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Analysis of Factors Influencing the Decision to Adopt 3D Printing Technology in a Case Study of Residential Housing Development

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Abstract. Construction is the sector that uses the most resources and energy. The amount of waste donated by the construction industry is expected to be 30% of the cost of materials. Furthermore, the construction industry is starting to focus on sustainable development, where technology is one of the enablers to realise it. Technology development is influenced by the level of technology adoption carried out by contractors who have a significant role in the production process. Additive Layer Manufacturing or 3D printing is one of the newest technologies that has developed as a pioneer in pushing the construction industry towards automation. It aims to increase construction productivity. Recently, 3D Printing material construction technology has begun to be applied in Indonesia in a residential project. This step has become a steppingstone for developing construction technology in Indonesia. The adoption of construction technology in a company is caused by many factors, both inhibiting and supporting. The factors influencing the adoption can be used to formulate strategies for subsequent technology development. The Technology Acceptance Model (TAM) and the Technology-Organization-Environment-Cost (TOEC) Framework are used in identifying these factors.

Keywords: *Technology; 3D Printing; Construction; Adoption Factors; Indonesian Company.*

1 Introduction

Construction is the sector that uses the most resources and energy. In the Global Status Renewable Report, the construction sector uses approximately 33% of total final energy consumption and shares 37% of the global greenhouse gas emissions in 2020 [1]. Furthermore, the total cost of waste is expected to be 30% of the cost of materials [2]. Other than that, the construction industry around the world has started to focus its activities on sustainable development, which focuses on three dimensions, namely economic, social, environmental, and technical dimension which means that this sustainable concept is also reviewed from a systematic and technical perspective carried out in the field [3]. The goal of sustainable construction has two functions, to increase efficiency and reduce

waste. In implementing the concept of sustainable construction, technology is the one that can encourage the implementation of this, especially material construction technology. The development of materials construction technology aims to save resources and energy requirements, save construction costs, simplify work by developing materials that are easy to obtain [4], extend the life span of buildings, and improve building quality and safety. The construction industry in Indonesia today has many challenges, such as low work productivity and high amounts of waste. These things occur due to the lack of utilisation of construction technology in construction projects. The construction sector in Indonesia has been slow to adopt new technologies [4]. On the other hand, unique construction projects challenge adapting technology in other industries.

The factor which affects the development of construction technology is the technology adoption by the contractor, whose role in the construction production process is significant [4]. The construction technology advancement that has been developed in many countries today should help contractors improve their quality and efficiency and reduce costs, which are expected to affect the development of the construction industry in Indonesia [4]. Additive Layer Manufacturing, more commonly known as 3D printing, has developed as a pioneer in the construction field, pushing the construction industry towards systems with automated methods [5]. The automated system aims to increase construction productivity by optimising time, minimising production costs, and minimising the use of resources and energy. Recently, 3D Printing material construction technology has begun to be applied in Indonesia in a residential project. The existence of a new step in adopting this technology can be a steppingstone in the development of construction technology in Indonesia. Therefore, knowledge and understanding of contractor mechanisms are needed in utilising construction technology to determine the focus of the steps needed to improve the construction sector environment and improve the construction industry's performance in Indonesia.

1.1 Research Objectives

This study intends to identify the factors that influence the adoption of construction technology in a company to produce an overview of construction technology adoption patterns and to evaluate the implementation of the technology to find out how the company intends to apply this technology for future projects.

2 Literature Review

2.1 Construction Project and Management

Construction work is commonly referred to as a project because of its temporary and unique nature [6]. Construction projects have a relatively high complexity where complexity consists of many interrelated parts, which can be characterised

by differentiation and interdependence [7], [8]. Consequently, a highly complex construction project must be managed. Project management can be defined as planning, organising, directing, and controlling all resources in each period to achieve a specific goal or various targets [9]. Project management is generally required by managing resources according to the 5M frameworks (Manpower, Method, Machine, Material, Money), which are based on the traditional view of the change management process as a technical control strategy for planning, implementation, and evaluation [10].

2.2 Construction Technology in Indonesia

In construction, technological developments aim to create a more productive construction process. Technology is a derivative of the Greek, *techne*, and *logos*. Egmond (2012) defined *techne* as the 'know-how' needed to create something [11]. Meanwhile, *logos* is defined as logic or a logical and structured procedure. Thus, technology is defined as a logical, structured, and applicable way to create something that answers human needs. The term technology in construction is often associated with things that are advanced, sophisticated, or something whose elements of renewal support increased efficiency and productivity to competitiveness both in production and during the implementation process [11]. Construction technology divides into several types depending on its function: product/material technology and process/management technology. For material technology, the history of the application of this technology in Indonesia can see in the following illustration [12].

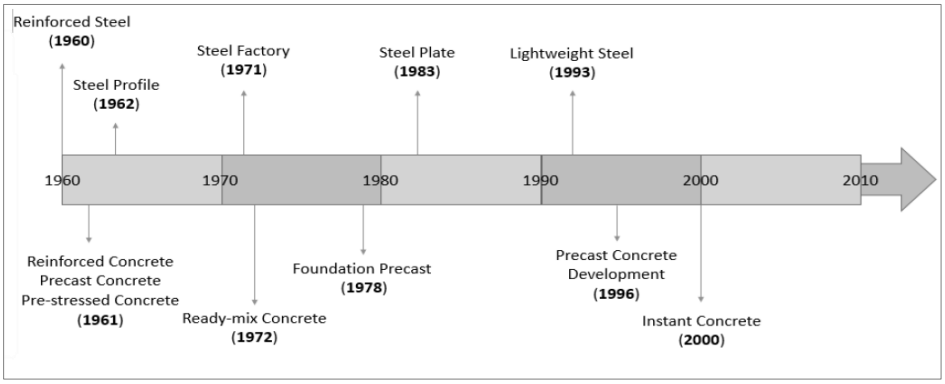

Figure 1 Timeline of Construction Material Technology in Indonesia [12]

Furthermore, in Indonesia, the construction process/management technology that has also begun to develop is BIM technology. Where most projects have used BIM technology, although, from research conduct, 54% only used BIM to make 3D models, 14% reached the scheduling stage (4D), 32% reached the cost estimation and parts list (5D) stages, and none used BIM until 6D and 7D [13]. Moreover, Indonesia is currently adopting 3D Printing technology, also known

as Additive Layer Manufacturing, which means manufacturing objects in three dimensions or any form from digital models.

2.3 3D Concrete Printing Technology

3D Printing technology has been widely applied in many countries in the world, such as the United States, Britain, Russia, United Arab Emirates, as well as China [14]. The use of 3D printing technology in projects in the United Arab Emirates has reduced labour costs by 50%-80% and construction waste by 30%-60%. Also, in Russia, a residential house was successfully constructed in 24 hours in Moscow with a surface area of 400 ft^2 [15].

3 Research Methodology

The flow and method of this research are described in the following flowchart.

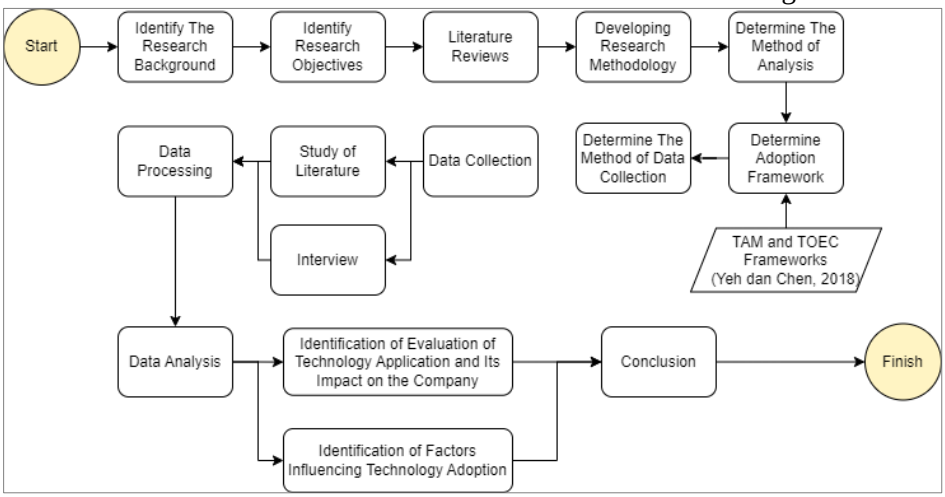

Figure 2 Research Flow

3.1 Adoption Framework

In adopting technology, various adoption models have been developed to understand the different dimensions that affect technology acceptance from a company [16], [17]. One is the Technology-Organization-Environment (TOE) framework, which was developed by Tornatzky and Fleischer (1990). This TOE framework has been widely used to explain steps in adopting technological innovation from an organisational perspective [17], [18]. The TOE Framework is carried out by identifying the factors that influence the implementation of technological innovations in the context of technology, organisation, and environment. In addition to these factors, another factor that is also important is the cost dimension factor for adopting 3D Printing technology from an organisational perspective. Thus, a review of technology adoption becomes TOEC [18]. In addition, another method that is also commonly used in analysing

the application of technology (especially user acceptance behaviour) is the Technology Acceptance Model (TAM) introduced by Davis et al. (1986) [19]. This model is based on social psychological theory and the Theory of Reasoned Action (TRA) [19]. TRA explains that users' beliefs influence the attitudes that lead to intentions and produce behaviour. Accordingly, Davis (1986) introduces the constructs in TAM in the following illustration [19].

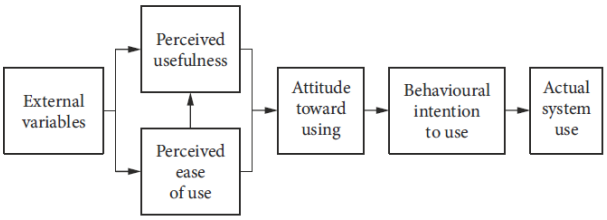

Figure 3 Illustration of Technology Acceptance Model (TAM) Framework

The factors observed in this method are Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude, and Behavioral Intention to Actual Use or how the technology is used/applied [19]. Another framework that can also use is the Diffusion of Innovation (DOI) [20]. Rogers (1983) defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" [21]. According to Rogers (1983), the speed of diffusion of an innovation is influenced by four elements, namely (1) the characteristics of the innovation; (2) The communication channel used to communicate the benefits of the innovation; (3) the time since the innovation was introduced; and (4) the social system where the innovation diffuses [20], [21].

3.2 Data Collecting and Analysis Method

This research is generally qualitative and based on the frameworks previously mentioned. This qualitative research was conducted based on the principle that qualitative data is emphasised on people's life experiences, basically very suitable to discover the meanings that people place on the events, processes, and structures of their lives and for relating these meanings to the social world around them [22]. The data collection method in this study is as follows:

1. Interviews aim to determine experts' opinions regarding the adoption factors of this 3d printing technology. The determination of sources (the experts) uses the principle of purposive sampling [23]. Purposive sampling is a technique widely used in qualitative research to identify and select information-rich cases for the most effective use of scarce resources [23], [24]. This technique involves the identification and selection of individuals or groups of individuals with specific knowledge or experience of a phenomenon [23], [25].

2. Document Analysis and Literature Study. Document analysis is carried out by collecting data, reviewing, dissecting, and coding content into research subjects.

Literature data analysis is done by the inductive approach, a systematic method of analysing qualitative data in which precise evaluation objectives can guide the analysis. In this research, inductive analysis refers to approaches that primarily use detailed readings of raw data to derive concepts, themes, or a model through interpretations made from the raw data by an evaluator or researcher [26]. In addition, for the interview data, Miles and Huberman's (1984) analysis method was also used, which included data reduction (condensation), data display, and conclusion drawing/verification [22], [26].

4 Discussion of The Research

4.1 Identification of Factors Influencing Technology Adoption

The factors that influence the application of this technology are obtained from several theories and frameworks taken from several references, including the Technology-Organization-Environment-Cost (TOEC) framework, Diffusion of Technology (DOI) theory, Technology Acceptance Model (TAM), as well as other influencing factors obtained from various references with the following details.

Table 1 Identification of Factors Influencing Technology Application Based on Several Theories and Thinking Frameworks

No	Teori/Framework	Faktor	Literatur
1	Diffusion of Technology (DOI)	Relative Advantage (Benefits of Technology for Companies), Compatibility (Compatibility with Company Needs), Complexity (Difficulty of Technology Implementation), Trialability (Easy to be Tried), Observability (Clarity of Appearance of Technology)	[20]
2	Technology Acceptance Model (TAM)	External Variable, Perceived Usefulness, Perceived Ease of Use, Attitude (Company's Attitude in Adopting), Behavioral Intention (Company's Intention to Implement Technology in Further Projects), Actual Use (Application of Technology)	[19]
3	Technology-Organisation-Environment-Cost (TOEC)	**Technology:** Can Improve the Quality of the Construction Process; **Organization:** Company Management System, Number of Experts or Research Conducted; **Environment:** Competition with Other Companies. Government Regulations; **Cost/Economic:** Investment Cost, Profit Prediction.	[19]

4	Other Technology Application Factors	Improving Construction Quality (Efficiency or Productivity Improvement), Software Requirements, Hardware Requirements for Software, Technology Implementation in the Field, Company Support, Government Support, Cost Investment, and Supporting Company Goals.	[27]
5	TOE Framework	**Technology:** Technology Competence, Relative Advantage (Benefits of Technology for Companies); **Organization:** Organisational Structure, Top Management Role, and Support, Company's Financial Readiness to Invest; **Environment:** Competitor in the Construction Industry, Government Regulations, Consumer Readiness.	[28]
6	Other Technology Application Factors	Advantages over Competitors, Improving Product and Process Quality, Increasing Productivity, Market Demand, Increasing Profitability, Expanding the Construction Market, and Reducing Production Costs.	[29]
7	Other Technology Application Factors	The linkage between Company Business Strategy and Adopted Technology.	[30]
8	Technology Acceptance Model (TAM)	External Variable: Conformity with Needs, Frequency of Use, Ease of Use; Internal Variables: Perceived Usefulness, Perceived Ease of Use, Attitude (Company's Attitude in Adopting), Behavioral Intention (Company's Intention to Implement Technology in Next Projects), Actual Use (Use/Application Technology)	[31]
9	Fishbone Diagram	Goals: Improvement Quality, Productivity; Project Characteristic: Complexity, Fit to Task, Compatibility; Vision/Mission: Tangible/Intangible Value, Company Policy; Strategic Finance Policy: RoI, Life Cycle Cost, Training Cost; Attributes of The Technology: Trialability, Specification, Ease of Use, Usefulness; Innovator: Technical Expertise, Reliability; Individual: Culture, Personal Motivation; Board: Network Effects, Socioeconomic Status.	[32]
10	Theoretical Framework	Culture: Organizational, National; Policy: National, Organizational; Cost: Direct, Indirect.	[33]

Factors developing from various references will be used in this study because the factors mentioned follow business conditions in Indonesia, especially for the construction business. From the various factors, the TAM-TOEC theoretical framework will be used to identify influencing factors. Factors that influence the application of technology from other literature will be grouped based on the categories of the TAM-TOEC framework, and the factors that have similarities will be combined. So, in simple terms, grouping results.

Table 2 Merging Factors Influencing Technology Application from Various Literature in the TAM-TOEC Framework

No	TAM-TOEC Framework		Factors	Resource
1	External Factors	Organisation	Company Purpose (Vision/Mission)	[20], [27], [32]
2			Company Business Plan and Strategy	[30]
3			Enterprise Management System	[19], [27], [28], [32], [33]
4			The Capacity of Experts and Number of Research	[19], [32]
5		Environment	Competitor in Construction Business	[19], [28], [29]
6			Construction Market	[28], [29], [32], [33]
7			Government Regulation	[19], [27], [28], [33]
8		Cost/Economic	Investment Cost	[19], [27], [28], [32], [33]
9			Profit and RoR	[19], [29], [32]
10		Technology	Supporting Software/Hardware Requirements	[27]
11			Work Efficiency and Productivity	[19], [27]–[29], [32]
12	Internal Factors	Perceived Ease of Use	Perceived Ease of Use and Complexity of Implementing 3D printing in the Field	[19], [20], [27], [31], [32]
13		Perceived Usefulness	Perceived Usefulness of 3D printing for Construction Companies	[19], [20], [28], [31], [32]
14		Behavioural Intention	The Construction Company's Behavioral Intention to Use 3D printing in Their Next Project	[19], [31]–[33]

The TAM-TOEC framework is used in this study because the chart model and categories used in this framework conform with the condition that 3D Printing technology has just been implemented in Indonesia in a residential project. Thus, these factors can be deepened to the acceptance of the newly used technology. The classification of each factor in each category in the TAM-TOEC framework is based on the literature, which identifies factors that influence technology adoption with the TAM and TOEC frameworks. Thus, similar factors from another theoretical framework are included following the factors that have already been included in the TAM-TOEC framework by these references. In simple terms, the TAM-TOEC model obtained for this study is depicted in the following chart.

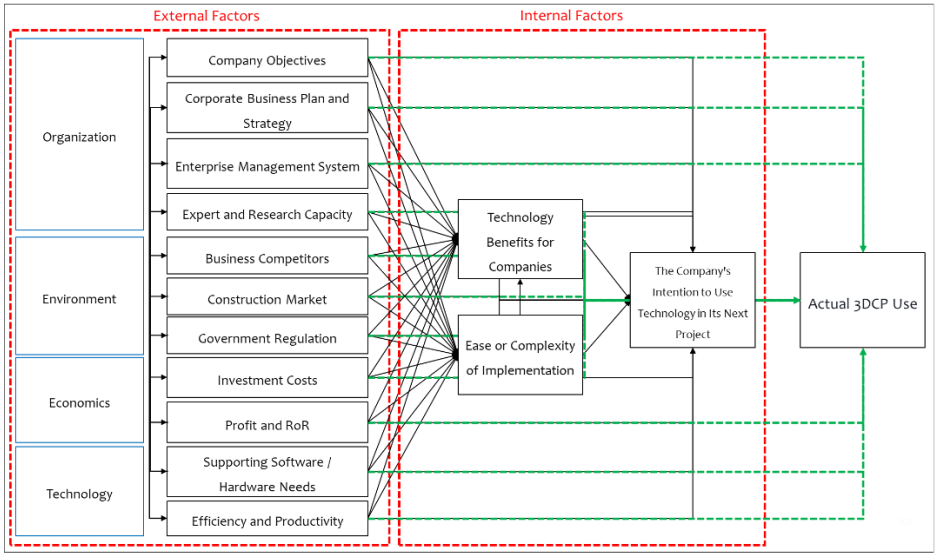

Figure 4 TAM-TOEC Model and Details Factors for This Study

The factors that have been previously identified are then asked by several experts who are directly involved in the application of this 3D printing technology. According to experts, the factors that most influence a company's decision to adopt 3D printing technology in their projects are the suitability of implementing this technology with business plans and company goals, the benefits of technology for companies, the resulting efficiency and increased productivity, the profitability of using technology, and the investment costs. The experts will assess whether the application of this technology can positively impact the company's business and how the applied technology will benefit the company after the project. In the TAM-TOEC model above, of course, it can also be calculated for the influence of one factor on other factors quantitatively, with the ANP method or SEM, but this is not done in this study, so what is produced is what Factors Affecting Technology Adoption, and which of these factors are the most influential according to the assessment of experts in a case study of the application of 3D Printing technology to the construction of this residential house.

4.2 Evaluation of Implementation of 3D Printing Technology in The Field

The implementation of 3D printing technology in residential construction is the first implementation of 3D printing technology for building scale in Indonesia. The implementation of technology in this project still has many shortcomings. Evaluation of the implementation of 3D printing technology is conducted to find out more about increasing performance and productivity from applying this technology. Performance is defined as the extent to which they successfully carry

out their duties and their ability to achieve their intended objective [34], [35]. Time, cost, and quality are the essential criteria for the project's success; almost all related papers mention these three and emphasise their importance in a construction project [36]. In this case, several evaluations of the essential criteria for the project's success are mentioned and explained as follows, with detailed calculations regarding efficiency and productivity improvements that cannot be shared by the company:

1. **Cost**. The company claims that this technology reduces the cost of wall materials for Type-36 houses by up to 10%-15%, assuming the average cost of wall materials in Indonesia is IDR 45,000,000.00. In addition, the need for labour for Type-36 houses in Indonesia with conventional methods is as many as seven people, and with 3D printing, only 4-5 people are needed. This reduction in labour requirements will affect productivity and overall construction costs.
2. **Quality**. The quality of the mortar material with this technology is better in terms of compressive strength, with the ratio of strength produced by 3D printing to red brick (3-5 MPa) or light brick (7-10 MPa), while 3D printing mortar has a strength of 25 MPa.
3. **Time**. In Indonesia, a Type-36 house is usually built within three months, whereas 3D printing can reduce it to 1.5-2 months. With notes, this duration is during project implementation in the field and does not include machine/equipment fabrication. This reduction in duration will undoubtedly affect the project's indirect costs, thereby increasing productivity.

In addition, construction project performance is also assessed by its quality, such as health and work safety, environmental impact, and its relation to sustainability. However, the work that can be done using 3D printing technology is still confined to non-structural elements, while the structural elements are still performed manually. The assessment of project performance is explained below:

1. Building Quality and Capacity/Strength. In general, as previously explained, the quality of mortar as a substitute for brick walls is better. However, this does not include shear tests and tests for the resulting intact structure. This building has also not been tested against earthquake loads. So, in this regard, it is necessary to carry out further tests related to Indonesia's location as an earthquake-prone country. Apart from that, it is also necessary to check whether the bond between the layers on the mortar wall is too rigid because this will, of course, be related to the response of the building to earthquake forces.
2. Occupational Health and Safety. In terms of OHS, this technology has fewer work accidents because most of the work is done by machines.

However, there has been no quantification of the reduction in the rate of work accidents resulting from the application of 3D printing technology.

3. Environmental Impact and Sustainable Construction. In general, all sources acknowledged that the use of this technology supports the concept of sustainability. The waste generated from this project is much less when compared to conventional methods. However, an evaluation regarding the emissions from the engine used has not been mentioned by the company or through sources. Of course, this needs to be studied more deeply because if engine emissions are high enough, the use of this technology is incompatible with the concept of sustainability.

However, apart from the advantages previously mentioned, all interviewees acknowledged that the overall production costs for the field process are still expensive, especially for architectural and operational costs. The cost of finishing the surface is quite a lot; wall work is done in two layers with a zigzag shape in between. Compared to the conventional wall method, the cladding may not be as expensive as a too-thick layer is not required. With this 3D printing, wall covering requires much mortar because the resulting surface is uneven and rough. However, if the wall is cast in situ, it may not be very costly to cover, but it will cost money to manufacture and install the formwork for the wall.

In addition, most sources felt that the residential project did not meet their expectations. The increase in cost efficiency, quality, and time mentioned is still considered not meeting expectations, mainly because production costs are still costly. So, the company has no plans to utilise/implement this 3D printing technology for future projects.

5 Conclusion

Factors influencing the application of 3D Printing technology in this case study were identified as 14 factors, with the enormous contribution being the connection between technology and company business plans and strategies, company goals, benefits of 3D printing for construction companies, work efficiency and productivity, profit and RoR predictions, and costs investment. Meanwhile, the most negligible contributions are government regulations, supporting software/hardware requirements, ease and complexity of implementing 3D printing in the field, and competitors in the construction business. After the project was implemented, most interviewees felt that this residential house project did not meet their expectations because the cost of producing a type 36 residential house was still too expensive. Thus, it is considered not to provide an increase in efficiency, and for now, the company still has no plans to utilise this 3D printing technology for future projects.

6 Acknowledgement

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7 References

[1] GSR, "Renewables 2022: Global Status Report," 2022.

[2] O. O. Fadiya, P. Georgakis, and E. Chinyio, "Quantitative Analysis of the Sources of Construction Waste," *Journal of Construction Engineering*, vol. 2014, pp. 1–9, Oct. 2014, doi: 10.1155/2014/651060.

[3] K. M. Patil and M. S. Patil, "Sustainable Construction Materials & Technology in Context with Sustainable Development," *International Journal of Engineering Research and Technology*, vol. 10, no. 1, pp. 112–117, 2017, [Online]. Available: http://www.irphouse.com

[4] R. Permatasari, I. Mahardika, and B. W. Soemardi, "Kajian Penerapan Teknologi Konstruksi Oleh Kontraktor Dalam Menghadapi Kondisi Pandemi Covid-19," in *Konferensi Nasional Teknik Sipil 15, Semarang 20 - 21 Oktober 2021*, 2021.

[5] S. El-Sayegh, L. Romdhane, and S. Manjikian, "A Critical Review of 3D Printing in Construction: Benefits, Challenges, and Risks," *Archives of Civil and Mechanical Engineering*, vol. 20, no. 34, Jun. 2020, doi: 10.1007/s43452-020-00038-w.

[6] J. R. (John R. Turner, *The Handbook of Project-Based Management: Leading Strategic Change in Organisations*, 3rd ed. McGraw-Hill, 2009.

[7] D. Baccarini, "The Concept of Project Complexity - A Review," *International Journal of Project Management*, vol. 14, no. 4, pp. 201–204, 1996, doi: 10.1016/0263-7863(95)00093-3.

[8] M. Nikolić and A. Cerić, "Classification of Key Elements of Construction Project Complexity From The Contractor Perspective," *MDPI Buildings*, vol. 12, no. 696, May 2022, doi: 10.3390/BUILDINGS12050696.

[9] M. A. El-Reedy, *Construction Management for Industrial Project*. Beverly: Scrivener Publishing, 2011.

[10] R. Badham, V. L. Cançado, and T. Darief, "An Introduction to The 5M Framework: Reframing Change Management Education," *BAR - Brazilian Administration Review*, vol. 12, no. 1, pp. 22–38, 2015, doi: 10.1590/1807-7692bar2015140033.

[11] A. Jayady, "Teknologi Konstruksi - Sebuah Analisis," *Jurnal Karkasa*, vol. 4, no. 1, 2018.

[12] R. G. K. Pradoto, B. W. Soemardi, A. Gazali, A. T. Putri, R. P. Purba, and I. Mahardika, "The Technology Landscape of Construction Material in The Indonesian Construction Industry," in *ICONCESS*, 2021.

[13] I. M. A. Megapathi, I. G. A. A. Putera, and N. M. Jaya, "Tingkat Implementasi dan Hambatan Adopsi Building Information Modeling Pada Pelaku Proyek

Konstruksi di Bali," *Jurnal Spektran*, vol. 9, no. 1, pp. 1–11, Jan. 2021, [Online]. Available: http://ojs.unud.ac.id/index.php/jsn/index

[14] F. Lyu, D. Zhao, X. Hou, L. Sun, and Q. Zhang, "Overview of The Development of 3D Printing Concrete: A Review," *Applied Sciences (Switzerland)*, vol. 11, Nov. 2021, doi: 10.3390/app11219822.

[15] M. Sakin and Y. C. Kiroglu, "3D Printing of Buildings: Construction of the Sustainable Houses of the Future by BIM," in *Energy Procedia, 9th International Conference on Sustainability in Energy and Buildings, SEB-17*, 2017, vol. 134, pp. 702–711. doi: 10.1016/j.egypro.2017.09.562.

[16] L. Muylle, "Technology Readiness and Adoption Of 3D Printing In The Construction Industry," Ghent University, Ghent, 2019.

[17] S. P. Sonwalkar, "Roadmap for Adopting 3D Concrete Printing Technology for Production of Affordable Houses," University of Twente, Enschede, 2020.

[18] C. C. Yeh and Y. F. Chen, "Critical Success Factors for Adoption of 3D Printing," *Technol Forecast Soc Change*, vol. 132, pp. 209–216, Jul. 2018, doi: 10.1016/j.techfore.2018.02.003.

[19] X. Qin, Y. Shi, K. Lyu, and Y. Mo, "Using a TAM-TOE Model To Explore Factors of Building Information Modelling (BIM) Adoption in The Construction Industry," *Journal of Civil Engineering and Management*, vol. 26, no. 3, pp. 259–277, Feb. 2020, doi: 10.3846/jcem.2020.12176.

[20] F. Wahid and L. Iswari, "Adopsi Teknologi Informasi Oleh Usaha Kecil dan Menengah di Indonesia," in *Seminar Nasional Aplikasi Teknologi Informasi*, Jun. 2007, pp. 75–79.

[21] E. M. Rogers, *Diffusion of Innovations*, 3rd ed. New York: The Free Press, 1983.

[22] M. B. Miles, A. M. Huberman, and J. Saldana, *Qualitative Data Analysis: A Methods Sourcebook*, 3rd ed. California: Sage Publications, Inc., 2014.

[23] L. A. Palinkas, S. M. Horwitz, C. A. Green, J. P. Wisdom, N. Duan, and K. Hoagwood, "Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research," *Administration and Policy in Mental Health and Mental Health Services Research*, vol. 42, no. 5, pp. 533–544, Sep. 2015, doi: 10.1007/s10488-013-0528-y.

[24] M. Q. Patton, *Qualitative Research and Evaluation Methods*, 3rd ed. California: Sage Publications, Inc., 2002.

[25] J. W. Creswell and V. L. Plano Clark, *Designing and Conducting Mixed Methods Research*, 3rd ed. California: Sage Publications, Inc., 2018.

[26] D. R. Thomas, "A General Inductive Approach for Analysing Qualitative Evaluation Data," *American Journal of Evaluation*, vol. 27, no. 2, pp. 237–246, 2006, doi: 10.1177/1098214005283748.

[27] H. Fitriani and W. P. Br Bangun, "Kesiapan Adopsi Building Information Modeling (BIM) Pada Konsultan Perencana di Kota Palembang," *Teras Jurnal*, vol. 11, no. 2, pp. 437–450, Sep. 2021, doi: 10.29103/tj.v11i2.568.

[28] M. I. Effendi, D. Sugandini, Y. Istanto, R. Arundati, and T. Adisti, *The Technology-Organization-Environment Framework: Adopsi Teknologi Pada UKM*. Sleman: Zahir Publishing, 2020. [Online]. Available: https://www.researchgate.net/publication/345989050

[29] L. Ellitan, "Factors Influencing the Success Of Technology Adoption: A Case Study Of Indonesian Manufacturing Firms," *Jurnal Manajemen &*

Kewirausahaan, vol. 4, no. 1, pp. 1–14, Mar. 2002, [Online]. Available: http://puslit.petra.ac.id/journals/management/

[30] G. D. Pires and J. Aisbett, "The Relationship Between Technology Adoption and Strategy in Business-to-Business Markets: The Case of e-Commerce," *Industrial Marketing Management*, vol. 32, no. 4, pp. 291–300, 2003, doi: 10.1016/S0019-8501(02)00237-7.

[31] E. S. Park and M. S. Park, "Factors of The Technology Acceptance Model for Construction IT," *Applied Sciences (Switzerland)*, vol. 10, no. 22, pp. 1–15, Nov. 2020, doi: 10.3390/app10228299.

[32] S. M. E. Sepasgozar and S. Davis, "Construction Technology Adoption Cube: An investigation on Process, Factors, Barriers, Drivers and Decision Makers Using NVivo and AHP Analysis," *Buildings*, vol. 8, no. 6, May 2018, doi: 10.3390/buildings8060074.

[33] N. Usman and I. Said, "Key Factors that Affects Adoption of Technology in the Nigerian Construction Firms: A Theoretical Framework," *International Journal of Accounting and Business Management*, vol. 2, no. 2, 2014.

[34] J. L. Gibson, J. M. Ivancevich, H. H. Donnely Jr., and R. Konopaske, *Organizations Behavior, Structure, Processes, Fourteenth Edition*, 14th ed. California: McGraw-Hill, 2012.

[35] A. Prasetya, "Analysis of Factors That Influence Employee Performance: Study on Permanent Employees in Operational Section of PT WIMCycle Indonesia - Surabaya," *Jurnal Profit*, vol. 12, no. 1, 2018, [Online]. Available: https://profit.ub.ac.id

[36] A. P. Chan, "Framework for Measuring Success of Construction Projects," Brisbane, 2001.