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CRITICAL CHALLENGES IMPLEMENTATION OF 3D PRINTING TOWARD INDUSTRY REVOLUTION (IR) 4.0: FROM CONTRACTOR PERSPECTIVE

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Abstract: *Industry 4.0, often referred to as IR 4.0 (the fourth industrial revolution), is a term used to describe the current trend of automation and data exchange in manufacturing technologies. It represents a significant shift in the way goods are produced, and it involves the integration of digital technologies, artificial intelligence, the Internet of Things (IoT), 3D printing, cloud computing, and other emerging technologies into the manufacturing process. The goal of Industry 4.0 is to create more efficient, flexible, and responsive manufacturing processes, leading to increased productivity, reduced costs, and faster time-to-market for products. It has the potential to transform industries across the globe and is often seen as a key driver of economic growth and competitiveness in the digital age. The study aims to determine the challenges of 3D printing implementation towards industry 4.0 in Kuala Lumpur, Malaysia. A questionnaire survey was distributed to the contractor company, and 108 contactor Grade 7 were chosen to fulfil the study's goal. Distribution of questionnaire techniques are used for data collection. Quantitative methods had been used and in order to achieve the research objectives and been analysed by using Statistical Package for Social Science (SPSS) version 26 software. The study identified the critical challenges on the implementation is regarding the cost, reduce job opportunities, high-skilled procedure, insufficient guideline, lack of* *experiences, and high technology. Hence, it is suggested that the government sector and private sector do the collaboration for the 3D printing implementation. Collaboration between public and private entities creates better and more effective public and private services and products particularly in solving the issues.*

Keywords*: 3D printing construction, IR 4.0, construction management, contractor perspective.*

Introduction

The fourth industrial revolution technologies, otherwise known as 4IR or Industry 4.0, permeate the human economy and every aspect of livelihood due to the technologies' efficiency, effectiveness, and dynamics. These technologies are also necessary for resource optimization to achieve economic, environmental, and social sustainability.(Love. O, et al 2022). The leading technologies in the IR 4.0 are the Internet of Things (IoT), Big data analytics, Cloud computing, 3D printing/Additive Manufacturing, and Robotic systems. The one of the key component and concepts if industry 4.0 is about additive manufacturing or 3D printing. 3D printing and other additive manufacturing techniques are becoming more prevalent in Industry 4.0, enabling rapid prototyping and customization of products.

3D printing has emerged as one of the most critical instruments of Industry 4.0, significantly easing the manufacturing process for firms. 3D printing, or additive manufacturing (AM), is a technology for fabricating objects by successively connecting layers of material based on a three-dimensional model (Baumers et al., 2020), and 3D printing is a process that utilizes data from a virtual model to create physical models, with full goods or components of them being printed (Straub, 2017).

Additive manufacturing, or 3D printing, is a technique where a digital such as CAD model is converted into a combination of 2D layers that are then deposited by a printer to form the 3D solid product. An updated definition of 3D printing is "the manufacture of objects by the deposition of a substance utilising a print head, nozzle, or another printer technology" (Olsson et al., 2019). To elaborate, additive manufacturing is "the process of combining materials to construct items from 3D modelling data, usually layer upon layer." Additive manufacturing is suitable to a wide range of materials and may produce things with complicated and complex shapes, created from customised materials with almost little material waste.

This technology (3D) has several advantages over traditional production techniques in terms of environmental sustainability. It's been shown to cut emissions of carbon dioxide (CO_2) as well as usage of energy (Nyika et al., 2021). However, the material utilised in 3D printing is the primary determinant of these variables. biodegradable and corn-based PLA material is being increasingly employed in 3D printing due of its low heat and energy needs, excellent print quality, as well as comparably lower emissions than other plastics (Kumar et al., 2018). The objective of this paper is to determine the critical challenges on the implementation of 3D printing towards industrial revolution (I.R) 4.0 based on the contractor perspective.

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Literature Review

History of 3D Printing

In 1984, Charles Hull invented Stereolithography, a technique for creating physical 3D objects from computer data. Throughout the history of manufacturing, subtractive processes have typically come first (Mathur, 2016). From filing and turning through milling and grinding, machining (creating precise, high-precision forms) was usually a subtractive process. The initial uses of additive manufacturing have been in the tool room end of the manufacturing range (Mathur, 2016). Rapid prototyping, for instance, was one of the earliest additive versions. Its goal was to shorten the lead time and cost of generating prototypes for novel parts and devices, which were previously solely created via subtractive tool-room techniques (typically slowly and expensively).

3-D printing in construction begins with mechanized and robotic construction, which are not novel in the construction sector. Building materials such as concrete, mortar, asphalt, and others function as the printer's ink on a mobile or stationary system composed of multiple robotic subsystems or components. A computer sends a digital image to a desktop printer so that it can be printed on a sheet of paper. Similarly, in building, the goal is to send a digital model to a printer to make a structure at, above, or below ground level. To most, 3-D printing is an automated technique of creating a product layer by layer, similar to how natural forces and processes form rocks (Khan et al., 2020). This is in contrast to generating a product by reducing a more significant mass to a smaller mass of the required size and shape by progressively removing materials, as is done when creating sculptures and other industrial products, hence the name "additive manufacturing" for this technology (Khan et al., 2020).

The construction sector is well-suited for 3D printing since the data necessary to make a 3D object already exists due to the design process, and the industry is already familiar with computer-aided manufacturing. 3D printing enables the use of various materials, the freedom of design, and the on-site or off-site fabrication of complex shapes (Tahmasebinia et al., 2020). Add the strength of automated and autonomous production to these features, and you have a near-perfect match for the requirements of the construction sector. It should be mentioned, however, that the use of 3D printing in the building business is still in its infancy.

Overview Construction Industry In Malaysia.

Malaysia's construction industry has various types, such as conventional and alternate methods, which is the Industrialized Building System (IBS). The conventional building system now being followed by the construction sector is unable to cope with the high demand, making it difficult for the country to meet the aim of 600,000-800,000 dwellings over this period (Kadir et al., 2006). The construction sector, therefore, needs to come up with another option, such as the industrialized building system (IBS), which offers significant benefits in terms of productivity, indoor quality, durability, and cost. When using conventional method in construction industry of course there will be a risk and uncertain outcome. The terms "risk" and "uncertainty" are used to describe situations in which the actual result of an event or action will differ significantly from the estimated value (Adnan & Rosman, 2018). This means the consequences of risk on building projects could be extremely severe. The risk significantly impacts the project's output, effectiveness, quality, and overall budget. The author need to discover an alternate solution, such as utilizing industrialized building systems in the construction industry, so that we can get past the problems including risk and uncertainty.

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Industrialized Building System (IBS) is a new technique of construction that emphasizes innovation and "green" characteristics; it is a more sophisticated version of the Industrialized Building System than its predecessor (IBS). It produces IBS products in a controlled setting which is employing high technology IBS plant generated by the sophisticated program and machine (Mohammad et al., 2016). Modular System (MS) is a coordinated, uniform system for dimensioning spaces, components, fittings, etc. Hence, all elements fit together without cutting or expanding, even when various manufacturers supply the parts and fittings.

Malaysia experiences an equatorial climate. During the annual monsoon season, such nations typically endure considerable precipitation. This results in the leakage problem, a severe issue for structures that employ IBS techniques. When a leak emerges, various problems such as moisture, corrosion, and so on may ensue. Other than that, site accessibility is major factor contribute to barrier using IBS in Malaysia (Tun et al., 2018). The conventional technique to IBS, various advances in the Malaysian building industry overview exist. Although IBS offers a solution for enhancing building sustainability, the deployment of this system is still in its infancy since it faces numerous obstacles.

Construction Cost Estimation

The utilization of 3D printing presents a new difficulty in assessing costs, a crucial aspect of building management. Due to the novelty of the technology, it is difficult to predict the building costs with the requisite precision (Goh et al., 2021). Additionally, the technology has a high initial price tag. This cost may reach up to 250,000 Euros, which could create hesitancy in purchasing the product (El-Sayegh et al., 2020). However, this is simply an initial cost, and the building costs while utilizing the printer would be significantly lower than with conventional methods. Moreover, large-scale printers are costly and require regular maintenance, which increases the price. However, this price is anticipated to decrease due to competition in the industry.

Less Demand for Workers

The construction industry's reliance on labor-intensive, high-skilled conventional methods has been a significant barrier to adopting automation technologies. In addition, using 3D printing in buildings necessitates construction workers acquiring new skills (El-Sayegh et al., 2020). These new abilities, which are crucial to the success of a project, are not readily accessible on a regular construction site. The use of 3D printing in the building reduces the necessity for workers, but it also creates new opportunities for vocations that require different skill sets than traditional construction.

Standard of Specification

The exchange of data is crucial to developing a vast database, which is required to operate Machine learning (ML) algorithms. With more groups of researchers focusing on creating new materials and processes, data gathering, and pre-processing standards would ensure data sharing and promote collaboration within the AM community (Goh et al., 2021). Aside from that, due to the novelty of 3D printing, particularly in a concrete building, specifications and norms are still lacking (Siddika et al., 2020). The selection of materials also presents difficulties. Moreover, design and construction guidelines are inadequate. Due to the lack of requirements, the shape and size selection of printed pieces still depends on the available printer properties and the material qualities (Avrutis et al., 2019).

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Material Choice

The minimal material palette used today is a significant barrier to modern 3D printing in the building industry. Many present-day showcases are not constructed from the high-quality materials necessary for a suitable service life under natural or industrial exposure circumstances (De Schutter et al., 2018). They are primarily predicated on the technological difficulty of stack layers without premature collapse. When analyzing material performance in some showcases in greater depth, striking inadequacies can sometimes be observed, such as shrinkage cracking, as illustrated in Figure 2 for an early showcase of a 3D-printed mortar structural piece with an excessive degree of shrinkage cracking (De Schutter et al., 2018).

Technology in 3D Printing and Large-scale Construction

3D printing technologies, remarkably Rapid Printer (RP) technologies, might not be well-suited for the construction of huge landscape models or buildings. There were two reasons that led to such speculation (Wu et al., 2016). As most 3D printers were small when the technology trend began, it was unknown whether the technology could be used to print large-scale models or structures, as the size of 3D printers is directly tied to the size of the models or buildings it can print. On the other hand, 3D printing widespread applications are limited by various constraints (Ghaffar et al., 2018).

Methodology

This study used a quantitative method, in which respondents were selected according to judgments made, also known as judgment sampling or targeted sampling, and only those who met the required characteristics were included in the data collection process. The questionnaire was distributed to G7 contractors in Kuala Lumpur. A survey questionnaire was used to achieve a broader coverage of the research and give the respondent more time to think about a proper answer for primary data. (Roslee, N.N et al, 2022)

The contractor company G7 in Kuala Lumpur, Malaysia was issued. 310 questionnaire was issues, However, only 108 respondents was collected. Thus, the response rate of these questionnaires is 83% where it is more than 20% of the population. According to Wu, M.J et al ,(2020) states that an average response rate by email is 40% to 50%. Most studies consider a 60% response rate to be acceptable.(Fincham,2008). It is supported according to Nulty (2008), Griffith University's online response rate is 20%. According to the table below, the respondent must exceed at least 20% of the sample, resulting in an 80 percent response rate to the questionnaire.

Table 1 Summary of the Respondent Rate

Description	Sample
Quantity of distributed questionnaires	310
Quantity of returned questionnaires	108
Percentage	35%

For this study, the first stage in the research process is to establish the issue statement, research aim, research objectives, and research question. This research uses both primary and secondary data. A literature review is conducted to investigate the research's relevant topic. Concerning the primary data, the questionnaire was carefully constructed to demonstrate its success in collecting the necessary information. Questionnaires were used for informative and empirical surveys to collect data, opinions, and perspectives. The questionnaire findings will be reviewed and summarised in order to achieve the study's aim. The data will be evaluated and summarised using SPSS software. The data analysis will be used to respond to the study's results. The

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conclusion and suggestions will be produced in the last phase based on the data analysis results and recommendations will be completed based on the results of the data analysis.

This paper used descriptive analysis to present the data and to get the finding. This type of analysis are specific methods basically used to calculate, describe, and summarize collected research data in a logical, meaningful, and efficient way. Descriptive statistics are reported numerically in the manuscript text and/or in its tables, or graphically in its figures (Vetter, 2017). The results for descriptive analysis which consist of frequency, average mean and analysis of ranking data are being calculated by using SPSS version 23.

All of the data results and findings were then discussed according to the aim and objectives of the research that has been set in the preliminary stage. (Zain, F. M. Y et al, 2023)

Respondent and State
This survey's respondents are G7 contractors who have already registered with CIDB. It is critical to recognise the CIDB registration in order to acquire legitimate responses and opinions on this topic. This procedure is followed in order to acquire reasonable and accurate information for the purposes of this study. G7 Contractors was picked to meet the specific needs and objectives of this issue. According to CIDB, G7 Contractor is the highest grade; this grade of contractor reportedly produces higher-quality products and has more expertise and resources. The reason of choosing Kuala Lumpur is because the state had the highest number of G7 Contractors, besides that, Kuala Lumpur can bee seen as most develop state in Malaysia with lot of construction projects.

State	Number of G7 Contractors
Johor	432
Kedah	163
Kelantan	98
Melaka	126
Negeri Sembilan	106
Pahang	126
Perlis	23
Perak	172
Pulau Pinang	378
Sabah	385
Sarawak	469
Selangor	1450
Terengganu	189
Wilayah Persekutuan	1563
Total	**5680**

Figure 1: Number of G7 Contractors by State
Source: Construction Industry Development Board (CIDB), 2022

Population
The sampling used in this study is stratified random sampling. This sampling technique is chosen because the data are categorized by state and more suitable to use stratified random sampling technique. The sample size is selected from the concept introduces by (Krejcie & Morgan, 1970). The researcher was used this technique to get the sample size from the total

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population. The list of G7 contractor company contains 1600 number of population and as shown in the figure 2 below, 310 of the questionnaire were distributed.

Table for Determining Sample Size from a Given Population

N	S	N	S	N	S
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368

Figure 2 : Sample Size Concept Introduces by Krejcie & Morgan, 1970

Analysis and Findings

The analysis on the challenges of 3D printing implementation consists of cost estimation, job opportunities and standard qualifications. Those challenges were distributed to 10 variables which analysed with frequency (F) and percentage (%) to know the level of agreement from the respondents.

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Table 2 Challenges of 3D Printing Implementation Towards Industry 4.0 in Kuala Lumpur

Variable	Agree		Strongly Agree	
	%	F	%	F
3D printing is a new technology, and it's hard to guess how much it will cost to build.	28.7%	31	71.3%	77
The 3D printing technology has a high initial price	29.6%	32	70.4%	76
large-scale printers are costly and require regular maintenance, which increases the price.	30.6%	33	69.4%	75
The 3D printing process involves specialized equipment that consumes more energy and costs more than conventional methods	29.6%	32	70.4%	76
Using 3D printing to construct a structure can reduce the need and cost for the general labor required.	28.7%	31	71.3%	77
3D printing will minimize job opportunities for some individuals in the construction industry.	28.7%	31	71.3%	77
large-scale printers are High-skilled procedures causing 3D printing construction to require highly skilled labor.	28.7%	31	71.3%	77
3D printing in concrete buildings is new. Therefore, requirements and guidelines still need to be provided.	30.6%	33	69.4%	75
The guidelines for design and construction are inadequate.	28.7%	31	71.3%	77
Lack of specifications, the shape and size of printed objects due to lack project experiences.	30.6%	33	69.4%	75

The aims for this research was achieved which is the critical challenges of 3D printing implementation can be identified by the respondent agree. As for the variable, the theme that can be conclude is about cost estimation, and majority of respondents strongly agree that 3D printing is a new technology, Costs are an essential consideration in various aspects of life, including business, economics, personal finance, and decision-making. Understanding costs helps individuals and organizations make informed choices, allocate resources efficiently, and evaluate the benefits and drawbacks of different options. Guamán-Rivera et al. (2022) indicated that the costs of materials and machinery were greater for the 3D Printing Construction. Different types of costs include fixed costs, variable costs, direct costs, indirect costs, and more, depending on the context in which they are used. and in considering this is new technology the cost is too expensive based on its need such as machinery, equipment, skill labour, training and etc which is supported by Goh et al., (2021) it is difficult to predict the building costs with the requisite precision. The project need to be cost-effective. A cost-effective is starting from the development of the project, then minimum operating and maintenance cost, has longest life span, inspires users to be productive and offers the greatest return on investment. (Saidin, M. Mohammad et al, 2020).

Besides that, the second element of challenges is job opportunities, most of respondents agree that implementation of 3D printing can reduce the job opportunities. This issue by Olsson et al., (2019) using a 3D printer to construct a structure reduces the labor required. Technology

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infiltrates building tasks that humans traditionally perform. It can be advantageous in terms of labor costs, but this new technology will minimize employment chances for several individuals in the construction business. However, the respondent also agree on Using 3D printing to construct a structure can reduce the need and cost for the general labor required as mentioned in the table 2. It's important to note that while 3D printing has clear advantages in terms of reducing labor costs in construction, it may not completely replace the need for skilled labor. Skilled workers are still required for tasks such as site preparation, equipment setup, quality control, and finishing touches. Additionally, not all types of structures are suitable for 3D printing, and traditional construction methods will continue to be essential for many projects. This can be supported in researched by Hutson, M (2023) no one is yet suggesting that Artificial intelligence can completely replace humans, the human touch is still needed.

Next challenges are about guidelines and experience, most all of the respondent strongly agree and agree on the inadequacy of guideline and specification. Demirkesen, S and Tezel, A. (2022) agreed that due to the complicated and ever-changing nature of projects, the construction sector is struggling to find qualified workers in the I4.0 era. Guidelines are intended to help individuals or organizations make informed decisions and take appropriate actions while maintaining consistency and adherence to established standards. From the data in the table 2, the author also able to state that, most of contractor still not ready to implement the 3D printing construction as the respondents highlighted on lack of experience and knowledge. 3D printing lacks universally accepted guidelines and standards, making it difficult to ensure consistency and quality across different printing technologies and materials. The absence of comprehensive industry standards can create confusion and hinder the adoption of 3D printing in various sectors. Eventhough guideline can be set up, all the knowledge can be learn, the contractor still need to have practical experience in the field as mentioned in Malik et al. (2022) those who possess knowledge do not also have relevant practical experience.

Conclusion

In conclusion, implementing 3D printing technology can be an exciting prospect, but it comes with several challenges that organizations and individuals may face. while 3D printing offers tremendous potential for innovation and customization, it is not without its challenges. The successful implementation of 3D printing depends on careful consideration of these challenges, investment in equipment and training, and a clear understanding of how 3D printing fits into the broader goals and needs of the organization or individual. As technology advances and these challenges are addressed, the adoption of 3D printing is likely to continue growing across various industries.

Addressing these challenges often requires collaboration between industry professionals, regulatory bodies, educational institutions, and research organizations to develop and disseminate comprehensive guidelines and provide accessible training and education opportunities. As the 3D printing industry matures, it is likely that many of these challenges will be met with improved resources and knowledge-sharing within the community.

Hence, collaboration between the government sector and the private sector in the field of 3D printing can yield numerous benefits and accelerate the adoption and development of this technology. Collaboration between the government and private sector is essential for creating an ecosystem that promotes innovation, economic growth, and the responsible adoption of 3D printing technology. Such partnerships can help address the challenges, bridge knowledge gaps,

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and create a supportive environment for the advancement of 3D printing in various industries and applications.

As a recommendation for future research in the field of 3D printing can be based on current challenges, emerging trends, and areas of potential impact. The research can be explore the adoption and impact of 3D printing in different regions and countries, taking into account cultural, economic, and regulatory factors..

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