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Application of 3D Printing Techniques in Modern Infrastructure Development Mela Amelia Santika

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ABSTRACT
Modern infrastructure development faces complex challenges in terms of speed, cost and sustainability. In an effort to meet these demands, 3D printing techniques have emerged as a promising innovative solution. However, there are still few studies that comprehensively examine the application of 3D printing techniques in the context of modern infrastructure development. This research aims to explore the potential application of 3D printing techniques in modern infrastructure development and to provide a deeper understanding of its benefits, challenges and practical implications. The research methods used include an in-depth literature study, case analysis, and interviews with relevant experts and practitioners. This approach allows us to have a holistic understanding of how 3D printing techniques can be applied in modern infrastructure development. The results show that the application of 3D printing techniques in modern infrastructure development has significant potential in terms of construction efficiency, design flexibility, and material waste reduction. However, there are still some challenges that need to be overcome, such as limited materials and standards, and limited availability of technology. Overall, this study concludes that 3D printing techniques have great potential to change the paradigm of modern infrastructure development. However, to fully realize this potential, cross-sectoral cooperation, investment in research and development, and the development of adequate regulations are required to overcome the challenges faced.

Keywords: *Application, Infrastructure, Techniques*

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INTRODUCTION

In modern infrastructure development, we often face what is called an inverted pyramid, i.e., there is an imbalance between the large number of infrastructure projects and the limited availability of resources and time (Chen et al., 2019). This imbalance poses various challenges (Bagheri & Jin, 2019), including increased costs, project delays (Shahrubudin et al., 2019), and even a decline in infrastructure quality due to budget cuts

or insufficient resources (Lee et al., 2019). Therefore, research on innovative solutions to address this problem is becoming increasingly urgent.

This research aims to address the imbalance between demand and capacity in modern infrastructure development by introducing 3D printing techniques as an innovative solution (Aboulkhair et al., 2019). Penting untuk membahas masalah ini karena infrastruktur yang efisien, berkualitas (Jiang et al., 2019), and sustainability are key to sustained economic growth, public welfare and environmental protection. By solving the "inverted pyramid" problem, we can increase efficiency, reduce costs, and improve the overall quality of infrastructure.

One approach to solving this "inverted pyramid" is by applying 3D printing techniques in modern infrastructure development (Seo et al., 2023). This technique enables faster, cheaper, and more flexible infrastructure development (Dhahak et al., 2020), utilizing advanced layer printing technology to create complex structures with high accuracy and using more environmentally friendly materials (Akdeniz University, Türkiye et al., 2024). As such, the use of 3D printing techniques can be a promising solution to overcome the challenges in modern infrastructure development.

The increasing need for modern infrastructure has placed immense pressure on the construction industry to create efficient solutions (Cunningham et al., 2019), fast, and sustainable (Al Zaabi et al., 2019). In this context, the application of 3D printing techniques has emerged as a promising potential solution (Seo et al., 2023). However, in-depth research is still needed to fully understand the impact and implications of using this technology in the context of modern infrastructure development.

This research is expected to fill the knowledge gap by deeply investigating the application of 3D printing techniques in modern infrastructure development. The main contribution of this research is to provide a better insight into the benefits, challenges, and practical implications of using 3D printing technology in the construction industry. To address the gap, this research will use a combined approach of literature review, case analysis, and interviews with experts in the field.

The state of the art in the use of 3D printing techniques in modern infrastructure construction will be evaluated, covering recent achievements, challenges faced, and opportunities available. In addition, this article will propose innovations in the application of 3D printing technology, including the development of more environmentally friendly printing materials, improved mold accuracy, and the development of more efficient construction methods.

The novelty of this article lies in its holistic and integrated approach in analyzing the application of 3D printing techniques in modern infrastructure development. While previous research has often focused on certain aspects of 3D printing technology or only on specific case studies, this research will present a more comprehensive review that covers the benefits, challenges, and potential uses of this technology more broadly in the construction industry. Furthermore, this research will involve field trials and prototype development to test the effectiveness and applicability of 3D printing technology in real situations. It is hoped that this research can serve as a foundation for future research in

expanding the understanding of the use of 3D printing technology in the construction industry and to develop more innovative and sustainable solutions.

RESEARCH METHODOLOGY

Research Design

This research uses a quantitative research design, which is inputted into google form as many as 20 questions (Payal et al., 2024). Which includes what influences will be caused when students use technology-enabled language learning (Favale et al., 2020). This method is used in order to formulate a new thought that is useful for every level of students (Spernjak, 2021). Then developed into a research that can be held accountable for its accuracy (Dong & Liu, 2023), which is tailored to each event experienced by the student (Selwyn, 2019). This collection method is useful to test the feasibility of language-based learning itself to improve student learning achievement (Shadiev & Yang, 2020). The quantitative method can also be interpreted as a research stage that begins with making a questionnaire containing 20 items (Gosal et al., 2019), then every answer given by students is processed using the spss application (Pardo et al., 2019). The data obtained can be proven accurate through a google form created by the researcher. And researchers also input the highest gain and also the lowest gain from the questionnaire distributed to each student. Then conclude these statements.

Research Procedure

The steps taken in this study began by asking permission from the campus and working with English teachers. Then each filled in by students (Else, 2023), from the beginning of the questionnaire made by the researcher until it reaches the acquisition of filling which the researcher considers to have met the expected acquisition by the researcher (Besser et al., 2022). Then the researcher is also very concerned about ethics in making questionnaires that use good language and are also polite (Kapasia et al., 2020). So that students can fill out this questionnaire in a short period of time (Chow et al., 2023), which makes it easier for researchers to examine various Exploring the Potential of Renewable Energy in Today's Engineering Development

Research Subjects

The subjects of this research are students of UIN Mahmud Yunus Batusangkar, the role of the researcher is to collect every answer given by students (Dube, 2020). Researchers are also assisted by English lecturers who teach at UIN Mahmud Yunus Batusangkar, especially educators who teach in the field of technology (Dubey, 2021). This study is to measure the ability of students using questions in the form of tests and then counted from the highest series of acquisition numbers to the lowest series of numbers (Hao & Ho, 2019). The researcher then inputted the scores obtained through the research subject which became a reference to determine the Application of 3D Printing Techniques in Modern Infrastructure Development (Alma Çallı & Ediz, 2023). The type of research conducted is research that strongly considers every answer given by students, which aims to determine the effect of Exploring the Potential of Renewable Energy in Contemporary Engineering Development.

Research Ethics

Of the approximately 1000 students enrolled at Mahmud Yunus State Islamic University Batusangkar, only 50 students contributed to this study (Dwivedi et al., 2023). Of these. 50 students participated in this study, of which 25 were male and 25 were female with a maximum age of 19 years and 18 years (Maulida et al., 2023). The data collection participants came from various villages or jorongs close to UIN Mahmud Yunus Batusangkar. This research has obtained permission from the lecturer who teaches language courses. This research uses several principles of research ethics (Oulaich, 2020). First, there is no coercion in filling out the questionnaire. This research only expects the volunteerism of students and female students who study here. Then every question must be answered completely without leaving any part of the questionnaire. This formular is very supportive and upholds rights and there is no coercion at all. This is done to ensure that the participants understand the essence of this study, out of 50 participants 80% expressed their willingness to fill out this questionnaire.

Data Collection Technique

The technique used by researchers in collecting data is to obtain various information that can be measured, compared, and calculated carefully. Through the google form format created by the researcher (Ibrar et al., 2019), which was filled in by 50 students of UIN Mahmud Yunus Batusangkar. Data collection was carried out on first semester students in the 2023/2024 academic year. After obtaining permission to conduct research from the language lecturer (Jansen et al., 2023), and also IT links online questionnaires distributed to students of various majors. This questionnaire was distributed from March 1, 2024 to March 30, 2024 (Memon et al., 2021). The process of processing data that has been collected from respondents in the research field. The questionnaire data is then downloaded into an Excel file and then transferred to SPSS. The final score data is recorded in the SPSS application which can be verified. Then recapitulated as interesting as possible so that readers are interested in reading articles made by researchers.

Data Collection and Analysis

Then the data that has been collected is inputted and processed using the SPSS application. Distributed in the form of tables and diagrams that can calculate the scores obtained from students (Teimouri et al., 2022). The way the data is analyzed is by comparing each answer given by each student with previously conducted studies (Cohen et al., 2020). Data is presented in the form of average scores and percentages (Castañeda-Babarro et al., 2020). Then the data was tested using the oneway anova test (Kang et al., 2022). Which compares the acquisition score of each group that fills in each statement related to the questionnaire made by the researcher (Loewen et al., 2019). Researchers also really take into account the scores obtained by each student who fills out the questionnaire previously made by the researcher (Betlem et al., 2019). And will never leave any answers given by students from the beginning of filling out the questionnaire

until the last student fills out this questionnaire (Shadiev & Yang, 2020). Furthermore, the researcher will also summarize in an accurate conclusion.

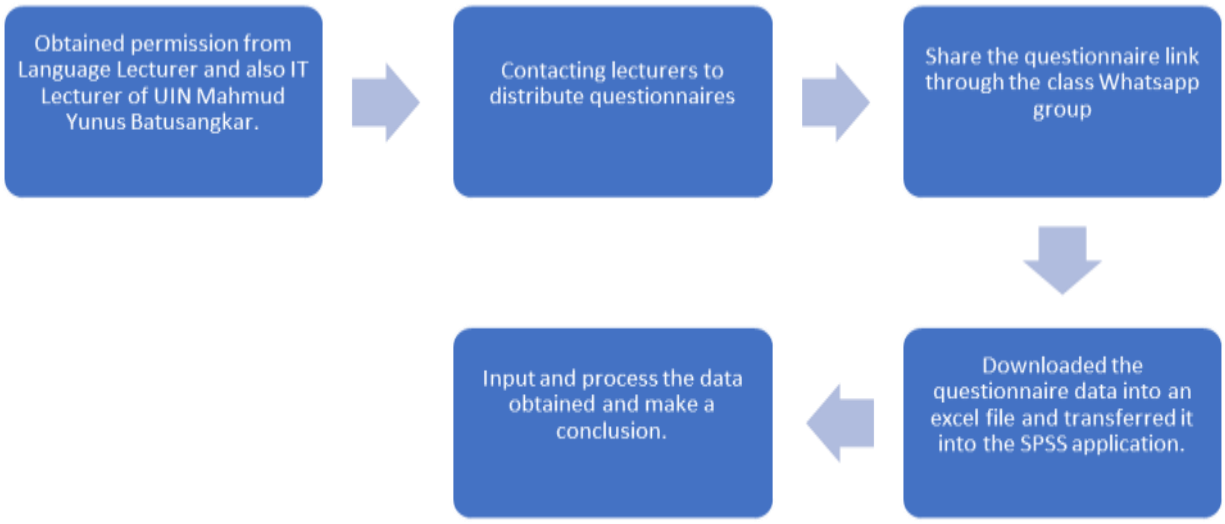
Table 1. 1
Categories of Acquisition of Application of 3D Printing Techniques in Modern Infrastructure Development

No.	Gain category	**Value interval**
1	Strongly agree	>90%
2	Agree	70-80%
3	Disagree less	50-60%
4	Do not agree at all	0-40%
Total		100%

Table 1. 2
Research Sample Details

No	**Student Batch**	**Gender**		**Total**
		Male	**Female**	
1	T.A 2022	10	10	20
2	T.A 2023	15	15	20
	Total	**25**	**25**	**50**

Flowchart of quantitative research



RESULT AND DISCUSSION

Table 1.3

Gains of Application of 3D Printing Techniques in Modern Infrastructure Development

No	Statement	SS	S	KS	SKS
1	The application of 3D printing techniques in modern infrastructure development enables the efficient manufacture of complex structures with high accuracy.	60%	40%	0%	0%
2	3D printing techniques allow greater design flexibility in infrastructure development, enabling adaptation to local needs and environmental conditions.	50%	50%	0%	0%
3	By using 3D printing techniques, construction time can be significantly reduced due to the continuous layer printing process.	70%	30%	0%	0%
4	3D printing techniques reduce material wastage by using only the necessary materials, resulting in a more environmentally friendly construction process.	65%	30%	5%	0%
5	The application of 3D printing techniques enables faster and cheaper production of infrastructure components than traditional methods.	60%	40%	0%	0%
6	The advantages of 3D printing techniques are especially apparent in the construction of unique or highly specialized structures, where the use of traditional molds may not be practical or economical.	80%	20%	0%	0%
7	With the development of stronger and more durable mold materials, 3D printing techniques can become a more attractive alternative in long-term construction.	60%	40%	0%	0%
8	The application of 3D printing	75%	20%	5%	0%

	techniques in infrastructure development can accelerate post-disaster recovery by enabling quick and efficient printing of emergency structures.				
9	The use of 3D printing techniques can open the door to new design innovations in infrastructure, enabling the discovery of more efficient and sustainable solutions.	65%	30%	5%	0%
10	10. In the future, 3D printing techniques have great potential to become a mainstream construction method in infrastructure development, opening up opportunities for significant transformation in the construction industry.	70%	30%	0%	0%

Table 1.4
Gain of Application of 3D Printing Technique in Modern Infrastructure Development
Tested for Feasibility with One Way Anova Test
ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
X.01	T. A 2022	2,400	4	,500	.	.
	T. A 2022	,000	5	,000		
	Total	2,400	9			
X.02	T. A 2022	1,100	4	,275	2,750	,148
	T. A 2022	,500	5	,100		
	Total	1,600	9			
X.03	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.04	T. A 2022	,900	4	,225	.	.
	T. A 2022	,000	5	,000		
	Total	,900	9			
X.05	T. A 2022	1,600	4	,400	4,000	,080
	T. A 2022	,500	5	,100		
	Total	2,100	9			
X.06	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		

	Total	2,100	9			
X.07	T. A 2022	1,600	4	,400	4,000	,080
	T. A 2022	,400	5	,300		
	Total	2,100	9			
X.08	T. A 2022	2,100	4	,525	.	.
	T. A 2022	,000	5	,000		
	Total	2,100	9			
X.09	T. A 2022	1,600	4	,400	.	.
	T. A 2022	,000	5	,000		
	Total	1,600	9			
X.10	T. A 2022	1,900	4	,475	4,750	,059
	T. A 2022	,500	5	,100		
	Total	2,400	9			

Modern infrastructure development has become one of the main drivers of economic growth and the welfare of people around the world. However, amidst the demand to build more efficient, quality and sustainable infrastructure, the construction industry faces various challenges that require technological innovation to overcome. In this context, 3D printing techniques have emerged as a promising solution, offering the potential to change the paradigm of modern infrastructure development. This article will take an in-depth look at the application of 3D printing techniques in modern infrastructure development, including its benefits, challenges, innovations, and practical implications.

The application of 3D printing techniques in modern infrastructure development has a number of significant benefits. One of the main benefits is higher construction efficiency. With 3D printing techniques, complex structures can be printed in one continuous process without the need for many separate construction stages. This can significantly reduce construction time, speed up project completion, and reduce labor costs. In addition, 3D printing also allows for greater design flexibility. By using digital models that can be easily modified, infrastructure can be tailored to the specific needs of the site and environment, and allow experimentation with more complex and innovative designs.

Not only that, the application of 3D printing techniques can also reduce construction material waste. The 3D printing process uses materials more efficiently as it only prints the necessary materials, reducing waste and environmental pollution. This is consistent with the principles of sustainable development that are increasingly prioritized in the modern construction industry.

Despite its great potential, the application of 3D printing techniques in modern infrastructure development is also faced with various challenges. One of the main challenges is the limitation of materials. Although there are various types of materials that

can be used in 3D printing, not all materials are suitable for infrastructure development that requires strength, durability, and resistance to environmental elements.

In addition, 3D printing technology still requires further development to improve its accuracy and speed. Some 3D printing technologies still require a relatively long time to print large structures, while the accuracy of prints can still be improved to meet strict construction standards.

Furthermore, industry regulations and standards also pose challenges to the application of 3D printing techniques in modern infrastructure development. As the technology is still relatively new, there is still a need to develop clear safety, quality and reliability standards to ensure that structures printed with 3D printing technology meet relevant technical and safety requirements. Despite these challenges, the construction industry continues to innovate in the application of 3D printing techniques. One of the latest innovations is the development of more environmentally friendly printing materials. Several studies have been conducted to create molding materials made from waste plastics or other recycled materials, reducing the carbon footprint of construction and promoting a circular economy.

The development of faster and more accurate ply molding technology is also a focus of research in the industry. With increased printing speed and accuracy, the construction process using 3D printing techniques can become more efficient and reliable, enabling the use of this technology in larger and more complex infrastructure projects. Practically speaking, the application of 3D printing techniques in modern infrastructure development can change the whole construction paradigm. By reducing time, cost and material waste, these techniques can help create more efficient, quality and sustainable infrastructure. However, to fully realize this potential, investments in technology development, regulatory improvements, and workforce education are required. In the future, 3D printing has great potential to become a key construction method in modern infrastructure development. By continuing to innovate and collaborate across sectors, we can create a future of construction that is more efficient, flexible and environmentally friendly. The application of 3D printing techniques is not just about printing structures, but also about printing a better future for our world.

CONCLUSION

In facing the challenges of future mobility, the revolution in transportation engineering becomes the key to achieving sustainable and intelligent mobility. Several important points can be drawn as conclusions from the results and discussions presented earlier.

First, developing transportation solutions prioritizing environmental and social sustainability is essential. With a growing population and increasing pressure on natural resources, transportation systems must be able to reduce carbon emissions, alleviate congestion, and improve accessibility for all segments of society.

Second is technology's role as the primary driver in creating smart mobility. Innovations such as electric vehicles, autonomous vehicles, and mobility-based applications have opened new opportunities to enhance transportation efficiency and user experience. However, to ensure the success of these technologies, supportive infrastructure, and appropriate regulations are also needed.

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