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Construction 3D Printing Concrete within Indonesia and Malaysia of the Sustainable Future Houses: Environmental Aspect

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Abstract

Global construction industry for construction 3D printing(3DP) is a novel technique that has started since 3DP innovation in 1981 while still, this technique has undergone a challenge in Indonesia and Malaysia's construction industry. Applying 3DP in the construction industry has given various benefits more than the conventional construction way. The most witnessed challenges in this technology are printing material, print equipment, stakeholders, and suppliers. Moreover, the absence of standard codes and policies, structural solidity, and extensibility have been over and over referred to as the most critical issues facing the designers. This research introduces the qualitative analysis based on a questionnaire to evaluate the environmental aspects and then analyze it by applying the strategic planning technique SWOT matrix to help identify strengths, weaknesses, opportunities, and threats related to this aspect. This research attempted to investigate the environmental aspects of Construction by 3D Printing (C3DP) will be the trending technology in the next 10 years. The research also offers some future research ideas, insights, and recommendations.

Keywords: 3D printing; Sustainable Construction; Construction Technology; Green Building; Smart construction.

1. Introduction

Considering one of the global megatrends shaking up the construction industry has started to change and move from the traditional method to the modern method such as pre-cut, panelized, modular, 3DP, and mobile home building system to face the increasing number of people. But before looking to the future, it would be useful to have a glimpse into the past. One hundred years ago, the world population was around two quarter billion people on the planet.

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The globe's population is still growing, albeit at a slower rate than at any other time since 1950. The global population in 2022 is estimated to be 7.9 billion people, with estimates of 8.5 billion and 9.7 billion in 2030 and 2050, respectively [1]. Figure 1 is shown, the estimates of the population worldwide between 1950 and 2050. The growth rate of the world's population could impact on construction sector which is one of the most important sectors worldwide. The construction sector represents an important part of the employment rate. The population in Indonesia and Malaysia are relatively young, and about 43% and 15% are living in rural areas, respectively [2]. In terms of scale and share, the construction market causes significantly in the development process for both countries. The Constructions are not only valuable for the final product, but it also utilizes a large number of people, therefore it influences the environmental and economic of the countries for the duration of construction time [3].

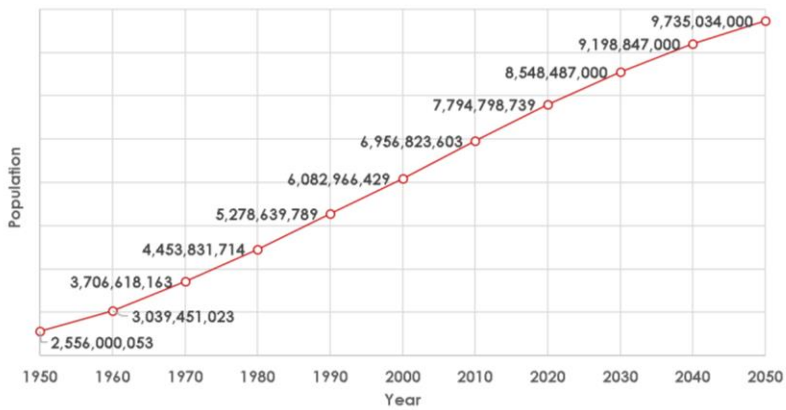

Figure 1: World Population Prospects [1]

Construction 3D printing (C3DP) could be a useful solution to keep resources and enhance the quality of residential buildings. As the construction skill continues to revelation, 3DP technology would be used to build everything from prototypes and simple products to highly technical complex products [4]. The beginning step for any 3DP procedure is a 3D digital model, which could be designed via 3D commercial programs. The digital model should be 'sliced' into 2D layers, in that way changing the digital model into a file understandable via the 3D printer device. 3DP is an automated additive manufacturing (AM) method of fabricating 3D items from computer-aided design models; the 3D printed material processed by layered according to layout. There are several different sorts of 3DP technologies, which process various materials in different ways to build the final object [5]. The advantage in 3DP for building and construction have risen significantly over the last few years. Though the increases of concern have improved the literature in this field, it introduces objections for investigators to obtain an outline of the study improvement [6].

C3DP, when compared to traditional house-building techniques, may be regarded as an environmentally friendly derivative that provides nearly limitless possibilities for geometric complexity realizations. C3DP is not only a varied set of technologies, however, but it is also a social phenomenon operating within the political imaginary. Many of the studies done to understand how C3DP could provide more sustainable development are based on three cases: opportunities to improve resource efficiency, life cycle beyond technical methods, and complexity, and bringing production closer to the consumer, which may be successful in changing the sustainable construction in the coming years. Figure 2 is shown, a mapping of countries has been used C3DP that to understand the marketing trend. Figure 2 provides an overview of areas that have houses built by using 3DP technologies as well as Indonesia and Malaysia were not one of these countries using C3DP in future house projects. C3DP could modify its settings to conform to the speed rate, amount, and kind of printing material being consumed in printing a three-room house [6].

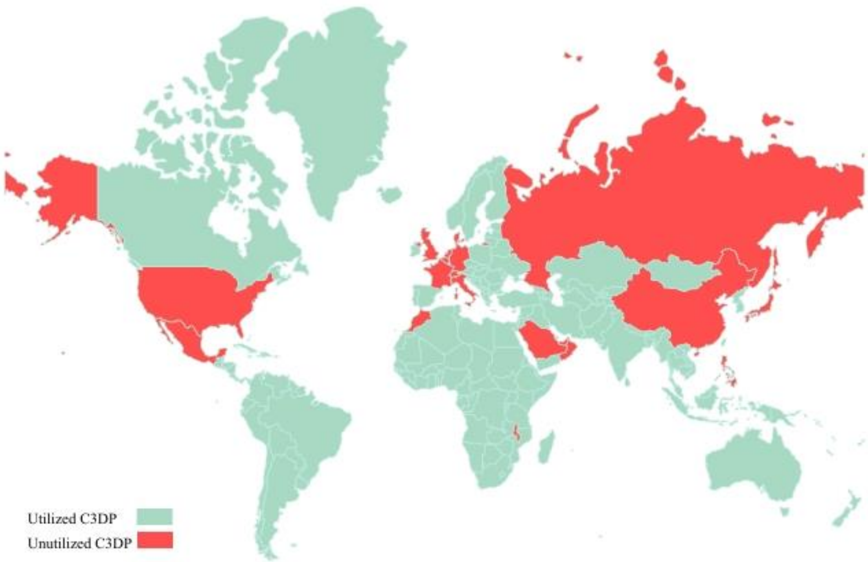

Figure 2: the World Map Showing the Globally Construction 3D Printing until 2022 (Source: made by Authors)

Several benefits of C3DP techniques, for instance reducing time and cost savings, decreasing the contamination of ecosystem and reduction of damages and accidents on construction sites might be refer to death. The C3DP has been operated by two persons and is the speediest construction techniques [7]. Several benefits of C3DP techniques, for instance, reducing time and cost savings, decreasing the contamination of the ecosystem, and reduction of damages and accidents on construction sites might be referred to death. The C3DP has been operated by two persons and is the speediest construction techniques [8]. Moreover, C3DP will also involve people with special skills attached to this new equipment but at the same instant, it would be creating a new chance for example a new Engineering and management education system and establishing a new manufacturing industry [9]. Figure 3 is illustrated the difference between Management systems for Construction 3D Printing Techniques and Traditional Construction Techniques. The diagram obtained a simpler description of the possible progress of the building system owing to the obtaining of C3DP techniques. On more transitory, it is predictable a fractional functionality of C3DP in the construction industry specializing in residential houses. During the planning phase, the planning experience has been established in a central software permitting the designer/engineer to apply this familiarity to propose the structure. A C3DP Programmer manages control of the on-3D printing during the construction phase, contributing modeling knowledge to the process. Therefore, the issue of on-site traditional construction responsibilities reduces, and the construction laborers purposed for them[10].

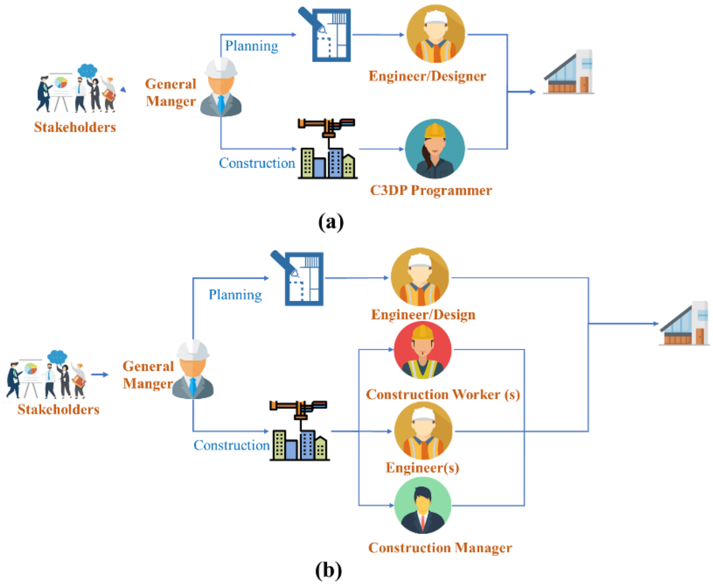

Figure 3: the Organizational System: (a) Construction 3D Printing and (b) Traditional Construction Way [11]

In conclusion of this section, the paper is organized into four other sections and section number three has five subsections. The first subsection is Artificial Intelligence in Construction (ALC). The second subsection describes 3D printer equipment. Also, it illustrates, how these parts have worked together to deliver the final product. The third subsection illustrates the 3D printer Material that could help the engineers to enhance the strength of this technology. The fourth subsection presents the stakeholders and suppliers as well as how could be effective in this construction system. The fifth subsection includes the regulations for the 3D printing house of this research and the final subsection is given an overall environmental aspect. Meanwhile, the third section is providing the research method used in this paper while the last two sections are included the questionnaire result and dissection, and the conclusions of this research. The fundamental objective of this paper might be used as guidelines for reaching a low-finances and safe design for the sustainable future houses by Construction 3D Printing Concrete within Indonesia and Malaysia and to lead to further research in this area. In brief, the research explains the behavior and environmental aspect of Construction by 3D Printing in a complete way and information on the main research into growing the critical layout suggestions for future houses.

2. Literature review

This section is including review of Construction 3D Printing and sustainability in housing projects for the construction industry as well as comparative research comparing Construction 3D printing and conventional techniques of concrete houses within Indonesia and Malaysia as following this sequence:

2.1. Artificial Intelligence in Construction

The study of how to make computers do things better is known as artificial intelligence (AI). The definition of Artificial Intelligence according to Russel and Norvig [12] can be categorized into two main dimensions that discuss thought thinking/reasoning (Reasoning) and behavior/actions (Behavior). Furthermore, the definition of Artificial Intelligence can be further elaborated based on performance and rationality. The four points of view form the definition matrix of Artificial Intelligence, shown in Figure 4.

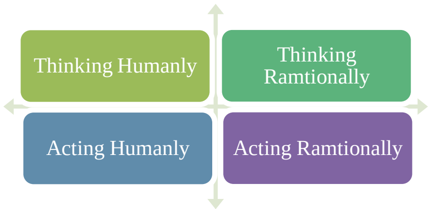

Figure 4: Artificial Intelligence Matrix

One branch of AI that is growing fast and has been implemented into a number of applicable technologies in various industries is Machine Learning (ML) and Deep Learning (DL). Samuel [13] might be the first to give the definition of ML as a branch of Artificial Intelligence that studies the method of designing algorithms that are able to "learn" from data without being explicitly programmed. DL is the disciplines of ML which applies artificial neural networks to fulfill problems with enormous data sets [14]

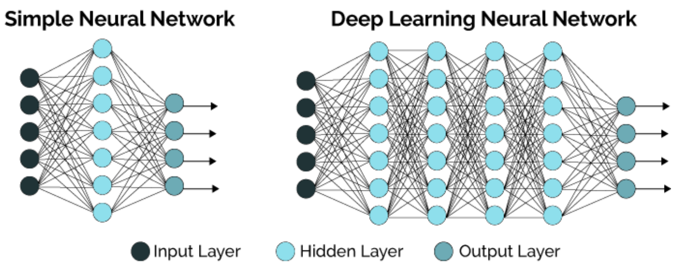

Figure 5: Simple Neural Networks and Deep learning Neural Networks [15]

Simple Neural Networks is a structure consisting of ML algorithms in which artificial neurons serve as the core computational unit, focusing on uncovering underlying patterns as well as connections within a dataset, much like the human brain does when making decisions DL Neural Networks is a division of ML that uses a series of nonlinear processing units with layers and layers for simple modification and extraction. The ML process is carried out by several layers of AL networks. The neural network's first layer processes raw data input and forwards it to the second layer [16].

Observation of the machinery's operation in 3D Printing has been essential for identifying its weaknesses in it. Therefore, the addition of a sensor device gives a prospect for predicting the flawlessness through data analytics. Data analytics with AI systems had applied to the sensors data for predicting the shortcoming in machinery [17]. Forecasting the weaknesses at an instant time prevents the humiliation of 3D Printing with minimum cost. A combination of AI with 3DP will be providing above-average capability in the future for the replacement of traditional production. Nevertheless, a massive investigation has been necessary for overcoming the challenges; specifically, 3D Printing techniques steps control, 3D Printing techniques augmented configuration, and 3D printer systems. In 3D printers, developing the 3D printer log on to the cloud platform is an area open to further research.

2.2. 3D printer Methods

3DP is a programmed, additive manufacturing method for generating 3D objects from a digital prototype. The 3D prototype is sliced into 2D layers, which are then laid down by a laser copier to create a 3D model. [18].The phrase "additive manufacturing" (AM) is normally defined as: "the procedure of joining materials to create items from 3D model data, normally layer upon layer" [19]. AM could produce elements with complex and intricate structures, constructed from customized components with near-zero production waste, and relevant to a wide range of materials. [20]. Geographic locations and governmental (including local council) regulations also influence the quantity and type of material required: because Indonesia and Malaysia are such large countries, different areas face different challenges, such as seismic activity, the atmosphere, floods, or fires. But before you even get to the material, you'll need software that can share information with the 3D Printer [21]. The steps created in 3D printer objective development using rapid prototyping are shown in Figure 6.

The 3D printer starts with a model in CAD model and then it is changed to a STL file type in which the sections are "cut in slices" including the information for each layer. The texture of each layer as well as the dimension depend on the equipment applied. 3D printer is created to anchor the piece and supporting the overhanging structures [26]. Then the UV laser is employed to the increasing the hardening in a specific location of each layer. Once the layer is completed finish the 3D printer is reduced and completely when the steps is done the extra material is drained and could be reused [27]. The following section provides an overview of (commercial) 3D printing methods as well as a brief introduction to 3D printing:

2.2.1. Contour Crafting (CC)

CC is the first additive technology established for in-situ manufacture of custom-designed structures. CC is using cementitious materials as well as CC is a 3D printing methodology for automating the construction of full, partial, and component structures in a single run with different designs and architectural scales [22].

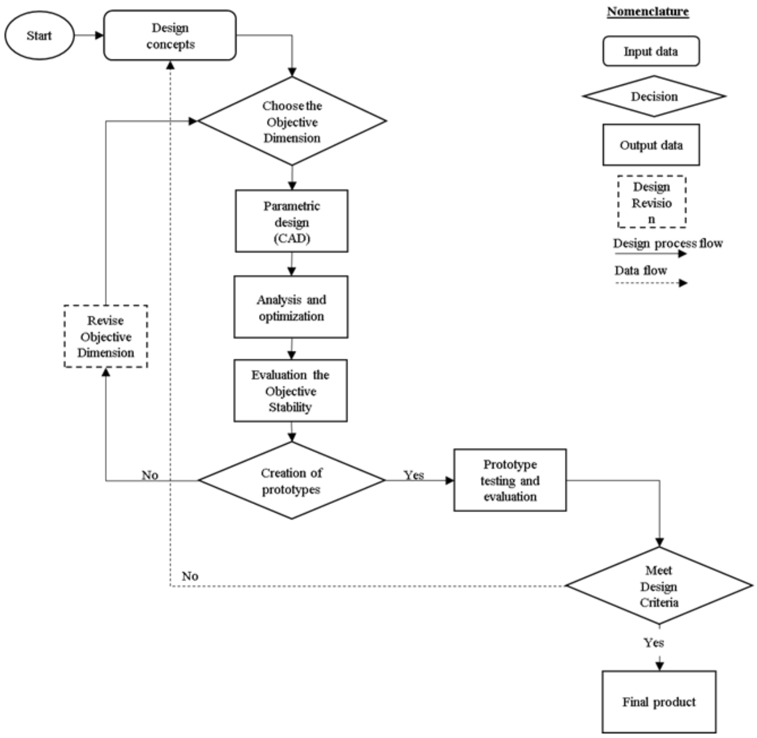

Figure 6: Flowchart 3D printer equipment Product development [22–25]

2.2.2. D-Shape (DS)

D-Shape invokes 3D objects using various materials such as stone chips mixed with chemical adhesives and sand powders. In this method, powders connection the process, which is then followed by a mixture of adhesives and hardeners sprayed over as a binding product, which is similar to the 3D printing process [28]. Once the surface has been created with the appropriate size, the installer operation should begin with the jet nozzles supported by the robotic crane system applying the binder to guarantee the structure's safety to transform out solid. Once a portion of a construction or the entire construction has been sanded, the plowing act shall remove any discarded materials on the completed structure [21].

2.2.3. Selective Paste Intrusion (SPI)

SPI is an Additive Manufacturing technology (AM) that uses particle beds, that disperses the material parts in tiny layers and locally bonds them with cement paste. It has hold myriad of features one of them this method in contrast with other AM operations is that no support structures for cantilevers are needed [29].

2.2.4. Selective Binder (cement) Activation (SBA)

SBA is method using layer by layer, the method of selective cement activation. The solid was created by layering dry particles (cement and aggregate) that were locally bonded by an aqueous binder. [30].

2.2.5. Concrete Printing (CP)

CP is a kind of additive manufacturing utilized to fabricate buildings or construction components in new brand shapes not previously potential with traditional concrete formwork [20]. CC and CP are utilizing cementitious resources

2.3. 3D printer Material

3D printer materials have to be thixotropic to guarantee the buildability, pumpability, injectability and extrudability in the allowed time [31]. Thixotropy is as indication of the proficiency to viscosity improvement and represent the rheology after and before extrusion. High properties of cement-based materials have been inconvenient in rheological and solidify properties, consequently had been not thixotropic in nature [10].

Additionally, the unique situation of 3D printer Materials that must consume a self-compacting ability and zero slumps are resisting but must be presented at the same time for 3D printing use [23]. Serval studies related on slump rate from 4 to 8 mm and slump flow between 15 between 20 cm with printable concrete mixture show soft surface after layering and show up good quality constructability. However, the slump amount could optimize in conjunction with other factors such as yield stress and viscosity throughout materials. The high yield stress has been a free slump for materials design directly after accumulation; hence, the layer does not deform [32]. In contrast, the quick reinforcing mixtures has suggested for rapid construction [33]. Election of printing supplies of the highest quality depends on printer types, printing techniques, type of printing and construction size. The determined size of materials based on the printer pumping capacity and nozzle's size.

Materials employed in 3D concrete printing establish great functioning and are coarse-aggregate concert, fiber-reinforced, that is thought superior to the mixture applied in contour crafting in conditions of stability [34]. Moreover, in CC method only mortar or fine-aggregate concrete be able to apply, but the materials should have an extraordinary optimum of powdered supplies, viscosity-modifying admixtures, and inorganic additives (silica fume, fly-ash) [35, 36].

The dry materials of 3D printing include Calcium Sulphoaluminate Cement (CSA) cement and silica sand, which are physically loaded and blended into the powder print bed. Several works have been examined numerous types of fine aggregates that could be consistently distributed by the printer's spreading mechanism. The 3D printers employed a roller bar to consistently spread out the 3D printing material, without compaction, and is sensitive to specific shape and size. Angular or large aggregates might be result in disfigurement within the powder bed prior to binder application [25, 30, 37].

2.4. Regulatory for 3D printing house

Regulatory for construction by 3DP still have been missing for the reason that technology, especially in concrete structure, is fairly recent novel. Additionally, construction and design regulations are insufficient. Due to a lack of specifications, the size and shape of printed elements are still determined by the available printer properties and material properties [38]. American Society for Testing and Materials (ASTM) committee and ISO members have been working on developing specific standards for additive manufacturing (AM) [19]. However, the guidelines and standards for construction by 3D printing and printable objectives had seriously absent. Some standards and guidelines are expected to innovate the 3D printing technology of concrete buildings [39]. Guidelines for testing printed specimens and printing materials in various boundary conditions and forcing with changing exposure conditions must be comprehensive by a specified regulation and codes [40]. Recent standards for the choice of acceptable printed layers, printing period, materials, preprocessing, and process must be itemized to develop the building sustainability [41].

Meanwhile, the Reinforced Cement Concrete (RCC) system in 3D printing buildings should also be regulated. Like as traditional RCC building parts, each fundamental elements have to printed though maintaining the standards for decide on mechanical characteristics, size and shape in the model. The most important challenges participating in construction by 3D printing of concrete materials are presented in next section with the general techniques required to enhance the risk associated with Strengths, Weakness, Opportunities and Threats.

After researching construction using 3D printing of concrete materials, the main challenges would be illustrated in last section that could be adopted by enacting measures involving the exclusion or inclusion of definite requirements, but optimization could be pointedly develop the sustainability and performance of in construction by 3D printing of concrete.

2.5. Environmental Aspects

For decades, the construction industry has been one of the world's top producers of waste. The construction industry's consumption sources account for 40% of all raw materials consumed worldwide [42]. Furthermore, it calculated the waste materials produced to build a single residential home from three to seven tons which are causing the construction industry to have less potential and become a source of hazardous emissions all over the world [42, 43]. Using additive manufacturing techniques Construction machines with C3DP reduce unwanted carbon emissions by reducing the number of transport movements in and to the construction site, saving a significant amount of fuel. Decreasing number of human resources reduce the number of vehicles [10,44] .The use of pre-designed data makes construction more accurate and reduces the occurrence of abortive works. Effective cost Using built-in moulds to save formwork. C3DP construction enables printers to pour only what is required. Control the designers to work within the budget. Finally, large-scale C3DP innovations include construction containment and provisions, which significantly reduce waste when doing builders' work [45]. In concept, C3DP strategy construction creates homogeneous formalized buildings without complicated interfaces during execution, significantly less error to avoid cost reworks, and it can protect the environment from waste sources. Diverse researches have investigated the environmental effects of 3D printing processes. Such as, [45], [46] Life Cycle Assessment (LCA) comparisons of additive manufacturing and conventional manufacturing that are well-done both studies concluded that the energy consumption of additive manufacturing has a negative impact on the environment.

3. Research Method

The fundamental research would be comparative research comparing Construction 3D printing vs conventional techniques of concrete houses. The approach selected to answer this matter will be case studies research which to prove or disapprove of 3D printed concrete in the construction industry could be useful techniques for future houses. A detailed literature review was done to analyze current state-of-art in 3D printing context.

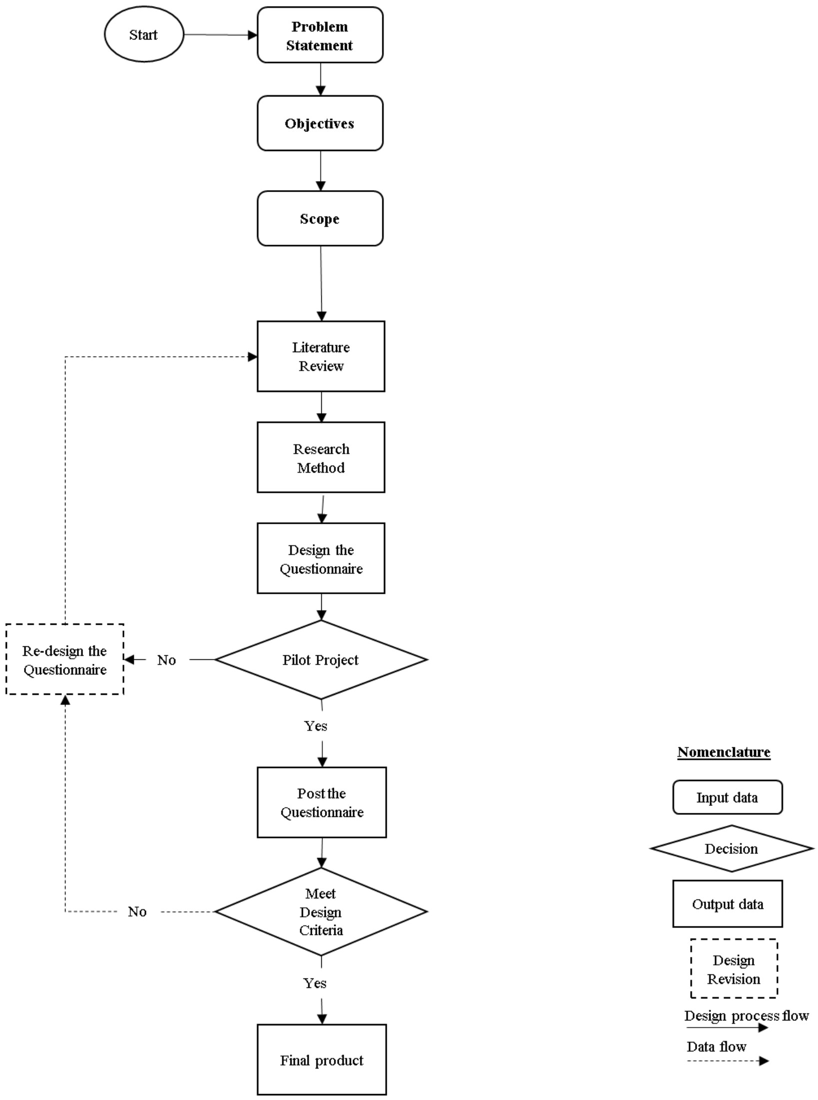

Figure 7: Research Methodology

4. Result and discussion

The number of respondents was 62 responses. Figure 8 is shown, 34% of the respondents were based in the Malaysia while 66% of the respondents were from Indonesia. No surprises here; the predominance of Indonesia is to be expected and is likely emphasized by the bias formed by the distribution of the call to the survey. Construction 3D printing is a method for manufacturing construction elements or entire buildings by means of a 3D printer printing concrete, it has a lot of benefits of using 3D Printing in construction. Figure 9 (a) is shown that the respondents heard about construction 3D Printing. A questionnaire was shown twine four percentage they never hear about construction by 3D printing while 76% of the total respondents to the questionnaire survey were heard about construction 3D Printing. Figure 9 (b) is shown, the question seeks to ascertain if respondents currently know the benefits of using 3D Printing in construction. According to the answers, (50%) No, while (50%) yes leads to an equal percentage about this phenomenon. The respondents clearly identify more with hear about construction by 3D printing that with fifty percentage responses are answered “No” to knowing the benefits of using 3D Printing in construction question.

However, such a trend and its importance is still a matter of speculation. In any case, in terms of benefits, in terms of the level of awareness, the 3D printing community is situated between typical software and typical hardware communities.

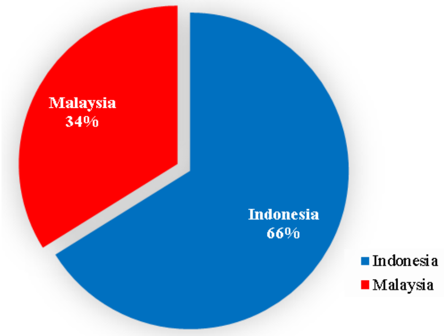

Figure 8: Distribution of respondents by country

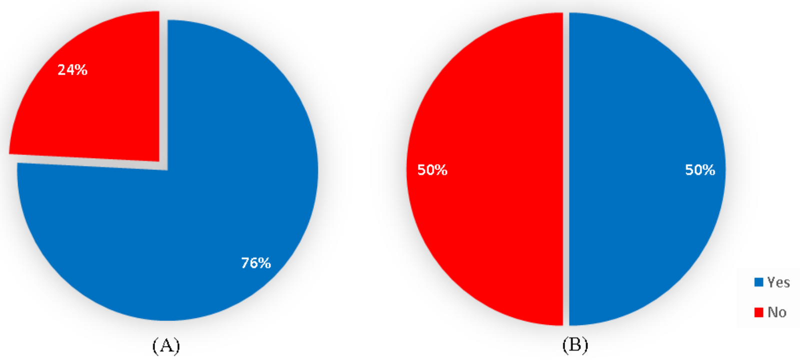

Figure 9 : (A) Distribution of respondents heard about construction 3D Printing and (B) Respondent's answer for ‘Do you currently know the benefits of using 3D Printing in construction

No surprises here; the predominance of respondents is House buyer and is likely emphasized by the bias formed by the distribution of the call to the questionnaire. As shown in Figure 10, distribution of respondents by occupation are 19 belonged to House buyer, 16 respondents from engineering student (Architect, Civil, Structure, Construction and Material), 7 Engineer (Architect, Civil, Structure, Construction and Material), 1 from Property developer company, 2 from Contractor and Consulting companies, 5 from university lecturers and Other 12 respondents were from Other Construction and Financial field.

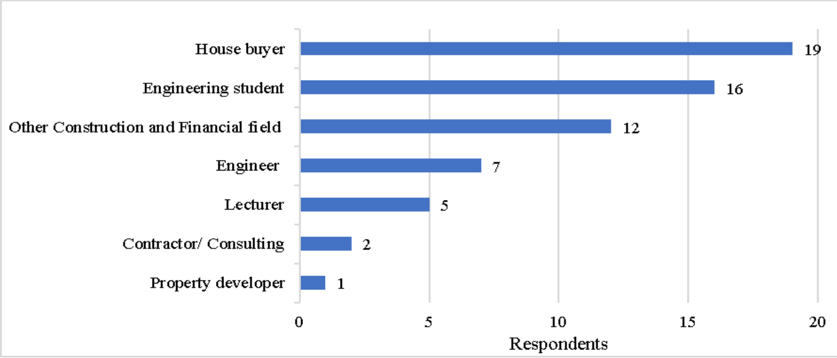

Figure 10: Distribution of respondents by Occupation

The participants were asked: "How long have you known about construction by 3D printing.?" Again, question contained predefined options: Less than 5 years, more than 5 years and First time I hear about it. Figure 11 is presented, 42 respondents have of knowledge about construction by 3D printing for less than 5 years (67.74%), 3 respondents have known about this technology in construction for more than 5 years (4.88 %), and 17 respondents are First time I heard about it (27.38 %).

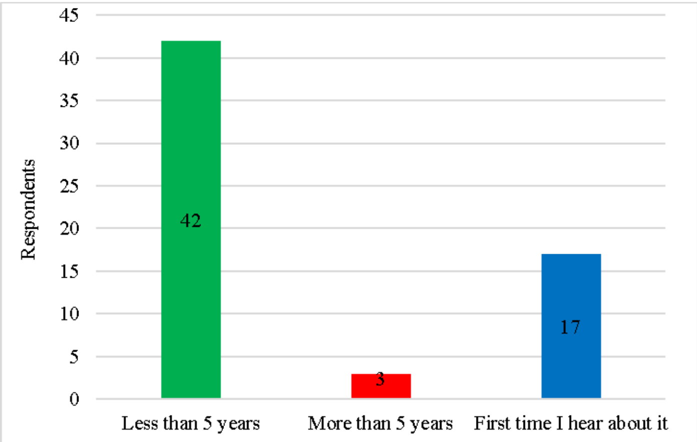

Figure 11: Respondent's period of knowledge about construction by 3D printing

Table 1 measure the strengths, weaknesses, opportunities, and threats according to environmental aspects. The top strengths measurement items according to 53.23 % respondents are concerned to improve productivity, stakeholder satisfaction, and improved performance in housing deliver on environmental aspects.

The participants of weaknesses of environmental aspects were asked "How do you respond to risks Environmental?" Again, question contained predefined options highly aware, very aware, moderately aware, slightly aware, and highly unaware. 48.39% respondents are very aware and 1.61 % are slightly aware while zero respondents are highly unaware.

On other hand, 45.24 % respondents of opportunities of environmental aspect are highly aware to reduce pollution from the construction project on environmental aspects, and 1.61% of respondents are highly unaware

Reduce CO2 emission, while Survey participants on were asked “Use locally available materials for by-products” and again they were given a predefined option set very important, important, moderately important, slightly important, and not important. Very important of respondents was high, with 50% respondents of threats section. SPSS is used to find the mean and Standard deviation while Level is based on the high value of mean and Standard deviation could be calculated in Equation (1):

Where σ is population standard deviation, N is the size of the population, x_i is each value from the population, and μ is the population mean.

Looking from an overall perspective, it is readily apparent that the respondents of 3D printing services has spread among multiple industry area. Interesting questions are selecting on environmental aspects. The majority of people involved is concerned and worried about the environmental aspect.

Following a detailed analysis of the data, the significance of each input factor linked with each factor in the environmental aspect of the SWOT Matrix of 3D printing technology for housing projects could be measured and compared. Table 2 and 3 illustrated the Questions of Questionnaire related to this environmental aspect as well as the pros and cons, at the end give a Critical comment.

Meanwhile, investigate the awareness of environmental aspects of the 3D printing technology for housing projects by post a questionnaire and using SWOT analysis about this technology have been done with the total respondents 62 responses.

In the meantime, when compared to other traditional manufacturing machines, 3D printers are still relatively expensive. 3D printers can range in price from $10,000 to $100,000 or more, depending on the size of the machine, its functionality, and the raw materials used. [28,47,48]. When purchasing 3D printers, there may be lengthy lead times, because many must have been custom-made to address the requirements of each producer. The running the machine may also be higher than that of traditional machinery, as 3D printers consume more energy than traditional industrial equipment.

Table 1: Response analysis

Questions		Likert scale					Mean	Std. Deviation	Level
The Strengths of Environmental Aspects									
		Very Important	Important	Moderately Important	Slightly Important	Not Important			
SE1: Suitability of printing conventional design elements:	N	28	30	3	1	0	4.3710	0.6587	1
	%	45.16	48.39	4.84	1.61	0.00			
SE2: To improve productivity, stakeholder satisfaction, and improved performance in housing delivery:	N	33	20	8	1	0	4.3710	0.7732	1
	%	53.23	32.26	12.90	1.61	0.00			
SE3 A possible option to reduce resource and energy consumption	N	30	24	6	2	0	4.3226	0.7846	3
	%	48.39	38.71	9.68	3.23	0.00			
		Strongly Agree	Agree	Undecided	Disagree	Strongly disagree			
SE4: The fast-building leads to growth and fixes the housing problem.	N	28	25	8	1	0	4.2903	0.7550	5
	%	45.16	40.32	12.90	1.61	0.00			
		Highly aware	Very aware	Moderately aware	Slightly aware	Highly unaware			
SE5: Good work environment	N	29	24	9	0	0	4.3226	0.7192	3
	%	46.77	38.71	14.52	0.00	0.00			
The Weaknesses of Environmental Aspects									
		Highly aware	Very aware	Moderately aware	Slightly aware	Highly unaware			
WE1: How do you respond to risks Environmental?	N	24	30	7	1	0	4.2419	0.7171	1
	%	38.71	48.39	11.29	1.61	0.00			
		Very Important	Important	Moderately Important	Slightly Important	Not Important			
WE2: Suitability of 3D printing with conventional design elements	N	20	30	10	2	0	4.0968	0.7832	2
	%	32.26	48.39	16.13	3.23	0.00			
WE3: Create dome-shape structures.	N	20	28	12	1	1	4.0484	0.8575	3
	%	32.26	45.16	19.35	1.61	1.61			
		Strongly Agree	Agree	Undecided	Disagree	Strongly disagree			
WE4: Printing process response to environmental	N	16	28	15	3	0	3.9194	0.8357	4
	%	25.81	45.16	24.19	4.84	0.00			
The Opportunities of Environmental Aspects									
		Highly aware	Very aware	Moderately aware	Slightly aware	Highly unaware			
OE1: Reduce pollution from the construction project	N	34	18	8	1	1	4.3387	0.8860	1
	%	54.84	29.03	12.90	1.61	1.61			
OE2: Reduce CO2 emission	N	34	17	7	3	1	4.2903	0.9647	2
	%	54.84	27.42	11.29	4.84	1.61			
		Very Important	Important	Moderately Important	Slightly Important	Not Important			
OE3: Reduce product quality problems	N	29	23	8	2	0	4.2742	0.8132	3
	%	46.77	37.10	12.90	3.23	0.00			

The cost of materials is generally the largest cost component of 3D printing. The current state of 3D printing technology limits the types of materials that can be used to only certain types of plastics and metals. The resources used throughout 3D printing have been frequently more costly than the one used in conventional manufacturing techniques. Additionally, many current 3D printers are still fairly slow when compared to other manufacturing processes. This restricts the ability of 3D printing to compete in the mass-production space.

Several benefits of C3DP techniques, for instance reducing time and cost savings, decreasing the contamination of ecosystem and reduction of damages and accidents on construction sites might be refer to death. In determining the measures for awareness C3DO Sustainable Future Houses, the respondents' measures identified from the review of literature. The significant difference between the different professionals was tested. (See Table 2 and Table 3)

Meanwhile, C3DP is adjusting the world of construction production. Environmental research on C3DP could pave the way for a much larger evolution in the construction industry [24,49,50] . Construction industry has taken several efforts to adopt C3DP technology. But despite being a great promise, its current usefulness is still limited [51–53]. Aside from economic factors, there are several social, market, and business factors of 3DP adoption that influence the extent and rate of adoption. The need to address these aspects and identify the factors influencing the success/failure of construction 3DP projects as the first step toward pursuing technology implementation prompted this research.

5. Conclusion

Construction industry has taken several efforts to adopt C3DP technology. But despite being a great promise, its current usefulness is still limited. Apart from economic reasons, there are several social, market and business aspects of the technology which affect the extent and rate of 3DP adoption. The goal of the C3DP technology is to foster the development of new technologies necessary to additively manufacture a habitat using local indigenous materials with, or without, recyclable materials. In an attempt to present an understanding of the possible possibility of C3DP in of the Sustainable Future Houses in Indonesia, and Malaysia, this research concluded to address three primary outcomes:

1. 3D printing has the potential to revolutionize the construction industry. 3D printing, along with advances in industry, has a high potential to lead to a more efficient and sustainable construction.
2. The limitations of the 3D printer technology, the quality of the final product, and the complexity of the construction process are the main reasons for the low adoption rate of 3D printing in constructio
3. Given concern for this topic and education the audience and public because 3D printing will definitely be part of the future of the construction industry such as public lecture and visit the big company in construction industry to provide and spread information related in this technology to achieve the purpose and founding this technology in Indonesian construction industry.

Table 2: The Strengths, and Weaknesses analysis of questionnaire responses

The Strengths of Environmental Aspects			The Weaknesses of Environmental Aspects		
Pros	**Cons**	**Critical comment**	**Pros**	**Cons**	**Critical comment**
SE1: Suitability of printing conventional design elements:			**WE1: How do you respond to risks Environmental?**		
C3DP allows for the design and print of more complex designs than traditional manufacturing processes. More traditional processes have design restrictions which no longer apply with the use of 3D printing.	Difficult to use this technology underground because the lateral load for soil as well as dead load and live load for building	C3DP is a procedure used to create 3D objects in which consecutive layers of a material are computer-controlled and produced. When using this technology for high raises building could face problem during used in foundation part	The environmental costs of assembling, transporting, logistics, maintaining, storing are completely or nearly eliminated.	Another negative impact of 3D printing comes directly from the printer itself. Studies have found that little bits of plastic and some volatile organic compounds end up in the air when printing and breathing these in isn't a good idea.	First, better identify, assess, and control risks that could impact air, land, water, and groundwater, as well as harm caused by noise. Then, prevent harm to human health and the environment. Finally, meet community expectations.
SE2: To improve productivity, stakeholder satisfaction, and improved performance in housing delivery:			**WE2: Suitability of 3D printing with conventional design elements**		
C3DP has the potential to outperform conventional construction due to its ability to improved productivity, performance, and stakeholder satisfaction	There are no regulations or processes to get 3D printed buildings approved for residential or commercial use. The government would first need to come up with standards that must be followed as far as electrical, plumbing, structural integrity and public safety codes.	These benefits, 3D printed construction is capable of greater strength than its conventionally cast counterparts and, thanks to the elimination of formwork, can be used in more complex structural applications	C3DP allows for the design and print of more complex designs than traditional manufacturing processes. More traditional processes have design restrictions which no longer apply with the use of 3D printing.	Difficult to use this technology underground because the lateral load for soil as well as dead load and live load for building	C3DP is a procedure used to create 3D objects in which consecutive layers of a material are computer-controlled and produced. When using this technology for high raises building could face problem during used in foundation part
SE3: A possible option to reduce resource and energy consumption			**WE3: Create dome-shape structures.**		
The traditional construction method outcome in above average energy consumption in terms of biomass/waste, non-fossil fuels and coal.	In the literature C3DP, researchers are focusing on the structural performance of the 3D printed products while other sides are not more concerned about it such as the thermal comfort of the inhabitants of the 3D printed buildings.	C3DP printing has emerged as a potential solution to reduce the energy demands, water wastage and carbon emissions. Anecdotally, these technologies proved to reduce production time, minimize wastage, and reduce labor costs significantly.	C3FP could be used to create complex, intricate designs that would otherwise not be possible with traditional manufacturing methods. This capability is particularly beneficial when creating customized functional parts.	Dome is curved structures that it has no angles and no corners printable by C3DP would be challengeable design in comparison with the traditional construction techniques	The hybrid construction methods are best way to build these construction shape.
SE4: The fast-building leads to growth and fixes the housing problem.			**WE4: Printing process response to environmental**		
Population changes leads to changing demand for housing. Population growth, and particularly the growth in the number of households, lead to a growth in housing demand. So, fast building is essential.	The fast building and shortage of quality building materials lead to serious design and construction flaws.	The residents of a building may experience discomfort in the event of living in low-quality buildings. The fast-building leads to growth and fixes the housing problem but should put into account the quality	3D printing can have a positive impact on the environment: it reduces manufacturing waste, lowers the carbon footprint, and supports the circular economy	3D printers consume a huge amount of electricity in comparison to other machining tools	On-the-spot and on-demand 3D-printed manufacturing reduces overall energy waste and has smaller carbon footprint. The environmental costs of assembling, transporting, logistics, maintaining, storing are completely or nearly eliminated
SE5: Good work environment					
C3DP is argued to give considerable advantages to the construction of structures in difficult environments, where access for construction workers is either impossible difficult or likely to cause injury or harm. Such technologies will prevent fatigue and accidents as well as minimize stressful workloads	The life cycle assessment of C3DP system has not been performed. Therefore, the environmental approach will be the core of the future research	On-the-spot and on-demand 3D-printed manufacturing reduces overall energy waste and has smaller carbon footprint. The environmental costs of assembling, transporting, logistics, maintaining, storing are completely or nearly eliminated			

Table 3: The Opportunities and Threats analysis of questionnaire questionnaire responses

The Opportunities of Environmental Aspects			The Threats of Environmental Aspects		
Pros	**Cons**	**Critical comment**	**Pros**	**Cons**	**Critical comment**
OE1: Reduce pollution from the construction project			**TE1: Use locally available materials for by-products**		
Using 3D printing to your construction project can be a step in the right direction when it comes to environmental sensitivity and sustainable practices, such as reducing your carbon footprint, creating less waste, and using less energy and fewer raw	New studies have confirmed that particles emitted from 3D printers can negatively impact indoor air quality and have the potential to harm respiratory health	Several new studies found that 3D printers emit toxic particles that may be harmful to humans. However, observing the 3D printing Eco-friendly status in comparison to all the other manufacturing process, especially mass production, demonstrates the facts that the technology has far less of an impact on our environment in comparison to traditional manufacturing.	The circular prototype is called TECLA (a combination of the words Technology and Clay) and was built in Massa Lombarda (Ravenna, Italy) using several synchronized 3D printers working at the same time. It is a circular house created with fully reusable and recyclable materials taken from the local land.	The solidity of locally available materials has not been carried out using binder jetting technology	There are many possibilities to include other materials for additive manufacturing - raw earth, sand, agricultural waste, plastics and other waste. The uses, in turn, range from complete buildings and pavilions, to helping regenerate ecosystems, and limb prosthetics and printed organs.
OE2: Reduce CO2 emission			**TE2: Domestic construction market is still going strong**		
C3DP could reduce the overall CO2 emission intensities of industrial manufacturing by up to 5% by 2025.	Another negative impact of 3D printing comes directly from the printer itself. Studies have found that little bits of plastic and some volatile organic compounds end up in the air when printing and breathing these in isn't a good idea.	The number of fumes emitted by the printer may not be harmful, especially if you install your printer in a spacious room. This is not ruling out the risk aspects of CO2 fumes	Inventions relating to the application of 3D scanning and modeling technology include the repair and reconstruction of buildings and other infrastructures such as roads and railways	Likewise, the sizes and development of printers are a challenge because many of the models that emerge in the market limit their use to the size of the structure to be printed	The enablement of a single print process for infrastructures should result in reduced construction time, moving the 3D printing of buildings an inch closer to becoming a fully automated process.
OE3: Reduce product quality problems			**TE3: Create 3D Printable Models**		
Invest in Technology and use the right materials. that will ensure safety and compliance.	Poor quality working practices in C3DP will demand considerably more management input to correct and can cause a higher number of health & safety incidents	Today, however, challenges seem to reduce product problems and technology limitations are the biggest 3D printing challenges	While there are a number of ways to create 3D models, most of them boil down to two basic methods: building a model in 3D modeling software, or taking an object from the real world and turning it into a digital model using a 3D scanner	Limited Materials of 3D Printing can create items in a selection of raw materials that is not exhaustive.	Creating 3D Printable Models is the more powerful thing because with Printable Models there is no benefits for C3DP
			TE4: 3D printing still lacks standards.		
			For all 3D printing methods, standard general ISO/ASTM terms for 3D printing should be utilized	One of the main problems of 3D printing is the lack of standardization of machines, and the potential for low-quality products.	There are existing standards for 3D printing terminology due to the fact that not all materials are be standardized enough to C3DP.

Additionally, the limitations presented in the preceding section also identify some potential recommended future studies for consideration by researchers as follows:

1. The research is established on a small number of responses. At times, responses might be selected before fully reading the question or the potential answers. Sometimes respondents will skip through questions, or split-second choices may be made, affecting the validity of the data.
2. Indonesia and Malaysia are considered but a major portion of respondents are Indonesia. No matter what form of delivery is used, lack of accessibility is a threat. Surveys may be unsuitable for users with a visual or hearing impairment, or other impediments such as illiteracy.
3. Some responses from all stakeholders with uncommon areas of practice are accounted. This drawback is tough to defeat, but if always choose a questionnaire platform that has accessibility options built in.
4. Research assumes that the responses are unbiased. The possible biases are addressed. Participants in 3D printing survey may have an interest in C3DP product, idea or service. Others may be influenced to participate based about the questionnaire. These proclivities can lead to inaccuracies in your data, generated from an imbalance of respondents who see your topic in an overly positive or negative light. Based on the previous, the following key conclusion and limitations are suggested to be considered for adoption by the construction industry to ensure an effective C3DP

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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