DOI: https://doi.org/10.24191/ijsms.v7i1.17777

Lean Manufacturing Practices and Integration of IR 4.0 Technologies for Sustainability in the Healthcare Manufacturing Industry

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Received: 29 November 2021
Accepted: 22 February 2022
Published: 31 March 2022

ABSTRACT

Providing affordable, safe, and reliable care while improving performance and efficiency remains a challenge in the healthcare sector. This study reviews the previous researches on the effect of lean manufacturing practice (LMP) and industrial revolution 4.0 technologies (IR 4.0 tech) on sustainability; however, there is still a paucity of literature on the implementation of the practices in the healthcare sector. Although studies have shown that LMP has significantly impacted organizational performance in the manufacturing industry, the integrated effects of LMP and IR 4.0 technologies on sustainable performance have not been empirically examined in the healthcare sector. This study, therefore, intends to have a preliminary conceptual approach to the joint effect of LPM and IR 4.0 technologies on sustainability before subsequently going for an empirical study to address the gap in the sector. The study aimed to confirm the future direction of the public health sector that has recently been employing new technologies in its service systems. The consequent study shall be based on data collected from the health practitioners who are *working and familiar with the smart tools to expedite services for healthcare. However, this present study unfolds the significant contribution of operations management practices and how sustainable performance can be enhanced through performance variation and strategic implementation in the healthcare sector. Lean practices and IR 4.0 technologies lead to improvement and operational sustainability when fully implemented in the healthcare sector.*

Keywords: *Lean manufacturing practices; healthcare service*

INTRODUCTION

In developing and developed countries, growing healthcare costs and the aging population are imparting challenges on the safety, reliability, and affordability of basic healthcare with the already constrained budgets (Deblois & Lepanto, 2016). Enhanced service quality, high performance, and improved efficiency are still expected to sustain the healthcare challenges. With these trending issues, healthcare policymakers and providers advocate for the incorporation of lean practices to reduce cost, increase value and eliminate waste as other industries have done (Hallam & Contreras, 2018). The human and control factors influence good service quality as a result of the successful incorporation of modern manufacturing equipment, human involvement, and statistical process control. An employee in an industry 4.0 environment must be empowered and trained to take corrective actions on real-time information received through many sources, and therefore are integrated as an important factor of this component (Kamble, Gunasekaran & Dhone, 2019). According to Kamble, Gunasekaran and Gawankar (2018), Industrial Revolution 4.0 technologiess (IR 4.0 Tech) expedite the rate at which manufacturing industries achieve sustainability through customized products, improved product quality, increased employee morale, improved work environment and reduced lead time.

With the advancement of technology and automation and integration of many processes, LMP is considered as an initiative created to be more efficient while giving the customers satisfaction beyond expectation, resulting in waste minimization, increased return on investments, and improvement in safety and health-related issues

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(Ratnayake & Chaudry, 2017). This study therefore proposes lean techniques as tools incorporated with IR 4.0 technologies for improving sustainability in the Malaysia healthcare sector.

LITERATURE REVIEW

Lean manufacturing practices, integrated with Industrial Revolution 4. 0 technologies are considered to create important impacts where most companies and operations tend to be service-oriented (Sony & Naik, 2019) rather than product-oriented such as in the case of Malaysia healthcare management. Lean manufacturing practices are improvement initiatives that use varieties of tools in a series of procedures and seek to uncover and remove the cause of defects and mistakes by focusing on results that are critically important to the customers in a business process. The practices are the combination of continuous improvement initiatives (CII) that organizations explore to enhance their competitiveness and performance. Industries with manufacturing experiences can avert risks associated with the implementation of a technological system, thus stimulating their continual use over time and improving their perception of usefulness. Also, the healthcare manufacturing industry around the world has implemented various process improvement strategies for the healthcare industry to achieve service excellence (Habidin et al., 2016).

Sustainability

The lean manufacturing philosophy appears to have the potential to improve healthcare performance significantly as it has been successfully adopted in many industries but may have nuances that make this industry-specific transformation more challenging and thus pose a threat to sustainability (Hallam & Contreras, 2018). The sustainability value of an organization has a few essential parts which are: making the shareholders and customers happy and more importantly, performing well for society (Hassan et al., 2018). The sustainable performance comprises activities that socially extend the useful life of an organization, enhancing the capacity to renew and sustain the viability of the biosphere, maintaining decent welfare, self-sustenance of a society, safeguarding all the living species and solving its main problems, personal freedom, and participation for current and future human generations.

In this changing and competitive business environment of today, manufacturing companies are struggling to achieve sustainable performance as it is part of the expectation from stakeholders. This is a pragmatic way that environmentally reduces impacts and enhances the company's performance to increase the values of their businesses (Ganapathy et al., 2014). Therefore, without measuring the current situation of any organization, it is impossible to facilitate sustainable performance. Companies that are in global competitions are expected to report more progressively and commit to the overall performance of sustainability in operative initiatives such as technological innovation or accomplished projects (Brent & Labuschagne, 2004). A comprehensive assessment has shown that the present indicator framework that is available to measure the total business sustainable performance does not address effectively all aspects of sustainability at the technological level. Indicators of sustainable development are introduced and discussed through an assessment procedure specifically for the environmental, economic, and social measurements of sustainable performance. The three dimensions of sustainable performance are critical to successfully run a business now and in the future to fully embrace the ideas of sustainable performance (Eweje, 2011). Figure 1 shows the three pillars of sustainability (Bortolotti et al., 2015).

A successful lean implementation faces many challenges such as effective communication within and between different organizational levels, long-term commitment to maximize stability in a changing environment and continuous and systematic focus on the customer to make sure there is a change in strategies reflecting the goals and objectives of the organization. The satisfaction of healthcare customers is crucial for healthcare providers in terms of the profitability and sustainability of the industry. Healthcare providers must identify the concerns and needs of patients, how to solve problems and fulfil the patients' needs in order to achieve patient satisfaction (AlJaberi et al., 2017).

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Figure 1
Pillars of Sustainability

Lean Manufacturing Practices

Lean manufacturing is a methodology that is designed to reduce the cost of production and minimize waste production (Alhuraish et al., 2016). In other words, lean manufacturing is a business methodology and strategy that enhances customer satisfaction, increases bottom-line results and processes performance. Lean manufacturing started as an integral part of Just in Time (JIT) practices within the Toyota Production System to improve time delivery and quality. Nordin et al. (2010) affirmed that the Toyota production system (TPS) started the lean manufacturing concept and aimed to improve quality and reduce cost through waste non-value added activities and waste abolishment.

Furthermore, lean manufacturing is formed from different practices (Yang et al., 2017). Lean manufacturing practices cluster comprises productive maintenance, human resources management, total quality management (TQM), total preventive maintenance, JIT, controlled processes, and employee involvement. Recent researches have proven the importance of customer participation and downstream collaboration (Martínez-Jurado & Moyano-Fuentes, 2014). Lean practices are further categorized into six major areas that are suitable for all industries: supplier relationships, customer relationships, product design, human resources, process and equipment, and manufacturing planning and control (Bergmiller, 2006).

Successful implementation of lean practices in the manufacturing sector enables the healthcare industry to adopt this continuous initiative for process improvement (Habidin et al., 2016). The practices are suitable for the service industry as lean expedites the speed of quality, flexibility and delivery (Snyder & McDermott, 2009). In addition, lean manufacturing practices are employed by healthcare organizations to minimise medical waste and error and give added values to the customers (Jimmerson et al., 2005). Reduction in errors can give high benefits in terms of productivity, staff motivation, time, cost and patient welfare.

Therefore, to have an effective implementation of LMP, forward coordination and backward coordination with customers and suppliers respectively along with supply chain is important to ensure designing, producing, packaging, and delivering a specifically standardized and manufactured product to meet the environmental and operational objectives (Dües et al., 2013). These objectives include achieving a sustainable ecological and natural environment through green or lean chain management performance.

Industrial Revolution 4.0 Technologies

The first promoters of the factory for the future have earlier found that the dedicated and inflexible production lines should be interchanged with computers and flexible machines to support the new paradigm of industrial technology (Buer et al., 2018). The idea of the present computing system has been predicted more than two decades ago by Weiser (1995). Then, the current computing system is created on the concept that computers are externally and internally equipped, making them invisible to users. The remarkably swift technological advancement in information and communication technology by introducing technological solutions such as the internet of thing (IoT) and cyber physical system (CPS) have ensured that the vision is getting closer to reality. For instance, with smart pharmaceuticals, the introduction of CPS to the medical domain and big data strategy is being tested for personalized care and individualization, the

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healthcare industry is likely to highly benefit from the implementation of IR 4.0 technologies and concepts (Ilangakoon et al., 2021).

Thuemmler and Bai (2017) reported that some of the applications of these technologies in the healthcare sector include connecting sensors and body area networks where doctors can access data of the patients online using internet independent of the patient's location for disease management, network connecting general practitioners, patients, nurses, smart pharmaceuticals or pharmaceutical companies etc., personalized medicine and patient-centred care. With IR 4.0, new technologies are available for integrating lean production with automation technologies. This simplifies the processes of healthcare by eliminating waste and understanding the value-adding activities.

In addition, the industry has gained attention on the idea of an interconnected world and the mission on how the fourth industrial revolution also known as Industry 4.0 is emerging (Kang et al., 2016). Wang et al. (2016) reported that industrial revolution 4.0 has gained tremendous popularity, both in the academic and industrial sectors with the vision of manufacturing customized products at the same costs as the mass production of the products. Thus, organizations globally are investing to examine how they can benefit from this technology-based manufacturing paradigm.

In 2011, Industrial revolution 4.0 was declared at Hannover Messe starting as a German governance program to maximize the competitive advantage of the manufacturing industries (Drath & Horch, 2014). It was a cooperation project between the private sector, academia, and the government revolving around manufacturing resource networks (such as production facilities, robots, conveyor and warehousing system and manufacturing machinery) that are independent, capable of self-controlling to attempt to different situations, spatially dispersed, knowledge-based, self-configuring and sensor-equipped with the power to integrate related management and planning system (Kang et al., 2016).

Nevertheless, the Industrial revolution 4.0 with time has evolved into a complete label to describe the next level of manufacturing and it has in the process turned to be defined poorly for the future of production. According to Hofmann and Rüsch (2017), there is no clear definition for Industrial revolution 4.0 yet even though the concept has been often used among academics and practitioners in the last few years. Therefore, there is no publication yet on the generally accepted understanding of Industrial revolution 4.0. Practitioners and researchers have different views on the constituents of Industrial revolution 4.0 and how these constituents relate with each other where Industrial revolution 4.0 is applicable.

Moeuf et al. (2018) reported that there are more than 100 different definitions of Industrial revolution 4.0 as found in the recent studies. It is therefore important to clarify the definitions applied to ensure construct validity. Heng et al. (2014) stated that only a few practitioners can give clear definitions of industrial revolution 4.0. In the same vein, Drath and Horch (2014) added that Industrial revolution 4.0 does not make a new contribution, that it is merely a combination of existing concepts and technologies into a new package with an enticing marketing name.

Therefore, Industrial revolution 4.0 is operationalized in this study as the use of intelligent processes and products to enable automatic data collection, analysis, and interaction through the internet between customers, suppliers, products and processes. These involve the integration of smart factories, IoT, digitalization, and CPS posited by Liao et al. (2017). The lack of clear definition and ambiguity leads to difficulties in communication and complications of education on the subject and complicates research as well as makes the companies suffer to recognize and implement a solution to Industrial revolution 4.0 challenges (Hermann et al., 2016).

The Link between LMP and Sustainable Performance

According to Singh et al. (2018), lean manufacturing practices (LMP) support improved profits and cost reduction leading to competitive advantage and increased productivity. Wong and Wong (2014) reported that LMP is regarded to be a necessity to achieve sustainable performance. The study reveals that LMP provides advantages such as quality products, reduced inventory level, and the benefits are connected to lower pollutant levels. Vinodh et al. (2011) added that one of the favourite lean techniques, value stream mapping contributes to protecting the environment through mapping of raw materials, water usage, and energy by a product and process. Similarly, Ratnayake and Chaudry (2017) stated that improvement in safety and health-related challenges, waste reduction, and increased return on investment are achieved through LMP.

Cherrafi et al. (2016) reported that the relationship between lean and sustainability is most studied initially as the general focus on waste minimization is common between the two concepts, thereby elevating the potential integration between the two constructs. On this association, Garza-Reyes (2015) stated that Lean offers courses of action and provides tools that allow total elimination of waste while sustainable performance provides visualization of the effects generated by financial, environmental, and social perspectives.

Belhadi et al. (2018) added that integrating environmental management system into lean leads to cost reduction of implementation associated with energy and resources savings, environmental improvement programme, dispersion of toxic compounds, and marginal costs connected to pollution management. From the perspective of social performance, Souza and Alves (2018) posit that the incorporation of high involvement work practices with LMP is found to have a significant effect on occupational safety. LMP aims at improving occupational safety and health, improving kaizen, material handling, and improving workplace safety leading to few accidents. Thus, there is a significant relationship between LMP and the measures (i.e., environmental, economic, and social performance) of sustainability (Sajan et al., 2017).

The Link between LMP and Industrial Revolution 4.0

According to Landscheidt et al. (2017), the implementation of autonomous equipment while making the manufacturing process more efficient raises product quality. Lasi et al. (2014) added that the trend is becoming a reality as transformation led by Industrial revolution 4.0 is taken into account by many industries. The further integration and development of autonomous digital production utilizing industrial robots, electronics, and information technology have led to computer integrated manufacturing systems also known as the cyber-physical system (CPS). Henning et al., (2013) added that the production system is enabled by these CPS to be changeable and modular which is a requirement to manufacture in mass production highly customized products. Kolberg et al. (2016) however reported that how Industrial revolution 4.0 technologies are incorporated into the existing production system and the processes they can support is still under evaluation.

In contrast to the general belief, Weyer et al. (2015) stated that automation will not lead to workless production facilities or less human interaction but there may be a change in the requirement for competence. Factually, the skill requirements for an individual are likely to increase more and become even more specialised. Furthermore, the capital expenditure required for industrial revolution 4.0 technologies is quite intensive, minimizing its desirability to be implemented specifically for manufacturing companies located in the context of developing countries (Anderl et al., 2013; Sanders et al., 2016). Thus, more strategies must be taken into consideration in this scenario for implementing Industrial revolution 4.0 such as the predominance of high production manufacturers in volume and the existing low-cost labour force.

In another vein, Jasti and Kodali (2019) stated that Lean production is an approach that is widely common among many industries aiming to improve the quality of productivity and reduce waste following the requirements of the customers. The lean practice implementation means a systematic human-centred approach of several management practices and principles. These practices are the elements at the strategic level representing the ideals of the system such as removal of all kinds of waste, producing in accordance with the continuous flow production and pull of customers, and identifying value from the perspective of the customers. The principles are the elements that operationalize the practices. The implementation of lean manufacturing practices in essence consists of a low-tech approach that triumphs on effectiveness and simplicity aligned with a shared business vision.

Through the creation of standardized routines, identification of unnecessary activities, and streamlining the processes, lean manufacturing focuses on removing all kinds of waste during the production process. Kolberg and Zuhlke (2015) mentioned that simple workstations and machines with low complexity expedite digitalization and automation of the manufacturing process. Transparency and virtual control are also emphasized by lean manufacturing which makes identifying problems in a system simpler. This has prompted some researchers to conclude that it is paramount to implement lean as a prerequisite to successfully achieve Industrial revolution 4.0 transformations (Staufen, 2019). From the survey of Staufen (2019) on 179 industrial companies, it is found that the pioneers

DOI: https://doi.org/10.24191/ijsms.v7i1.17777

of Industrial revolution 4.0 have initially implemented lean manufacturing practices, revealing that lean is an ideal foundation when implementing industrial revolution 4.0. Similarly, to maximize manufacturing performance, lean practices are necessary to support advanced manufacturing technologies (AMT) (Khanchanapong et al., 2014).

In numerous cases, the implementation of lean manufacturing has been proven to have performance benefits as it covers a wide range of different performance metrics. The performance benefits are classified by Marodin and Saurin (2013) into five groups: (1) financial, (2) environmental, (3) market, (4) human, and (5) operational. On the observed performance of the Industrial revolution 4.0 implementation, Moeuf et al. (2018) found that increased flexibility is the commonest reported performance benefit followed by reduced delivery time, improved cost and productivity, and reduced cost. Thus, the synergistic performance impacts of such integration encourage joint optimization of two rather than optimizing one source alone about the performance impacts of integrating lean manufacturing with AMTs (Khanchanapong et al., 2014).

The Industrial Revolution 4.0 Technologies and Sustainable Performance

IR 4.0 technologies play important roles in moving industrial and social organizations towards sustainable development (de Sousa Jabbour et al., 2018). Kamble, Gunasekaran and Gawankar (2018) reported that industrial revolution 4.0 improves integration of process resulting in improvement in the organizational performances on all three sustainable measures. On the economic measure, Industrial revolution 4.0 technologies strongly contribute to product customization, value creation, and manufacturing flexibility resulting in increased customer satisfaction (Stock & Seliger, 2016). From this economic perspective, Ramadan, et al. (2017) added that the digitization and automation features of industrial revolution 4.0 technologies motivate the manufacturing organizations towards superior quality, lower manufacturing costs, and reduced lead times. From the environmental perspective, the real-time information gathered from several value chain partnerships helps the organizations to allocate efficiently their manufacturing resources such as the products, energy, and material, and water (de Sousa Jabbour et al., 2018).

Industrial revolution 4.0 technologies also support the use of advanced monitoring and tracking system, reduction in fuel consumption due to improved transport and logistics planning (Müller et al., 2017), efficient capacity utilization, and inventory level of raw material (Wang et al., 2016), energy consumption and reduction on greenhouse gas emission (Hermann et al., 2016; Peukert et al., 2015). From the perspective of social measures, Industrial revolution 4.0 technologies provide abundant opportunities to adapt to new technologies by the employees thereby increasing their motivation and morale (Peukert et al., 2015). Therefore, Industrial revolution 4.0 technologies provide safe working conditions and improved work environments for the employees (Kamble, Gunasekaran & Sharma, 2018).

METHODOLOGY

This study employs an exploratory research design as it focuses on the aspects of study where past researches have been conducted while further studies are still required to attend to other questions yet to be answered. The approach of this research design is chosen following the techniques and methods used to research as it clarifies how data would be gathered and analysed toward the realization of the research aims. Undoubtedly, past researches have examined the effects of lean manufacturing practices and Industrial revolution 4.0 on sustainability, although majorly in manufacturing industries with variables that are specific to that field. Asides from the fact that this study is contextualised in an attempt to meet the measures of lean manufacturing practices and the specificity of best quality initiative for the Malaysia healthcare industry, the hybrid of lean manufacturing practices and Industrial revolution 4.0 technologies are newly introduced to test the model of the research. The above statement shows the importance of quantitative-type of exploratory study; an exploratory study helps to understand the situations being more accurately and comprehensively studied (Sekaran & Bougie, 2019).

The variables to be studied are lean manufacturing practices (JIT, Customer Involvement, continuous flow, pull, supplier development, employee involvement, total preventive/productive maintenance, and supplier feedback, and Industrial Revolution 4.0 technologies. The other variables are economic, social, and environmental dimensions under

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sustainable performance as the dependent variable (Zikmund et al., 2003). Questionnaire administration shall serve as the best approach of collecting data due to the reliability of data from quantitative research being numeric. Since the interest of this study is to capture the opinions of the healthcare manufacturing employees both in the services and operations of the Malaysian healthcare industry, this is undoubtedly justified. This implies that responses to be deducted shall be from the perception of individuals on the reality of the work environment and its distinctiveness. Items to measure sustainability in terms of economic, social and environmental sustainability (Akanmu, Hassan & Bahaudin, 2020), lean manufacturing practices and IR 4.0 technologies are presented below.

Sustainability Dimensions

Sustainability is measured using social, economic and environmental performance with 20 items, adopted from the study of Akanmu, Hassan, Mohamad, et al. (2021) and Caiado et al. (2018). The last three years are designated as the assessment period for the organization. Table 1 below presents the items measuring sustainability and their respective coding:

Table 1
Sustainability Coding

Items	Code
Economic Sustainability	
Reduced costs of production	EP01
Improved profits	EP02
Reduced product development costs	EP03
Decreased energy costs	EP04
Reduced inventory costs	EP05
Reduction in rework and rejection cost	EP06
Decrease in the purchase cost or raw material	EP07
Decrease in the cost of the waste treatment	EP08
Social Sustainability	
Improved condition of work	SP1
Improved safety in workplace	SP2
Improved health of the employees	SP3
Improved relations on labour	SP4
Improvement in morale	SP5
Decrease in work pressure	SP6

Environmental Sustainability	
Reduced solid wastes	EVP01
Reduced liquid wastes	EVP02
Reduced gas emission	EVP03
Reduction in energy wastes	EVP04
Decreased consumption of toxic/hazardous/harmful materials	EVP05
Improved environmental condition of the company	EVP06

Lean Practice Dimensions

The construct domain specification and item generation are developed using the first set of lean practice constructs as proposed by Shah and Ward (2007). These constructs are continuous flow, employee involvement, supplier involvement, and set-up time reduction, customer involvement, just in time, supplier development, statistical process control, pull system and total productive maintenance as indicated in Table 2.

Table 2
Lean Practices Coding

Item	Code
Supplier Involvement (SI)	
Our organization is in close connection always with the suppliers	SI1
Our company provides feedback to the suppliers on delivery and quality performance	SI2
Our company applies utmost efforts in creating long-term relationship with the suppliers	SI3
Just-in-time (JIT)	
All our key suppliers involve in new process of product development	JIT1
Our organization is delivered by our suppliers on just-in-time basis	JIT2
Our organization has supplier certification programme in place	JIT3
Supplier Development (SD)	
Our company’s supplier strives to achieve cost reduction annually	SD1
Our key supplier is situated at a close vicinity to our organization	SD2
We have established system to convey important issues to the suppliers	SD3
Our company makes effort to have lesser number of suppliers in every category	SD4
The inventories are managed by the key suppliers	SD5
Supplier evaluation is not done per unit price but on the total cost purchase	SD6
Customer Involvement (CI)	
Our organization is in close relationship with the customers	CI1
Our company gets feedbacks on delivery and quality performance from the customers	CI2
Our firm involves customers in new and existing product development and improvement process	CI3

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The customers/clients participate in the existing and new product development and improvement process	CI4
The customers share their future and present demands with our organization	CI5
Continuous Flow (CF)	
Our products are categorized into classes with the same processing criteria	CF1
Our products are categorized into classes with the same routing criteria	CF2
Our equipment is classified to provide continual flows of products	CF3
Our product determines the factory layout	CF4
Pull System (PS)	
Our productions are pulled by the shipments of the completed products	PS1
Our productions are at workstation are pulled by the present requirement of the next workstation	PS2
A production system of pull is adopted	PS3
Our company uses container of signal or Kaban for production control	PS4
Total Productive Maintenance (TPM)	
Our company daily dedicates to plan activities related to equipment maintenance	TPM1
Our company carries out daily maintenance of all equipment	TPM2
Our company maintains excellent conditions for all equipment	TPM3
Our company posts records of equipment maintenance for active sharing with the employees	TPM4
Statistical Process Control (SPC)	
Our company covers most of the process/equipment under SPC	SPC1
Our company uses statistical techniques to control the process variance	SPC2
Our company uses charts as tools to show defect rates	SPC3
Our company uses fishbone illustration to identify causes of quality problem	SPC4
Our company conducts research on process capability before product launching	SPC5
Employee Involvement (EI)	
Our company believes that employee plays a significant role in solving problems	EI1
Our employees motivate the company through suggestion programme	EI2
Our employees do lead the process/product improvement efforts	
Our company provides cross functional training for the employees	EI3
	EI4
Set Up Time Reduction	
Our company provides various practices on setup reduction techniques for our employees	STR1
Our company work continuously towards setup time reduction	STR2
Our company has high setup time of equipment	STR3

Industrial Revolution 4.0 Technologies Dimensions

Most of the organizations are yet to explore the sophisticated features of IR 4.0 technologies; therefore, they are uncertain about what benefitsIR 4.0 Technologies would provide in the future (Zu et al., 2008). The IR 4.0 technologies adoption in service industries is still at infant stage but slowly gathering momentum (Kamble, Gunasekaran & Gawankar, 2018). Therefore, the degree of implementation of IR 4.0 Technologies is aimed to be measured by items but not the successful level of its implementation. Table 3 presents the measuring items for IR 4.0 Technologies as adopted from the study of Kamble, Gunasekaran and Gawankar (2018):

Table 3
Industrial Revolution 4.0 Technologies Coding

Items	Code
Our company is planning to implement cloud computing	IR1
Our company is planning to implement big data analytics	IR2
Our company is planning to implement internet of things	IR3
Our company is planning to implement addictive manufacturing	IR4
Our company is planning to implement robotic system	IR5
Our company is planning to implement augmented reality	IR6

DISCUSSION

Lean is an integrated socio-technical system to remove waste by simultaneously minimizing and reducing internal, supplier, and customer variability. This study takes into consideration ten constructs from the previous literature to conceptualize the definition of Lean. Six out of the ten constructs address the internally related issues to the firm, three constructs measure the supplier involvement while only one measures customer involvement.

Moreover, scholars have started to look into lean manufacturing practices with a renewed interest towards creating greener solutions capable of eliminating waste and minimizing by updating, extending, and modifying lean methodologies and the social and environmental adverse effects of the conventionally employed industrial practices (Bortolotti et al., 2015). Similarly, the lean manufacturing philosophy has been adopted successfully

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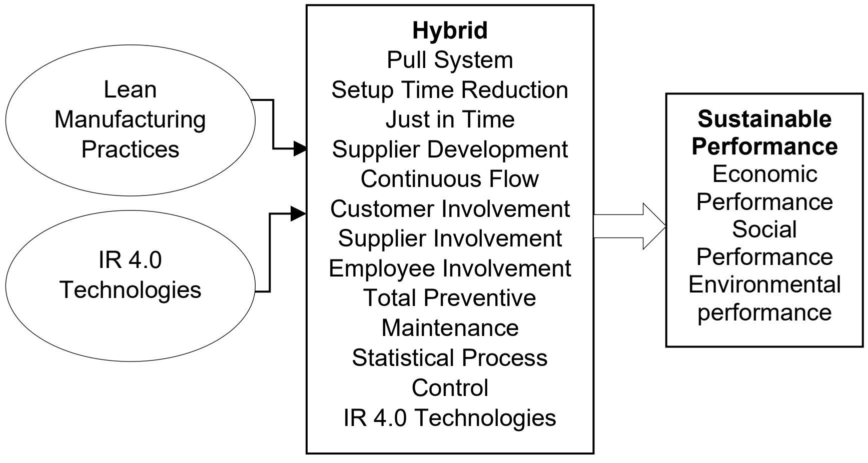
in many industries and appeared to have the potential to significantly improve healthcare performance but may have nuances that make the industry-specific transformation more challenging; thus, poses a threat to sustainability (Hallam & Contreras, 2018).

In the same vein, Naik et al. (2012) considered sustainability to be challenging and suggested four approaches to improving sustainability: in servicing (i.e., training) and clear communication on new process; representation from all lean teams as each shift has different conditions; implementing new process at off-peak hours with executives and process owners; and developing mid-level and clinical management champions necessary to sustain change. Also, the issues in the implementation of LMP are addressed by employing the suitable application of ICT (Buer et al., 2018). Many IR 4.0 technologies serve as integrated solutions that align with lean practices taking into account the aim of the organization. Therefore, LMP and IR 4.0 technologies are necessary to improve sustainability (Luthra & Mangla, 2018).

The insights from the theoretical background and a comprehensive literature review are deployed to establish the conceptual framework as presented in Figure 2.

Figure 2
Development Stage of The Conceptual Framework of The Study (Source: Researcher)



Manufacturing companies are continuously stepping up their activity performance to remain competitive and improve sustainability. Anand et al. (2009) mentioned that organizations can be helped to reach a high level of performance and remain competitive with Continuous Improvement Initiatives (CII) by incorporating operational procedures to enhance their capability to make quick and cohesive process changes. According to Drohomeretski et al. (2013), the CII are concepts connected with different initiatives which among them are the six sigma and lean manufacturing practices. According to Hines et al. (2004), Lean manufacturing focuses on improving values or perceived values to customers by integrating additional features of products and services and eliminating wasteful activities. Similarly, the practices seek to reduce the causes of defects and mistakes by focusing on the results that are important to the customers in the business processes. Therefore, lean manufacturing unifies the capacity of both initiatives to enhance the performance of an organization through customer satisfaction while improving the bottom-line results (Snee, 2010).

In summation, this study contributes to the conceptual evidence of the relevance of contingency factors related to the characteristics of the healthcare industry in the implementation and adoption of lean manufacturing practices and Industrial revolution 4.0 technologies. Furthermore, it can be observed that the practices create opportunities for the companies when applying tools like big data analytics (BGA) and cloud computing (CC) to decrease the set-up time and increase pull system adoption. Other demanded strategies such as mix to order in replace of make to stock are equally enhanced. Increase in the implementation of statistical process control to minimize process variations connected with product deviation in size or weight, increase in the employee participation, reducing losses and costs and the use of belt specialists who are knowledgeable in the implementation of CII and programmes also improve the benefits of lean manufacturing practice implementation in the healthcare manufacturing sector.

The fact that lean manufacturing practices are effective and relevant to the healthcare sector is another contribution. Therefore, the adoption of lean manufacturing practices is affected significantly by the performance within the healthcare service industry. The theory of practice-based view is supported by two performance indicators (product quality and financial

DOI: https://doi.org/10.24191/ijsms.v7i1.17777

benefit), valued by the sector can be enhanced by IR 4.0 technologies. The potential benefits and satisfaction derived from the healthcare industry increase as more lean practices are implemented to enhance process efficiency, improve operational efficiency and quality of care. Thus, this study posits that there is a need for managerial awareness about the relevance of implementing lean manufacturing practices and IR 4.0 technologies to improve performance and service quality and the adoption of technologies that come with industrial revolution 4.0 in the healthcare industry.

This study highlights current case studies, tools and practices that have worked for healthcare providers such as lean implementation and integration of IR. 4.0 technologies, but few have addressed sustainability. Lean implementation is now gaining acceptance in healthcare through both large-scale enterprise transformations and localized process improvement. Therefore, this present research develops a conceptual framework to explore lean and derive practical lean health management system practices that can improve overall efficiency, quality and reduce cost.

CONCLUSION

This study suggests that lean manufacturing practices and IR 4.0 technologies should be effectively incorporated into the system of the healthcare service industry of Malaysia to meet the high demand for quality service. The policymakers and managers of the industry should pay attention to re-strategize the policies, structures, and practices to align them with the technological advancements. The integration of the practices such as supplier involvement, customer involvement, pull system, just in time, employee involvement, total preventive maintenance, set-up time reduction, statistical process control, continuous flow, and IR 4.0 technologies can help the industry holistically to increase its performance and competitive advantage. The implementation of a management improvement initiative on the scope indicated by implementing LMP and adopting IR 4.0 is very applicable and relevant in the work settings and processes of the healthcare industry. Notably, the healthcare service and industrial sector is one of the main generators of income and employment worldwide. The sector has significantly grown and has affected the policies on the national economy and development to change to a wider system of institutionalised strategies and value creation. This study shall support managers and policymakers in the healthcare service industry to devise the best quality management to achieve the best healthcare service performance.

CONTRIBUTIONS OF AUTHORS

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

FUNDING

This work was supported by Universiti Malaysia Perlis through financial grant 9001-00677

CONFLICT OF INTERESTS

All authors declare that they have no conflicts of interest.

ACKNOWLEDGMENT

The authors are grateful to Universiti Malaysia Perlis for the financial support through 9001-00677.

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