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An Exploration of the Best Value Perceptions of Small Housebuilding Developers towards Offsite Construction

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Abstract: Offsite construction is increasingly being presented as a way to increase housing delivery and reduce the housing crisis. Large developers play a pivotal role in the delivery of affordable homes and therefore offsite construction could be beneficial in alleviating the crisis. Previous Offsite Construction (OC) studies conducted into the drivers, barriers and decision factors provide qualitative analysis from manufacturers and larger developers appear to be taking advantage of the UK government's renewed interest in offsite manufacturing and have begun investing in these methods. However, the role of smaller housebuilding developers in the use of offsite construction systems is rather more uncertain. This research addresses this gap in the literature through an exploration of small housebuilding developers' best value perceptions of offsite construction methods within the UK housebuilding sector. A questionnaire survey was used to ascertain perceptions of the 134 small developers towards the drivers, barriers and decision factors identified in the extant OC literature. Although survey respondents had not widely used offsite manufactured systems previously, the results indicate a high level of agreement with the drivers identified within the offsite construction literature. The respondents identified the buyers' perception of traditional methods as superior to OC systems and creating higher sales figures. Many any of the respondents also believe that best value, and hence maximised profit, higher sales value, and greater returns on investment, is achieved through traditional methods of construction. These two factors combined are more desirable for small developers, rather than the perceived increase in sustainability and efficiency offered by OC systems, due to their positive effect on profit.

Keywords: best value; environmental sustainability; housebuilding; offsite methods

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1. Introduction

In the UK, there is a belief that mass housebuilding's future relies on combining innovative building techniques and creative design [1]. Previous periods of alternative methods of construction have been introduced to increase housing output throughout the 20th century and have been associated with significant benefits [2]. The conclusion of the Second World War emphasised the need for increased housing output and provided a strong push for innovation; as a result, prefabrication was implemented to remove and replace labour intensive skills, and numerous advantages were claimed by those supporting these methods, including increased quality, efficient use of labour, improved working conditions, and cost and time efficiency [3]. However, techniques focused on quantity rather than quality leading to numerous catastrophic failures and a return to traditional methods. The Egan report Rethinking Construction, 1998, revived interest in the potential new systems could have to deliver greater efficiency and quality, but the use of these new systems has not been realised on the scale anticipated [4]. The Centre for London (2019) [5] believes that modern methods of construction (MMC), specifically offsite construction (OC) technologies, subassemblies, panelised systems, and volumetric systems, are thought to increase time and cost efficiency and create more sustainable housing due to controlled factory conditions [2,3].

As large developers including Laing O'Rourke, Legal and General, Berkeley Group and Capital and Centric begin to invest in offsite manufacturing, due to the perception of sustainability, improved speed, and reduced costs compared to traditional methods, there is scope for greater dissemination of these construction methods [6,7].

Traditional construction techniques dominate the UK's residential property sector. The National House Building Council (NHBC), who represent over 80% of new developments in the UK, reported that 70% of new developments were constructed using traditional methods. The remaining 30% used timber or light steel gauge frames, which has been consistent over the last eight years [4]. Several themes have been identified as barriers to the uptake of panelised systems, including systematic issues, processes, regulations, logistical difficulties, resources, and costs [8]. However, a series of initiatives are being developed by the UK government to encourage innovation, and national developers appear to be taking advantage of this renewed interest, but small housebuilding developers have a significant role to play. If best value is believed to be achieved through traditional methods of construction, take-up of offsite manufacturing will continue to be low [7,9].

The global financial crisis of 2008 had an extensive impact on the housing market and the construction industry. Since 2013, growth within the sector has been caused by large companies, contrasting with previous downturns where smaller developers made substantial contributions: for example, in 1998, 40% of homes were constructed by small builders, compared with just 12% in 2017. The building industry is diverse and made-up of developers operating at local and regional scales, and there are various developers trying to build more homes despite thousands being lost to the Global Financial Crisis [10]. A report conducted by the Home Builders Federation (HBF) (2017) [11] identified the reasons for the decline of small housebuilding developers as the Global Financial Crisis, but also the 1990 Planning Acts which placed obtaining planning permission beyond the scope of many small developers. On average, permissioned residential development schemes have increased by 17% in under ten years, making numerous sites allocated in local plans unviable for small housebuilding developers and issues encountered during the planning stage increased delays and risks and affected lender attitudes, leading to growth restriction [10,12]. There is an opportunity through offsite manufacturing, specifically panelised systems, to address some of these issues by supporting alternative delivery methods, supplementing existing capacities and allowing the exploration of other ideas when navigating the development process [13].

Small housebuilding developers miss out on opportunities allocated in local plans, due to the increased size of schemes, and there has been a substantial drop in the total number of houses built by small housebuilding developers in the last 20 years. The benefits regarding efficiency and sustainability of offsite manufactured panelised systems are well documented and suggest housing delivery can be increased through the use of the methods.

This research explores whether small housebuilding developers believe that best value is achieved through traditional methods of construction and OC systems have a future in residential developments at their scale of operation. OC refers to the "planning, design, fabrication, and assembly of building elements at a location other than their final installed location to support the rapid and efficient construction of a permanent structure" [4].

Other terms are used similarly, including prefabrication, offsite manufacturing (hereafter OSM), and modern methods of construction (MMC), which also incorporate innovative onsite methods. OC is being used in this research to encompass methods described in Table 1.

The population of this study is limited to small housebuilding developers and will not consider larger developers who have been identified as providing significant infrastructure for the increased uptake of offsite manufacturing, such as Laing O'Rourke, Legal and General, and Berkeley Group [7]. The NHBC published a list of systems that have been reviewed and deemed acceptable at meeting warranty requirements including technologies such as sub-assemblies, panelised systems, volumetric systems, and site-based MMC [2].

The main focus of this research will be the use and best value perceptions of timber panelised systems within the UK housebuilding sector.

Table 1. Types of offsite construction with descriptions and examples. Adapted from Goodier and Gibb (2005) [14]; and NHBC Foundation (2016) [4].

Type of OC	Description	Example
Components and sub-assemblies	Relatively small-scale items, assembled offsite.	Roof and floor cassettes, prefabricated chimneys, door sets, I-beams.
Open-panelised systems	Large category of items assembled in a factory; units do not enclose a useable space.	Timber frame, light-gauge steel frame.
Closed-panelised systems	Large category of items assembled in a factory; units do not enclose a useable space.	Structural insulated panels.
Volumetric pods	Factory fitted units that enclose useable space which are installed within another construction method.	Bathroom pods, plant rooms.
Volumetric/modular construction	Three-dimensional units which enclose usable space and form the structure and fabric of the building.	Mobile classrooms, forecourt stores, restaurants, permanent homes.

2. The Housing Crisis, Efficiency and Sustainability

There are an estimated 28 million properties available in the UK and those vacant for at least six months has risen to over 216,000 with an estimated market value of £53.6 billion [15,16]. This housing stock is ageing, and repairs increase demands on traditional construction methods, which according to the National Housing Federation is the reason the gap in the UK's supply and demand is widening [17]. Coupled with a shrinking social rented sector, housing benefit cuts and slower wage growth, UK house prices have risen 160% since 1996 [18].

It is accepted that increased supplies will reduce rents, but academic research suggests any increase in supply would not significantly lower house prices. The UK government aims to deliver 250,000 homes a year by 2022, and to do this there is a need for change in the way housing is delivered. Systematic and workforce challenges need consideration and central government has encouraged the implementation of MMC, as evidenced in the Housing White Paper, 2017, which documented the need for assessing the costs of MMC against traditional methods [3,19]. The Housing Forum suggest efficient construction requires renewed focus on quality due to an aging and shortage of skilled workers, faster delivery times, greater productivity, increased flexibility, quicker completion, and increased control [20]. Addressing sustainability, construction methods should increase a building's energy efficiency by producing its own heat or energy, reducing water consumption, and introducing schemes to decrease wastage [21].

3. Background and History of Offsite Manufacturing in the UK Housebuilding Sector

According to O'Neill and Organ and Nadim and Goulding, MMC intend to improve predictability, business efficiency, environmental performance, quality and sustainability [9,22]. However, Nadim and Goulding also suggest adopting offsite manufacturing is challenging and an intricate understanding of the industry's perception of its characteristics is required [9]. The first systematic attempt to raise MMC's profile was the Buildoffsite Property Assurance Scheme (BOPAS), launched in 2013—a database was set up providing details of housing units by scheme with the aim of addressing confidence issues with MMC [13]. Recently, the UK government introduced the Home Build Fund, a £3 bn fund set up to assist small housebuilding developers in increasing use of offsite manufacturing, and the Accelerated Construction Scheme, which encourages developers to use time-saving construction methods. In the latest government budget, it was announced the offsite manufacturing would be promoted through government purchasing powers and

a presumption offsite manufacturing would be adopted where it represented best value [6]. The NHBC found that the second most common form of MMC was panelised systems, as 42% of those surveyed had used them for at least one home [4]. As such, panelised systems have been subject to increasing levels of interest within the construction industry, Thuesen and Hvam [23] found 36 large construction organisations suggested it has a future within the industry and research by Goodier and Gibb identified that 75% of suppliers thought take-up was increasing [24]. Furthermore, Pan, Gibb, and Dainty identified external walls, timber frames, and roofs as the best opportunities for growth [25], as housebuilders believe there is little need for complete modular houses.

4. Drivers and Barriers to Offsite Manufactured Timber Systems

Numerous drivers have been identified for offsite manufacturing increasing efficiency in construction. Time, quality, and cost appear to be the most important factors according to Philip [8]. Furthermore, Pan, Gibb, and Dainty identified the most important drivers as ensuring time and cost certainty, minimising on-site periods, addressing skills shortages and achieving quality [25]. However, Goodier and Gibb (2007) and Nadim and Goulding (2010) found reduced construction times as the number one consideration, with nine out of 13 and 97% of respondents, respectively [9,24]. According to Mesaros and Mandiak (2015), these reduced construction times were created in decision making, choosing materials and construction methods [7].

The RICS who found that offsite manufacturing boosted productivity, allowed faster realisation of projects with reduced risk of disruption, believe when used on a larger-scale costs may be further reduced [13]. The NHBC also observed that housebuilders realised faster construction using offsite manufacturing, additionally, 44% of housebuilders and 27% of housing associations realised improved cash flow, reduced preliminary costs and faster sales [4]. As well as increasing efficiency and reducing construction times, offsite manufacturing had positive connotations for residents who experienced less disruption from nearby construction [1]. Other sustainability benefits are offered and according to previous studies, offsite manufacturing led to increased sustainability performance compared with conventional construction [26]. Pan, Gibb, and Dainty [25] found that benefits included reductions in environmental impact and health and safety risks, and improved life performance, predictability and profits. These results have been reiterated by Pan, Gibb and Dainty (2008) and BSA (2016) [1,27]. Other research has also identified offsite manufacturing as a remedy for waste reduction reflecting Spisakova and Mackova's sustainability definition [21,28,29]. Furthermore, Faludi, Lepech and Loisos (2012) [30] suggest the most crucial environmental design priority of offsite manufacture is reducing operational energy effects. Kamali and Hewage (2016) [31] show studies generally conclude offsite manufacturing outperforms traditional construction methods in terms of environmental sustainability, energy consumption, air pollution and waste generation. However, Thuesen and Hvam (2011) [23] observed previous studies are inconsistent when comparing construction methods, and there is a lack of literature explaining why.

Goodier and Gibb (2007) [24] found that suppliers believe there is a large misunderstanding of offsite manufacturing methods from all sectors of the construction industry leading to break downs in efficiency and a growing believe more education, communication and experience is required. Greater collaboration in design projects is paramount for increasing delivery and usage, including the need for standardisation of terminology and ensuring accurate understanding of its advantages [32]. Pan, Gibb, and Dainty (2012) suggested that it is crucial to establish overall offsite strategies into the development process from the start and sharing of information is required for developers to embrace offsite manufacturing methods and improve efficiency [33]. Pan, Gibb, and Dainty (2008) and Nadim and Goulding (2010) identified factors contributing to problems with uptake were associated to a resistance to change, inadequate processes, technical difficulties in methods used, lack of overall strategy, procurement methods and on-site management [9,27]. Pan, Gibb, and Dainty (2008) highlighted the risk averse attitude towards offsite manufacturing with

42% of housebuilders surveyed planning to maintain current levels of usage [27]. Although, Goodier and Gibb (2007) suggest the demand for offsite manufacturing is growing, the stigma surrounding the methods needs to be overcome through transparent information, especially relating to costs and comparisons with traditional construction techniques [24]. Furthermore, Rahman (2014) found inflexibility for design changes and high initial costs were significant barriers and overcoming cost related problems was identified as crucial for implementing offsite manufacturing [17], an opinion shared by Nadim and Goulding (2010) and Elnaas, Gidado and Philip (2014), suggesting the industry does not appear to fully appreciate the long-term appeals [8,9]. Additionally, Blismas and Wakefield (2009) found perceived health and safety risks increased due to logistical issues and requirements [19].

Offsite manufacturing can provide developers with more options by introducing a new dynamic into traditional construction methods around resourcing, planning and environmental sustainability performance [13]. Yet, Rahman (2014) and Pan, Gibb, and Dainty (2008) argued decisions made when choosing offsite manufacturing over traditional methods are often based on cost rather than value [17,27]. The perception value is best obtained through traditional methods has meant issues including sustainability, efficiency and health and safety are often disregarded in evaluations.

5. Effect on Development Construction

Nadim and Goulding (2010) found 73% of those surveyed believed offsite manufacturing is the future of the UK construction industry, and 65% of respondents believed the industry was ready to accept offsite manufacturing [9]. Further analysis showed this is due to lack of skilled labour, speed, low carbon options, research, measurable track records and satisfaction of client demand, building regulations and government promotion. However, only 33% of developers surveyed were making use of offsite manufacturing, meaning the role of the developer is less certain in deciding whether to use offsite manufactured panelised systems or traditional methods. Evidence from the BSA (2016) differs, demonstrating that developers are accepting of offsite manufacturing, as Legal and General invested GBP 55M in offsite construction factories and Laing O'Rourke have received funding from the government to accelerate the use of offsite manufacturing methods [1]. The NHBC expects the use of panelised systems to increase and the RICS recognises that it can play a crucial role in impacting the problems faced in the UK construction industry [4,13]. There appears to be a general belief that panelised systems have the potential to meet housing demand increases; however, when delivering large-scale building projects, offsite manufacturing has gained a stigma due to the complications encountered [17].

6. Critical Appraisal

The literature conducted from 1998 to 2008 is positive, there is an awareness of offsite manufacturing's potential and positive effect on sustainability and efficiency within the residential development sector. Goodier and Gibb (2007) and Pan, Gibb, and Dainty's (2007; 2008) research shows take-up in offsite manufacturing on the rise and a large demand for external walls, timber frames and roofs with many studies showing increased efficiency and sustainability achieved (Kamali and Hewage, 2016) [24,25,27,31]. However, research conducted from 2010 to 2014 shows developers as more aware of the barriers in using offsite manufacturing techniques and greater collaboration between manufacturers and developers is identified by several studies as crucial for improving [8,9,32,33]. However, according to Nadim and Goulding (2010) numerous respondents believed offsite manufacturing was the future of the construction industry and the lack of uptake and demand between 2008 and 2014 [9], can be attributed to many factors, including the Global Financial Crisis which caused the decline of small housebuilding developers [10,34]. Research from 2016 onwards recognises a need for change in housing delivery and highlights a lack of skilled workers, reduced health and safety risks, quicker completion, and lower costs as its reasoning. Several studies conclude increased uptake in offsite manufacturing can

have a significant impact on increasing housing output, although it cannot be the only solution [1,3,13,19,26,31].

The previous literature studied provides a comprehensive and in-depth analysis of the drivers and barriers to the implementation of offsite manufacturing methods and suggests they can have meaningful impacts on the delivery of affordable housing [13]. According to Kamali and Hewage (2016) previous research concludes that offsite manufacturing outperforms traditional methods of construction but Thuesen and Hvam (2011) found inconsistencies between study's conclusions and comparisons of the methods [23,31]. There appears to be a large belief offsite manufacturing has a role to play moving forward by manufacturers, policy makers and contractors. However, there appears to be a lack of take-up from developers and although this view seems to be changing for larger developers, the role of small housebuilding developers still requires consideration as the Ministry of Housing, Communities and Local Government (2019) shows low levels of offsite manufacturing applications by developers [1,9,11].

7. Research Methodology

7.1. Research Aim

The purpose of this study is to investigate why small housebuilding developers believe best value is achieved through traditional methods of construction and whether the use of panelised systems would allow them to develop more housebuilding schemes. The study also provides an opportunity to extend the research carried out for larger developers [35] to a sample of smaller-scale housebuilders in the UK.

7.2. Research Objectives

1. Explore why offsite manufacturing has become subject to increasing levels of interest within the construction industry, including panelised systems and investigate the current degree of utilisation of panelised systems by small housebuilding developers working on local and regional scales.
2. Identify to what extent small housebuilding developers perceive the benefits and barriers to offsite manufactured panelised systems for use on their residential developments.
3. Investigate why offsite manufactured panelised systems are not being utilised in the UK by small residential developers.
4. Analyse whether there is demand from small residential developers for panelised systems in the UK and whether systematic, regulatory, logistical, and economic developments would result in greater use.
5. Examine small developers' thoughts on the future of offsite manufactured panelised systems on their scale of operation, and whether they are a viable means of increasing efficiency and sustainability in their residential developments.

7.3. Research Design

Qualitative research is subjective, and its purpose is to determine a precise statement of the research via diagnosis, determining alternatives and discovering solutions to a problem. Focusing on descriptions and experiences it is typically conducted where there is limited knowledge on the area of research using the interview technique [36]. Due to the impact of COVID-19 pandemic, conducting semi structured interviews with small housebuilding developers would prove more difficult than initially thought. It was therefore proposed that conducting a questionnaire with a qualitative focus would provide similar types of information and reach a wider audience.

Open-ended questions were used to allow for flexibility in responses and discover as much as possible about the specific issues relating to efficiency and sustainability and the future of construction for small housebuilding developers using panelised systems [36].

7.4. Sample Design

Selected sampling is commonly chosen when conducting qualitative research as respondents need to have knowledge and experience on the subject area. Offsite manufacturing is a relatively new construction method, and a selected sample of respondents was thought to be more appropriate than random sampling [36].

7.5. Population and Sample Frame

The population of this study consists of small housebuilding developers working on a local or regional scale. This population has been chosen due to the role small housebuilding developers play in UK housebuilding and the effect they could have on the increased use of panelised systems. The sampling frame for developers was the Home Builders Federation (HBF) Directory housebuilders members list, which included 209 small-scale housebuilding development companies [10]. Only responses from developers acting on a local or regional scale were used in the analysis.

7.6. Survey Instrument

A questionnaire was developed based on the findings from the literature review with the aim of investigating developers' perceptions and utilisation of panelised systems on increased efficiency and sustainability, in residential housing and why traditional methods appear to achieve best value. The survey included four sections:

- Section A: General information about the respondent and extent to which they currently implement panelised systems in housebuilding.
- Section B: Perceptions of the drivers associated to the uptake, utilisation, efficiency, and sustainability of panelised systems within the residential development sector. Measured using a seven-point Likert scale.
- Section C: Perceptions of the barriers associated with the implementation of panelised systems within the residential development sector. Measured using a seven-point Likert scale.
- Section D: The identification of decision factors in material choice for developments and examination of requirements of future implementation of panelised systems for small residential developers.

8. Research Procedures

The following procedure was carried out to collect data and discuss the research objectives. A comprehensive literature review conducted into the UK's housing crisis and current usage of offsite manufactured panelised systems identified themes and trends from previous research and informed the present study. The information on the drivers, barriers and decision factors used in the selection of panelised systems for housing developments from the literature review was used to design a questionnaire written in four sections. Developers from the HBF Directory were selected and emailed the questionnaire and a consent form to fill in. In line with previous research conducted [35] their responses were recorded into Excel Spreadsheets and analysed using the following analytical methods, to inform the discussion of the research objectives.

8.1. Analytical Methods

Sections B and C of the questionnaires investigated the respondents' perception of panelised systems using a seven-point Likert scale. The responses for each statement were coded to the numerical options 1–7 with 1 indicating, strongly disagree, 2 moderately disagree, 3 slightly disagree, 4 neutral, 5 slightly agree, 6 moderately agree and 7 strongly agree. Likert scales produce ordinal data and therefore the median (Mdn) and Inter-Quartile Range (IQR) was calculated for each statement. The median is a measure of central tendency and was used to show the most likely response. The IQR is the measure of the data's spread and was used to show whether the respondents views were similar or more varied regarding each statement [37]. The results from this section were used to help

answer Research Objective 3. For Section D, analysis techniques were tailored to suit the qualitative nature of the data collected. The most frequently used method of analysing open-ended questions is to code the data into themes or ideas. The purpose of coding is to reduce the number of individual responses to general categories which are assigned a numerical code and used to critically analyse the study being undertaken [36]. Categories were derived using an inductive approach, analysing data collected with no predetermined theories, structure or framework [38,39]. The data collected were read to identify key themes and categories centring on either; type of behaviour, use of particular phrases or incidents. The process is inclusive and more subjective than quantitative analysis, and rather than reducing data to a few numerical codes, categories are added to reflect as many themes as possible [38,39].

Appropriate responses were used to illustrate the key findings and are accompanied by a discussion linking the data to previous research [38]. A topic-by-topic approach has been found to be more effective with the topic results shown and directly followed by discussion with each other and the previous literature studied [40]. Completed properly, it will provide a rigorous and systematic analysis on whether panelised systems can create more sustainable homes efficiently and help overcome the perception best value is achieved through traditional methods of construction through reference to the gathered data [39]. The views of small housebuilding developers will be examined to determine Research Objective 4, whether there is demand for panelised systems in the UK and whether systematic, regulatory, logistical and economic developments would result in greater use, and Research Objective 5, developers' thoughts on the future of offsite manufacturing and the impact they believe panelised systems could have on their scale of development.

8.2. Findings and Analysis

The HBF Directory has a total of 209 developers Table 2 illustrates that developers were sent emails and 62% were delivered to the recipient. In total, 19% of the developers replied, 89% of them with their consent and the completed questionnaire.

Table 2. Response rate.

	Total	Sent	Replied	Local/Regional	Usable
Developers	209	62%	19%	89%	89%

In certain cases, some of the sections were left blank, and although incomplete, their responses provided valuable insights into the perceived drivers, barriers, and decision factors for use of panelised systems by small housebuilding developers and were included in the results. It is recognised that a higher response rate would have been beneficial to avoid overgeneralisation of the responses in the following analysis.

8.2.1. Section A

Table 3 shows the types of offsite manufacturing used previously by the respondents.

Table 3. Use and satisfaction with offsite-manufactured panelised systems over the past five years.

	Panelised Systems	Volumetric	Site-Based	Other	No Reply
Type of offsite manufacturing techniques used for developments	32%	5%	30%	0%	27%

Overall, 67% had previously used some form of offsite manufacturing: 32% had used panelised systems, 5% had used volumetric systems and 30% had used site-based offsite manufacturing including insulated render systems.

Table 4 shows how many of the respondents had used panelised systems over the last five years and whether they were satisfied with the results. Of the 32% who had previously used panelised systems, only 17% said they were satisfied with the results—the remainder of those surveyed provided no response, as they had no previous experience with panelised systems. It must also be noted that although the respondents worked on a local or regional scale, the number of houses completed in the last year varied from two to 2000. As a result, the responses to the questions in later sections varied between developers building over 50 houses and those building less than ten. The 67% having previously used offsite manufacturing is higher than Nadim and Goulding's result (33%) [9] and corresponds with recent evidence from the BSA (2016) suggesting developers are continually accepting of offsite manufacturing [1]. Even though this is a glimpse of the industry, the results regarding the previous use of panelised systems (32%) highlight that, at present, panelised systems are not widely used by small developers. The NHBC Foundation expected the use of panelised systems to increase [4]; however, 32% is less than the 42% of developers surveyed by the NHBC, showing minor disagreement with their expectation. However, this corresponds with Pan, Gibb, and Dainty (2008), who suggest developers have a risk averse attitude towards implementing panelised systems and offsite manufacturing on an increased scale [27].

Table 4. Use and satisfaction with offsite-manufactured panelised systems over the past five years.

	Yes	No	No Reply
Have any of your developments over the previous five years incorporated the use of offsite manufactured panelised systems?	32%	0%	68%
Were you satisfied with the results?	17%	0%	83%

Table 5 shows the statements' median perception of the drivers towards the implementation of panelised systems by small developers. A median response of moderately agree (6) was found for statement H and slightly agree (5) responses were found for statements A, D, F and K. The remaining statements all had neutral (4) median responses. The IQR indicates the respondents' views on statements C, D, E, F, G, H, and I were similar (1).

Table 5. Average, median, perception of the drivers towards the implementation of offsite-manufactured panelised systems.

	STATEMENTS	MEDIAN	IQR
A	Panelised systems can increase housing output.	5	1.5
B	Panelised systems can prevent the impacts of projected skills shortages.	4	1.5
C	Panelised systems can increase the quality of new developments.	4	1
D	Integration of project processes can provide economic benefits for developers.	5	1
E	Use of panelised systems reduces overall project costs.	4	1
F	Panelised systems can increase the environmental performance of buildings.	5	1
G	Use of panelised systems reduces the overall environmental impacts of construction.	4	1
H	Offsite manufacturing increases employment opportunities away from site.	6	1
I	Use of panelised systems reduces accidents on site.	4	0.5
J	Panelised systems focus on end user benefits.	4	1.5
K	Revisions to building Regulations have a significant impact on the use of panelised systems.	5	2
L	The Government and industry's agenda have a significant impact on the use of panelised systems.	4	2

8.2.2. Section B

Figure 1 shows a bar chart of the percentage levels of agreement and disagreement with the drivers towards the implementation of panelised systems. Interestingly, strong agreement was shown towards eight of the eleven statements identified in the research and statements A and H provided the strongest levels of agreement. For four of the statements, the respondents provided no disagreement, and no statement received a response of strongly disagree (1).

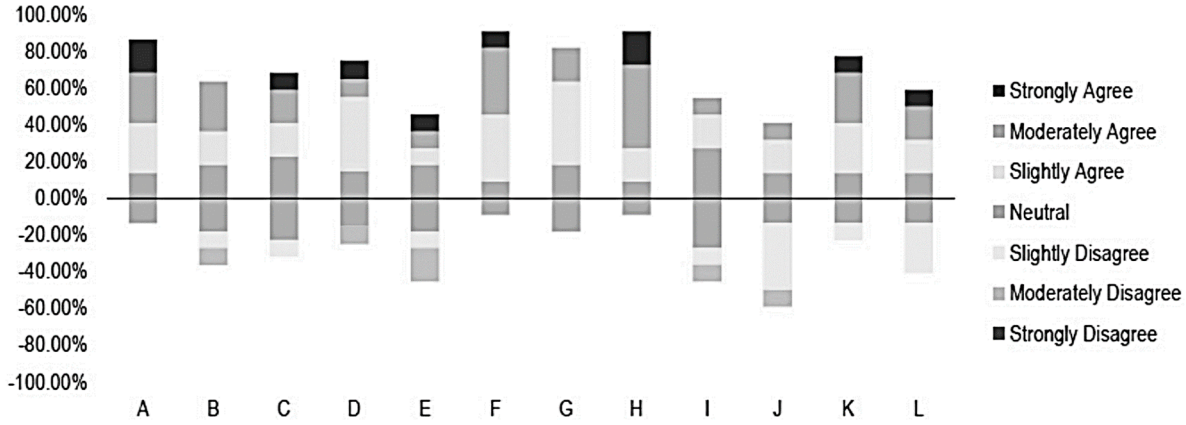


Figure 1. Perception of the drivers towards the implementation of offsite manufactured panelised systems.

Statement J shows the strongest levels of overall disagreement, and E shows the highest amount of moderate disagreement. Both Table 4 and Figure 1 show a general level of agreement with the drivers towards implementing panelised systems in residential development. The response to statement A (Mdn = 5, IQR = 1.5) corresponds with Rahman's (2014) and Elnaas, Gidado, and Philip's (2014) belief that the use of panelised systems had the potential to meeting housing demand increases and numerous research studies have similar conclusions [1,3,8,13,17,19,26,31]. However, the high level of agreement is undermined by respondents' previous usage of panelised systems, suggesting that increasing housing output is not an essential condition for small developers. Median responses above slightly agree were found for statement F (Mdn = 5, IQR = 1), statement H (Mdn = 6, IQR = 1), statement D (Mdn = 5, IQR = 1), and statement K (Mdn = 5, IQR = 2). Each statement has previously been recognised as a significant driver for panelised systems, suggesting that the perception of these drivers has not changed [8,9,24,25]. For statement L (Mdn = 4, IQR = 2) the median response is neutral; however, the IQR is >1, and the same IQR can be seen in the response to statement K.

The reason for the higher IQRs could be because the questionnaire does not reference whether the impact is positive or negative and therefore the respondents may not have fully understood what they were answering. However, as 18% of the respondents identified statement L as the most significant driver, the result suggests correspondence with previous research showing policy makers as the main driving bodies for increasing the use of panelised systems [1,9]. Neutral views were found for statement B (Mdn = 4, IQR = 1.5), statement C (Mdn = 4, IQR = 1) and statement G (Mdn = 4, IQR = 1).

These results suggest that small housebuilding developers would find no difference in using either traditional methods of construction or panelised systems for developments, contradicting previous research which identified them as crucial for increasing up-take [8,9,24,25]. Pan, Gibb, and Dainty (2007; 2008) and BSA (2016) found that panelised systems reduced environmental impacts, health and safety risks and improved life performance [1,25,27]. However, respondents remained neutral on statement I and there was little variation in responses (Mdn = 4, IRQ = 0.5). For statement E (Mdn = 4, IQR = 1), 27% moderately disagreed and the 9% of respondents who agreed strongly stated reduced costs were only realised after developments had been completed, suggesting small

housebuilding developers believe that higher initial capital costs outweigh the potentially lower costs seen later, which was also identified by Nadim and Goulding (2010), Elnaas, Gidado and Philip (2014) and Rahman (2014), who suggest issues in overcoming cost related problems means the industry does not fully appreciate offsite manufacturing's long-term appeals [8,9,17]. The respondents identified the potential for panelised systems to be used in social housing schemes, provided registered providers allow their use as another driver. Additionally, respondents suggest increased speed of construction is an important driver, which was identified by Pan, Gibb, and Dainty (2007) and Goodier and Gibb (2007) [24,25].

Table 6 shows responses to the current most significant driver in the use of panelised systems by the developers surveyed. Overall, 19% believed it was statement B, 15% believed it was statements A, H, and L, 11% thought it was statement F, and 9% believed it was statement K. Each response is backed by previous research, but the varied response shows no one driver standing out. This may provide a reason as to why only 32% of the respondents have used panelised systems previously and why traditional methods continue to be used extensively, echoing Nadim and Goulding's (2010) research [9].

Table 6. Currently the Most Significant Drivers for the Use of Panelised Systems.

	A	B	C	D	E	F	G	H	I	J	K	L
Currently the Most Significant Driver	15%	19%	0%	0%	0%	14%	0%	16%	0%	0%	9%	18%

8.2.3. Section C

Table 7 shows the statements' median perception of the barriers towards the implementation of panelised systems by small developers. The highest median response was found for statement L, moderately agree (6). Slightly agree responses (5) were found for statements A, E, I and K, and the remainder of statements received a median response of neutral (4). The IQR calculations show a much higher spread in individual responses than SECTION B. IQRs >1 were found for six of the eleven statements—B, C, D, F, H, and K.

Table 7. Average, median, perception of the barriers in the implementation of offsite-manufactured panelised systems.

	STATEMENTS	MEDIAN	IQR
A	Culture resistance and poor public perception have a significant impact on the use of panelised systems	5	1
B	There is a low market demand for homes built using panelised systems	4	1.75
C	There is a lack of understanding from local authorities preventing the use of panelised systems	4	1.75
D	A lack of historical data and awareness from financial lenders prevents increased usage of panelised systems	4	1.5
E	Early design freeze is a significant problem for developers	5	1
F	Complex interface and tolerance issues prevent increased efficiency of panelised systems	4	1.5
G	Building Regulations do not cover all aspects of offsite manufacturing and make use of panelised systems difficult	4	1
H	A lack of existing codes and standards relating to offsite manufacturing prevent usage of panelised systems	4	2.5
I	Changes in crane requirements, transport difficulties and site access constraints require more consideration than traditional methods	5	0.75

Table 7. *Cont.*

	STATEMENTS	MEDIAN	IQR
J	Skills shortages and limited expertise in the marketplace hamper panelised systems' use	4	1
K	Limited UK capacity means efficiency is not fully realized	5	1.75
L	Higher capital costs than traditional methods mean increased sustainability and efficiency is often disregarded when delivering developments	6	0.75

Figure 2 illustrates the Perception of the Barriers in the Implementation of Offsite Manufactured Panelised Systems. The responses to statement L (Mdn = 6, IQR = 0.75) found 80% slight to strong agreement, following Elnaas, Gidado, and Philip (2014), who identified cost as a challenging factor to offsite manufacturing [8], however, their research noted the perception of offsite manufacturing would dramatically change if long-term benefits are considered. Another reason the long-term benefits of panelised systems are not considered is partly due to statement E (Mdn = 5, IQR = 1). Statement E's median response is slightly agree (5); however, 20% of respondents moderately disagreed. Those disagreeing built less than ten houses last year and the 80% of respondents agreeing built in higher volumes. Nadim and Goulding (2010), Elnaas, Gidado, and Philip (2014) and Rahman's (2014) research identified inflexibility for design changes as a significant barrier for implementing offsite manufacturing [8,9,17]. However, the results suggest early design freeze is not a problem when developing smaller numbers of houses but becomes more of an issue at a slightly larger scale.

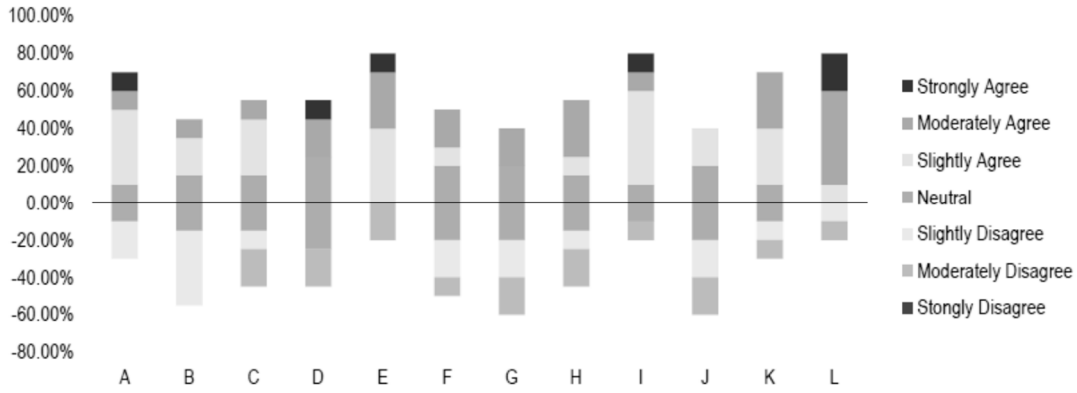


Figure 2. Perception of the Barriers in the Implementation of Offsite Manufactured Panelised Systems.

The response to statement A (Mdn = 5, IQR = 1) matches Blismas and Wakefield's (2009) research which found negative cultural perception as an important constraint [19]. Slightly agree median responses (5) to statement K (Mdn = 5, IQR = 1.75), and statement I (Mdn = 5, IQR = 0.75) corresponds with the results of Elnaas, Gidado and Philip (2014) and Gibb (1999) who acknowledged offsite manufacturing increased site and transportation constraints [8,41]. Statement H (Mdn = 4, IQR = 2.5) had the highest IQR result of all the statements, suggesting small housebuilding developers have differing views on whether a lack of existing codes relating to offsite manufacturing prevent usage. Those agreeing with the statement echo previous research suggesting offsite manufacturing is significantly hampered by differing design standards and a lack of harmonisation, and hence achieving efficiency is more difficult [42].

Statements C (Mdn = 4, IQR, 1.75) and D (Mdn = 4, IQR = 1.5) also had high IQRs compared to the other statements in the study. As with statement H, the results for statement C and statement D suggest offsite manufacturing is hampered by differing design standards [42]. However, the disagreement shown in the response to statement G (Mdn = 4,

IQR = 1), coinciding with the results from SECTION B, revisions to Building Regulations having a significant impact on the use of panelised systems, does not resonate with the responses to statements H, C, and D, but suggests efficiency and the use of panelised systems by small housebuilding developers has no link [42]. Overall, 40% of respondents slightly disagreed with statement B (Mdn = 4, IQR = 1.75), suggesting traditional housing developments constructed by small housebuilding developers may not be the best place for the implementation of panelised systems.

Although, the emergence of social housing and build to rent, has seen the need for faster completion and life-cycle quality due to a retained interest, and because of their long-term benefits, panelised systems are more likely to be used and may provide reasoning for the IQR > 1 [43]. The response to statement F (Mdn = 4, IQR = 1.5) varied from moderately agree to moderately disagree. However, the results from SECTION B statement D suggest the integration of project processes enhance the economic benefits of panelised systems which slightly disagrees with the views found here. This suggests economic benefits and efficiency are not linked. A lack of repeat product for residential small housebuilding developers makes the set-up costs for panelised systems prohibitive, the ability to turn off and on supply to meet economic fluctuations was also identified as a barrier in using panelised systems, echoing results found by Killingsworth, Mehany, and Ladharie (2019) [44]. Other respondents referred to the quantity of units, stating the greater the number of identical units the more cost-effective panelised systems become, however, as small housebuilding developers do not build at a high enough volume the benefit is lost.

Table 8 shows which statement is currently believed to be the most significant barrier to the use of panelised systems by small developers. Statement L was identified by 60% of the respondents, as currently the most significant barrier. As panelised systems are not used due to costs involved sustainability and efficiency are overlooked which corresponds with Elnaas, Gidado, and Philip (2014) [8] and suggests why the emergence of new housing markets means panelised systems are more likely to be used because of retained interest and requirements for lower running costs [43].

Table 8. Currently the most significant barrier to the use of panelised systems.

	A	B	C	D	E	F	G	H	I	J	K
Currently the most significant barrier	0%	0%	0%	10%	8%	8%	7%	7%	0%	0%	60%

8.2.4. Section D

Greater numbers of responses to the justification of answers to questions asked in Section D of the questionnaire would have provided more reliable analysis. However, the responses received highlight aspects that require further consideration and add valuable insight into the decision factors used by small housebuilding developers in choosing traditional methods over panelised systems.

Figure 3 shows the responses to whether use of panelised systems would increase efficiency in the delivery of developments—64% replied yes, 27% replied no, and 9% suggested it was dependent on other factors. The 64% of the respondents believing efficiency would be increased identified themes including precision design and speed of construction as their main reasoning, also citing further reasons such as less waste and time spent on site, and buildings being watertight sooner compared to traditional methods. However, they suggest increased efficiency would only occur if the whole site is programmed efficiently, corresponding with Killingsworth, Mehany, and Ladharie (2019) [44]. The 27% of respondents replying no found two common themes, firstly that efficiency was not increased on their scale of operation but a belief that benefits translate to volume building, and secondly that increased efficiency was dependent on-site programming which was also identified by the 9% who provided a dependent response. This suggests that if building to sales rates increased, efficiency would be lost and as developments are typically phased to aid cash flows, small housebuilding developers require certain amounts of flexibility, which is why

traditional methods are typically used [45]. This may be why panelised systems have not been used previously by the respondents.

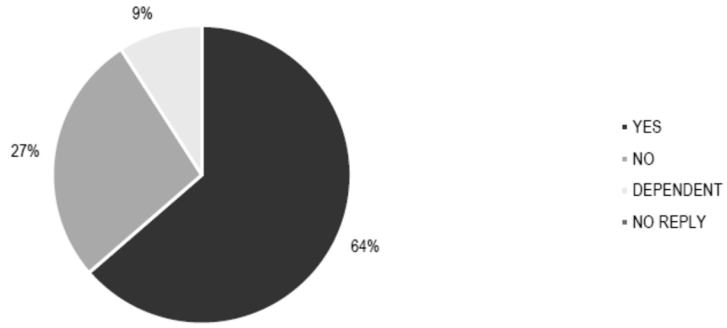


Figure 3. Do panelised systems increase efficiency in the delivery of developments?

Faludi, Lepech, and Loisos (2012) suggest the most crucial environmental design priority of offsite manufacturing is reducing operational energy effects and the results of this study agree [30]. Figure 4 shows the respondents views on whether panelised systems increase sustainability in the delivery of developments with 73% of respondents believing panelised systems do increase sustainability. Themes identified by the yes responses were increased thermal efficiencies, less waste, use of sustainable materials, reduced CO_2, increased insulation, and airtightness. Furthermore, the respondents stated use of panelised systems reduces a developments carbon footprint meaning low energy houses are easier to construct echoing Pan, Gibb, and Dainty (2007; 2008) and BSA (2016) who found reductions in environmental impact risks, and improved life performance [1,25,27]. The themes identified by the respondents also resonate with research conducted by Tam, Zeng, and Ng (2007) and Jaillon, Poon, and Chiang (2009) which concluded prefabrication is a remedy for waste reduction [28,29]. The 18% responding no identified two themes—adaptations to traditional methods to meet renewable requirements and maintaining localised construction. However, these opinions have not been identified in the previous research studied.

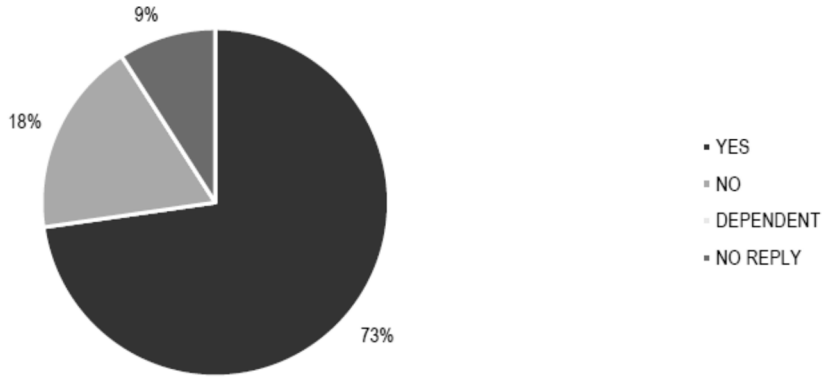


Figure 4. Do Panelised Systems Increase Sustainability in the Delivery of Developments?

Figure 5 shows surveyed small developers' views on whether efficiency and sustainability are considered as highly as time, cost and quality. The overwhelming majority (91%) of respondents identified efficiency and sustainability as not being considered as highly which corresponds with Elnaas, Gidado, and Philip (2014) [8]. One theme identified was when efficiency should be considered as it could lead to a lower cost base and respondents believed it depended on whether any long-term interest was retained in the development. Interestingly, another theme showed that respondents believed sustainability should be considered as highly as time, cost, and quality but efficiency had no links. This has also been identified in previous sections of the questionnaire. The most common theme identified by

the respondents was maximising profit. Efficiency and sustainability do not increase sales values and as most small housebuilding developers look to maximise profits, time, cost, and quality are more precious. If traditional methods allow developers to generate profit and meet Building Regulations, there is no need to change. Suggesting the role of Regulations and Government agendas have a larger influence in the use of panelised systems rather than a perceived increase in efficiency. The harmonisation of design standards has been identified as making scale and efficiency easier to achieve, in turn enabling increased volume of construction using panelised systems by small housebuilding developers [42].

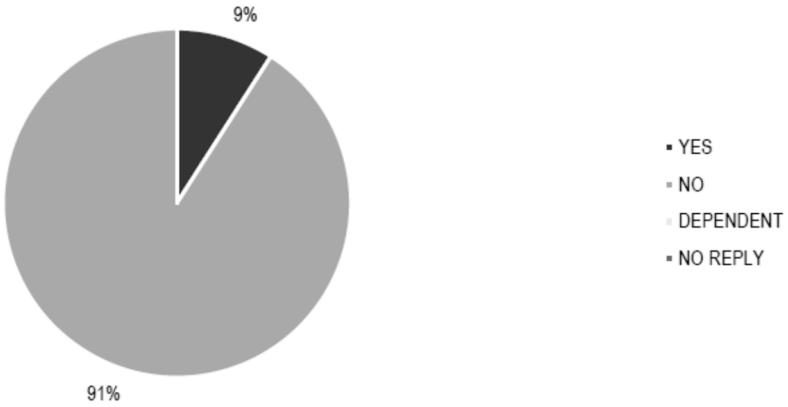


Figure 5. Are efficiency and sustainability considered as highly as time, cost, and quality?

Panelised systems have been subject to increasing levels of interest within the construction industry and previous studies suggest it had a future, however, the respondents in this study appear to differ from these assessments [1,9,23]. Figure 6 shows the respondents' opinions on whether offsite manufacturing is the future of the construction industry. Overall, 45% of respondents replied that it was and the remaining 55% disagreed. Justification of their responses identified panelised systems as having more of a future for small housebuilding developers than volumetric techniques which the NHBC (2016) and RICS (2018) also recognized [4,13].

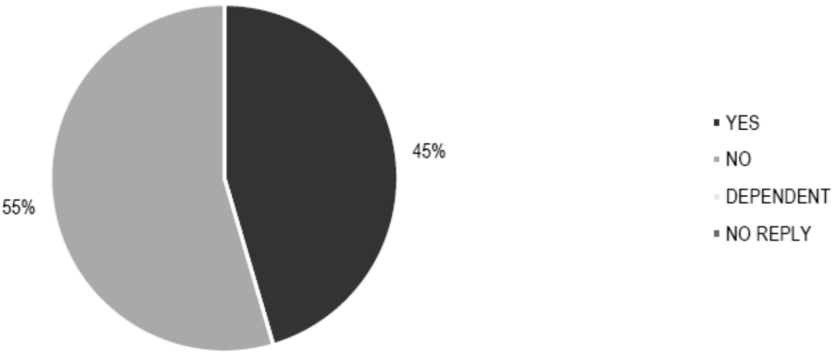


Figure 6. In your opinion, is offsite manufacturing the future of the construction industry?

Those believing panelised systems have a future in the construction industry citied projected skills shortages and increased quality performance as their reasoning. Others suggested as panelised systems are widely used in other countries their future use in the UK makes far more sense. However, the results are far lower than found in previous research including Nadim and Goulding's (2010) where 73% of respondents believed offsite manufacturing was the future [9]. The 55% who believe that offsite manufacturing is not the future of the construction industry do so because there is a large demand for traditionally constructed houses based on the markets in which they operate and until

traditional methods of construction no longer meet Building Regulations, they will not use panelised systems.

Figure 7 shows whether the respondents believe best value is achieved through traditional methods of construction. Overall, 73% of respondents believe traditional methods do achieve best value and 27% disagree. The 73% of respondents replying yes identified three main themes in justification of their response. Firstly, comparison of methods—in every development scheme analysed, traditional methods of construction worked out cheaper and, schemes are more easily costed as traditional methods are more frequently used. Secondly, European development—respondents stated that because the UK's panelised system industry is not as developed as the rest of Europe, a lack of usage equates to a lack of perceived value. Thirdly, sales perspectives—house buyers perceive traditional construction as better, meaning from a sales point of view best value is achieved as criticism is rarely received. Suggesting until traditional construction methods are no longer viable, they will continue to be used by small developers, reflecting previous results found regarding time cost and quality as the most important factors for developers [8]. The 27% of the respondents replying no identified similar themes—comparison of methods and European development. Although costs may appear cheaper at the outset, evaluations conducted on energy efficiency show the benefits on value of space and build programme, suggesting until higher capital costs are overcome, traditional methods will continue to be used as initial costs outweigh the benefits achieved later, including lower construction times and quicker completion rates. These results correspond with the views of Elnaas, Gidado, and Philip (2014) and Gibb and Pasquire (2005), who found that whilst developers accept lowest cost rather than perceived best value, traditional methods will continue to be used [8,14].

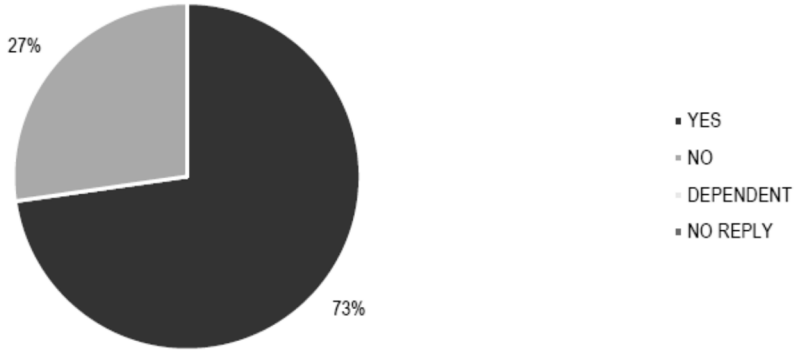


Figure 7. Is best value obtained through traditional methods as opposed to panelised systems?

Figure 8 shows the respondents views on whether increased use of panelised systems could increase housing output and positively impact the UK's current housing crisis. Overall, 82% believed panelised systems could positively impact the housing crisis and 9% it was dependent on other factors. Although this question refers to the UK housing crisis, which has not been discussed in this study, the response to this question provides insight into other aspects of panelised systems use by small developers. Namely, whether it is the developments and developer who can be blamed for the housing supply shortage or whether there are other factors which have a more prominent role in housing delivery. In total, 82% of respondents believe faster construction equates to increased output, more houses per available plots, and faster build programs. However, as identified by the RICS (2018), the responses show delivery of housing using panelised systems will only be increased on higher volume developments, exhibiting high degrees of repetition [13]. However, where timber frame construction was used by the respondents, it was used for its environmental performance and not its speed of build. Therefore, increased efficiency is not the main reason to use panelised systems, echoing responses showing best value achieved through traditional methods of construction, despite a belief that panelised systems increase housing output. Overall, 9% believed that panelised systems could

impact the housing crisis depending on levels of demand post COVID-19, stating if demand drops significantly long lead-in times and issues with supply flows will hamper offsite manufacturing's efficiency and create additional problems for the factories, which Gibb and Pasquire (2005) also identified [14]. The most common theme identified by the respondents is the need for changes in both Building Regulations and the UK's planning system. The respondents believe that these factors have the most significant effect on the UK's housing crisis rather than the rate at which developments are completed and the methods used in their construction. Design standards make scale and efficiency harder to achieve and by amending these standards development construction using panelised systems may be increased [42].

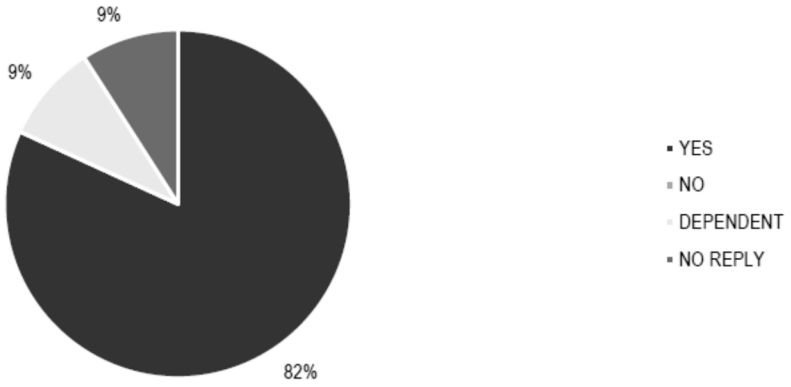


Figure 8. Could increased use of panelised systems positively impact the UK's current housing crisis?

9. Conclusions

This research identified several reasons as to why panelised systems are not being used by small housebuilding developers in the UK. These include early design freeze, a lack of historical data and awareness from financial lenders, building regulations not covering all aspects of offsite manufacturing, and a lack of existing codes and standards relating to offsite manufacturing. The main reason panelised systems are not used by small housebuilding developers is due to their inability to maximise profit. Firstly, panelised systems have higher capital costs compared to traditional methods. Respondents found, when analysed, that traditional methods worked out cheaper than panelised systems. Secondly, respondents identified the buyers' perception traditional methods as superior to panelised systems, creating higher sales figures.

These two factors combined are more desirable for small housebuilding developers, rather than the perceived increase in sustainability and efficiency offered by panelised systems, due to their positive effect on profit. Therefore, small housebuilding developers have little need or desire to change from traditional methods.

The findings of this study identify a wide variety of responses which agreed with the statements on why panelised systems should be used by small developers, but demand is low due to the current systematic, regulatory, logistical, and economic situation. The small housebuilding developers identified the need for changes in both building regulations and the UK's planning system; however, with the results suggesting there is still a significant demand for traditionally built homes, only revisions which make traditional methods unviable for small housebuilding developers will see the demand for panelised systems increase. Although the results identify issues and resolutions for increased demand for panelised systems, only 32% of the small housebuilding developers surveyed had used panelised systems in the last five years, which could be seen as a limitation of this study, as the reliability of the remaining 68% of responses in agreement with the statements might be perceived as negatively affected.

The results show a substantial belief among respondents that the use of panelised systems may be viable, but for developments with larger volumes of homes and limited numbers of house types. This suggests a difference in the future of construction depending

on the scale of the developer. Although the respondents believe sustainability and efficiency is increased in the delivery of developments by using panelised systems, the respondents identify increased efficiency as a non-essential reason for the use of offsite manufacturing.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of University of Strathclyde (Approved on 10 October 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The author declares no conflict of interest.

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