EVALUATION OF CRITICAL SUCCESS FACTORS OF 3D PRINTING TECHNOLOGY IMPLEMENTATION USING ANALYTIC HIERARCHY PROCESS (AHP)

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I hereby declare that the work in this project report is my own except for quotations and summaries which have been duly acknowledged.

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MADAM ROHAIZAN BINTI RAMLAN

Especially dedicated to my beloved parents,
Mr. Shahrubudin Bin Kasa and Mrs. Yusnitza Binti Ismail,

My Everything: Nik Shuammar,

My little brother,

My big family,

My supportive friends,

Most respective and super awesome supervisor,

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ABSTRACT

The study focused on the Critical Success Factors (CSFs) for implementing 3D printing technology in manufacturing firms of Malaysia. This technology has emerged during recent years as a flexible and powerful technique in advance manufacturing industry. However, while 3D printing technology is beginning to emerge in manufacturing sector, given the lots of benefits, but, more information is needed to progress on ways to enhance adoption. This study aimed to identify the Critical Success Factors (CSFs) for 3D printer technology implementation in manufacturing industry and to evaluate the Critical Success Factors (CSFs) by using Analytic Hierarchy Process (AHP). The process of data collection was obtained using quantitative methods where a set of questionnaires was prepared. 40 experts in 3D printing technology was selected to respond to the questionnaire. There are 9 criteria and 33 sub-criteria for adoption of 3D printing technology in manufacturing industry. Among the 33 sub-criteria, the most important sub-criteria are time taken or speed to produce the 3D printed object, with different type of nozzle and cost of worker prioritized as the second and third sub-criteria. The result shows element technology (0.156) is the most important factor, followed by quality and accuracy (0.150), cost (0.135), and materials (0.133). This study was done to help the company to identify the Critical Success Factors (CSFs) for implementing 3D printing and to evaluate the Critical Success Factors (CSFs) for implementing 3D printing technology in manufacturing firms by using AHP method. The results indicate that technology and quality and accuracy are the most important factors for the implementation of 3D printing.

Keywords: 3D printing, implementation, manufacturing, quality, technology

ABSTRAK

Kajian ini memberi tumpuan kepada faktor kejayaan penting untuk menerapkan teknologi percetakan 3D di firma pembuatan di Malaysia. Teknologi tersebut telah muncul sejak beberapa tahun kebelakangan ini sebagai teknologi yang fleksibel dan hebat dalam industri pembuatan. Walaubagaimana pun teknologi percetakan 3D yang baru muncul telah memberikan banyak faedah kepada pengguna namun lebih banyak maklumat diperlukan untuk meningkatkan penggunaan teknologi percetakan 3D. Kajian ini bertujuan untuk mengenal pasti Faktor Kejayaan Kritikal (CSFs) dalam pelaksanaan teknologi percetakan 3D dengan menggunakan Proses Hierarki Analitik (AHP). Proses pengumpulan data diperolehi dengan menggunakan kaedah kuantitative dimana satu set soal selidik telah disediakan. Responden yang dipilih adalah terdiri daripada 40 orang pakar dalam teknologi percetakan 3D di Malaysia untuk memberikan menjawab kajian soal selidik tersebut. Terdapat 9 kriteria dan 33 sub-kriteria dalam penggunaan teknologi percetakan 3D di Malaysia. Sub-kriteria yang terpenting adalah masa atau kelajuan untuk menghasilkan objek bercetak 3D. Manakala, jenis nozel dan kos pekerja berada di tahap kedua dan ketiga. Hasil daripada analisis kajian ini mendapati teknologi (0.156) adalah faktor yang paling penting, diikuti oleh kualiti dan ketepatan (0.150), kos (0.135), dan bahan (0.133). Kesan daripada kajian ini telah menunjukkan bahawa teknologi dan ketepatan kualiti adalah faktor terpenting bagi pelaksanaan percetakan 3D di firma di Malaysia.

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LIST OF EQUATIONS

LIST OF SYMBOLS AND ABBREVIATIONS

3D	-	3 Dimension
°C	-	Celsius
ABS	-	Acrylonitrile Plastic Butadiene Styrene
AHP	-	Analytical Hierarchy Process
ASTM	-	American Society for Testing and Materials
CAD	-	Computer-Aided Design
CI	-	Consistency Index
CR	-	Consistency Ratio
CSFs	-	Critical Success Factors
DLP	-	Digital Light Processing
EBM	-	Electron Beam Melting
ELECTRE	-	Elimination and Choice Expressing Reality
FDM	-	Fused Deposition Modelling
FGMs	-	Functionally Graded Materials
FMM	-	Federation of Malaysian Manufacturers
IoT	-	Internet of Thing
ISO	-	International Organization for Standard
IR	-	Industrial Revolution
LENS	-	Laser Engineered Netshaping
LEDs	-	Light-Emitting Diodes
LOM	-	Laminated Object Manufacturing
MAB	-	Malaysian Association for The Blind
MAUT	-	Multiple Attribute Utility Theory
MCDM	-	Multi-Criteria Decision-Making

PMMA	-	Poly(Methyl Methacrylate)
MIDA	-	Malaysian Investment Smart Manufacturing
PLA	-	Polylactic Acid
PE	-	Polyethylene
PEEK	-	Polyether ether ketone
PMMA	-	Poly(Methyl Methacrylate)
PROMOTHEE	-	Preference Ranking Organization Method
PP	-	Polypropylene
R&D	-	Research and Development
RI	-	Random Index
SHS	-	Selective Heat Sintering
SLA	-	Stereolithography
SLCM	-	Stereolithographic Ceramic Manufacturing
SLS	-	Selective Laser Sintering
SMEs	-	Small and Medium-Sized Enterprises
SMP	-	Shape Memory Polymer
.STL	-	Stereolithography File
TM	-	Telekom Malaysia Berhad
UAM	-	Ultrasound Additive Manufacturing
UKM	-	Universiti Kebangsaan Malaysia
UM	-	Universiti Malaya
UV	-	Ultraviolet

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Fourth Revolution permits big data to be collected and processed by given the advancement of computing powers, which provides vastly improved information and deep insights. The result of these Industry 4.0 can be harnessed by governments in order to govern better, become more accessible and increase sincerity and trust. Agile governance will allow the leaders in public sector to work with end users in the future smoothly, to design and deliver meaningful services. It is also expected that in the future, more technological innovation will be made in the science, technology and engineering field (Tajuddin *et al.*, 2018). These new and advanced technologies will allow certain established industries like the construction and manufacturing industry to deliver a more sustainable solution to economy, society and environment.

At the same time, Industry 4.0 is getting the navel of the scene with respect to the future of social and economic implications in Malaysia and to its manufacture systems. It is considered as the new important paradigm shift in industrial manufacturing and production. The new paradigm is based on the advanced digitalization of factories, the Internet, and future-oriented technologies bring intelligence in device, machines and system. Despite its growing popularity and the countless expectations in terms of innovation impact, the concept of Industry 4.0 powerfully linked to frameworks and technologies that have been analysed in the last decades (Chiarello *et al.*, 2018). These phenomena can change the way people work live and related to one other.

3D printing technology is the one vital technology that drive the achievement of Industry Revolution 4.0. Digital fabrication technology, also stated to as additive manufacturing or 3D printing, produces physical objects from a geometrical representation by successive addition of materials (ISO/PRF 17296-1, 2015). 3D printing technology is a fast-emerging technology. 3D printing technology can print an item layer by layer deposition of material directly from a computer aided design (CAD) software (Ze-Xian *et al.*, 2016). Cutting-edge technologies such as additive manufacturing or 3D printing technology will provide the ability to create complex products without the need of complex equipment. 3D printing technology also provides a chance for industries to reduce waste to a minimum level as stated by Tajuddin *et al.* (2018) that there is a change in the economic model of the manufacturing industry from a "take, make and dispose" approach to a "circular" approach aiming for zero manufacturing waste in Malaysia. Hence, 3D printing technology is one suitable alternative to achieve manufacturing waste.

There are series of advantages that automatically can give effect to large-scale development of this technology such as 3D printing technology offers the possibility of creating objects in a quick time and can use variety raw of materials, possibilities to print out complex objects and shapes with specification and design required that are incredible to obtain through any other current technology and enable rapid production with a higher number of prototypes in less time than using conservative methods. This can support designers to upgrade and enhance the quality of their prototype. Moreover, 3D-printer can print required object by the customer, and the cost only for materials and no cost on storage of goods required. Although, the initial cost of setting up 3D printing technology is very high, the total production cost includes labour costs, time to produce the printed object and the effort for small scale and mass manufacturing indicate the production cost is relatively low (Pirjan & Petrosanu, 2013). Thus, the adoption of 3D printing technology will increase the production speed while reducing costs. At the same time, the demand of the consumer will have more influence over production.

Nowadays, 3D printing is extensively used in the world. 3D printing technology increasingly used for the mass customization, production of any categories of open source designs in the field of agriculture, in healthcare, automotive industry, and aerospace industries (Keleş *et al.,* 2017). To sum up, 3D printing technology has emerged during current years as a flexible and powerful technique in advance manufacturing industry. This technology has been widespread used in many countries, especially in the manufacturing industry. However, while 3D printing technology is beginning to arise in industrial sector, given the lots of benefits, but, additional knowledge is needed to improve on ways to boost implementation. Therefore, this research is coming out to investigate the Critical Success Factors (CSFs) for implementing 3D printing technology in Malaysia.

Critical Success Factors (CSFs) can be understood as organisational arrangements essential to ensure attractiveness and success, thus supporting a company's administrative transformation processes (Bullen & Rockart, 1981). According to Boynton & Zmud (1986), Critical Success Factors (CSFs) are those few things that essential accomplish to ensure success for the organization. Identifying Critical Success Factors (CSFs) is relevant to list and rank the important factors for implementing 3D printing technology. Understanding the Critical Success Factors (CSFs) for adoption of 3D printing technology will be the key to achieving more technological innovation will be made in the science, technology and engineering field in future (Boynton & Zmud, 1986).

1.2 Research Background

By 2020, world population estimates reach 7.6 billion, and currently, technological developments predict 50 billion electronic devices will interact with each other. This shows the number of devices communicating is over the human population with each human being having about 6.58 electronic devices. This interconnected device generates a modern world. The emergence of Industry Revolution 4.0 becomes a key concept in modern manufacturing (Yusof, 2017).

Industry Revolution 4.0 (IR 4.0) is an ingenious manufacturing system, which focuses on the design, manufacturing and in providing customized services and

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