literally translated as “energy leap”). This is a radical retrofit approach that involves enveloping an existing dwelling with customised cladding optimised for off-site manufacture, to deliver a highly insulated, low maintenance house with an assured net zero energy performance (Smith & Abbot 2017). Energiesprong UK Ltd claim that BIM plays a central role in the off-site manufacturing process as the properties are scanned using 3-D lasers and BIM produces working drawings that are sent to a flexible factory to produce the package of prefabricated panels (Energiesprong 2016). The creation of an accurate pre-retrofit model could, potentially, benefit from the use of a combination of photogrammetric and laser scanner systems to overcome the problems of resolution, accuracy and operational requirements.

The laser scanning (or Light Detection and Ranging [LiDAR]) of existing buildings to produce digital documentation has become popular in the construction industry due to its speed and accuracy of measurement. This process can capture complex geometry and small details but the limitations of using multiple point clouds to transform the 3D survey points collected is acknowledged (Laefer & Truong-Hong 2017). Similarly, photogrammetry extracts input data from 2D photo images to map them onto a 3D space and as the models are made up of photographs, they have highly textured detail that cannot be obtained using laser scanning. But environmental and site conditions such as lighting can affect the accuracy of the image processing (Omar & Nehdi 2016).

Over the last few years both laser scanning and photogrammetry have been used in conjunction with UAV’s and drones for the aerial surveying of buildings as they provide a very cost-effective alternative to hiring a plane. High mega pixel cameras are being combined with the latest GPS drone technology to create UAV photogrammetry which, potentially, is quicker than laser scanning especially when used in, say, the retrofitting of the external facades of tower blocks or inaccessible roof areas (Scanair 2017). A process to combine all these digital technologies to enable BIM to be implemented and improve productivity in retrofitting contracts has already been theoretically devised (Scherer and Katranushkov 2018).

Retrofitting of existing buildings using smart technology is currently being used to reduce energy consumption and improve the lives of the building end users. It is anticipated that smart technology will offer a number of functions ranging from recording how much energy is being used to reporting a broken light bulb. A number of smart thermostats such as Switchee have been retrofitted into social housing stock with the combined aim of reducing resident's energy consumption by up to 15% and providing RPs with analytics to optimise their ability to allocate energy efficiency retrofit budgets (SSEIR 2017). These systems contain sensors that pass readings to a secure cloud which, using algorithms based on historical data, produce an occupancy profile for each dwelling and controls the temperature and humidity levels within the properties. It is reasonably foreseeable that by using the external weather sensor data that exist on the Internet and comparing it with the data held in a secure cloud, real time control for heating and humidity in individual properties by smart thermostats could be achieved (Scaysbrook 2016).

Virtual Reality technologies have been used in construction for a number of years primarily for design review, end-user training and marketing. Despite the benefits of VR, it has not been widely adopted in retrofit contracts as the industry still lacks a general understanding of the technology in addition to a lack of expertise in the use of VR tools and display systems (Liu et al 2014).

RESEARCH AIM AND METHODOLOGY

The overarching aim of the research was to establish if the innovative use of DT has, to date, been accepted within the UK social housing sector with respect to retrofitting works. It also endeavoured to identify new areas and roles where DT may contribute to improving the productivity of retrofitting works.

The research methodology collected data from senior professionals working within the social housing retrofit supply chain using semi-structured interviews. Thematic analysis was used to analyse the resulting datasets.

The research took the position that if DT is to be adopted within the SHS then the first step is for it to be procured by organisations within the SHS retrofitting supply chain. The research focused on actors who, prima facie, could be influential in the decision-making process to procure DT for use in retrofitting projects. The 10 interviewees were selected on a purposive sampling basis using the criteria that they were representative of experienced senior professionals within the SHS supply chain. The sample included; the director of a RP, a senior manager within a different RP, a geomatics specialist, a chief engineer of a residential development company, a software developer and a senior construction consultant. All of them were decision-makers within their own organisations, i.e. working at either board or executive management level and had the knowledge to supply perceptive and useful comments on some or all of the research topics. 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.

TA was used to examine themes and identify ideas within and across datasets. It is acknowledged that reliability with this method can sometimes be a concern because of the wide variety of interpretations of the themes and the potential to miss nuanced data. The written records of the interviews were analysed using Braun and Clarke's (2006) six-phase TA process which comprises: a) immersion in the data, b) generating initial codes c) probing for themes, d) reviewing themes e) naming themes and f) final analysis and production of a written report. The main themes were derived using Patton's (1990) dual criteria which states that themes must be clear and distinct from each other and the data contained within the themes must be cohesive and meaningful. The two themes established were; Construction Innovation and Digital Inclusion.

RESEARCH FINDINGS

Theme One: Construction Innovation

Though BIM is already used for retrofitting projects in a very limited way the general consensus was that there was no real client requirement for BIM to be introduced as the concept of BIM is not readily understood. Many actors in the SHS supply chain are satisfied with their existing design software. Nor was BIM always seen to be currently compatible with the sector's culture. The senior construction consultant held the view that;

"A couple of years ago everybody was talking about BIM but now nobody is talking about it… BIM has to become part of the social housing culture before it becomes effective"

Several respondents expressed views on how perceptions could be changed so that BIM and associated DTs could be adopted for retrofitting in the SHS. Several of the interviewees foresee the BIM database being ideally placed to assist in health and safety compliance issues, notably, fire risk assessments, gas safety checks etc and clients would be able to see the cost benefits of purchasing the software. The ability to store photogrammetric data and geotagged photographs also allows BIM to build up a visual record of the condition of the subject property over the lifetime of the asset. The software developer commented on this issue:

"The future following Grenfell …council's kind of thought contractors were keeping an eye on it, evidently now they will want to have that insight themselves"

A number of the respondents highlighted the issue that a good quality pre-retrofit BIM model can help to reduce waste and generate savings for clients and that laser scanning could be used to produce an accurate pre-retrofit model. The geomatics specialist stated that;

“it’s fairly easy to scan a building,” “you need a good quality base model and laser scanning will provide it”

However, the difficulties with the use of the technology around laser scanning for retrofit models was also acknowledged. 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;

“there were some trials with laser scanning but it kind of died a death because of some of the challenges [encountered] and everything has gone back to being measured now”

“the point cloud straightened up all the co-ordinates, it was the right size house, but it turned out as a square house when in fact it wasn’t perfectly square… the contractor would have ended up with the wrong shaped components…”

Both the geomatics specialist and the software developer agreed that the use of UAV’s would become more prevalent for retrofit works and that they would be used in more innovative ways such as obtaining real time data to monitor the progress of both internal and external construction works on site. The software developer mooted the point that;

“perhaps Grenfell could have been avoided if the data obtained from drone images taken from multiple locations and point clouds could have been used to view and analyse the construction details that were employed as the cladding was installed?”

Theme Two: Digital Inclusion

The general response was that there is not a widespread use or adoption of digital technologies within the SHS. The senior construction consultant’s experience was that;

“At the moment, my Clients (mainly Housing Associations and Local Authorities) have hundreds of thousands of properties and no digital records. Even those new building that have digital records, are not referred to, as, generally, there is no effective filing system to recover the files when needed.”

The utilisation of smart data may help to change the perception of DTs in the SHS. Though the use of smart technology is very much a nascent process it is anticipated that it will probably become an integral part of the daily lives of many social housing tenants. The RP director was very supportive of this idea as it can be used not only to monitor energy use but also to assist in dealing with vulnerable residents;

“We are currently trialling a scheme known as “Switchee” which is a remote monitor and sensor with a SIM card so that it can be remotely accessed…It has been a success with respect to controlling the environment within our tenanted properties and also acts as a warning detector for vulnerable tenants who are at risk.”

The use of smart sensors means that energy consumption can be optimised with a consequential reduction in fuel bills to assist in mitigating fuel poverty. The Software Developer advised that RPs are also using smart technology on communal heating systems in order to reduce their fuel bills;

“They are using smart technology diagnostically have already saved about £50,000 per year, so [potentially] we think the savings could be huge”

Apart from the software developer most of the interviewees were sceptical about tenants using BIM models and VR with it being described as “gimmicky” and a “novelty” but his contrary view was that users can engage with a 3D model via applications on smartphones or tablets using simple VR viewers for wayfinding purposes;

“That games engine technology has developed so quickly that software can now link into existing user tracking interfaces to provide real-time refreshing of the users view, with the ability for the user to interrogate data directly from the BIM model”

CONCLUSIONS

The overarching view was that, currently, there is a negative perception regarding the use of digital technologies within the SHS. However, since the tragedy at Grenfell and the publication of the Hackitt Report, the SHS is beginning to realise the importance of digital data to record and store the “golden thread of information” proposed by Dame Hackitt. The use of BIM as an Asset Information Model could, potentially, act as the single repository for this information, from initial design through construction and for all subsequent changes during the use of a building.

The utilisation of BIM in conjunction with other developing technologies such as the use of drones and laser scanning, or photogrammetry can be used to produce an accurate pre-retrofit 3D BIM model. This also affords the industry the opportunity to explore the possibility of increasing productivity by implementing new service delivery models such as “Energiesprong” to deliver volume retrofitting of zero carbon homes.

In addition to this, an accurate pre-retrofit BIM model could lead to the production of enhanced construction drawings which can be printed out on-site to address specific tasks. This could include detailing at materials joints to eliminate or reduce the occurrence of thermal bridging within retrofit projects which, consequently, should increase operational on-site productivity.

The benefits of the installation of smart thermostats such as Switchee are acknowledged in reducing carbon emissions across a housing portfolio and remotely monitoring its thermal performance. In addition, they can increase resident wellbeing through alerts for vulnerable residents, pre-emptive repairs and lower energy bills. This has synergy with the holistic viewpoint put forward by the CIOB that construction and the built environment can possibly have major direct impacts on the productivity within the wider economy by making people “happier, safer and wealthier”.

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 the AIM could play a role in the real-time optimisation of internal temperature and humidity levels within retrofitted social housing dwellings, reducing energy consumption and resulting in lower fuel bills.

The use of virtual reality and augmented reality to access a retrofit BIM model has a potential role in allowing social housing tenants to monitor the progress of works. They could report any quality issues with workmanship via the model though, clearly, they would not be able to make any amendments to the model itself. 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 within the foreseeable future. This has a strong implication in terms of productivity, given that many retrofit projects are undertaken with tenants still residing within the properties. RPs understand the importance of tenant engagement in the successful and timeous delivery of retrofit projects.

The findings, of this research, indicate that DT could be employed throughout the whole-life of a retrofitted property from the initial design and construction stages through to playing a pivotal role in the management of the asset. This could include the utilisation of smart data and encouraging collaborative engagement with all stakeholders including end users. However, for the diffusion of DT within the social housing sector to be successful a change in the perception of DT by actors within the sector is required.

The limitations of the research are also acknowledged in so far as the interviewees represent only one specific section of the SHS supply chain which may have given rise to narrow or restricted views in the semi-structured interviews. It is suggested that further research could be undertaken taking a more holistic approach which seeks the views and ideas of a more widespread sample of actors within the SHS supply chain such as stakeholders including end-users, digital technology operatives etc as this may produce a different or more varied set of results.

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