

Benefits of 3D Printing as A Sustainable Building Technology for Post-Disaster Housing

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Abstract:
In previous years, many countries were exposed to many natural and artificial disasters. Iraq is considered one of the countries most affected in the recent period by wars and natural disasters. These disasters were accompanied by many losses in lives, equipment, and infrastructure. One of the most prominent losses resulting from disasters is the loss of many residents of their homes because they were destroyed and forced to flee or seek refuge in safer and more habitable areas. As a result, the demand for housing increases during disaster recovery, whether temporary or permanent, to meet the housing needs of IDPs or refugees. Therefore, the research examines the prospects of using 3D printing (3DP) as a sustainable building technology to meet the needs of temporary or permanent housing for those affected by disasters. The research aims to clarify the benefits of using this technology, compare it with traditional construction methods, and study the obstacles that prevent its use to form a reliable knowledge base to meet the housing needs of those affected by future disasters. The research found that 3D printing technology during disaster recovery has many advantages, such as providing housing at the required level and speed, reducing construction waste, increasing construction safety, achieving sustainability goals, and reducing construction errors and costs. It also includes some obstacles related to his condition, economic conditions, and availability. Workers with experience in dealing with these modern technologies in construction.
Keywords: 3D Printing, 3D Printed House, Sustainability, Post-Disaster Housing.
DOI: 10.7176/JETP/12-2-04
Publication date: May 30th 2022

1. Introduction

Providing housing after disasters is essential in the recovery and reconstruction process and plays a vital role in restoring the affected people to their daily activities and strengthening social bonds among the disaster-affected population. Because of the urgent and urgent need to provide housing quickly after disasters, developed countries have developed new construction techniques that ensure the success of their post-disaster housing policies. One potential future solution in the manufacture of additives through 3D printing technology. Today, 3D printing technology has found its way into the construction industry. More than 30-year-old, technology has gained attention and been used in developed countries such as the United States, Russia, and China. With a 3D printer, buildings or components can be printed "as a 3D exterior from a 3D digital model". Developing countries can see that many benefits are accruing to the use of DP3 due to restrictions on some building materials and a shortage of skilled labor(Rivera, 2018).

Additionally, (Afolabi *et al.*, 2019) reported that 3DP through personal manufacturing could reduce poverty, waste, and the gap between large and small manufacturing firms in developing countries. While some fear that DP3 technologies are expensive to implement, it has been argued that the technology has become economical due to free online 3D digital models. Can well integrate the concept of 3DP into the construction industry as other ICT products are in use (Afolabi *et al.*, 2017, 2018).

Therefore, the study discusses the technology of 3D printing for homes as one of the sustainable construction techniques that can use in post-disaster conditions, and this study examines the benefits that can achieve from the use of 3D printing (DP3) for homes as a sustainable housing solution for the displaced or refugees after disasters. Whereas, can broadly apply 3D printing technology to building homes in disaster-affected areas when home construction is required at an urgent pace, where traditional building practices and techniques cannot provide. By using 3D printing technology, one can build a home in days or even hours. If implemented in such cases, there would be no need to build temporary shelters or temporary housing for the affected but a need to create a permanent structure in place of their damaged or collapsed homes. The urgency of mitigating the disaster conditions will justify the high cost of providing the printer and the cost of operating the damaged equipment, not to mention the huge funds allocated to relief and rehabilitation efforts if not dealt with promptly (Dancel, 2019). This scheme will make the government's relief, rehabilitation, reconstruction, and recovery efforts in line with the urgent needs of the affected people and achieve "more secure, resilient and resilient societies in the face of disasters towards sustainable development".

2. Methodology

The study used content analysis based on previous studies on 3DP in developed and developing countries. Thus, a framework has been outlined for the many benefits of 3DP in various dimensions, from the process, operation, types, firms, and materials, to the negatives associated with its use. The study focuses on the advantages that the 3DP program can bring to a developing country like Iraq, which is experiencing a crisis in providing temporary or permanent housing units for those displaced due to the recent war. With the difficulty of returning the displaced to their areas of original residence due to the destruction of their homes, this problem presents an opportunity to apply this innovative technology in building housing that meets the needs of the displaced over the short and long term of the disaster recovery period.

3. Discussion

Significant advances in technological tools and computational practices in design and engineering have progressively changed the building industry standards during the previous century. Successful management and effective response to post-disaster situations require a product that meets required standards and provides opportunities for options not found in traditional building techniques. In addition to successful and appropriate design, modern construction techniques play a role in translating this product, as technological developments and new tools, emerging generation after generation, continue to change standards related to construction methods in an endless quest to reduce cost, time and effort and improve the quality of design results(Salta *et al.*, 2020). It is worth noting that the construction industry, in its traditional form with manual labor, faces many complex issues that call for the need for the intervention of automation and modern technologies (Warszawski and Navon, 1998), most notably:

- The efficiency of manual work is very low.
- The rate of accidents at construction sites is alarmingly high.
- The quality of work is low.
- Low-level construction site management.
- Skilled workforce is few.

Accordingly, the following paragraphs discuss the technology of 3D printing of housing (3DP) as a proposal for one of the modern technologies that can use in post-disaster contexts. Although it was not previously used as construction technology and systematically in housing construction in post-disaster contexts (Savonen, 2015), its use may be A new opportunity to support innovative solutions. It is an ideal technology to explain the necessity of optimal production in terms of time and cost while keeping pace with the structural and aesthetic requirements in the semi-automated design and manufacturing process (Tatham, Loy and Peretti, 2014). Sustainability issues have also been taken into account in this study 3DP can serve as an A sustainable housing solution that meets the needs of post-disaster housing under the following essential headings:

3.1 Stages and Forms of Shelter and Post-Disaster Housing

Loss and damage to housing are among the most noticeable physical effects of disasters(Davidson, Lizarralde and Johnson, 2008). The reconstruction process assumes that the reconstruction and repair of housing is a specific and influential component of the recovery programs due to its significant role in re-establishing and strengthening social bonds among the affected population. Often, the post-disaster reconstruction process starts from the beginning of the destructive work until the provision of permanent housing solutions(Hany Abulnour, 2014), and this process faces incredible difficulties due to the urgent and urgent need to provide housing and take short-term actions taking into account the long-term concerns of sustainable development ((Davidson, Lizarralde and Johnson, 2008). In addition, there must be aware of the number of people looking for temporary residence and the duration needed for them, as these factors act as important variables in determining the most appropriate residence alternatives for each case, as more permanent residence options are recommended as the duration and the need for temporary residence increase.

In this context, there is no distinct and officially followed an approach by the concerned authorities regarding the classification of the stages of shelter and housing after disasters (Wagemann, 2012)and to track the process and define the goals and roles of the actors in this process, we can follow the division of (Quarantelli, 1995) to clarify the options for shelter and housing after a disaster and the form they take as shown in Figure 1. These phases constitute independent structures and are usually followed in sequence, considering the timeline for each step and the vulnerabilities that result from each disaster situation.

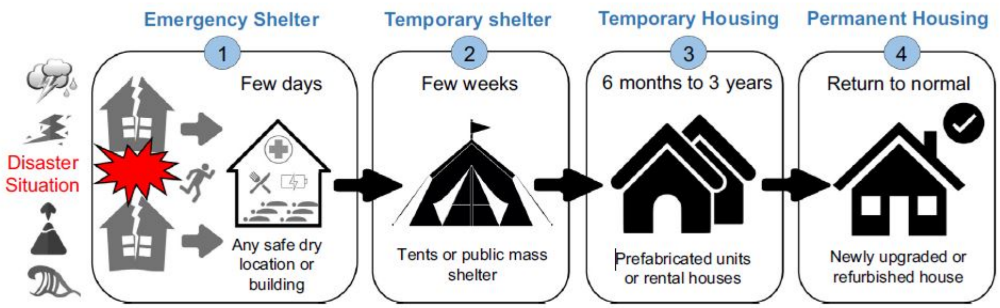

Figure .1 Stages of Post-Disaster Housing Classified by Quarantelli (1995).
Source: (Sukhwani *et al.*, 2021)

3.1.1 A Key to Permanent or Temporary Housing for Displaced Persons (IDPs)

Over the past years, Iraq has witnessed many wars and internal conflicts, which had a clear impact on all aspects of life, the most recent of which was the Iraq war against (ISIS), which began in late 2013 and continued until (2017), during which the governorates of Anbar, Mosul, Salah al-Din and Kirkuk were exposed. And parts of Diyala Governorate for primary military operations to recover those cities and restore security in them. During that period, many homes, infrastructure, and cultural monuments in these cities were destroyed, and the economic situation collapsed, causing the loss and injury of many people and the displacement of millions of residents.

The city of Mosul is one of the major Iraqi cities that have been subjected to massive destruction. The military operation to retake Mosul, which began in October 2016 and ended nine months later in July 2017, was the most protracted battle since World War II, during which evacuated one million civilians from the city. With the largest evacuation conducted from a combat zone in modern history, and according to preliminary estimates in the report of the United Nations Human Settlements Program for the year (2016), up to 20,000 buildings were damaged or destroyed in Mosul, and a high percentage of these buildings were residential buildings, as well as About many historical and iconic sites and buildings, most of which are located on the western bank of the Tigris River (Fig.2). Its economy has almost completely collapsed, its infrastructure and services have deteriorated, its public institutions have been destroyed, and its history and cultural heritage have been erased(Al-Samurai and Al-Qaraghuli, 2021).

The insecurity in cities due to exposure to terrorist attacks led to the emergence of an unprecedented displacement crisis, as the number of displaced persons from the affected areas reached (3.5 million) all over Iraq, and (850000) displaced persons were registered distributed in (59) official camps in Iraq (OCHA, 2017). Despite the end of the crisis, Iraq still faces enormous challenges represented in providing the humanitarian needs of many families who are still unable to return to their cities; Because of damaged or destroyed homes, concerns about explosive remnants of war, lack of security, lack of services, especially health care, education and lack of livelihood opportunities, and despite the efforts made by the Iraqi government to return the displaced, the latest statistics in (2021) show that there are still about 37,000 (displaced people) distributed in (28) camps, including (26) camps in the Kurdistan region, which increases the possibility of protracted displacement and this requires a comprehensive approach to meet the needs of the displaced and work to find durable solutions.

In this context, most of the camps suffered from social, economic, and environmental problems, as most of the centers were equipped with solutions in the form of prefabricated buildings or tents from the UNHCR for a long time. Among the most critical problems of the solutions provided:

- The lack of sufficient infrastructure to support safe and dignified living conditions, as most camps suffer from sewage and rainwater drainage problems and the paving of internal roads (Fig.3) .

- Difficulty accessing essential services such as hospitals and educational centers; most camps are far from urban centers, and academic centers are not available inside them.
- Difficulty providing livelihoods.
- Weak services and lack of quality standards for essential services, including water, health, and education.
- Social problems due to the lousy distribution of temporary housing units, as well as the lack of quality of the housing unit provided by the competent authorities, as most of the displaced overtime began to modify and add to these units to suit their needs and privacy (Alsaadi, 2019).

We conclude from the above that there is a need to reconsider the study of the foundations and determinants that must be followed to organize the recovery process during the phase of the temporary presence of the displaced in these camps and what are the sustainable strategies through which it is possible to enhance the quality of life inside these camps and work to use them in the long term, given that the duration of displacement It has exceeded five years, and those camps are continuing to accommodate the displaced, and therefore must reconsider the techniques and systems used in housing the replaced; The fact that shelter or adequate housing is the most influential element in meeting basic needs and enhancing the quality of life.

Figure .2 Destruction in the city center of Mosul. Source: (Al-Samurai and Al-Qaraghuli, 2021)

Figure.3 Poor infrastructure in winter, Hajj Ali camp, south of Mosul. Source: (IMO, 2019)

3.2 3D Printing (3DP)

3D printing (3DP) is a practical construction strategy that is more than (30) years old and has gained interest in many developed countries such as the United States, Russia, and China. Tangible objects or products in a 3D model from digital information by the layer-by-layer placement of composite building materials (Sakin and Kiroglu, 2017) was an early use of DP(3) mainly to recreate prototypes in industrial environments, which was called rapid prototyping, and due to advances in information and communication technology (ICT) which in turn led to lower costs, 3DP has been used effectively in other sectors including the construction industry (Fig .4) (McAlister and Wood, 2014).

3D printing technology was first introduced in 1981 by Hideo Kodama at Nagoya Municipal Industrial Research Institute in Japan, and since then, the variety, quantity, speed, cost, and accuracy of 3D printing methods have increased dramatically in the construction industry (Kodama, 1981).

Figure.4 illustrates the process of building a house using 3D printing technology. Source: (Tobi *et al.*, 2018)

3.2.1 3D Printing Technology and Materials

The starting point for any 3D printing process is a digital 3D model, which can be created using various 3D software. The designed model is then "cut" into layers, thus turning the design into a file that the 3D printer can read. The materials processed by the 3D printer are then placed according to the design and process. There are different types of 3D printing techniques, which process materials in various ways to create the final model.

In general, additive manufacturing (printing technologies) is generally classified into three main categories: liquid (SLA), powder-based (SLS), and solid. Fusion Deposition Modeling (FDM) belongs to the stable category of additive manufacturing categories of the most prominent 3D printing techniques (Fig.5); this technology was developed in (1989) by S. Scott Crump, and the basis of its work is extrusion. The material is passed through a nozzle and layer by layer and has the advantage of being the most common method nowadays at an affordable cost and using different materials (Sakin and Kiroglu, 2017).

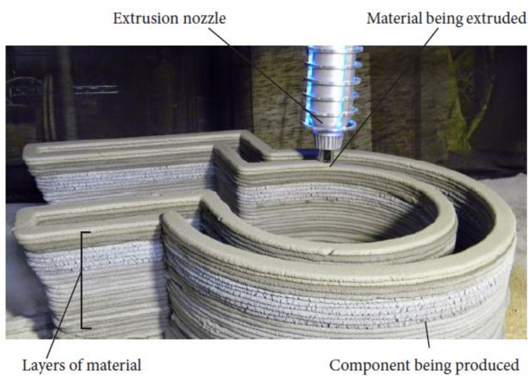

Figure .5 The Fused Deposition Modelling method. (FDM). Source: (Russell, 2015)

In terms of materials, plastics, metals, ceramics, and sand are now routinely used in industrial prototyping and production applications. Materials available for 3D printing have come a long way since the early days of technology, and there is now a wide variety of materials, which are supplied in different states (powder, filament, pellets, granules, resins, etc.) (Sakin and Kiroglu, 2017). On the other hand, modern industries in construction have been concerned with reducing the use of raw materials in the construction industry to achieve more economical and environmental efficiency through the most efficient methods and techniques (Bajgiran, 2018). Based on this, the research proposal follows this logic in the selection of materials through a bid for the use of earth materials (soil) in the construction of local temporary housing, as they are local, sustainable materials with low embodied energy and can be easily recycled and adapted to the nature of the temporary or permanent function of housing and housing cases, after disasters.

3.3 Applications of 3D Printing in the Construction Industry

3.3.1 Dubai Office of The Future

The UAE National Committee's 3D-printed office is intended to be the headquarters of the Dubai Futures Corporation. The so-called "Office of the Future"(Fig.6) primarily acts as a conference area for parties worldwide. The 3D-printed office is a fully working structure with electrical, water, communication, and air conditioning facilities. Produced China's 3D printed house. Transported The printed parts to Dubai. The initiative ultimately lowered labor expenses by 50% to 80% and construction waste by 30% to 60%. It is the driving force behind Dubai's building 3D printing boom. (MacRae, 2016).

Figure. 6 Side and Front view of Office of the Future in Dubai. Source: (Sakin and Kiroglu, 2017)

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3.3.2 House of Apis Cor Printed in Russia

A Russian business recently completed a 400-square-foot home in Moscow in under 24 hours (Fig.7). The building costs $10,000, demonstrating the future potential of 3D printing technology. The house was produced entirely on-site using a portable 3D printer, with outstanding results. It is a livable dwelling with limited room. The fact that it was created quickly and cheaply. After construction, I printed all of the walls and foundations of this structure using a concrete mix and other sections such as windows, fixtures, and added furniture. The house was finished with a fresh coat of paint at a low total project cost of $10,134 (Sakin and Kiroglu, 2017).

Figure 7. Figure showing a frontal view of the Apis Cor House in Russia and also showing the subsistence crafting process of Apis Cor House. Source: (https://www.apis-cor.com/)

3.3.3 Two-Story House 3D Printed On-Site

In contrast to the five-story highest 3D-printed home, which was printed and constructed on-site using steel reinforcement, this two-story house (Fig.8) was printed on-site by HuaShang Tengda in China (Scott, 2016). As indicated in (Hossain *et al.*, 2020), on-site 3DCP may not be an appealing option due to the high cost and workforce required for shipment and installation on-site. (Woetzel, Sridhar and Mischke, 2017)made a similar comment, stating that the savings from modular building construction, particularly for a lower-cost home, may be negated by shipping costs.

Even though the two-story house was printed on-site, the entire building, including plumbing and other connections, was completed in one and a half months. A comparable structure built using the traditional method would take 6–7 months. Unlike other 3D-printed constructions, this structure was made using a unique printing process. Install the house's frame with rebar support and plumbing first. The printing was then completed using a massive 3D printer. Without any additions, ordinary Class C30 concrete was used. One of the primary benefits of this concrete mix is that it can employ locally produced cement to save material transportation expenses. Furthermore, this construction can resist earthquakes of magnitude 8.0. (Scott, 2016).

Figure 8. Two-story house entirely printed on site.
Source: (Hossain *et al.*, 2020)

3.4 Benefits of 3D Printing

Many benefits result from the use of 3D printing technology in construction, and the most important of them can be summarized as follows:

3.4.1 Cost Reduction

There are a variety of ways that the use of 3DP in construction will provide financial benefits over other construction methods, the largest of which is the reduction in labor costs required during the production of components, as the 3DP way will require only one person to load materials into the printer and control the graphical interface that Components are printed. Also, assembling the building from the printed components requires only two people of unskilled labor to transport the parts, lift them and make them produce the final installation, and the time required will depend on the size of the building(Rivera, 2018). Thus, it will contribute to:

- Reducing the time required for construction and thus reducing the cost.
- Less cost of wasted energy to operate automated devices.
- Lower cost of forming complex shapes with greater efficiency, structural strength, and diverse functions.

Although, there is a fear that the use of 3DP in developing countries could lead to a massive loss of jobs for skilled labor. Argued (McAlister & Wood 2014) that new technology-based job skill sets are created, which can be learned through the 3DP application.

3.4.2 The Speed

Building production speed can be divided into four main sections, raw material extraction, material preparation and production, wall production, and wall installation time, where the use of (3DP) provides quality and speed in all previous sections(Russell, 2015).

For example, the Russian company (Apis Cor) (2017) built a small house in (24) hours. The (Apis Cor) system consists of a mobile tower 3D printer and a portable robotic supply and mixer unit that can be easily transported to any location by a regular truck, and the on-site operation takes no more than an hour, according to the company. The technology saves up to (25-40%) of Building construction costs compared to traditional construction, which requires multidisciplinary labor (Dancel, 2019).

3.4.3 Precision

Inaccuracies and omissions in the design and during the implementation process and neglect of the persons benefiting from construction are the leading causes of errors observed during traditional construction processes. However, there are other errors in structure due to lack of experience, poor supervision, poor equipment, etc. (Atkinson, 1999). 3DP does not leave room for error during the construction process, and the main focus will be on the digital design ((CAD), from which will read the 3DP program to produce the building and other forms of contrast that arise during the construction process traditionally are significantly reduced, which leads to a reduction Rework on the final structure (Rivera, 2018).

3.4.4 Ease of Implementation

The use of 3D computer-aided modeling and then the use of the same digital models directly for the building manufacturing process leads to a variety of benefits to 3DP compared to other standard construction methods (Russell, 2015) as follows:

- Unlike traditional building design and construction methods that require many 2D technical drawings and skilled workers to perform construction work, 3DP requires neither drawings nor skilled workers; Because the building will be viewable in 3D on the GUI of the computing device used to print from it, and because the printer will print the component by design in a specific order.
- The (3DP) program provides the ability to produce a variety of shapes without any difficulty in manufacturing or construction.
- Ease of making a modification or change in the building design; with traditional building systems, more drawings must be made, then understood by the builders who must learn how to build the new design; with (3DP), there will be no problem as the (CAD) model can be adapted and printed Using the new assembly method represented as animation without the need for any new graphics.

3.4.5 Freedom of Form and Composition

The use of 3DP has reduced the limitations imposed by traditional construction methods that require additional costs, time, and complexity when implementing, for several reasons, the most important of which is that straight forms are the least structurally stable, and 3DP can provide curved walls without additional cost, or Wasting time or complicating the construction process (Behrokh Koshnevis, 2015) (Fig.9).

Also, different and complex shapes can add additional functions, such as earthquake resistance or integrated ventilation, while traditional construction methods require special molds for difficult and other conditions, leading to increased costs and complexity in work (Fig.10).

Figure.9 The possibility of (3DP) in printing complex shapes and elements. Source: (Russell, 2015)

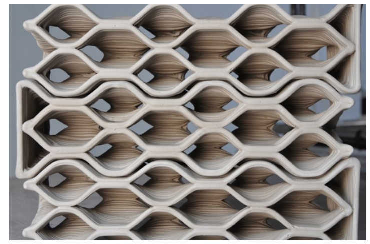

Figure.10 The 3DP system enables the formation of a wall that uses fewer materials, where materials can be added when needed with the same structural strength. Source: (Russell, 2015)

3.4.6 Increase Safety in Construction Work

The construction industry is often one of the most dangerous occupations globally, as it causes more deaths and injuries than any other occupation. In 2001, there were 1,225 deaths in the United States (13.3 per 100,000 workers) and (481,400) non-fatal injuries, and a disease rate of (7.9) per (100) full-time workers in the construction industry, and these numbers are higher in developing countries where safety equipment and training are less standard. The higher number of accidents is attributed to various factors at construction sites. Still, can trace most of it back to human error, so the use of 3DP in operations can significantly reduce the accident rate in the construction industry because 3DP programs are extensive, come programmed in a CAD file, and are repeatable without any form of interference. Human or subsidized building delivery (Russell, 2015), any building technology that uses little labor in building construction almost always reduces accidents.

3.4.7 Reduce Construction Waste

Construction waste and waste issues appear in most construction industry sites, from iron used in scaffolding, wood formwork, new concrete, plastics, rebar cutters, tie wires, tiles, and broken nails, so construction waste has become a matter of concern; it is not economical to the contractor or customer and the environment, so there is need Building techniques that reduce waste generated during construction operations, and that (3DP) technology contributes to helping reduce waste because it uses only the materials that are entered into the printer, and if there is waste, it is few It is very similar to traditional construction methods (Fig.11), and thus cost and sustainability issues are dealt with ideally (Rivera, 2018).

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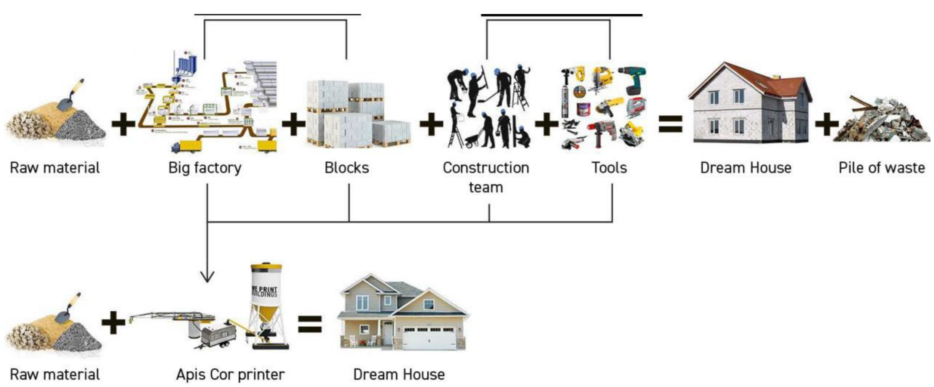

Figure.11 Comparison of the waste generated using traditional construction methods and 3D printing technology. Source: (Cheniuntai, 2108)

3.4.8 Locally Available and Natural Materials

Although most 3D printing research continues to use cementitious materials, some studies focus on using natural and locally available materials, which can help save transportation, construction, and manufacturing energy because most locally available materials are processed and installed using much less energy (M K Dixit, 2019). Natural materials can also lower the toxicity of built environments if hazardous chemicals in traditional materials are substituted. Local materials are frequently appropriate for local climatic conditions and may also supply some heating and cooling loads (Manish K Dixit, 2019).

3.5 Challenges with 3D Printed Construction

Despite the potential benefits outlined in the preceding points, such as job site safety, rapid construction, low labor requirements, reduced waste, and so on, Weinstein and Nawara (Weinstein and Nawara, 2015)expressed reservations about the large-scale implementation of 3DP for joint cost/affordable housing development.
One of the challenges is the availability of low-cost labor and local resources in developing nations, which would favor the high-tech hazardous materials required for 3DP procedures. Another mystery surrounding this technology is its demonstrated lack of success in mass adoption. Michelin et al. (Mechtcherine *et al.*, 2019) also claimed that ample cheap labor is usually available in less developed countries, even though many are not competent enough to build high-quality structures.

Furthermore, as summarized in (De Schutter *et al.*, 2018), significant barriers to 3DP adoption include:

- The limited availability of automated manufacturing techniques for large-scale construction.
- The high initial cost of mechanical equipment.
- Traditional design methods are unsuitable for automation.
- A lack of a sufficient quantity of materials suitable for the 3DP program.
- Management issues with the formal organizational structure.

Severe weather might have an impact on the 3DP system. For example, due to the extreme heat that reached 50°C in June 2019, most of the construction work for Dubai's largest 3D-printed structure was completed at night (Molitch, 2020). Furthermore, as noted in (Jewell, 2021), the temperature and humidity fluctuated considerably throughout the day and night, requiring the materials used in the printing process for this building to survive high heat and cold. Furthermore, the building business (Apis Cor) realized the need to produce a printing medium suitable for harsh weather conditions, such as those in the UAE. To realize the full potential of this construction technology, we must investigate the impacts of temperature (e.g., extreme heat/cold, wind, humidity, etc.) on 3DCP in greater depth.

Another problem for autonomous printing of a full-size structure (building, bridge, etc.) is the risk of losses or accidents if the 3D modeling or printing settings are incorrect. (Zuo *et al.*, 2019) experimented and proposed testing the model and parameters at a 3D scale before beginning full-size 3D printing. However, this examination's difficulty and added expense have not been investigated.

Using a mobile robot to identify a robot and define business rules for 3DP is difficult (Subrin *et al.*, 2018). A physical barrier between human activities and the moving parts of a printing machine may be required to prevent unforeseen collisions (Tay *et al.*, 2017). It is common to deploy a team of mobile robots concurrently to print huge buildings, which requires good robot planning and coordination for optimal location and movement (Zhang *et al.*, 2018). As a result, skilled employees who understand programming, robot technology, and construction methods are required. Engineers, in particular, must be numerically adept and capable of doing advanced computational analysis in design and structure design verification (Buchanan and Gardner, 2019).

Furthermore, establishing codes, standards, and specifications for these non-traditional buildings, particularly public safety code requirements, further hurdles to the 3DP system's general implementation (Hossain *et al.*, 2020). Strauss (Strauss and Envelope, 2013) has also stated that the lack of regulation governing 3D-printed structures is an issue for additive manufactured dwellings, as any building activity will result in such behavioral norms in injuries or fatalities.

Finally, as indicated in Table 1, a SWOT analysis of 3DP technologies compared to traditional building methods aids in discussing the strengths, weaknesses, opportunities, and threats used in 3DP.

Table 1. SWOT analysis of the use of (3DP) technology in construction. Source: (Afolabi *et al.*, 2019)

strength point	**Weak points**
Increased flexibility in design	The cost of saving the printer
The need for binders is reduced.	The speed of printing the printer and the sizes that can produce from the housing
Reducing the waste of building materials	Power
Rapid and intensive production	Difficult to use
No need for custom tools	Not controlling the printers.
Labor cost optimization	
Ease of marketing	
Opportunities	**Opportunities**
can customize Building products	can customize Building products
Encouraging small production operations	Encouraging small production operations
Improve product testing	Improve product testing
Create new jobs	Create new jobs
Encourage the manufacturing process.	Encourage the manufacturing process.
Eliminate unwillingness and moodiness at work	
Increasing innovation	

4. Conclusion

The study presented the prospects of 3D printing (3DP) as a sustainable housing solution to meet the needs of temporary or permanent housing for the displaced in Iraq due to previous disasters and crises. Because of the difficulty of returning the displaced to their original homes due to the great destruction that has befallen them. Therefore, the research identified critical areas in which 3D printing of homes could solve housing needs in Iraq that would provide a permanent or temporary housing solution for internally displaced persons (IDPs), reduce construction waste, increase construction safety, achieve sustainability goals and reduce construction errors, construction waste and Labor cost. Can widely apply this technology to building homes in disaster-affected areas where homes need to be built at an urgent pace that day-to-day construction practices and operations cannot achieve. Using 3D printing technology can create a home in days or even hours. If implemented in such cases, there would be no need to build temporary shelters for the affected but a need to create a permanent structure in place of their damaged or collapsed homes. This scheme will provide governments with a rapid response in delivering housing and meeting the basic needs of those affected.

However, there are many challenges faced by this technology, such as the high cost of equipment, lack of computational methods for the structural design of 3D printed walls, selection of suitable construction materials, and many more.

5. Recommendations

- Develop low-cost 3D printers.
- Develop computational methods for analyzing and designing 3D printed output.
- Development of other renewable materials for 3D printing of homes.

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