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COLLABORATIVE NETWORK IN INDUSTRY 4.0 TOWARDS SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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ABSTRACT

The Fourth Industrial revolution has taken the world into storm with its new developments such as Internet of Things (IoT), robotics, virtual reality among others. Supply chain is also one of the key areas affected by this transformation. There are various variables that contributes to the sustainable supply chain management ranging from processes, the people and its involvement and the technology aspects such as collaborative e-grid. This paper weaved together various fascets of collaborative network in Industry 4.0 that contributes significantly towards a sustainable supply chain management.

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INTRODUCTION

Industry 4.0 has transformed the manufacturing industry with new decentralized and digitalized manufacturing outcomes. As a result, decision-making is greater environment friendly and offer greater flexibility to the manufacturer. The evaluation of the real-time data is an influencing factor of decision-making and pose an impact on the profitability of the manufacturing by implementing enterprise as an integrated, adapted, optimized, service-oriented and interoperable manufacturing technique in which algorithms, huge data, and inclusive with excessive applied technology. (Koh, Orzes, & Jia, 2019). The fourth industrial revolution are followed toward revolution 3.0, the digital revolution that has been happened on account that the centre of the last century. It is characterised with the resource of a fusion of applied sciences that are blurring the traces between the physical, digital, and biological spheres. (Xu, David, & Kim, 2018). For the past few years, Industry 4.0 is a rising concept deriving from technological development and disruptive traits in the industrial globally. (Dallasega, Rauch, & Linder, 2018).

The fourth industrial revolution is the new and evolving world in which disruptive technologies and developments like the Internet of Things (IoT), robotics, virtual reality (VR) and artificial intelligence (AI) transform our way of living and working. It is a revolutionary change marked by the omnipresent and wireless Internet; cheaper, simpler and more robust sensors; and computer and artificial intelligence (Schwab, 2014). The industrial revolution 4.0 is widely used by all over the manufacturing area due to the intense competition amongst each other. Large manufacturers quickly adopt the technology changes in the industrial revolution 4.0, which will result in high volume and profit maximization. However, smaller manufacturers also impacted as they are bound to follow the transition towards manufacturing digitization, such as digitizing their purchaser relationship management or manufacturing planning and control. The governments worldwide start focusing on implementing the industrial 4.0, which aims to decentralize, integrate, automate and waste-averse production system that supports customization of products under the conditions of highly flexible mass production (Ghobakhloo & Fathi, 2019). According to Machado, Winroth, and Da Silva (2019), most of

the governments have to enforce the guideline for industrial revolution 4.0 to be broadly used in all operations and manufacturing. It is additionally necessary for them to represent a perfect place of business for people focusing on collaboration, learning, and improvement of competencies, the company can commence greater subtle focusing on employee benefit, for instance, working at home, work-life balance initiative. The 4th Industrial Revolution is an enabler of sustainable development, but the convergence of digital transformation and sustainability stays underdeveloped. In Southeast Asia, Industrial four has the more significant potential to put in force through manufacturing which potentially delivering productivity gains worth $216 billion to $627 billion. Masahiro Furusawa recently published a blog about Prof. Dr Henning Kagermann's keynote address at SAP Now. Kagermann describes Industry 4.0 as an initiative for social transformation that transforms society, allowing communities to deal with the challenges of climate change and Malthusian pressure on resources. (Teck Ch'ang Lim, 2019). However, the industrial 4.0 have significant benefit and opportunity in ASEAN economy, but it also can be disruptive. (Menon & Fink, 2019).

The multinational company has a significant positive correlation in four different dimensions, which are Information and Communication Technologies (ICT) competency; Innovation Management competency; Organizational Learning competency and environment competency compared to a local company in Malaysia (Kowang *et al.,*., 2019). Industry four implementation can support the construction industry to transform into a technology-driven industry significantly and to hold up with different industries in phrases of overall performance improvement.(Aripin, Zawawi, & Ismail, 2019). The introduction of cloud computing system in Malaysia has given more beneficial to the manufacturer which able to improve the process efficiency of the manufacturing firm. (Ooi, Lee, Tan, Hew, & Hew, 2018). Despite the fact that Malaysia was one of the driving mechanical nations back at that point, a more substantial part of our neighboring nations and beyond are as of now building the bridge from Industry 3.0 to 4.0 whereas expanding productivity by 4.1% every year throughout five a long time. Organization are willing to pay the massive cost within the trusts of fortifying their influences and positions within the multi-faceted mechanical environments (Low, Kasmuri, & Rubaneswaran, 2017). While transitioning to a digitized, computerized and completely interconnected supply chain requires critical endeavors and long-term ventures, the pay-offs are colossal. Bringing supply chains online can offer assistance undertakings reach the following level of operational viability and realize noteworthy cost decreases. The critical benefit of supply chain 4.0 is an excellent transparency and accuracy, data-backed decision making leading to cost-saving, Increased Interconnectedness and Collaboration, Improved Warehouse Management, "Intelligent" Supply Chain and Greater Agility (Wren, 2003).

The introduction of Industry 4.0 into manufacturing has numerous impacts on the total supply chain. Collaboration between suppliers, producers and clients is significant to extend the transparency of all the steps from when the arrange is dispatched until the end-of-life of the product (Tjahjono, Esplugues, Ares, & Pelaez, 2017). Collaborative networks in IR 4.0 can be defined as interconnection" and collaboration through networking, value chains, vertical and horizontal integration, and engineering (Hernandez *et al.,*., 2014).

Literature Review

Based on the study done by Kusmin, Tammets and Ley (2018), collaborative network in Industry Revolution 4.0 (IR 4.0) includes use of information and communication technology, Cyber Physical Systems (CPS), network communications, big data and cloud computing, modelling, virtualization and simulation as well as improved tools for human computer interaction and cooperation in order to achieve a sustainable supply chain management. IR 4.0 would improve efficiency, quality and cost pressure through digitization and networking technology, as well as individualized services at mass production costs (Birkel, Veile, Müller, Hartmann, & Voigt, 2019).

Support of Research Institutes and Universities: With the support of research institutes and universities, it will benefited the industries in terms of infrastructure development, skills development, human resource training and transfer, created intellectual property to industries and reduce risks and chances of IR 4.0 failure in the supply chain network (Telukdarie, Pretorius & Gupta, 2018). In manufacturing industries, IR 4.0 aimed at institutionalizing innovation structures that includes industry, academia and politics, an innovation system paradigm known as the Triple Helix mode of innovation. Reischauer (2018) outlined the high-tech approaches in the IR 4.0 that look into the development of ideas in the public interest involving research institutes and universities in information technology and engineering sciences through research and development (R&D) teams. Previous studies have shown that stakeholders interact with each other in the IR 4.0 labour market situation in order to recognize the difference between what is provided in universities, the real need for the labour market, consolidate stakeholder input in order to provide continuous insight into the labour market situation and establish collaborative incentives for the university industry to build integrated working learning models. Therefore, it is essential to create a very close cooperation between government, universities and technology and manufacturing companies in the long-term strategy of IR 4.0 competences (Kusmin *et al.,*., 2018).

Improved IT Security and Standard: IR 4.0 will transform the traditional manufacturers practices by using their digital tools to improve their organizational, operational, technological and legal readiness in IR 4.0(Ghobakhloo & Fathi, 2019). Furthermore, big data analytics are required that help reduce standard deviations (demand variance) and build a forecast factor Nevertheless, it is also crucial to be wary of the data protection concerns in supply chains management, which relates to data ownership, data storage or accessibility and data ownership, and is related to the risks of data sharing across the supply chain (Fernando, Chidambaram, & Wahyuni-TD, 2018). Weak IT security and low standards would result in financial losses to supply chain operations (Bag, Telukdarie, Pretorius, & Gupta, 2018)The security triad of confidentiality; integrity and availability may impact the theft of intellectual property (Chhetri, Rashid, Faezi, & Faruque, 2017). Due to that, high investments are necessary concerning experts with new and rare skills, for instance, computer science, programming, data security, or data scientists(Birkel, Veile, Müller, Hartmann, & Voigt, 2019). Therefore, service companies need to explore the critical areas of service supply chain efficiency to achieve competitive advantages through the use of IR 4.0 movement and cyber-physical production

systems (Fernando, Chidambaram, & Wahyuni-TD, 2018). However, there is still a shortage of of analytical tools and techniques for service companies to produce useful insights from data to drive strategy and boost service and business efficiency in IR 4.0 (Fernando *et al.,* 2018). Third party is also required to audit the IT policy for mitigation strategies, crisis management strategies and assesses the cyber insurance (Bag, Telukdarie, Pretorius, & Gupta, 2018). The product lifecycle of manufacturing systems has always been challenged by various threats for intellectual property loss (Chettri *et al.,.,* 2017). There is also the existence of cyber security technologies and protection for improving control system security example standards NIST SP800-82, ISA-99 or IEC 62443 (Bag *et al.,.,* 2018). Service companies also enable the Chief Data Officer to assess the required data and develop data management in the organization to remove any security issues (Fernando *et al.,.,* 2018). Regardless, manufacturing companies aiming at digitization should be prepared to take responsibility for their digitalization processes and direct them towards ensuring economic, social and environmental sustainability at the same time (Ghobakhloo & Fathi, 2019).

Information Transparency: A key element for achieving accountability and transparency across the supply chain in IR 4.0 is mutual information sharing between stakeholders where it is n cessary to end the exposure of real-time information across all entities (Kache & Seuring, 2017). Linking Big Data Analytics and Supply Chain Management in production and logistics operations increases information visibility and transparency across the supply chain (Kache & Seuring 2015). One of the method for real-time information flow includes appropriate sensor technology to track the single product and allow the product to manage itself to ensure an optimal material flow through the use of RFID technology and intelligent sensors to promote transparency and traceability in the supply chain(Bienhaus & Haddud, 2018)). Moreover, supplier and consumer integrations within the IR 4.0 environment allow a hub company to manage the flow of information, products and finances through the supply network with its consumers and suppliers (Bienhaus & Haddud, 2018). The visibility and transparency of customer information becomes the key driver of marketing decision making, ultimately determining the success of the company in the marketplace (Kache & Seuring, 2015). Real time supply chain transparency will be a future capability for organisations to achieve competitive advantage of technologies and developments by using Big Data from supply chain interfaces (Bienhaus & Haddud, 2018). The author also suggested importance of people and face to face meetings in the before mentioned context of trust and transparency as a basis for a long-term buyer supplier relationship for procurement.

Collaborative E-Government: By recognizing that the adoption of technology in government is affected by the complexity of social, organizational, technical, political and other factors, the socio-technical perspective has also increased(Pardo, Nam, & Burke, 2012). The primary goal of e-governance is to continuously improve service delivery, democratic engagement and governance by integrating internal and external ties through technology, the web and digital media (Fang, 2002). Although new technologies and channels are gradually making it possible for people to communicate with governments, governments are under pressure to change their public engagement and policy making processes. New technologies allow resources to be shared and decentralized. Committed governmental agencies and obligations is one of the key success factors for industrial revolution to progress. (Lee *et al.,.*, 2018). The first convergence between how governments plan to address problems relevant to the Fourth Industrial Revolution is demonstrated through innovation and technology (Liao, Loures, Deschamps, Brezinski, & Venâncio, 2018). Information-rich ecosystems challenge collaborative networks and associated decision-making processes through the use of detectors and smart devices, incorporated as virtual-physical systems, combined with the hyper-connection of organizations, people and structures, produce rapidly increasing data volumes. New collaborative management services that monitor the value of big data because data resources also increase data validity and reliability issues, data protection, accessibility and possession (Serrano, Greenhill, & Graham, 2015).

Collaborative Smart Grid : Camarinha-Matos, (2016) stated that important thing in the collaborative smart grid which is the ability to collect input from different power grid sites in a timely and accurate manner is the foundation for creating a more efficient, secure and sensitive system. The author also explains that advanced data analysis and associated processing power, contributing to smart devices, play an important role here. A analytical structure is developed to measure the tradeoff between the gains of partnership and privacy loss, namely the conflicting priorities of value versus privacy. In corresponding with technological development, as a result of the growing number of shareholders involved in the division, an organizational transformation is taking place, including new roles for consumers. Asset sharing and combining skills across various organizational forms, depending on the needs of each market opportunity, provide businesses with a higher degree of versatility and flexibility compared to working alone. While primarily present in production and supply chains, CNs are being implemented in various forms in an increasing number of applications, including services and provider-enhanced goods, smart transport systems, elderly treatment, intelligent environments, agriculture and food industries, disaster response and education (Camarinha-Matos, 2016). Karnouskos (2013) introduces a dream for a "collaborative smart grid environment" that incorporates connected networked technologies and vast data from these systems for the creation of value-added services. Examples of services include real-time energy tracking, asset management, real-time pricing, energy sector place services, customized business services. The performance of value-added services in smart grid relies not only on technical dimensions, but also on company problems being taken into consideration and analyze the various players participating in an environment of smart technology and their strategic alliances and agreements (Álvarez, Ghanbari, & Markendahl, 2015)

Distributed Manufacturing: As mentioned in the literature by Ul Haq & Franceschini, (2019) , Distributed Manufacturing is an industrial model relating to the decentralization of manufacturing operations, reconfigurable manufacturing approaches, new manufacturing technology, end-user-driven manufacturing, advanced digital infrastructure and increased consumer engagement in product design. DM is considered one of many industrial organizations ' approaches to meet their productivity objectives and targets. DM is an effective strategy for sustainable production thanks to its micro-production units that allow local production on demand, lower transport costs and strengthen the local economy. (Rauch, Dallinger,

Dallasega, & Matt, 2015; Rauch, Seidenstricker, Dallasega, & Hämmerl, 2016). DM is addressed in this analysis as a potential production model for sustainable operations and the operational skills needed to implement it.(Ul Haq & Franceschini, 2019).

Sustainable Supply Chain Management: Chopra & Meindl, (2019) define the supply chain as all parties involved in the performance of a customer order. In particular, highlight the idea that more than one decision maker is engaged in the management of resources, knowledge and/or systems that may not be completely within their company's control**.** Secondly,the author describe supply chain management as managing the supply chain processes, services, knowledge, and funds to increase the supply chain productivity or surplus — the gap between the revenue generated from a customer's order and all the costs incurred by the supply chain when meeting the order of that customer. The Sustainable Supply Chain Management (SSCM) relies on knowledge base is the vital issue to accomplish superior implementation and performance results. The SSCM consist on the fundamental scopes of people, procedure, management, equipment, resources and atmosphere (Roy, 2019).

2019) Dealers, principal companies and clients are linked by information, material and capital movements. In line with the value of the goods comes the environmental and social burden sustained during different phases of production. With regard to this, focal companies of supply chains might be held accountable for the environmental and social performance of their dealers (Seuring & Müller, 2008).

Academic Construct and Conceptual Framework: From the literature, the following academic construct and conceptual framework has been developed as per Figure 1 below.

Hypotheses

There are six hypotheses suggested by this study as follows:

H1 Support of research institutes and universities will influence the collaborative network in industry 4.0 towards sustainable supply chain management

H2 Improved IT security and standard will influence the collaborative network in industry 4.0 towards sustainable supply chain management

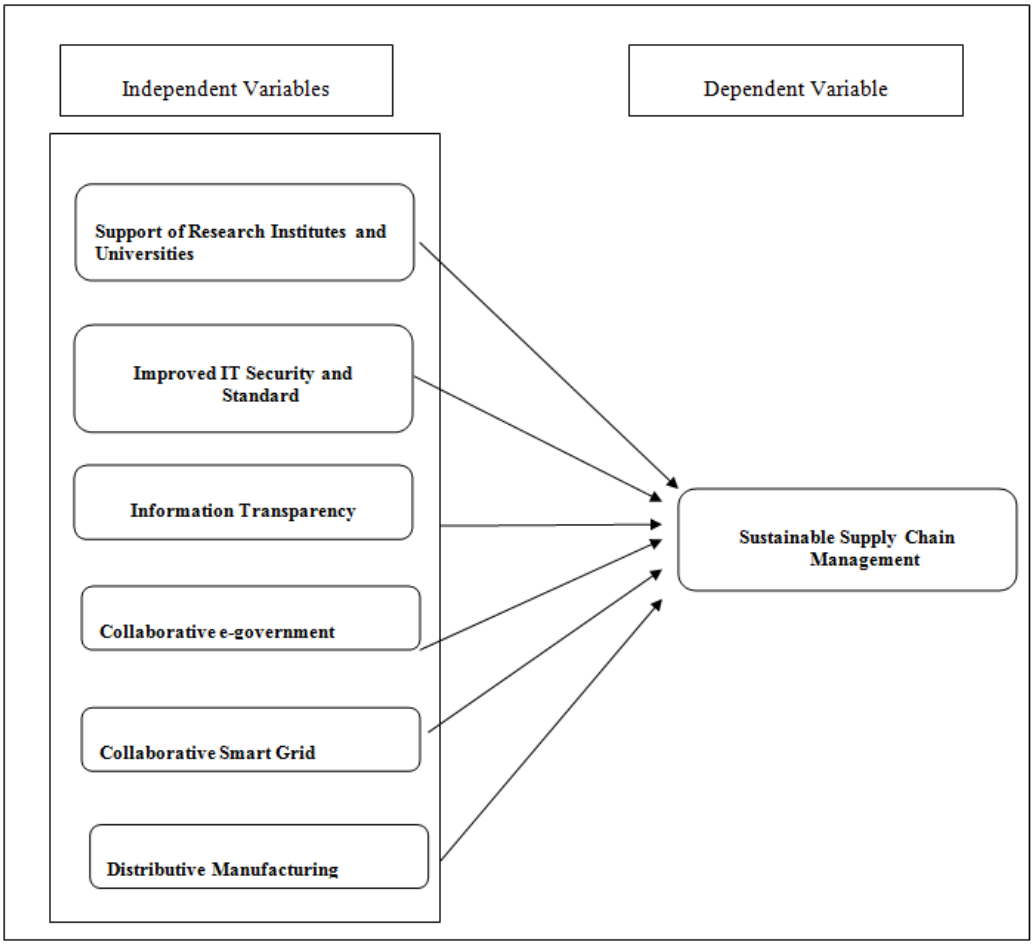

Figure 1. Research Framework and Academic Construct of the Study

Effective supply chain management (SCM) has develop a potentially appreciated way of securing competitive benefit and improving organizational performance since competition is no longer between organizations, but among supply chains(Carter & Easton, 2011). Potential competitive advantage the supply chain members can generate through the SSCM by access to trade opportunities which stipulate sustainability as the essential condition to supply chain.(Roy,

H3 Information transparency will influence the collaborative network in industry 4.0 towards sustainable supply chain management

H4 Collaborative e.government will influence the collaborative network in industry 4.0 towards sustainable supply chain management

H5 Collaborative smart grid will influence the collaborative network in industry 4.0 towards sustainable supply chain management

H6 Distributed manufactured will influence the collaborative network in industry 4.0 towards sustainable supply chain management

MATERIALS AND METHODOLOGY

Summary of the Internet of Things (IoT) definitions and Supply Chain Management (SCM) applications and challenges in IR 4.0 are used to measure the understanding and implementation of disruptive technology purposely for big data analytics and the IoT (Aryal, Liao, Nattuthurai, & Li, 2018). There are three key aspects in defining IoT applications and challenges in SCM as per following:

a. IoT as a network of interconnected objects Radio-frequency identification (RFID), wireless sensor network, and robotics in supply chains of different industries, such as automotive, medical, and aerospace; the ecosystem of the IoT

b. IoT as a capability via Inventory management optimization; Carbon footprint of logistics; Grocery shopping experiences such as automatically checking out using biometrics, allergen detection and personalized marketing. Moreover, they also optimize the supply and demand in the utility industry and identify the risks of the supply chain

c. IoT beyond technology to interact with environment through product design, service differentiation and demand and channel management. strategies

Delphi methods are able to use to get expert opinions with the aim of making predictions for opportunities and challenges linked to the emergence of Big Data Analytics from a corporate and SCM in IR 4.0 (Kache & Seuring, 2015). The consultation of knowledgeable experts was seen as a reasonable way to collect the required insights. Co-author network (CN) analysis schema as per shown in Figure 1 is used to measure a systematic computing and analytical procedure that is applied to the co-author network to identify the temporal evolution and growth of research collaborations in the area of e-governance towards IR 4.0 (Bindu, Sankar, & Kumar, 2019).

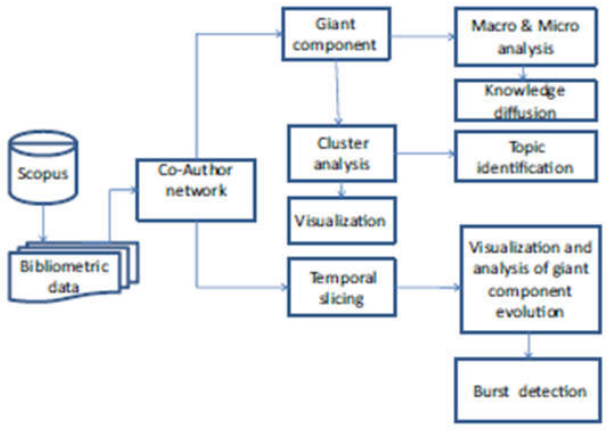

Figure 1. CN analysis schema

The Osterwalder Canvas model is used to measure collaborative business models the success of value-added services in smart grid depends not only on technological aspects but also on the consideration of business challenges (Camarinha-Matos, 2016). The cluster analysis using hierarchical clustering methodology is to measure Distributed Manufacturing (DM) competitive advantage and sustainability of manufacturing companies as per shown in Figure 2 (Ul Haq & Franceschini, 2019). This measure scale is used to analyze companies' status by plotting on the scale and compare with reference profiles.

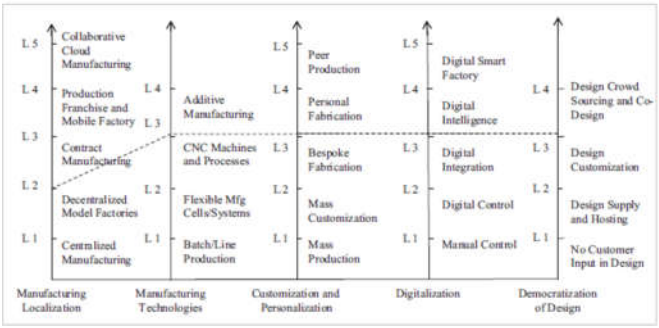

Figure 2. Hierarchical Clustering of Distributed Manufacturing

FINDINGS AND DISCUSSION

Studies concluded that integration between company's logistic function with the new security managerial dimension is crucial to be incorporated into the organisation's strategy and organization alongside the whole supply chain (Rauch *et al.,*., 2015) . Furthermore, it is the role of the logistician to ensure managers understand why it is important to consider the security demands from the initialization and development of the product until the final product is distributed to the client (Rauch *et al.,*., 2015). According to (Rauch *et al.,*., 2015), more and more expanded and new businesses are now working around supply chain security management (SSCM). Companies from diverse sectors such as aerospace and defence technologies, security technologies and services among others are looking for new business opportunities. Nevertheless, it is still an open question as to which sectors and partnerships will be able to create the most reliable and cost-efficient solutions and services for the long-term success in this field. In future, the researchers are looking into the pricing and financing aspects of security, public-private-partnerships and other business aspects. In order to guarantee the reactivity and performance of the company, logistics should be the function capable to integrate the security dimension along the whole supply chain or product or service.

Researchers are just beginning to investigate how supply chains can be most effectively managed (Ballou *et al.,*. 2000; Cheng and Grimm). Individual enterprises must work in tandem to provide customers with goods and services that they required in a manner that is efficient and effective (Stock, Boyer, & Harmon-Kizer, 2010). Another angle of discussion is how leaders in supply chain leads towards eliminating waste and redundancies that will lead to the successful management of the supply chain. These leaders or industry captains includes IBM, Procter & Gamble, Toyota and Walmart (Stock *et al.,*., 2010). From a global perspective, efficient and effective management of supply chain networks is vital. The procurement of materials from Asia, Africa and South America, the outsourcing of labor to underdeveloped nations (e.g., telephone call centers, engineering design tasks), and the

acquisition of technologies, processes and management approaches by US firms from Japan, Korea and other industrialized Asian nations, are significant aspects of SCM.

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