Case study

Automated Onsite Construction: 3D Printing Technology

.

ABSTRACT

3D printing is an innovative construction technology that has a significant positive impact on the environment. This study aimed to know the trend of construction technology in onsite construction. Specifically, it aimed to examine the 3D printing form of onsite construction; Identify the innovation patterns of 3D printing; and explore the drivers for the 3D printing in construction. 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. Some benefits of 3D printing include decreased costs and time, less environmental pollution, and a decline in accidents and fatalities on construction sites. In terms of the industrial revolution, 3D printing is automated, digitalized, and renewable.

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 building 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 These innovative approaches serve to handle pressure to modernize many parts of the sector, such as outdated supply chains and business models and working habits.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 which attracts the attention of the researcher as how printing technology become 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. The impact of 3D printing on the construction sector should not be understated because it has the potential to reduce several key variables, including the duration of the project, the cost of materials, and the construction process itself [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 3D printing form of onsite construction.
2. Identify the innovation patterns of 3D printing.
3. Explore the drivers for the 3D printing in construction.

2. 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 industrial revolution, the drivers behind this case study, and its impact on the environment are presented in this discussion.

HISTORY OF 3D PRINTING

Computer technology is used in 3D printing to produce three-dimensional solid objects. In 3D printing, solid objects are printed using a computer program and the additive process of building the material in thin horizontal cross sections. With 3D printing, you can make practically anything, including toys, weapons, and machine parts. As 3D printing grows in popularity and becomes more widely accessible to the general public, it is crucial to understand its history in order to comprehend the future of manufacturing. The Japanese inventor Hideo Kodama used the additive method to create the first 3D printed object in 1981. He developed a product that hardens polymers and produces solid objects using ultraviolet light. This serves as a foundation for stereo lithography (SLA) [4].

Charles "Chuck" Hull developed stereolithography (SLA), a 3D printing technique that allows designers to build 3D models that are then printed one layer at a time into actual, tangible objects. In the SLA procedure, liquid photopolymer is solidified by the UV laser. Printing tabletop scale models for architecture firms was one of the earliest applications for 3D printing. In the pre-BIM era, these models aided in the design process and served as useful planning and sales aids for construction projects. Although the development of 3D and 4D Building Information Modeling (BIM) largely rendered physical models obsolete, many businesses still take pride in showcasing their work in this manner. By the 1990s, a number of businesses started experimenting with employing 3D printing to create modular parts for larger projects. By the 2000s, these applications were well underway and poised to revolutionize the whole sector [5].

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. Figure 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 [6].

Figure 1. Timeline of 3D Printing Technology [6]

2.1 3D PRINTING FORM OF ONSITE CONSTRUCTION

3D printing technology is a new method being utilized in an onsite method of construction. In the study of Sakin and Kiroglu, 3D printing focus on contour crafting as a potentially game-changing method for the construction sector. There are many benefits to this technique, including decreased costs and time, less environmental pollution, and a decline in accidents and fatalities on building sites [7].

The Office of the Future in Dubai as shown in figure 2, which was unveiled in May 2016, is thought to be the first fully operational, entirely 3D-printed office structure. The building is made completely of 3D printed parts, both inside and out, and has a retro-futuristic rectangular exterior that looks like a television from the Jetsons era [8].

Figure 2. The 3D Printed Office of the Future. [8]

Figure 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 [9].

Figure 3. 3D-printed house in Eindhoven, Netherlands [9].

2.2 INNOVATION PATTERNS OF 3D PRINTING

Figure 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.

The artificial intelligence software that enables automated 3D printing for construction projects uses automation. A 3D digital model is the prerequisite for any 3D printing process and may be made using a few 3D software tools. The design is then "sliced" into layers, making it into a file that can be read by the 3D printer. The 3D-printed material is subsequently layered in accordance with the design and technique. 3D printing technologies use various methods to process various materials to produce the finished object [10]. Concrete "contour crafting" has been used by the University of California to create miniature versions of exterior and interior walls of houses. The team of scientists led by Professor Behrokh Khoshnevis is currently putting a massive portable 3D printer to the test. With it, a whole house's worth of walls may be constructed in just twenty-four hours [11].

3D printing belongs to the third revolution's digitization on the innovation's scale axis. With the second revolution in construction technology, the construction industry addresses issues like client dissatisfaction, speed of construction, etc. by mass production construction components including beams, slabs, columns, and walls. The third industrial revolution created 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 Lozano et al. (2018), it shows the ability to obtain three-dimensional objects that are more defined and similar to real images and original objects is made possible by the development of increasingly advanced digitalisation technology. By digitalizing bone fragments with various scanner models and creating images that can be transformed for 3D printing with a Colido X 3045 printer by digital treatment with various software, the various modalities of designing 3D anatomical models of bone pieces are presented for use by students of various disciplines in the health sciences [12].

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 [13].

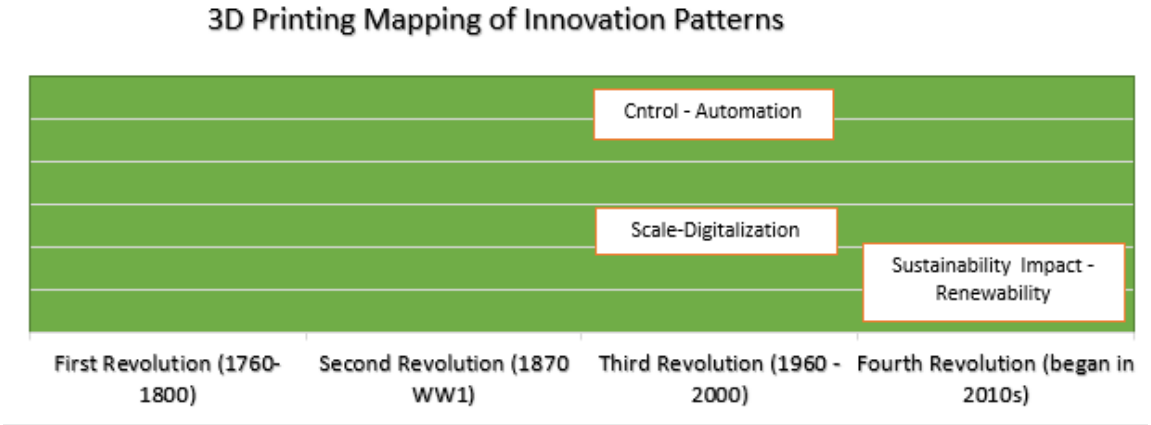

Figure 4. 3D Printing Mapping Innovation Patterns

2.3 DRIVERS FOR THE 3D PRINTING IN CONSTRUCTION

Education

Educating the construction industry across the globe means shaping the future of the new generations toward embracing the third revolution in construction with the digitalization approach of 3D printing in the construction industry. According to an article “Training the key to future success of 3D printing in construction”, engineers will soon need to understand how material selection influences mechanical qualities as well as how to organize printed parts for maximum efficiency and durability. Increased acceptance of 3D printing will result from training and upskilling engineers to lead digital transformation in the construction industry. Additionally, increased understanding of additive manufacturing will result in industry-wide 3D printing standards that will assist produce structures of greater quality [14].

Sustainable Construction Methods

The academic institutions have integrated sustainability methods of construction as one subject in the curriculum for the purpose of educating the construction industry on how to achieve sustainable methods in protecting the environment. This initiative is a global drive in trying to protect the environment working together with the different disciplines in society. The introduction of 3D printing is one of the methods in construction which addresses the issues in mitigating carbon footprints.

The building industry now produces a significant quantity of waste, and sustainability advancement is gradual. Green management initiatives have had a limited impact because of the complex supplier chains in the building industry. However, disruptive technologies like 3D printing have the power to profoundly alter supply chains by altering how goods are created and produced. According to research, 3D printing can make the construction sector leaner, more productive, and more environmentally friendly [15].

3. IMPACT TO THE ENVIRONMENT

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, it 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 because it consumes more energy but also lessens waste in terms of both time and materials [16].

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, 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. In terms of the industrial revolution, 3D printing is automated, digitalized, and renewable.

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.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

REFERENCES

[1] K. Jones, "Construction Technology is Reshaping the Industry," Construct Connect, 16 April 2020. [Online]. Available: https://www.constructconnect.com/blog/technology-reshaping-construction-industry#:~:text=Companies%20that%20are%20researching%20and,resulting%20in%20higher%20profit%20margins.. [Accessed 3 July 2022].

[2] S. Pessoa, A. Guimaraes, S. Lucas and N. Simoes, "3D printing in the construction industry - A systematic review of the thermal performance in buildings," *Renewable and Sustainable Energy Reviews,* vol. 141, 2021.

[3] A. S. Elfatah, "3D Printing in Architecture, Engineering and Construction," *Engineering Research Journal,* pp. A1-A18, 2019.

[4] Matt, "History of 3D Printing," ME3D, 6 February 2018. [Online]. Available: https://me3d.com.au/2018/02/06/history-of-3d-printing/. [Accessed 3 July 2022].

[5] H. Head , "A History of 3D Printing in Construction & What You Need to Know," AUTODESK BIM 360, 19 May 2017. [Online]. Available: https://bim360resources.autodesk.com/connect-construct/a-history-of-3d-printing-in-construction-what-you-need-to-know#:~:text=In%201984%2C%20Charles%20%22Chuck%22,photopolymer%20which%20makes%20it%20solid.. [Accessed 3 July 2022].

[6] C. M. Gonzales, "Infographic: The History of 3D Printing," The American Society of Mechanical Engineers, 30 January 2020. [Online]. Available: https://www.asme.org/topics-resources/content/infographic-the-history-of-3d-printing. [Accessed 4 July 2020].

[7] M. Sakin and Y. C. Kiroglu, "3D Printing of Buildings: Construction of the Sustainable Houses of the Future by BIM," *Procedia Engineering,* pp. 702-711, 2017.

[8] M. McRae, "The 3D Printed Office of the Future," The American Society of Mechanical Engineers, 7 October 2016. [Online]. Available: https://www.asme.org/topics-resources/content/3d-printed-

office-the-future. [Accessed 28 June 2022].

[9] D. Boffey, "Dutch couple become Europe's first inhabitants of a 3D-printed house," The Guardian, 30 April 2021. [Online]. Available: https://www.theguardian.com/technology/2021/apr/30/dutch-couple-move-into-europe-first-fully-3d-printed-house-eindhoven. [Accessed 3 July 2022].

[10] "3D PRINTING INDUSTRY," [Online]. Available: https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide. [Accessed 28 June 2022].

[11] "3D concrete printer," Designing Buildings: The Construction Wiki, 15 October 2020. [Online]. Available: https://www.designingbuildings.co.uk/wiki/3D_concrete_printer. [Accessed 29 June 2022].

[12] U. Lozano , F. Blaya, A. Ruggiero, S. Manzoor, S. Nuere and J. Juanes, "Different Digitalization Techniques for 3D Printing of Anatomical Pieces," *Journal of Medical Systems,* vol. 42, no. 3, pp. 42-46, 2018.

[13] A. Karslioglu, M. H. Alkayis and M. Onur, "3D Printing Technology in Construction Sector: A Short Review," in *2nd International Conference on Applied Engineeringand Natural Sciences*, Turkey, 2022.

[14] R. McEachran, "Training the key to future success of 3D printing in construction," Institution of Mechanical Engineers, 21 September 2021. [Online]. Available: https://www.imeche.org/news/news-article/training-the-key-to-future-success-of-3d-printing-in-construction. [Accessed 28 June 2022].

[15] "Emerald Publishing," Emerald Publishing, 2022. [Online]. Available: https://www.emeraldgrouppublishing.com/archived/realworldresearch/innovation/how-3D-printing-can-make-construction-better.htm. [Accessed 28 June 2022].

[16] M. Shuaib, A. Haleem, S. Kumar and M. Javaid, "Impact of 3D Printing on the environment: A literature-based study," *Sustainable Operations and Computers,* vol. 2, pp. 57-63, 2021.