ROBOTICS AND AUTOMATION AS A SOLUTION TO BRIDGING THE UK HOUSING GAP

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The construction sector is reliant on manual labour for the completion of projects. Yet, low labour retention, skilled workers retiring at an alarming rate and falling numbers of graduates joining the sector are all adversely affecting construction capacity and output. Embracing the broader utilisation of robotics and automation is becoming more prevalent through technology-driven approaches such as the use of drones, autonomous machines, and 3D printers churning out new structures. Despite such technologies being considered a potential solution to improving productivity and efficiency, the uptake by the construction sector is not comparable to advances in other industries such as manufacturing and electronics. As a result, this research employs a mixed method approach consisting of 11 content analysis reports and 10 housebuilder surveys. The research aims to ascertain whether or not robotics and automation is being embraced by UK housebuilders, and in what form, and to what extent it is aiding in bridging the gap between current output and desired housing targets. The research indicates that automation is preferred over robotics, with large housebuilders predominantly leaning towards timber and steel frame solutions. However, several internal business conditions have to be met before widespread investment across the industry is likely. Criticism of the house building process, in terms of continuity between targets and local authority development plans, is recognised as a viable obstacle which currently prevents the sector from benefitting from modern technology.

Keywords: Automation, housing, labour, robotics

INTRODUCTION

The housing sector within the United Kingdom (UK) has a reputation for poor performance when compared to Government targets, which is currently set at 300,000 new homes per year (HM Treasury, 2017). However, since 1992 there have only been four occasions when this target has been achieved resulting in a chronic undersupply (HM Government, 2018). Despite Latham (1994) and Egan's (1998) attempts at promoting off-site manufacturing (OSM) in the form of pre-fabrication and modularisation as a way of increasing output, the industry has yet to fully embrace their proposals and have continued to under-deliver when compared to current housing targets. In line with work already carried out into the benefits of employing automation and robotics, this research explores whether or not the housing industry is already embracing or is preparing to embrace the change that is required to bridge the

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ongoing housing gap. In addition, an exploration into the factors that influence housebuilders decisions is also considered.

LITERATURE REVIEW

Poor productivity within the UK construction industry has been apparent for some time. The Department for Communities and Local Government (2017) provides evidence that the past 25 years has seen the UK economy's productivity grow by 41% while the construction industry has only experienced an 11% increase. When compared to other industries, the advantage construction had during the early 1990's no longer exists. There are several factors that contribute to low levels of productivity such as the fragmentation of the industry, the high number of smaller firms, an ageing workforce and the lack of investment in new technologies. Such new technology includes the use of robotics and automation which have been employed within a number of other industries and have demonstrated several benefits when compared to previous performances. However, the investment required for new technologies is significant and there has not been sufficient widespread investment which has led to fewer technological changes when compared to the likes of the automotive industry, consumer goods and home electronics (Fulford and Standing, 2013). Bogue (2013) advocates that as technologies have developed, the automotive industry has been able to use robots for more complex tasks while improving not only productivity but quality too. Michaels and Graetz (2015) concur that overall productivity and output gains can be made by employing automation on a number of tasks. However, given the complexity and uncertainty of construction, when focusing on output gains alone, measures that improve efficiencies may compromise the projects ability to be delivered effectively (Fearne and Fowler, 2006). Efficiency within the construction context is time-based and a measure of the relationship between organisational inputs and outputs which is inherent within robotics and automation (Quain, 2019).

Robotics and automated solutions have the potential to combat some of the existing issues as they can often work faster than traditional labour with comparable quality and no requirement for downtime. In an industry so focussed on health and safety and lost time accidents it is surprising that there has not yet been more interest in automation and robotics due to their potential to improve safety (Nawari, 2012).

Brick laying, for example, is a major part of the housebuilding process and is generally labour intensive to ensure precision and consistency. There are robotic innovations that have the ability to lay bricks such as the FastBrick: Hadrian series of robotics which is accurate to 0.5mm (Bock and Linner, 2016). In terms of productivity, a similar system known as SAM (Semi-Automated Mason) has the ability to lay 1,200 bricks a day compared with a manual workers average of 500 (Sklar, 2015). The benefits that robotics of this nature can bring to the construction industry, not only for their speed but for their quality, consistency and efficiency too, are clear. There have been similar developments of this nature in the past with Mahbub and Humphreys (2005) citing two UK based companies who developed masonry robotics in the late 1970's. While the technology of the 1970's would have been far less complex than today, it is interesting that the technology was not embraced 40 years ago; potentially preventing further development and thus widespread adoption in the current day.

Regardless of the condition of the site before construction, groundworks need to be carried out for levelling, piling or excavation. Currently, this is achieved through land excavators operated by humans. There have been developments in technology which

allow for these works to be carried out using the same excavators but with no need for an operator. Instead, the machinery relies on GPS which allows for an accuracy with 25mm. A main benefit would be the reduced likelihood of collisions/ incidents as the machinery is able to determine its position relative to others.

One particular area where publications disagree is whether robotics and automation will reduce the number of jobs within the industry. The International Federation of Robotics (2017) suggests that less than 10% of all jobs can be fully replicated by a robot but will result in the creation of wealth and opportunities elsewhere; while The McKinsey Global Institute (2017) suggest that the construction industry has the potential to employ automation on 47% of the tasks that are carried out. Berriman and Hawksworth (2017), on the other hand, argue that 30% of jobs (or 500,000) in construction will be at risk. In connection to the types of robotics discussed earlier, they are intended to be used alongside the labourer as they will be responsible for ensuring the robot operates with precision and quality. With humans and robots working in harmony there is the potential for fewer lost time accidents thus increasing productivity and output. As with any new technology there is likely to be investment required and construction robotics and automation will be no different. Ownership, or liability, could also be a potential issue with implementation. As there has been very little information gathered on liability of robotics it is hard to argue either way who may be responsible in the event of a failure; the manufacturer of the robot/automated machinery, the project manager, the person who logged the sequence or the individual overseeing its use. Kelley *et al.,* (2010) highlights that laws relate to the society that we live in today and so there has been very little consideration for human-robotic interactions. Until there is clarity on this issue it is hard to see developers adopting robotics on site. Compliance and insurance issues may also be a limitation to the widespread adoption of alternative solutions with Decker *et al.,* (2013) highlighting that there are extensive statutory, contractual, and performance-based requirements that must be satisfied in order for a project to be considered complete. With innovative methods, there may not yet be the necessary approvals and assurances in place that provide evidence that they are suitable for housebuilding which may influence the direction of all housebuilders.

METHODS

From a theoretical standpoint it is suggested that automation and robotics can positively influence productivity and output within the construction industry. As such, this research is concerned with identifying whether the housing sector is willing, planning or has already pursued alternative off-site, or indeed, on-site solutions in an attempt to meet housing targets and reduce the existing shortages. The research interprets a phenomenon (robotics and automation) on a personal level and uses this insight to develop an understanding of the bigger picture in practice. A phenomenological philosophy with inductive research has been utilised.

A mixed-method research approach was selected to understand the views and opinions of all sizes of housebuilders in the UK. Content analysis was used to assess qualitative publications from large housebuilders, meanwhile, a qualitative questionnaire was developed and circulated to SME housebuilders to gain an insight into their approach. However, while the source of data for this research is largely qualitative, which is in line with phenomenology, the results from each stage will be presented quantitatively with some qualitative aspects to contribute to the validity and understanding of the phenomena (McKim, 2017).

The first stage of the research was to undertake a content analysis using the computer program NVivo. The HMIR (2017) which ranks UK housebuilders, was used as a reliable source for selecting the top 5 large housebuilders. However, as several authors advise against solely relying on convenience sampling (Koerber and McMichael, 2008), an additional 6 housebuilders were determined using purpose sampling in an attempt to create a sample which truly reflects the approach of the top end of the sector. This approach reduces bias and maximises variation thus achieving a diverse study with a number of perspectives. As such, rank 7, 14, 20, 21, 23 and 25 were randomly selected. Annual reports are used by companies to showcase their excellence and performance and so are an ideal source of information relating to current projects and future plans. Table 1 summarises the housebuilder HMIR rank.

Table 1: Large Housebuilders Selected

Company	Rank	No of Homes Built
Barratt Developments Plc	1	17,319
Taylor Wimpey Plc	2	13,881
Persimmon Plc	3	15,171
Bellway	4	8,721
Berkeley Group	5	3,776
Galliford Try Plc	7	3,604
CALA	14	1,151
Kier	20	2,139
Keepmoat	21	2,416
Telford Homes	23	600
Avant Homes	25	1,210

To obtain an understanding of the documents, key words were queried with the corresponding results being assigned to a node. The text queries selected for this research were influenced by themes identified in the literature review and are summarised as; “Automation and Robotics”, “Housing of the Future”, “Innovation, Research and Development”, “Modern Methods of Construction”, “Off-Site Manufacturing, “Skills Shortage and Strategy” and “Government Housing Targets”. The intention of this stage was to identify common themes among large housebuilders with regards to the future strategy and approaches to delivering homes. In addition, it was hoped that it would identify positive advancements being made by large housebuilders in a bid to increase their output and efficiency. Secondly, the results can be used as a benchmark for assessing the approach of smaller housebuilders, therefore facilitating an understanding of the whole industry.

The rationale behind the questionnaire was to target small to medium size housebuilders to understand their viewpoint on automation and robotics. Saunders *et al.,* (2012) suggests that questionnaires are best suited in a method where there is at least one other type of data collection. As over 90% of firms in the construction industry employ fewer than 7 people (Office for National Statistics, 2017) gaining their perspective is essential in answering the research question. The samples gathered for the questionnaires relied on two methods. First was cluster sampling with the initial large group originating from the House Builder Federation Directory yielding 147 contacts. In an effort to gather a sample which represents locations throughout the UK, stratified sampling was used. The NHBC directory was consulted as it filters housebuilders by location. Samples were taken depending on the availability of contact information and a further 158 firms were selected resulting in a

total sample size of 305 SME housebuilders. All 305 questionnaires were distributed, 10 of which were completed, representing a 3.2% return rate. The low response rate perhaps suggests that SME housebuilders do not wish to engage in discussions surrounding automation and robotics.

RESULTS

The term "automation" showed in Taylor Wimpey and Barratt reports, respectively. The surrounding context suggests that Taylor Wimpey are considering several alternative methods with their focus being timber frame. Similarly, Barratt is developing automated solutions to improve speed and consistency; two of the many benefits of automation (Fulford and Standing, 2013). More results were expected but given the variety of names given to modern solutions it is no surprise there were only 4 results.

The sole reference to "robotics" was from Kier. The context of which is not directly related to housebuilding, but it does refer to using robotics to improve safety. As no other large housebuilder directly referenced construction robotics, it is a fair assessment that the application of on-site robotics is not yet at a stage where the industry is prepared to trial it. Nine out of ten questionnaire respondents said they had never heard of on-site construction robotics while the remaining housebuilder referred to a masonry robot being used in controlled trials. One of the respondents went on to suggest that "robotics will be the natural evolution of OSM assuming it proves to be an industry-wide success", but given that this was a minority view, it should not be taken as conclusive. Again, the application of robotics is possible in theory, as highlighted by The Mckinsey Global Institute (2017), but the many constraints to its application in the real world prevent it from being a feasible and widely available option for UK housebuilders. Six housebuilders referenced the term "future" with the majority being in the context of the direction of the organisation based on the use of different methods. A particularly interesting reference is from Galliford Try, "we see a strong future for on-site construction but there is a slow evolution towards manufacturing partly or wholly off-site". Galliford Try delivers over 3,500 homes yearly, which is approximately 2% of 2017 completions. If they have the finances to invest in OSM, but choose to not fully embrace it, it might suggest that there are other constraints that need to be satisfied before the industry can benefit from adopting OSM.

When asked about their thoughts on the industry's willingness to adopt new methods, there was overwhelming agreement that the industry is open to change. However, the biggest caveat to the widespread implementation of modern methods was that the technology had to be fully developed, compliant and financially beneficial. However, while this result may appear positive, the fact that OSM has been available for a number of years, yet it has taken until 2018 for it to be partially embraced may suggest that the industry is not as open to new methods as it thinks it is. With regards to future plans, 8 out of 10 returned questionnaires highlighted that housebuilders were planning on adopting more OSM in the future. "Innovation" gave the second highest frequency at 23 with almost 50% coming from Kier and the remainder from 5 other developers. The main focus appears to be finding innovative solutions to overcome persistent issues. Additionally, operational efficiency and safety were also key drivers behind the push for innovation. Investment in new technologies is costly, which the Government is aware of given their £205m planned investment in innovation. Kier has an estimated £30m R&D spend which will benefit their

operations and hopefully the rest of the industry in the near future. R&D is central to increasing the number of homes being completed and the UK Government is seeking methods to speed up the delivery of housing via a review of build rates. The National House Building Council (2018) states that 160,606 new homes are registered to start, up 6% from 2016 and the highest number since the start of the financial crisis in 2007.

"MMC" delivered 16 references from 6 housebuilders. Persimmon has the most references due to their investment in Space4, an MMC which "address three main challenges in housing delivery: Affordability, energy efficiency and construction industry skills shortage". Telford Homes referred to MMC as "an area of focus" and directly mentions the Government and how the industry is being encouraged to pursue modern methods. Barratt Homes discussed MMC trials including timber and steel frames. Both ends of the spectrum reported on MMC with Barratt Developments (Rank 1) and Avant Homes (Rank 25) making specific references. As large housebuilders begin to invest in MMC, it is possible to build up to four times as many homes with the same onsite labour required for one traditional build making it a potential solution to deliver the additional housing that is needed by the country.

"Off-Site" was referenced 20 times from 8 developers with Persimmon having 9 direct references. The results were able to identify some of the motivations for the large housebuilders to adopt off-site manufacturing. Interestingly, there was no mention of increasing output, instead, efficiency appears to be the biggest motivation. It may well be that increasing efficiency allows for more developments to be completed throughout the year thus leading to higher output. However, the housebuilders did not explicitly state this.

When asked about whether their organisation used any form of OSM, 7 of the 10 respondents said they had used it to varying degrees. The 3 which did not use it referenced insufficient output, cost and required finish as justification. The most common form was timber frame at 5 references, followed by prefabricated timber roofing (3), floor cassettes (2), light gauge steel frame (1), precast concrete foundations (1) and pre-fabricated bathroom pods (1). As identified by Fleming (2018), timber frame is competitive in terms of cost which may indicate why it is a chosen preference for SME housebuilders. Of all the MMC's available to SME's, CLT did not appear as a result. Given the reasons for adoption, it is perhaps not a surprise that this option is not a primary focus for SME's as it can be costly (Sutton and Black, 2011). While modularisation is an area of focus for large housebuilders, it would appear, from the results of the questionnaire, that SME's are less keen on the idea.

The consensus between the respondents appeared to be that using OSM was not for increasing output and there was no defined benchmark for them to judge their performance against. Further, the output of small builders varies year on year and so it is hard to solely attribute increased output to the use of OSM. Given the response to this question, there are concerns that the increase in output, productivity and quality demonstrated in other industries (Michaels and Graetz, 2015) may not translate positively to the housebuilding sector. Speed of construction was identified as the most prominent benefit, followed by quality, reduction in waste, H&S, planning and logistics, and cost. In terms of drawbacks, cost had the highest frequency with some discussion surrounding acceptance and compliance of OSM and logistical and planning issues. Taking both parts of the research together, it would appear that warranty and mortgage providers are wary of the use of new methods simply due to it

being different to tried and tested methods. The literature review introduced liability is a potential issue with the application of robotics (Kelley *et al.,* 2010) and so to a certain extent it would appear from the responses that a similar issue is present with particular MMC's. The trials carried out by large housebuilders will hopefully provide a level of assurance to not only SME housebuilders but other interested stakeholders too, providing the opportunity for new and innovative methods to be encouraged and welcomed. The UK Government has pledged its support to increase the use of offsite construction to help address the challenges. This commitment is reinforced by the House of Lords (2018) committee report into offsite manufacture which called for a radical overhaul of the construction industry in order to increase the number of homes being built.

This query gave the highest frequency at 42 with a total of 9 of the 11 large housebuilders referring to it. The term "shortage" was used within the context of housing and skills (labour), which is consistent with the figures and arguments presented by NHBC (2017), Farmer (2016) and Griffith and Jefferys (2013). There were a number of outputs following shortage which include the development of schemes for new employees in the industry as well as expanding on the extent of the housing shortage. Large housebuilders have the opportunity to invest heavily in skills and housing solutions and so the results from this query are positive. They suggest that large housebuilders are not only aware of the issues in the industry but are going to some lengths to tackle the problems related to all forms of shortage, which is in line with the recommendations made by Farmer (2016) and Barker (2004).

There was general agreement among the questionnaire respondents that sourcing labour was an issue. Only one of the respondents explicitly mentioned that they employ their own labourers and so it can be assumed that the rest of the respondents relied on sub-contracted labour. Interestingly, only half of the responses suggested that their organisation is addressing the skills shortage through the use of apprenticeship and graduate programmes. So, while they agree there is a skills shortage, not all of them are prepared to invest in order to overcome the problem. This may partially explain why the industry does not always achieve in encouraging young people to work in the industry and so perpetuates the issue of an ageing working population leading to poor productivity and output. This result is consistent with Farmers (2016) report which identified that while apprentice numbers are rising, the increase is not translating to more 16-19-year olds pursuing careers in construction.

The questionnaire asked SME housebuilders about their opinions of Government targets which gave a true insight into whether housing targets will ever be met. Of the 10 respondents, only one said its output was influenced by Government targets. There seemed to be a common theme among those sampled that business needs are the priority of housebuilders, rather than continually increasing the UK housing stock. 7 of the 10 respondents suggest that housing targets are nothing more than made up figures, with no clear linkages between Government targets, local council development plans and housebuilders. "There is often a lack of development due to council and local Government bureaucracy" (Respondent 2); "it would be foolish for us to dramatically increase our output to satisfy arbitrary Government targets" (Respondent 3); "...the Government really don't understand the housing industry and have not put in place any tangible measures to help developers meet that demand" (Respondent 5). Furthermore, it was evident that the industry is not structured to meet the demand and whist housebuilders would like to increase their output and turnover,

councils and local communities are wary of change which slows progression. "Government targets are ideals and are totally detached from reality. The Government wants X number of homes per year, but local councils can make it so difficult for developers to actually develop" (Respondent 7). It was also suggested that additional investment and support is required to encourage SME builders to increase their output. None of the housebuilders questioned mentioned the recent Government investment of £15bn for housebuilding or £204m for innovation and skills improvement; suggesting that A) they are not aware of it, B) they are not eligible to benefit from the investment, or C) there is no clear indication as to how the investment will directly benefit housebuilders.

CONCLUSIONS

The results of the content analysis are interesting as they show a focus towards off-site manufacturing and modern methods of construction, rather than robotics. It is clear that there are a number of options available and that the housebuilders are undertaking trials to determine which will best meet the needs of their business. It would appear that timber framing is at the forefront of the large housebuilders focus, followed by steel frame. However, one thing which is not clear from the analysis is the true motivation as to why housebuilders are investing and trialling new technologies. The results suggest that efficiency is a reason, but the issue remains as to what efficiency means to an organisation. There was no clear indication from any of the housebuilders that increases in efficiency on a particular development leads to more developments, and therefore more housing being completed. A similar assessment can be made from the questionnaire results. Timber framing appears to be the solution that small housebuilders are keen on adopting assuming it meets financial constraints and business requirements. Again though, the adoption of OSM is for no reasons related to dramatically increasing output. Further, the SME section of the industry has very little faith in the Governments targets to build 300,000+ homes per year and so will continue with their current approach of building a manageable number of homes that satisfies their business needs.

There were concerns from both samples that while OSM and MMC's bring several benefits, they cannot be fully realised at this point due to several constraints, some of which are brought on due to the current state of the industry while others stem from the fact that new methods are expensive and untested. While there was an increase in newly registered homes in 2016 of 6%, if SME builders do not have confidence that the targets are realistic then the industry will forever be set targets which cannot be met. It would appear from the research that large and small housebuilders are keen to build and invest but the landscape of the industry is not robust enough to support increases in development of up to 50%. The introduction of OSM, or in the distant future robotics, will potentially increase efficiency and reduce time spent on site, but if there are no possibilities of that gain being applied to starting another site then it is unlikely that output will ever significantly increase to meet targets. The current ideal of 300,000 homes per year is unrealistic with traditional methods and given the current development stage of modern solutions, it is unlikely that OSM, MMC's or robotics will contribute to bridging the gap in the near future either.

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