Automated Onsite Construction: 3D Printing Technology

ABSTRACT

3D printing is an innovative construction technology that has a significant positive impact on the environment. It addresses issues on speed, labor costs, accuracy, and efficiency. This study aimed to know the trend of construction technology in onsite construction. Specifically, examine the history of 3d printing; discuss the 3D printing form of onsite construction; identify the innovation patterns of 3D printing; and explore the impacts of 3D printing technology. Although 3D printing has been around for a long time, the construction industry has just lately been neither affected nor disrupted. In some parts of the world, 3D printing has changed the way that industries operate. It enables the construction industry to swiftly create models and prototypes, enabling them to test and perfect new products more quickly. It is a fully automated, well-planned method that boosts output while lowering human error. The discussion shows some benefits of 3D printing including decreased costs and time, less environmental pollution, and a decline in accidents and fatalities on construction sites. 3D printing is automated, digitalized, and renewable which impacts regulatory agencies, culture and environment, economy, and society.

Keywords: Automated onsite construction; 3D printing in construction; construction technology.

1. INTRODUCTION

Recent construction technologies are attracting the construction industry due to factors in consideration like cost, environmental impact, speed and efficiency, quality, safety, and durability. New and innovative technologies, materials, and forms of construction are enabling new kinds of buildings that are more effective, safe, and environmentally friendly. These innovative approaches serve to handle pressure to modernize many parts of the sector, such as outdated supply chains and business models, and working habits. Construction companies are starting to integrate technology, and those that do so are reaping the benefits through higher production, better teamwork, and the completion of projects on time and within budget, all of which lead to higher profit margins [1].

3D printing in construction is one method of onsite construction that attracts the attention of the researcher as to how printing technology becomes possible like in the construction industry. In addition, 3d printing technology is first used in the manufacturing industry and now becoming helpful in the construction industry as well. The state-of-the-art demonstrates that 3D printing (3DP) is still in its early stage and that structural capability and printability are still the key areas of research [2].

As a civil engineer, these technologies have shown significance to me in the field of civil engineering due to some issues and trends in the profession like labor and material shortages, working conditions, skills availability, health and safety, cost, speed of construction, and automation. If project managers can take advantage of the potential, 3D printing can improve the efficiency of construction processes [3].

The lack of knowledge among professionals on current construction technologies appears to be a problem. Some parts of the world, particularly poor nations, continue to use some obsolete construction methods. The researcher would like to make use of the case study by undertaking related studies that will be used in classroom instruction as a way to raise awareness of the benefits that 3D printing technology brings to industry and academia and to promote sustainability initiatives.

1.1 Objectives

This case study aimed to know the trend of construction technology in onsite construction. Specifically, it aimed to:

1. Examine the history of 3d printing.
2. Discuss the 3D printing form of onsite construction.

3. Identify the innovation patterns of 3D printing.
4. Explore the impacts of 3D printing technology.

2. METHODOLOGY

This paper uses the case study method in determining the trend of construction technology in onsite construction. The data was collected from published research, related studies, journals, and available news report on the web.

3. RESULTS AND DISCUSSION

Construction companies are using 3D printing to solve onsite construction problems. It has a significant impact on the building's economic and environmental aspects. A structure is printed layer by layer using a 3D printer. An overview of 3D printing's brief history, how it innovates in this period of the industrial revolution, the drivers behind this case study, and its impact on the environment are presented in this discussion.

3.1 History of 3D Printing

Rapid prototyping or additive manufacturing, sometimes referred to as 3D printing, is a technique with a long history. Only a small number of businesses were able to establish themselves in the sector in the early days of 3D printing technology. But now that the technology is more widely used and accessible, a number of businesses are establishing themselves and turning 3D printing into a standard engineering tool. Since the first 3D printing patent was submitted in the 1980s, numerous businesses have competed to establish their name as the industry leader. Fig. 1, shows a timeline of significant events in the development of 3D printing, from the invention of the technology to its current status as a global industry leader [4].

Fig. 1. Timeline of 3D printing technology [4]

3.2 3D Printing Form of Onsite Construction

3D printing technology is a new method being utilized in an onsite method of construction. It is anticipated that the construction industry will significantly alter present processing techniques and maybe give rise to disruptive technologies like 3D concrete printing (3DCP), which will cause considerable changes in the sector [5].

Fig. 2 shows the largest 3D-printed building in the world at the time of its completion, a two-story office in Dubai, was constructed by the robotic construction company Apis Cor. The building, which was created for the Dubai Municipality, has a floor area of 640 square meters and a height of 9.5 meters [6].

Fig. 3 shows a fully 3D printed home in a project that sponsors hope will provide homeowners of the future a wide range of options for the size, shape, and design of their dwellings. The property is the first of five homes that the construction company Saint-Gobain Weber Beamix has planned for a plot of land by the Beatrix canal in the Eindhoven suburb of Bosrijk. It is inspired by the shape of a boulder, whose dimensions would be difficult and expensive to construct using traditional methods [7].

Fig. 2. Two-storey office building for Dubai Municipality [6]

Fig. 3. 3D-printed house in Eindhoven, Netherlands [7]

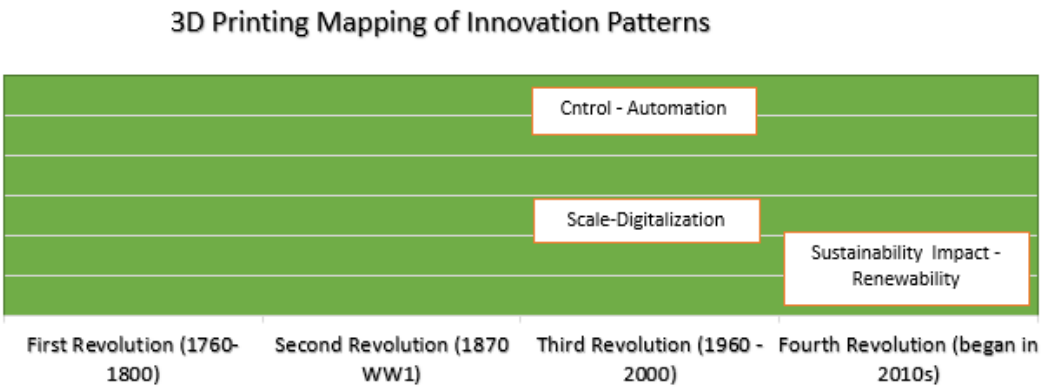

Fig. 4. 3D printing mapping innovation patterns

3.3 Innovation Patterns of 3D Printing

Fig. 4 shows the mapping of innovation patterns of 3D Printing in Construction. It identifies the kind of innovation against the industrial revolution. It illustrates that while sustainability impact is already in the fourth revolution utilizing renewability methods of onsite construction, 3D printing is already on the third revolution employing automation and digitalization.

3D digital model is a requirement for any 3D printing procedure and the BIM artificial intelligence software enables automated 3D printing for construction projects. A&C processes such as architectural planning, geometrical data, scheduling, material, equipment, resource, and manufacturing data, as well as post-construction facility management, are all covered by the building information modelling (BIM) approach to management. BIM is essential to 3D printing in construction's success because it keeps large-scale digital operations safe and productive [8].

The third industrial revolution developed onsite construction methods like 3D printing, BIM (Building Information Modelling), and other artificial intelligence software to the construction sector to handle construction-related challenges and assist sustainable environmental protection methods. In the study of Ge et al. (2022), it shows that the production of soft materials is thought to be a perfect application for 3D printing, a new sophisticated manufacturing technique. In contrast to other 3D printing methods, digital light processing (DLP)-based 3D printing creates 3D objects by targeted photopolymerization and can produce very complicated geometries with excellent resolution [9].

In terms of its influence on sustainability, 3D printing lessens the production of waste at construction sites and does away with the need for formwork during onsite construction, which indirectly reduces the amount of carbon footprints that are contributed to the environment. The utilization of drones for land surveys, modular building, and artificial intelligence in construction are some more techniques in today's industry. In the study of Karslioglu et al. (2022), the use of 3D printing technology is gaining popularity since it is more efficient than conventional construction methods in terms of speed, cost, labor, and error margin. With the use of this technology, it is possible to create complexly crafted structures and a range of small-scale products. As the study's findings emphasized a zero-waste approach to material utilization, consideration is given to the use of sustainable building materials in structures created with this technology [10].

3.4 Impacts of 3D Printing Construction

- **Legislation and regulation.** Regulatory agencies need to address the design and construction procedures along with health and safety requirements in 3D printing construction technology. Owners, contractors, manufacturers, and software developers will be impacted legally using 3D printers in the construction industry.

There are requests for building projects to adopt more efficient technology because of the decreased reliance on foreign labor and the developing problem of a personnel shortage. The need for creating a regulatory framework to establish the bar for the performance of 3D printed objects is driven by the inability to tolerate structural failures and compromises on the health

and safety of both workers and the public. Based on the research, a subsidiary piece of legislation for 3D printing in buildings was recommended to balance the inherent dangers of this new technology without sacrificing public safety on the grounds of quality, health, and safety [11].

There are also steps needed for those policymakers can promote to the next generation of employment opportunities that may be disrupted or assisted by the 3D printing construction technology. Growing economic inequality and increasing automation are causing fears of widespread technical unemployment and a renewed call for regulatory frameworks to deal with the effects of change in technology. In the US and other developed and developing nations, AI has the potential to change the skill requirements, and labor distribution across industries and professions. Researchers and decision-makers, however, are inadequately to predict changes in the labor market brought on by particular cognitive technologies, such as AI [12].

- **Cultural.** In the field of object reconstruction, particularly in the construction industry, 3D printing will be essential. It will be useful in their cultural experience thru research and education because it can perform these tasks in a straightforward and realistic manner.

The accessibility of cultural heritage is greatly enhanced by these multidimensional methods of experiencing it, particularly for those with learning disabilities, children, the elderly, and people who are blind or visually impaired. Technology is advancing quickly, and 3D printing promises to bring more beneficial experiences to the study of cultural heritage. This would allow for a more comprehensive understanding of the manufactured things, but it would necessitate the creation of fundamental criteria for 3D printed models [13].

- **Environmental.** 3D printing is an innovative construction technology that has a significant positive impact on the environment. It is a modernized form of construction that requires less labor and material on the construction site and produces less pollution. By eliminating the use of formworks, which produces waste, promotes the use of a sustainable construction method.

According to the study on “Impact of 3D Printing on the environment”, 3DP is a better option for producing complex parts as it lessens waste in terms of both time and materials [14].

- **Economic.** 3D printing has greatly affected the economic growth of a country as the construction industry has started to embrace this new technology.

The size of the global market for 3D printing in construction was estimated at USD 11,268.9 million in 2021, and from 2022 to 2030, it is anticipated to increase at a CAGR of 100.7 percent. The market is expanding because of the expanding use of 3D printing in the construction sector. Using modeling software, it is frequently utilized to develop complex building structures [15].

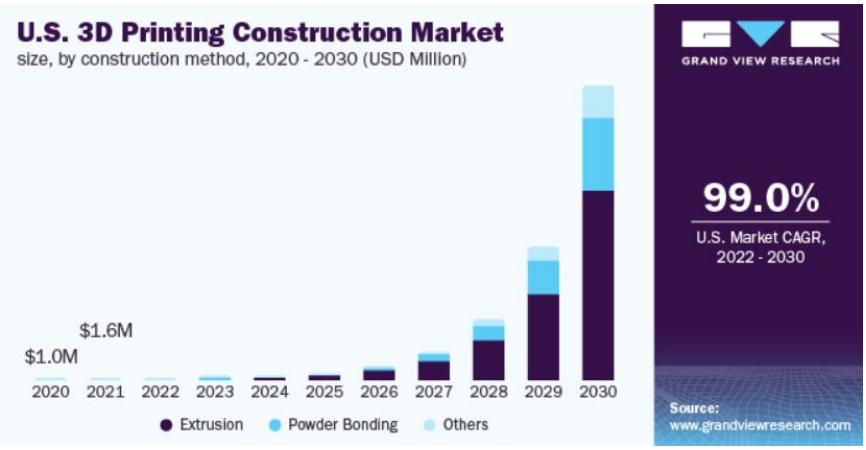

Fig. 5. US 3D printing construction market [15]

- **Society.** Due to the need for housing created by the rapid population expansion in many regions of the world, 3D printing addresses issues with labor shortages in the housing building sector.

The construction industry, one of those with the highest demand for workers, has struggled with productivity and technological advancements.

Various automation technologies, such as 3D printing, have recently attracted growing interest in the construction industry. Construction industry experts believe that 3D printing holds great promise for automating processes and reducing time-consuming labor, material waste, and unsafe operations involving people. It has been discovered that 3D printing can significantly cut down on labor costs, which can help countries where the reliance on foreign labor in the building industry is high. For nations where the building industry employs a large portion of the working force and where labor is more affordable, 3D printing may not be advantageous. Additionally, 3D printing in the building industry will call for workers with specialist skills of this new technology [16].

- **Engineering.** The use of 3D printing technology results in increased speed, lower labor costs, higher accuracy, and improved efficiency. The construction industry's increasing use of 3D printers for accurate end-product prototyping, design, and creation while lowering production costs is propelling the market's expansion. Furthermore, one of the key reasons for enhancing the market growth is the increase in the adoption of green initiatives on a global scale.

The use of 3D printing technology is gaining popularity since it is more efficient than conventional construction methods in terms of speed, cost, labor, and error margin. A building material recipe should be created by getting the proper mixing ratios to accomplish 3D printing without shrinkage cracks and to be able to stack layers on top of one another without collapsing [17]. To improve the understanding and experience of this technology and to accurately adapt the process parameters to the needs of the construction sector, the construction industry needs to participate more actively in the research on metal 3D printing [18].

- **End-users.** Amazing designs and fast completion demand will highly impact the end users of construction projects. 3D printing construction technology will address issues of complex constructions and the need for fast-track construction.

The technology of the near future is thought to be 3D printing. When compared to traditional ways, it is an innovative technology that offers cost savings, time savings, and limited emissions. For instance, a three-bedroom house produced by Apis Cor in December cost slightly over $10,000. In contrast, a home constructed by Habitat for Humanity costs about $50,000. Those who are below the poverty line may obtain affordable housing because construction costs are now one-fifth of what they once were. With all these advantages, 3D printing technology has the potential to revolutionize the construction business in the near future [19].

4. CONCLUSION

Although 3D printing has been around for a long time, the construction industry has just lately been neither affected nor disrupted. In some parts of the world, 3D printing has changed the way that industries operate. It enables the construction industry to swiftly create models and prototypes, enabling them to test and perfect new products more quickly. It is a fully automated, automated, digitalized, renewable, and well-planned method that boosts output while lowering human error. Some benefits of 3D printing include decreased costs and time, less environmental pollution, and a decline in accidents and fatalities on construction sites.

From the discussion on the different impacts of 3D printing technology, the significant effects on several aspects of a country are listed below.

- Regulatory agencies need to address the design and construction procedures along with health and safety requirements in 3D printing construction technology.
- Culture. It will be useful in their cultural experience thru research and education because it can perform these tasks in a straightforward and realistic manner.
- Environment. 3D printing is an innovative construction technology that has a significant positive impact on the environment.
- Economy. 3D printing has greatly affected the economic growth of a country as the construction industry has started to embrace this new technology.

- Society. Due to the need for housing created by the rapid population expansion in many regions of the world, 3D printing addresses issues with labor shortages in the housing building sector.
- Engineering. The use of 3D printing technology results in increased speed, lower labor costs, higher accuracy, and improved efficiency.
- End-users. Amazing designs and fast completion demand will highly impact the end users of construction projects

5. RECOMMENDATIONS

From the results of the study, the researcher recommends conducting study on 3D printing's structural capability for more than one-storey building. In terms of project cost, it is suggested to conduct cost comparative studies with other offsite and onsite construction technologies. Lastly, research has to be conducted in terms of project feasibility for construction in the Philippines.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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