

# Advantages and disadvantages of prefabrication as construction method constructio...



The aim of this research is to establish whether an increased use of off-site manufacture will produce a more energy efficient housing stock, as the UK gets closer to its carbon reduction deadline. The objectives of this study are;

To identify the key advantages and disadvantages of prefabrication as a construction method, and to establish how these are achievable compared to traditional methods.

To identify the current requirements for energy efficiency in new build houses.

To identify the requirements of the Climate Change Act 2008 and how this will affect the construction industry.

To establish the current use and opinion of prefabrication/off-site manufacture in the construction industry

The UK is legally bound to cut its green house gas emissions under the Climate Change Act 2008. These cuts are a 34% reduction by 2022 and an overall 80% reduction by 2050, compared to the baseline emission value from 1990.

This is not a scientific quantitative study of the actually energy efficiencies of the construction method, but more of an in-depth qualitative study of the features of prefabrication. This will be done by reviewing existing literature on the topic and comparing this to actual opinions and use in the construction industry. These opinions and the level of implementation of prefabrication within the construction industry will be established using questionnaires. From this analysis it is hoped that there are environmental

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benefits to using off-site manufacture/prefabrication. This should then be shown in the construction industry by it's increasingly use.

With the UK's housing stock producing approximately 30% of the UK's total carbon emissions, it is a sector where huge environmental gains can be made (House of Commons 2005). Although the Climate Change Act 2008 is not specifically aimed at the construction industry, the Chief Executive of the Committee on Climate Change, David Kennedy has called for action in “ four key areas”; the method by which electricity is produced, increasing the use of electric transport, reducing the carbon footprint of farms in the UK and an increase in the construction of energy efficient homes (Adam 2010).

Many reports, especially from prefabrication manufacturers themselves state the benefits of off-site construction over traditional methods. These include an increased speed of construction, better health and safety conditions on-site, better quality of final product and a lesser total cost when economies of scale apply. However when observing construction sites; off-site construction seems to not be included and traditional methods of construction seem to dominate. This study aims to find out the actual use of prefabricated, off-site components within the industry, and the reasons professionals have for either using, or not using this construction method.

The hypothesis for this study states that the current use of off-site manufactured components will have a positive correlation to the perceived benefits from using them. For example if the perceived benefits of the using off-site manufactured components are great, then it is predicted that their use will be common within construction. Conversely if the features of

prefabrication are not greatly beneficial compared to traditional methods, it is predicted that the use of off-site manufacture in the construction industry will be low. These assumptions have been made due to common reasoning, being that; if something is more beneficial than another, it will be chosen more often.

Some basic problems that may occur in this particular research project could involve the participant design. For example because this is a small scale research project, only a reasonably small number of professionals will be contacted to complete the questionnaire. This will mean that the results from the data collected can not be generalised to the rest of the construction industry. Another problem may occur with the return rate of the questionnaire. The expected return rate is 30%; this means that from the 60 questionnaires sent, around 18 are expected to be returned. Another problem may occur because the information produced about the systems is usually produced by the manufacturers themselves, and may be biased.

The hypothesis will be accepted if the primary literature search states that there are clear advantages to prefabrication, and the industry study shows that it is being increasingly used as a construction method. It will be rejected if there is no significant correlation between the reported benefits and the use of the construction method.

This dissertation will take the following structure. First a literature review will be undertaken to establish all known information on the subject area. This section will include analysis of literature to establish what the stated benefits of prefabrication are compared to traditional methods of construction.

Examples of each construction method will be analysed and areas where the benefits or disadvantages arise will be highlighted. The Climate Change Act 2008 will be reviewed to ascertain the requirements the UK is legally bound to fulfil. The current energy efficiency requirements will be taken from a study of the Building Regulations.

Then a methodology will be created which will involve formulating questions that have not been answered from the literature review. A participant design will be identified and a justification for its selection made. The selection and the rationale behind the research method chosen will then be made.

The questionnaires will then be sent out and the data analysed from the information collected. A series of tables and graphs will be produced to identify any significance in the results collected.

A discussion will then take place to deduce why the data collected has been produced and the impact it may have on the information we already know.

Conclusions will then be made that will summarise the findings and show any limitations to the study that should be rectified if done again. This section may highlight areas for further research. At the end of the document, a section of references and appendices will be included.

## 2. Literature Review

### 2. 1 Prefabrication

“ Prefabrication is a term used to describe the construction of buildings or building components at a location, usually a factory, remote from the building site.” (Emmitt, S. 2010)

Prefabrication can also be known as off-site prefabrication (OSP), off-site manufacture (OSM) and as a modern method of construction (MMC) (Taylor 2010). It has been used in mass production of housing since the early twentieth century (Arieff, A 2002). Prefabrication “ need only affect the construction process and not the end-product” (BRE 2001).

It is common practise nowadays to use prefabricated components such as trussed roofs and precast concrete sections, however for the purposes of this study, the terms ‘ prefabrication’ and ‘ off-site manufacture’ are applied to bigger components, such as fully fitted toilet ‘ pods’ shown in Figure 1a&b and external wall blocks with windows preinstalled and internal finishes applied.

Figure 1a

Source; <http://www.archiexpo.com>

Figure 1b

Source; <http://www.stcinc.net/bahamar.html>

Figure 1a/1b; a prefabricated toilet and kitchen pod, ready to be lifted and secured on-site.

Image and performance problems in the past have hindered the use of prefabrication, so it is useful to study the history to see if the same problems exist today.

The mass production of prefabricated components started in the early twentieth century; however there are examples of its earlier use, including the UK's first iron bridge constructed in 1779 at Colebrookdale (BRE 2001).

The major push for the use of prefabrication in the housing market occurred after both the First and Second World War (Arieff, A 2002). This was due to the period of reconstruction to account for the lack of new buildings constructed during the conflict, and the existing buildings that were damaged as a consequence of the conflict. Prefabrication suited the needs of the times as it provided a fast and affordable solution to the housing shortage. It addressed the lack in construction skills that existed after the wars and provided jobs in the factories for many people. It also provided a solution as to what to do with the large facilities that were constructed for armament manufacture during the war. Prefabrication enabled effective material management, reducing wastage. This was important at the time as there was a shortage in materials after the massive focus on production of components used for war. In October 1944 the Housing (Temporary Accommodation) Act was passed that gave the Government the power to spend £150M on the construction of temporary housing. This led to around 157, 000 temporary houses being erected from 1945-1948 (BRE 2001). This figure is less than was anticipated by the programme and subsequently led to the poor perception of the construction method.

Factors that have also slowed development of off-site manufacture include the poor quality of earlier systems, the difficulty involved with the maintenance of systems installed after the war and the poor attention to detail that was incorporated into their design also hampered the development (BRE 2001).

Due to the difference in physical construction processes compared to traditional construction, prefabrication produces the opportunity to capitalise on many benefits. Therefore new OSM systems boast many advantages from using off-site manufacture as a primary construction method.

These include an increased speed of construction. A case study from modular building contractors Unite Modular Solutions reports of a “ 76 module, 32 self contained flats scheme in London” that was fully erected in 8 days (Unite 2009). A study undertaken by Davis Langdon and Everest found that for the Peabody Trust’s Murray Grove project in East London, a “ saving of 18 weeks was achieved compared with a conventional project” (Davis Langdon & Everest 2002).

Due to the factory conditions in which the components are constructed, a higher level of quality can be incorporated into the end product. Problems occur on-site when adverse weather conditions affect the quality of components such as concrete. When the weather is adversely hot, too much water evaporates from the concrete whilst it is curing. If the temperature is too low the chemical reactions that happen during curing will take place too slow. Both these extremes will have detrimental effects on the compressive strength of the cured concrete (Mittelacher 1985). There is also less



movement and shrinkage when the project is completed that means that the quality of the finishes and the level of attention to detail permissible mean that snagging time is reduced at the end of the project. This is the added time of making sure the finishing quality is satisfactory.

The use of prefabrication can improve the health and safety conditions on-site. This done by eliminating the congestion on site as well as the amount of working from height that is necessary. This is because anything that is needed to be done at height can be done in the factory conditions on platforms under correct supervision. A paper produced by the Health and Safety Executive reports that HSE:

“...statistics indicate that fatal accidents in construction are five times more likely than in the manufacturing sector.” (Taylor 2009)

The main advantage that makes OSM relevant to this study is the environmental benefits it is reported to bring to a construction project.

With a higher standard of quality, optimum thermal efficiencies and air permeability's can be achieved consistently using OSM. When construction takes place on-site, there is more of a chance of thermal bridges and insufficient workmanship to reduce the thermal efficiencies of a component. In a factory, standardised components can be used in a controlled environment with correct supervision to achieve minimal tolerances in products.

Less waste is produced during the manufacture stage compared to traditional methods of construction. This is due to lean processes and the

efficient use of resources. The opportunity to re-use and recycle materials is also increased due to the controlled factory conditions. The factory environment means that components are produced correctly the first time, limiting waste. Another benefit is that the final design is locked at an early stage, so the opportunities for variations on-site are limited, and so less waste is generally produced.

New OSM systems are constructed of a light weight steel frame, which has a reasonably low amount of embodied energy compared to materials such as concrete (Greenspec 2010).

Clearly systems could be used that are more harmful to the environment than traditional methods of construction, however reports show undoubtedly that there is more potential to produce more environmentally friendly buildings using OSM.

However there are disadvantages to using OSM. One contentious aspect is the cost. There are two sides to the argument; the first being that the process of using prefabrication is more expensive. A study by Davis Langdon showed that there is on average a cost premium of using OSM of between 10% and 25% (Rawlinson 2009). Others accept the premium in cost, however believe the loss in money is regained due to the reduced construction time and reduced snagging time due to the better quality. They also argue that the components are better designed for ease of maintenance and repair and so a saving can be made in the long term. The report by Rawlinson (2009) does state that the costs are regained through these savings for some or all of the costs, but does not quantify the amount.

Other problems include the high set up costs of using the construction method. The majority of the construction work that is undertaken in the UK uses traditional methods of construction. Therefore there is only a very small skill base of trade's people who are competent with the OSM processes. Although the training to learn these skills is not rigorous, over the entire United Kingdom it would amount to a sizeable sum. The cost of establishing prefabrication facilities is also very high and so this may be a factor as to why the construction method is not widely used.

The aesthetics of OSM may also be a factor that has reduced the use of the construction process throughout the UK. The poor perception to past systems and very modular design of many OSM structures mean that the construction method does not suit everyone's tastes.

## 2. 2 The Climate Change Act 2008

The Climate Change Act 2008 is a piece of legislation that legally binds the United Kingdom to reduce its green house gas emissions. The main green house gas (GHG) which causes concern is carbon dioxide (CO<sub>2</sub>). The reduction targets are an overall GHG emission cut of 80% by 2050, with an interim deadline of a reduction of 34% by 2022. This is compared to a baseline figure from 1990 of 593 million tonnes of carbon dioxide (MtCO<sub>2</sub>) (National Audit Office 2008). Therefore a reduction of 34% is an emission level of 391MtCO<sub>2</sub> in 2022, and a proposed emission of 119 MtCO<sub>2</sub> for the year of 2050. The other GHG's named in the Act are methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (Climate Change Act 2008 s24. 1). The Act also makes provisions for other gases to

be added to this list by the Secretary of State if they become of interest (s24.1g).

Section 32. 1 of the Act states that an independent body must be created, named the Committee on Climate Change. The duties of this body include providing advice on whether the GHG reduction targets should be altered and to what extent in order to meet them (s33), advising on the carbon budget (s34), advising on aviation and shipping emissions (s35), presenting progress reports to Parliament (s36) and to provide advice and assistance upon request (s38).

The Act states that the Secretary of State, currently Chris Huhne, must set a carbon budgeting system. This is the process of stating the allowable GHG emissions within 5 year periods. This figure is set with the advice of the Committee on Climate Change (s9). Three of these periods are set at a time. The first 3 periods are 2008-2012, 2013-2017 and 2018-2022. The next 3 budget caps must be set by June 30th 2011 (Climate Change Act 2008 s4.2a+b).

The United Kingdom is the first country to legally show its intentions for cutting its carbon emissions. The Act is aimed to pave the way for cutting emissions for other countries. In a video made by the Committee on Climate Change about building a low-carbon economy, Martin Parry member of the Intergovernmental Panel on Climate Change says that the Act will set a "... landmark example to what other countries can do". It is hoped that the Act will increase the UK's ' energy awareness' and help improve our carbon

management. The Government hopes that this will move the UK into a low-carbon economy.

It is hoped that because the Act is a long term measure, covering 40 years, it will encourage businesses to invest heavily in low carbon technologies, as there is reassurance that returns will be made from investments now.

It has been established that the main area where the UK's GHG emissions can be reduced is in electricity production. In EcoCentroGen newsletter August 2009, it is reported that the Government predicts that " around 40% of electricity will be from low carbon sources" by 2020. However significant savings in emissions can be made in both the transport and housing industry. In the same newsletter, it is reported that by 2020:

"...7 million homes will be involved in energy saving schemes, and more than 1.5 million households will be supported to produce their own clean energy"

The Chief Executive of the Committee on Climate Change, David Kennedy, highlighted four key areas where emission cuts can be made. These were electricity production, housing, transport and farming (Adam 2010). With about 27% of the UK's energy being consumed in the housing sector, there are substantial savings to be made (Farookhi 2008). Producing more energy efficient homes will reduce this figure. The Government will try to implement these savings through a variety of means. Examples of these may be through more stringent Building Regulations, financial initiatives for implementing renewable energy technologies, such as grants for installing solar panels or ' feed-back' tariffs or by raising fuel prices.

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There is however some concern and criticism over the rate of decarbonisation the Act implies. The Kaya identity is an equation that shows the relationship between energy and human factors and the effect the combination of these has on total carbon emissions of a country. This equation states that the only method for reducing carbon emissions is to reduce either population, per capita GDP or the carbon intensity of the UK's economy. Governments tend not to manipulate population or GDP per capita as they do not receive public backing and disrupt economic growth.

Therefore Government policies for reducing carbon emissions tend to focus on reducing the carbon intensity of the economy, and the Climate Change is no exception. It is argued that by using the Kaya Identity, the Climate Change Act 2008 has not taken into consideration the effects of population growth and per capita economic growth. It is argued that with the effect of a growing population and economic growth, to meet the reduced emission targets of 2050, the UK would have to reduce the energy intensity and increase energy efficiency by a rate of 5.4% a year (Pielke Jr 2009). Pielke Jr argues that for this rate of decarbonisation to occur, the UK would have to have the same carbon efficiency as France achieved in 2006, by 2015. This would involve constructing around 30 nuclear power plants. It is argued that this is simply not feasible.

Pielke Jr concludes by pointing out these unachievable targets have been set as the Act's approach to emissions reduction is " backwards". Opposed to assessing what the ultimate rate of decarbonisation the UK is capable of achieving, and setting targets suitable to this, the Act has set " practically

impossible” targets, and only now they have been made in law, the UK is thinking of ways of achieving them.

## 2. 3 Building Regulations

The current Building Regulation requirements are of interest to this study as they show the current energy efficiency standards of houses being constructed today. They will also be the means by which the Government will enforce changes in construction practice in order to meet the GHG emission reduction targets.

Building Regulations are statutory instruments that are used to enforce the relevant legislation that dictate good standards of construction and safety in England and Wales. Schedule 1 of the Regulations consists of fourteen approved documents that cover the following subjects (<http://www.planningportal.gov.uk/buildingregulations>);

Part A – Structural safety

Part B – Fire safety

Part C – Site preparation and resistance to contaminants and moisture

Part D – Toxic substances

Part E – Resistance to sound

Part F – Ventilation

Part G – Sanitation, hot water safety and water efficiency

Part H – Drainage and waste disposal

Part J – Heat producing appliances

Part K – Protection from falling

Part L – Conservation of fuel and power

Part M – Access to and use of buildings

Part N – Glazing safety

Part P – Electrical Safety

The Building Regulations are the statutory instruments of the Building Act 1984. The Act makes provision for the Secretary of State to update or create new regulations for the purposes of health and safety, increasing the conservation of fuel or power and preventing waste of water (Building Act 1984 s1).

Building Control was first used in London in 1189. This involved the enforcement of rules dictating party walls, rights of light and drainage. Around this time the introduction of consideration in design for fire-resistance buildings and means of escape in case of a fire were developed (Stephenson 2005). After the Fire of London in 1666, the first building Act became law. This Act made provisions for surveyors to be selected to ensure that the regulations were obeyed on construction sites.

In 1984 the Building Act was passed and consolidated the various previous regulations to produce one main piece of legislation.

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Most building work requires Building Approval. This is the process of checking work done onsite complies with the Building Regulations. The duty of checking compliance with the Regulations is undertaken by Building Control Bodies. These approved inspectors can be from the Local Authority or they can be from the private sector (<http://www.planningportal.gov.uk>).

Some forms of construction are exempt from the Building Regulations. These include porches, conservatories and some garages which are all subject to size, use, description, design, location and other requirements. If these requirements are not strictly met then the construction work requires building approval (<http://www.kingston.gov.uk/browse/environment/buildingcontrol>).

The responsibility of following the Building Regulations falls to the person carrying out the work. To whom this responsibility falls to should be confirmed at the start of the work (Building Regulations Explanatory Handbook s2. 4 2005).

The Building Regulations state the allowable U-value of components to be used in new dwellings. U-values show the ability of a building component to conduct heat. Approved document L1B 2000 outlines the target minimum U-value of building components. To increase the energy performance of the overall building, the U-values of components must be as low as possible. Under Part L 2002, the U-Value of new build cavity walls is 0.35 W/m<sup>2</sup>K. For a comparison a 225mm solid brick wall has the average U-Value of 2.0 W/m<sup>2</sup>K ([http://www.syec.co.uk/factsheets/U\\_value\\_factsheet.pdf](http://www.syec.co.uk/factsheets/U_value_factsheet.pdf))

The Building Regulations also state the allowable air permeability of new build dwellings. This is the rate of air leaving the building as well as the rate of new air entering the building. A low air permeability figure means that the air will not escape and energy will not be wasted. Under Part L of Schedule 1 of the Building Regulations the allowable air permeability is stated as 10m<sup>3</sup>/hm<sup>2</sup> at 50Pa.

These figures are relevant to this study as the benefits of a higher quality product coming from a factory environment, mean that these figures may be more easily achieved using prefabrication and off-site manufacturing techniques.

## 2. 4 Literature Review Summary

From the research of the respective literature the benefits of prefabrication have been presented. These are the increase in quality, speed of construction, health and safety on site and the environmental benefits these bring. The disadvantages the OSM produces as a construction method are an increase in the project cost, a potential unattractive aesthetic aspect and the high set up costs associated with new OSM facilities.

The Building Regulations have been studied to show the standard to which new homes are built as a comparison to OSM.

The targets of the Climate Change Act 2008 have been established. These are a 34% reduction by 2022 and an overall 80% reduction by 2050 compared to a baseline figure from 1990. In order for the UK to meet these targets, four key areas have been highlighted for action; one of these is the

energy efficiency of the UK's housing stock. Studies have shown that these targets are very ambitious and for them to be achieved a radical change in how we design and build houses must be undertaken. From identifying the benefits of prefabrications, an argument can be made that this construction method could be the answer to producing more energy efficient homes.

A methodology must now be formulated in order to collect data from the construction industry. This will involve identifying the participants for the study and a method for collecting data from them. It will also involve creating questions that will produce the required data.

### 3. Methodology

#### 3. 1 Scope of the Chapter

This chapter will establish the method for collecting the data relevant to this study. It will set out the research aims and the rationale behind their selection. A section that explains the types of information studied will be included as well as an explanation of the participant design. A method for the analysis of the collected data will then be established.

#### 3. 2 Statement of Research Aim

The aim of this research is to establish whether an increased use of off-site manufacture will produce a more energy efficient housing stock, as the UK gets closer to its carbon reduction deadline. The objectives of this study are;

To identify the key advantages and disadvantages of prefabrication as a construction method.

To identify the current requirements for energy efficiency in new build houses.

To identify the requirements of the Climate Change Act 2008 and how this will affect the construction industry.

To establish the current use and opinion of prefabrication/off-site manufacture in the construction industry

### 3. 3 Rationale of the Research

With the UK's housing stock producing approximately 30% of the UK's total carbon emissions, it is a sector where huge environmental gains can be made (House of Commons 2005). Off-site manufacture enables an improved finished quality so that optimum thermal efficiencies and air permeability's can be achieved consistently. Other benefits are that less waste is produced during the manufacture stage compared to traditional methods of construction and there is an increased opportunity to re-use and recycle materials in factory conditions. With the UK legally bound to reduce its GHG emissions by 34% by 2022 and 80% by 2050, action is required to make housing more energy efficient.

### 3. 4 Secondary Research

To establish the advantages and disadvantages of prefabrication, the current Building Regulations for energy efficiency and the targets set by the Climate Change Act 2008, a literature review was undertaken. This was done to establish all the information that is already known on the topic and to

highlight any areas of study that have already been conducted.

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3. 5 Primary Research

3. 6 Research Sample

3. 7 Method of Analysis

3. 8 Summary of Chapter