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3D House Printing: A sustainable housing solution for Nigeria's housing needs

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Abstract. In a country that has between 17 to 20 million housing deficit with an uncontrolled growing population, there is need for innovative and sustainable solutions to reduce the rate of homelessness and sub-standard living conditions. The study presented the prospects in the use of three-dimensional printing (3DP) as a sustainable housing solution to cater for the housing needs of Nigerians. Nigeria is at the centre of this study due to its population and housing challenges. The study utilized content analysis based on previous studies on 3DP in developed and developing countries. The study identified critical areas that 3DP of houses can solve Nigeria's housing needs which are mainly in reducing housing deficit, provide permanent housing solution for IDPs, reduction of construction waste, increased construction safety, achievement of sustainability goals, reduction in construction errors and labour cost.

1. Introduction

The provision of housing plays a crucial role in the existence of man in the earth's ecosystem. Different definitions have been attributed to the concept of housing. Researchers have termed it as a place of abode for habitation, a permanent structure, an identity and a private place. This assertion means that housing should be considered beyond a place to lay one's head. [1] opined that the interwoven nature of housing in the socio-economic and health space makes it critical to be considered in developed and developing countries.

Considering the challenges associated the state of the Nigerian housing sector is something to be concerned about bearing in mind the large population [2]. The inadequacies experienced in the housing sector can be attributed to government negligence, ineffective government housing policies, failed housing financing system, unavailability/inadequate access to long-term housing funds, high rate of poverty, meagre household income compared to expenses, unattractive interest rates, high land prices, high fluctuation of building materials, high bureaucracy in the town planning agencies for approvals, difficulties in obtaining government clearance for buildings and the high spate of corruption. These challenges has left an enormous housing deficit within the country. These challenges may be evident in both developed and developing countries. However, developed countries have developed frameworks that have ensured the success of its housing policies and developed new technologies such as the 3D printing of houses. The Nigerian housing deficit stands at 18 million units with homelessness at 24.4 million, there is need for an effective strategy that addresses the number of housing units produced per year [2].

An effective building strategy is the 3D printing of houses. The concept which is over 30 years old has been gaining attention and utilized in developed countries such as in the United States,



Russia and China. 3-dimensional printing (3DP) also referred to as “additive manufacturing” is the process of printing tangible objects or products in a three-dimensional model from a digital information through a layer-by-layer placement of the composite building material [3]. Early use of the 3DPs were mostly to recreate prototypes in the industrial environments which was called rapid prototyping. However, due to advancement in information and communication technologies (ICTs) leading to reductions in cost, the application of 3DPs are been used effectively in other sectors including the construction industry [4].

By using a 3D printer, buildings or their components can be literally ‘printed’ out as an object in three dimensions from a 3D digital model. For developing countries, [5] opined that there are numerous benefits accrued to the implementation of 3DP due to the limitation on some building materials and shortage of skilled labour. In addition, [6] recorded that 3DP through personal manufacturing can result in the reduction of poverty, decrease in waste and decrease the gap between large and small manufacturing firms in developing countries. While some fear that 3DP technologies are costly to implement, [5] argued that the technology is becoming economical due to the availability of free 3D digital models online. The concept of 3DP can be well integrated in the construction industry like other information and communication technologies (ICTs) products in use [7, 8]. Therefore, this study examines the benefits that can be accrued in the use of 3-dimensional printing (3DP) of houses as a sustainable housing solution for Africa’s most populous country in solving its housing needs.

2. Methodology

An analysis of the SWOT analysis of 3DP technologies compared with the traditional method of construction as shown in Table 1 helped in discussing the strength that Nigeria can capitalize on in the use of 3DP.

Table 1. SWOT breakdown of 3DP technologies

STRENGTH	WEAKNESS
<ul style="list-style-type: none"> • Increased Flexibility in Design • Joint connections are reduced • Reduction in waste of building materials • Condensed supply chain • Negates dedicated tooling • Improved cost associated with labour • Easy market entry 	<ul style="list-style-type: none"> • Materials are limited • Cost • Speed and Volumes • Strength • Usability • Lack of Control over Printers
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> • Building products can be customized • Encourages small production • Improved testing of products • New jobs are created • Manufacturing process is encouraged • Undesirability is eliminated • Increased innovation 	<ul style="list-style-type: none"> • Copyright & ethics • Consumer rights • Frivolous printing • Job losses (traditional)

Source:[4].

The study is focused on Nigeria; Africa’s most populous country. The population as at the last census in 2006 stood at 181 million with an annual growth of 3 percent. The United Nation Population Prospectus of 2010 projected that by 2020, Nigeria’s population would have reached 204 million. Nigeria is at the centre of this study due to its population and housing challenges. The study utilized content analysis based on previous studies on 3DP in developed and developing countries. Ground breaking studies from [9, 10, 11] paved the way for analysing the benefits of 3DP to developing countries as a sustainable housing solution. Using a review of literature a framework of enormous benefits were identified. 3DPs are in different dimensions, from process, operation, types, companies,

materials, to cons associated with its use. The study focuses on the pros that the use of 3DP can bring to a developing country such as Nigeria. With a housing deficit of over 18 million, the location is a good recipe for implementing the innovative technology.

3. Discussion

The issues of sustainability has been taken the fore in several studies. A sustainable solution in the housing sector would be such that encompass effective cost, time and quality with other items of environmentally friendly, innovation and client satisfaction. This study showed how the use of 3DP helps Nigeria to solve its housing deficit. 3DP can be asustainable housing solution meetingNigeria's housing needs under the following critical headings;

3.1 Reduction in Housing deficit.

The Nigerian housing sector offers opportunities to those that see the challenges as such. This is so in that with over 180 million Nigerians, the shortfall in the housing sector as at 2012 was put at over 17 to 20 million housing units with a cost tag of over 6 trillion naira (\$16.7 billion) and a housing demand of 20 percent annually[11]. In addition, the rate of homelessness continues to increase compared to other developing countries. This means that developers and construction stakeholders can take advantage of the housing provision needs to make profit for their construction businesses. Across several cities in Nigeria, urbanization continues to increase at 5.5 percent annually. Therefore, the need for an urgent framework to speedily address the housing deficit by various stakeholders in the built environment and government agencies. Economist have forecast a total average of 100,000 houses can be built in the country per annum. This capacity is inadequate to meet the needs of the country even in the next 40 years.This makes the use of 3DP technologies to augment the traditional process in the delivery of housing projects a novel idea. [5] noted that different 3DP construction companies are springing up daily with the ability to use large scale 3DP as shown in Figure 1 to construct buildings layer by layer within 24 hours. An important aspect of 3DP that makes it applicable for solving the housing deficit in Nigeria is the speed of delivery of the houses. The whole construction process is automated, therefore, it surpasses the limitation of the human factor of fatigue while working to deliver the product (house) on schedule. There are no forms of breaks or constraint in lighting at night [12].For example, Apis Cor Company asserted that they have a large-scale 3DP that has the capacity of producing a 20 by 20 ft buildingwith cement walls in a day at a total cost of just over \$10,000 (=N= 3.6 million naira)[5]. This is inclusive of the labour and building material cost. Other elements were installed manually, which include roofing system, electrical, HVAC and mechanical systems. Before the advent of the whole-structure 3D printing, some 3DP construction companies have used 3DP to produce independent elements in buildings. With the development of 3DP, the use of concrete composite is being used to build the houses. CyBeConstruction Companyhas developed composite for the 3DP that ensures the cement wallsexsiccate with an hour [5].



Figure 1. A 3DP construction of houses on a railing system
Source: iconbuild.com

3.2 Permanent housing solution for internally displaced persons (IDPs)

Nigeria has witnessed unprecedented high levels of violence since its independence. These violence can be mainly attributed to three themes: ethnicity, religion and politics. This has led to conflict induced displacement creating large numbers of internally displaced persons [13]. Although, there are other reasons for internal displacement of people resulting from various government decisions, natural and man-made disasters, economic and boundary conflicts etc. Estimated figures of IDPs from the International Organization for Migration (IOM) as at June, 2016 is put at 2,066,783 (344,564 households) identified from 13 states in the North including the Federal Capital Territory. In terms of housing, the basic necessity that internally displaced persons (IDPs) require on an immediate basis is a temporary shelter solution [14]. Once they have been relocated to the urban centres, there is need to provide long-term sustainable housing solutions for them. In both cases of temporary and permanent housing solutions, 3DP can be speedily employed to deliver the required shelter for the IDPs. In the report by [5], 3DP Construction firms affirmed that the technology can be adequately and swiftly deployed in cases of natural disaster such as earthquakes, floods and so on, in developing countries to provide the necessary succour of temporary shelter. Although, [10] and [12] recorded that these innovative step has not been methodically explored as a humanitarian relief in developing countries. After any form of disaster, logistics is very crucial. The use of 3DP can help streamline the process of providing temporary shelter by eliminating the need for high labour requirement [15].

3.3 Reduced construction waste

In the Nigerian construction industry, the issues of construction waste is evident on most landfills and construction sites. From bamboos used for scaffolds, wooden formworks, unused concrete, plastics, steel reinforcement offcuts, binding wires, broken tiles and nails, construction waste is becoming alarming. They are not economical to the contractor or client and the environment. In the space of just 5 years, Nigeria generated more than 40m tons of waste [16] with construction waste contributing a significant amount [17]. Therefore, there is the need for construction methodologies that decreases the waste generated during construction operations. The innovation of 3D in helping to reduce waste is that it makes use of only the materials that has been inputted in the printer [5]. There is no form of waste as the materials are laid layer by layer. With issues of climate change, sustainability and spread of infectious diseases, building materials waste generation needs to be brought to a minimum. By reducing construction waste in 3DP operation, cost and sustainability issues are adequately dealt with.

3.4 Increased Safety of Construction Works

The construction workspace is a very dangerous place to work. The rate of accidents leading to fatalities on Nigeria's construction sites is becoming worrisome. The accident rate situation highlighted in developing countries such as Nigeria is worse [18] and in most cases are not documented. Although, there are accidents in different workplace in the economy, the construction site accounts for 25 percent of the total accidents at workplace. Different factors have been attributed to the high number of accidents on construction sites, but most of them can be traced back to the human error factor. The use of 3Dp to build houses can greatly reduce the poor safety record in the construction industry. This can be achieved mainly because the large-scale 3DP are programmed on the CAD file to replicate without any form of human intervention or support to deliver the buildings [12]. Any construction methodology that uses few labour in constructing buildings invariably reduces accidents at construction sites.

3.5 Achievement of Sustainability goals

In comparison with the traditional construction methodology, 3DP offers a more sustainable solution to building houses [12]. Buildings make use of raw materials that are gotten from the environment and therefore they should be optimized. Any operation that encourages efficient use of the scarce raw materials in producing buildings should be well explored. In the study by [19], 3DP used only 40 percent of the total raw materials that would have been used for constructing a house using the traditional process. Many 3DP companies are thinking sustainability in the type of raw materials they are using in their 3DP operation. Construction company Cazza's mix for their 3DP building is made from up to 80 percent recycled material [5]. In addition, [19] recorded that the energy required for constructing buildings by 3DP is reduced by 30-70%. The fact that safety increases and labour use decreases is a fundamental goal in achieving sustainability in building construction. Another benefit 3DP introduces in building construction is the elimination of the use of formwork. Most formworks used in developing countries are made from wood and by eliminating the need to fell trees, sustainability goals are promoted.

3.6 Reduction in construction errors

Inaccuracies in design, omission during design and construction and carelessness of construction stakeholders are some major reasons for errors noticed during construction operation [20]. However, there are other construction errors due to lack of experience, poor supervision or poor equipment and so on. Experts of 3DP opined that the printing technology leaves no room for errors during the construction operation [5]. The main concentration would be focused on the digital CAD design from which the 3DP would read to produce the house. Other forms of variation that arise during the construction process in the traditional method is greatly reduced leading to less rework on the final building.

3.7 Reduced Labour cost

A large portion of the work carried out by 3DP mode of building uses robotics and programming, therefore, few labour is required throughout the construction lifecycle [5]. There are few points where labour is required, from setting up the large-scale 3DP, loading the raw materials into the 3DP and programming the 3DP to the CAD file [12]. The use of skilled or unskilled labour for 3DP operation is quite minimal. Although, there is the fear that the use of 3DP in developing countries could lead to massive loss of jobs for skilled labour. [4] argued that new job skill sets which are technology-based are created which can be learnt through 3DP application.

4. Conclusion

The study presented the prospects in the use of three-dimensional printing (3DP) as a sustainable housing solution to cater for the housing needs of Nigerians. Due to the population growth of Nigeria at 3 percent annually, rapid urbanization and high poverty profile, there is need for a novel idea to address the housing deficit that continues to increase. Without addressing the housing deficit, there would be continued spread of infectious diseases, high rate of slum creation and homelessness. From the study, critical areas that three-dimensional printing of houses can solve Nigeria's housing needs are mainly in reducing housing deficit, provide permanent housing solution for internally displaced persons (IDPs), reduction of construction waste, increased construction safety, achievement of sustainability goals, reduction in construction errors and labour cost. These areas are crucial in the building and construction industry that 3DP can solve in the housing needs of Nigerians. Solving Nigeria's housing deficit is about speed of delivery. In a country that can only maximally produce 100,000 units of houses annually in an increasing housing deficit of over 17 million units, the innovation of 3DP should be welcomed. It is highly recommended that through a private-public partnership (PPP) framework, the use of 3DP can be integrated in increasing the stock of housing produced annually in the Nigerian housing industry.

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