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Integration of IR 4.0 Into Six Sigma for Sustainability in Malaysia Manufacturing Industry

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ABSTRACT

The high competition among manufacturing companies in relation to the food and beverages industry has triggered the industry to evolve into a smart manufacturing system. The present reviewed literature reveals the relationship between industrial revolution 4.0 technologies (IR tech), six-sigma (SS) and sustainable performance. Studies have shown that six sigma practices have significantly impacted organizational performance in the manufacturing industry. However, the integrated effects of six-sigma practices and IR 4.0 technologies on sustainable performance are yet to be empirically investigated in the context of the food and beverage industry in Malaysia. Therefore, this research intends to address the gap by having a preliminary conceptual approach to the joint effect of SS and IR 4.0 technologies on sustainable performance by reviewing, analyzing and synthesizing previous studies. The study aims to confirm the future direction of the food and beverages industry that is recently employing new technologies in its manufacturing system. The consequent study shall be based on data collection from middle management employees who are working and familiar with the production phases of the industry. This study is pivoted from the theories of practice-based view and contingency posing as the underpinning theories. The study reaffirms the importance of operations management practices for any strategic implementation to be successful and how sustainable performance is enhanced through performance variations.

Keywords: *Contingency Theory, Industrial Revolution 4.0 Technologies, Practice-based View, Six Sigma Practices, Sustainable Performance*

INTRODUCTION

The competition among manufacturing industries has motivated a lot of organisations to upgrade to smart systems from the conventional manufacturing system (Zhong, Xu, Klotz & Newman, 2017). The manufacturing processes are agile, intelligent, well equipped and more flexible to meet the challenges in global and dynamic markets in smart manufacturing systems. Kamble et al. (2018) reported that industry 4.0, also known as intelligent and smart manufacturing, expedites the current manufacturing system towards improving intelligent, open, automated and digital manufacturing platforms for industrially-inclined informative applications. A manufacturing environment in a value chain equipped with industry 4.0 provides all the information flows and physical processes in real-time to the connected partners (Vaidya, Ambad & Bhosle, 2018). Also, Kamble et al. (2018) added that, manufacturing

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organisations employed Industry 4.0 technologies (IR Tech) to achieve sustainability through improved product quality and work environment, reduced lead time, employee morale, and customised products. Luthra and Mangla (2018) identified IR tech as a significant initiative for manufacturing systems to achieve economic, ecological and social sustainability in an emerging economy.

Malaysia as a country, located strategically at the centre of south-eastern Asia provides huge opportunities for international component and product manufacturing organisations to standardize operations and distributions in many industries. In current years, enormous attention was given to sustainable manufacturing practices as efficient solutions to improve expansion and continuous growth in the manufacturing industries of Malaysia (Habidin, Zubir, Fuzi, Latip & Azman, 2015). Evidence from the Malaysia-German Chamber of Commerce and Industry (2012) have shown that international component manufacturers (such as Continental, Delphi and Denso and Bosch) and manufacturing companies have attracted Malaysia to launch their products and meet the demands of the consumers in the country. Nevertheless, there is a need for the Malaysian government to redefine and re-strategize its policy on technology advancement to meet up with foreign product standard entry. This is a step to ensure there is consistency in the performance of the local companies and safely compete in the global and regional markets. Thus, standardized structural and manufacturing practices are urgently needed to enhance and computerize manufacturing activities.

LITERATURE REVIEW

Sustainability in services and manufacturing organizations has attracted significant attention from various research projects and business practitioners in the world. The practices and theories of sustainability have become a crucial issue within the dynamic business development of manufacturing (Despeisse, Mbaye, Ball & Levers, 2012). The integration of IR 4.0 and six- sigma provides a lucratively cost-saving advantage in a critical situation to apply lean technique practices. However, there are still scanty researches that considered the relationships between IR 4.0, six-sigma and sustainability (Tortorella & Fetterman, 2018; Wagner, Herman & Thiede, 2017). There is a lack of awareness of how IR 4.0 Tech enables and facilitates the successful application and integration of IR 4.0 and six-sigma to influence sustainability (Buer, Strandhagen & Chan, 2018). As there is no study yet to date that empirically investigated the relationship between IR 4.0, six-sigma and sustainability performance specifically in the food and beverage industry, the current study is undertaken to fill in the gap. This study draws on the emerging research on IR 4.0, six-sigma and sustainability performance to develop and validate a model that examines the relationships between the constructs.

Sustainability

Globally, there is growing deliberation on sustainability in the manufacturing industries; while this discussion was mainly focused on the society level at first and then on environmental problems, it is now obvious that the topic is increasingly relevant worldwide for companies (Zink, 2014). Many international organizations in terms of product quality, customer relationship, competitive positioning, environmental management and supply chains management, operational practices, strategic plan and action, material selection, and continuous growth and expansion have taken the opportunities to implement sustainable practices (Ullah, Hashimoto, Kabo & Tamali, 2013; Yuan, Zhai & Domfeld, 2012). Furthermore, the awareness of sustainable practices in manufacturing industries has turned out to be paramount due to the rise in contemporary issues. This broad array of manufacturing practices has been attempted to be redefined into the framework of sustainability by some researchers. Additionally, Yuan et al. (2012) posit that sustainable manufacturing practices are the best approaches to enhance the continuous expansion and growth of the manufacturing industry. From the Annual Report of PROTON (2011), it is reported that the company utilized optimization techniques, standard products and processes and productive models to increase scoring methods of sustainability in the Malaysian business environment. Thus, a development programme through six sigma practices is an approach to facilitating

the competitiveness and efficiency of a firm with the current business needs in the manufacturing industry (Habidin & Yusof, 2012; Nordin, Deros & Wahab, 2010).

Moreover, sustainable performance is a product of performing business and transactions towards sustainable enterprise which are made by creating an innovative and constructive culture (Hassan, Akanmu & Yusoff, 2018). A developed healthy culture can enable environmentally high performance to maximize the use of available assets in a way that leads to good outcomes within the environment, economy and society (Dunphy, 2011). According to Chen, Okudan and Riley (2010), there are three categories of sustainability: social, economic and environmental sustainability. The sustainable management addressed by Guan, Cheng and Ye (2010) referred to it as a new management paradigm focusing on the incorporation of the environment, economy and society through some sets of practices and processes such as procuring, producing, packaging, transporting, consumption, disposal of the end life products and storage as enhanced by sustainable management technologies with a final goal of achieving social, economic and environmentally sustainable development. By making emphasis the significance of social cohesion to work together, economic growth, environmental protection and a sustainable development strategy are published by the European Commission for organizations (Pei, Amekudzi, Meyer, Barrella & Ross, 2010). Notably, the food and beverages industry is a spectacular industry that offers significant economic growth and creates employment (Akanmu, Hassan & Bahaudin, 2020). However, the sector is facing challenges as the current market demands a diverse product with price reduction and frequent delivery within a short period of time. Due to this situation, continuous improvement initiatives (CII) could serve as an enhancer to tackle the challenges for global market survival. Six-sigma is one of the two widely employed and best CII that can be incorporated with IR 4.0 Technologies as a hybrid system.

Within the past three decades, Malaysia has experienced spontaneous growth. The economy of Malaysia and its society at large has been technologically affected by industrial resources and globalization with encouraging opportunities from foreign direct investment (FDI). However, the depleting resources and competition from neighbouring countries have led to the recent challenges of de-industrialisation (Hussain & Byrd, 2016). Securing jobs, safe food and environment and sustainable income will be challenging without industrialization. Food and beverages manufacturing firms, in particular, are facing a difficult time surviving due to unfriendly operating environments and the global economic meltdown. Despite the lucrative potentials of agro-based product business, many challenges (such as lack of distribution capabilities and marketing to penetrate the regional and international market; low quality in productivity and products; low productivity among entrepreneurs) are the proffered solutions to remain competitive in the industry.

Therefore, the proposed framework applied to assess sustainable performance in this study is classified into three measurements as supported by previous studies on sustainable performance. The measurements are environmental sustainable performance, social sustainable performance and economic sustainable performance (Akanmu, Hassan, Bahtiar & Nordin, 2021; Eweje, 2011). Thus, to embrace the idea of sustainable performance absolutely, these three measurements are crucial to paddle a business success now and in the future.

Six Sigma Practices

The present highly and rapidly changing market has placed many companies under pressure to adopt sustainable practices in terms of maintaining an equilibrium of social, economic and environmental performance (Abualfaraa, Salonitis, Al-Ashaab & Ala'raj, 2020). In this vein, the approach of six sigma manufacturing combines the practices that focus on the demand of customers and reduce environmental adverse impact that has gained popularity. However, the six sigma practices are still new, lacking clear structured definitions and evidence of successful cases in the industry. A significant number of services and manufacturing organisations have internationally and widely adopted six-sigma as a strategy since the middle of the 1980s for business process improvement (Antony

& Sony, 2019). Also, high profile companies such as Bank of America, Caterpillar, Johnson and Johnson, General Electric, Cummins, American Express, Allied Signal and ABB have popularised and legitimised this methodology of problem-solving leading to bottom-line savings of millions of dollars (Antony, Snee & Hoerl, 2017).

Six-sigma is adopted by the organisation as an effective tool and problem-solving approach spearheaded by specialists in process improvements, such as the Green Belts (GB) and Black Belts (BB). The six-sigma focuses more on reducing errors during a critical process that can lead to low quality among its consumers. Shah, Chandrasekaran and Linderman (2008) stated that the principles under the operations of six-sigma are set to create robust products, services and processes, improve the process average and minimise variations in processes. Schroeder, Linderman, Liedtke and Choo (2009) in their study defined six-sigma as "an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics to achieve strategic objectives". This definition of six-sigma is considered to be the most comprehensive definition to date as it contains both the "what" and "how". Moreover, several service sectors and industries have adopted the six sigma initiatives (Aqlan & AL-fandi, 2018; D' Andreamatteo, Ianni, Lega & Sargiacomo, 2015). The manufacturing practices have been used to effectively improve companies' performances (Drohomeretski, Gouvea da Costa, Pinheiro de Lima & Garbuio, 2014; Negrão, Godinho Filho & Marodin, 2017). Its adoption is however still very low in the food and beverages industry (Dora, Van Goubergen, Kumar, Molnar & Gellynck, 2014), both in developing and developed countries (Manzouri, Ab Rahman, Saibani & Zain, 2013; Scott, Wilcock & Kanetkar, 2009).

As indicated by past studies, there are still insufficient papers that illuminate the shortcomings of Six Sigma (Chakravorty, 2010). The emerging trend of six-sigma offers the platforms needed by both the academic and industrial fraternities to grow further in the problem-solving situation with this powerful methodology (Antony & Sony, 2019). Therefore, this study systematically reviewed previous literature to examine the emerging trends and shortcomings of six sigma followed by evaluating the findings from a conceptual approach. The study shall subsequently employ questionnaire survey protocols targeting process improvement experts in both service and manufacturing organisations (such as the Green Belts and Black Belts). Both the leading academics and the practitioners should understand the shortcomings of six sigma so that organisations can develop strategies to reduce their impacts by addressing such shortcomings.

Industrial Revolution 4.0 Technologies

Malaysia is considered one of the countries keeping abreast with the emergency of industrial revolution 4.0. "The success of (ride-sharing and e-hailing app) Grab and a home-grown service is an example of the dependence on internet technology for advancement. Malaysians are ready to become a player and mobiliser of this new revolution" said Dr Sawal Hamid, a Senior Lecturer from the Department of Electrical, Electronics and System Engineering, Universiti Kebangsaan Malaysia (The Sun Daily, 2018). Thus, Malaysia is on its way to becoming an internationally renowned manufacturing country if access to the latest industrial technologies is made easier through the adoption of modern manufacturing practices.

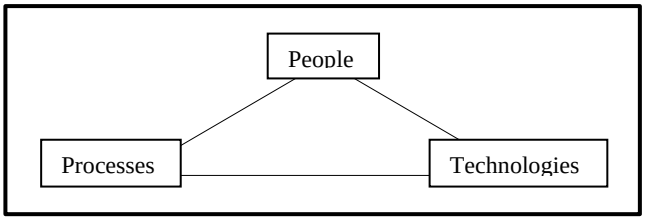

Figure 1: Three Pillars of the Industrial Revolution

The historical background of industrial revolution 4.0 in the last two centuries unfolds a dynamic change to automation (e.g., automated production) and information technology from the power sources, and then connectivity. The industrial revolution revolves around three resources: process, technology and people with each of these initiating a circular pattern of mutual effect and driving the change as shown in Figure 1. Furthermore, Industrial Revolution 4.0 is a digital manufacturing system provided by the incorporation of systemic techniques, information technologies and production processes. Ahuett-Garza and Kurfess (2018) mentioned that the main aim of Industrial Revolution 4.0 is to offer improvement in terms of responsiveness and efficiency in a manufacturing mechanism. The principles of vertical and horizontal incorporation of manufacturing systems guide the operations of Industrial Revolution 4.0 and are orchestrated by the real-time data interchange between many partners in the manufacturing value chains (Fatorachian & Kazemi, 2018; Li, Tang, Wang & Liu, 2017). The Internet of Things (IoT), big data analytics (BDA), additive manufacturing (AM), robotic systems (RS), cyber-physical system (CPS), augmented reality (AR) and cloud computing (CC) are considered significant Industrial Revolution 4.0 technologies that improve the integration of the processes resulting to improved sustainable performance (Kamble, Gunasekaran & Gawankar, 2018; Liao, Deschamps, Loures & Ramos, 2017).

The core components of the Industrial Revolution 4.0 technologies are IoT, CPS and CC. The CPS is the integration of several physical systems such as a computer system (e.g., central processing unit), lathe machine, and other equipment, milling machine and CNC that allow the adaptability of the entire factory arrangement (Ivanov, Dolgui, Sokolov, Werner & Ivanova, 2016; Karakose & Yetis, 2017). As shown in Figure 2, communication between products, humans and machines are enabled by the CPS.

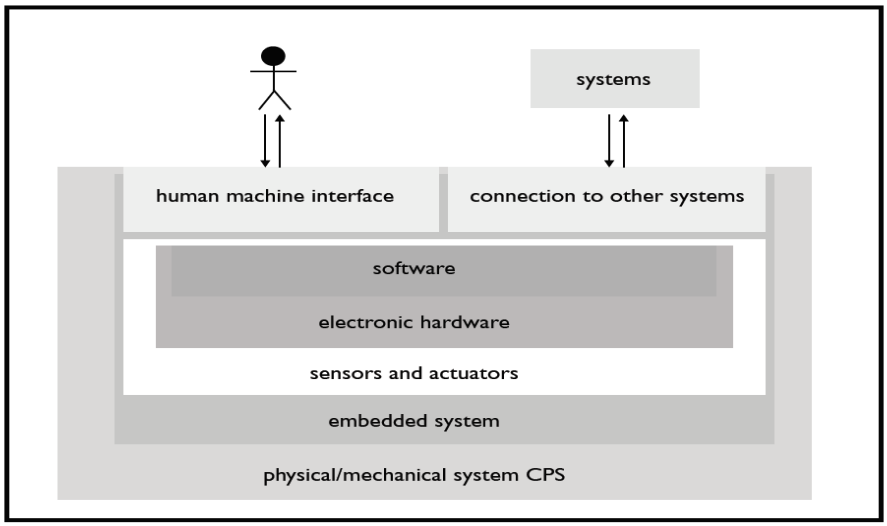

Figure 2: Interaction via Cyber-Physical Systems between Machines and Humans

According to Liu and Xu (2017), the CC serves as a third-party service provider for the purpose of creating a database and storing data on a website. Notably, the cloud is not based on where the manufacturing activities are located, rather on a remote area. Yu, Ouyang and Peng (2017) added that ease of accessibility, improved speed of service and economy of operations are offered by the CC. Similarly, Da Xu, He and Li (2014) reported that interaction between machines without the involvement of humans is enabled by IoT. The IoT with each device possessing its unique feature utilizes a network of devices to the connected computer system. Lee, Yoon and Kim (2017) also stated that the IoT-controlled manufacturing system as a smart system remotely controls all the devices in connection with accuracy and efficiency.

A massive amount of data collection, analysis, sharing and storage technologies are generated by Industrial Revolution 4.0 technologies that enabled production systems. Also, Jeble et al. (2018) referred to business data analytics (BDA) as computer algorithm, real-time data collection and the use of analytical techniques to derive insightful patterns to improve decision-making. Also, Wamba et al. (2017) added that BDA enhances competitive advantage and business performance sustainability. In addition, BDA is extensively used by manufacturing organizations and they are required to improve the capability of the BDA to explore the benefits of virtual manufacturing systems (Moyne & Iskandar, 2017; Yuan, Qin & Zhao, 2017). According to the report of Brito, Ramos, Carneiro and Gonçalves (2019), the transformation of technology to the present Industrial revolution 4.0 is intensified by nine grounds of advanced technology (as shown in Figure 3): cyber-security, cloud computing, simulation, vertical and horizontal systems integration, augmented reality, autonomous robots, industrial IoT, bi-data and analytics and additive manufacturing.

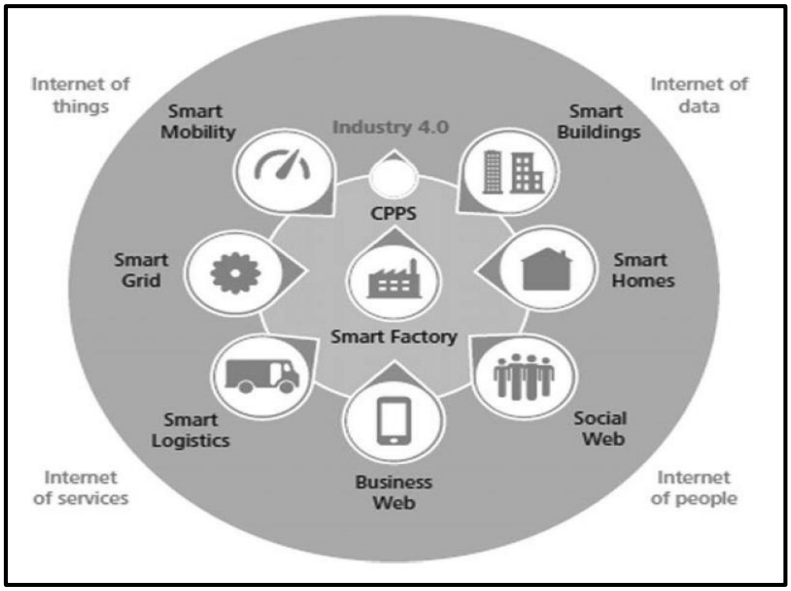

Figure 3: Nine Technologies of Industrial Production (Source: Doh, Deschamps & de Lima, 2016)

Nonetheless, implementing Industrial revolution 4.0 technologies is not devoid of limitations. Carvalho, Chaim, Cazarini and Gerolamo (2018) posit that it is a major barrier as human controls the adjustment goals and implementation process even though Industrial revolution 4.0 technologies can adjust quickly to the manufacturing environment. Nevertheless, past studies predicted that Industrial revolution 4.0 technologies would contribute to the objectives of organizational sustainability (Carvalho et al., 2018; Kamble, Gunasekan & Gawankar, 2018; Lin, Lee, Lau & Yang, 2018). Thus, this study found that six sigma integrated with IR 4.0 Tech has a great impact on the manufacturing industry and it is worthwhile to be explored specifically in the food and beverages industry in Malaysia.

METHODOLOGY

The research approach is post-positivism which is considered a research pattern performed with the activities starting from the problem identification, review of literature, identification of research purpose, data collection and analysis, data interpretation and reporting (John & Ngoasong, 2008). These steps are followed in achieving the aim of the study in strict terms. As the objective of this study is to determine the effects with the view of predicting and analysing the nature of the relationships using hypothesis testing and statistical computation, a quantitative approach is suitable and employed in this

study (Zikmund et al., 2010). The variables of this study are all continuous, so a questionnaire survey is therefore appropriate as a survey instrument.

Data shall be collected from the employees of the companies who are in middle/top management capable of attending to issues discussed in the background of the study. Hence, the sample is drawn from the accessible population. This survey shall be individually administered to the companies' representatives. The items to be designed are the questions developed to ask under each construct. On this foundation, the food and beverages companies of Malaysia which is a subset of the agro-allied industry is the target population. The population is addressed from the directory of the Federation of Manufacturers in Malaysia in collaboration with the External Trade Development Corporation (FMM MATRADE industry directory, food and beverages, 2017). In addition, this study shall employ simple random sampling as every individual within the target population has the same probability of being selected. This study shall use smart PLS 3.0 by Ringle et al. (2015) as the analysis tool. The tool is a powerful multivariate analysis technique comprising special case versions of other analytical methods (Ringle et al., 2015).

In accordance with the research problem, the study investigated the relationship between the dimensions of six sigma (i.e., six sigma role structure, six sigma structured improvement and six sigma focus on metric) and sustainable performance concerning environmental, economic and social sustainable performance and the significant impact of industrial technology 4.0. Therefore, to examine the effects of the six sigma role structure, six sigma structured improvement and six sigma focus on the metric being practised under six sigma on sustainability performance by involving industrial revolution 4.0 is the purpose of this research.

DISCUSSION

This study raises many ideas and insights regarding the trending issues related to sustainable performance in Malaysian food and beverages companies. This current study is one of the few research to be conducted in the Asian region, Malaysia in particular to investigate the impact of six-sigma on sustainability performance using IR 4.0 technologies in the food and beverage manufacturing industry. From the literature review, a conceptual model is developed as illustrated in Figures 4 and 5 below:

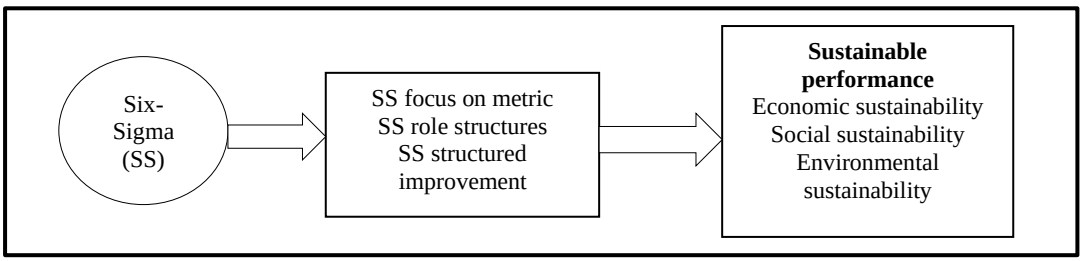

Figure 4: Development Stage of the Conceptual Framework of the Study

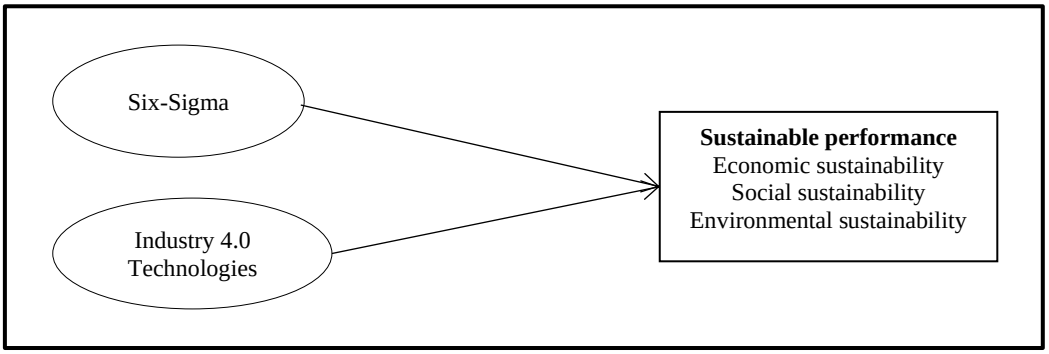

Figure 5: Research Model

The Practice-Based View (PBV) and Contingency Theory are the underpinning theories premised on the theoretical background of this study. The contingency theory provides protocols for selecting a set of management practices that are best appropriate for a given context of an organisational operation (Sousa & Voss, 2008) while Bromiley and Rau (2016) stated that, some firms do not fully utilise all the beneficial practices; so the use of the practices that can better explain performance variation is the central argument of adopting PBV. Some of the potential contributions of this study are highlighted below:

Theoretical Contribution

The topic of industrial revolution 4.0 has drawn attention from various fields of research from the existing significant number of research papers from reputable journals. Therefore, this study is carried out to expand the knowledge on the relationship between six sigma practices, IR 4.0 technologies and sustainability performance. In accordance with the findings from the previous research, the conceptual model of the study is developed and shall serve as a guide to hypothesising the relationship between the variables. Also, this study demonstrates the importance of six-sigma specifically in Food and beverages companies. It contributes to the theories of the six sigma literature by re-examining the unresolved matters regarding the relationship between the existing manufacturing practices, six-sigma and sustainability. The discrepancies among scholars on the effect of manufacturing practices on sustainability have called for further investigation and discussion. Moreover, this study significantly contributes to past research by incorporating IR 4.0 Tech as the new innovative practice and strategy to the theoretical framework to explain the variances in the constructs of sustainability performance.

Practical Contribution

Similarly, the study presents critical implications for the consultants and practitioners engaging in the application of IR 4.0 Tech and six-sigma in manufacturing companies. The review shows that the IR 4.0 Tech is in different stages of implementation in manufacturing industries. The IoT, the BDA, CC are given the highest consideration for implementation, followed by robotic systems (RS), additive manufacturing (AM), and augmented reality (AR). Challenges in this industry such as poor management support, lack of competency, reluctant behaviours, financial constraints, and low awareness are the significant barriers to implementation that can be solved by the right application of IR 4.0 Tech (Luthra & Mangla, 2018). The results also have significant implications and contributions for policy-makers, practitioners and managers. Thus, there are many advantages from the insights on how the aforementioned manufacturing practices will enable the overall sustainability performance.

Methodological Contribution

Furthermore, this study strengthens and expands the existing boundary of literature by examining the relationship between the dimensions (i.e., six sigma structured improvement procedures, six sigma focus on metrics and six sigma role structure) and sustainable performance concerning environmental, social and economic sustainability and the significant impact of Industry 4.0 Tech using Smart PLS-SEM as the analysis tool. Therefore, by integrating the joint effects of those constructs and employing the analysis technique, this study has uncovered a unique approach to better understanding the constructs of the research.

The study focuses on the effects of six sigma and industrial revolution 4.0 technologies on sustainability in the food and beverages industry. With this aim, the food and beverages companies in Malaysia are selected to be the population of the study; and as stated earlier, data shall be collected from the top/middle management of the companies. This study shall employ a quantitative approach to meet the aim of the study. This comprises a questionnaire survey that will be administered to the heads of sections or sub-department among food and beverages companies. The study considers the FMM food manufacturing group (FMM MAFMAG) and Malaysian Food Canners' Association (MFCA) for the production and packaging of food and beverages respectively.

CONCLUSION

From the previous studies on Six Sigma, IR 4.0 Technologies and sustainability performance and current issues in the manufacturing companies, the problems in the industry are discovered to be a low level of disposable income, unfriendly operating environment, weak innovation capacity, low sustainability performance, toxicity from waste generated, limited development and growth opportunities, poor infrastructure and scarcity of products throughout the year. Thus, more studies are needed on mechanisms by which manufacturing firms operate and their impacts across multiple levels of organization in terms of competitive advantage and development aiming at environmental, economic and social impact assessment. These long-term benefits directly affect organizational sustainability. Sustainable practices offer a new strategic approach to increase both the efficacy and effectiveness of business performance when it has been successfully implemented.

Due to the complexity of the questionnaire structure capturing aspects like sustainability, financial performance, environmental practices, modern technologies, six-sigma elements, the questions can be responded to together by the directors managing research and development, marketing, finance, exports, operations management, secretarial and legal issues, human resources technicalities and other relevant departments based on the discretions of the company.

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