Cost viability of 3D printed house in UK

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Abstract: UK has been facing housing crisis due to the rising price of the property on sale. This paper will look into the viability of 3D printing technology as an alternative way for house construction on UK. The analysis will be carried out based on the data until the year of 2014 due to limited resources availability. Details cost breakdown on average size house construction cost in UK were analysed and relate to the cost viability of 3D printing technology in reducing the house price in UK. It is found that the 3D printing generates saving of up to around 35% out of total house price in UK. This cost saving comes from the 3D printed construction of walls and foundations for material and labour cost.

Keywords: UK, house price, 3D printing

1. Introduction

The UK’s housing crisis is increasing in severity, with an ever growing gap between the supply and demand of housing. The average house price for England and Wales in 2015 is £179,492 with areas such as London experiencing average prices of £458,283 [1]. The average 2014 salary for individuals who had been in the same role for more than 12 months is £27,200 [2]. By using average house price data from HM Land Registry [1], this makes the average house price for England and Wales 6.6 times the average annual salary as shown based on data from and of average salaries from Office for National Statistics [2]. Figure 1 shows a plot of the house price to earnings ratio for various areas in the UK.

House price is growing at an average rate of 6.7% per annum from Jan 2014 to Jan 2015 (Table 1) with average salaries only increasing at 0.7% per annum [1]. Homeownership is put further out of reach for many people as time goes by. Whilst many solutions to this issue are posed, one commonly suggested solution is to simply build more houses. If the supply of housing increases, the price should fall and allow easier acquisition of houses.

In 2007, the UK government set a target to build 240,000 new houses per year by 2016 [3]. In 2014, only 118,760 houses were built, an 8% increase from the previous year [4]. The lack of production is largely due to lingering risk aversion from the 2008 recession [5]. Private construction enterprises do not wish to risk their money by investing into new housing, when there are no buyers due to economic downturn. For 3D printing house construction to be a suitable solution to the UK’s housing crisis, it needs to perform better than traditional methods. It must reduce the costs of construction significantly.
Reducing the costs of construction reduces the risk to construction companies and encourages them to commit to new projects.

**Figure 1.** Plot of house price to average earning ratio for various areas in the UK. This plot uses house price data from [1] and earning data from [2].

**Table 1.** Average house price by property type adopted from [3].

| Average price by property type (England & Wales) | January 2014 | January 2015 | Difference |
|-------------------------------------------------|--------------|--------------|------------|
| Detached                                        | £265,814     | £282,338     | 6.2%       |
| Semi-detached                                   | £159,184     | £170,926     | 7.4%       |
| Terraced                                        | £126,931     | £134,757     | 6.2%       |
| Flat/maisonette                                 | £160,016     | £171,669     | 7.3%       |
| All                                             | £168,231     | £179,492     | 6.7%       |

2. **3D printed house technology**

The early technology of 3D printed house is pioneered by a technology called Contour Crafting [6]. It is a technology resulting from the application of the principles of 3D printing to the construction of houses. The technology is a method of automated additive fabrication applied to construction. Single layers of concrete are repeatedly extruded using a three dimensional gantry system. Layers of concrete are built upon each other sequentially until the wall structure is complete (**Figure 2**). The technology applies the modern principles of automation to the traditional principles of construction.
Historical construction tools such as trowels, sculpturing knives and putty knives have been used for thousands of years in construction [7 & 8]. The 3D printed house uses the same approach by extruding wet concrete and using the trowel like attachment to shape it, as it would be done with manual tools. The additive approach employed by the technology also allows complex geometries to be created as easily as planar walls, whereas these may take significant expertise to create by manual methods.

Each layer is constructed in two passes. In the forward pass, two parallel surfaces are extruded. These surfaces bound a hollow cavity, and are known as the “filling rims”. On the backwards pass, triangulated filler is extruded in the space between the filling rims, in order to provide strength to the wall. This can be seen in Figure 3. By only providing a triangulated filling between the rims, a lot of material is saved compared to traditional construction which required filling the entire cavity with solid material. These savings can be rather significant and easily predicted. Figure 3 shows that curved walls are also possible. These are built as easily as standard rectilinear ones; allowing for geometries not easily acquired by traditional methods.

![Figure 2](image1.jpg)

**Figure 2.** Illustration of house construction using Contour Crafting 3D printing technology. Image adopted from [6].

![Figure 3](image2.jpg)

**Figure 3.** A section of wall constructed using Contour Crafting. Image adopted from [8].

3. Development in 3D printed house

Winsun, a construction company based in Shanghai, China are well known for 3D printed construction. In March 2014, Winsun announced that they had constructed ten concrete houses, in the space of 24 hours. Each house has 200 m² usable floor area and cost only £2,970 (Figure 4). The 3D printed parts of the house are mainly the exterior wall structure and base. They were mentioned that the total cost for the house construction to be halved from the traditional one [9].
In January 2015, Winsun completed a 3D printed villa that costs about £105,000 (Figure 5). The construction of the villa took eight people in a month to be completed. It is also claimed to have otherwise taken 30 people in three months. The claim indicates that a reduction of 91% in man-hours is possible by using 3D printing house construction. Saving from the labour cost is also contributed by employing less skilled workers since the wall construction is mainly done by the printer. Not only that, the number of workers has been reduced. Less expensive workers can also be employed [10].

Figure 4. A selection of the 10 3D printed houses made in 24 hours for £2,970 each by Winsun construction company in March 2014. Image adopted from [9].

Figure 5. Image of the villa created using 3D printing technology by Suzhou Ltd, a construction company in Shanghai, China. Image adopted from [10].

4. Construction cost analyses

A study done by Cuéllar-Franca & Azapagic [11] looks at the cost of building a house in UK for detached, semi-detached, and terrace house. The cost of the house construction can be divided in terms of labour cost, material cost, energy cost and profit taken by the developer. The construction cost in building a semi-detached house in UK with 90 m² usable floor area is about £68,000. While 52% of this contributes to the labour cost in the construction, another 37% for materials, less than 1% on the energy cost and the remaining are the profit taken by the construction company. The average size of the house presented in [5] which is about 91 m² usable floor area is similar to the one used in the study.

Based on the information from [11], the construction cost of internal wall, external wall and foundation for a semi-detached house is about £36,000 in material and labour cost (Table 2). These constructions are potentially can be built using 3D printing technology. This is about 53% from total construction cost of £68,000 as mentioned above. Assuming of 90% reduction in labour (as claimed by Winsun [10]) and 50% reduction in materials [9], the estimated savings can be gained are £19,000.
from labour cost and £7,400 from materials cost. This total up to £26,400 saving in construction cost per house.

Table 2. Construction cost for semi-detached house in UK, adopted from [11].

| COMPONENTS         | Materials cost (£) | Labour cost (£) | Fuel and machinery cost (£) | Construction company’s profit (£) |
|--------------------|--------------------|-----------------|-----------------------------|----------------------------------|
| Construction       |                    |                 |                             |                                  |
| activities         |                    |                 |                             |                                  |
| External wall      | 9,568              | 13,733          |                             | 390                              |
| Internal wall      | 3,911              | 6,041           |                             | 995                              |
| Foundation         | 1,396              | 1,433           |                             | 283                              |
| First Floor        | 2,423              | 3,880           |                             | 630                              |
| Ground Floor       | 1,605              | 3,384           |                             | 499                              |
| Roof               | 5,077              | 5,137           | 81                          | 1,021                            |
| Ceiling            | 663                | 1,019           |                             | 168                              |
| Windows            | 359                | 592             |                             | 95                               |
| Doors              | 603                | 377             |                             | 98                               |
| TOTAL              | 25,605             | 35,596          | 471                         | 6,119                            |

UK development land price in average for England during 2007 peaked at £4 million per hectare [12]. Combining data form Savills [13] and Land Registry [12] the estimated price for land development in 2013 was about £2.4 million per hectare. By assuming 100 m² land being used for building average-sized UK house, the cost of the land equates to £24,000 per house.

As mentioned earlier, the average house price in UK is around £180,000 [1], the construction cost is £68,000 [11] and the land cost is £24,000 [12, 13]. As calculated earlier, the 3D printing house creates saving in construction cost of about £26,400. By assuming the same ratio of profit to cost being taken by the developer with the same land cost, the new 3D printed house can be priced at 30% lower than the traditional construction house (Figure 6). However, it is important to note that the cost of the 3D printing technology that is going to be used is not included in this calculation. The investment in the 3D printing technology is a one off setup cost which will be reduced with the quantity of the houses built. The cost of the technology is not publicly available yet.

Figure 6. House price comparison for traditional construction and 3D printed house for average sized house in UK.
5. Conclusion

It has been discussed that the technology of 3D printed house must able to construct houses at lower cost than traditional construction methods in order for it to be a viable method. Work presented is a simple analogy on saving estimation for 3D printed house to be implemented in UK. The work will encourage further detail analyses on the cost implication of the technology in the future. This paper investigates the cost viability for 3D printed house technology in UK for average sized house with usable space of 90 m². The presented results allow the following conclusions to be made:

- 3D printing technology is able to replace the traditional construction of internal wall, eternal wall and foundation.
- There is possibility of house price reduction up to 30% which can be obtained through the introduction of 3D printed house in UK.
- The cost of the technology is not included in the calculation due to data unavailability.

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