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Housebuilding & BIM

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Building Information Modelling has grown in popularity in the Irish construction sector. In 2017 the government indicated their intention to incorporate BIM into the public procurement of construction projects. The UK government mandated BIM for this purpose in 2016. It has been identified that the housebuilding /residential sector has been slow to adopt BIM.

Currently there is a housing shortage in Ireland. The governments Rebuilding Ireland action plan seeks to address this by increasing the level and speed of delivery of social housing and to increase the output of private housing at affordable prices.

This paper examines the relationship between BIM and housing and makes proposals on how BIM can help alleviate the housing crisis in Ireland. Its findings have been established from an in-depth literature review and qualitative research of the housing sector.

It concludes that BIM is a tangible mechanism to enhance offsite manufacture. OSM will improve both housing outputs and performance. Cross laminated timber is a sustainable alternative to concrete and steel and is proven in offsite manufacture.

This paper recommends direct government involvement in CLT manufacture, Off site construction and BIM training and implementation.

Keywords – BIM, Housing, Crisis, Ireland

I Introduction

The Rebuilding Ireland Action Plan for housing and homelessness was published by the Irish government in July 2016. It acknowledges that since the economic collapse in 2008 very low levels of housing have been constructed. Pillar 2 and 3 of the plans aim to accelerate social housing and build more homes respectively. The Pillar 2 action is to increase the level and speed of delivery of social housing and other state supported housing. The Pillar 3 action is to increase the output of private housing to meet demand at affordable prices. One of the key actions of the pillar 3 objective is to support construction innovations and skills. [1]

The Energy Performance of Buildings Directive requires all buildings to be Nearly Zero Energy Buildings (NZEB) from 31st December 2020. For all new domestic buildings, it is proposed that NZEB will be the equivalent of a 25% improvement in energy performance on the 2011 building regulations. "The NZEB process aligns closely with offsite construction" [2]

At the end of 2016 DKM consultants identified that an additional 76,000 workers would be required in the construction industry in the following four years. From 2007 to 2015 the number of skilled craftsperson's had decreased from 144,700 to 68,200. [3] In a trade and apprenticeships skills survey in 2018 86% of respondent companies s noted that there was an inadequate supply of qualified trades people. [4]

The Society of Chartered Surveyors Ireland have indicated that tender prices will rise by 7% this year. The skills shortage combined with increased construction demand has led directly to increased costs. Significant rate increases were identified for concreting, rebar and formwork. In Dublin the shortage of disposal tips for construction waste was also driving up construction costs. [5]

With skills shortages and cost increases in materials a review of how we traditionally build houses is required.

Between 2006 and 2016 the owner occupier v rental sector moved from an 80:20 ratio to 70:30. With the populace now more predisposed towards renting and a housing supply shortage in Dublin, the build to rent sector is expected to grow exponentially. Purpose built residential rental accommodation is acknowledged in the

Government Rebuilding Action Plan and the Housing Minister has requesting the planning authorities to prioritise all actions to deliver build to rent housing. [6].

In a recent report the Department of Housing recommend raising height restrictions for apartments to at least six storeys in urban areas and up to 10 storeys in strategic sites. [7] This recommendation may make developing existing sites for residential apartments a viable proposal whilst also improving housing densities in urban areas.

The Goodbody BER Housing Tracker is forecasting 18,000 housing completions this year. Economic commentators estimate the demand to be 36,000 units. This housing supply deficit is expected to continue until 2020. The number of apartments built fell by 11% compared to the same quarter the previous year. Uncertainty about building standards is believed to have contributed to this. [8]

Project Ireland 2040 is the Government's overarching policy initiative to make Ireland a better country for all of us, a country that reflects the best of who we are and what we aspire to be. By 2040 it expects an additional one million people to be living in Ireland. An aging population and smaller family sizes mean that an additional half a million homes will be required to accommodate this population growth. [9]

BIM is defined as "an intelligent 3D model-based process that gives architecture, engineering and construction professionals (AEC) the tools to efficiently plan, design, construct and manage buildings and infrastructure." [10] BIM provides a common data environment for all stakeholders to collaborate and share information. Key product data and parametric rules embedded in 3D images allow building performance to be evaluated in multiple aspects such as structural, energy efficiency, cost, scheduling and maintenance. Building Information Modelling (BIM) is now widely used in the commercial sector in Ireland and the government have indicated it will be a requirement for it to be incorporated in public sector construction projects in the next four years. The governments rationale for its implementation is that it delivers projects more efficiently, to a higher quality and more safely. The governments BIM adoption strategy recognises the housing sector in three different categories, low density housing projects, low rise apartments schemes and high-density apartment schemes. The time line period in months from mandate to the introduction of BIM in contract notices is 48, 36 and 24 months respectively. [11]

The above plans, directives and statistics show the housing industry is currently facing unprecedented demand for improved quality housing whilst it is still recovering from the economic downturn and enduring a skills shortage. There is little data to support the current use of BIM in housing here however in the UK there has been a slow uptake of BIM in the house building sector. [12]

II Aims and Objectives

This study looks to examine the opportunities and barriers to the use of BIM in the house building sector and make recommendations on how its use can alleviate the housing crisis. The following aims and objectives will be reviewed.

- To critically appraise the elements of BIM that are relevant to house building
- To review the benefits of BIM to clients/owners in the commercial construction sector
- To determine the barriers to the adoption of BIM in the Irish residential sector's current practices
- To critically evaluate the transferability of the commercial construction benefits to the residential sector
- To recommend possible contributions that BIM can make to the provision of multiple occupancy units

III Methodology

This study includes a review of existing evidence and literature from around the world with the aim of ensuring all research objectives have been accomplished.

BIM is a new topic in relation to housebuilding in Ireland and from the literature review it was learnt that there was a lack of awareness and utilisation of BIM in the sector. The study therefore did not lend itself to quantitative research where responses from a large sample with good knowledge of the topic would be required.

The purpose of the research is to examine the relationship between BIM and the housing sector and to make proposals on how BIM can help alleviate the housing crisis in Ireland. The author found no evidence of BIM being optimised on a housing project in Ireland and therefore a case study was not considered. The attitudes views and opinions of those involved in the sector therefore had to be examined and a qualitative research approach was chosen.

Following the literature review a targeted set of semi-structured interviews will be conducted with leading members of the public and private

housebuilding sector. A list of pre-interview questions will be forwarded to each participant and the answers reviewed to identify common, recurrent and emergent themes. The author will then seek to develop these themes at interview stage to gain an in-depth understanding of the attitudes, opinions and thoughts of the interviewee. This qualitative approach to the research is subjective and confined to a small number of interviewees and therefore may not be representative of all in the sector.

IV Literature Review

a) *To Critically Appraise The Elements Of BIM That Are Relevant To Housebuilding.*

The 2013 report by the UK National House Building Council on BIM and Housebuilding highlights the elements of BIM that are relevant to this sector of the industry. [13]

- Information Exchange: The NHBC notes that communication is vital between the client, design team and developer/ contractor. With all projects a large range of information is exchanged as shown In Fig 1. Traditionally the methods of transferring the information shown are email, post and file transfer.

Box 3: Information type	
Briefing documents	Costing/supplier enquiries
General correspondence	Quotations
Feasibility studies	Requests For Information (RFIs)
Utilities and infrastructure reports	Tender/contract documents
Site surveys	Commissioning sheets
Ecology studies	Working drawings
Design drawings	O&M manuals
Specifications	Statutory certificates
Schedules	Local authority submissions and approvals
Programmes	Financial management

Fig. 1 Project Information Exchange [1]

To organize and manage this information the house builder will use a document management system.

Paul Wilkinson an author of a book on construction collaboration shows this traditional process works and the information flows in fig. 2 screen slides. Whilst he acknowledges the process works, it does have a heavy reliance on paper. It can lead to 'islands' of information and the lack of a complete project record may lead to disputes and litigation. [14]

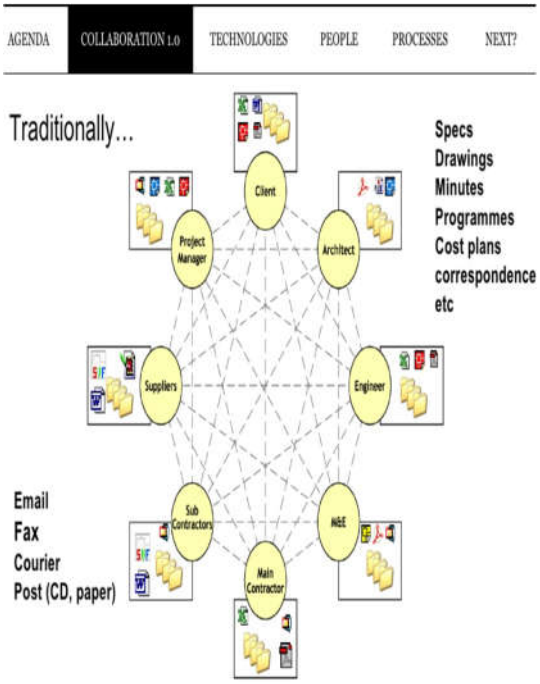


Fig 2. Traditional Collaboration Method [14]

The BIM process overcomes these inefficiencies with a fully collaborative method of working. Project members access and retrieve data from a Common Data Environment (CDE). See fig. 3. The CDE ensures all stakeholders are working on accurate up to date information. The information loaded on to the CDE is only shared with those stakeholders who have permissions to access it and only when it has been approved. This process of information delivery is in accordance with British Standards Institute standard PAS 1192-2[13]

Acknowledgement of the advantages of a CDE has been made in the 2017 NBS National BIM report where 78% of respondents agreed that BIM is the future of project information. [15]

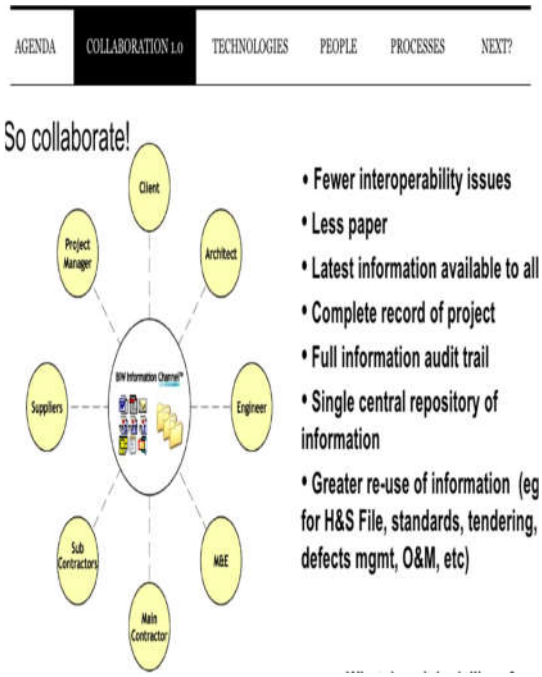


Fig. 3 BIM Collaboration using CDE [14]

- Planning and Building Control: In 2017 Nottingham City Homes (NCH) built the first social housing project, The Meadows, in the UK using BIM. Richard Whittaker their head of regeneration commented that *"We have had schemes designed previously that didn't fit on the land available,"* and *"We had one where the last house in a row finished on the pavement because the measurements were wrong – there was no way of telling that because they were all on separate bits of paper."*[16] The architects design for a site is influenced by external factors, topography, wind direction, sun path, over-shadowing. With BIM these factors can be integrated into the model and conceptual analysis performed. Where required alternative designs can be produced and costed quickly. [17]
- 3D Modelling: BIM software can be used to build a 3D model from which drawings and schedules can be generated. These can be accessed from all stakeholders including suppliers providing they have the appropriate permissions. Improved access leads to better communication between all stakeholders and issues can be resolved promptly without numerous 2D drawings and printouts to-ing and fro-ing between parties. The models are information rich so in addition to generating schedules for windows it can give you the height, width, fire rating, U value, finish and warranty details. At design and budget stage different finishes and manufacturers can be run through the model. Cost estimates for these changes are generated from the model instantly allowing for quick decisions to made. [13]
- Clash Detection: At initial design a project can be virtually built using the 3D model. Before any work starts on site designers can ensure everything fits and functions properly. A clash detection program will highlight for example if a heating pipe is running through a beam at design stage. This can be rectified in the model whereas otherwise a re-work on site could prove expensive. The BIM handbook notes that on the One Island East Project over 2,000 clashes and errors were found prior to tendering and construction and substantial cost savings were achieved compared to the traditional 2D process. [18]
- Cost Accuracy and Control: Using BIM project designs, schedule and quantities are available from a single source. The cost and schedule impact of design changes can be viewed quickly as opposed to traditional methods. This gives the project team better control of costs and schedules and allows decisions to be made faster. NCH noted at tender stage that the accuracy of the model and material schedules gave rise to closer tender results with a differential of under 2% between first and second. On traditional projects NCH experienced a 3% differential. [16] In the 2017 SCSI BIM survey of Chartered Surveyors 82% of respondents believed BIM improved the accuracy of quantity take off. [19] Model accuracy also allowed NCH to reduce their contingency budget from 10% to 5%. "We spent 4.9% of the contingency (on The Meadows)," said Richard Whittaker (NCH) and "On the traditional site, I spent 9% of the contingency. These were pretty similar jobs so that is a real success." [16]
- Visualisation: Visualisation is an important attribute of the BIM 3D model. At design stage clients can walk through the proposed building and request alterations. NCH noted it was beneficial to prospective tenants at The Meadows. The Meadows was a regeneration scheme and residents wanted to move away as they disliked the area. At consultations prior to construction residents were able

to do a walk through the model on an iPad. This helped change their minds. Traditionally a house builder will first build a sales area with showhouses on a new development to generate sales. 3D visualisations can assist in off plan sales once design is complete. NUbuild a modular home builder allows prospective buyers to select their plot and then create their home using specialized software. [27] These 3D visualisations can be produced inhouse without the need for an external agency to be commissioned. Off plan early sales can boost cash flow and aid the decisions of external lenders to provide financing to the house builder.

- Maintenance: At maintenance stage the manager can access the model for the manufacturer, lifespan and warranty details. [13] Client demand for this attribute in the housing market may be increasing with Insurance and pension funds investing in the rental market.
- Safety: BIM is increasingly being used as tool for safety on-site. GKR Scaffolding workers are being trained using VR technology. The "key objective was to engrain safe behaviour by exposing them to high-risk situations impossible to simulate in the real world." [20] So realistic was the simulation that workers had to take 'a break between modules to unwind'
- Sustainability: BREEAM is the world's leading sustainability assessment method. The key input to Breeam assessment is building and Building related data. According to the BRE "BIM rationalises the location and format of this data and in doing so increases the potential for informed decision making compared to traditional approaches to design, construction and management." [21]

One of the drawbacks in relation to BIM is that it is not universally used within the housebuilding sector. [13] The supply chain and subcontractors may not have the software or training to access the model and therefore communication with them may need to revert to 2D drawings and email enquiries. Implementation of BIM requires the purchase of software, the upskilling of staff and a change of work processes. All of this comes at a cost which can only be justified if the use of BIM is fully optimised and there is a positive return on investment is a relatively new process in Ireland and the legal complexities of its use have still to be settled so there exists a risk in its use until this occurs. This will also hinder its adoption by the supply chain.

b) To Review The Benefits Of BIM To Clients/Owners In The Commercial Construction Sector

The McGraw Hill report titled 'The Business Value of BIM for Construction in Major Global Markets' examines the growth of BIM globally and the key drivers that give added value to in the commercial construction sector. A positive return on investment was reported by most contractors in all countries except South Korea. Reduced cost, higher profitability and higher productivity were categorized as the most important metrics for measuring ROI followed by project delivery metrics such as less unplanned changes and requests for information. [22]

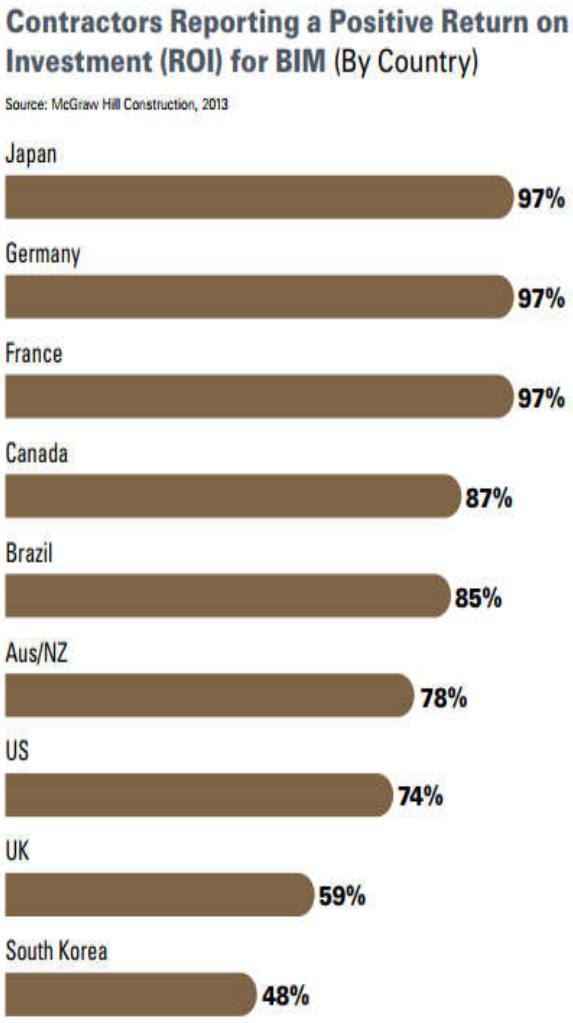
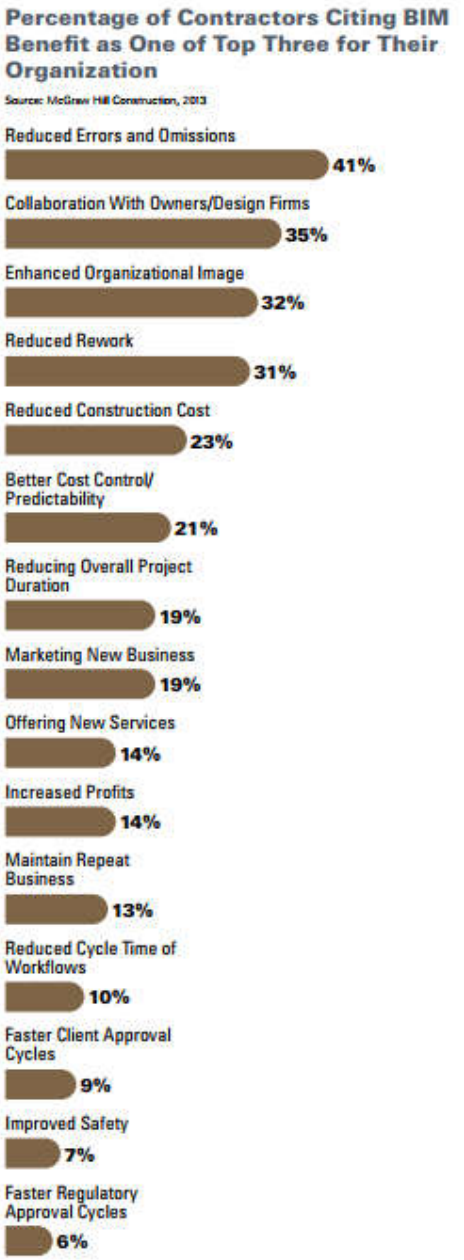


Fig 2.1 Positive ROI for BIM

The greater the BIM engagement by contractors the more positive the ROI. Over a third of those contractors with the lowest engagement however were experiencing negative or break-even ROI.

Contractors were surveyed for the top three BIM derived benefits for their projects. Reduced errors and omissions were the top benefit. Reduced rework also figured highly. Both these benefits lower construction cost and overall project duration which contribute positively to ROI.



The report categorized the benefits into internal, project and process benefits. BIMs ability to enhance collaboration between key team members is its most important contribution to improving the project delivery process. Better cost control / predictability and reduced cycle time for work flows and approvals are also cited as important process benefits of BIM.

The more a company became engaged with BIM the greater their ability to receive the benefits of BIM and realize a strong return on investment. Those with the highest engagement

had a return on investment of over 25% compared with 11% to those who had the lowest level of investment. High engagement contractors had reduced rework of 40% whilst low engagement contractors achieved only 28%.

Balfour Beatty utilised BIM in the construction of the 23 storey , 1001 room Omni Dallas Hotel. Their senor project engineer said "BIM allowed us to explore multiple options as design decisions were being made" and "it made it easier for us to coordinate the project, help the client make more informed decisions, and stick to the tight schedule. Thanks in part to efficiencies in the BIM process….we finished two months early." The team estimated they issued 50% less RFIs on the project. Clash detection meetings were help on-line with subcontractors and resolved quickly. There was also seamless off-site construction as fabrication was based on co-ordinated 3D models. BIM added a high degree of precision to the process where normally there would be a degree of fine tuning and fitting adjustment when OSM materials arrive on site. [23]

ESB International utilize BIM in their substation and windfarm design and construction. Substation RFIs have been reduced by 80% because of the application of advanced clash detection. Health and Safety has been enhanced using the 3D model to provide safe walk through areas avoiding live cables for workers. For windfarms BIM supported software is used to create a 3D model of the sub surface stratum of peat, rock etc. from survey data. From the model cut and fill quantities can be calculated, road embankment slopes determined, transport routes mapped, and hardstanding's designed. [24]

c) To Determine The Barriers To The Adoption Of BIM In The Residential Sectors Current Practices

The main source of information regarding the barriers to the adoption of BIM in the residential market was from the UK. The UK government mandated the use of level 2 BIM on publicly funded projects in 2016. In 2013 the National House Building Council (NHBC) surveyed 18 of the largest house builders in the UK on the awareness and use of BIM. 64% of those surveyed were aware of BIM but not using it whilst 25% of respondents were not aware of BIM. 11% were using BIM but were not using it to its full potential. [13]

BIM4Housing is a task group setup to raise awareness of and develop BIM in the UK housing sector. Nigel Whalley was involved in setting up BIM4Housing and during seminars to promote BIM in 2014 he received feedback from Developers and house builders on why they felt BIM was not suited to them. Most house builders are small or medium sized and they believed BIM was best suited to large scale projects and BIM benefits were harder to achieve on a smaller scale. Their perception was that standardization, automation and modularization advantages were also best suited to larger companies with multiple sites. Smaller house builders often had irregular and fragmented landbanks which they believed precluded offsite and modular construction and required greater design.

Housebuilders thought the 3D model as too rigid a template to work to when their onsite teams had leeway to procure locally and to adjust overcome site conditions. House builders believed the final built home may not conform to the model. The majority of the house builders operated in the private sector. There was no client driven demand for BIM models and data for FM purposes. The lack of demand also influenced manufacturers targeting the residential market who were doing little to create new information models and BIM data for their products. [12]

The NBS National BIM Report 2017 surveyed non-users of BIM as to what the barriers to BIM adoption are. Those surveyed were principally designers. Reasoning for non-implementation included both internal and external factors. Internally lack of training, expertise and cost were the primary factors whilst externally lack of client demand and projects perceived as being too small to warrant BIM. 73% of respondents cited lack of inhouse expertise and 65% lack of client demand. [15] The first Irish National BIM Survey was published in 2015. It surveyed 100 industry professionals and had a 67% response rate. The top barrier to BIM identified was cost at 66%. This was followed by lack of client demand, lack of inhouse expertise, lack of training and lack of time to get up to speed. [25]

In 2016 post the implementation of the UK mandate the barriers identified in Ireland differed. Lack of client awareness of the benefits of BIM was the main barrier. This was followed by a lack of capability of small and medium enterprises to implement BIM which was no doubt influenced by a BIM skills shortage cited. The lack of standardised framework for BIM in Ireland together with liability and legal issues were also hindering BIM implementation. 66% of those surveyed believed Ireland should mandate BIM. [26]

The National House Building Council (NHBC) foundation had identified a shortage of professionals with BIM modelling skills as a factor affecting BIM implementation in the housing sector. Training existing staff would incur costs as would the purchase of new software and hardware. Some of the larger software packages required new

higher specification hardware. This hardware was not commonly used in the house-building sector. [13]

The housebuilding sector in the UK is similar to Ireland and the barriers experienced there are likely to be mirrored here. Ireland has only recently emerged from an economic recession. There is currently a large emphasis on increasing the supply of housing to meet current demand. Many workers have left the construction industry in Ireland to work abroad or in other sectors. It is a difficult time to for housebuilders to implement BIM and expand output when current processes have proven delivery.

d) To Critically Evaluate The Transferability Of The Commercial Construction Benefits To The Residential Sector

Having reviewed the BIM benefits realized in the commercial sector it is important to evaluate their transferability to the residential sector.

Reduced errors and omissions together with reduced rework have been highlighted by commercial contractors as top project benefits of BIM. The Meadows regeneration scheme by Nottingham City Homes (NCH) was the first social housing scheme to be built in the UK using BIM technology. [16] Designing the building using BIM meant fewer corrections had to be made when construction started. The designers were able to ensure everything fitted and functioned correctly prior to construction commencement. Early engagement and collaboration between team members showed up any clashes between trade disciplines on the 3D model which again allowed changes to be made which would have been costlier at construction stage.

Better Cost Control/Predictability and reduced construction cost. NCH built another similar sized development Cranwell Road in parallel with the Meadows using traditional methods and the same contractor. With the BIM model of the Meadows, accurate materials schedules were produced. At tender stage, price differential between first and second place tenderers was under 2%. On traditional projects this would be upwards of 3%. The cost certainty on the BIM project gave the NBC the confidence to reduce the contingency from 10% to 5%. 4.9% of this contingency was spent whilst on Cranwell Road the contingency remained at 10% of which 9% was spent. On a per unit basis the Meadows cost 5% less than Cranwell Road. The head of regeneration at NCH commented that The Meadows was the cheapest scheme they had ever built. [16]

BIM offers visualisation as a new service to clients and owners. At the Meadows tenant were allowed conduct a walk-through of the development on an iPad prior to construction. NUbuild a modular home builder allows prospective buyers to select their plot and then create their home using specialized software with a range of options for open/closed plan layouts, number of bedrooms, level of specification for doors, floors, sanitary, kitchen and wall finishes. Buyers can configure their home via the website from the comfort of their own sofa and the software calculates the additional cost of nonstandard choices and additions. [27]

e) To Recommend Possible Contributions That BIM Can Make To The Provision Of Multiple Occupancy Units

The Rebuilding Ireland Action Plan published in 2016 targets annual residential construction of 25,000 houses and to deliver 47,000 social housing units to 2021. Increasing the level and speed of delivery of social housing and increasing the output of private housing to meet demand at affordable prices are two pillar objectives of the action plan. Two of the key actions to deliver more private housing were '*efficient design and delivery methods to lower housing delivery costs*' and '*measures to support construction and innovation skills.'* [1] The action plan does not cite the use of Building Information Modelling. The Energy Performance of Buildings Directive requires all buildings to be Nearly Zero Energy Buildings (NZEB) from 31st December 2020. "*The NZEB process aligns closely with offsite construction*" [2]

In the UK London needs 50,000 new homes per annum. Currently housebuilders and developers deliver 50 to 60% of this target. (London Assembly, 2017) Through the affordable homes program and innovation fund the Mayor of London has signalled support for off-site manufacture. (OSM) "*Designing for manufacture is increasingly assisted by technology, namely Building Information Management (BIM) software. "... "OSM offers a route to delivering homes that can be built to higher sustainability standards, with potential advantages in terms of build quality, speed of delivery, construction health and safety, energy-in-use, whole life carbon footprint and reduced transport pollution."* [28]

Several case studies from the London assembly report on OSM utilise cross-laminated timber (CLT). CLT is an engineered wood building system comprising layers of boards glued together under pressure with the grain of the boards in one layer running perpendicular to the grain in adjoining layers. it has high strength and dimensional stability and can be used with or as

alternative to concrete, masonry and steel in many building types including multi-storey buildings. [29] Dalston Lane is the world's largest cross-laminate timber (CLT) building. It is a ten-storey mixed use development with 121 homes, 3500 m2 of office space and 1500 m2 of retail and restaurant space. The external party and core walls together with floors and stairs are all constructed of CLT. It weighs one fifth of a concrete building of the same size. The CLT building saved 2400 tonnes of carbon compared to a concrete building. Nubuild can deliver 300 modular homes per annum from its purpose built 75,000 square foot high tech factory in Basildon Essex. Nubuild delivers a modular home in six weeks… half the time of a traditional build. It manufactures its modules in cross-laminated-timber (CLT). CLT is used as it is capable of being manufactured to high tolerances, is structurally stable and can achieve high levels of airtightness. The BIM model is used for digital fabrication and the 5-axis machine cuts out all door, window and service openings with an accuracy that would be difficult to replicate on site. Cost savings of 10% are anticipated on production of 100 homes per year increasing to 15 to 20% on full capacity of 300 homes per year. Time saving is estimated to be 50 to 60%. The combination of BIM with offsite manufacture and the use of CLT all contribute to these savings. The project 'Innovation in Irish Timber Usage' had an objective to investigate the suitability of Irish grown Sitka spruce for the manufacture of cross-laminated timber panels and to develop the necessary engineering data to support the commercialisation of Irish made CLT. The outcomes of the research were the viability of using Irish Sitka spruce had been established. Between now and 2035 it is estimated that the roundwood supply from Irish forests will double to 7.3 million cubic metres. Currently 10.7% of Ireland is afforested whilst the EU average is 40% so there is potential to grow this sector. [38] CLT comprises several layers of board making it feasible to use small diameter trees. These trees previously had little commercial value and would have been removed as part of forestry thinning. CLT now provides the opportunity to produce a high value product. This presents new opportunities for the Irish timber in home and export markets. [30] A small CLT manufacturing facility costing €5 million was established in Spain in four years including European approval of its product. [39] The fire performance of CLT has been researched and tested. This allows safe fire design with the thick section sizes of the panels achieving an inherent fire resistance with a charring layer. A CLT building fire resistance can be improved with gypsum boarding and sprinklers. The use of CLT in Europe is regulated to standard EN 16351:2015. The use of CLT in Ireland has been limited compared to the UK. The main constraint to its use is the current building regulations relating to fire safety. Technical guidance documents limit the use of combustible building materials. A change in the building regulations to allow performance-based design would allow the use of CLT in multi-storey buildings. A performance-based design would mean the national fire performance targets would be specified and the designers would be required to demonstrate that the building meets those requirements. [31]

The government plans and directives require more homes to be built, at a faster rate, to improved standards and at an affordable cost.

Current market conditions provide an opportunity for BIM in conjunction with OSM to provide multiple occupancy units for several reasons.

- Speed of construction and delivery: Berkeley homes had units delivered in 10 weeks compared to 40 weeks using traditional methods at their Urban House Kidbrooke site. [28] OSM homes are quick to build and therefore quick to generate rent.
- Lower labour input: OSM can reduce labour input both onsite and in the factory. Timber frame construction is estimated to reduce labour by 25% whilst labour onsite can be reduced by 75% using modular construction. [28] Highpoint, a 7-storey block of affordable rented accommodation developed by Mace in CLT required just eight installers on site compared to 'a concrete gang of about 25 and an army of steel fixers, concrete formwork chippies and back-propping gangs' [32]
- Environmental Performance: OSM can lead to improved environmental outcomes. Rosie Toogood , CEO of Legal & General Modular homes who manufacture in CLT said ' *We believe the way we are designing and precision manufacturing these homes makes them more airtight and delivers homes of a higher quality ...which are more energy efficient….the factory-manufactured environment allows us to look at innovations in the way energy is captured and stored to be able to take homes off grid and deliver new energy solutions*. [33] Gas bills were reduced by up to 80% and water by up to 30% on Berkeley's CLT Urban House in Kidbrooke. Dalston Lane CLT building saved 2400 tonnes of carbon and its embodied carbon was 2.5 times less than a concrete building of the

same size. The building structure is carbon negative. [28] The BIM 3D model has enabled precision manufacturing and energy use simulations.

- Less Waste: Precision factory manufacturing using standardised components leads to less waste generation. Deliveries to site are also reduced dramatically leading to less noise and traffic pollution. At Dalston Lane site deliveries were 80% less than a traditional build. The 3D model enables precision manufacturing when linked CNC machinery. Building the model virtually allowed for the optimum schedule of deliveries. [28]
- Cost: Digital construction combined with OSM provides more cost certainty as clashes and errors are corrected at design stage and there will be better quality control when manufacturing in factory conditions. With 4D and 5D BIM the integration of construction scheduling, cost planning and cost management with the 3D model can provide cost outcome certainty to both clients and contractors. BIM also allows consideration of the lifecycle costs reducing the ambiguity of maintenance costs.

Build Offsite a UK Business organisation that promotes offsite construction methods recognises the value of BIM in offsite construction. “BIM is a tangible mechanism to encourage the consideration of offsite solutions as early as possible in the project planning process.”. [34] In the paper BIM and Offsite Manufacturing: Recent Research and Opportunities they review how BIM has helped overcome the traditional construction barriers to offsite construction. [35]

- Information Technology: OSM requires a high level of Information Technology integration for streamlining its processes. BIM models have that capability.
- Image: In the past “Prefab” systems have a poor image and reputation. BIM helps OSM be recognised as a modern method of construction. BIM promotes better control pre-construction and manufacture. Visualisation can provide assurance to clients and financiers of the merits of OSM.
- Design: Traditional Designers and Contractors do not have experience of OSM. From a design perspective 3D and 4D modelling enhances communication and visualisation allowing for better design, structural analysis and MEP coordination. For contractors the whole assembly can be visualised, and difficult operations sequenced virtually prior to construction. The parametric modelling of BIM objects provides accurate information for contractor to work to.
- Modifications: Prior to BIM, changes to accommodate site conditions or client changes were difficult to implement. BIM visualisation allows clients to have walk throughs prior to any construction and make desired changes. The models position on site can also be previewed and adjustments made to overcome site conditions. Parametric modelling ensures any changes to an object will automatically update those objects related to it and highlight clashes. This reduces re-work and changes made post construction start.
- Transport: With BIM an objects attributes are fully known. Large components can be made into smaller sub-components which are easier for transportation. BIM can provide simulations for re-assembly. BIM 4D scheduling improves logistics planning at every stage from manufacture to transport to installation.
- Lead times: BIM has helped overcome longer lead in times for off-site components. Improved collaboration, scheduling, visualisation and better logistics all contribute to shorter lead in times.
- Higher Capital Costs: BIM enables monitoring and control of construction costs. In the 2011 Smart Report on Prefabrication and modularisation McGraw Hill reported 17% of users of model driven prefabrication cited cost savings as their primary driver. Early collaboration, clash detection and design freeze, reduce design fees as the need for rework is minimised. BIM also improved training through sequence visualisation which improved productivity and lowered cost. [36]
- Poor Aesthetics: Offsite Construction has borrowed heavily from the manufacturing industry where architectural design is not prominent. BIM allows designers to present different model views using a multitude of finishes. The variety and speed at which these views can be produced over traditional 2D drawings allows for more experimentation and informed decision making.

The author has focused on the use of CLT in the offsite manufacturing process. It’s an engineered timber which can be precision cut allowing ease, speed and accuracy of construction

with simple connections. It is lightweight in comparison to concrete and steel and therefore reduces plant and labour on site. It's of parametric design and has valuable environmental benefits of carbon sequestration, sustainability, airtightness, good thermal insulation and mass values and end of life re-use. [39]. As a material it optimizes all the functionality of BIM from its ease of precision cutting to scheduling it delivery and erection on site through to its environmental performance analysis and life cycle costing.

There are some notable barriers to OSM

- Lack of Demand: Offsite manufacturing requires up-front capital investment to build the facility. There needs to be continuity of demand to justify the initial investment.
- Financing: OSM requires greater initial financing than traditional build. Banks may be initially reluctant to lend for a new process until it has proved itself.
- Insurance: Insurers may be reluctant to provide insurance for modular homes until there is a design code and certification process in place.
- Design Code: The absence of a design code for manufactured housing may make local authorities and housing associations nervous about adopting the process.
- Scale: OSM advantages are dependent on scale, standardisation and continuity of demand. Most house builders are small to medium enterprises who do not have the volume of work to justify investing in OSM.

Barriers to the use of CLT include;

- Supply: There are no manufacturers of CLT in Ireland, so supply is dependent on imports.
- Fire Regulations: Existing fire regulations limits the use of combustible materials.
- Design Co-ordination: Early design co-ordination is required for panelised construction as all window, door and service openings must be factory formed. Openings set too close panel edges could be subject to damage in transportation.
- Damp Proof Course: Use is limited to above dpc.
- Weatherproofing: Requires external cladding or render for weatherproofing.

V Interview Analysis

The author conducted interviews with the following personnel involved in housebuilding and those of relevance following the literature review. These included

Local Authority - BIM Manager
Local Authority – Executive Architect
Local Authority – Chief Fire Officer
Building Contractor – Managing Director
Building Contractor – Contracts Manager

The Chief Fire Officer was chosen to give an insight on the use of combustible materials and performance-based design with queries arising from the literature review. Both local authority interviewees were tasked with BIM implementation in their respective organisations. The Managing Directors' company are involved in both public and private sector housing so could give an insight on BIM in each sector. The Contracts Manager had completed two BIM projects for a local authority.

The authors main observation from the interviews was that BIM is in its infancy in the residential sector. With the local authorities there is not a coordinated approach. One authority had a definitive implementation plan whilst the other specified BIM as a prerequisite for tendering but in practice was using BIM for data collection only. Changing people's mindsets to implement BIM was proving difficult. There was resistance to upgrading and sharing software from both architectural and IT departments. The LA was extremely cautious regarding the legal implications of BIM. Both LAs believed greater cost control, visualisation and improved FM were the key benefits of BIM.

Building contractors would implement BIM when there was client demand, or it was mandatory. There was no evidence of developers seeking to implement BIM of their own accord. One developer had not used BIM as his architect had never requested it to date. The general attitude was traditionally building was working so there was no incentive to change it. They believed BIM being of more benefit in offsite construction. Lack of proof of a positive return on investment was hindering BIM implementation. Training needs and an overhaul of company processes were also seen as a barrier. There was an acknowledgement of a lack of BIM skills throughout the companies, so they would be starting at a low base. Contractors with mixed portfolios saw BIM in housing being implemented as a drip down from their commercial projects. Compared to the literature review the house builders main concern was compliance with government implementation and they did not voice opinions on the suitability of BIM for housing.

The housebuilders interviewed had not engaged in offsite construction however both local authorities had. As with BIM they had different levels of engagement from each other with one authority requesting offsite construction in design

and build tenders for low level housing as part of its rapid build initiative whilst the other was more proactive in reviewing modular construction techniques for mid-rise construction. One local authority expressed an interest in acquiring an OSM facility but believed Government and EU procurement policy would hinder its use. The LA has since interview requested bids for factory built volumetric apartments with an estimated value of €950 million.

The interviewees had not used CLT previously but were impressed with its attributes as a material and its use in panellised and volumetric construction. A local authority had previously experienced difficulty getting a performance-based design approved. The Chief Fire Officer confirmed this was the norm as did the literature review. The LA believed public perception regarding the fire safety of timber would be a barrier to CLT use. The interviewees believed the government should get directly involved in the OSM sector given the housing crisis and their association with Coillte.

There was a small number of interviewees, so the findings of the research may not accurately represent the house building industry in its entirety.

VI Conclusions and Recommendations

This study evaluated BIM and its potential to alleviate the housing crisis in Ireland. The research undertaken has shown that BIM used in conjunction with OSM can provide opportunities to improve housing output. Homes can be built to higher sustainability standards, with the advantages of speed of delivery, build quality, energy in use, carbon usage and reduced labour requirement.

Studies in the U.S. and UK have shown there is a slow uptake of BIM in the housing sector. The government needs to implement a specific strategy for BIM in the house building. or. Public and private providers need to be educated firstly on the proven benefits of BIM and incentives provided for staff training and BIM implementation in the workplace.

Where private developers have social housing obligations as part of their planning permission, BIM should be made a requirement in the provision of these obligations. The local authority involved should be required to work in a collaborative rather than enforcement manner with the private developer to achieve this. Creating this client demand for BIM in the sector will encourage manufacturers, suppliers and subcontractors downstream to adopt BIM.

The need to increase housing output and to meet new energy targets are key drivers for off-site construction. Energy targets will be achieved more easily under factory conditions than building on-site. This should help reduce the cost to house builders of implementing more stringent regulations. The government needs to encourage the construction industry to embrace offsite methods. There is sufficient domestic demand to develop an offsite construction industry and potential to export to the UK marketplace. Tax breaks on capital investments in offsite production facilities should be considered.

Between 2014 and 2017 Irelands largest landlord I-RES REIT nearly trebled its number of state funded tenancies to 2,678 number. The Department for Public Expenditure and Reform in a value for money analysis found in parts of Dublin the State could build houses for half the cost of what it would have to spend on rent for social housing tenants. [37] The government need to take a long-term view on the provision of social housing and increase its direct involvement in building houses.

Cross laminated timber is a material that has had little use in Ireland to date, but it has been proven use in the UK for typical housing and mid to high rise construction in both modular and panel form. Research in NUIG concluded that Irish Sitka spruce is suitable for the manufacture of CLT. The biggest obstacle to its future use in Ireland is the fire regulations which limit the use of combustible materials. A move to a performance-based design approach is required where minimum fire performance targets are specified, and designers demonstrate that their buildings meet those targets. Both designers and fire officers from the UK could provide useful guidance on design of mid and high rise CLT residential for fire safety.

The embodied carbon of timber is low compared to concrete and steel. Carbon is stored throughout CLTs use as a building material. The environmental advantages of CLT combined with its structural properties make it an ideal material for housing. CLT has been successfully used for both panelised and volumetric constructions. It is considerably lighter than constructions of steel or concrete. This advantage allows it to be used on sites where traditional construction with deep foundations would make the site unviable. In Ireland height limits for apartments have been raised at strategic sites which includes railway transportation hubs. As with Dalston Lane it may be possible to construct directly over rail tunnels because of the reduction in weight. CLTs lightness can also allow additional storeys on a new building where concrete design could not. This can improve housing densities in urban brownfield or infill sites. This advantage can also be used on existing buildings. An example in Germany laid a new

CLT slab on existing load bearing external and centre walls under the flat roof block of apartments and an additional two levels of CLT apartments were constructed on top. This provides a low-cost option to avail of new apartment height limits. CLT buildings can be erected quickly and quietly. Deliveries to site are reduced substantially. There is less waste, and dust generated, and on-site labour requirements are minimised. It's a construction process that is friendly to its existing neighbours and ideal for infill sites. CLT is mass engineered timber and must be built above the dpc. A positive outcome to this restriction is the ground floor is constructed in concrete and commercial enterprises are located on this floor with residential above. Co-locating employment with residential reduces travel demand in urban areas. In panellised construction CLT requires no back propping and is ready for follow on first and second fixing immediately.

Coillte is a state-owned forestry and board manufacturing industry with a capacity to manufacture CLT. There exists a further opportunity to vertically integrate offsite manufacturing facilities on location. This would provide rural job opportunities and negate the requirement for construction workers to relocate or commute to urban areas. The author believes the long-term demand for social housing nationally makes a government owned OSM facilities a feasible proposal. Centres of excellence providing BIM and OSM training courses could also be sited here. A modern technologically advanced indoor factory environment with good training may encourage new entrants to the construction industry. In conjunction with developing the OSM facility the government should develop a Manufactured Housing Design Code. A set of criteria and rules for OSM will ensure conformity to standards throughout the industry and provide reassurance to financiers and insurers regarding the OSM product. Best international practice from our peer countries should be reviewed as part of this development. Irish manufactured CLT should also seek European Technical Approval (ETA) to conform to European testing standards. The government should follow the lead of South Dublin County Council (SDCC) which encourages the use of wood as a primary building material where practical in all new and modified SDCC funded buildings.

In conclusion the government is looking to the future with its towards Project Ireland 2040 policy document. At present traditional building methods are failing the housing market and it is highly unlikely future housing output will improve without radical reform and modernization. The government need to kickstart this modernisation by implementing BIM and encouraging OSM in the housebuilding industry.

CLT is a sustainable material that will help us meet our present and future environmental commitments. Coillte have the resources and proven capability to manufacture CLT. Internationally the demand for this product is increasing rapidly and domestically there is enough housing demand to develop an OSM facility for both panellised and volumetric residential construction.

There exists an opportunity for the government to lead us out of a housing crisis rather than depending on the market forces that have failed us presently

VII Bibliography

1. Department of Housing, Planning and Local Government. (2016). *Rebuilding Ireland, an Action Plan for Housing and Homelessness* (pp. 1-113). Dublin: Government of Ireland.
2. English, D. (2018). Damien English's Speech at the Rapid Build Housing Conference - Rebuilding Ireland. Retrieved from http://rebuildingireland.ie/news/minister-englishs-speech-at-the-rapid-build-housing-conference/
3. DKM Economic Consultants. (2016). *Demand for Skills in Construction to 2020*. Dublin: Construction Industry Federation.
4. O'Murchadha, E., & Murphy, R. (2018). Trades and Apprenticeships Skills Survey. The Employers Perspective. Retrieved from https://cif.ie/wp-content/uploads/2018/05/CIF-DIT-REPORT-LOW-RES-2018.pdf
5. Society of Chartered Surveyors Ireland | Construction Tender Prices rise 6.2% in 2017 with 7% increase predicted for 2018. (2018). Retrieved from https://www.scsi.ie/news/view?id=100
6. McMahon, T. (2018). The emergence of Build to Rent – Ireland's Housing Magazine. Retrieved from http://www.housing.eolasmagazine.ie/the-emergence-of-build-to-rent/
7. Department of Housing, Planning and Local Government. (2017). *Lifting our Cities: Minister Murphy unveils initiative to increase apartment output and urban renewal in cities by easing parking and height requirements and encouraging*

more build-to-rent projects. Dublin: Department of Housing, Planning and Local Government.
8. Hamilton, P. (2018). Irish housing supply deficit forecast to continue through 2020. *The Irish Times*. Retrieved from https://www.irishtimes.com/business/construction/irish-housing-supply-deficit-forecast-to-continue-through-2020-1.3577126
9. Government of Ireland. (2018). GOV.IE - Project Ireland 2040. Retrieved from http://www.gov.ie/en/project-ireland-2040
10. autodesk.com. (2017). What Is BIM | Building Information Modeling | Autodesk. Retrieved from https://www.autodesk.com/solutions/bim
11. A Public Sector BIM Adoption Strategy. (2017). Retrieved from https://constructionprocurement.gov.ie/wp-content/uploads/BIM-Adoption-Strategy-Statement-of-Intent.pdf
12. WALLEY, N. (2018). Is BIM failing the house building sector? | BIM+. Retrieved from http://www.bimplus.co.uk/people/bim-faili6ng-hou8se-bu2ilding-sector/
13. BSRIA Limited. (2013). Building Information Modelling: an introduction for house builders. *NHBC Foundation*, *NF-49*(NF-49), 1-15.
14. Wilkinson, P. (2010). The State Of (Construction) Collaboration. Retrieved from https://www.slideshare.net/EEPaul/the-state-of-collaboration
15. McPartland, R. (2017). NBS National BIM Report 2017. Retrieved from https://www.thenbs.com/knowledge/nbs-national-bim-report-2017
16. Brandon, S. (2018). Modelling the future. Retrieved from https://www.insidehousing.co.uk/insight/insight/how-the-first-bim-project-in-social-housing-could-provide-a-model-for-the-future-52464
17. Yusuf, J. (2018). *Investigation into the adoption of Building Information Modelling (BIM) in architectural SMEs in the United Kingdom* (MSc). The University of Salford.
18. Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2008). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers* (1st ed.). Hobeken, New Jersey: John Wiley & Sons, Inc.
19. Society of Chartered Surveyors Ireland. (2017). *Chartered Quantity Surveyors' Perspective on Building Information Modelling*. Dublin: SCSI.
20. Cousins, S. (2018). Can digital tech make work at height safer? | BIM+. Retrieved from http://www.bimplus.co.uk/technology/can-digital-tech-make-work-height-safer/
21. Breaam and BIM. (2018). Retrieved from https://www.bre.co.uk/page.jsp?id=3357
22. McGraw Hill Construction Research and Analytics. (2014). *The Business Value of BIM for Construction in Major Global Markets: How Contractors Around the world are Driving Innovation with Building Information Modelling* (pp. 4-5). McGraw Hill Construction Research and Analytics. Retrieved from https://www.construction.com/toolkit/reports/bim-business-value-construction-global-markets
23. Balfour Beatty | BIM Case Study | Autodesk. (2012). Retrieved from https://www.autodesk.co.uk/case-studies/balfour-beatty-construction-omni-dallas-hotel
24. McAuley, B. (2017). BICP Case Study: ESB International. Retrieved from http://www.bicp.ie/irish-bim-case-studies
25. CitA release First National Survey on BIM adoption in Ireland | BIMIreland.ie | Ireland's Only Dedicated BIM Exclusive Resource. (2015). Retrieved from http://www.bimireland.ie/2015/10/21/cita-release-first-national-survey-on-bim-adoption-in-ireland/
26. BIM Rising: Second National Survey on BIM adoption in Ireland. (2016). Retrieved from http://www.bimireland.ie/wp-content/uploads/2016/11/EI-CitA-BIM-Ireland-2016-Survey.pdf
27. Home :: NU build. (2017). Retrieved from https://www.nubuild.co.uk/
28. London Assembly. (2017). *Designed, sealed, delivered: The contribution of offsite manufactured homes to solving London's housing crisis*. London, UK. Retrieved from https://www.london.gov.uk/sites/default/files/london_assembly_osm_report_0817.pdf
29. ITIC. (2016). Talking Timber. Retrieved from http://www.wood.ie/wp-

content/uploads/2012/01/Cross-laminated-timber.pdf
30. Department of Agriculture, Food and the Marine. (2017). *'Innovation in Irish Timber Usage (IITU)'* (pp. 1-9). Galway: Department of Agriculture, Food and the Marine CoFoRD. Retrieved from https://www.agriculture.gov.ie/media/migration/research/cofordprogramme/finalreports/5FinalReportIITU070917.pdf
31. COFORD Department of Agriculture, Food and the Marine. (2017). *Timber in Multi-storey Construction* (pp. 1-4). Dublin: COFORD, Department of Agriculture, Food and the Marine.
32. Cousins, S. (2018). Is cross-laminated timber coming of age? *Construction Manager*. Retrieved from http://www.constructionmanagermagazine.com/insight/clt-coming-age/
33. House of Lords - Off-site manufacture for construction: Building for change - Science and Technology Select Committee. (2018). Retrieved from https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/169/16904.htm
34. BIM and DFMA | Buildoffsite. (2018). Retrieved from https://www.buildoffsite.com/themes/bim-dfma/
35. Ezcan, V., Isikdag, U., & Goulding, J. (2013). BIM and Off-Site Manufacturing: Recent Research and Opportunities. In *CIB World Building Congress*. Brisbane, Australia: CIB World Building Congress.
36. McGraw-Hill Construction Research and Analytics. (2011). *Prefabrication and Modularisation: Increasing Productivity in the Construction Industry*. Bedford, Mass. Retrieved from https://www.construction.com/about-us/press/prefabrication-and-modularization-increase-productivity.asp
37. O'Callaghan, D., & Kilkenny, P. (2018). *Spending Review 2018 Current and Capital Expenditure on Social Housing Delivery Mechanisms*. Dublin: Department of Public Expenditure & Reform. Retrieved from https://static.rasset.ie/documents/news/2018/07/19.-current-and-capital-expenditure-on-social-housing-delivery.pdf
38. IFFPA. (2016). An overview of the Irish forestry and forest products sector 2016. Retrieved from http://www.iffpa.ie/Sectors/IFFPA/IFFPA.nsf/vPages/Press_and_Publications~iffpa-annual-review-2016-18-01-2017/$file/IFFPA%20Annual%20Review%202016.pdf
39. Taylor, S., & Wilson, P. (2013). *The use of cross-laminated timber in high-density affordable housing and the potential to manufacture this engineered timber product in the Dumfries & Galloway region*. Edinburgh, Scotland: CIC Start Online.