PalArch's Journal of Archaeology of Egypt / Egyptology

EXPLORING THE SMART TECHNOLOGIES OF THE FOURTH INDUSTRIAL REVOLUTION – A TRIPLE BOTTOM LINE PERSPECTIVE

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Sreenivasan Jayashree, Chinnasamy Agamudai Malarvizhi, Mohammad Nurul Hassan Reza. Exploring the Smart Technologies of the Fourth Industrial Revolution – A Triple Bottom Line Perspective – Palarch's Journal of Archaeology of Egypt/Egyptology 17(2) (2020), 1-11. ISSN 1567-214X.

Keywords: Smart Technologies, Industry 4.0, TBL Sustainability

ABSTRACT:

Industry 4.0 and smart technologies are the most recent development of the manufacturing system that involves an uncertain potential effect on the execution of Industry 4.0 towards attaining sustainability. Therefore, this paper adds to the existing literature by scrutinizing the role of Industry 4.0 technologies on its successful implementation and Triple Bottom Line (TBL) sustainability. A new framework is proposed considering the role of smart technologies that may be played to determine TBL sustainability and effective employment of Industry 4.0 as a mediating variable. As the existing literature did not pay much attention to sustainability from the financial, environmental, and social dimensions while executing Industry 4.0, this study intends to evaluate the links among the variables from the Malaysian perspective.

A quantitative analysis will be conducted through a questionnaire-based survey where the SMEs will be the study population. The study intends to strengthen the literature on Industry 4.0, offering a well-structured discussion and a framework on sustainability and smart technologies to produce useful understandings for future research.

INTRODUCTION

The rapid-growing global population, the need for a better life, and the continuing misuse of natural resources have grown a massive consciousness about sustainability to live, organize, perform, and manage tasks (Köhler et al., 2019). Nowadays, sustainable practices are essential for organizations, prompted by the growing population's demand for strategies and procedures that may be considered from financial, environmental, and social aspects (Alayón et al., 2017). Hence, organizations are encouraged to execute sustainable practices; simultaneously, they intend to optimize the profit and minimize the expense (Seidel et al., 2010). The term ‘sustainability’ has come to refer to ‘maintain the business running’- an idiomatic definition by Colbert & Kurucz (2007). In contrast, the term can be denoted as the ‘future-proofing’ of the enterprises. Sustainability can be referred to as attaining the accomplishment now without negotiating future requirements (Boudreau & Ramstad, 2005). Sustainability can be defined as a business strategy that involves long-term and long-lasting value creation and improves economic, ecological, and social resources. “The Chartered Institute of Personnel and Development” (CIPD, 2012) describes sustainability as the basics of developing the financial, ecological, and social atmosphere where the organizations perform their business. This definition establishes the initiative of a triangular spotlight for enterprises motivating to achieve sustainability. This concept is close to Purvis et al. (2019), who define that sustainability involves concurrent attention to financial, ecological, and societal dealings. The definition is critical to extending the presumed “Triple Bottom Line (TBL) Sustainability,” that would be concentrated in this study. The purpose of sustainability tends to refer to the technological development in which environmental efficiency can be developed by using eco-based technologies (Gouvea et al., 2018; Song & Wang, 2016). The green technologies of Industry 4.0 will assist organizations in attaining the full potential of sustainability. Thus, the organizations can enter into the era of sustainable society with top-class production (Dubey et al., 2016).

In the current manufacturing setting, sustainability and Industry 4.0 are significant and crucial developments. Similar to the expansion of Industry 4.0, sustainability has boomed through the combination of financial and ecological concerns into organizations’ decision-making procedures (Gunasekaran et al., 2014). Currently, researchers have given substantial importance to sustainability, with a crucial emphasis on the ecological aspect of sustainability. However, the research is inadequate to integrate the financial and environmental challenges into sustainable manufacturing (Gunasekaran et al., 2014). For the guidance and enhancement of sustainable manufacturing decisions, enterprises should follow Alayón et al. (2017) principles where the authors suggest reducing, reusing, and recycling (3Rs) of the resources, helping develop the product life cycle. The implementation of eco-based technologies will help build a green and healthy environment by reducing pollution (Alayón et al., 2017).

SMEs are an essential contributor to the world economies’ springboard (Nor-Aishah et al., 2020). Likewise, researchers compared SMEs with the backbone of the Malaysian economy, leading 98.5% of entire business organizations. SMEs added 37.1% to the GDP, 66% of employment, 17.3% of Malaysia’s total exports, and played a crucial role in assisting the domestic large business organizations (SME Corp Malaysia, 2017/2018). While SMEs are one of Malaysia’s leading contributors to the economy, their business activities cause ecological destruction (Khan et al., 2017). However, most SMEs are also using old technology, are inefficient in managing their energy, and have no facilities for handling pollution (Pathirana & Yarime, 2018). SMEs are the main concentration of this paper because if they ignore the paradigm of sustainability, their inheritance may be affected by growing requirements very quickly. So, it is high time for Malaysian SMEs to employ smart technologies to gain competencies. Thus, the country's economy will be developed, and TBL sustainability can be achieved for society's well-being.

Based on the enlightenment above, the research examined the current literature in-depth to answer the questions, how the smart technologies influence the successful execution of Industry 4.0, how these technologies can assist organizations in attaining TBL sustainability, does successful implementation of Industry 4.0 affect TBL sustainability and is there any mediating impact of Industry 4.0 between the smart technologies and TBL sustainability at the organizational level? From an organizational standpoint, these issues are critical, and organizations must learn how smart technologies can help them to attain TBL sustainability while implementing Industry 4.0.

LITERATURE REVIEW

Industry 4.0

Industry 4.0 works through the interconnection and alignment of machines, programs, and processing devices to deploy the "Internet of Things (IoT)" and "Cyber-Physical System (CPS)". Communication technologies play a massive role in creating 'things' that cover the potential for data to be transferred to it and finally add value to the production process successfully (Bahrin et al., 2016). Industry 4.0 offers a flexible, transparent, smart, and upgraded platform for information systems. Through the implementation of Industry 4.0, organizations of all sizes can take access very merely to shape and analyse the technologies as required to fill up their needs. A precise definition of Industry 4.0 may be a "smart factory" where the virtual and physical worlds combine through CPS, and the employed smart technologies operate the entire manufacturing procedures (Bunse et al., 2014). Industrial manufacturing evolves with various concerns; it increases the uniqueness of buyers' needs and orders, enhances the volume of production, product distribution channels, recycling, and additionally involves all other associated services (Qureshi, 2016).

Industry 4.0 technologies are supported through process integration, which is highly standardized. The CPS and human-tools build process integration by introducing smart technology where CPS plays the primary function (Monostori et al., 2016; Thramboulidis & Christoulakis, 2016). The process integration permits organizations to create elegant products, services, and procedures (Schmidt et al., 2015); thus, the organizations can accommodate the increasingly shifting market demands in the context of various aspects and difficulties (Persson, 2016), and the manufacturer can minimize the cost and maximize the productivity through the efficient allocation of resources. Industry 4.0 enables organizations to achieve ongoing digitalization and connect all production units in the financial system through the employment of smart technologies including the "Internet of Things (IoT)", "Cyber-Security", "Cloud Computing", "Big Data Analytics", "Simulation", "Additive Manufacturing (3D printing)", "Augmented Reality", and "Autonomous Robots" (Rüßmann et al., 2015).

Smart Technologies

Internet of Things (IoT)

It integrates smart machines, sophisticated project analysis, and human-computer associations to develop competence, expertise, and production quality (Thramboulidis & Christoulakis, 2016; Wong & Kim, 2017). IoT enables organizations to enhance the capability for real-time sensing and rapid circulation of data. IoT allows organizations to increase their ability to sensitize and circulate data in real-time. Production processes and well-organized coordination between stakeholders are more straightforward, efficient, and easy to reach (C. Yang et al., 2017). IoT technologies involve resource efficiency by increasing the proportion of renewable energy consumed in the manufacturing process, which leads to sustainability (Beier et al., 2018).

Big Data

Manufacturing companies need to have the ability to analyse data to drive the technological transformation. Therefore, to create the algorithms and interpret data, they must have a wide range of skill sets (Lee et al., 2017). Big data and associated technology enable organizations to collect information from various sources and interpret data entirely simultaneously. Therefore, big data allows assessing real-time and guides to increase production flexibility, best quality product, resources efficiency, and tools and equipment's maintenance service (Bahrin et al., 2016; Rüßmann et al., 2015). These sustainable practices can help organizations to achieve sustainability by deploying big data. Additionally, big data plays a huge function in monitoring the production procedure and checking the product fault through analysis (Qian et al., 2017; Yuan et al., 2017).

Cloud Computing

Cloud computing enables the network in a manufacturing platform that builds a smart and connected world of production equipment, materials, information, and humans. It helps organizations to enjoy the full potential of smart productivity in the manufacturing industries (Yue et al., 2015). Cloud computing facilitates the data sharing across organizations' boundaries and improves the system's performance with flexibility; thus, it reduces the manufacturing cost by connecting systems over the internet (Tao et al., 2014; Yue et al., 2015) helps to attain sustainability.

Simulations and Prototype

Simulations and prototyping allow organizations to exploit immediate information in imitating the material things into a virtual model where technological equipment, goods, and humans are included. In the virtual atmosphere, organizations will track and automate the technical instruments' implementation for the following items before any material modifications occur. Thus, the machine setup times can be controlled, and the product quality is increased (Bahrin et al., 2016). The CPS can be examined through prototyping (Tao et al., 2014; Thramboulidis & Christoulakis, 2016). Yuan et al. (2017) suggested apps that permit organizations to allocate the resources proficiently, and thus they can achieve sustainability.

3-D Printing and Augmented Reality

In conventional manufacturing processes, the subtractive or removal technique is allowed for cutting, drilling, grinding, and sanding of the product parts and elements. In the final finishing of the product, these parts and elements are assembled. On the other hand, in 3-D printing, the product is made by strengthening consecutive covers of materials where the assembly of product parts and elements is unnecessary. These techniques can allow organizations to produce small groups of categorized products that can easily be constructed as light as possible patterns (Rüßmann et al., 2015; Stock & Seliger, 2016).

Robotics

Modern robots are autonomous, flexible, and cooperative, and they will soon start working together and work carefully with humans. In a smart factory, the robots will perform most of the works (Sjödin et al., 2018). Organizations can employ twin-handed robots to distribute product materials in the assembly line, as Mueller et al. (2017) suggested. Organizations will enjoy cost-effectiveness, brilliant competencies, and sustainable practices through the accuracy, energy, sensing, and computational capacity of modern robots, which will lead them to achieve sustainability (Ogbemhe et al., 2017).

Cyber-Security

Cyber-Physical Manufacturing Systems (CPMSs) may be affected by cyber-attacks. Harmful software can affect the system, and it can spread to all of the machines through communication systems. Deploying CPMSs involves a high risk of cyber-attacks, and information thefts are crucial; thus, data protection is highly suggested to enhance the system's dependability and suitability (Yu et al., 2017). Cyber-security is vital as manufacturing information is very responsive; it includes all information about the product, trade policies, organizations, etc. (Wolf & Serpanos, 2018).

Sustainability

In sustainability, the organization’s only focus on revenue generation is not significantly desirable without considering stakeholder concerns (Mcwilliams et al., 2016). Thus, the organizations’ policies and strategies regarding Corporate Social Responsibility (CSR) are increasing and have grown special attention to sustainability (Strand et al., 2015). Although this concept evolves in various dimensions, sustainability is mainly observed from the environmental perspective (Gunasekaran & Irani, 2014). Hence, researchers approached the design of sustainability from the ‘Triple Bottom Line’ viewpoint that includes profit, planet, and people, and this idea works with financial, ecological, and societal perspective (Norman & MacDonald, 2004).

Financial earning is a must for any organization's survival (McDonald & Wilson, 2011). It tends to enhance liquidity, production, and return more than the capital invested (Schulz & Flanigan, 2016). Thus, the organizations can assure a long-lasting financial continuation and achievement. From an environmental perspective, organizations can achieve sustainability when they use only the resources that can be repeated (Yang et al., 2017). Additionally, organizations should follow the eco-friendly production procedure, where the emissions will be absorbed automatically by the existing environment. These facets help organizations to establish their ecological measures (Long et al., 2017). The social dimension of sustainability involves the precise and definite initiatives of organizations that protect and improve human and societal standards in society, where the organizations work for value creation (Schulz & Flanigan, 2016).

A few investigations have been made on these three dimensions of TBL sustainability, focusing on their interdependencies (Glavas & Mish, 2015). Because of the correlation of the information with various aspects of simplicity from an interior and exterior viewpoint, it is not easy to calculate and compare the dimensions (Ozanne et al., 2016). Additionally, TBL sustainability offers a confused and uncertain result for mixing the partially conflictive financial achievement objectives, environmental stability, and societal fairness (Lehtonen, 2004). Therefore, this paper intends to examine the links between Industry 4.0 and TBL sustainability to understand the role of Industry 4.0 technologies to create and enhance sustainability from the TBL perspective.

Smart Technologies, Industry 4.0 and Tbl Sustainability

In current literature, Industry 4.0 is mostly attributed to the financial and ecological dimensions of sustainability; the social dimension did not receive so much attention, although it is one of the three dimensions of TBL. Because of the vast potential of sustainable production, it is necessary to realize the social dimension of sustainability, and this paper aims to address this.

Smart Technologies, Industry 4.0 and Economic sustainability

Industry 4.0 enables organizations to decrease product cost and product development costs and produce small groups of customized products to meet customer demand. Industry 4.0 is the best way to reduce production costs for smart manufacturing (Ramadan et al., 2017). Additionally, Industry 4.0 allows enhancing financial competencies of production processes and strength (Ghobakhloo, 2018) and builds worldwide manufacturing connectivity at low cost (Schuh et al., 2014). Saunders & Brynjolfsson (2016) reported that industry 4.0 is cost-efficient and capital-intensive, offering numerous advantages for the organizations. A complete platform in big data management was built by Lee et al. (2017) to help organizations attain sustainability.

Smart Technologies, Industry 4.0 and Environmental Sustainability

The awareness to develop the living standard of human is growing high in society. Organizations are very conscious of offering top-quality living standards for their employees. By deploying the latest technologies and smart manufacturing system, Industry 4.0 helps organizations decrease production waste and excess production and enables companies for materials assembling, resource efficiency, and energy utilization. Additionally, additive manufacturing helps produce customized products that reduce raw materials; thus, the capability can be utilized more effectively (Wang et al., 2016; Yao et al., 2017). In smart manufacturing, organizations can build connectivity with product materials, assembly lines, power stations, and human systems through communication technology.

Smart Technologies, Industry 4.0 and Social Sustainability

According to Stock & Seliger (2016), Industry 4.0 enables enterprises to develop the worsening financial, ecological, and societal values by implementing the latest and updated technologies of Industry 4.0 and process incorporation. Apart from economic and environmental sustainability, Industry 4.0 can open organizations' full potential to realize sustainable manufacturing value creation from a social perspective. The social dimension of sustainability denotes social impartiality with regards to education and living standards of humans and equal business policies toward the workforce and the society in which the enterprises operate their business (Steurer et al., 2005). Primarily ecological issues were the primary focus in the sustainability dispute, and social and economic dimensions were addressed as they were supposed to be related to environmental problems. Nonetheless, these three features have developed into equally essential dimensions of sustainability. Hence, for social sustainability, organizations should look forward to improving the living standards of the employees. Researchers suggested providing safety training in hazardous work locations for the employees' well-being (Oesterreich & Teuteberg, 2016) and life-saving tools and equipment in dangerous areas. Three essential strategies can be taken to cope with the societal dispute in Industry 4.0, such as improving employees' training performance by mixing smart tools, techniques, and technologies, developing essential inspiration and promote innovativeness to facilitate decision making, and motivating employees through executing personal incentive plans based on their productivity (Stock & Seliger, 2016).

Research Framework and Hypotheses

The conceptual framework of the study is as follows,

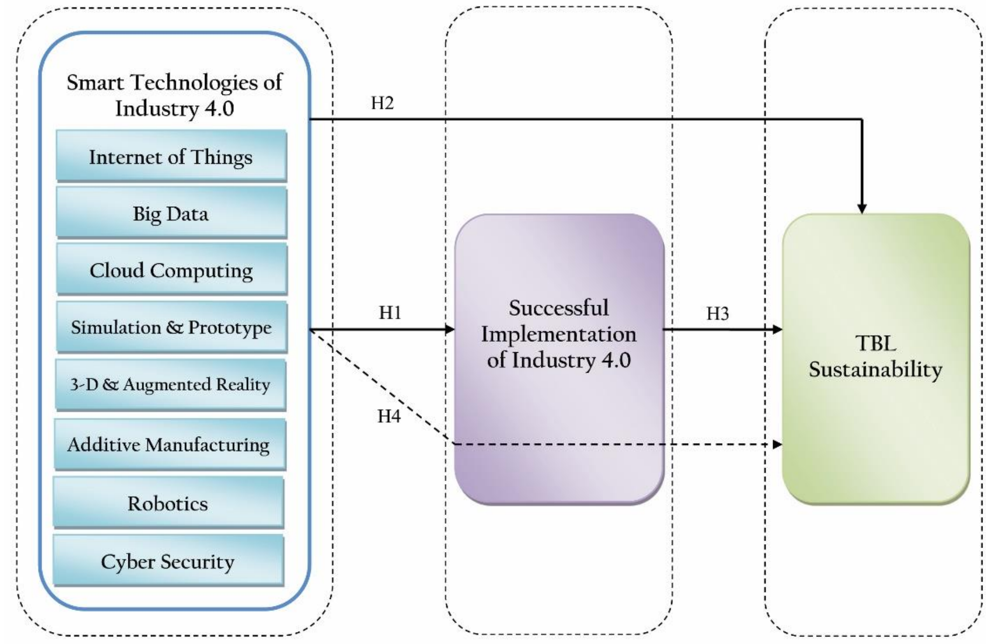

Figure: Research Framework

According to the proposed framework, the relationship between smart technologies and successful implementation of Industry 4.0 is significant (H1), the relationship between smart technologies and TBL sustainability is significant (H2), the relationship between successful implementation of Industry 4.0 and TBL sustainability is significant (H3) and successful implementation of Industry 4.0 mediates the relationship between smart technologies and TBL sustainability (H4).

RESEARCH METHODOLOGY

This study proposes a new model, including smart technologies and their impact on the successful execution of Industry 4.0 and TBL sustainability. A quantitative analysis will be conducted through a questionnaire-based survey, and SMEs will be the study population. The survey will be conducted in various regions of Malaysia. The data collection procedure will be guided through a structured questionnaire, and the measurement items will include questions related to all the variables proposed in the framework. The statistical analysis will be performed through the employment of the Structural Equation Modeling (SEM). The study will test the relationships between smart technologies, Industry 4.0, and TBL sustainability; the study will also test the mediating impact of Industry 4.0 implementation.

CONCLUSION

The study offered a new framework from a realistic viewpoint that will provide professionals, decision-makers, and anyone concerned or interested in obtaining a more detailed understanding of the principles of smart technologies, Industry 4.0, and TBL sustainability. This paper aims to establish TBL sustainability among organizations by implementing smart technologies in Industry 4.0. Thus, it would be beneficial for organizations to understand how Industry 4.0 can help achieve TBL sustainability in Malaysian SMEs. The theoretical study mainly limits this research, but it involves an exciting opportunity for future research to expand.

ACKNOWLEDGMENT
“The authors wish to thank the Ministry of Higher Education (MOHE), Malaysia, for the financial support to conduct the study under the FRGS grant.”

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