An Investigative Study to Examine Impact of Digitalisation on Manufacturing Supply Chains

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Abstract: - This study delves into how the COVID-19 pandemic impacted the Malaysian glove industry's supply chain and triggered the adoption of digitalization to enhance supply chain performance (SCP). Through surveys and interviews, it was discovered that the pandemic negatively affected business performance but prompted increased digitalization adoption. Commonly utilized digital solutions include Big Data Analytics (BDA), Internet of Things (IoT), and Cloud Computing (CC), while less commonly adopted solutions include Augmented Reality (AR) and Additive Manufacturing (AM). The research underscores a positive link between digitalization and SCP, stressing the significance of digital capabilities in sustaining supply chain resilience and responsiveness. However, challenges such as cultural shifts in work practices and investment apprehensions impede digitalization endeavors. The study provides insights for industry practitioners on harnessing digitalization to alleviate supply chain disruptions and offers recommendations for effective digitalization strategies.

Key-Words: - Digitalisation, Supply Chain, Manufacturing, Pandemic, Supply Chain Disruption

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1 Introduction

The impact of Coronavirus was catastrophic to human history with profound negative impact on global economies and industries. The pandemic has severely disrupted Supply Chain (SC) operations at a global level that was unprecedented in the recent history of Supply Chain Management (SCM) literature. The drastic impact has deprived the capabilities of global SC of healthcare system with critical shortages of gloves and other personal protective equipment (PPE) [1]. Disposable medical rubber glove is one of the most important safety products or PPE used by medical frontliners [2] to protect their hands against any kind of harmful substance or disease transmission such as Human Immunodeficiency Virus (HIV) and Hepatitis B Virus (HBV) [3]. The rubber glove industry is mainly driven by the growth of global healthcare industry resulted from factors such as increasing awareness of hygiene, improving rigorous health regulations, infections prevention, aging population and arising of new diseases [4,5,6]. Malaysia glove industry has started dominating the global supply during the demand surge triggered by AIDS epidemic back in 1980s [5]. Currently, Malaysia supplies about 65% of total global medical gloves [5]. Malaysia exported about 182 billion gloves in 2019 with revenue of USD4.31 billion [5]. It is forecasted that the global demand for disposable surgical gloves will increase at Compound Annual Growth Rate (CAGR) of 7.87% over the period of 2020-2026 [7]. Top Glove Corporation, Hartalega, Kossan Rubber Industries, and Supermax Corporation Berhad are among Malaysia's major glove producers [8,6,9]. As one of the largest natural rubber producers worldwide, Malaysia has plenty of key material resources for rubber gloves production which has provided a competitive advantage to local glove manufacturers [4]. In addition, the support of Malaysia government through tax incentives such as investment tax allowance and pioneer status are the driving forces for the growth of rubber glove industry [4]. Malaysia rubber glove industry highly depends on foreign labours due to low labour cost. In addition, the rubber glove margins are also affected by other factors including price fluctuation on key raw materials such as latex and natural gas; packaging material, weakening US currency and increase of minimum wage [4]. The SC of glove industry has received less research attention, let alone from the digitalisation perspective. Considering the current unprecedented SC interruption resulted from Covid-19 pandemic and with active government encouragement to adopt the disruptive advance technologies, the research hopes to fill this gap by exploring how the adoption of digitalisation would impact the Supply Chain Performance (SCP) from the impact of Covid-19 pandemic in the Malaysia glove industry. To this research, Covid-19 pandemic will be referred as pandemic throughout the report.

2 Background to Research Study

As a mean to curb the chain of Coronavirus, Malaysia implemented various types of Movement Control Order (MCO) at various stages of the pandemic from 18th March 2020 and it is still in place at the time of writing the research. With this implementation, all economy sectors are mandatory to comply with strict standard operating procedure (SOP) such as practicing physical distancing, avoid crowded and confined places to stop virus transmission. Factories were ordered to shut down temporary if employees were infected with Coronavirus [5] at the workplace and thus abrupted company operations. The pandemic was a wakeup call to businesses to evaluate the potential benefits of investing in advance technologies to transform and step up their manufacturing infrastructure and capabilities to meet the current and future market demand. Numerous articles claimed that the pandemic had motivated the industries to tap into digitalisation and grasp the opportunity to leverage technologies to improve SCP [1,10-16]; farming [17]; education [18], and insurance [19].

RQ1: To what extend does the pandemic have an impact on digitalisation adoption in Malaysia glove industry?

2.1 Digitalisation in Malaysian Manufacturing

In recent years, several major glove manufacturers have started investing in R&D and automated high-speed dipping technology in the glove production lines in recent years [20] to boost up production capacity and operation efficiency with the intentions to better manage cost and minimise reliance on foreign workforce [4]. One of the major glove producers, Top Glove has significantly succeeded in reducing the number of workers per million gloves output to less than two workers from five to ten workers a decade ago. This has proven that automation in rubber glove production lines can alleviate the requirement for foreign labour [21]. Top Glove also has been aiming to intensify the adoption of AI and autonomous robots as plant wide digitalisation journey by penetrating all aspect of the operations to boost production efficiency and quality control, improve workplace safety and security [22]. Apart from Top Glove, other key players in the glove industry namely Hartalega has also embarked on digitalisation [20]. At the same time, studies to escalate their digitalisation journey by adopting robotics in its manufacturing processes in 2020 [20]. On the upstream of rubber glove industry, the rubber agriculture sector has conducted ‘on-going efforts on the trial of Automated Rubber Tapping System (ARTS), which mechanises timed tapping, latex collection and bulking to increase yield, with data crunching of gram per tree per tapping (GTT)’ [20]. The Plantation Industries and Commodities Ministry has suggested that Global Positioning System (GPS) to be adopted in the farming section to ease the execution of planting process of annual crops such as rubber trees. From aforementioned information extracted from industrial articles such as Rubber Journal Asia, Channel News Asia (CNA) and Nikkei Asia, clearly, various glove producers have embarked on different pace of their automation adoptions. Top Glove, Hartalega and Kossan have implemented automation into their manufacturing processes over the past few years and are now focusing on intelligent technologies to reap the benefits of digitalisation. While other glove producers are at the beginning stage to automate their production lines. Nonetheless, it is worth noted that major glove producers are largely focusing on manufacturing processes as the starting point on new technology adoption.

2.2 Supply Chain Disruption in Manufacturing

Studies define SC disruption as incidents that interrupt the movement of goods from upstream to downstream of the SC chain [23]. With the outbreak of the pandemic, businesses in various industries across the globe were hugely affected. To curb the spread of the disease, countries adopted extreme measures by restricting movement through closing borders and lockdown. This drastic action with immense geographical impact has negatively influenced worldwide economic activities and global SC operations [12, 24,25]. According to The Organisation for Economic Co-operation and Development (OECD), countries around the world has shown negative year-on-year real GDP growth [26] as shown in figure 1. Global SC has been unprecedentedly broken with extremely limited capabilities to function in which emergency supplies of key materials or products from overseas fail to meet and match the surging demand. Subsequently global economy experienced fluctuation in stock prices and declined in business earnings [12, 24] resulted from factories shutdown and shipments delayed. A 25% reduction in global air traffic as of October 2020 compared to a year ago was reported while 40% airplanes were not operating resulting from travel ban [27]. The glove industry and its supporting industries were experiencing the ripple effects from the pandemic with sudden spike of demand on key raw materials; i.e.: chemicals, latex and pigment; machinery; packaging and logistics services resulted from measures putting in to limit the spread of Covid-19.

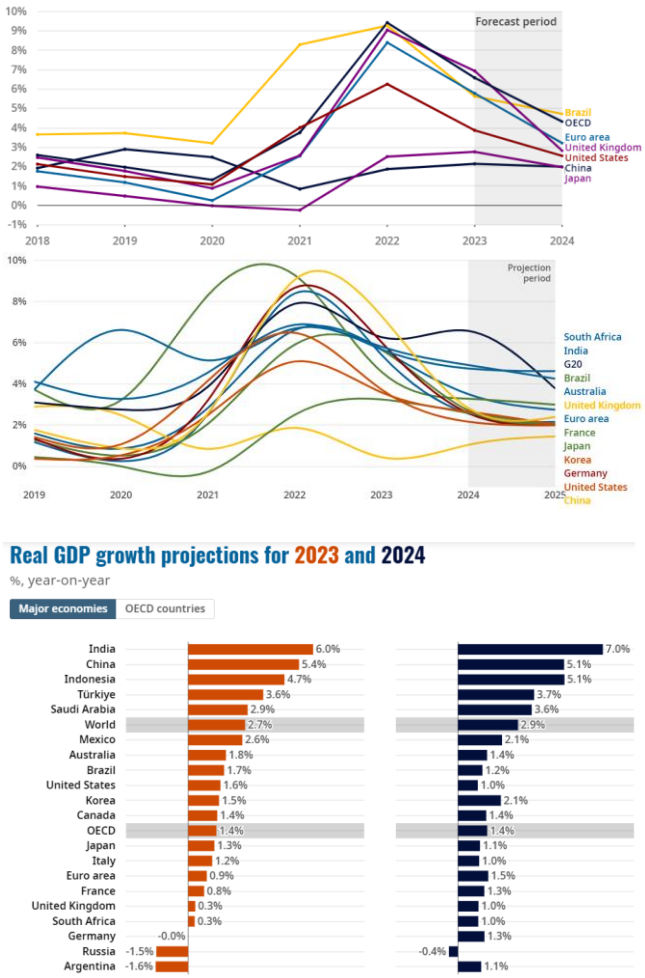


Figure 1: Percentile Headline Inflation (2023, 2024) and Real GDP Growth [26]

Hence, paper explores what digital technologies were adopted within the SC network to help the partners to connect and response to external market uncertainty with fast and accurate information to maintain and strengthen SCP while mitigating any possible supply risks.

RQ2: What digitisation solutions were adopted within the Supply Chain structures of the Malaysia glove industry?

RQ3: How will digitalisation impact Supply Chain Performance of the Malaysia glove industry?

The research objectives cover three main aspects: firstly, to identify to what extend the impact of pandemic has on digitalisation adoption in Malaysia glove industry. Second, to identify what digitisation solutions were adopted within the SC structures of Malaysian glove industry, and to identify how digitalisation impacts SCP of Malaysian sector.

3 Literature Studies

The research explores the impact of digitalisation on supply chain in the glove industry through the impact of Covid-19 Pandemic in Malaysia. The literature review shall cover areas concerning to pandemic and digitalisation, SC and digital solutions as well as digitalisation impact on SCP as set out by the research questions below and area on digitalisation challenges also be reviewed.

3.1 Pandemic and Digitalisation

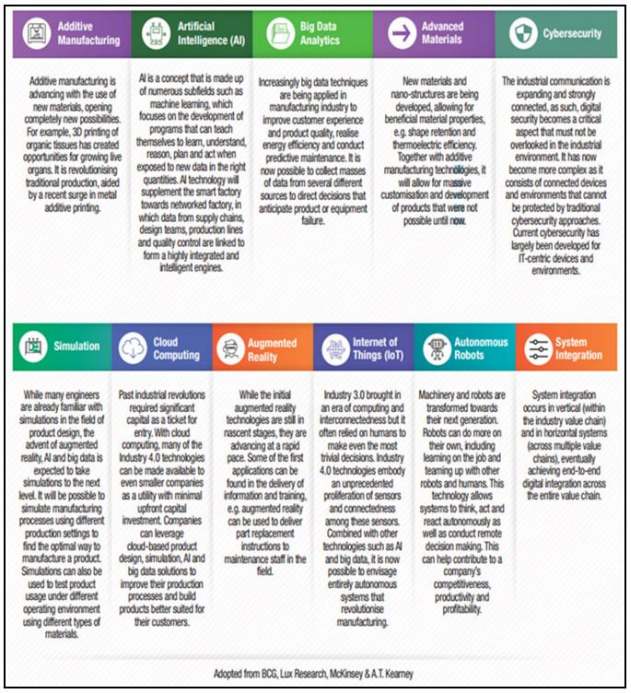
The impact of Coronavirus was catastrophic to human history with unexpected speedy infectiousness rate that has spread across the globe coupled with high fatality rate resulted a profound negative impact on global economies and industries. The severe disruption in SC operations triggered by the impact of Coronavirus was unprecedented in the recent history of SCM literature. Covid-19 has unveiled the importance of digitalisation and many countries made substantial progress in deploying new technologies that are vital to manage a larger aspect of daily activities such as education, healthcare, distance connectivity and e-commerce [16]. Scholars and industry experts had been intensively debating that adopting innovative technologies could help the industries to recover from the disruption and to sustain business continuity [11,28,19,29,16]. The rapid growth of digital transformation has amplified the demand on advance technologies, for instance, Cloud Computing, Artificial Intelligence, Internet of Things and Big Data Analytics thus, has elevated digital capabilities to enable better management on daily issues such as physical interactions, business operations and processes [16] which include working from home to ensure business continuity. With remote working, digital technologies enable data to be stored in the cloud with customised secured access for employees and employers [30]. These technologies enable seamless virtual coordination in flexible and mobile virtual office environment to drive business activities. The state-of-the-art technologies enable virtual exhibitions, business conferences and trainings to be conducted virtually over the internet platforms that allows global access and interaction [30]. With the speedy expansion in the digital space where industries steer to maximise operations efficiency and competency to stay ahead of market competition, technology innovations has fast-tracked from five years to 18 months [31].

3.2 Digitalisation

The development of World Wide Web has connected global population and greatly changed the business environment [32,33]. With vigorous

innovative technology development and increased usage of digital technologies, new business models have been dramatically created and redefined. This evolvement has prompted the change in consumer behaviours and social trends [34] that resulted a shift of business competitive position in many industries [32]. Furthermore, this has driven the path for digitalisation whereby businesses and consumers are creating and utilizing vast amount of digital information online without restriction of time and borders [32]. As of October 2020, 59% of the world population were active internet users which comprised of almost 4.66 billion people where 89% were active social media users [35]. Digitalisation or digital transformation is interpreted as adoption of smart technologies BD, CC, AI, robotics, IoT and 3D printing [36] to thoroughly boost business performance with lower cost, increased precision and speedy response that strengthen efficiency [37]. Digitalisation also refers to the process of transforming organisation operations and processes by using digital technologies in terms of digital platforms, infrastructures, artifacts, business and management applications [38,28,39] identify that technologies that commonly adopted by leading companies in the era of Industry 4.0 are autonomous robots, simulation, system integration, Industrial IoT, cyber security, CC, Additive Manufacturing (AM), Augmented Reality (AR), BDA shown in Table 2.

Table 2: Enabling Technologies [40]



Through the advancement of technological innovations, digitalisation solutions have becoming increasingly intelligent and with smarter features and options. Studies find that technology has changed the way how information is communicated, i.e.: from paper to digital [41-43]. Furthermore, digitalisation has reshaped economy, society and industry with its ubiquitous nature in influencing and changing the ways how modern society communicates and interacts in areas such as social, economic and culture [44,10]. With the evolvement of different stages of industrial revolution since 18th century till today as depicted in Table 3, many developed nations have benefited from deploying advance and innovative technologies at various stages of the revolutions. These efforts have boosted and changed the competitiveness of the industries landscape and contributed to economic growth.

Table 3: Stages of Industrial Revolution [45]

Revolution	Time Period	Technologies
First	18th and 19th centuries	Water- and steam-powered mechanical manufacturing
Second	late 19th century – 1970s	Electric-powered mass production based on the division of labour
Third	1970s-Today	Electronics and information technology drives new levels of automation of complex tasks
Fourth	Today	Based on Cyber- Physical System

Table 4: Deployment of Advance Technology in Different Countries [45]

Countries	Key Technologies / Methods	Researcher
Germany	Key Technology: Smart Manufacturing Core Technology: CPS, IoT, Big Data, Sensor, Cloud Computing	Kang et al. (2016)
	Exoskeleton emulating the anatomy and physiology of the human hand. Wear as a glove and support straining manual movements	Wee et al. (2015)
	Dynamic model & algorithm in supply chain scheduling in smart factories	Ivanov et al. (2015)
	Apply latest software NX, Team center, Product Lifecycle Management (PLM), SIMATIC controllers and SIMATIC IT, Manufacturing Execution System (MES)	Kuge et al. (2015)
	ALLROUNDER injection moulding machine and a free former for additive manufacturing are linked by means of a seven-axis robot monitor using tablet PC	Rauen et al. (2015)
China	Intelligent autonomous machine and assistance system, CPS technologies, IoT	Kegermann et al. (2013)
	Digital factory, Big data, Cloud service, Intelligent robot	Chunxi (2015)
USA	Core Technologies: CPS, IoT/wireless platform, Big Data/data analytics, Sensor, Cloud Computing, Smart energy, Additive manufacturing	Kang et al. (2016)
	Additive manufacturing (AM) - 3D Printing	Huang et al. (2009)
South Korea	CPS, IoT, 3D printing, Big data Cloud Computing, Sensor, Smart Energy, Hologram	Kang et al. (2016)
Switzerland	Additive manufacturing (AM) - 3D Printing	Schlaepfer et al. (2015)
Singapore	Cyber-infrastructure, high performing computing (HPC) Eco-industrial parks (EIPs) data storage	Pan et al. (2015)
India	Existence of Cyber-Physical Systems Innovation Hub Autonomous robots/machine and assistance system, IoT	Kegermann et al. (2013)

Key technologies such as Cyber Physical System (CPS), IoT, BDA, AM, CC and intelligent robots were commonly adopted [45] in countries such as Germany, China, USA and South Korea as tabulated

in Table 4. As presented in Figure 1, countries like USA, Germany, Japan, France, India and China are developing cutting-edge technologies in different sectors to attain Smart Manufacturing [45].

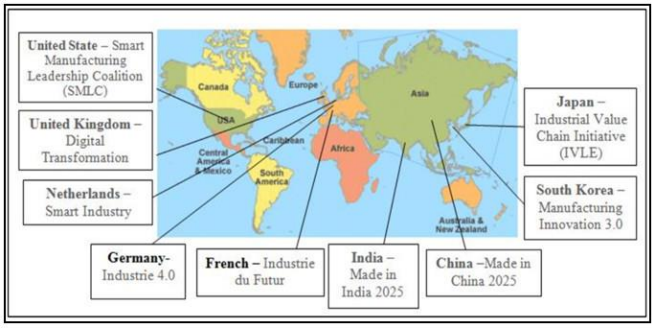


Figure 1: Countries in the Fourth Industrial Revolution [45]

3.3 Digitalisation Outlook in Malaysia

Malaysia is still at the beginning stage of digitalisation with the implementation of several digital technologies namely, automation, IoT, robotics, and BDA according to research [45]. Statista discloses the number of internet users in Malaysia has been on the rise from 21.42 million in 2015 to 29.01 million in 2019 with 35% increase and it was forecasted to increase another 15% from 2020 to 2025. Based on total population of 32.58 million recorded in 2019, about 89% of Malaysia population are accessing to internet [35]. Within Malaysia, the level of low to high technology adoption was 76.3% in which high technology consists of 43.2% [46]. According to Global Industrial Competitive Performance Index 2020, a benchmark of countries' ability to produce and export manufactured goods competitively; Malaysia was ranked at 23rd among 152 countries [46]. The top three countries were Germany, China and Republic of Korea. Among the eleven Southeast Asia countries, Malaysia was ranked 2nd with a massive gap behind Singapore. Thailand came in as 3rd and followed by Vietnam and Indonesia [46]. The Malaysia government has acknowledged the benefits of intelligent technology and has taken several strategic initiatives to promote the adoption of advance technologies through providing allowances, training and education [45].

First initiative, The Economic Transformation Programme (ETP) was launched in 2010 with the vision to transform Malaysia into a high-income nation in 2020 with innovative technologies in the economy and industry sectors [47,40,48]. ***Second initiative***, Transformasi Nasional 50 – or TN 50 was launched in January 2017 with the purpose to develop Malaysia through technologies [49]. ***Third initiative***, The Malaysia National Policy on I4.0 was launched in October 2018 with the mission to steer toward smart manufacturing by adopting I4.0 technology [40] to strengthen and streamline the manufacturing sector and other related sectors. Four main elements were identified under this initiative, i.e.: interoperability, digital twin, modularity and flexibility [40]. One of the primaries focuses of the third initiative is to adopt Information and Communication Technology (ICT) associated with innovation and automation related to the segment of SCM, operations and management systems to improve efficiency and business performance [45]. At present, Malaysia businesses in the manufacturing sector have taken efforts to adopt smart technologies to heighten their competency to be at par with other developing nations [45]. The manufacturing is crucial sector that contributed average 39% to the nation's GDP from 2009 to 2019 [35]. Forbes reported that Malaysia businesses have begun the deployment of digital technologies from sector such as manufacturing, healthcare, electrical and electronics to e-commerce to improve and support the country's recovery from the pandemic [50].

3.4 Supply Chain and Digital Technologies

Researchers argue that the primary objective of SC is to maximise customer satisfaction [51] by providing the right product to the right customer in the right quantity at the right time at the right place for the right price [52,44,53]. The actors within the SC are interrelated and aligned their operations of different natures to improve SC cost, lead time, quality and flexibility in the process of transforming raw materials until the finished product reaches end customer [53,54]. This SC objective will be hindered in the event of SC disruptions. The pandemic crisis resulted loss of revenue, shortages of essential materials, closure of factories, escalated transportation cost, and alternatives of products [23]. Likewise, SC structures that are traditional, inflexible and difficult to access to required data with arm's length business relationships [44] also contributed to operations disruption and affected the capability to achieve the objectives. Intelligent technological approach aids to redesign, reconfigure and foster SC systems integration to sense, communicate, react, coordinate and manage the process flows along the SC networks according to market dynamic via orchestrating and synchronising digital devices, business applications and networks [44]. The studies further articulate that digitalised SC structure resulted in automation, agility and virtual management that minimised the impact of supply chain interruption [44]. In addition, deployment of smart technologies enables streamlining processes and operations,

improvement in quality, time, cost and flexibility [55]. Moreover, [56] evocate that embracing innovative technologies will reap benefits in terms of 'speed, flexibility, granularity, accuracy and efficiency'. Also, [11] concluded that digitalisation will bring business survival, shorten recovery process and enhance business sustainability. According to research, generally, CC, IoT and BDA have received more attention and were widely studied especially during the period of 2011 to 2017 while AM gained more popularity in 2016 comparing to other technologies such as blockchain, AI, drones, autonomous vehicles, AR, or robotics. However, for the purpose of current research, the nine technologies discussed below shall be used to answer research question RQ2 as most of them were listed under Malaysia National Policy On Industry 4.0 and these technologies are equally important to drive improvement in SCP.

Big data analytics (BDA) - BDA is an innovative tool that enables analysis to be performed speedily and effectively on data that are massive, complicated and high velocity [51,52]. Information generated from analytical tool could be used to forecast events such as market price, consumer behaviour, voting patterns as well as to influence perceptions [57].

Internet of Things (IoT) - IoT is physical devices embedded with sensors and software that are interconnected physically and virtually to collect, process and share information in the internet platforms [52,55,58].

Cloud Computing (CC) - CC enables a series of networks, servers, databases, storage devices, and software applications via internet connectivity [27,59] in which massive data could be universally obtained in real time from shared pools of customisable resources [51,60].

Autonomous robots - Autonomous robots are intelligent products of latest robotic technology that are designed and programmed to carry out tasks by themselves with minimal to no human interaction or interference [51,61].

Additive Manufacturing (AM) - It is a technology that "adjoins materials together by knitting or solidifying it using computer controls" [51] directly and instantly from digital data to form three-dimensional final products in variety of desired shapes or structures [62,54,51,59].

Augmented Reality (AR) - AR is a technology that enables human machine interface [63] in which virtual images or information generated by computer are overlaid on real-world environment in real-time thus created a virtual world with intensified reality and user experience [63] that aids timely decision making [64].

Artificial Intelligence (AI) and Machine Learning (ML) - AI is a technology that connects with several innovative devices to perform a task through thinking, sensing, recognizing and collaborating with humans [33]. Machine Learning (ML) is part of AI. It is a technology that enables machines access to data, learn and identify pattern for the machine to automatically make decision [33].

Cyber Physical System (CPS) - A new group of system that integrates physical with digital system with communication capabilities between them [65].

Table 5: Summary of Key Technologies from Recent Research

Researchers	Key Digital Technologies
Szozda, 2017	IoT, Cloud Computing, Big Data Analytics, Advance Robotics, Touch Interfaces, AI, Machine Learning, VR, 3D Priting
Tjahjono, et al., 2017	VR/AR, Additive Manufacturing, Simulation, Big Data Analytics, Cloud Technology, Cybersecurity, IoT, Miniaturization of electonics, Automatic indentification and Data Collection, RFID, Robotics, Drones, Nanotechnology, Machine to Machine Communication, BI
Büyüközkan and Göçer, 2018	AR, Big Data, Cloud Computing, Digital Supply Chain, Robotics, IoT, Nanotechnology, OmniChannel, Robotics, Sensor Technology, Self-Driving Vehicles, Unmanned Aerial Vehicle, 3D Printing
Aćimović and Stajić, 2019	Blockchain, AI, AR, Big Data Analytics, Drones, Self-driving Vehicles, IoT
Menon and Shah, 2019	Big Data, IoT, Cloud System, Autonomous Robotics, Sensor & Geolocations, 3D Printing, User Interface
Crittenden, et al., 2019	AI, AR, Blockchain, Drones, Gamification, ML, robots, 3D printing, IoT, VR
Bragazzi, 2020	Smart Sensors, Nano (bio) Technologies, Quantum, Imersive,Cloud and Ubiquitous Computing, "IoT" / "IIoT", Block Chain, Next-Generation Telecommunication Networks, Big Data Analytics
Rymarczyk, 2020	IoT, AI, Advanced robots, Autonomous vehicles, Cloud computing, Big data sets, AR, 3D Printing, Nanomaterials, Blockchain, Digital Twin
Ghadge, et al., 2020	Big data analytics, Autonomous robots, Cloud technology, Simulation, IIoT, Additive manufacturing, AR, BI, Cybersecurity

Research on these technologies is summarised briefly in table 5 as the key digital technologies that received most attention from recent research. It also reflects blockchain, virtual reality and AR, autonomous robots and ML have beginning to receive increasing emphasis. The evolution of integrating information and communication technology (ICT) in business operations and processes [60] which not only focusing on machines and production but also including activities within the value chain of the entire SC [55]. As demonstrated in Figure 2, apart from cloud blockchain, autonomous robots and smart machines, business applications such as Customer Relationship Management, Supplier Performance Management and Data Analytics as well as intelligence devices, i.e.: sensors and hardware are enhancing the primary and supporting activities of the value chain. Researchers articulate that digital technologies contribute to system and process-based cogitation in which real time information generated at each value

chain is readily made available to support the dynamic information integration process within and beyond the SC boundaries [39].

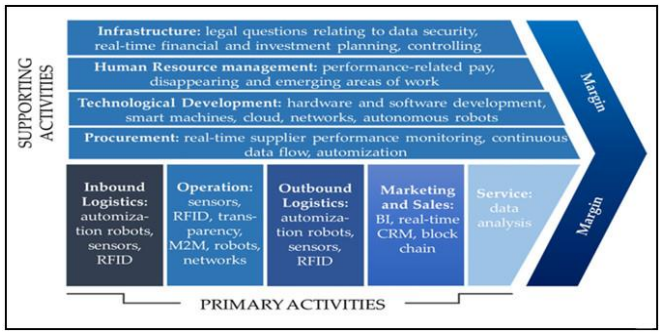


Figure 2: The Tools of Industry 4.0 in the Corporate Value Chain [39]

Studies find that modernized SCs are moving toward automated systems where information and data are integrated in the cloud while operations are carried out in virtual place [60,55,30]. This has transformed the value chain processes and operations and customer experience.

3.5 Digital Solutions and Supply Chain Structures

The process of SC focuses on five areas of the supply chain which include plan, source, make, deliver, and return [53,44]. Thus, within the scope of current research, it adopts a more comprehensive approach that involve five key supply chain structures, i.e.: Procurement, Manufacturing, Distribution, Supplier and Customer.

Digital solutions in the procurement area are moving toward automation with broader intelligent technologies where routine and repetitive transactional processes are automated coupled with AI, IoT and BDA [38,66]. Procurement software enables digitally exchange of end-to-end information in a transparent and real-time manner through adopting cloud technology, BDA, and platforms with intelligent execution capabilities [41,43] to respond continuously and vigorously toward ever-changing demand and supply restrictions of the external environment [56]. Intelligent procurement analytics enables business applications such as ERP and contract management systems (CMS) to collect, analyse and process information for prompt purchase decisions [41,66] while managing supplier networks in a simplify [67], transparent and traceable SC networks [38]. With the combination of highly advance technologies, machines, objects and human allows communication and interaction (Brunetti et al., 2020) electronically to control and organize machines and production processes independently and flexibly on their own in real-time to optimize operation [38,60,58,55,68]. The intense integration and interconnectivity help to minimise the requirement of human intervention, reduces monotonous tasks, improves accuracy and optimise yield that drives operations efficiency and responsiveness, ultimately this leads to improvement in developing competitive strategies that creates opportunities and value in manufacturing operations [45] and subsequently benefit organisation bottom line [39, 31]. Study finds that nine technologies, i.e.: IoT, Simulation, Horizontal and Vertical Integration, Cyber Security, CC, AM, AR, BDA and Autonomous Robot [45] that steer toward smart manufacturing are critical to develop intelligent manufacturing processes to achieve the smart factory environment [39].

AI, IoT, Drones, Unmanned Aerial Vehicles (UAVs), Cloud Platforms and Blockchain play a remarkable role in shaping the way physical goods are handled and delivered from one end to another along the SC partners [69] thus drastically uplifted the distribution infrastructure [39, 70]. Leveraging modern technologies significantly optimise distribution route planning, optimise truck utilization, reduce carbon footprint and costs [70,71] thus increase efficiency, flexibility in the distribution process [56]. Automatic guided vehicles (AGV), mobile collaborative robots, mobile robotic storage and retrieval systems, RFID, bar code scanners, heads-up displays and other vision technologies supervised by advanced control systems optimize storage efficiency & material handling systems [69].

Supplier is a crucial SC partner that has direct implication toward organisation competitiveness. It is vital to establish effective relationship to mitigate supply risk for sustainable performance. Creating an eco-system which encompasses computer, BDA, cloud technology, telecommunication networks, software such ERP and EDI is essential for supplier collaboration initiatives [42] and holistic view on supplier performance [72]. Integrating supplier management software into one digital platform could seamlessly linked with related value chain activities [42] and enables SC partners to achieve higher integration and maximize information sharing, transparency, visibility and consequently facilitate communication effectiveness within the SC [42]. Transparency and traceability within the SC ecosystem will strengthen buyer-supplier relationships and level of trust [38]. Organisations are increasingly putting efforts to create lasting and effective customer relationship [73] with highly competitive and uncertain market environment.

Table 6: Digital Solutions Adopted within the Supply Chain Structures

Example of Digital Solutions Adopted in SC Structures	Source
Procurement	
AI - fully automate the bidding invitation process (Maersk)	SupplyChainDive, 2020
Prescriptive analytic and Machine learning - automate the reading and interpretation of contracts (Maersk)	SupplyChainDive, 2020
Touchless technology (SAP Ariba-based e-procurement system) – to optimise procurement operations that minimises mistakes, enables better control and visibility in the procurement processes (SATS)	SourceToday, 2020
Manufacturing	
Predictive analytics - Machine status – spare parts demand	Aćimović and Stajić, 2019
IoT - control and monitor wireless sensor networks, resource allocation and resource bundling	Hausberg, et al., 2019
Distribution	
5G network, RFID technology and smart sensors - optimum management on flow of information and physical products	Bienhaus and Haddud, 2018; Osmolski and Kolinski, 2020
GPS - New transport solutions offering overview of transport fleet with exact positioning in transport network.	Aćimović and Stajić, 2019
Supplier	
BDA - performance evaluation, supplier selection and supplier risk profile	SourceToday, 2020
Customer	
AR - new product development, promotion and strengthening customer relationship (Amazon, BMW, Wrigley and IKEA)	Crittenden, et al., 2019
Data analytics, IoT, AI, ML - flexible and continuous services at a speed of 10 times faster (DBS digital banking)	TechTarget, 2020.

AI, AR, Blockchain, drones, IoT, ML and AM have been identified as some of the digital technologies that will reshape the business and customer relationship [33]. Accurate demand forecast [56], data-driven decision-making and responsiveness to disruptions through employing advance technologies improve SC efficiency and hence lead to improved customer satisfaction [60]. Gartner forecasts that in 2022, 70% of customer interactions will associate with innovative technologies such as chatbots and ML application comparing to 15% in 2018 [74]. Table 6 illustrates examples of digital solutions such as AI, DAB, IoT, 5G, GPS and ML that have been adopted within SC structures to improve SC operations.

3.6 Digitalisation and Supply Chain Performance

The ultimate target of digitalisation is to improve Supply Chain Performance (SCP) [44]. Digitalisation reinforces SCP by maximising connection, integration and creation of knowledge [44], accelerate SC innovations, drive down production cost and optimise business revenues especially in uncertain global condition [63]. 93% of corporate leaders agreed that leveraging digitalisation is vital in achieving corporate objectives and maintaining competitive edge [15] by realign management strategies and critical resources with real time, reliable and quality information to drive organisation toward performance improvement [75,38,60]. The current research shall examine the SCP through the lens of transparency, communication, collaboration, flexibility and responsiveness which were adopted from 'Improved activities and business operations in an integrated supply chain ecosystem through the deployment of Digitalisation in Supply Chain (DSC)' [56]. These five improvements are improvised into three main perspectives which are integration, visibility and responsiveness.

An integrated SC ecosystem includes external stakeholders such as suppliers, customers and internal value chain such as manufacturing, procurement, logistics, distribution and marketing [75,44,60]. Study finds that digitalisation simplifies SC ecosystems and lead to improved productivity and amplified integration between internal and external SC operations [38] through information integration, cooperation and sharing of resources and organizational relationship connection [44]. Meanwhile, [28] identifies SCI as one of the measurements for production recovery strategies in their research. Studies find that integrated value chain gather, analyse and share information from various sources within the network and resulted complete awareness and coordination of all levels of the value chain with real-time feedback [75,68]. This leads to increase visibility which ultimately increase flexibility and resilient in SC [76]. Subsequently, it drives greater trust and fosters deeper relationships between the SC partners [60]. It is evident that heighten integration of value chain is crucial in SCM to maintain competitiveness in the dynamic business world [51]. In essence, SCI is considered as an important aspect in SCP with the positive impact through digitalisation [77].

In general, SCV is defined as "traceability and transparency of SC process" [78]. Research finds that 79% of large organisations acknowledged their top concern on SCV [79]. Absence of visibility will result in inadequacy of knowledge, diminished capability to access or provide relevant and timely information for better and accurate decisions [80], inability to manage, disruption and doubts which lead to greater SC risk [78]. Maximising the utilization of intelligent technologies will benefit SCM in accurate forecasting and planning from the visibility of materials and products flows [60], ability to obtain updated information related to order fulfilment, inventory location, cost and visibility of end to end operations thus, greatly increase traceability and visibility [80] and reduces bullwhip effects [58], augment company's flexibility to respond and adapt in dynamic market situation [81], influence the effectiveness and efficiency of the SC overall performance [78,79,44]. With escalated SCV, the capability to assess potential risk also could be expanded and timely deploy appropriate response strategies to suppress SC disruptions [80].

With globalisation, cost driven SCs have become long, complex and dynamic multi-national supply networks have increase SC risks [82] and increasingly challenging and costlier to control and manage effectively in complex and uncertain [52] global conditions with mismatch of supply and demand [52]. Lacking responsiveness is associated with SC risks. Organisations with higher SC risk has lesser capability to react to disruption results in negative consequences on the businesses [82,83]. Global SCs are under huge pressure to overcome challenges such as longer response time, conflicting priorities, lack of visibility and agility with the outbreak of pandemic. Studies [44] articulate that advance analytics with quality information enables speedier responses such as adjusting competitive strategies to stay ahead of competitors, detecting changing pattern in demand and supply, technological changes as well as increasing elasticity in scaling operation capacities. This results in magnifying SC robustness [84,60] which helps to mitigate SC risks and bottlenecks [84] for long term competitiveness and sustainability in current extremely uncertain and high-risk market condition [60]. Researchers [55] views that the advance technologies result in optimise capabilities, increase analytical usages and simplify SC activities hence, digitalisation in SCM is mandatory to ensure SCR.

4. Research Framework

Studies have vigorous debated benefits of digitalisation toward SCP; therefore, this research intends to identify how will digitalisation impact SCP in Malaysia glove industry as per conceptual framework illustrated in Figure 3.

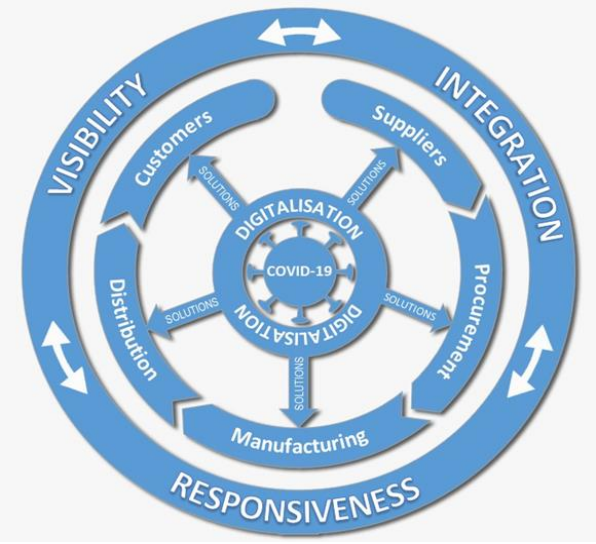


Figure 3: Conceptual Framework [85]

Under this framework, the researcher has incorporated the elements extracted from conventional SC [51] and four levers of SC [68] by tabulating five key SC structures, i.e.: supplier, procurement, manufacturing, distribution and customer. The framework explains that with the adoption of various digital technologies under the influence of pandemic, the entire SCP will be elevated through improved visibility, integration and responsiveness in which the connections among visibility, integration and responsiveness are interrelated within an integrated SC ecosystem. Researchers find that businesses will become complacent and eventually will be replaced by those who embraces innovative technologies to enhance their business performance [33]. Nonetheless, challenges in implementing digital transformation should be well noted and addressed to ensure greater success. The research is unique as it throws lights to the current states of digitalisation in the SC of Malaysia glove industry during the pandemic. The significance of the research is twofold: firstly, it contributes to the developing knowledge of digitalisation in the SC of Malaysia glove industry. Secondly, it advances the understanding and knowledge on the impact of digitalisation on SCP.

4.1 Research Philosophy

This research adopted positivism philosophy based on ontological assumptions as it was orientated on the theory of the existence of "nature of social world" [86] and "nature of reality or being" [87] of a phenomenon that existed independently from the researcher [86-88]. This research anchored in ontological assumptions has associated with quantitative method with deductive approach to test the theory. The research employed both online survey and interview as primary data collection methods as it was cross-sectional research. The data gathered from this strategy explained the research questions. This research strategy enabled standardized data to be obtained for the ease of comparison and analysis from administering survey questionnaire [87]. A set of self–administered online questionnaire was prepared for primary data collection through survey and interview. Online survey from cluster sampling of target respondents from Malaysian Rubber Glove Manufacturers Association (Margma) were conducted. The main research questionnaire was categorized into two sections that make up of closed-ended and open-ended questions. Apart from structured questionnaire, face to face structured interviews with the management of a manufacturing company who is pioneer in the glove industry were conducted.

4.2 Constructs Development

Under the deductive approach, the researchers adopted hypotheses to be tested which enables explanation of the findings between theory and social research that are subjected to detailed scrutiny [86]. Five main constructs with respective measurements focusing on major aspects of digitalisation in the condition of current pandemic and its impact on SCP were developed and illustrated in in construct tables for each of the five constructs.

The first construct consisted of five questions that examined the relation between pandemic and business performance. There were five measurements for this construct, i.e.: sales revenue, production output, and customer satisfaction, delivery commitment to customer and supplier delivery performance.

No	Constructs	Measurements	Multiple Choice Answer
1	Covid-19 pandemic and business performance	Sales revenue	Range of Decrease 50% to Increased
		Production output	Range of Decrease 50% to Increased
		Customer satisfaction	Range of Decrease 50% to Increased
		Customer delivery commitment	Range of Delay 6 month to Improved
		Supplier delivery performance	Range of Delay 6 month to Improved

Respondents were able to select predefined multiple-choice answers ranging from the category of 'decrease more than 50%' to 'increase' for questions related to sales revenue, production output and customer satisfaction. Questions related delivery performance were given the options of 'delay more than 6 months' to 'improved'. This construct measured the glove industry's business performance during the pandemic.

The second construct consisted of four statements that explored the relation between pandemic and adoption of digitalisation. The first three statements were associated to three close-ended questions that measured company investment, implementation pace and company performance. Respondents were able to select options of 'strongly disagree', 'disagree', 'neutral', 'agree', and 'strongly agree' with the use of five-point Likert-style rating scale. The Likert scale was preferred as it measured the strength and magnitude of the respondents' replies that could be statistically evaluated [86]. The fourth statement was created with multiple choice answers that enabled respondents to select more than one answer and to include addition comments despite the suggested answers. The purpose of this statement was to examine impact of digitalisation on company performance in terms of sales, production output, customer satisfaction, decision making, and real-time information and exploit new market. The participants answered the questions based on their general perspectives. With the responses obtained from this section, the researcher was able to analyse the influence of pandemic on digital transformation.

No	Constructs	Measurements	Multiple Choice Answer
2	Covid-19 pandemic and digitalisation adoption	Investment	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Implementation pace	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Company performance	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Area of improvement	Sales, Production output, Customer satisfaction, Decision-making, Real-time information, Exploit new market, Others

The third construct explored digital solutions that have been adopted and the intensity of the adoption level within the SC structures. In research conducted by [28], the researchers measured company's level of digitalisation through the adoption of technologies, i.e.: Big Data, AI, Mobile, CC, IoT, Social and Platform development with five-point Likert scale. Current research adopted nine measures, i.e.: BDA, IoT, CC, AM, Autonomous Robots, AI, AR, ML and CPS to examine this construct as most of them were listed under Malaysia National Policy On Industry 4.0 and these technologies are equally important to drive improvement in SCP. Mobile and social were not examined individually as these technologies were embedded into the nine digital technologies identified above while platform development was not included as the research focused on the aspect of SC operation of the manufacturing industry. This study adopted the question and expanded it into two questions that measured digital technologies or related digital management platforms currently adopted within SC structures and the adoption level at each SC structures which were associated to research question RQ2.

No	Constructs	Measurements	Multiple Choice Answer
3 (i)	Digital solutions within supply chain structure	Digital solutions	Big Data Analytics, IoT, Clouds, Autonomous Robots, Additive Manufacturing, AI, AR, ML, CPS, Not implemented
3 (ii)	Level of digitalisation adoption	Procurement	Very low to very high (5 Points Likert Scale)
		Manufacturing	Very low to very high (5 Points Likert Scale)
		Distribution	Very low to very high (5 Points Likert Scale)
		Supplier Coordination and Relationship Management	Very low to very high (5 Points Likert Scale)
		Customer Coordination and Relationship Management	Very low to very high (5 Points Likert Scale)

The fourth construct comprised of four sub-sections with fourteen questions to examine the relationships between digitalisation and SCP. In this respect, SCP constituted of elements i.e.: SCI, SCV and SCR. The responses to this section assisted the researcher to identify the impact of digitalisation on SCP. A fourth element, relationship with customer and supplier which was termed as CSR was included to examine the performance under the impact on digitalisation as it has direct implication toward SC operations and SCP. The measurements of this section were ranked with five-point Likert scale from 'Strongly disagree' to 'Strongly Agree'.

No	Constructs	Measurements	Multiple Choice Answer
4 (i)	Digitalisation and customer and supplier relationships	Sales revenues	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Customer relationships, forecast and demand planning	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Customer satisfaction	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Supplier relationship with higher degree of trust and partnership	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Product quality and delivery commitment	Strongly disagree to Strongly Agree (5 Points Likert Scale)
4 (ii)	Digitalisation and supply chain integration	Communication and information sharing	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Cooperation and collaboration	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Planning and forecast accuracy	Strongly disagree to Strongly Agree (5 Points Likert Scale)
4 (iii)	Digitalisation and supply chain visibility	Quality and usefulness of information	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Availability and accessibility to real-time information	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Clarity and visibility of upstream and downstream operations	Strongly disagree to Strongly Agree (5 Points Likert Scale)
4 (iv)	Digitalisation and supply chain responsiveness	Speedy and quality decision making	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Core competency	Strongly disagree to Strongly Agree (5 Points Likert Scale)
		Deploy appropriate strategies and react timely	Strongly disagree to Strongly Agree (5 Points Likert Scale)

This study examined SCI with three measures, i.e.: communication and information sharing [44, 89]; cooperation and collaboration [44,60] as well as planning and forecast accuracy. The responses shed lights on the state of SCI with the adoption of digital solutions. Attributes such as quality and usefulness of information, availability and accessibility to real-time information [81,38,90], quality and usefulness of information [90] as well as clarity and visibility of upstream and downstream operations [38] were used to examine SCV of the SC operations because of digitalisation. The study adopted speedy and quality decision making [38], core competency, deploy appropriate strategies and react timely [91] to measure SCR through the impact of digitalisation. Measurements such as raw materials quality standard, reject rate and service level [68] were adopted and were re-categorized as product quality and delivery commitment. A total of five statements were used to measure CSR which included sales revenues, customer relationships with forecast and demand planning [92], customer satisfaction, trust and partnership [38], supplier product quality and delivery commitment [92,68] because of higher degree of trust and partnership [92].

In the fifth construct, the researcher took the opportunity to seek the perspectives of different respondents concerning challenges in implementing digitalisation during the pandemic and potential for digitalisation after the pandemic. Multiple choice answers were developed in the effort to examine the challenges encountered by the respondents which included capital allocation, ROI, awareness, job opportunity, work culture and threats. The question allowed respondents to express their general viewpoints about digitalisation challenges to enrich the dimension of data collected. The researcher also interested to find out the industry perception on digitalisation adoption after the pandemic with a question as such as 'yes', 'no' or 'maybe'.

No	Constructs	Measurements	Multiple Choice Answer
5 (i)	Barriers to digitalisation adoption during Covid-19 pandemic	Challenges	Minimise capital investment allocation due to market uncertainty
			Unknown Return on Investment (ROI) in volatile economy
			Lacking awareness to embrace advance technologies
			Advance technologies reduce job opportunities
			Change of work culture
			Cybersecurity threats
			Others
5 (ii)	Digitalisation adoption in post Covid-19 pandemic	Adoption of digitalisation	Yes, No, Maybe
		Adoption timeframe	Open-ended Questions
		Expectation of ROI	Open-ended Questions
		Most critical area for digitalisation	Open-ended Questions

Lastly, the researcher opted for open-ended questions on three remaining questions to explore the respondents' expectation toward digitalisation after the pandemic. Aspects such as adoption timeframe, ROI expectation and critical area for digital

technologies deployment were examined. The additional information collected at this section have not influenced the research objectives but were useful information paving the path for potential research in the future.

4.3 Data Collection

The scope of the research population covered the supporting industries within the SC of glove industry in Malaysia including raw materials, machinery, equipment, latex, chemicals and others. With the diverse nature of most businesses and their markets coverage that spread across various industries, both local and abroad, cluster sampling method was identified to be more appropriate to narrow down the population of the targeted industry for this research.

The Malaysian Rubber Glove Manufacturers Association (Margma) is an official representative and official voice of glove industry in Malaysia since 1989 with members comprising Malaysian rubber glove manufacturers, associated suppliers and supporting organizations [93]. Companies registered under Margma were deemed to be most appropriate as the targeted respondents for this research. As the research focused on companies operating in Malaysia, the total number of companies as published at Margma website provided a sample size of 185.

Out of the total number, glove manufacturers comprised of 31% with 58 members while the supporting industries consist of 127 members. The next largest groups were chemicals and industry equipment and machinery sectors which represented 28% and 23% of the targeted participants.

Table 7: Profile of Targeted Participants

Member Category	MARGMA	
	No of Members	%
Gloves	58	31%
Chemicals	51	28%
Industrial Machinery & Equipment	43	23%
Service and Maintenance	11	6%
Packaging	9	5%
Latex	7	4%
Lubricants	6	3%
Total	185	100%

Balance 18% constituted from other sectors, i.e.: latex, service and maintenance, packaging and lubricant. With this cluster sampling approach, the researcher managed to eliminate sampling bias in which [86] articulates that sampling bias represents a distortion in the sampling size selection method that resulted some members of the population have no opportunity to be selected. Primary or raw data were gathered through internet-mediated survey and structure interview. Interview was targeted at the management of a pioneer company in the industrial equipment and machinery sector who has been the key supporter to glove industry for over 30 years. Secondary data were collected from association publications, newsletters, academic journals, whitepapers as well as data available from related organisations' website such as Margma and other websites pertaining to the aspect of digitisation.

4.4 Data Analysis Techniques

Responses collected from online survey and interviews were recorded while responses to open-ended questions were transcribed and coded to enable these responses to be analysed similarly to close-ended questions [86]. Pattern of similarities were examined for all responses from open-ended questions. The data were measured using computer software, i.e.: IBM SPSS. The calculated results were analysed and further interpreted to explain the relationship of the examined variables of the research. Variables were attributes [86] such as events, time periods, objects, process that the research tried to measure. In this research, the variables were impact of pandemic, digitalisation, and SCP; i.e.: SCI, SCV, SCR and CSR, barriers to digitalisation. To test the reliability and validity of the study, Cronbach's alpha values was used to examine internal reliability and consistency of the scale for the data collected using five-point Likert scale. Reliability test provides an indication of the uniformity of the scale in measuring the variables of respective constructs that reflects how well the survey result relates to the true population [38]. In other words, it examines the consistency and reliability of data collection and analysis procedures which leads to consistent findings [87]. Further to that, descriptive analyses were conducted to examine the mean and standard deviation of the constructs. Mean was the average score of the responses while standard deviation measured how far the scores of responses were located on left and right side of mean to support the consistency of the responses [38]. More analysis techniques such as correlation and regression analyses were conducted based on the necessity of the survey outcome.

5 Data Analysis and Findings

The table 8 exhibits the profile of 65 respondents which constituted of 61 online survey and 4 face to face structured interviews. Three follow up emails were sent. The total final response rate was 35% from the 185-sample size. According to studies, a sample size of 30 is the minimum number accepted for

statistical analyses within the overall sample [87,94]. Thus, the response rate for the current research was considered acceptable. The largest respondents came from industrial machinery and equipment sector with 60% while 16.9% from service and maintenance and the third largest respondents came from chemical sector with 7.7%. There was only 1 respondent from the healthcare industry (glove producer). The low response rate was probably linked to high infected cases in the glove industry that has limited their time and attention to participate the survey. More than 80% of the respondents came from locally owned companies in which their business operations have been more than 5 years. 61.5% of the respondents were from small enterprise with less than 50 employees and annual sales revenue for 49.2% of the respondents were less than RM50 million.

Table 8: Respondents Profile

Respondents Profile		Count	Column Valid N %
General Information - Industry	Industrial Machinery and Equipment	39	60.0%
	Service and Maintenance	11	16.9%
	Chemicals	5	7.7%
	Electronic and Electrical	4	6.2%
	Latex	2	3.1%
	Digital Solutions Providers	2	3.1%
	Lubricants	1	1.5%
	Healthcare	1	1.5%
	Others	0	0.0%
	Packaging	0	0.0%
	Total	65	100.0%
General Information - Company Ownership	Local	53	81.5%
	Foreign	10	15.4%
	Others	2	3.1%
	Total	65	100.0%
General Information - Years in Operation	> 5 years	56	86.2%
	2 to 5 years	5	7.7%
	> 2 years	4	6.2%
	Total	65	100.0%
General Information - Annual Sales	< RM50,000,000	32	49.2%
	RM50,000,001 to RM200,000,000	18	27.7%
	> RM500,000,000	9	13.8%
	RM200,000,001 to RM500,000,000	6	9.2%
	Total	65	100.0%
General Information - Number of Employees	< 50	40	61.5%
	51 to 200	14	21.5%
	> 200	11	16.9%
	Total	65	100.0%

5.1 Reliability Test: Cronbach's alpha

Table 9 presents Cronbach's alpha for the six sub-constructs ranged from 0.725 to 0.894. The threshold for the acceptable level of internal reliability is usually 0.80 [86] while other researchers suggest Cronbach's values 0.50 is also acceptable [38]. As such, Cronbach's alpha value 0.725 for the first sub-construct impact of Pandemic on digitalisation adoption is considered acceptable.

Table 9: Cronbach's Alpha Reliability Statistics

Constructs	N of Items	Cronbach's Alpha
Impact of Covid-19 Pandemic on Digitalisation Adoption	3	0.725
Digital Solutions Adoption Level	5	0.846
Impact of Digitalisation on Customer and Supplier Relationships	5	0.891
Impact of Digitalisation on Supply Chain Integration	3	0.873
Impact of Digitalisation on Supply Chain Visibility	3	0.894
Impact of Digitalisation on Supply Chain Responsiveness	3	0.863

N = 65

While Cronbach's value for the rest of the sub-constructs were higher than the threshold of 0.80. Thus, all these six sub-constructs were considered as research tools that have strong internal reliability and consistency.

5.2 Exploratory Data Analysis (EDA)

Tukey's exploratory data analysis (EDA) is an approach deployed to understand the relationships between the variables using diagrams and non-diagrams and acts a guide for the selection of analysis techniques [87]. This approach provides the flexibility to use any analysis methods that are needed to evaluate new outcomes that enriches the research findings in which the research did not planned to investigate initially [87]. The research adopted a simple and understandable approach to analyse and present the survey result in a coherent manner.

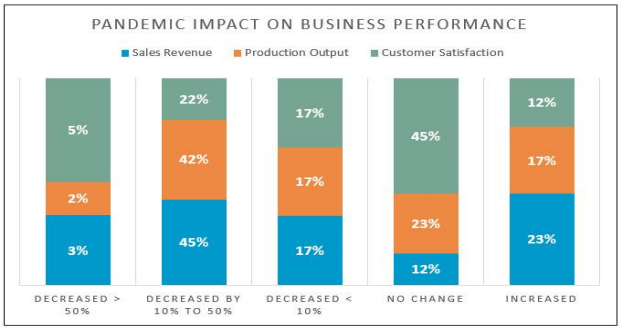


Figure 5: Impact of Pandemic on Company Performance

The first construct examined the pandemic impact on business performance of the glove industry in terms of sales revenue, production output and customer satisfaction as well as customer and supplier delivery. Figure 5 depicts that 65% and 61% of the respondents indicated that company performance on sales revenue and production output have decreased while only 44% responded that customer satisfaction has also decreased. Majority of the decreases were within the range of 10% to 50% and followed by less than 10%. On the contrary, some respondents informed that

there were increase in sales revenue, production output and customer satisfaction during the pandemic with 23%, 17% and 12% respectively. Meanwhile 45% of the result affirmed that there was no change on customer satisfaction. On the delivery aspects, Figure 6 demonstrates that 68% responses disclosed that customer delivery has suffered delayed from less than one month to more than six months in which the category for delayed from 1 month to 3 months and more than six months have the most responses with 25% and 23% respectively. Supplier delivery performance has not suffered any delay for more than six months, however, 69% responded the delay from supplier delivery was slightly higher than delivery to customer.

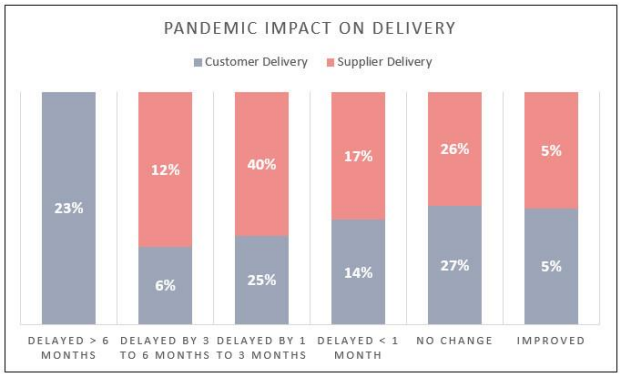


Figure 6: Impact of Pandemic on Customer and Supplier Delivery

Out of the 69% responses, 40% of them responded the delay were within 1 month to 3 months, while 17% opted for delayed less than one month. Improvement in customer and supplier delivery during the pandemic were observed with 5% responses each while about 26% to 27% respondents opted for no change. As a result, more than 60% responses indicated deterioration in the performance of sales revenue, production output, and customer and supplier delivery while 44% responded deterioration in customer satisfaction during the pandemic. The findings for this construct reveal that there were different results pertaining to business performance in terms of sales revenue, production output and customer satisfaction as well as customer and supplier delivery. Overall, more than 60% of the responses expressed that the pandemic has negatively impacted their business performance. A small percentage (10%) of the respondents voted for improved performance while the rest (27%) indicated the pandemic has not impacted their performance.

5.3 RQ1: Impact of Pandemic on Digitalisation Adoption

This section examines the impact of pandemic on digitalisation adoption from two perspectives.

The first perspective explores the changes in digitalisation adoption during the pandemic with two statements focused on company's investment on digital technology in 2020 compared to 2019 and pandemic accelerated the implementation of digital transformation in various industries. Five-point Likert scale ranging from '1=strongly disagree' to '5=strongly agree' were used to measure the construct.

- The result in Table 10 indicates that 60% of the respondents from the combination of both categories, agree and strongly agree revealed that company has invested more in digital technology in 2020 as compared with 2019 (mean=3.74).
- The result also declared that 78.5% responded that pandemic has accelerated the implementation of digital transformation in various industries (mean=4.06).
- The standard deviation for these two statements were ranged from 0.788 to 0.923 which reflected that responses were normally distributed around the mean to support the consistency of the responses [38].

Therefore, the results of this construct have answered research question RQ1 as it is evident that pandemic has impacted the adoption of digitalisation in the glove industry as well as other industries. This finding is consistent with previous studies [1,10-13,16,29] that argue pandemic has expanded the development of digitalisation. The second perspective consists of two statements that explore how digital transformation will impact company performance.

- In the first statement, 76.9% of the respondents agreed that digital transformation will improve company performance from current pandemic (mean=4.06) with standard deviation 0.726.
- The result for second statement was summarised in Figure 7 where 20.5% of the respondents found that digitalisation will improve company performance in terms of availability of real-time information while 19.5% found that adoption of advance digital technology improves the opportunity to exploit new market, 17.3% and 16.8% of the respondents found that digitalisation will improve sales and customer satisfaction.
- This is followed by 13.5% found that digitalisation will improve decision making and

only 12.4% responded on production output improvement.

- There was no additional opinion received from the respondents to enrich the knowledge.

Table 10: Impact of Pandemic on Digitalisation Adoption

Statistics

		Digitalisation - Do you agree that your company's investment on digital technology in 2020 was more than 2019?	Digitalisation - Covid-19 pandemic has accelerated the implementation of digital transformation in various industries.	Digitalisation - Do you agree that digital transformation will improve company performance from current pandemic?
N	Valid	65	65	65
	Missing	0	0	0
Mean		3.74	4.06	4.06
Std. Deviation		0.923	0.788	0.726

Frequency Table:

Digitalisation - Do you agree that your company's investment on digital technology in 2020 was more than 2019?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	6	9.2	9.2	9.2
	Neutral	20	30.8	30.8	40.0
	Agree	24	36.9	36.9	76.9
	Strongly Agree	15	23.1	23.1	100.0
	Total	65	100.0	100.0	

Digitalisation - Covid-19 pandemic has accelerated the implementation of digital transformation in various industries.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	3.1	3.1	3.1
	Neutral	12	18.5	18.5	21.5
	Agree	31	47.7	47.7	69.2
	Strongly Agree	20	30.8	30.8	100.0
	Total	65	100.0	100.0	

Digitalisation - Do you agree that digital transformation will improve company performance from current pandemic?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	15	23.1	23.1	23.1
	Agree	31	47.7	47.7	70.8
	Strongly Agree	19	29.2	29.2	100.0
	Total	65	100.0	100.0	

The second perspective unveils the perception of the respondents in recognising that digitalisation has the potential to improve company performance with regards to availability of real-time information to drive strategic functions, exploit new market potential, improve sales, enhance decision making and production output. The outcome of this construct is like previous research [28] in which the studies articulate that companies have becoming increasingly aware of the potential that digitalisation could bring during pandemic. Overall, the findings of this construct indicates that pandemic has positively impacted the adoption of digitalisation. This has supported the answer to research question RQ1. Majority of the respondents agree that their companies invested more in digital technology in 2020 as compared with 2019 and that pandemic has accelerated the implementation of digital transformation in various industries. The respondents also agree that through digitalisation, company performance could improve with accessibility to real-time information, potential to exploit new market, increase sales and customer satisfaction, improve decision making and production output.

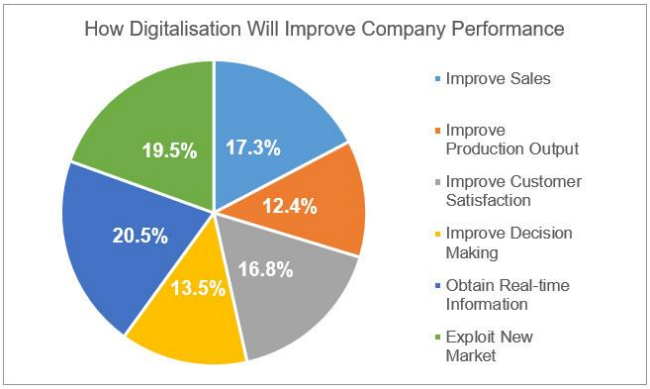


Figure 7: How Digitalisation Will Improve Company Performance

5.4 RQ2: Digital Solutions Adopted within Supply Chain

This construct examines digital solutions that have been adopted within the SC structures specifically in Procurement, Manufacturing, Distribution, Supplier and Customer. One statement was developed with multiple choice answers that allowed participants to select more than one answer in respective of each SC structure. The survey outcome of digitalisation adoption rate across the five SC structures was displayed in Table 11.

Table 11: Digital Solutions Adopted within Supply Chain Structures

Supply Chain Structures	BD	IoT	CC	A.Robots	AM	AI	AR	ML	CPS	Adopted	Not Adopted
Procurement	**30.0%**	**20.0%**	**19.1%**	4.5%	2.7%	5.5%	3.6%	6.4%	0.0%	91.8%	8.2%
Manufacturing	**20.1%**	**18.7%**	10.4%	7.5%	5.2%	**11.2%**	3.0%	8.2%	9.0%	93.3%	6.7%
Distribution	**25.9%**	**16.4%**	**14.7%**	6.9%	5.2%	10.3%	1.7%	5.2%	4.3%	90.5%	9.5%
SCRM	**26.3%**	**21.5%**	**16.8%**	4.7%	3.7%	4.7%	4.7%	7.5%	3.7%	93.5%	6.5%
CCRM	**29.5%**	**23.8%**	**15.2%**	4.8%	1.9%	2.9%	4.8%	8.6%	4.8%	96.2%	3.8%
Overall Adoption Rate %	26%	20%	15%	6%	4%	7%	4%	7%	4%	93%	7%

BDA was the most adopted digital solution in each individual SC structure where it was highly adopted in Procurement and CCRM with 30% and 29.5% responses respectively. On the contrary, BDA was least adopted in Manufacturing with 20.1% responses. IoT was most adopted in CCRM with

23.8% responses, followed by SCRM and Procurement with 21.5% and 20% responses respectively. While IoT was least adopted in Distribution with adoption rate of 16.4%. CC was highly adopted in Procurement with 19.1% responses. However, CC was least adopted in Manufacturing with only 10.4% response which was the lowest adoption rate among the top three solutions, i.e.: BDA, IoT and CC. The adoption rate for CC in Distribution, CCRM and SCRM were quite balance within the range of 14.7% to 16.8%. Autonomous Robots was highly adopted in Manufacturing with 7.5% and followed by Distribution with 6.9%. It was not commonly adopted in rest of the SC structures with the low response rate of 4.8% to 4.5%. AI was highly adopted in Distribution and Manufacturing within the range of 10.3% to 11.2% while it was least adopted in CCRM with 2.9% responses. The result showed that AM and AR were among the two least adopted solutions with adoption rate ranged from 1.9% to 5.2% for AM while 1.7% to 4.8% for AR across all individual SC structures. Meanwhile, ML has slightly higher adoption rate compared to AM and AR with the range of 5.2% to 8.6% across all individual SC structure. Lastly, CPS has the highest adoption rate at Manufacturing with 9% responses. However, CPS was not being adopted in Procurement. CPS was also one the least adopted solutions among the SC structures.

The overall adoption rate indicated in Table 11 explains that BDA was the most adopted digital solution with 26% adoption rate. This was followed by IoT and CC with 20% and 15% responses respectively. The adoption rate for AI, ML and Autonomous Robots were relatively low within the range of 7% to 6%. AR, AM and CPS were the three least adopted solutions with 4% responses individually. CCRM has the highest adoption on digital solutions of 96.2% while Distribution was reported to have the lowest adoption rate of 90.5%. SCRM and Manufacturing were having similar adoption rates of 93.5% and 93.3% respectively. Procurement was the second SC with least digital adoption of 91.8%. There was an average of 7% responses indicated no digital solution was adopted within their SC structures.

The construct of digital solutions adopted within SC structures has been expanded to measure the adoption level. Five statements were created to measure the SC constructs with five-point Likert scale ranging from '1=very low' to '5=very high'.
Table 12 demonstrates that CCRM has the highest level of digital solutions adoption among the five SC structures with 81.6% responded from medium to very high adoption level (mean=3.14). The data was distributed relatively near the mean with standard deviation 0.899.

Similarly, SCRM also has a significant response rate of 78.5% combining medium to very high adoption level (mean=3.05). 50.8% responded on medium digital adoption level with standard deviation 0.856. On the contrary, Procurement has the lowest adoption level (mean=2.78) among the five SC structures. The responses ranged from very low to very high where 52.3% responded to medium and 29.2% opted from low to very low. Thus, only 18.4% responded to high and very high with standard deviation 0.927. Likewise, Distribution demonstrated second lowest adoption level (mean=2.86). The result detects that 30.7% responded to either low or very low while 44.6% responded to medium. The responses were spread slightly outward from the mean with standard deviation 1.074. Similar trend was observed at Manufacturing with third lowest adoption level (mean=2.94) and 1.088 standard deviation. 43.1% responded to medium while only 27.7% responded to either high or very high. From the overall perspective, Table 12 expresses the adoption level was ranging between low to medium (mean=2.9538) and standard deviation 0.76548 without any outliers. In short, the findings of this construct denote that even though respondents have acknowledged the great potential of digitalisation toward company performance, the average adoption level was still considerably low.

Table 12: Adoption Level within the Supply Chain Structure

Statistics

		Digital Solutions Adoption Level - Procurement	Digital Solutions Adoption Level - Manufacturing	Digital Solutions Adoption Level - Distribution	Digital Solutions Adoption Level - SCRM	Digital Solutions Adoption Level - CCRM
N	Valid	65	65	65	65	65
	Missing	0	0	0	0	0
Mean		2.78	2.94	2.86	3.05	3.14
Std. Deviation		0.927	1.088	1.074	0.856	0.899

Digital Solutions Adoption Level - Procurement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	8	12.3	12.3	12.3
	Low	11	16.9	16.9	29.2
	Medium	34	52.3	52.3	81.5
	High	11	16.9	16.9	98.5
	Very High	1	1.5	1.5	100.0
	Total	65	100.0	100.0	

Digital Solutions Adoption Level - Manufacturing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	8	12.3	12.3	12.3
	Low	11	16.9	16.9	29.2
	Medium	28	43.1	43.1	72.3
	High	13	20.0	20.0	92.3
	Very High	5	7.7	7.7	100.0

	Total	65	100.0	100.0	

Digital Solutions Adoption Level - Distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	9	13.8	13.8	13.8
	Low	11	16.9	16.9	30.8
	Medium	29	44.6	44.6	75.4
	High	12	18.5	18.5	93.8
	Very High	4	6.2	6.2	100.0
	Total	65	100.0	100.0	

Digital Solutions Adoption Level - SCRM

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	3	4.6	4.6	4.6
	Low	11	16.9	16.9	21.5
	Medium	33	50.8	50.8	72.3
	High	16	24.6	24.6	96.9
	Very High	2	3.1	3.1	100.0
	Total	65	100.0	100.0	

Digital Solutions Adoption Level - CCRM

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	3	4.6	4.6	4.6
	Low	9	13.8	13.8	18.5
	Medium	33	50.8	50.8	69.2
	High	16	24.6	24.6	93.8
	Very High	4	6.2	6.2	100.0
	Total	65	100.0	100.0	

Statistics

Mean. DSAL

N	Valid	65
	Missing	0
Mean		2.9538
Std. Deviation		0.76548

This finding is consistent with previous research [55]. Research cautions that digitalisation has been a crucial aspect of SC performance to compete and survive in highly dynamic business environment [44,60]. The type of digital solutions and adoption level are greatly depending on digitalisation objectives and nature of the supply chain functions of a particular industry. For example, although previous research identified that AI, BDA and IoT were the three core solutions adopted in Procurement to automate routine processes and improve strategic role [55], apart from BDA and IoT, current study finds that AI was not commonly used in Procurement as well as throughout the SC structures where AI adoption rate was found to be lower than BDA, IoT and CC. This finding is consistent with research conducted by [28] who comment lower AI adoption rate compared to BDA and IoT in their studies on digital adoption among the Chinese SMEs. The finding from current research also found to be consistent with previous research [95]. The researchers find that BDA, IoT and CC have been more developed and matured [95] whereby have been largely successfully integrated into fundamental business operations, i.e.: search engine, social media, and web analytics [33]. Whilst AR, AM, CPS, ML and Autonomous Robots have begun to evolve in recent years with emerging industrial applications. Thus, lower adoption rate as shown in current research. To determine any relationships between the adoption levels among all SC structures, Spearman's Correlation Analysis was conducted. This analytical method is preferred as the data set consists of ordinal variables. The result in Table 13 explains that Procurement and Manufacturing has a weak correlation (r_s=0.363, ρ<0.01 at 99% confidence level). While Manufacturing and Distribution was moderately correlated (r_s=0.627, ρ<0.01 at 99% confidence level). Strong correlation was observed between SCRM and CCRM (r_s=0.765, ρ<0.01 at 99% confidence level). Thus, the correlation analysis suggests that respective SC structures were positively correlated in terms of adoption level in a multidimensional manner. This insight leads to knowledge expansion in the respect of how adoption level among SC structures will affect each other.

Table 13: Relationships on Digital Adoption Level Correlations

Correlations

			Digital Solutions Adoption Level - Procurement	Digital Solutions Adoption Level - Manufacturing	Digital Solutions Adoption Level - Distribution	Digital Solutions Adoption Level - SCRM	Digital Solutions Adoption Level - CCRM
Spearman's rho	Digital Solutions Adoption Level - Procurement	Correlation Coefficient	1.000	.363**	.648**	.664**	.488**
		Sig. (2-tailed)	.	.003	.000	.000	.000
		N	65	65	65	65	65
	Digital Solutions Adoption Level - Manufacturing	Correlation Coefficient	.363**	1.000	.627**	.570**	.454**
		Sig. (2-tailed)	.003	.	.000	.000	.000
		N	65	65	65	65	65
	Digital Solutions Adoption Level - Distribution	Correlation Coefficient	.648**	.627**	1.000	.574**	.472**
		Sig. (2-tailed)	.000	.000	.	.000	.000
		N	65	65	65	65	65
	Digital Solutions Adoption Level - SCRM	Correlation Coefficient	.664**	.570**	.574**	1.000	.765**
		Sig. (2-tailed)	.000	.000	.000	.	.000
		N	65	65	65	65	65
	Digital Solutions Adoption Level - CCRM	Correlation Coefficient	.488**	.454**	.472**	.765**	1.000
		Sig. (2-tailed)	.000	.000	.000	.000	.
		N	65	65	65	65	65

**. Correlation is significant at the 0.01 level (2-tailed).

Different solutions were adopted across the SC structures at various adoption level. The most adopted solutions are BDA, IoT and CC while AR, AM and CPS are least adopted. 7% of the result indicated some organisations do not adopt any digital solutions in their SC structures. Overall, the adoption level is considerably low in which CCRM has the highest adoption level while Procurement has the lowest adoption among the five SC structures. The analysis also reveals that SC structures influence each other positively at varying level of adoption.

5.5 RQ3: Impact of Digitalisation on Supply Chain Performance (SCP)

This main construct has expanded into four sub-constructs which examine the impact of digitalisation on SCP from the perspective of CSR, SCI, SCV and SCR. The participants may select the answer based on five-point Likert scale ranging from '1=strongly disagree' to '5=strongly agree'. The survey result in Table 14 reveals the standard deviation for all these fourteen statements were ranged from 0.673 to 0.842 which indicates that the responses were closely gathered near the mean without any outliers.

Table 14: Digitalisation Impact on Supply Chain Performance

Descriptive Statistics	N	Mean	Std. Deviation
CSR - Digital transformation has improved sale revenues.	65	3.69	0.683
CSR - Digital transformation has improved customer relationships and improved forecast and demand planning.	65	3.92	0.692
CSR - Digital transformation has improved customer satisfaction.	65	3.80	0.754
CSR - Digital transformation has improved buyer-supplier relationship with higher degree of trust and partnership.	65	3.62	0.842
CSR - High degree of trust and partnership between buyer-supplier lead to improvement in product quality and delivery commitment.	65	3.89	0.773
SCI - Digital transformation has improved communication and information sharing within my company, suppliers and customers.	65	3.97	0.809
SCI - Digital transformation has improved cooperation and collaboration within my company, suppliers and customers.	65	3.98	0.696
SCI - Digital transformation has improved the efficiency on planning and forecast accuracy.	65	3.98	0.673
SCV - Digital transformation has enabled quality and usefulness of information.	65	3.97	0.684
SCV - Digital transformation has enabled availability and accessibility to real-time information.	65	4.08	0.735
SCV - Digital transformation has enabled clarity and visibility of upstream and downstream operations.	65	3.97	0.706
SCR - Digital transformation has enabled speedy and quality decision making.	65	4.00	0.685
SCR - Digital transformation has improved company's core competency	65	3.92	0.835
SCR - Digital transformation has improved company's ability to deploy appropriate strategies and react timely to counter challenges in difficult situations.	65	3.85	0.755
Valid N (list wise)	65		

Two statements with the highest means were found to be suggesting positive responses to the construct, i.e.: SCV-Digital transformation has enabled availability and accessibility to real-time information (mean=4.08) and SCR-Digital transformation has enabled speedy and quality decision making (mean=4.00). This was closely followed with three statements under SCI with the mean ranged from 3.98 to 3.97. Compared to the above statements, two statements that least suggesting positive responses to the construct both fell under CSR which were digital transformation has improved sale revenues (mean=3.69) and digital transformation has improved buyer-supplier relationship with higher degree of trust and partnership (mean=3.62).

5.5.1 Supply Chain Integration (SCI)

SCI was examined with three measurements, i.e.: communication and information sharing, cooperation and collaboration as well as planning and forecasting. The standard deviation for these three statements were ranged from 0.673 to 0.809 where data were close to the mean as tabulated in Table 14. 76.9% of the respondents agreed that digital transformation has improved the efficiency on planning and forecast accuracy (mean=3.98) as illustrated in Table 15.

Table 15: Digitalisation Impact on Supply Chain Integration

SCI - Digital transformation has improved communication and information sharing within my company, suppliers and customers.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	3.1	3.1	3.1
	Neutral	16	24.6	24.6	27.7
	Agree	29	44.6	44.6	72.3
	Strongly Agree	18	27.7	27.7	100.0
	Total	65	100.0	100.0	

SCI - Digital transformation has improved cooperation and collaboration within my company, suppliers and customers.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	16	24.6	24.6	24.6
	Agree	34	52.3	52.3	76.9
	Strongly Agree	15	23.1	23.1	100.0
	Total	65	100.0	100.0	

SCI - Digital transformation has improved the efficiency on planning and forecast accuracy.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	15	23.1	23.1	23.1
	Agree	36	55.4	55.4	78.5
	Strongly Agree	14	21.5	21.5	100.0
	Total	65	100.0	100.0	

While 75.4% of the respondents found that digitalisation has improved cooperation and collaboration within the company, suppliers and customers (mean=3.98). Lastly, 72.3% of the respondents found that digitalisation would improve communication and information sharing within the company, suppliers and customers (mean=3.97). The result implies that significant numbers of the

respondents acknowledged that digitalisation would improve SCI. Studies find that SCI is crucial to SCP with the integration between internal and external SC operations [38] and heighten integration is crucial to maintain competitiveness in the dynamic business world [51] through the impact of innovative technologies.

5.5.2 Supply Chain Visibility (SCV)

SCV was examined with three measurements, i.e.: quality and usefulness Information, availability and accessibility as well as clarity and visibility. The standard deviations ranged from 0.684 to 0.735 claimed there was no outliers as data were clustered around the mean as tabulated in Table 14. As explained in Table 16, the statement digital transformation has enabled quality and usefulness of information received 80% positive responses (mean=3.97). Similarly, digital transformation has enabled availability and accessibility to real-time information received 80% positive responses (mean=4.08). While 73.9% positive responses for digital transformation have enabled clarity and visibility of upstream and downstream operations (mean=3.97).

Table 16: Digitalisation Impact on Supply Chain Visibility

SCV - Digital transformation has enabled quality and usefulness of information.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	1.5	1.5	1.5
	Neutral	13	20.0	20.0	21.5
	Agree	38	58.5	58.5	80.0
	Strongly Agree	13	20.0	20.0	100.0
	Total	65	100.0	100.0	

SCV - Digital transformation has enabled availability and accessibility to real-time information.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	1.5	1.5	1.5
	Neutral	12	18.5	18.5	20.0
	Agree	33	50.8	50.8	70.8
	Strongly Agree	19	29.2	29.2	100.0
	Total	65	100.0	100.0	

SCV - Digital transformation has enabled clarity and visibility of upstream and downstream operations.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	17	26.2	26.2	26.2
	Agree	33	50.8	50.8	76.9
	Strongly Agree	15	23.1	23.1	100.0
	Total	65	100.0	100.0	

Overall, the result signifies that majority of the respondents agreed that digitalisation will impact positively toward SCV as literatures find that SCV enhances SCP [80,78, 44].

5.5.3 Supply Chain Responsiveness (SCR)

SCR was examined through the measurements of speedy and quality decision making, core competency as well as ability to strategies and react timely. The responses of this construct were distributed closely to the mean with standard deviation ranged from 0.685-0.835 as per table 14. Results in table 17 shows 80% of the respondents agreed that digital transformation has enabled speedy and quality decision making (mean=4.00).

While 72.3% of the respondents agreed that digital transformation has improved company's core competency (m=3.92). 69.3% of the respondents agreed that digital transformation has improved company's ability to deploy appropriate strategies and react timely to counter challenges in difficult situations (mean=3.85). Hence, a substantial number of respondents agreed that digitalisation has positive impact on SCR.

Table 17: Digitalisation Impact on Supply Chain Responsiveness

SCR - Digital transformation has enabled speedy and quality decision making.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	1.5	1.5	1.5
	Neutral	12	18.5	18.5	20.0
	Agree	38	58.5	58.5	78.5
	Strongly Agree	14	21.5	21.5	100.0
	Total	65	100.0	100.0	

SCR - Digital transformation has improved company's core competency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	1	1.5	1.5	1.5
	Disagree	1	1.5	1.5	3.1
	Neutral	16	24.6	24.6	27.7
	Agree	31	47.7	47.7	75.4
	Strongly Agree	16	24.6	24.6	100.0
	Total	65	100.0	100.0	

SCR - Digital transformation has improved company's ability to deploy appropriate strategies and react timely to counter challenges in difficult situations.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	3.1	3.1	3.1
	Neutral	18	27.7	27.7	30.8
	Agree	33	50.8	50.8	81.5
	Strongly Agree	12	18.5	18.5	100.0
	Total	65	100.0	100.0	

This finding is consistent with previous studies in which enhance SCR with innovative technologies is crucial for long term competitiveness and sustainability in extremely uncertain and high-risk market condition [44,60].

5.5.4 Impact of Digitalisation on Customer and Supplier Relationship

There were five measurements under this construct, sales revenues, customer relationships with forecast and demand planning, customer satisfaction, supplier relationships with trust and partnership as well as product quality and delivery commitment that measure the impact of digitalisation on CSR. Among the five statements, three statements examined digitalisation impact on customer relationships. As explained in Table 18, 72.3% of the respondents found that digital transformation will improve customer relationships, forecast and demand planning (mean=3.92) while 63.1% agreed that digitalisation will also improve customer satisfaction (mean=3.820). However, only 56.9% of the respondents agreed that digitalisation will improve sales revenues (mean=3.69). Table 14 shows the standard deviations for these three statements were 0.692, 0.754 and 0.683 respectively. The data implies that the responses were spread closely to the mean.

Table 18: Digitalisation Impact on Customer and Supplier Relationship

Customer and Supplier Relationship - Digital transformation has improved sale revenues.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	28	43.1	43.1	43.1
	Agree	29	44.6	44.6	87.7
	Strongly Agree	8	12.3	12.3	100.0
	Total	65	100.0	100.0	

Customer and Supplier Relationship - Digital transformation has improved customer relationships and improved forecast and demand planning.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	18	27.7	27.7	27.7
	Agree	34	52.3	52.3	80.0
	Strongly Agree	13	20.0	20.0	100.0
	Total	65	100.0	100.0	

Customer and Supplier Relationship - Digital transformation has improved customer satisfaction.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	1.5	1.5	1.5
	Neutral	23	35.4	35.4	36.9
	Agree	29	44.6	44.6	81.5
	Strongly Agree	12	18.5	18.5	100.0
	Total	65	100.0	100.0	

Customer and Supplier Relationship - Digital transformation has improved buyer-supplier relationship with higher degree of trust and partnership.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	4	6.2	6.2	6.2
	Neutral	28	43.1	43.1	49.2
	Agree	22	33.8	33.8	83.1
	Strongly Agree	11	16.9	16.9	100.0
	Total	65	100.0	100.0	

Customer and Supplier Relationship - High degree of trust and partnership between buyer-supplier lead to improvement in product quality and delivery commitment.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	1.5	1.5	1.5
	Neutral	20	30.8	30.8	32.3
	Agree	29	44.6	44.6	76.9
	Strongly Agree	15	23.1	23.1	100.0
	Total	65	100.0	100.0	

The results from two statements created to measure the impact of digitalisation on supplier relationships received 50.7% responses agreed that digital transformation will improve buyer-supplier relationship with higher degree of trust and partnership (mean=3.62). While 67.71% of the respondents agreed that higher degree of trust and partnership will lead to improvement in product quality and delivery commitment (mean=3.89). The responses were close to the mean without outliers with respective standard deviation 0.842 and 0.773. In addition, the participants agree that an increase in transparency and traceability will strengthen buyer-supplier relationships and the level of trust. [38].

Overall, the result declares that respondents agreed that digitalisation will improve customer relationships under the studied measurements. However, the survey also reflects that half of the respondents agreed that digitalisation will improve buyer-supplier relationship with high degree of trust and partnership even though larger number of respondents agreed that higher degree of trust and partnership will lead to improvement in product quality and delivery commitment.

A Spearman's Correlation Analysis was performed to determine any significant relationships between digitalisation and SCP. The results in Table 19 disclose that there are significant positive correlations between digitalisation (D) and SCP, i.e.: SCI (rs=0.569), SCV (rs=0.592), SCR (rs=0.603) and CSR (rs=0.544), $\rho<0.01$ with 99% confidence level. As such we could validate the conclusion that digitalisation will positively impact and elevate SCP as research question RQ3 sets out to examine. It is worth noting the survey result also unveils that variables among the SCP are also found to be positively correlated. For instance, SCI is strongly correlated to SCV, SCR, CSR with Spearman's Correlation Coefficient (rs) 0.701, 0.714 and 0.824 respectively with $\rho<0.01$. Thus, the results enrich knowledge development in another dimension with regards to the intensity of interrelationships among the variables toward SCP under the impact of digitalisation.

Table 19: Digitalisation and Supply Chain Performance Relationships

Correlations

			Mean. Digitalisation	Mean. SCI	Mean. SCV	Mean. SCR	Mean. CSR
Spearman's rho	Mean. Digitalisatio	Correlation Coefficient	1.000	.569**	.592**	.603**	.544**
		Sig. (2-tailed)	.	.000	.000	.000	.000
		N	65	65	65	65	65
	Mean. SCI	Correlation Coefficient	.569**	1.000	.701**	.714**	.824**
		Sig. (2-tailed)	.000	.	.000	.000	.000
		N	65	65	65	65	65
	Mean. SCV	Correlation Coefficient	.592**	.701**	1.000	.739**	.758**
		Sig. (2-tailed)	.000	.000	.	.000	.000
		N	65	65	65	65	65
	Mean. SCR	Correlation Coefficient	.603**	.714**	.739**	1.000	.646**
		Sig. (2-tailed)	.000	.000	.000	.	.000
		N	65	65	65	65	65
	Mean. CSR	Correlation Coefficient	.544**	.824**	.758**	.646**	1.000
		Sig. (2-tailed)	.000	.000	.000	.000	.
		N	65	65	65	65	65

**. Correlation is significant at the 0.01 level (2-tailed).

Overall, the finding for this construct supports the assumptions of the conceptual framework developed for current research that digitalisation will enhance SCP. It is evident that by leveraging digital technologies and elevating digital capabilities will positively impact SCP through improvement in SCI, SCV and SCR. Hence, this finding has answered research question RQ3 on how digitalisation will impact SCP. At the same time, the result is also consistent with previous studies [44,60,63] on the positive impact of digitalisation on SCP. Moreover, it also aligned with the research outcome conducted by [14,15] in which majority of the corporate leaders agreed that digitalisation is crucial to meet corporate objectives and sustain business core competency.

In addition, digitalisation also contribute to improvement in CSR in terms of increasing sales revenues and customer satisfaction, accurate forecast and demand planning, enhance trust and partnership, heighten product quality and delivery commitment. It is also found that the variables such as SCI, SCV, SCR and CRS are strongly correlate and the interrelationships among these variables will have implications toward SCP under the impact of digitalisation.

5.6 Barriers to Digitalisation

As summarised in Figure 8, change of work culture has the highest responses (30%). The second highest responses were minimising capital investment allocation due to market uncertainty (17%). While, advance technologies reduce job opportunities, cybersecurity threats, unknown return on investment (ROI) in volatile economy and lacking awareness to embrace advance technologies were 11% to 15%.

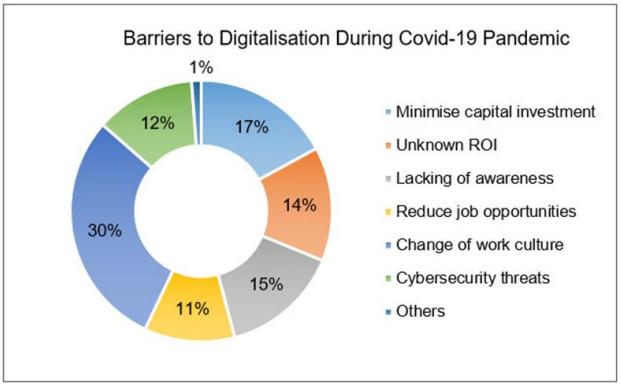


Figure 8: Barriers to Digitalisation during Pandemic

Additional comments were received from two responses where both found that increased in production capacity as barriers to digitalisation. The result reflects that the respondents were particularly concerned with change of work culture as key barrier for digital transformation. This finding is consistent with previous research [60]. Apparently, workforce's acceptance and adaptability have impactful consequences due to their direct involvement in digitalisation [38]. Study evocates that it is important that digital culture within the organisation can foster transparency and optimistic behaviours among the workforce toward digitalisation [10] and address the challenge on cybersecurity threats.

Moderate response rates of 14% ~ 17% on minimise capital investment allocation and unknown ROI which did not respond highly to researcher's assumption as the two key barriers to digitalisation during pandemic. Nonetheless, these factors should not be neglected as they were ranked second and forth respectively. Lacking the awareness to embrace advance digital solutions was obviously a critical barrier as witnessed during the interview sessions. Two interviewees demonstrated limited understanding on AM, ML and CPS and sought for explanation on 'What is CPS, ML, AM?' and 'What are their functions?'

The result also suggests that respondents were less concerned on reduced job opportunities in relation to digitalisation. This was inconsistent with previous studies as the studies alarmed that digitalisation have negatively impacted employment at some occupations [95-97]. In this regard, the researcher seeks to determine if company's plan on digitalisation after pandemic would moderate the response toward reduce job opportunities. A linear regression test was conducted, and the result showed in Table 20 reflects that Model Summary, R2 = 0.033 which shows company's plan to digitalisation after pandemic accounts for 3.3% of the variance in reduce job opportunities; while ANOVA, F (1, 63)=2.155,

ρ=0.147 which was more than 0.05 significant level. This reveals that company's plan to digitalisation after pandemic was not a significant predictor of reducing job opportunities. This finding could imply the perspective of the respondents that Malaysia is still at the beginning stage of digitalisation [45] and therefore the threat of reducing job opportunities to advance technologies is less impactful. Nonetheless, future studies could be carried out when there is more digitalisation in Malaysia glove industry.

Table 21: Digitalisation Plans after Pandemic

Will your company plan to adopt or accelerate its digital transformation after the pandemic?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	31	47.7	47.7	47.7
	No	2	3.1	3.1	50.8
	Maybe	32	49.2	49.2	100.0
	Total	65	100.0	100.0	

The next stage constitutes three open-ended questions where the replies were categorised and coded. Table 21 reflects the responses on company's digitalisation plan after the pandemic were divided into two categories which were maybe and yes with 49.2% and 47.7% respectively.

Table 22: Correlation of Digitalisation during and after Pandemic

Correlations

			Digitalisation - Do you agree that your company's investment on digital technology in 2020 was more than 2019?	Will your company plan to adopt or accelerate its digital transformation after the pandemic?
Spearman's rho	Digitalisation - Do you agree that your company's investment on digital technology in 2020 was more than 2019?	Correlation Coefficient	1.000	-.481**
		Sig. (2-tailed)	.	.000
		N	65	65
	Will your company plan to adopt or accelerate its digital transformation after the pandemic?	Correlation Coefficient	-.481**	1.000
		Sig. (2-tailed)	.000	.
		N	65	65

**. Correlation is significant at the 0.01 level (2-tailed).

A minority of 3.1% responded to no implementation. As the research was being conducted between third quarters of 2020 till first quarter of 2021, the researcher is keen to find out any change of digitalisation initiation in view of the progress and development of the coronavirus and the vaccine development during this period. A Spearman's correlation is conducted to examine the relationships between these two variables.

Table 22 verified that digital technology investment in 2020 was more than 2019 was negatively correlated to digitalisation after pandemic (rs = -0.481, ρ<0.01 at 99 percent confidence level) with moderate influences. This finding suggests that there was a change in the digitalisation initiatives with the progress of the pandemic. The digitalisation initiatives will accelerate during the pandemic and will decrease after the pandemic. Therefore, the researcher concluded that digitalisation is impacted by Covid-19 pandemic. This outcome has provided further evidence to support the assumption behind research question RQ1.

Table 23: Adoption Duration and ROI Expectation Adopt or accelerate.

Adopt or accelerate Duration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	31	47.7	47.7	47.7
	1 to 3 years	16	24.6	24.6	72.3
	3 to 5 years	4	6.2	6.2	78.5
	Unsure	12	18.5	18.5	96.9
	No Intention	2	3.1	3.1	100.0
	Total	**65**	**100.0**	**100.0**	

Expectation ROI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	1	1.5	1.5	1.5
	1 to 3 years	40	61.5	61.5	63.1
	3 to 5 years	8	12.3	12.3	75.4
	Unsure	14	21.5	21.5	96.9
	No Intention	2	3.1	3.1	100.0
	Total	**65**	**100.0**	**100.0**	

Survey result in Table 23 also revealed that 47.7% respondents felt that digitalisation should be carried out in less than 1 year. While 24.6% opted 1 to 3 years. The rest were either unsure or opted for longer period whilst 3% responded no intention to digitize. In the aspect of ROI, 61.5% expected ROI within 1 to 3 years while 21.5% replied unsure and 1.5% expected less than 1 year. Likewise, 3% responded no intention to embark on digitalisation and the rest responded 3 to 5 years. The last statement for this construct was to find out the most critical department to adopt digitalisation to improve company performance. As it was an open-ended question, eight respondents provided more than one answers and two responded all the departments. To prevent any intentions of wrong interpretation which leads to false conclusion [87], the researcher has summarised and coded the responses [86] in two methods to determine if the results were consistent.

The first method was to consider only the first answer based on the assumption that most important department would usually be first listed out. The two 'all' answers were disregarded as the answers did not

inform which department and it would not impact the outcome. The second method was to consider all answers received including the two answers on all which implied every department. The results of both methods were exhibited in Table 24 and Table 25.

Table 24: Most Critical Department to Adopt Digitalisation (1st Method)

Most Critical Department to Adopt Digitalisation (Consider 1st Answer)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	*Marketing*	21	32.3	32.3	32.3
	Distribution	1	1.5	1.5	33.8
	Procurement	1	1.5	1.5	35.4
	Production	23	35.4	35.4	70.8
	Others	6	9.2	9.2	80.0
	No Comment	9	13.8	13.8	93.8
	Not Relevant	4	6.2	6.2	100.0
	Total	65	100.0	100.0	

Table 24 depicted three most critical department were Production (35.4%), Marketing (32.3%) and others (9.2%). Meanwhile, Table 25 confirmed that Production (33%), Marketing (29.8%) and Distribution (12.8%) were the three most critical department to adopt digitalisation.

Table 25: Critical Department to Adopt Digitalisation (2nd Method)

Most Critical Department to Adopt Digitalisation (Consider All Answers)

		Responses		
		N	Percent	Percent of Cases
Critical Dept. to Adopt Digitalisation [a]	Most Critical Department - Production	31	33.0%	47.7%
	Most Critical Department - Marketing	28	29.8%	43.1%
	Most Critical Department - Procurement	9	9.6%	13.8%
	Most Critical Department - Distribution	12	12.8%	18.5%
	Most Critical Department - Other Section	3	3.2%	4.6%
	Most Critical Department - No Comment	8	8.5%	12.3%
	Most Critical Department - No Intention	2	2.1%	3.1%
	Most Critical Department - No Reply	1	1.1%	1.5%
Total		**94**	**100.0%**	**144.6%**

a. Dichotomy group tabulated at value 1.

Both methods reflected consistent results for top two answers in which Production and Marketing were ranked first and second in the same order. Overall, the major barrier to digitalisation was change of work culture and followed by mindset in terms of minimise investment and unknown ROI during pandemic. The initiatives for digitalisation were higher during the pandemic and lesser after the pandemic. Averagely, respondents expected to embark digitalisation within 1 year and expected ROI within 1 to 3 years. The most critical department to implement digitalisation is Production that matched the general perspective in the glove industry.

6 Conclusions and Recommendations

This research contributes to SCM literature by developing an integrated conceptual framework to promote better awareness on how digitalisation could contribute to a heighten SCP under the influence of pandemic and broaden the understanding of the underlying instruments that link and correlate to drive SCP improvement. Additionally, the research framework serves as a useful mechanism for in-depth SCM research for other industries. The research hypothesizes digitalisation will impact SCP in which SCP is conceptualized in a perspective that embraces SCI, SCV and SCR. Moreover, the research has extended the approach by integrating CSR with other key aspect of SCP, i.e.: SCI, SCV and SCR thus create a holistic overview to achieve a comprehensive dimension of SCP unlike other study [38] that focused on specific aspect of SC. This conception was motivated from the aspect of an integrated SC ecosystem in which suppliers and customers are critical SC partners who are crucial to SCP. This approach is consistent with previous research [89] who examined the SCP through the aspects of supplier, customer and internal integration under the effect of SC innovativeness.

Through this study and by adopting this comprehensive approach of integrating SCI, SCV, SCR and CSR, the research enriches the understanding on how each construct significantly links and contributes toward magnifying SCP in a holistic perspective. Furthermore, the fundamental element of each construct correlates the constructs and overarches the impacts from within internal dimension toward external dimension of the SCP and subsequently resulting a complete and well-integrated supply chain ecosystem. The results also enrich knowledge development in another dimension with regards to the intensity of interrelationships among the variables toward SCP under the impact of digitalisation. These findings support the assumption made by the researcher through the development of the conceptual framework.

The research constructs were critically developed and were closely associated to research objectives in which the constructs were critically articulated with sufficient analysis to examine the key variables where the impacts were adequately explained to answer the research questions. Although the findings are not exhaustive, the researcher contemplated that they are inclusive as they answered all the research questions set out in the research. Furthermore, the research has led to expanding the knowledge on the subject matter. As the research is an ‘initial’ or ‘pioneer’ in examining digitalisation in gloves

industry in Malaysia under the impact of pandemic. This study enlightens the practitioners on the understanding of innovative technologies which could help company to minimise negative impact triggered from unexpected events that disrupted SC activities. The research presents several key digital technologies such as BDA and IoT that have been developed in recent decades and their usage within the SC operations have enhanced various businesses performance in different dimensions. Thus, the importance of digitalisation in current era could not be underestimated as it touches every aspect of organisation [44].

The research advances the knowledge of the managers on the positive impacts of digitalisation in fostering better SCP among the identified SC partners. The research measures SCP in terms of integration, visibility and responsiveness that are closely related to digitalisation as shown in the survey findings. This finding presents critical implications of adopting advance digital technologies within an organisation improves its core competency for business survival during volatile economy as study stresses that competition in current business environment is centred on digitalisation [45]. At the same time, the research alerts the importance of addressing challenges to digitalisation. With this important understanding, managers would be able to scrutinise the company's objective, readiness and develop suitable strategies for the implementation of digitalisation.

6.1 Research Limitations

Even though the research produces important findings and implications for the SCM literature and practitioners, there are several limitations. The limitations have restricted the generalisability of the findings across other industries and other countries.

First, the sample size is small with 35% of response rate. Within this 35% respondents, 61.5% were from small enterprise with less than 50 employees while half of the respondents reported their annual sales revenue were less than RM50 million. Thus, there is limited diversity in terms of business scale and operations hence, data collected were unable to represent the whole industry and this has restricted the generalisability of the findings.

Second, the study adopts a general overview and assumption that pandemic has accelerated the adoption of digitalisation and digitalisation drives positive outcome toward SCP during pandemic. The researcher acknowledged the gaps existed in addressing the literature of this research topic and the development of the theoretical framework. Critical discussions on the aspects of business processes and operational changes in relation to the types of digital technologies and how these would impact the company performance could be further explored.

Third, the research presents the SCP from the perspective of five SC components, i.e.: Procurement, Manufacturing, Distribution, Supplier and Customer. Other components such as Marketing and Sales, Warehouse, Technology Development and Infrastructure were not included in data evaluation. Fourth, the research has limited the scope of digital solutions and did not comprehensive review all available technologies such as Blockchain, Simulation and 5G. Moreover, several technologies such as ML and CPS have been more intensively researched and developed in recent years, thus the application of these technologies have yet to realise its fullest potential and received lesser attention comparing to BDA, IoT and Cloud [95]. Fifth, in-depth discussion on interrelationships between adoption level and influence on SCP among the SC partners were limited in respect of the correlation of dependent and independent variables to help explain their influences through the effect of moderation or mediation. Sixth, the structured research strategy has limited the ability to collect more comprehensive information to enable a more detailed analysis as compared to mixed method approach [94]. Therefore, the current research is unable to cover extensively the pandemic impact on digitalisation in the field of SCM across the vast industrial sectors.

6.2 Recommendations for Future Research

The current research has led to new knowledge development. For instance, does pandemic impact the level of digitalisation at different SC partners? Does the level of digitalisation adopted at respective SC partners affect the adoption level of other SC partners and the influence on the performance of respective SC partners? Will the performance of SC partner impact its digital adoption level? Therefore, future studies with multidimensional approach to address these aspects are recommended. Detailed examination could be augmented to explore the digitalisation impact in the coordination and relationship management with supplier and customer. This will extend the boundary of internal operations by including external operations ranging from upstream to downstream of a well-integrated SC network. The scope and location of the research could be expanded to other industries such as automotive, agriculture, construction, electrical and electronics within Southeast Asia with comprehensive research on similarities and differences on adoption of innovative technologies and industry performances, digitalisation strategies

and challenges encountered among the industries and countries. The process of SC focuses on five areas of the supply chain which include plan, source, make, deliver, and return [53,44]. Future research could explore how to leverage digitalisation to manage the aspect of return in a closed loop SC ecosystem.

Finally, further exploration on digitalisation and job security could be conducted as current study find that it is not a critical barrier to digitalisation which is not inconsistent with previous research [96,97].

6.3 Final Conclusions

Scholars and industry experts have debated recent pandemic has driven rapid digital transformation [1,10,11]. Thus, the research is set out to identify to what extend the impact of pandemic has on digitalisation adoption, what digitisation solutions were adopted within the SC structures and how will digitalisation impact SCP by focusing on Malaysia glove industry.

The current research adopts quantitative method with structured online survey and interview. The research questionnaire is categorized into two sections that make up of closed-ended and open-ended questions. Five main constructs with respective measurements focusing on major aspects of pandemic and business performance, pandemic and digitalisation, digital solutions and level of adoption, digitalisation and SCP and barriers to digitalisation are developed. The calculated results are analysed and interpreted to explain the relationships of the examined variables. The research findings indicate that majority of the respondents expressed that pandemic has negatively impacted their business performance and pandemic has positively impacted the adoption of digitalisation. The finding has answered research question RQ1.

BDA, IoT and CC are identified to be commonly adopted within the SC structures while AR, AM and [95] are least adopted. Survey also revealed not all SC structures adopt digital solutions. Different solutions were adopted across individual SC structures with different adoption level. The finding has answered research question RQ2. Overall, the adoption level is considerably low in which CCRM has the highest adoption level while Procurement has the lowest adoption. The analysis also revealed that SC structures would influence each other positively at varying level of adoption. Digitalisation has positively impacted SCP with improved digital capabilities. The interrelationships among SCI, SCV, SCR and CRS are found to be correlated and they have implications toward SCP. This finding supports the assumption of the conceptual framework and answered research question RQ3. Change of work culture has been identified as the key barrier to digitalisation comparing to mindset, i.e.: minimise investment and unknown ROI. The initiative for digitalisation is negatively correlated to pandemic. This finding has reinforced evidence for research question RQ1.

The research contributes to the knowledge development in SCP under the influence of pandemic and broaden the understanding of the underlying instruments that link and correlate to drive SCP improvement. This study also enlightens the practitioners on the understanding of innovative technologies which could help company to minimise negative impact triggered from unexpected events that disrupted SC activities and the challenges in implementing digitalisation. The research highlights the findings restriction and ends with several recommendations related to digitalisation and coordination with supplier and customer, digitalisation strategies and challenges, leverage digitalisation in a closed loop SC ecosystem and interrelationships among digitalisation, level of adoption and performance of SC partners in a multidimensional approach.

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