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COMPARATIVE STUDY OF LEAN SIX SIGMA PRACTICES FOR SUSTAINABILITY: A BLUEPRINT FOR POST COVID-19 PANDEMIC

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ABSTRACT

The global crisis caused by Covid-19 and its impact on the healthcare system has been far-reaching and challenging in virtually all countries. Lean six sigma in Malaysia has never improvised an account for this case of the uncommon event as it only focuses on daily operations and productions that are in stability and in alignment with the demand to capacity. This study, therefore, attempts to make comparison from the previous researches on lean practices, six sigma, industrial evolution, and healthcare sustainability to investigate where the paucity of literature lies and to deploy new strategies for the post-pandemic. The study employs a review of literature methodology by following 3 stages: review planning; conducting of the review; and report of the review. Currently, the healthcare industry is motivated to update its conventional delivery systems to smart sophisticated systems due to the growing challenges within the services organization. The study found that integrating industrial revolution (IR) 4.0 technologies into the services optimizes sustainable healthcare management. As providing affordable, reliable, and safe healthcare while improving efficient performance remains challenging in the healthcare industry, this study posits that a hybrid of lean practices, six sigma and industrial revolution technologies are enhancers of economic, social and environmental sustainability. The study also reveals the contribution of services and operations management practice and how the strategic implementation of modern technologies and performance variation can improve sustainable performance in the healthcare sector.

Keywords: Healthcare industry, lean practices, sustainability, six sigma, industrial revolution technologies.

INTRODUCTION

According to Leite et al. (2020), the outbreak of Covid-19 and the increase in patients who need hospitalization has shown the setbacks in the present healthcare operations and systems. These healthcare systems lack the capacity to sustain the sudden outbreaks, as for instance, there are insufficient ventilator, personal protective equipment and intensive care unit (ICU) beds. Similarly, the growing in the cost of healthcare services are impactful to the present challenges of affordability, safety and reliability in the basic healthcare of limited budgets on healthcare in both developed and developing nations while high performance, service quality and improved efficiency are still expected to sustain the healthcare challenges (Deblois & Lepanto, 2016). The healthcare providers and policymakers with the current trending issue are now advocating for integration of lean practices to minimize waste and cost, and to optimize healthcare delivery values as done by other industries (Hallam & Contreas, 2018). Due to this, there has been increasing demonstrated interests among industries in both leaning and greening activities (Zhu, Johnson & Sarkis, 2018). The lean manufacturing practices on one hand laid emphasis on waste elimination with an affinity with environmentally sustainable practices within industries. One the other hand, lean six sigma has diffused into the manufacturing and service industry while interest in the industrial revolution 4.0 has simultaneously grown in the healthcare industry. As good service quality is influenced by human and environmental factors, implementation of statistical process control, human involvement and integration of modern manufacturing equipment has become imperative in healthcare environment. Therefore, this study tends to compare past studies on lean practices, six sigma, industrial revolution 4.0 as applicable to sustainability in healthcare sector from Malaysian and international perspectives.

LITERATURE REVIEW

Sustainable Performance

An organization achieved sustainability when there is continuous creation of values for the shareholders and customers while complying with environmental regulations (Akanmu & Mohamad, 2021; Brent & Labuschagne, 2004). There are few essentials to the sustainability performance value of a firm: catering for the satisfaction of the customers and the shareholders and performing adequately well in the society at large (Hassan et al., 2018; Hassan et al., 2019). Sustainability performance entails practices that improve useful life of an organization, maintain personal freedom, welfare, participation of people in the present and future generation, promotes the capacity of renewal and maintenance of the ecosystem viability, sustain standard living and enhance the societal ability to maintain itself when solving crises (Dunphy, 2011). Hassan et al. (2018) added that sustainability is the result from making transaction and businesses comprising constructive and innovative corporate culture.

In addition, Dunphy (2011) reported that a well-developed healthy culture can lead to a sustainable environment thereby creating efficient performance to optimally utilize available resources in such a manner that expected results are achieved within the economy and society. The three existing classification of sustainability are: social, environmental and economic performance. Also, the European commission emphasises on sustainable development strategies from the perspectives of social cohesion to work together, economic growth, and environmental protection (Pei et al., 2010). Thus, sustainable management is a new style of philosophy that concurrently focuses on the

environment, economy and society through processes such as procurement, production, packaging and storage, transportation, consumption and end-life product disposals (Guan et al., 2011) as facilitated by technologies with the end results of achieving societal, economic and environmental sustainability (Akanmu, Hassan & Bahaudin, 2020; Akanmu et al., 2021).

Lean Manufacturing Practices

An approach called lean manufacturing is intended to minimize waste and lower production costs (Alhuraish et al., 2016). Lean manufacturing is a business strategy, according to Snee (2010) that promotes process performance, higher customer satisfaction, and the triple-bottom-line outcome. Lean manufacturing had its start with the Toyota production method, which was merged with techniques like just-in-time production to increase delivery speed and quality. According to Nordin et al. (2014), the Toyota production system (TPS) was the forerunner of the lean manufacturing concept and its goal was to eliminate non-value added and waste in order to increase quality and lower costs. Lean manufacturing is created through several techniques (Yang et al., 2017). Similar to this, the cluster of lean manufacturing methods comprises just-in-time and regulated processes, total quality management, productive maintenance, total preventive maintenance, employee participation, and total quality management (Martinez-Jurado & Moyano-Fuentes, 2014). The significance of consumer involvement and downstream collaboration has been demonstrated by recent studies. Product design, supplier relationships, production planning and control, process and equipment, and human resources are further categories under which lean approaches can be further divided. All industries can use these three categories (Bergmiller, 2006). Therefore, for lean principles to be successfully implemented, backward and forward cooperation between suppliers and consumers is crucial. To satisfy the environmental and operational goals, the items supplied are carefully produced, packed, distributed, and delivered (Dues et al., 2013). Natural environment, sustainability, and ecological performance characteristics are included in these goals aiming to achieve lean management performance.

Six Sigma

Six sigma was created by Motorola in the 1980s as another method to minimize variations and errors in the processes of production (Akanmu & Nordin, 2022a). Antony et al. (2017) stated that the importance of data analytical techniques and other statistical approaches are stated by the six sigma to create a well-optimized business processes in a way that 99% efficiency rate is achieved and variations in the results are reduced. Six sigma has been labelled a “parallelmeso” structure as it operates at macro- (organizational processes) and micro- (worker behaviour) levels simultaneously (Schroeder et al., 2008). Specifically, incorporation of individual specialists, performance metrics and structured flow chat is employed by the six sigma approach to attain the aim of minimizing error and variation. According to Gutpa et al. (2020), the fundamental phases of six sigma known as DMAIC are: define, measure, analyse, improve and control. The probable challenges, expected goals, and related factors of the six sigma initiatives are all identified by specialists; this provides the entire DMAIC stages.

The “measure” stage starts with data collection to know the present outcome, quality, and procedure after defining the scopes of the issues. The analysis phase comprises understanding the practices, processes and the procedures required to achieve the aimed result from the process. The phase of “improve” introduces the changes to the procedure or/and processes after identifying the root cause in order to address the sources thereby reducing the variations and error in the outcomes to achieve 99% rate of efficiency. Lastly, the policies and plans are set forth in the phase of control in order to ensure that the improvements in the previous phases are moved forward (Gutpa et al., 2020). Specifically, each of the phase utilizes a statistical technique to guide the steps involved.

Industrial Revolution 4.0 Technologies

For the past three decades, a paradigm of change to power source from power, then to automation, internet connectivity and information technology has been highlighted from the history of industrial revolution (IR). Notably, the industrial revolution revolve around three major classifications: technology, people and process (Akanmu & Nordin, 2022b; Akanmu, Nordin & Gunasilan, 2022) with one capable to change the direction and initiate reversible patterns of mutual impact. In the same vein, industrial revolution is the smart service and manufacturing systems provided by effective integration of information technologies, techniques, processes and production (Ahuett-Garza & Kurfess, 2018). Thus, the aim of industrial revolution 4.0 is to enhance responsiveness and efficiency in the manufacturing system. Fatorachian and Kazemi (2018) added that the digitalized technologies from industrial revolution operate on the concept of horizon and vertical incorporation of manufacturing system but are affected by the real-time data inter-change between many actors in partnership of the manufacturing supply chain. The cloud computing, the augmented reality (AR), the internet of thing (IoT), the additive manufacturing, the cyber-physical system (CPS), the big data analytics (BDA) and robotic systems (RS) are considered as the most important technologies of Industrial revolution that enhance the incorporation of different processes, thereby leading to sustainability (Kamble et al., 2018).

METHODOLOGY

This paper employs a review of literature methodology by following 3 stages: review planning; conducting of the review; and report of the review. From the objective of this study, the authors considered keywords such as “lean”, “six sigma (SS)”, “lean six sigma (LSS)”, “IR 4.0” and “healthcare industry” in publications from both international and Malaysia perspectives when searching online articles. Although the study focused more on journal articles published within the range of last five years but exceptions are given in few cases to give more comprehensiveness to the proposed revision and comparison. The related articles are searched from different article repositories such as google scholar and the web of science. These databases are selected as they have high relevance in terms of publications on the subject and ease of search by customizing the desired date range. The Table 1 presents the articles that focuses on the keywords in healthcare industry from the international perspective while the Table 2 presents studies on Malaysia health sectors.

Table 1

International Articles in Healthcare Industry

Authors	Context	Lean	SS	LS	IR	Sustainability	Country	Gap/Future Research
Ahmed et al. (2013)	Lean six sigma application in healthcare services	√	√	√	×	×	Open	The healthcare organizations must improve their workforce management, provide training, and increase team motivation, commitment and involvement
AlJaberi et al.	Framework for measuring	×	×	×	×	√	United Arab	Limited to Abu Dhabi in UAE.

(2017	sustainability in healthcare systems							Emirates	Future studies may focus on measuring the social sustainability of healthcare system
Antony et al. (2018)	Six sigma in Healthcare	×	√	×	×	×		All continents.	In healthcare industry, six sigma sustainability is required as a powerful business process and improvement methodology.
Bhat et al. (2020)	Lean six sigma for healthcare sectors	√	√	√	×	×		India	The implementation of LSS is still at infant phase due to lack of cross-functional collaboration among practitioners of LSS, researchers and academicians.
Britol et al. (2019)	Ergonomics: analyses of Industry 4.0 and lean manufacturing	√	×	×	×	×		Open	For the practitioners, it is more valuable if a lean implementation monitoring tool putting ergonomics aspects in consideration is developed in a more restricted scope.
Chiarini & Bracci (2013)	Healthcare issues in lean six sigma	√	√	√	×	×		Italy	There is no clarity on how many lean tools are being used within the lean six sigma DMAIC pattern and there is difference between LSS implementation in healthcare industry and manufacturing sector
Dias et al. (2018)	Lean manufacturing in Healthcare	√	×	×	×	×		Open	Only few jobs related to lean manufacturing areas

									explored healthcare environment despite the importance of the theme.
Hallam & Contreras (2018)	Lean and Sustainability	√	×	×	×	√	Open	Better comprehension of how healthcare performances can be improved through practical lean healthcare management practices	
Henrique & Godinho (2018)	Lean and six sigma in healthcare	√	√	×	×	×	Open	More comprehensive and empirical studies on potential and results of lean and six sigma –related works in healthcare	
Ilangakon et al. (2021)	Industry 4.0 and lean for healthcare operational performance improvement	√	×	×	√	×	Sri Lanka	The study is limited to IR technologies such as IoT, cloud computing and big data alone, and lean practices such as 5S and value stream.	
Improta et al. (2019)	Lean Six Sigma in healthcare - surgery for patients	√	√	√	×	×	Italy	The patients may be studied using a method the same as the analysis of the length of hospital stay (LOS) through LSS methodology.	
Kuiper et al. (2021)	Lean Six Sigma in healthcare after the COVID-19 crisis	√	√	√	×	×	Netherlands	The result generalizability might be limited for focusing just on Netherlands	
Mason et al. (2015)	The application of Lean and six sigma in surgery	√	√	×	×	×	Open	There is no formal recommendation on the use of LSS methodologies in improving outcomes in surgical practices	
Swarnak	Sustainable lean	√	√	√	×	√	India	The study can be	

ar et al. (2020)	six sigma framework implementation in healthcare organization								replicated in other countries with a small modification in critical failure factors
Taner et al. (2007)	Implementation of six sigma in the healthcare industry	×	√	×	×	×		Open	Focusing on the core healthcare issues and quality improvement of lives of the patients is impactful through six sigma
Vaishnavi & Suresh (2020)	Using total interpretive structural modelling technique to develop lean six sigma in healthcare organization	√	√	√	×	×		India	The study focuses only on factors of readiness in implementation of LSS in healthcare industry. Future studies can extend total interpretive structural modelling approach to structural equation modelling
Vaishnavi & Suresh (2021)	Using fuzzy logic method on lean six sigma healthcare organizations	√	√	√	×	×		India	The study used only one hospital. Fuzzy readiness for LSS index implementation may be applied at various levels of healthcare organizations.

Notably, the international articles focusing on countries such as India, Netherlands, Italy, Sri Lanka and some cases, the whole continents suggested the limitations in their studies and the voids the future researches need to fill. Some of these papers do not cover all the required themes as highlighted in this study such as how six sigma and lean manufacturing combined with implementation of IR 4.0 can lead to healthcare sustainability. Therefore, this study capitalizes on the gaps and employ the approaches to improve healthcare operations in Malaysia after the Covid-19 pandemic. Table 2 reveals that authors who are interested in this aspects of health sectors in Malaysia are significantly small although are renowned scholars. Due to this, it is necessary to urge more researchers and research institutes to rethink how to account for the event as the pandemic is likely to become endemic. On top of that, the variations in the healthcare demands and the possibility of outbreaks will increase just like there is another variant virus called the SARA-CoV-2 Omicron (Cele et al., 2021). Thtrefo, there is a need to prepare for the future in case of any reoccurrences.

Table 2

Malaysian articles in healthcare industry

Authors	Context	Lean	SS	LSS	IR 4.0	Sustainability
Ahmed et al. (2018a)	Quality performance (effects)	√	√	√	×	×
Ahmed et al. (2019)	Six-sigma initiatives in private hospitals	×	√	×	×	×
Ahmed, et al. (2018b)	Quality performance (measures)	√	√	√	×	×
Anuar et al. (2018)	Operations performance in private hospitals	√	×	×	×	√
Habidin et al. (2014)	Supply chain innovation in lean healthcare practices (exploration)	√	×	×	×	×
Habidin et al. (2015)	Improving emergency department waiting time	√	√	√	×	×
Habidin et al. (2016)	The mediating roles of supply chain management between healthcare lean practices and healthcare performances.	√	×	×	×	×
Khaidir et al. (2013)	Effect of six-sigma practices on the performance of an organization	×	√	×	×	×
Khaidir et al. (2014)	Process innovation in six sigma practices	×	√	×	×	×
Norazlan et al. (2014)	Kaizen blitz and sustainability	×	×	×	×	√
Norazlan et al. (2014)	Supply chain management for sustainable performance	×	×	×	×	√
Raja Sreedharan et al. (2018)	Synergizing LSS and Human Resources practices	√	√	√	×	×

RESULT AND DISCUSSIONS

Sustainability in Healthcare

AlJberi et al. (2017) found that there is urgent need to study the measure of social sustainability in healthcare organizations. Sustainable performance is attained in any organization when continuous values are built for the stakeholders and the shareholders while complying with the environmental and social regulations. According to Hassan et al. (2018), there are few essentials parts of sustainable

performance values: adequately performing for the environment and the society at large and making the customers and shareholders satisfied. Sustainable performance entails practices that: promote the capability to resuscitate and sustain the viability of the society and the ecosystem, and providing panaceas during crises and maintain decent life; enhance useful life of an organizations; promote personal freedom and participation for current and future human generation; and provide for the living beings. In addition, Hassan et al. (2018) reported that sustainable performance is an outcome of a successful execution of business transaction towards sustainable enterprises that are created through constructive and innovative corporate culture. The philosophy of sustainable lean practices appears to possess the potentials to enhance significantly the healthcare system performance as it has been tested and approved by many industries (Hallam & Contreras, 2018). However, the practices may have subtle difference that make them industrially specific transformations more critical and thus posing a challenge to sustainable performance.

Furthermore, Akanmu et al. (2021) investigated the three categories of sustainable performance to be environmental, economic and social sustainability performance. Also, Pei et al. (2010) reported that the European commission confirmed sustainable development strategy to entail practices align with economic growth, environmental protection and social cohesion. Similarly, sustainability consists of practices that improve socially the useful live of a firm and safeguard all the living species (Akanmu & Nordin, 2022c). Thus, there is need for better comprehension of how healthcare sustainability is improved using practices under lean healthcare management (Hallam & Contreras, 2018).

Lean Practices in Healthcare

Lean practices, according to Snee (2010), are a corporate strategy or approach that improves customer satisfaction, triple bottom line results, and process performance. Lean is intended to minimize waste and lower manufacturing costs (Alhuraish et al., 2016). This kind of philosophy based on improving the standard of living of people together with the demands of customers has led to growing quality service demands, has resulted in the increasing generation of wastes and pollution. As a consequence, lean practices are seen as a movement developed to be more effective while providing consumers with pleasure that goes above and beyond their expectations, leading to a reduction in waste and an improvement in safety and health-related challenges (Ratnayake & Chaudry, 2017). Furthermore, different techniques combine to make lean practice (Yang et al., 2017). Just-in-time, complete preventive maintenance, employee participation, productive maintenance, total quality management, just-in-time, and regulated processes are included in the cluster of lean practices. According to recent research (e.g., Martinez-Jurado & Moyano-Fuentes, 2014), consumer involvement and downstream collaboration are crucial in lean practices.

Also, various strategies of process improvement have been implemented by many healthcare establishments around the world for the manufacturing industry to achieve service excellence (Habidin et al., 2016). In this study, lean techniques that are combined with IR 4.0 technologies are thought to have significant effects since most business activities are more likely to be service-oriented than product-oriented, as in the case of Malaysian healthcare management (Sony & Naik, 2019). For the successful use of lean principles, forward cooperation with customers and backward coordination with suppliers are important. Accordingly, the goods are created and provided in order to achieve the operational and environmental goals (Dües et al., 2013). Environmental, sustainability, and ecological performance characteristics are among these goals that aim to achieve lean management performance.

Six Sigma in Healthcare

Sustainable sigma is required as an effective business process methodology and improvement in healthcare industry (Antony et al., 2018). The importance of data analysis and statistical techniques are highlighted in six sigma to create an effective business process and to achieve 99% rate of efficiency

and variabilities within the results (Antony et al., 2017). In furtherance, the incorporation of structured procedures, individual specialists and output criteria (performance metrics) is employed in six sigma to achieve the objectives in minimizing variations and errors. Gutpa et al. (2020) reported that, the fundamental phases of six sigma practices coined as (DMAIC) are: define; measure; analyse; improve; and control. The relevant factors, the potential problems and the expected goals of the six sigma initiatives are identified by the specialists. Focusing on the main issues and improving the healthcare quality of the patient lives is impactful through six sigma (Taner et al., 2017).

The practices, procedures and processes are evaluated under the phase “analysis” under six sigma in order to get to get the expected results after understanding the processes. To improve subsequently, the root causes are identified by introducing new changes to the procedures and processes, thereby addressing the root causes to reduce the variability and error in the outcomes and achieve 99% efficiency rate. The policies and plans are set ahead in the control phase in order to facilitate forward movement in the improvements of the previous stages (Gutpa et al., 2020). Statistical techniques are utilised by the each phase of the six sigma to guide the followed steps and final steps. Therefore, six sigma with IR 4.0 technologies are expected to be effectively integrated into the Malaysia healthcare system in order to attain the expectation and high demand of quality services. Thus, the managers and industrial practitioners of the industry should pay full attention to re-strategizing the practices, structures, and policies to meet up with the technological advancement.

Industrial Revolution 4.0 Technologies for Healthcare

Adoption of 4.0 Industrial Revolution technologies is increasingly required in the healthcare industry (Ilangakoon et al., 2021). Notably, Malaysia as a member of the Association of Southeast Asian Nations (ASEAN) is regarded as a country that keeps up with the present industrial revolution in the healthcare business. Malaysia is quickly gaining a reputation as a manufacturing powerhouse due to its adoption of contemporary production techniques, which make it simple to acquire and deliver the newest industrial technology. The history of the industrial revolution over the past two centuries reveals a dynamic shift toward automated manufacturing, quick communication, and information technology from the power source. The effective integration of manufacturing processes, information technologies, and methods into a digital manufacturing system, which is centered on three primary elements: people, technology, and processes, has enabled the industrial revolution 4.0 during the past three decades (Ahuett-Garza & Kurfess, 2018).

The adoption and use of industrial revolution (IR) on the ideas of horizontal and vertical integration of manufacturing systems is influenced by the real-time data exchange between several enterprises working together in a manufacturing value chain (Fatorachian & Kazemi, 2018). Additionally, the use of IR 4.0 technology offers employees the chance to accept and adjust to new automation systems, improving their performance at work (Kamble et al., 2020). These technologies offer a vast quantity of data collection, processing, storage, and sharing technologies to enable enhanced production systems (Akanmu & Nordin, 2022b). For instance, healthcare manufacturing companies frequently use the BDA to improve company performance, sustainability, and competitive advantage (Moyne & Iskandar, 2017). To enhance the capabilities and advantages of the virtual manufacturing system, the BDA is necessary. Thus, IR 4.0 technologies provide employees a better working environment and secure working circumstances.

CONCLUSION

The Covid-19 pandemic has led to many healthcare processes, personnel, facilities and their external organizations to act as subordinates in order to continuously seek new approaches in performing activities and improve performances to treat Covid-19 patients. The lean practices and six sigma as

parts of continuous improvement initiatives have sustained organizations to achieve optimum level of performance, make cohesive and quick process and changes and remain competitive by integrating new industrial revolution 4.0 technologies. The incorporation of IR 4.0 technologies to these practices would create more values for customers and stakeholders by minimizing waste activities and improving quality of products and services. Also, the synergy of lean practices and six sigma will increase the sustainable performance of any organization of any industry. In addition, past literature has revealed that one of the adopted practices among organizations venturing into healthcare establishments is lean six sigma integrated with IR 4.0 technologies as many healthcare service organizations are still struggling to control the influx of Covid-19 infections using smart digital system. Mabkhot et al. (2021) stated that from the advancement of several technologies, integration of IR 4.0 is considered as a promoter, enabler, and enhancer of greener future and economic growth which are equally the aim of Sustainable Development Goals (SDG).

It is now understandable that curtailing Covid-19 requires financial resources which poses challenges to low margin organizations that are constantly seeking for ways to reduce the costs of series and productions. The trend in the industry and focus on the uses and efficiency of lean practices and six sigma to attain significant improvement is paramount as the healthcare industry has posed as a wonderful generator of employment and income. The industry had grown immensely and for a long time has always had influence on the policy to develop the economy of a nation to a broader system of value creation and institutionalized strategies. This study is a blueprint to guide the policy makers and the medical practitioners in the healthcare sector in finding the best quality approach and technique to achieve sustainable performance. As the main aim of the study is to capture the way forward from the international and Malaysia healthcare researches both in services and operations, a relative advanced and complex in this distinctive integrated system has urgently called for further empirical study to re-strategize the present and future directions of the sector.

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