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Digital Fabrication and How It Affects the Future of Indonesian Construction World

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***Abstract*— the rapid advancement of technology in the field of industry is changing the construction world, and it comes in different forms, one of which is digital fabrication technology. As the technology of fabrication process that is aided by computer, such as 3d printing and CNC machines, becoming more affordable and more user friendly, they are slowly becoming a core component in the construction process in the future, as the result has a guarantee in precision and speed, even for a complex structure or geometry. The base material in this fabrication type has also varied greatly over time, and some of the base materials have the capabilities to withheld heavy load, rendering it perfect for construction. The technology also allows the creation of precise prototypes and scale models that can help the design process. In this golden age of internet and computer-aided design, the user-friendly factor of digital fabrication means that the technology can be used by all sorts of people, even those who have limited knowledge in structure, design, and development, making it a universal tool of development. Such numerous advantages will eventually affect the construction world, whether in the design process, the cost, the timeframe, and more importantly, the workforce, the people whose job can be reduced or even fully replaced by the digital fabrication technology. By using qualitative and descriptive analysis, and combined by the literature study approach, this research wishes to evaluate the effects of digital fabrication in Indonesia's current construction world, and how it will affect the country's construction world soon. As of now, the digital fabrication is still being used scarcely in the construction world in Indonesia, due to the price and due to the limited knowledge of it by those who worked in the construction world. By knowing and defining the potentials, the threats, and the effects of using digital fabrication as a core component in the construction process, this paper can become an introduction on how the construction world, the society, and the government should act correctly towards digital fabrication, as it is a major element in the fourth industrial revolution.**

Keywords: digital fabrication, 3d printing, architecture, construction, workforce, Indonesia

I. INTRODUCTION

In the past years, the world is preparing to experience the fourth industrial revolution. It is a revolution based on technology, the easiness to connect through the internet, and the blurring of the line between digital technology, physical presence, and biological spheres [1]. As in the previous revolutions, there will be major world-changing effects that will be felt by all the stakeholders who are involved in the industrial world, such as when the rise of mass production in the second industrial revolution, the world experience an economic crisis due to the lack of need of huge labor force [2]. As we have yet to truly enter the fourth industrial revolution, we still have time to analyze the effects of such revolution, trying to touch the full potentials of it and mend the negative effects before it happens on a major scale.

The Indonesian government has tried to include the industrial revolution into its policy [3], trying to harness the advancement into its strength to make Indonesia one of the major leading countries in the world, as it was being predicted by OECD [4]. Due to the very essence of the revolution and the presence of a huge blue-collar workforce in Indonesia, Indonesia will become one of the countries most affected with the revolution if they do not prepare themselves correctly.

The major parts of the fourth industrial revolution production line are the technology and the workforce. The rise of digital technology that we experienced in the third industrial revolution is being used as the base of the next revolution, giving birth to digital fabrication technology as one of its products. In the industrial world, 3D printing and CNC machines are two of the most commonly used technology today that embodies the spirit of the fourth industrial revolution. The digital fabrication process uses computers and software to compute the design of the product digitally, and with the aid of machines, translate that digital design into a physical product that can be applied in daily life.

In Indonesia, as with other countries in the world, the major workforces that will experience the fourth industrial revolution are the millennial generation and the generations that follow them. These generations are already adept at the use of digital technology in their daily lives [5], becoming attached to the digital gadget and the connectivity of the internet. The fate of the workforce will depend on how these generations use the technology into their advantage in their work.

II. METHODOLOGY

As of now, the digital fabrication has not become a dominant source of production in Indonesia's construction world, but as we move closer to the industrial revolution, Indonesia will eventually feel the effect. This research will use a qualitative literature review methodology to analyze

the effects of digital fabrication for the future of the workforce in Indonesia [6]. The literature review is being used due to the slow development of study cases that can be found in Indonesia, so a comparison with cases from already developing digital fabrication cases in the other part of the world, where it has been well documented and studied, will be used. Using the comparison, we can then create a prediction of the future of digital fabrication development in Indonesia, as digital fabrication will inevitably develop strongly in Indonesia sooner rather than later. By using literature review, we can also learn the past researches in different parts of the world that has experience in digital fabrication of those who just began to use digital fabrication, creating a conclusion that can be used as a base of research in Indonesia.

III. Literature Review

A. Digital Fabrication Technology Today

Starting with MIT's numerically controlled mill, digital fabrication has been developed even further with the arrival of more advanced and more affordable technologies. The digital fabrication itself can be described as a manufacturing process in which the tool that is used is being controlled by a computer [7]. Some of the more popular types of digital fabrication are the 3d printing, CNC routers, and laser cutter [8], of which the 3d printing machines are becoming more and more affordable to the society. There is a need to create the model inside the computer but the software that can be used as the base of 3d printing technology have an easy learning curve. Some models can be downloaded from community-based websites and crowd sharing sources. After we obtained the digital model that we needed, it became easier to create prototypes, components, and other parts with cheaper production price. The material that can be produced by the 3d printing today is also diverse, from plastic to metal, from powder to bio-degradable materials. This technological evolution changes the working mindset of society. As the cheaper, the technology can become, the more people began to think to jump into the field of entrepreneurship [9]. Due to the easiness of obtaining and or creating the digital model, there is also the risk of losing copyrighted design and infringement issues [10] to people, and the spreading of unsafe products that have not been tested inside the regulation. 3d printer is also more appropriate to be used as prototyping but not for the large production system in today's technology due to the higher cost injecting molding and other technologies [11].

Another example of digital fabrication that has also been used regularly is the CNC (computer numerical control) routers. The main difference with the 3d printing technology is that CNC routers extract material from the base to achieve the intended shape. The materials that can be processed range from wood to metal, and it is mostly being used due to its speed, precision in cutting and extracting [12]. And CNC routers also limit the waste of the materials, reducing the production costs. The only disadvantage of CNC routers is the initial cost of buying the equipment. Both CNC router and the 3d printer have their advantages and disadvantages. CNC milling is the better solution when creating objects that have to be extremely strong and robust, precise, and/or heat-resistant, due to the range of materials the CNC can manage. 3D printing has more expansive usage, as it can be used for bio-printing, for printing food, for building purposes, and it can be used almost everywhere due to the machine's size and power consumption. In today's level of technology for both of these digital fabrication tools, both of the machines should be used as complementary to each other.

B. Digital fabrication within the construction industry

T The construction industry has begun to accept digital fabrication into its work process, although the integration process is slower than some of the other industries. This is due to the complexity of the construction industry itself, as buildings are unique from one and another due to specific conditions, the stakeholders, the clients, and eventually, the humans that will use the building when the construction process is complete [13]. If the digital fabrication is used, it can rapidly help the construction of complex forms [14] with minimum waste of materials, faster timing, and fewer workers needed.

Fig. 1. Complex digital fabrication of a bridge by MX3D (*source : https://mx3d.com/projects/bridge-2/ accessed on 30 Juli 2019*)

There are also examples of completely 3d printed houses and companies that specifically work in that field, such as Apis Cor, which manage to print a whole 38sqm house in less than 24 hours that costs a little over $10.000 [15] and other companies that build digital fabrication machines that specialized in large scale construction printing. The construction cost is also further reduced due to the reduced logistics and manual labor costs, removing intermediaries in the construction process. The digital side of the construction also enables the non-linear design to be done in high precision.

It is important to understand that the fabrication process is limited in the construction of walls because the main material of the fabrication is limited mainly to a form of concrete mix. Other parts of the building, such as windows, doors, ceiling, roof, plumbing, and wiring, cannot be printed alongside the walls with today's technology. Some of these parts, parts that can also be digitally fabricated, can be applied later after the wall printing process is done. The CNC application in the construction sector usually involves in the cutting process used to form structural steel members and milling processes employed to create large molds from polystyrene for casting concrete or shaping glass [16]. This process is being used such as in projects done by Frank

Gehry in Zollhoff Tower, Dusseldorf, Germany, and in Conde Nast Employee Cafeteria in New York.

In the construction process involving digital fabrication, architects are more involved in the construction phase due to the ability of digital fabrication to physically create the design intended by the architects. Architects can also build precision prototypes for the new buildings or the elements of the buildings without the need to learn the traditional construction procedure. This new approach of design also creates new possibilities of design shape that cannot be easily achieved by the traditional construction process, such as the steel structure by Arup [17]. By using a 3D printing procedure called direct metal laser sintering, the process selectively melts and fuses metal powder with lasers in a layer-by-layer approach, producing a stainless steel component that weighed 75% less than a conventional plate-based version, creating a more cost-effective structure for the building construction. Thus, such possibilities eventually create a new dynamic in the construction world between the architects and the constructors.

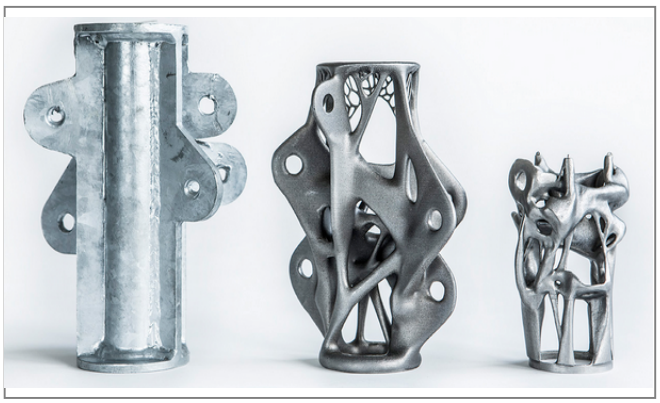

Fig. 2. The steel structure comparision made by Arup (*source : https://www.arup.com/projects/additive-manufacturing, accessed on 30 Juli 2019)*

As with other new techniques, the main problem with digital fabrication in the construction world today is the lack of testing of the durability of the digital fabrication result. There are no researches that can give assurance of the strength of digital fabrication, and aside from the BOD house by COBOD that has fulfilled the building code standards, other digital fabricated buildings have not been tested by the standards.

C. Digital Fabrication and the construction worker

Due to its nature, the construction process that uses digital fabrication will have a large impact on the workforce, in the sense of number and the skills needed. Digital fabrication in the construction world today still needs the manual workforce for the completion of the building due to the system's limitation on creating a fully working building. The workforce is needed in the assembling phase, the finishing phase, and the completion of parts of the buildings that the digital fabrication cannot create. There is also the need for other types of workers to be integrated into the construction process, the machine operator and the digital modeler/programmer. The machine operators have to be present on-site while the digital worker may work in the office, without having to be present in the construction site. In the future, where digital fabrication can construct a complete and functioning building, there is a need to create specific education for these workers for them to have the needed skills to work [18]. The positive side of the future is that the workforce will be mainly consisting of the millennial, a generation that is adept in technology and information sharing and gathering. This type of workforce will have an advantage in the learning curve to understand the complex system of digital fabrication [19].

Even so, digital fabrication will eventually reduce the number of workers needed inside a construction project. It is predicted that by 2030, digital technology will replace labors in increasingly complex tasks [20]. This will create massive unemployment for people who are not equipped with needed skills, especially those who have low educations and those who are only able to do manual labors. This situation reminisces the economic crisis from the second industrial revolution, where the industry lacks the need for a huge number of workers due to the presence of machines.

D. Digital Fabrication in Indonesia

Digital fabrication has not become a common tool in the construction process in Indonesia, due to numerous reasons, such as the price of the tools, the lack of needs, and the lack of workers sufficient to use the technology. As far as the fourth industrial revolution, the Indonesian government has acknowledged the need to prepare itself for the fourth industrial revolution by creating government laws and regulations to ensure the readiness of the nation, dubbed 'Making Indonesia 4.0' [21]. This movement focuses on 5 major sectors that account for 60% of manufacturing GDP, 65% of manufacturing exports, and 60% of manufacturing workers. The sectors are food and beverage, textile and apparel, automotive, electronics, and chemicals. Unfortunately, the law did not include the necessary steps to prepare the construction industry to face the inevitable rise of digital fabrication that will disrupt the unskilled labor force in Indonesia. The digital fabrication is becoming more and more common in practice in the upcoming future, and Indonesia is lacking the preparation to accept the change. There will be risks, especially from the workforce, if the government does not begin to realize the threat.

IV. FINDINGS

Based on the literature review above, four sectors in the construction world are being affected by the rise of digital fabrication, which are the design and construction process, the cost, the timeframe, and the workforce.

A. Design and Construction process

Digital fabrication can significantly cut the construction process due to its ability to create complex structures in high precision, and with the advancement of technology in the future, the speed of the digital fabrication will increase significantly. The relationship between the architects and the constructors will also change, as the architects will be able to apply their design into reality with more ease. The architects as the designers will need to create precise models in CAD with specific format and programming so that the machines can fabricate them. The design process will become longer due to the need to model the important elements of the buildings, but the result will be more precise and correct.

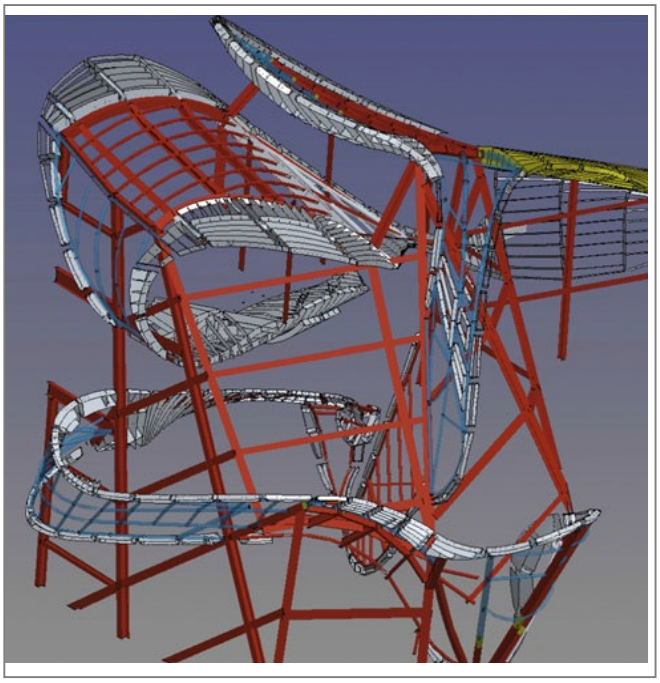

Fig. 3. The model of the structure and of the substructure in Tekla (*source Caneparo, Luca. Digital Fabrication in Architecture,Engineering, and Construction)*

The easiness to create prototypes will also increase new possibilities of design and materials for the construction process. This will eventually significantly push the construction to be able to create designs that are currently not possible to be built due to these limitations. Such ability will surely alter designers' thought processes and the resulting designs [22]. The working environment will also change due to the need for maintaining the machines and the type of skilled labors that will work on-site.

B. Cost

At present, Digital fabrication is not fully able to replace the current construction system due to its initial cost and the limitations of the machinery. The cost comparison of creating a wall between using the regular system and using digital fabrication is also not very different [22]. But in the future, when the technology will become more affordable and more efficient, the cost of the construction will become much more different.

The three main reasons for the cost reduction by using the digital fabrication technologies are the reduced number of workers needed, the reduction of logistics, and the reduction of waste. Skilled workers are paid highly for their service. By reducing the number and the time needed for them to be present in the construction process, the budget can be allocated into other sectors. The logistics of materials can also be reduced. In the example of the 3d printing of the walls of the house, there is no need to send numerous types of materials to erect the walls. The walls were built by a singular specific material. The expedition cost will be significantly reduced. The waste reduction of the construction process is an important factor in why the world should embrace digital fabrication. The dwindling natural resources of the world are a real threat that humanity is facing. By reducing waste, digital fabrication will make the construction process more sustainable for the world.

Fig. 4. The BOD house by COBOD (*source : https://cobod.com/, accessed on 30 Juli 2019)*

C. Timeframe

The main problem with digital fabrication is that they are not able to create a fully functioning building. There is the need for the assembly process and the completion of the building for elements that are currently not possible to create by digital fabrication. But for the elements that the digital fabrication can cover, even with the currently limited digital fabrication technology, it is much faster than the traditional construction technology, as with the example of Spartan house by Apis Cor or the BOD house by COBOD. The speed difference is exponentially larger with the ability of digital construction to create complex irregular shape walls with precision [24], or impossibly complex shape. When the fabrication technology can cover most of the essential elements of a building, the working timeframe distribution dynamic will change. Most of the construction process will be spent in the design and modeling process, while the physical construction period will be much shorter.

D. Workforce

The workforce, the type of labors needed for the construction world, will be the element most affected by the rise of digital fabrication. There will be less and less demand for unskilled laborers, and there will be more demand for soft-skilled laborers that can operate the digital fabricators. This is a crucial change in the workforce demand, and the stakeholders should consider the threat seriously to evade the booming of unemployment. The future workers of the construction world will need a much different set of skills to work, and constant training should be given to the current

workers for them to stay employed when the fourth industrial revolution took off.

E. Digital Fabrication and the Future of Construction World

The digital fabrication is inevitably the future of the construction world, due to its value addition to the construction world. The reduction of the cost of laborers and the reduction of construction time will benefit all the involving stakeholders, while the ability to create a currently impossible design and the possible creation of new materials will surely expand the construction into new levels. Thus, even though it is still with the risks and there are negative impacts, the world should fully embrace the digital fabrication into the construction world.

V. Analysis

Out of the four sectors that are being affected by digital fabrication, Indonesia is affected more on the workforce. As of now, no regulation prepares the unskilled workforce for the industrial revolution. This is due mainly to the current state of construction in Indonesia, which is concentrated on the development of infrastructures, such as roads, bridges, dams, and other projects that do not wholly able to apply the current technology of digital fabrication [25]. These infrastructure projects absorb mostly laborers that do not need the necessary skills to understand the digital fabrication process, and even with the low skills needed, they are mostly not able to have the necessary skills needed to work in the sector [26]. There is an effort from the government to raise the qualifications of the construction workers in Indonesia by creating the certification procedure [27], but there is a lack of urgency to include the digital fabrication skills inside that certification. With the future of the world of construction lies in digital fabrication, this will create the risk of the huge number of unemployment of unskilled workers in Indonesia. Even without the digital fabrication, the unemployment rate will rise by itself when there are no more infrastructures to be built consisting mainly of unskilled laborers. This is a real threat to Indonesia that wishes to become one of the leading economic nations in the future. The lack of urgency can also be seen from the Indonesian people themselves, as they have not seen the potentials of digital fabrication.

Several steps can be done in Indonesia to reduce the threat while embracing the rise of digital fabrications in the future. Indonesia has the chance to become a leading nation in digital fabrication and become one of the more adapt nations to embrace the future of the construction world. The first step is the acknowledgment from the government that the construction world is also needed to be embraced into the ‘Making Indonesia 4.0' movement. Although the construction world is not as dominant as the other five sectors, with the government focusing more on the building of infrastructure as one of the ways to absorb the workforce, the government must be more responsive to that sector as well. By having the support from the government, there will be more capital investment to the workforce to prepare themselves towards the fourth industrial revolution.

The second step is to prepare the necessary skills needed by the construction workers to evolve alongside digital fabrications. The certification process must include the knowledge and understanding of digital fabrication into the laborer. The changing dynamic of skills needed by laborers should also be taken care of, as there will be more soft skills needed in the construction site than the hard skills. The government should create learning centers that prepare future workers to have the necessary skills. The thirds step is to have the government also allocate the necessary funding to the research centers and the private sectors that focus mainly on the development of digital fabrications. The development of technologies that have distinct locality will surely help the society to embrace digital fabrication better.

The fourth step and the most profitable step that can be done by the government is to give a chance and apply more digital fabrication into the infrastructure that the government currently builds. By doing so, it creates a rare chance where the workers will have direct experience in the digital fabrications and the chance for digital fabricators to experiment with the design and the creation of new materials. The new design and materials can be then used to cut off the work timeframe and the cost of construction in the infrastructure process. Indonesia has the chance to expand what the MX3D has done with its bridge design in a much larger and more complex project.

The fifth step is to raise the interest of the people to fully embrace the potentials of digital fabrication. Today's Indonesian only sees the potential of digital fabrication on a more private and smaller scale, but they have not realized that digital fabrication can be used in a more complex and interesting way. The lack of compulsory education for the people in the school to have the necessary skills needed to tap to the potential is also a problem. Those who wish to learn have to follow workshops or to learn by themselves through the information provided on the internet. The already steep learning curve becomes much steeper, and thus, the interest of the people is low.

These steps will need huge funding from the government and the rising interest from the people, especially those who are connected directly to the construction world, but as the fourth industrial revolution is at hand, there should be a sense of urgency from the government and the people to prepare them for the digital fabrication in the construction world.

VI. Conclusion

A fourth industrial revolution is an event that will happen sooner rather than later, and inside it, digital fabrication is one of the major elements that move the revolution. The construction world will become one of the major sectors that are heavily affected by the changing of the system, and it will affect the design and construction process, the cost, the timeframe, and the workforce. As of today, Indonesia has not realized the upcoming threat of digital fabrication towards their unskilled workforce. The threat of booming unemployment is real, and the government must take the necessary steps needed to embrace this revolution. This research proposes four steps that the government can take to not only survive the revolution but due to the huge potentials, Indonesia has the chance to become one of the leading nations in the digital fabrications. The steps do need huge funding and active participation from the government, the stakeholders that are directly involved in the construction world, and the society itself to embrace the change.

VII. Continuation of the Research

The research proves that there are significant effects that digital fabrication has on Indonesia's construction world. This research will become a base for further researches that can concentrate on the four sectors in the construction world that are being affected by the rise of digital fabrication, which are the design and construction process, the cost, the timeframe, and the workforce that happened in Indonesia.

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