UNIVERSITI TEKNIKAL MALAYSIA MELAKA

READINESS ASSESSMENT FOR IMPLEMENTING INDUSTRY 4.0: A CASE STUDY AT AN AEROSPACE MANUFACTURING COMPANY

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MASTER OF MANUFACTURING ENGINEERING (INDUSTRIAL ENGINEERING)

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Faculty of Industrial and Manufacturing Technology and Engineering

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A master project submitted
in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this master project entitled “Readiness Assessment For Implementing Industry 4.0: A Case Study at an Aerospace Manufacturing Company” is the result of my own research except as cited in the references. The master project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :..

Name :..

Date :..

APPROVAL

I hereby declare that I have read this master project and in my opinion this master project is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Industrial Engineering)

Signature :...

Supervisor Name :...

Date :...

DEDICATION

To my beloved mother and father, my husband, my daughter, and my sibling.

ABSTRACT

The aerospace is one of the industries that has great capabilities and is continually striving to come up with innovations. In the context of impacts of the Fourth Industrial Revolution (IR 4. 0), there is a need to evaluate the level of readiness of organization within this industry. This study aims to examine the readiness of an aerospace manufacturing company in Malaysia toward IR 4.0. The problem addressed under consideration is lack of research on the topic related to the readiness, particularly aerospace manufacturing industry, for IR 4. 0 adoption. The methodology employed involves a comprehensive readiness assessment using the IMPULS model, which evaluates dimensions. The added dimensions to it combine strategy and organization, employees, smart factory, smart operation, data-driven services, cost and financial and customer aspects. Information from the questionnaire was utilized to analyze the relationship constructs and validated through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). In the same respect, the Fuzzy Delphi Method (FDM) was employed to categorize the barriers and drivers essential to IR 4. The findings based on the relationship significance showed that strategy and organization, and cost and financial aspects, as well as employees leave a significant impact on IR 4. 0 readiness. The FDM results highlighted critical barriers such as the shortage of capable training providers and low digital readiness and connectivity, while drivers included higher operational efficiency and the growth of market and new markets. The results show a moderate level of readiness at level three (3). The company scored higher in strategy and organization (SO) and employee readiness (EMP), indicating strong strategic planning and a well-prepared workforce. However, there are significant gaps in smart operations and data-driven services that need substantial improvement. The conclusion drawn is that while the company demonstrates potential for adopting IR 4.0 technologies, focused efforts are needed to address specific dimensions to enhance overall readiness.

PENILAIAN KEBOLEHAN UNTUK MELAKSANAKAN INDUSTRI 4.0: SATU KAJIAN KES DI SEBUAH SYARIKAT PEMBUATAN AEROANGKASA

ABSTRAK

Industri aeroangkasa adalah salah satu industri yang mempunyai kemampuan besar dan sentiasa berusaha untuk menghasilkan inovasi. Dalam konteks kesan Revolusi Industri Keempat (IR 4.0), terdapat keperluan untuk menilai tahap kesiapsiagaan organisasi dalam industri ini. Kajian ini bertujuan untuk mengkaji kesiapsiagaan sebuah syarikat pembuatan aeroangkasa di Malaysia terhadap IR 4.0. Masalah yang dihadapi ialah kekurangan penyelidikan mengenai topik yang berkaitan dengan kesiapsiagaan, terutamanya industri pembuatan aeroangkasa, untuk penerapan IR 4.0. Metodologi yang digunakan melibatkan penilaian kesiapsiagaan yang komprehensif menggunakan model IMPULS, yang menilai pelbagai dimensi. Dimensi tambahan ini menggabungkan strategi dan organisasi, pekerja, kilang pintar, operasi pintar, perkhidmatan berasaskan data, kos dan kewangan serta aspek pelanggan. Maklumat soal selidik digunakan untuk analisis hubungan pembinaan dan disahkan menggunakan EFA dan CFA. Dalam konteks yang sama, Kaedah Fuzzy Delphi (FDM) digunakan untuk mengkategorikan halangan dan pemacu yang penting untuk IR 4.0. Penemuan berdasarkan kepentingan hubungan menunjukkan bahawa strategi dan organisasi, serta aspek kos dan kewangan, serta pekerja mempunyai kesan yang signifikan terhadap kesiapsiagaan IR 4.0. Walau bagaimanapun, operasi pintar dan perkhidmatan berasaskan data menunjukkan korelasi yang lebih lemah, menunjukkan kawasan yang memerlukan peningkatan yang ketara. Hasil FDM menyoroti halangan kritikal seperti kekurangan penyedia latihan yang berkemampuan dan kesiapsiagaan digital yang rendah serta kesalinghubungan yang rendah, manakala pemacu termasuk kecekapan operasi yang lebih tinggi dan pertumbuhan pasaran serta pasaran baru. Hasil kajian menunjukkan tahap kesiapsiagaan yang sederhana, dengan jurang yang ketara dalam bidang operasi pintar dan perkhidmatan berasaskan data. Kesimpulannya, walaupun syarikat menunjukkan potensi untuk mengadaptasi teknologi IR 4.0, usaha yang lebih fokus diperlukan untuk menangani dimensi tertentu bagi meningkatkan kesiapsiagaan keseluruhan.

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LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
IR 4.0	-	Fourth Industrial Revolution
EFA	-	Exploratory Factor Analysis
CFA	-	Confirmatory Factor Analysis
FDM	-	Fuzzy Delphi Method
OEM	-	Original Equipment Manufacturer
SMEs	-	Small and Medium-sized Enterprises
MITI	-	Ministry of International Trade and Industry
AI	-	Artificial Intelligence
IOT	-	Internet of Things
PLS-SEM	-	Partial Least Squares Structural Equation Modelling
SPSS	-	Statistical Package for Social Science
KMO	-	Kaiser-Meyer-Olkin
CR	-	Composite Reliability
AVE	-	Average Variance Extracted
HTMT	-	Heterotrait-Monotrait ratio
VIF	-	Variance Inflation Factor
LOC	-	Lower-order Construct
HOC	-	Higher-order Construct
R&D	-	Research and Development

LIST OF SYMBOLS

α	-	Significance level
λ	-	Eigenvalue
χ^2	-	Chi-square
μ	-	Mean
σ	-	Standard Deviation
ρ	-	Pearson correlation coefficient
d	-	Threshold value
A	-	Fuzzy score value
R^2	-	Coefficient of determination

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Industry Revolution 4.0, also known as the Fourth Industrial Revolution, or IR 4.0, is the next stage of the industrial sector's digitization. It is being driven by a number of revolutionary factors, such as the growth of data and connectivity, analytics, robotics advancements, and human-machine interaction. In industrial technologies, automation, data interchange, and digital innovation are integrated to create IR 4.0. It plays a crucial role in supporting the development of new kinds of technical data and systematic, highly flexible value chains by combining intelligent machines, people, materials, manufacturing lines, and procedures across organisational stages (Anil Kumar et al., 2021). Digital and physical technologies are all integrated into IR 4.0 to improve flexible and effective management. In the age of digitization, this IR 4.0 system links businesses, facilitating informed decision-making based on comprehensive information and establishing a new dynamic between business and society (Puhovichova & Jankelova, 2022). The potential of IR 4.0 to improve production efficiency and lower costs has made European manufacturing researchers and corporations eager to adopt it (Ing Tay et al., 2018). This has fostered readiness for the adoption of IR 4.0 across all manufacturing industry.

The significance of the IR 4.0 implementation has become greatly popular in recent times, since manufacturers companies are growing dramatically in many industries including aerospace sector. The globalised market has a significant impact on the modern manufacturing industry, requiring a combination of increased productivity, digitalized processes, improved product quality, flexibility, and shorter product life cycles. IR 4.0 is introduced as a new technological era according to the framework. It makes use of Internet-based technology, with an emphasis on intelligent systems that continuously collect and process data and enable information sharing across devices and systems (Zutin et al., 2022). Aerospace manufacturers have been examining these cutting-edge technologies in order to increase their competitiveness as a result of this new industrial revolution. In this way, the increasing number of digital technologies has forced aerospace manufacturers to concentrate on prospecting, R&D, and creating the circumstances necessary for their manufacturing processes to become more intelligent towards IR 4.0 implementation (Frigo et al., 2016).

Several selections of assessment models are available to help understand the company's readiness for IR 4.0. A number of maturity models and readiness models for the implementation of IR 4.0 have been published. One of the most well-known readiness models for starting a development process is IMPULS, which identifies obstacles and offers solutions. Schumacher et al., state that a readiness model gauges a company's level of readiness for the development process, whereas a maturity model gauges the maturation process. Six aspects strategy and organisation, smart manufacturing, smart operations, smart goods, data-driven services, and workers are used in the IMPULS model to measure IR 4.0 readiness. Alongside the right indicators, these characteristics serve as a framework for measuring IR 4.0 readiness (Schumacher et al., 2016). Assessing readiness for IR 4.0 adoption is crucial as it offers an overview into a company's readiness for substantial changes in products or business models towards the implementation of IR 4.0.

A variety of categories involved in the aerospace sectors. The aerospace sector includes the production of satellites, planetary probes, orbital stations, shuttles, spacecraft launch vehicles, and related components (United Nations. Statistical Division., 2004). Component aircraft like large assemblies' fuselages, wings, doors, control surfaces, landing gear, fuel tanks, and nacelles are including in the manufacture of components class.

Furthermore, the aerospace industry encompasses various tiers, including original equipment manufacturers (OEMs) until raw material suppliers. Tier 1, Tier 2, and Tier 3 are the three primary tier levels in the aircraft industry. In the manufacturing of a single aeroplane, every tier is essential (Azian Ibrahim, 2023). According to (Igor Ortiz Bilbao, 2019), the revamped 787 supply chain structure enables Boeing to establish closer connections with its strategic partners, numbering around 50 tier 1 collaborators. Within the B787 supply chain, Boeing's tier strategic partners are tasked with delivering complete sections of the aircraft. This streamlined process allows Boeing to assemble these sections within a mere three days. The integration of both virtual and physical structures is imperative for facilitating swift adaptation across the entire lifecycle, spanning from innovation to production and distribution. This holds particular significance within manufacturing companies but to reaching this integration, complexity of manufacturing processes will increase and lead to challenge in implementation of IR 4.0 (Schumacher et al., 2016).

1.2 Problem Statement

As technology continues to advance significantly, interest in IR 4.0 has been expressed by both academics and industry. IR 4.0 is a revolutionary development that has transformed ways manufacturing operates. The emergence of IR 4.0 and the consequent growth of the concept and its field of study are an outcome of advancements in market dynamics, market development, internationalization, and growing competition (Salam, 2019; Tiwari, 2021). Currently, only 30% of Malaysian manufacturers are familiar with the idea of IR 4.0 (Ling et al., 2020). Several research works focused on the readiness of IR 4.0, focusing specifically on SMEs because of their prominence in the nation's manufacturing sectors. According to (Ghafar et al., 2020), small and medium-sized aviation firms in Malaysia are still in the early phases of preparation. In order to determine the direction of these companies in the context of IR 4.0, (Saaid et al., 2019) used the technology readiness level methodology and appropriate maturity models to assess the preparedness of Malaysian aerospace companies with regard to the scope of IR 4.0. Furthermore, Malaysia's readiness level for IR 4.0 is currently rated as average, which presents challenges, especially with regard to facilities and human resources. As such, a great deal of effort is being put into helping SMEs understand and invest in IR 4.0 (Saleh et al., 2022). Though SMEs are the main focus, not much research has been done in Sendirian Berhad (Sdn Bhd) companies in the aerospace industry. Moreover, studies evaluating the IR 4.0 readiness of aerospace manufacturing companies are limited, especially at the Tier 2 supply chain level. In other words, there is a limited number of studies on the relationship between IR 4.0 dimensions and the readiness for IR 4.0 technology. Therefore, it is believed that an IR 4.0 readiness assessment is essential to determine the level of readiness of aerospace companies for IR 4.0 implementation.

The aerospace industry is well known for its high costs involved with each mass production and development. This industry is working towards encouraging innovation by investigating ways to improve production in order to achieve optimal efficiency and high levels of flexibility. Despite being perceived as adventurous in exploring new technologies, aerospace industry usually takes a cautious and conservative approach and tends to prioritize safety and limit uncertainties. This conservative strategy is essential due to small profit margins and strict safety requirements which critically assessing them to ensure meaningful benefits (Eike Stumpf, 2022). IR 4.0 have potential save costs related to new technology and product development by enabling aircraft manufacturers in reducing waste and avoiding errors. Given that IR 4.0 technology reduces time and money, it thus proves to be economically feasible in the long term. However, as new technology and development in aircraft manufacturing cost is higher, the adoption of digital technologies of IR 4.0 may