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Modular Construction in the United Kingdom Housing Sector: Barriers and Implications

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Abstract

Modular construction is relatively new type of construction method, where houses are built in an off-site facility and brought to the site when ready to be set up. Many sources, such as, websites, videos, books, show that modular housing is extremely efficient regarding time and cost. However, this construction type is not more popular than on-site building. The purpose of this project is to find the reason, why is not modular construction taking over traditional building style and what are the barriers of implementing prefabricated houses in UK housing sector. The primary and secondary data analysed in the project shows that building modularly has many great advantages, for example, lower costs, faster construction, modern design and significant sustainability. Moreover, the project analyses main barriers when implementing modular in the housing sector of United Kingdom, which are high costs of land, low land availability, transportation costs, quality relation to time and cost. The project indicates research on barriers and implications that lay behind modular construction in the United Kingdom housing sector.

Keywords: Barriers; Implications; Modular construction; Traditional buildings; Housing; UK

Introduction

Permanent modular construction is described as premade buildings that consist of prefabricated parts or so-called modules, which are produced in an off-site facility and brought to the site and put together as needed. Prefabricated modules are brought to the site and set up with cranes and attached to the foundations. Building modules can be placed onto each other and side to side, in order, to give vast variety of building layouts. Modular buildings can serve as educational, industrial, housing and commercial facilities. Also, widely used for cruise ships, hotels, retail, fast-food restaurants [1]. Furthermore, modular buildings can be made for temporary (in case of natural disasters, army camps or construction) or permanent use, however, this definitive project is focused on permanent use of modular buildings, more specifically, on modular construction in housing sector of the United Kingdom.

The building prefabrication reaches goes back to year 1837, when a carpenter Henry Manning from England, London, made a modular house for his son who was emigrating to Australia. By year 1853, the interest for prefabricated buildings significantly increased due to historical reasons as well as cost efficiency. Approximately the same time in the past (1850's), the demand for modular houses increased due to Californian Gold Rush. Also, historians have found traces of modular building instructions translated in Chinese and shipment information in Singapore, also happening around year 1850. The history of modular housing is larger than most people expect, however, compared to the "traditional" on-site construction strategies, this is a relatively new building technique [2].

Literature Review

Modular construction is a separate method of prefabricated houses, and it is an extremely fast method to build residential houses, as it eliminates many onsite factors that traditional construction methods use. There are several types of prefabricated construction. One of the highest advanced methods is modular construction. Modular houses are built off-site and transported to the site. When a modular house is transported to the site, it may need cladding, and internal finishes, which requires comparatively minimal work. The advantage of building off site is that the building process can be more technologically advanced and fewer mistakes can be made due to the design which has been thought thoroughly. It is important to state that building modularly decreases the construction waste significantly, due material reuse and recycling. The main market of modular houses is in the residential sector in UK and Scandinavia, as well as in the medical sector in UK. There are many modular house suppliers in the United Kingdom, although the demand of them is not as high as expected. Modular houses are mostly used for hospital accommodations, student accommodations and retail sector. In UK specifically, modular construction reached its peak in 2007, producing 8000 steel modules and approximately 500 concrete modules in various applications [3].

Modular houses tend to be extremely sustainable and durable. For example, a famous design of a modular house is "Weehouse", designed by Alchemy Architects. They have produced a design of a prefabricated house that is built in a warehouse with sustainable and durable materials, like wood, steel, glass. The house can suit many clients' needs, because it can serve as an office, residential house, rentable cabins and more [4].

However, Kunz and Galindo proposed two barriers which can affect modular house implementation. Firstly, a contractor company is involved to investigate the site and build foundations, which increases the costs of the building, unless the company who produces the

Houses are providing these services. Secondly, there are three transportation methods. The cheaper options are to transport the house on a truck or via rail, although there are places which are not accessible by a truck. If that is the case, then a helicopter must be used, but the costs of this service can be extremely high. A great advantage of modular housing is that the houses can have different layouts and can be extended if needed. "Haus Ott", an energy globe award receiver in 2003, serves as a great example. The Austrian architects/developers "Fuerrot" produced a "Flexible Building System", which allowed building extremely efficiently, whilst keeping the costs as low as possible. The house offers extremely vast variety of internal design and layout, because the bathroom units, balconies, stairs and more are produced off-site as well. The owner has the advantage of choosing the design and layout, depending on the number of inhabitants. The architects state that under ideal circumstances, this modular house can be built in 10 days [4]. Overall, there are many great advantages of modular houses, like sustainability, durability, level of comfort, variable design, minimalized costs and more [5]. Although, it is important to identify the barriers, to understand why this beneficial construction method is not vastly used in the United Kingdom.

Sustainable and Durable Materials used for Modular Houses

Cambridge Dictionary defines the term sustainability as the "idea that goods and services should be produced in ways that do not use resources that cannot be replaced and that do not damage the environment". This means that sustainable materials are the ones that do not diminish the natural sources and has no extreme impact on the environment when consumed. In construction, this is nearly impossible to achieve, although the aim is to move this direction. The benefit of using sustainable materials is that it helps to achieve more credits if BREEAM, LEED or any other environmental assessment tools are used. There are many ways how we can preserve the natural sources and improve the sustainability of houses, for example, create less waste, design minimum weight structures, match demand supply, use recycled materials, using renewable materials, using materials with lower embodied energy, reduce the transportation of materials [6]. Furthermore, it is important to state which materials exactly are sustainable. Concrete is one of the most used materials in the Construction Industry, because of its' high fire resistance, strength and vast variety of use, also to produce concrete sustainable materials are used, like sand, water, gravel or crushed stone and mixed together with cement powder [7].

However, the amount of concrete in the housing sector and the rest of the construction industry should be reduced, because making it releases significant amount of carbon dioxide. Concrete is the second most consumed material on earth, after water. Cement industry is growing by 2.5% every year. In 2006 2.55 billion tonnes of cement were made and is expected to rise to 3.7-4.4 billion tonnes by 2050 [8]. The high-rise buildings will use concrete as the main material, and it is nearly impossible to avoid it. Although, the housing sector, specifically in the UK, has many opportunities to build houses from recycled and renewable materials, and it must be implemented, due to the fact, that climate change is an extreme problem today. These materials are:

Ferrock

This is a new material, which is still being research. Ferrock is made from steel dust, taken from steel factories, to create a similar material to concrete which can even be stronger than concrete [9].

Grasscrete

This material is used to replace concrete used for walkways, sidewalks and driveways. There are open patterns allowing the grass to grow, which reduced the overall usage of concrete and provides a great advantage-improved storm-water absorption and drainage. Regarding the durability of this material, the load bearing capacity can support approximately 29.5 tonnes and it has long life-cycle [10].

Hempcrete

Is a relatively new material that is made from wet-mixing hemp shiv with lime binder. Hempcrete is natural, vapour-permeable, airtight insulation material, also has great thermal mass giving effective thermal performance. "UK Hempcrete" states that this material is "better than zero-carbon material" [11].

There are many more materials, like bamboo, recycled plastic, wood, mycelium, ferrock, ashcrete and timber-creteew. Although, specifically in the United Kingdom, not all previously mentioned materials are accessible for affordable prices. The sustainable materials that are accessible in the United Kingdom are hempcrete, recycled plastic, grasscrete, wood, ashcrete, ferrock and timbercrete. Modular houses like "Living Box" designed by "Architeam 4 Basel" from Switzerland used wood as their main material, which gave great appearance and most importantly, is a sustainable material. "The Retreat" designed in London by Buckley Grey Yeoman, serves as another great example, proving that a comfortable and sustainable modular house can be built. The British architect eliminated materials like plastic or chemical surface treatments, and used materials which are as natural as possible, also being 100 per cent recyclable [4]. Overall, there are many materials that are environmentally friendly that can be great substitutes for concrete. It is possible to create houses that would minimize the impact to the environment, which is the aim of construction today.

Wide design possibilities

Building modularly does not limit the design variety, because any materials can be used and it depends on the clients' choices. To prove the fact that the design of prefabricated houses can be vast, see examples listed below:

- Prefabricated modular house in rural Spain-Baragano Architects designed the house to fit into the rural area of Spain. It is made from galvanised steel, wood and slate, and it took only 5 hours to erect. The house was built for a British landscaper and his family, which cost £ 137,952. The house was made in four months, in a factory in Madrid. Then shipped 600 miles to Cantabrian mountain range. The house is modern in its way of construction, however the applied finishes fits aesthetically with the old fashioned rural surroundings. The wooden cladding is durable and sustainable; additionally it gives a great look for the house. House was built with four modules and the client can move the house to a different location if needed [12].

- A great example is Kodasema's tiny, prefabricated house. This one module house was built in BRE Innovation Park, Watford. The total cost of this house was £ 150,000, which is comparatively cheap

for the UK market. The price included planning and building regulations, delivery, site preparation, installation and connections to water, electricity and sewage. The purpose of the house was to create a solution for UK housing shortage [13]. The external design of this house is extremely simple, yet modern and sustainable. The large window provides the room with daylight, and the walls are made from thin, vacuum insulated concrete panels. The house also has solar panels on the roof. The internal design looks natural, because the main material used is wood [14].

To summarize, it is strongly noticeable that main materials for modular houses in UK and Europe are wood, steel, glass and concrete. These materials give modern, natural look for the house, meanwhile, ensuring high thermal and sound insulation, high fire resistance and most importantly high comfortability for the occupiers.

Transportation of Modular Houses

Studies have shown that modular house shipping becomes more expensive if the distance from factory to site is greater than 300 km [15]. Modular houses can be transported by a truck, train or helicopter. The type of transportation depends of the accessibility of the site. The cost of modular house transportation by a truck depends on the size and weight of it. In the UK maximum vehicle weight is 44 tonnes. The maximum length of the truck can be 18.75 meters, which are allowed only for road trains. Individual truck length cannot exceed 12 meters and articulated truck and trailer length is limited to 16.5 meters. The maximum width for all trucks and load is 2.55 meters [16]. UK government website also states, that there is an option of transporting “Abnormal” loads, which are exceeding the maximum allowance. To do this procedure the house transporter must fill a document called “Notification requirements for the movement of abnormal indivisible loads or vehicles” and notify “Highways England” 10 weeks before transporting the house modules. The allowed transporting measures can be a significant barrier when transporting house modules, because the design must adapt to the transportation method, otherwise the modules cannot leave the factory. The larger the modules the higher the cost of transportation. The option of transporting house modules via rail is possible; however it can be more expensive, because the house must be transported to the train and from the train. However, it depends on the distance. Moving the modules from a transport to another increases the possibility of damaging them. Although, using train can increase the module allowance, because the train platforms are larger. There are companies which provide these services in UK, like “Direct Rail Services”, “Freightliner”, “and GB Railfreight”, “DB Cargo UK”. DB Cargo UK is the largest company in the United Kingdom, as well as one of the most sustainable companies regarding carbon dioxide reduction [17]. A great advantage of using a train is that the load can be larger than a truck can hold.

Transportation by a helicopter is a complicated way to transport heavy loads, like modular houses. It expensive and requires significant planning. Any transportation by a helicopter must be agreed with UK Civil Aviation Authority and Rules of the Air Regulations 1996 apply. However, transporting with aerial crane increases delivery speed. But the main disadvantage is that a helicopter transports on average 4,500 to 5,000 kg [18]. A price comparison between all three services is not available, due to lack of information on pricing for helicopters and trucks. Although, “DB Cargo” has a price list on their official website which gives information on the prices and services available depending on the weight and distance of the load. Wagon size can go

up to 27 meters in length, approximately 4.5 meters in width and 3.5 meters in height [17].

Land Cost and Availability in UK

The availability of land is significantly restricted due to the historical facts and protected land. It is possible to buy land in the UK, but the price can be extremely high as well as the competition. Market research shows that there are several websites, where it is possible to find land for sale, for example, rightmove.co.uk, primelocation.com, plotfinder.net. The price of land can vary from approximately £ 100,000 to £ 1000,000. The price of the land depends on the location. Factors that affect price of the land are: distance from the city centre, soil quality, appearance of the land, accessibility of house services, aesthetics, and neighborhood. For an individual to build a house in the United Kingdom can be extremely difficult because of the high competition. It is because the winning bidder of the land will usually be the one that combines highest new build price, highest density and the lowest build cost [19] (Figure 1).

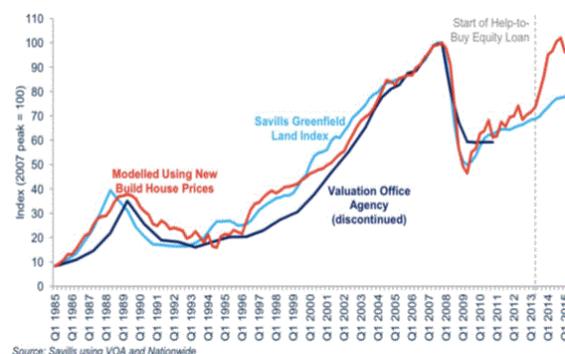


Figure 1: Residential Development Land Values.

The diagram shows the link between houses prices and land values, using Nationwide new build house prices as a proxy for Gross Development Value (GDV) and the only input. “GDV is the expected value when a property development or refurbishment is complete” [20]. GDV is multiplication of new build house price and the number of homes to be built. It is based on a rule that one third of GDV is the land value, assuming, that two thirds of the value are the remaining effective costs and profit. In this case, the land absorbs the full impact of any falls in house price and the full advantage from any rises while house prices are below their previous value [19]. The red line in diagram indicates the previously, explained model, which traces the land values in the market. The figure above shows an index from 0 to 110, which is the measured Residual Land Value (RLV). To measure RLV, Development Costs and Profit is taken away from GDV. The formula:

Residual Land Value=Gross Development Value-Development Cost-Profit. The price index has reached its peak of 40 in 1988, but slightly decreased until year 1995. Starting year 1996 it gradually increased and reached the peak of 100 in 2007. After the financial crisis in 2008 the land value dropped significantly to in half. However, it has reached its peak in a fast pace in year 2015 (Figure 2).

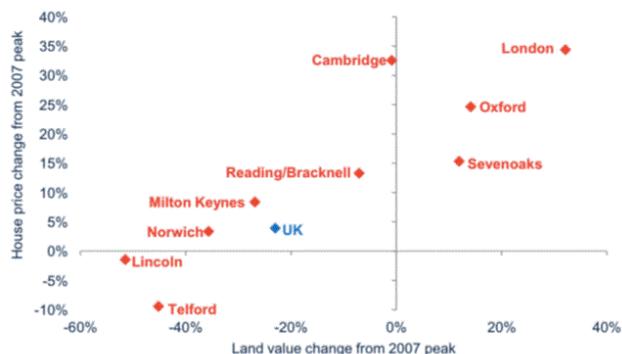


Figure 2: Development Land Value and House Price Change from 2007 Peak.

The figure above indicates the price change in per cent after the 2007 peak of the land value. London, Oxford and Sevenoaks significantly increased the price in both, land and house prices. But, Cambridge land value did not change at all, however the house prices increased by 32.5 per cent. Cities like Reading, Milton Keynes increased the house prices by 10 to 15 percent, but the land values dropped to 20 and 40 per cent. Norwich increased the house prices by approximately 5 per cent, but the land value was at minus 38%. Lincoln and Telford suffered a price decrease in both areas. To summarize, buying a land in the United Kingdom is possible, but the disadvantage is that buying a land involves high competition, high costs and limited availability of land.

Building Modularly Reduces Construction Waste

The off-site manufacturing process presents many benefits due to efficient manufacturing and construction processes, the improved in-service performance of the completed building and the potential reuse of modular buildings. Mark Lawson, Ray Odgen and Chris Goodier in their book “Design in Modular Construction” have listed several benefits of off-site manufacturing (Table 1).

Sustainability benefits of off-site manufacture as a construction process	Sustainability benefits of off-site manufacture in in-service performance
I. Social	I. Social
• Fewer accidents on site and in manufacture	• Acoustic insulation is improved due to sealed double-leaf construction
• More secure employment and training	
• Better working conditions in the factory	• Improved finished quality and reliability
• Reduced traffic movements to site	• Future point of contact to the modular supplier
• Less noise and disturbance during construction	• Modular buildings can be extended or adapted as demand changes
2. Environmental	2. Environmental
• Less pollution, including traffic, dust, noise, and volatile organic compounds (VOCs)	• Improved energy performance by better airtightness and installation of insulation, hence, reduced CO ₂ emissions

• Less wastage of materials on site and in manufacture	• Renewable energy technologies can be built in and tested off site
• More recycling of materials and use of materials with higher recycled content	
3. Economic	• Modular buildings can be "sealed" against gases, e.g., radon, and use on brownfield sites
• Faster construction programme	3. Economic
• Site preliminary costs are reduced	• Savings in energy bills, including by use of renewable energy systems
• Less snagging and rework	• Longer life and freedom from in-service problems, e.g., cracking
• Economy of scale in production reduces manufacturing cost	• Reduced maintenance costs
• Higher productivity on site	• Modular buildings can be extended and adapted
• Less site infrastructure and hire charges	• Asset value of the modules can be maintained if they are reused

Table 1: Sustainability benefits of off-site manufacturing as construction process.

Sustainability assessment tool for residential houses in UK

Sustainability, regarding planning of buildings, is assessed in measures of environmental, social and economic performance. Public buildings are assessed using BREEAM manual, but the housing and residential buildings are assessed by the government’s Code for Sustainable Homes (CfSH). The CfSH is an environmental assessment tool similar, to BREEAM manual, and the purpose of it is to use it in the design and construction of new homes to encourage continuous sustainability development of home building in the UK [21].

Modular construction reduces material waste and CO₂ emissions

On-site construction waste is made due to: over-ordering materials, damage and brakeage on site, workmanship errors. Build Research Establishment states that construction industry wastes on site approximately 10 per cent of materials. However, for modular construction, waste is reduced in the factory and installation process. Also, off-cuts are fully recycled in factory [3]. A study on precast concrete panels made in Hong Kong made by Jaillon and Poon showed that, production of prefabricated concrete panels leads to 65 per cent reduction of construction waste compare to *in situ* concrete [22]. A study in 2012 by University of Alberta researchers proved that building modularly significantly reduces the CO₂ emissions. A non-profit company, Sturgeon Foundation, in Canada was in need for additional housing inventory in St. Albert. The company turned to “Integrated Management and Realty Ltd” for professional advice. The president of IMR suggested using modular construction. Eventually they built a 4 storey, 48-suite facility in 7.5 months. Gordon White, the president of IMR decided to research if this project serves as an example where carbon dioxide emissions are reduced when building modularly. White assigned Dr. Mohamed Al-Hussein to complete a study on this project, where he compared the transportation from the factory to the site and on-site construction transportation and CO₂

emissions. The study results showed that building modularly saved 55% of time and reduced CO₂ emissions by 43%. Conventional Construction would have made the house in 14.3 months and created 98.9 tonnes of carbon dioxide emissions, whilst the off-site construction produced 56.3 tonnes of CO₂ emissions [23].

Methodology

The “Business Dictionary” defines methodology as “A system of broad principles or rules from which specific methods or procedures may be derived to interpret or solve different problems within the scope of a particular discipline” [21]. Methodology employed in an experiment or a research paper is essential in order, to succeed, and bad methodology has harmed many research projects. Methodology is the way how the project is completed and there are different research types, like descriptive, analytical, applied, fundamental, qualitative, and quantitative. Methodology can also be a combination of these research types. The research methods are the tools and actions used in order, to complete the research, for example, interviews, questionnaires, case studies, analysing and examining science journals, videos, books and more [24]. Methodology of the project “Modular Construction in the United Kingdom Housing Sector: Barriers and Implications” involved both, qualitative and quantitative research methods. The use of mixed research methods allowed the researcher to examine the topic in greater depth.

The qualitative research methods used were literature review and interviews. The researcher produced literature review analysing books, journals, web documents, web sites. The books describing modular construction gave wide information, which was deeply analysed and discussed. The articles from journals presented previous studies on this topic and helped to find a gap in the studies. Web sites and web documents were used to find statistical information and the latest information on modular construction.

Semi-structured interviews were completed using video communication tools “Facetime” and “Skype”. Interviews are transcribed and analysed using a Content Analysis method. Content Analysis is a research tool used to determine the presence of certain words or concepts within the text, in this case interview [25]. This method gave a major influence for the project, because five construction professionals were interviewed, who gave a different opinion and view of the modular construction in the United Kingdom. Interviewees gave original opinions on the possible barriers of implementing this construction method. The interview consisted of five questions, asking the interviewees to express their opinion on modular construction in the UK, its’ implementation barriers and the future of it. The quantitative research method used for this project was questionnaire. The questionnaire was made using an online tool. The survey was produced with an objective, to see what the publics’ opinion on modular construction is. The questionnaire helped researcher to understand what people prioritize in their house and what their opinion on modular construction is. The questionnaire consisted of eight questions and 33 participants from the United Kingdom completed the questionnaire.

Data Collection and Analysis

Researcher’s objective was to approach construction specialists and people from the United Kingdom, to examine their opinion and understanding of the modular construction, specifically in the housing sector. Five construction specialists were interviewed, who are from

different companies working in different sectors, quantity surveying, construction management, contracts management and project management. The questions were based on assumptions made after literature review, to support the study with specialists’ opinions. The interviews provided deeper insight on the topic. The interviews are analysed with Content Analysis method. Questionnaire was made using an online tool “Smart Surveys”, and the researcher approached 33 people by personally asking them to complete the survey. The questionnaire consisted of 8 questions which were asking the participants to evaluate the importance of design, sustainability and maintenance costs in their households. The questionnaire helped the researcher to understand publics perspective on modular housing, and if this construction method would suit their requirements.

Interviews

Question 1: Participants were asked to state their opinion on which is the main barriers of modular house implementation in the United Kingdom.

Question 2: Interviewees were asked to state their opinion, if the fast-paced construction method of building modularly can be a reason for people to buy and live in a modular house.

Question 3: Participants were asked if they think that people are not educated enough about other construction methods, in this case modular construction, therefore individual house developers choose to build traditionally.

Question 4: The interviewees were asked if they see modular construction significantly developing in the future, specifically in the housing sector.

Question 5: The participants were asked whether they agree or not that the land availability in the United Kingdom is limited, and to state their opinion if this is why people tend to buy existing houses to be closer to the city centre.

To summarize, the construction specialists are saying that modular construction can be very beneficial for the commercial companies, although individuals who are willing to own a house would rather buy an existing house or build a house using traditional methods, as the design can be more flexible, and the quality is expected to be higher. Table 2 indicates that between all five construction professionals the answers were very similar; however after examining the answers, participants mostly mentioned the quality of the building, and their concerns if the speed and cost can affect the quality (Table 2).

Question	Repeated Terms	Frequency
Main barriers of implementing modular housing in the UK	Lack of quality	3
Fast construction of modular houses can influence clients’ choice towards the method	Commercial companies prefer fast construction	4
People lack knowledge about modular housing	People having more options presented by the contractor can educate them	4
Development of modular housing in the future	Not at this moment of time, maybe in 15-50	4

	years. Quality must be improved	
Development of modular housing in the future	Not at this moment of time, maybe in 15-50 years. Quality must be improved	4
Land availability affects the development of modular construction	Building a new house and owning a land involves risk, client has too many responsibilities and it is a complicated process	3

Table 2: The frequency of similar answers from the participants in each question.

Questionnaire

The purpose of questionnaire was to approach people who are living in UK, and to understand what are their preferences in their household regarding design are, sustainability, space, maintenance costs. Also, they were asked if they wish for a house to be built fast or slower, but to be more flexible in design. The survey included questions related to the land availability and if they agree that people should be more educated about modular construction. The aim of the questionnaire was to examine their preferences, and to analyze the differences or similarities between the construction specialist opinions.

First question asked about the importance of external and internal design of participant households. 72% of the participants stated that it is highly important for them to have great design of their houses, whereas approximately 25% of participants answered that the design is important or not important at all of this project supports the modular construction stating various existing modular houses with highly advanced design and the wide possibilities of the design (Figure 3).

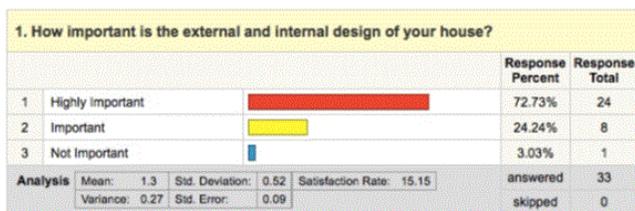


Figure 3: Questionnaire question 1.

The bar chart indicates that 66.67% of participants list the sustainability of their houses highly important and 30% lists it as important, and only 1 person answered that the sustainability is not important for them. It is great to see that people prioritize the sustainability, from this project shows the possible materials that can be used to build sustainable houses. Figure 4 shows that sustainability of domestic houses can be measured.

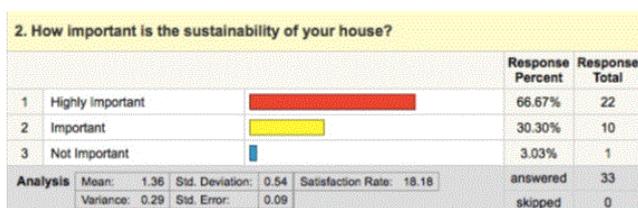


Figure 4: Questionnaire question 2.

Question three asked participants to choose an option how they would prefer to build their house. 85% answered that they wish to have their house to be personalized for their requirements, even though it may be more expensive and time-taking process, shown in (Figure 5).

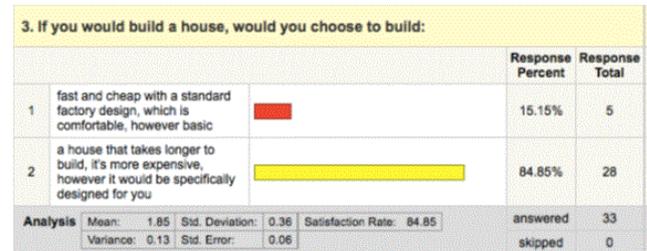


Figure 5: Questionnaire question 3.

Participants were asked to rate the importance of the amount of space in their households, and more than half answered that the space is highly important, and 40% stated that it is important. No participants selected option "Not Important" (Figure 6).



Figure 6: Questionnaire question 4.

Question five shows that participants rated the importance of household maintenance costs important and highly important, and none of the people selected option "Not Important". Modular houses are made to be sustainable, which is a significant factor in decreasing the maintenance cost (Figure 7).

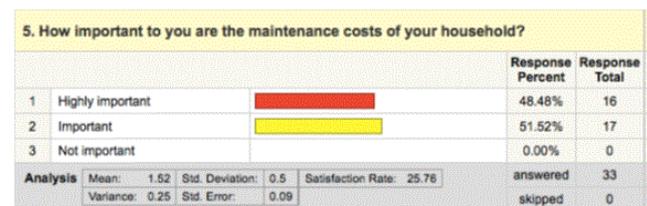


Figure 7: Questionnaire question 5.

Figure 8 show that, most of the participants (90%) agree, that people should be educated about modular construction, as it would help to increase the demand to this construction method.

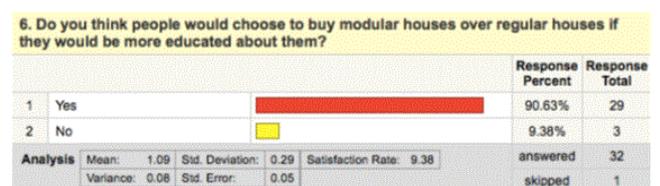


Figure 8: Questionnaire question 6.

Figure 9 illustrated that, participants agree, that the construction industry in the United Kingdom is based on traditional construction methods, and this can decrease the demand for modular houses.

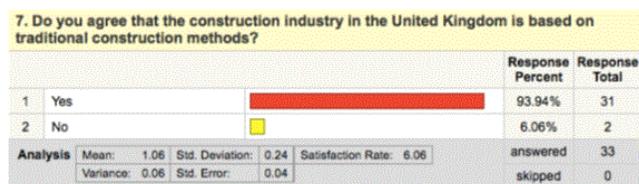


Figure 9: Questionnaire question 7.

The land costs are high and availability of land is low in the United Kingdom. The questionnaire participants (90%) agree that the land availability is limited and costs are high, therefore the higher demand is for existing houses that are located closer to the city Centre. To summarize, participants for questionnaire have proved that modular construction can meet peoples' needs regarding, sustainability, design maintenance costs and more, because people listed these as their priorities and the literature review indicates information proving that modular construction can be sustainable, modern and comfortable for the end users. Furthermore, if people would be more informed about the option of building modularly, it could increase the demand of it. One of the project objectives was to underpin and analyse the main barriers of modular construction implementation in the United Kingdom, and the questions in survey proposed the possible barriers, and the participants answered, that lack of knowledge of modular houses and the land cost and availability in the United Kingdom is a major barrier (Figure 10).

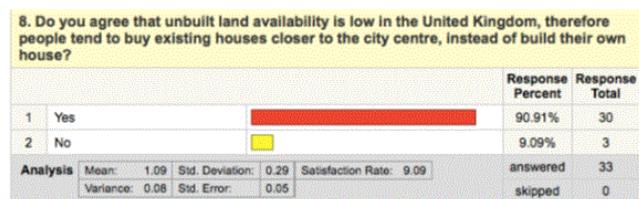


Figure 10: Questionnaire question 8.

Conclusion

Modular construction is a relatively new construction method which can be applied in various sectors, like housing, commercial buildings, hospitals, military and more, but this study is focused towards modular construction in the housing sector of United Kingdom. Modular construction is a specific method of building houses by adjusting modules on site which are built in an off-site facility. The process of modular building involves various challenges, for example, land cost and availability, transportation, market demand, design. The project was aimed to investigate the barriers and implications of modular construction in the United Kingdom housing sector. The objectives were to understand the principles of modular construction, evaluate the current practice of it, identify the challenges and implication, and analyze the main barriers of modular construction in the United Kingdom. To achieve the aim and objectives of this project, the researcher used qualitative and quantitative research methods. The research mostly consists of a vast literature review, interview and questionnaire analysis.

Modular construction has a great potential to find its place in the market, as the main advantage of building modularly is the significant sustainability and reduction of carbon emissions. Also, people highly appreciate design in their houses, as proved by the questionnaire, and the wide design possibilities of modular houses can increase the demand. Modular construction can not only significantly reduce the CO₂ emissions due to elimination of regular material transportation to site, as traditional construction methods need, but also reduce material waste, as the materials in factories are reused and recycled. Modular construction can become a highly used construction method, as the population is growing in the United Kingdom, however, it cannot replace the traditional building methods in the housing sector, because people have different requirements. The demand can increase in the commercial sector, as the time and money is more important than extensive quality.

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