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IDENTIFYING FUTURE PROSPECT OF 3D BIOPRINTING IN MALAYSIA

Eta Wahab[*a], Alina Shamsuddin[b], Wan Nurul Karimah Wan Ahmad[c], Nurazwa Ahmad[d], Law Xin Wei[e]

[a,b,c,d,e]**Universiti Tun Hussein Onn Malaysia, Malaysia**
E-mail: [*a]eta@uthm.edu.my.com

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Abstract
This study aims to determine the key drives and future trend of 3D bioprinting in Malaysia. Both qualitative and quantitative method had been used in this study. A STEEPV (social, technology, economic, environment, political and value) analysis had been used to determine the drivers and to develop the scenario of 3D bioprinting in Malaysia. A total of 384 questionnaire had been distributed to medical industries with a response rate of 37.26%. Impact-uncertainty had been utilized in the second phase of the study. The top two drivers found were availability of funding for 3D bioprinting adoption and the focus of medical researcher on 3D bioprinting. Four scenarios had been proposed at the end of the study, which is prosperous of 3D bioprinting, sluggish of 3D bioprinting adoption, deficiency of funding, and destructibility of technology. This paper provided additional knowledge about future trend of 3D bioprinting in Malaysia.

Keywords--3D bioprinting, STEEPV, foresight

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INTRODUCTION

3-dimensional (3D) printing which also known as additive manufacturing (AM) has been used in a various production such as food, manufacturing construction and aerospace. In a recent time, awareness on 3D bio printing in medicine and tissue engineering applications had been increased. 3D bioprinting is a multifaceted construction printing human organ through a layer-by-layer approach by using different categories of living cells and tissue engineering application (Ventola, 2014).

The living cells are a mixture of both biological substances such as collagen, fibrin, and gelatine to assist the development of complete tissues and organs. At the early stage of 3D bioprinting, prototypes on how to print medication, new skin, cartilage and bones, replacement tissue and replacement organs need to be demonstrated (Sue et al., 2013). 3Dbioprinting is a route to produce patient specific tissues and organs in which when the patient need a donor and at the same time there are shortage of donor, 3D bioprinting can be a used as solution (Hsieh & Hsu,2015;Tasoglu et al., 2018; Hussain et al., 2018; Zhu et al. 2016;Zhang & Wang, 2018)

Currently, the only way to replace human organ such as kidney and liver is with a donor organ (Houtman, 2015). The lack of organ donor is a main challenge to solve this problem. Although ministry has established partnership with other government agencies, non-governmental agencies government-linked companies, and private sector had tried to encourage more Malaysians to become organ donors, however, the shortage of human organ remains unsolved. On the other hand, there is a risk of accepting organ transplant. Most of the patient's body reject organ from other donor in which they must use immunosuppressive drugs to keep their bodies from rejecting the foreign tissue (Houtman, 2015).

Therefore, researchers are developing 3D bioprinting as an alternative. Majid (2018) proposed that if 3D bioprinting technology is matured in Malaysia, it can bring benefit to society especially in replacing internal organ, skin and broken bones. Currently, less studies had been conducted on the foresight to investigate 3D bioprinting adoption in Malaysia. This study will thus review the future trend of 3D bioprinting adoption in Malaysia.

LITERATURE REVIEW

Definitions of 3D Bioprinting

In 1986, the first 3D printing was created by Hull (Murphy & Atala, 2014). The additive manufacturing and 3D printing signify the creation processes where a solid 3D structure is invented layer by layer. The potential of 3D bioprinting applications may be more desired compared to other application areas as it permits individualized design, for instance for implants, prostheses, surgical guides or tissues (Bechthold et al., 2015).

Benefits of 3D bioprinting

3D bioprinting have many positive impacts especially towards health care industry. The first benefits of 3D bioprinting is cost efficiency (Schubert et al., 2014). For example, forthe large-scale production, the price might become less expensive. However, the cost of printing is still becoming more competitive for small production (Schubert et al., 2014). Thus, 3D custom-made medical products might become more accessible and pervasive due to minimal cost. The second benefits of 3D bioprinting is it will permits customization and personalization (Ventola, 2014). Specifically, this technology will provides the autonomy to produce custom-made medical products and equipment. For instance, customize prosthetics and implants produced using 3D printing could benefits both patients and physicians (Banks, 2013)

Thirdly, Mertz, (2013) stated that the use of 3D printing could enables cooperation in the design and manufacturing of products and tools. It allows researcher, including those from medical fields, to produce or design novel products for commercial or personal use. In addition, it offers opportunities for collaboration among researchers through sharing of designs (Gross at al., 2014) and (Hussain et al., 2017). For example, researchers might use open source database to produce an exact replica of a medical device or model that had been used by the previous researchers.

Lastly, 3D bioprinting could increase the productivity of the medical industry in manufacturing products needed for healthcare industry (Mertz, 2013). The technology can be much faster compared to the previous methods, for example in processing, manufacturing, for medical items such as implants and prosthetics (Banks, 2013).One of the biggest positive impact is patient who in the organ transplant waiting list are able to get custom-fit organ before final stage of organ failure. Except for organ, 3D bioprinting also able to print bones, skin, and tissue. Patient will be able to enjoy longer life with new printed organ. Patient in the waiting list of organs transplant also able to decrease due to 3D bioprinting.

Issues and drivers of 3D bioprinting

The scanning of previous literature related to the 3D bioprinting had been conducted and analysed. STEEPV analysis which was an acronym that refers to Social, Technology, Economy, Environment, Politics and Values had been utilized in this process. Table 1 summarizes the results of STEEPV analysis discussed.

Table 1. Issus and drivers

	Drivers and issues
Social	• High quality of life • Not accepting bioprinted organ • Enhance athlete's performance • Waiting for organ transplant • Longer life • Social impact • Waiting list for organ transplantation • Increase demand of organ transplant • Shortage of organ
Technology	• Produce tissue • Print material contain living cells • Tools for control stem cell • Major impact on medical instrument • Potential on regenerative medicine • Application of tissue and organ engineering • Limitation of materials • Adoption of hard tissue and organ engineering • Large tissue and organ defect healing and repair • damage effects to cells • Clinical application • Regenerative medicine applications • Focus medical field • Print medicine • 3d printed skin, bone and cells • Living cells were used to construct tissues and organs • 3d bioprinting use in skin care industry and cosmetic procedure • Repair deep wound • Visualization techniques • Create 3d structures • Summarize special features of human tissue • Unable to mimic human physiological conditions • Cover medical range
Economy	• Reduce medical costs • High expenses compare to organ transplant • A budget was funded to develop a 3D-printed • Market acceptance • Investment • Reduce public health cost • Increase demand of organ • Higher innovation cost • Negative economy impact • Positive economy impact • High dialysis costs • Decrease revenue • Global bioprinting market
Environment	• No positive environment impacts • Modify natural material • Tissue development not environmentally friendly • Cruelty-free
Political	• Policy of this technology is provided • Special legal framework • Ethical and regulatory issues • Government's rule • Government support 3D bioprinting • Rules for bioprinting • Unregulated and untested biomaterial were printed • Regulation on printed medicine • High treatment costs

	• Decrease costs on transplant logistics
Value	• Ethical framework • Solve ethical issue • Attention of medical researcher • Future direction and growth of 3D bioprinting

The social driver aspects relates to societal issues with regard to the usage of 3D bio printing technologies. This includes quality of life and longer life as well as social impact. There would be possibility that the 3D bioprinting technology being used to enhance human performance such as in sport (Munoz-Abraham, 2016). In terms of technology aspect, it relates to the effects of the 3D technology usage especially on the limitations of material, adoption of hard tissue and organ engineering, potential on regenerative medicine, clinical application and damage effect to cells (Gao& Cui, 2016). Furthermore, potential users need to be aware before applying such technology while creating implantable usage of biocompatible materials to avoid allergic reactions during the creation of the tissues or other implantable (Thangaraju & Chaudhary, 2014).

As for economic aspect, there are claims that 3D printing technology could reduce the medical cost which could reduce the budget for the potential users. 3D technology also been forecast to be a good investment in health care industry in future (Parkhe, 2017) and could give a positive impact towards economy (Boucher,2018). However, higher funding is needed to support the 3D bioprinting research. Environmental aspect that relates to the 3D printing technology is the possibilities that tissues development is not environmentally friendly and could modify the natural material (Bishop,2017; Murphy, 2014). However some study suggested that by applying the 3D bioprinting technology, materials and resource efficiency could be increased as well as provides opportunities for recycling of 3D-printed material (Sendel et al., 2015).

In terms of political driver, government regulations and policy could destruct towards development of 3D biprointing. Government might regulate the legal aspect of 3D bioprinting for example on the printed medicine. The acceptance and involvement of government are also need to ensure medical application of 3D printing been implemented (Parkhe, 2017; Futurist,2018; Vijayavenkataraman,2016). Ventola (2014) highlights that this technology must be legally defined as manufacturing or compounding equipment to better regulate the suitable laws that it falls under. Finally, the values aspect of 3D bioprinting mostly relates to ethical elements of 3D printing technology. For example, if this technology is successful, the demand for organ transplant will be increase which could raise the risk of ethical consequences for potential users (Vermeulen, 2017). Furthermore 3D printing technology has earned huge attention of medical researchers which could enhance the future direction and growth of 3D bioprinting (Sue et al., 2013)

Merged of issues and drivers

The issues and drivers found for each STEEPV factor were further analysed and grouped into thirteen merged issues and drivers that could influence the 3D bioprinting implementation. The merged issues and drivers are shown in Table 2.

Table 2. Merged of issues and drivers

No	Issue and Drivers
1	3D bioprinting adoption have major impact on medical instrument and able to expand to global market
2	Growth of 3D bioprinting will give impact on economy in future
3	Attention of medical researcher will increase efficiency of 3D bioprinting adoption.
4	Fund from private and public sector for 3D bioprinting adoption is needed.
5	Adoption of 3D bioprinting can be done when there is less negative impact towards the environment.
6	Support from government can achieve high market acceptance.
7	Successful of organ transplant will bring high quality of life to patient.
8	Easier for the modified natural material to enter global market.
9	Ethical and regulation will affect application of 3D bioprinting in clinic.
10	Public acceptance towards 3D bioprinting due to cruelty-free
11	Adoption of 3D bioprinting can reduce medical cost.
12	Guideline were provided to public about application of 3D bioprinting.
13	Rules and regulation on bioprinting able to solve ethical issue.

METHODOLOGY

Both qualitative and quantitative methods had been utilized in this research.The research starts with qualitative approach by using STEEPV analysis. STEEPV analysis (brainstorming tool) had been used to identify the drivers of 3D bioprinting (Bailey, 2014).STEEPV analysis was an acronym that refers to Social, Technology, Economy, Environment, Politics and Values. In the later part of the study, data were collected through structured questionnaire and analysed using the statistical software SPSS.

The product of the STEEPV analysis is the merged key issues and drivers which will be developed into structured questionnaire. Questionnaire that rate the impact and uncertainty of each drivers was then developed and distributed among the health care practitioners in Malaysia. The sample of 5 represent the highest impact and highest uncertainty while scale of 1 represents the lowest impact and lowest uncertainty of drivers towards 3D biprinting adoption. The sample of the respondents for this research was 384. Meanwhile the data collected from the questionnaires had been analysed into the impact-uncertainty analysis. This is followed by scenario building to anticipate the future trends of 3D bioprinting in Malaysia.

MAIN RESULT

Only 136 valid questionnaire had been returned and analyzed. Majority of the respondents of this study were female (52.2%), aged below 30 years old (72.85%), Chinese (66.9%), have a bachelor degree (71%), monthly income below RM 3000 (65.4%) and have been working in the organization for less than 5 year (71.35%).

The impact-uncertainty analysis had been conducted to identify the drivers that give impact towards 3D bioprinting implementation in future. Table 3 below shows the mean of issues and driver based on level of impact and uncertainty

Table 3. Mean of the issues and drivers on level of impact and uncertainty

No	Issue and Drivers	Impact	Uncertainty
1	3D bioprinting adoption have major impact on medical instrument and able to expand to global market	4.0735	3.0882
2	Growth of 3D bioprinting will give impact on economy in future	4.0515	3.2794
3	Attention of medical researcher will increase efficiency of 3D bioprinting adoption.	4.1250	3.3309
4	Fund from private and public sector for 3D bioprinting adoption is needed.	4.1176	3.4265
5	Adoption of 3D bioprinting can be done when there is less negative impact towards the environment.	3.9853	3.2353
6	Support from government can achieve high market acceptance.	4.0000	3.3824
7	Successful of organ transplant will bring high quality of life to patient.	4.1176	3.2868
8	Easier for the modified natural material to enter global market.	4.0368	3.1985
9	Ethical and regulation will affect application of 3D bioprinting in clinic.	3.8088	3.2574
10	Public acceptance towards 3D bioprinting due to cruelty-free	3.8529	3.3456
11	Adoption of 3D bioprinting can reduce medical cost.	3.8603	3.3088
12	Guideline were provided to public about application of 3D bioprinting.	3.7721	3.2794
13	Rules and regulation on bioprinting able to solve ethical issue.	3.6765	3.0294

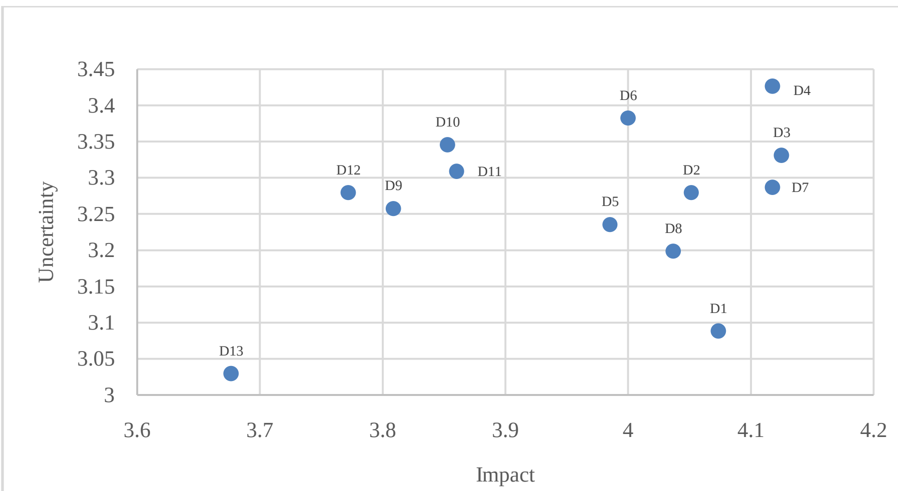

Figure 1. Impact-Uncertainty Analysis

Based on Figure 1 and Table 3, the top two drivers that had high impact and high uncertainty are focus of medical researcher (D3) and the availability of funding for 3D bioprinting adoption (D4). These two drivers were used to generate scenario building of the future trend of 3D bioprinting adoption in Malaysia.

DISCUSSION AND CONCLUSION

Scenario building

Figure 2 shows four alternative scenarios that were developed based on impact-uncertainty analysis. These four scenarios give an insight or overview to four possible possibilities that can occur in 10 -15 years ahead based on the findings.

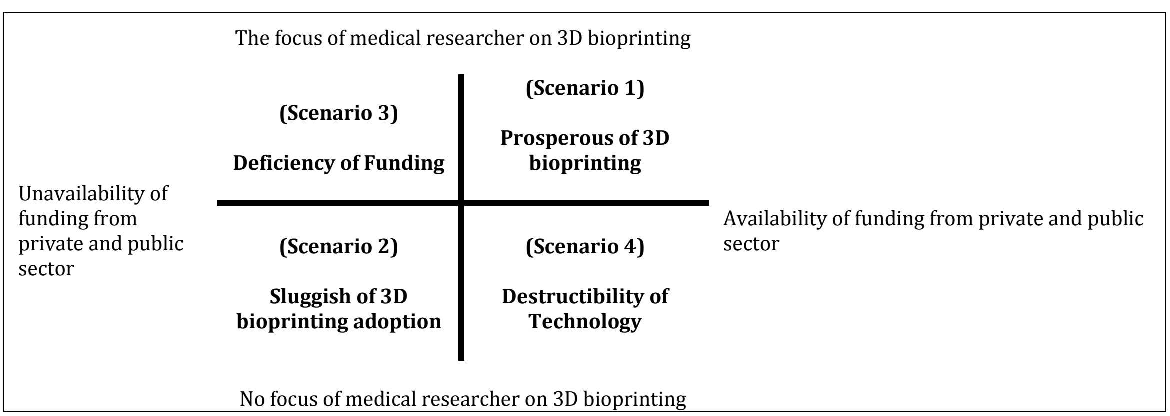

Figure 2. Future scenario matrix

Scenario 1: Prosperous of 3D bioprinting

The first scenario points towards an ideal situation for 3D bioprinting adoption in the future.The first scenario occurs when there is a focus of medical researcher on 3D bioprinting and availability of funding from private and public sector. In this condition, there is a prospect in future to adopt the 3D bioprinting in health care industry with the condition that there is a numerous medical researchers that focus on 3D bioprinting research and supported by good funding from both public and private sector on 3D bioprinting research.

There will be an increase in the adoption of 3D bioprinting among health care industry due to the rigorous focus of medical researchers towards 3D bioprinting which will further stimulate the growth of new advanced technology on 3D bioprinting, which will be certainly be a key steps towards producing of high quality medical product especially for the usage of the organ transplant patients. Furthermore, incentive and funding provided by both private and public sector will reduce the cost of research and development on 3D bioprinting which will in turn enhance the adoption of 3Dbioprinting. It is anticipated there will be a huge improvement of health care industry while at the same time could reduce the cost of medication produced especially on 3D bioprinting.

Scenario 2: Sluggish of 3D bioprinting adoption

This scenario is the least desirable scenario. This scenario reflects a lack of funding from both public and private sector and no focus on 3D bioprinting among medical researcher. This scenario will be marked by sluggish of 3D bioprinting adoption. With low progression of research on 3D bioprinting among researchers and lack of funding towards research on 3D bioprinting, health care industry has a low possibility to survive in future. This is a destructive environment for the growth of 3D bioprinting and would thus decrease the chances for success of these practices in Malaysia. In 2030, the growth of 3D bioprinting is predicted to be dormant. Thus, we are in a dangerous situation, where there is a need to take immediate action to encourage 3D bioprinting among healthcare practitioner. Involvement of the government as well and private and public sector to increase 3D bioprinting are needed as some of the 3D printing laboratories imposed very high operational cost (Murphy & Atala, 2014).

Scenario 3: Deficiency of Funding

In scenario 3, the researchers realize the importance of focusing on 3D bioprinting research. Researcher are anticipate to aggressively involve in research related to more genetic engineering and stem cell development that can be used in 3D bioprinting adoption, which could support the 11th Malaysian Plan that strives for the adoption of Industry 4.0 related technologies. This scenario would nurture a 3D bioprinting practices among health care providers. According to Pando (2018), the 3D bioprinting technology will be expected to be worth $1.3 billion by 2021. In this scenario, a strong government policy need to be executed through strengthening governance towards 3D adoption, and enhancing governing practices, monitoring and evaluation of 3D bioprinting adoption practices. It is also projected that as Generation Y and Z , which is highly apprehensive with technologies, will dominate the workforce in 2030, the adoption of 3D bioprinting will be increased. However, lack of financial support from private sector as well as government will discourage the adoption of 3D bioprinting in health care industry.

Scenario 4: Destructibility of Technology

The last scenario predicts that the funding from private and public sector are available but no attention of medical researcher on 3D bioprinting been done. It is expected that more funding on 3D bioprinting could stimulate the growth of 3D bioprinting in health care industry. However, as the researcher are not willing to focus on 3D bioprinting research, they are not be able to generate a low-cost 3D bioprinting product such as bioprinted organ. The low cost of 3D bioprinting is crucial because it will allow patient to have organ transplant in low cost compared to traditional organ transplant (Pando, 2018). Thus, if the level of understanding regarding 3D bioprinting research is low among the researchers, there is a need to focus on promoting 3D bioprinting adoption practices at the national level as well as providing education on 3D bioprinting concept to the society through government involvement. Vijayavenkataraman, (2016) suggested that a new technology can only be succeed if it is accepted by the general public.

CONCLUSION

The aim of this study is to understand the key drivers and future trend of 3D bioprinting in healthcare industry. Foresight technique and tools as well as statistical analyses were used to achieve this objectives. This findings reveals thatavailability of funding from private and public and focus of medical researcher on 3D bioprintingas the most important drivers that can influence future 3D bioprinting. The scenario analysis reveals four alternatives scenario associated with the key drives. As a conclusion from the findings, impact uncertainty analysis and the scenario buildings, it is clearly shows that 3D bioprinting could benefits future health care industry in Malaysia.

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