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Optimising 4IR Digital Supply Chain Technologies to Enhance the Caribbean Banks' Recovery from the Hurricanes

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ABSTRACT

Even if banks often introduce an array of strategies to recover from a crisis, the effectiveness of the supply chain system that procures and delivers the required equipment and materials is often not considered as an essential part of the bank crisis recovery strategies. In the Caribbean banking sector, this often causes a sluggish supply chain management system that affects the procurement and delivery of the required building reconstruction materials, computers, and all the required banking equipment for the banks to quickly recover from the crisis. To address such challenges, this study used qualitative interviews to explore the opinions of purposively selected bank managers from different selected banks in the Caribbean region with the motive of assessing how 4IR digital supply chain technologies are optimized to enhance the Caribbean banks' recovery from the hurricanes. In the event of hurricanes, findings revealed most of the Caribbean banks to experience a lot of damage to the banking infrastructure, computers, documents, and equipment. However, to improve supply chain efficiency to influence the effectiveness of the procurement of bank recovery materials and equipment, interviews revealed the major impediments of 4IR digital technologies' usage to arise from an unsupportive management approach, cultural impediments, and poor maintenance. To improve the efficiency of supply chain management during crisis recovery situations, it is suggested that banking managers must consider adopting Liker's (2020) "Lean-Digital Hybrid Supply Chain Model". Derived from the Toyota Production System (TPS), Liker's (2020) "Lean-Digital Hybrid Supply Chain Model" proposes the creation of a "Lean-Digital Hybrid Supply Chain Model" that integrates the use of lean principles with the application of digital supply chain management technologies like robotics to improve process automation and artificial intelligence to improve inventory management. But given the increasingly more instrumental roles of 4IR digital technologies, it is suggested that future studies must still continue exploring the best models for optimizing 4IR digital technologies in the global supply chain management processes.

INTRODUCTION

During the processes for the implementation of various strategies for the bank to recover from the devastating effects of the hurricanes, the efficiency of supply chain management leverages a bank's faster recovery (Nkwenkwe, 2024). Efficient supply chain management improves the flow of the required equipment and computers from the points of sourcing to the points where they are required. In the Caribbean, hurricanes often cause a lot of turbulence. It destroys the banks' infrastructure, equipment, and computers. For the bank to begin its operations again after the hurricanes, this implies the banking executives will need to assess the situation and acquire new equipment, computers, and vehicles to begin operation (Malope, van der Poll, & Ncube, 2021).

In certain cases, the banking executives are required to make a lot of infrastructural repairs and changes. This comes along with the building and repairs of the destroyed banking infrastructures. However, because just like banks, most of the Caribbean businesses

are also destroyed, it implies after the hurricanes, most of the new required goods, equipment, computers, vehicles, and building materials must be sourced from overseas.

The efficient management of how these required goods, materials, and equipment are sourced and transported from the US, Canada, or Europe to various points in the Caribbean influences the pace of the bank's effective recovery from the devastating effects of the hurricanes. Delays or the importation of damaged goods or the building materials that do not meet the designated specifications implies the bank may not be able to implement all the strategies essential for it to come out of the crisis (Alexander, 2022). Some of the bank's recovery strategy may require building the damaged buildings or the destroyed branch infrastructure. Delays or poor management of the supply chain system implies it can be difficult for the bank to quickly recover from the crisis.

Unfortunately, even if that is so, effective supply chain management is often not considered as part of the critical bank recovery strategies. Even as banks seek to source and replace the damaged computers, equipment, and banking infrastructure, effective supply chain management influencing the efficient management and flow of such goods is often not considered as part of the essential bank recovery strategies (Bayode, van der Poll, & Ramphal, 2019). This explains why some banks often experience delays that affect faster recovery. It also explains why some banks have often sourced goods that do not meet the designated specifications, only to delay the recovery from the crisis.

Yet as the bank delays to recover from the crisis, it also affects its seamless operation. This affects the ability of the bank to begin generating the required sales and profitability to recover from what the hurricanes damaged. Even if that is so, some banks often still fail to develop and use an effective supply chain strategy as part of the bank crisis recovery strategy (Malope, van der Poll, & Ncube, 2021; Sekgololo, Gondwe, & Ndzendze, 2021). As they never recognise the value of an effective supply chain management, even the use of the required Fourth Industrial Revolution (4IR) digital supply chain technologies has never been part of the initiatives that some banks use to improve supply chain management effectiveness during the crisis recovery strategy. It is such a mishap that motivates this study to explore how the modern 4IR digital supply chain technologies can be optimized to enhance the Caribbean banks' recovery from the hurricanes.

LITERATURE REVIEW

Thriving in the increasingly competitive modern 4IR (Fourth Industrial Revolution) business landscape requires businesses to optimize the existing 4IR digital supply chain technologies in a way that leverages their operational excellence. It requires the unique ways of optimizing the existing 4IR digital supply chain technologies in a way that creates unique values that bolster a firm's operational excellence and competitiveness (Pournader, Ghaderi, Hassanzadegan, & Fahimnia, 2021). Global businesses often have all the adequate resources for digital supply chain technologies' investment. This implies as every global business introduces different versions of digital supply chain technologies; the winners are only the businesses adopting a unique approach of optimising the available digital technologies. Effective optimization of the existing digital supply chain technologies improves the efficacy of activities' coordination and integration (Alexander, 2022; Nkwenkwe, 2024; Mofokeng, 2023; Bayode, van der Poll, & Ramphal, 2019).

Using digital technologies like Internet-of-Things and Cloud Computing, 4IR digital technologies improve a business' capabilities to constantly interact and interface with customers (Bahrami & Shokouhyar, 2022). During supply chain planning, this improves the understanding and tracking of market dynamics to enhance capabilities to create and deliver not only what the customers want, but also in the way and place that they want it. Using multitudes of interconnected mobile devices, Internet-of-Things and cloud computing improve the level of internal and external activities integration, interface, collaboration, and tracking of not only the production processes, but also the flow of activities from the points of sourcing, manufacturing, storage, distribution, and sale (Modgil, Gupta, Stekelorum, & Laguir, 2022).

In the event of operational glitches affecting operational excellence, this aids proactive analysis and mitigation of such glitches before they become costly to ameliorate. While optimising digital technologies like digital twins, businesses are able to map and visualize the interconnectedness of their entire global supply chain networks. Such simulations aid the comparing and contrasting of the business' physical supply chain network with its virtual computer-based configuration (Iftikhar, Ali, Arslan, & Tarba, 2024). This aids discerning how such configuration adds value to the organisation as well as the improvement initiatives that must be adopted to improve delivery speed, quality management, costs, and efficiency management throughout the entire global supply chain system.

Digital technologies like Starlink and 5G improve the interconnectedness, communication, collaboration, and effective activities' coordination between critical supply chain actors like suppliers, manufacturers, warehouse operators, transporters, distributors, wholesalers, retailers, and customers (Belhadi, Mani, Kamble, Khan, & Verma, 2021). This improved linkage bolsters the seamless flow and movement of goods along the supply chain system. Even in various rural settings around the world, Starlink is revolutionizing internet connectivity by not only improving the speed, but also accessibility and ease of use.

When artificial intelligence, deep learning, and machine learning technologies as well as robotics are integrated as part of the used digital supply chain technologies, businesses are able to automate most parts of their supply chain operational activities (Okwu, Dominic, Orji, Mbachu, & Ayomoh, 2020). Using delivery robots, automated warehouses, manufacturing processes, and transport

systems, the business can be able to significantly reduce costs, improve operational efficiency, reduce waste, and improve delivery speed to spur improved operational excellence. In turn, this bolsters a firm's improved competitiveness. In line with Barney's (1991) "Resource-based Theory", this implies how a global business optimizes its digital supply chain technologies can turn into a unique strategic value-creating resource that bolsters its competitiveness.

Unfortunately, even if that is the case, the research problem indicates optimizing the available digital supply chain technologies in a way that bolsters a firm's competitiveness is an operational dynamic that most South African-based multinational firms are still grappling with in the quest to edge out rivals (Sekgololo, Gondwe, & Ndzendze, 2021; Mofokeng, 2023). It is such dynamics that motivate this study to analyse how South African-based multinational corporations optimize the available 4IR digital supply chain technologies to enhance their operational excellence and competitiveness. As reflected in the research aim, objectives, and questions below, through such analysis, the study aims to glean not only challenges, but also some of the best practices of 4IR digital supply chain management that the other businesses can also emulate.

4IR Era's Digital Supply Chain Management

Increasing competition in the 4IR era is driving most of the global business operators to discern the best ways of optimising the existing digital technologies to achieve the desired state of operational excellence (Özkanlısoy, 2024). In that quest, digitization of the supply chain operational system is often perceived as the pivotal game-changer that leverages a firm's overall competitiveness. Supply chain management falls at the heart of a firm's operational system. It is through effective supply chain management that the global business manages and controls costs to bolster its cost competitiveness. It is also through effective supply chain management that the global business identifies and eliminates all the slacks affecting quality management, causing delays as well as the quality of customer services (Wu, Zhang, & Huang, 2025). These create enormous points-of-difference that spawn a firm's overall competitiveness on the basis of differentiation.

To leverage a global business' competitiveness, the effectiveness of supply chain management improves the seamless flow and movement of the required goods from the points-of-manufacturing to any location that the customer desires in any part of the world. It is through the effectiveness of supply chain management that a global business is able to ensure the timely response to the needs of customers at anytime and anywhere in the world that the customer desires the product to be created and delivered. Supply chain management is the engine, fulcrum, game-changer or pivot that drives the global business' operational excellence (Ivanov, Tsipoulanidis, & Schönberger, 2021). It enhances the delivery of the products of the right quantity, quality using the selected best partners to the right place and at the right time. This often delights customers to bolster improved customer satisfaction, retention, loyalty, sales, and returns on shareholders' value.

Supply chain management connotes the strategic process of analysing, planning, organising, leading, and controlling the process of moving finished or unfinished goods or inventory from the points of sourcing, through the production points to the points of distribution and sale (Ali, Arslan, Khan, & Tarba, 2021). As the 4IR era ushered in several new digital technologies for improving operational excellence, most global businesses have also adopted and integrated several digital technologies in their supply chain management operations. This has led to the emergence of the concept of digital supply chain management.

In the 4IR era, the Agile Digital Supply Chain Model suggests that to achieve speedy, flexible, agile, and responsive supply chain operations, the critical enablers require usage of machine learning and AI for forecasting and production scheduling, cloud computing for enhancing flexibility and agility, and AI for supply chain planning (Kamakela, Callychurn, & Hurreeram, 2025). The Platform-Based Supply Chain Model proposes the coherent integration of critical actors like suppliers, customers, manufacturers, transporters, warehouse operators, distributors, wholesalers, and retailers to be essential for improving supply chain operational efficiency. Digital supply chain management connotes the strategic process of analysing, planning, organising, leading, and controlling the process of integrating and using a combination of the required digital technologies in a way that spurs a firm's operational excellence (Liker, 2020).

Digital supply chain management is the strategic process of using digital technologies like Internet-of-Things, cloud computing, artificial intelligence, robotics, digital twins, augmented and virtual reality, and blockchain technology. It is not just the random use of any 4IR digital technology that spawns a firm's operational excellence and competitiveness. Instead, it is essential to discern a more systematic process of using a combination of digital strategies that can transform a firm's operational excellence to bolster its overall competitiveness.

If balanced, Internet-of-Things provide mobile devices, trackers, and sensors that are not only used for linking with various suppliers, transporters, and customs' clearing and forwarding agents (Gupta, Modgil, Meissonier, & Dwivedi, 2021). Instead, it also leverages real-time analysis, monitoring, and tracking of inventory during the manufacturing processes, warehouse storage, and goods' movements to different distribution points.

In that process, artificial intelligence and robotics improve the automation of supply chain processes as well as demand analysis and forecasting to enable the supply chain system to balance demand with supply. This improves inventory management to reduce risks of waste and stock shrinkages. As artificial intelligence and robotics improve the efficiency of production planning and scheduling, it also bolsters the efficacy of predictive maintenance (Dubey, Bryde, Blome, Roubaud, & Giannakis, 2021). Using predictive maintenance, artificial intelligence and robotics improve proactive analysis and response to failures that may affect manufacturing

machines, equipment, or transportation vehicles and trucks. Using real-time analysis, this enables management to identify and avoid incidents that could have affected supply chain operational efficiency.

Combined with the use of big data, cloud computing, digital twins, augmented and virtual reality, digital supply chain management improves a firm's operational efficiency to bolster its overall operational excellence (Bag, Rahman, Srivastava, Chan, & Bryde, 2022). However, to achieve that, most theories highlight the use of the appropriate digital supply chain management strategy to be pivotal for achieving outcomes that improve a business' operational excellence.

Digital Supply Chain Strategy

Digital supply chain strategy outlines the vision and the areas like planning, sourcing, making, delivering, and returning where the integration of the required digital technologies is essential for bolstering supply chain operational efficiency. Some of the visions of digital supply chain management strategy are usually to reduce costs, improve operational efficiency, reliability, flexibility, activities' integration, and control of the supply chain operational systems (Tian, Wu, Ciano, Ardolino, & Pawar, 2024). While improving product availability and customer satisfaction, digital supply chain strategy also aspires to leverage a firm's competitiveness. For the areas requiring digital technologies' integration, during planning, the use of the required digital supply chain technologies like big data improves demand forecasting. In turn, this enhances the effectiveness of planning. During sourcing, usage of the required digital technologies like cloud computing also enhances the identification of the suppliers that can be used (Sengupta, Narayanamurthy, Moser, Pereira, & Bhattacharjee, 2022).

Digital technologies' usage influences manufacturing efficiency by proactively identifying and mitigating production risks of failure that can affect manufacturing efficiency. While using the required digital technologies like robotics and artificial intelligence, Internet-of-Things, and cloud computing, the logistics/delivery aspects of supply chain management also improve. This enhances the efficiency of warehouse management, storage, transportation, and distribution of goods to the designated customers and locations. During the management of after-sales services, usage of Internet-of-Things and cloud computing enables the business to assess the level of customer satisfaction with the delivered goods and the associated quality of customer services. However, as cited in Christopher's (2016) "Systems Theory of Supply Chain Management", the existing digital supply chain technologies can only be optimized to influence a firm's operational excellence and competitiveness if supply chain is viewed as an integrated system.

Viewing supply chain as an integrated system improves the effective management and response to actors like suppliers, manufacturers, warehouse operators, transporters, distributors, retailers, and customers that play more instrumental roles in the global supply chain management system. The systems approach aids the evaluation of the overall configuration of the global supply chain network (Ivanov, Tsipoulanidis, & Schönberger, 2017). This aids identification and response to problematic areas that can affect the efficiency of the overall supply chain system. Systems theory of supply chain management suggests the critical principles that must be embraced to encompass holism, integrated planning, feedback loop, agility, flexibility, interdependence of systems, cross-functional teams' usage, and coordination.

Yet as all the required digital supply chain technologies are optimized, Flynn et al.'s (2010) "Supply Chain Integration Theory" implies it also improves the level of supply chain system's internal and external integration. When digital technologies like Internet-of-Things and cloud computing are used, they improve the integration of internal activities like procurement, production, and sales with the external actors like suppliers, distributors, wholesalers, retailers, and customers (Flynn, Huo, & Zhao, 2010). Such improved collaboration and interface enhances the level of information sharing and exchange to bolster the capabilities of all the players in the supply chain system to come together and deal with the problem affecting supply chain operational efficiency.

Even if that is so, the successful integration of 4IR digital technologies for improving supply chain operational efficiency is often still undermined by higher implementation costs, risk of employee resistance, silo-based operations, and poor management commitment. Fear of data security breach compromising confidential business information frustrates the effective use of the available supply chain digital technologies (Qader, Junaid, Abbas & Mubarik, 2022). Other impediments arise from inadequate talents and competencies to manage digital supply chain technologies in a way that creates enormous cost and efficiency advantages to bolster a firm's competitiveness. Such constraints are not different from the management, organisational, resources, and technology challenges affecting the effective optimisation of 4IR digital supply chain technologies to leverage the Caribbean-based multinational banking corporations' operational excellence during crisis management periods. To respond to such challenges, the study used a qualitative research method to discern the solutions that can be adopted.

METHODOLOGY

As the study uses an interpretivist research paradigm; the overview of the empirical methodology that will be used during the primary research process is elucidated as follows:

Qualitative Research Approach

To assess how 4IR digital supply chain technologies are optimized to leverage the operational excellence of the selected Caribbean banks during the crisis recovery processes, the study used an interpretivist research paradigm. Interpretivist research paradigm is an epistemological process of thinking that emphasises the extraction of the detailed descriptions of the phenomenon being investigated

(Pervin & Mokhtar, 2022). It aids in-depth analysis of the concept being investigated. Compared to the positivist research paradigm that uses certain statistical parameters to limit the amount of information that can be gathered, it is construed that the use of an interpretivist research paradigm would enable the study to extract detailed information on questions like why, how, when, who and what affects or improves the effectiveness of 4IR digital supply chain technologies used during bank crisis recovery strategy. To achieve that, the use of interpretivist research paradigm was integrated with the use of exploratory research design and qualitative research method (Kouam, 2024).

While using interviews as the main qualitative research technique, it was anticipated that the use of a qualitative-exploratory research design will enable the study to elicit detailed rich information on the kinds of the modern 4IR digital supply chain management technologies as well as the techniques that are used for improving the banks' operational excellence during crisis management periods. Interpretivist-qualitative research approach also offered detailed descriptions of how the use of 4IR digital supply chain management technologies has impacted the selected Caribbean banks' operational excellence and competitiveness, as well as the challenges that must be mitigated. Through such analysis, the study detailed insights essential for discerning the 4IR digital global supply chain model that can be extracted and adopted going forward into the increasingly technologically-driven business era of the Fourth Industrial Revolution. However, to obtain the required data, the sample banks participating in the study were purposively sampled.

Sampling

Sampling is the systematic process of selecting the units of analysis from the target population. Target population is the larger subjects for the study. In this study, the target population refers to multinational banking corporations that are operating in the Caribbean region. However, to draw the desired sample population, purposive sampling was used to draw about thirty (30) supply chain managers from thirty selected multinational banking corporations that are operating across various countries in the Caribbean region. Usage of purposive sampling is aligned with the ideology that sampling can be accomplished using probability or non-probability sampling techniques. Probability sampling that uses chance and randomness often uses techniques like simple random, systematic, cluster and stratified sampling (Elliott, 2020). This contrasts with non-probability sampling that does not use chance and randomness, but the criteria in techniques like convenience, purposive or snowball sampling techniques. While using purposive sampling, this study only focused on interviewing about thirty sample supply chain managers. As compared to the other bank managers, it is the supply chain managers who are better placed to understand and hold valuable information on the 4IR digital supply chain technologies that the Caribbean-based multinational banking corporations can use for improving their operational excellence during crisis management periods. In such quests, it is semi-structured interviews that were used as the data collection method.

Data Collection

Compared to structured and unstructured interviews, it is semi-structured interviews that were used as the data collection method. Use of semi-structured interviews was accomplished using the pre-designed interview questions and additional questions during the interviews. This enriched the details of the narratives that were elicited during the interview processes. To accomplish that, the semi-structured interviews were guided by the pre-designed Interview Guide designed in alignment with the research objectives and questions. As this permitted the gathering of only the information relevant to the study, the first section of the Interview Guide assessed the kinds of the modern 4IR digital supply chain technologies that are used for improving the Caribbean-Based Multinational Banking Corporations' operational excellence during crisis management periods. The second section will examine the techniques used for optimizing the existing 4IR digital supply chain technologies in the improvement of the Caribbean-Based Multinational Banking Corporations' operational excellence during crisis management periods. The third section analysed how the use of 4IR digital supply chain technologies has impacted the Caribbean-Based Multinational Banking Corporations' operational excellence during crisis management periods. The fourth section evaluated the management, organisational, resource, strategy and technology-related challenges affecting the optimization of the modern 4IR digital supply chain technologies in the way that improves the Caribbean-Based Multinational Banking Corporations' operational excellence during crisis management periods. The fifth section explored the interview participants' suggestions on the 4IR digital global supply chain management model that can be extracted and adopted going forward into the increasingly technologically-driven business era of the Fourth Industrial Revolution. Once the Interview Guide was formulated, it was subjected to a brief pilot testing on five sample interview participants to test its suitability. Once the identified errors were corrected, the process of one-on-one interviews commenced until all the thirty (30) supply chain managers from the purposively selected Caribbean-Based Multinational Banking Corporations were all interviewed. The gathered detailed qualitative data was analysed using thematic and narrative analysis.

Data Analysis

Even if qualitative data is often analysed using discourse, narrative and thematic analysis techniques, this study used only thematic and narrative analysis to aid the accurate extraction of themes and narratives that offer relevant explanatory insights on how 4IR digital supply chain technologies are optimized to leverage the Caribbean-based multinational banking corporations' operational excellence during crisis management periods. To accomplish that, thematic and narrative analysis were structured according to four

steps encompassing reading of each interview script to improve familiarisation, reading to extract themes/codes, reading to extract subthemes and extraction of narratives explaining each of the extracted themes and subthemes. Through usage of these processes, thematic and narrative analysis aided the extraction of themes and narratives explaining the 4IR digital supply chain management technologies as well as the techniques that are used for improving the Caribbean-based multinational banking corporations' operational excellence during crisis management periods. It also extracted important themes and narratives elucidating how the use of 4IR digital supply chain technologies has impacted the Caribbean-based multinational banking corporations' operational excellence during crisis management periods. Through thematic and narrative analysis, the study will also emerge with themes and narratives explaining the management, organisational, resource, strategy and technology-related challenges affecting the optimization of the modern 4IR digital supply chain technologies in the way that improves the Caribbean-based multinational banking corporations' operational excellence during crisis management periods. After such analysis, the study will reach a logical conclusion on the 4IR digital global supply chain management model that can be extracted and adopted going forward into the increasingly technologically-driven business era of the Fourth Industrial Revolution. All these will be accompanied with the use of the measures for improving credibility and trustworthiness as well as the ethical considerations of the study.

Credibility and Trustworthiness

Credibility and trustworthiness of the study was improved by enhancing credibility, dependability, confirmability and transferability of the study (Ahmed, 2024).

Research Ethical Consideration

Research ethics that were considered entail adherence to the principles of informed consent, anonymity and confidentiality, respect and integrity, avoidance of harm and avoidance of conflict of interest (Ali, Mohamed, Abdullah & Khairuddin, 2025).

From this analysis, the details of the findings are as analysed, presented and elucidated below.

RESULTS

In the event of hurricanes, findings revealed most of the Caribbean banks to experience a lot of damage to the banking infrastructure, computers, documents and equipment. However, to improve supply chain efficiency to influence the effectiveness of the procurement of Bank Recovery Materials and Equipment, interviews revealed the major impediments of 4IR digital technologies' usage to arise from:

— Unsupportive Management Culture

— Cultural Impediments

— Poor Maintenance

Details of these themes and narratives are evaluated as follows.

Damage of Bank Infrastructure and Equipment

Even if building plans are often integrated with the initiatives for mitigating the damage caused by the hurricanes, the narratives of most bank managers noted that it is often still difficult to estimate and predict the strengths of the hurricanes. For that reason, they revealed that the hurricanes have often been punctuated by torrential rains, high winds and flooding that render it difficult for banks to mitigate some of the damages using the available proactive strategic plan. Due to heavy torrential rainfall that comes with the hurricanes, they revealed that the banks' corporate vehicles left in various parking yards have often been submerged in water as a result of floods. By the time the hurricanes end, most of the essential parts of the vehicles like engines, gearboxes and the seats will have been damaged to require replacements.

Yet as heavy wind, rain and floods come with the hurricanes, some of the bank managers noted the roofs of the buildings for some bank branches to be blown off. As windows are also shattered by strong winds, this causes flooding in the building to damage the interior decorations, electrical wiring, computers and all the essential documents left in different bank branches. Wall paintings are also damaged as some of the walls collapse due to the submersion in water for a longer period of time. Such a finding is corroborated in the narratives of one of the interviewed bank managers who noted that:

> *"Crisis caused by the hurricanes is the worst form of crisis, because the damage from the hurricanes affects all aspects of the bank's organisational operations. After the hurricanes, one realizes that the computers, ATMs, vehicles, buildings, files and documents, telephone lines and a lot of other things are all damaged to require rebuilding. Compared to just a crisis arising from cyber-attack or destructive actions of the competitors introducing new banking products, a crisis caused by the hurricane's occurrence requires a lot of efforts and resources to restore the bank to its pre-hurricane's state of operation and performance."*

Combined with smell from the decaying plants and flowers and other things, this renders most of the banking infrastructure and facilities unsuitable for usage without rebuilding, repairs, refurbishment and thorough cleanup as part of the bank's crisis recovery strategies. In addition, they revealed that the flooding of some buildings causes short-circuiting that causes fire to damage some of the critical IT infrastructure and networks. This destroys several banks' servers and data centres, banking equipment like printers,

computers, scanners, card readers and cash-counters. Combined with the destruction of several ATM machines and CCTV cameras and banking security information systems, this implies it becomes difficult for the bank to immediately commence operations when the hurricanes have subsided. Due to these extensive damages, some of the banking managers noted that immediately after the hurricanes, the banking executives have been involved in the procurement of a lot of materials aimed at implementing a lot of recovery strategies.

Procurement of Bank Recovery Materials and Equipment

Contrary to the assumption that effective supply chain management is not part of the bank crisis recovery strategies, narratives of most bank managers noted effective supply chain management to be essential for improving the procurement processes. During the initial stages of the recovery processes, some of the bank managers explained that the preliminary recovery strategy has often entailed cleaning and repairing the equipment and machinery that can be repaired. They explained that as hurricanes are predicted to occur, the bank has often undertaken the initiative of ensuring all the equipment, computers, printers and other documents are stored in the right places. However, as the roof is blown off or the wall collapses, all the equipment and machinery stored in various safe places are exposed to damages. This causes problems. In effect, when the hurricane has subsided, some of the bank managers noted that the first preliminary analysis has often been to assess, clean and repair what is damaged. This is followed by the analysis of branch after branch to assess what is damaged or not.

Once the damage is assessed, the recovery process has often entailed cleaning and repairing damaged computers, printers, desks, filing cabinets, cubicles, ceilings and lighting. Though when submerged in water, some of the generators get spoilt, some of the bank managers revealed that repairs or purchase of the required generators is often part of the initiatives undertaken to ensure the banks have the energy to power some of the computers that can be powered. This enables the bank to start operations even if on just a limited scale. Such a view is accentuated in the narratives of one of the interviewed bank managers who noted that:

> *"Even without hurricanes, we usually have backup generators so that when there is a problem with the normal electricity supplies, the backup generators can be used. However, when the hurricanes occur, some backup generators are affected and damaged as others are not affected. This often means if we are to start operation and implementation of the required recovery strategies, cleaning and repairs of the generator is usually essential. Because when the generators are on, the bank can start operation on a small scale to link up with clients and keep improving until it fully recovers from the crisis. In some cases, new banking equipment and computers may also be required as the existing ones could have been damaged beyond repairs."*

However, if procurement of new equipment, machinery and materials is to be undertaken, some of the bank managers noted that most of the required goods and services are sourced from the United States, Canada, China or Europe. If the building of the bank branch is damaged, some of the managers noted that the strategy has often been to procure concrete, bricks, cement, windows, doors, roofing materials, electricals and floor tiles from the United States. Besides data recovery, some of the bank managers noted procurement of computers, printers, scanners and cash counters to also be undertaken to replace the ones that are damaged beyond repair.

However, as various Caribbean banks execute various procurement initiatives, some of the managers noted problems to arise from slow payment of compensation from the insurance companies. This delays the commencement of the procurement processes for the required essential bank equipment. Yet as various procured goods move through various ports from the US or Europe into the Caribbean, delays have also affected the faster movement of the required equipment, materials and resources in the way that aids faster recovery of the bank from the crisis. Quite often, these challenges are exacerbated by the existence of an unsupportive management culture.

Unsupportive Management Culture

Management philosophy in some multinational banks does not support the effective optimisation of the available digital supply chain technologies in the way that leverages operational excellence and competitiveness during the bank crisis management periods. Since all the other well-resourced banking businesses are using various forms of digital technologies, some global banking executives feel even if all the required digital supply chain technologies are used, not much unique business value leveraging operational excellence and competitiveness would be attained. Because not all the essential 4IR digital technologies are used, it often becomes difficult for the bank to integrate and use more advanced 4IR digital technologies in their operations. In such management philosophy, there is a misconception that the unique advantages leveraging supply chain operational excellence to bolster competitiveness will come from other sources other than the used digital supply chain technologies. Such thinking explains why despite the use of the required digital supply chain technologies, most global banks' supply chain processes are still characterised by delays, delivery of damaged goods as well as accidents affecting delivery. It also explains theft of goods along the way and poor networking with actors like customs' clearing and forwarding agents to facilitate faster cross-border movements of goods. Such a view is echoed in the views of one of the supply chain managers who noted that:

> *"In a banking sector, some digital technologies are not quite relevant for improving effective supply chain management. That is why we are selective in the kinds of 4IR digital technologies that we use. We use satellite-supported tracking devices to trace and follow the movements of our goods from the points of sourcing to the points of delivery. We also use the internet and cloud computing, but not automation and other robotics because there are other players at different points. For that reason, the technology which is required at one point may not be required for our level of operations at the bank operation's management level."*

Yet as most global banks evolve from their tiny bases in North America or Europe to the other parts of the world, they also develop extensive structures that are not only amorphous, but also encourage more silo-based operations. Instead of adopting a unified collaborative approach, most multinational banks often adopt a disintegrated silo-based approach. When digital supply chain technologies are being introduced, they are also implemented along such silos. This causes disintegration of digital supply chain systems to affect the seamless management and coordination of activities across various global banks' departments and units. Because each silo is using its own rules and not the wider organisational rules, decisions are delayed to affect speedy response to customers' orders and the delivery of the required goods to the desired points-of-sale. With such constraints, some global banks often use all the required digital technologies, but never gain cost and efficiency advantages that bolster their competitiveness. They use and operate using various digital technologies, but they never gain advantages that bolster their competitiveness due to poor optimisation of the existing digital technologies. Yet as silo-based operational approach undermines the effective optimisation of the required digital supply chain technologies during a bank's crisis management, other limitations often arise from the change of the operational culture.

Cultural Impediments

Since the use of some approaches are known to lower costs and increase profitability, senior bank managers may not change such a process. If the introduction of any digital supply chain technology would distort such a process, bank management would not allow it. Even if the distortion would only occur in the short run, with the motive of creating more disruptive business value in the long run, some senior managers would opt to use the current system instead of introducing a new technology. This causes problems that affect the successful optimisation of the existing digital technologies. It creates a situation where some areas of supply chain operations use advanced digital technologies as the other areas are lacking. During the response to more complex crises, this dualism and incompatibility affect interoperability of the established digital supply chain technologies. A speedy process in a particular area of supply chain management is slowed down by the areas that do not use proper digital supply chain technologies. Such a view corroborates the interview narrative from one of the bank managers who noted that:

> *"In the banking sector, banks survive and make profits using aggressive cost minimisation and saving initiatives. Hence, if something or the technology cannot produce any value, it is often abandoned or the required financial resources are not invested. Hence, for us in the event of a crisis, effective supply chain management is essential for the bank to source and deliver the tools that are essential for the bank to come out of the crisis. But because we do not experience a crisis all the time, our supply chain system is often very small and less equipped with all the required digital technologies. In the event of a crisis, we spend time revamping it and that affects our capabilities to quickly source and respond to the crisis. It also affects our capabilities to quickly recover from the crisis because we cannot quickly recover if the required computers and other banking equipment are not quickly sourced and delivered."*

Combined with the use of more aggressive cost savings, some of the global banking businesses also often do not invest in all the required digital technologies. They may tend to opt for cheaper versions that affect operational speed to undermine the efficiency of supply chain management. Quite often, global banking businesses are assumed to have enormous resources, but because of their extensive nature of global operations, they also tend to spend a lot, which if not controlled can affect their profitability. Organically, this often induces aggressive cost minimisation and control behaviours that affect even the commitment of the required resources in training and competency development. In most cases, some multinational banking corporations invest in the establishment of more complex digital supply chain technologies without considering the required training budget. Because the employees lack the required skills and competencies, this causes the introduction of digital supply chain technologies that cannot be optimised to improve operational excellence and competitiveness during the implementation of various crisis recovery strategies.

Poor Maintenance

As lack of skills and competencies affect the faster adoption and acceptance of the available digital technologies, poor maintenance may also affect the maintenance of the supply chain digital technologies that can aid a bank's effective response to the crisis. As this affects the optimization of the available digital technologies, the challenge arises from poor maintenance. Because the digital supply chain technologies are over-optimized in the process of meeting various targets, frequent analysis and maintenance is often ignored. Even if some sensors are used for early warning and alert, such warnings are often ignored as the senior managers adopt a reactive approach of waiting for the machines to breakdown first before repairing. During a crisis, such operational culture becomes

a problem for improving the flexibility and agility of the bank to respond and recover from the unfolding crisis. In response to the interview questions on the challenges affecting the use of 4IR digital supply chain technologies during crisis management, one of the interviewed managers noted that:

> *"A culture of poor maintenance is a problem because if the crisis occurs and the digital technologies are not working well, it becomes difficult for the bank to respond and recover from the crisis with the requisite degree of flexibility and agility."*

Even if the sensors are warning, the use of aggressive cost savings causes the wait and see attitude. Such approach often causes sudden breakdown or failures that affect the optimization of the available digital supply chain technologies in the way that improves a firm's operational excellence and competitiveness. Combined with the higher implementation costs, poor data security management, budgetary constraints, poor standardization and failure to invest in all the required digital technologies, all these often affect the optimization of digital supply chain technologies in the way that bolsters a bank's operational excellence and competitiveness. Yet in the constantly evolving and competitive 4IR era, improving supply chain operational excellence is essential for leveraging a bank's overall competitiveness.

In otherwords, during a crisis situation, these findings raise a lot of managerial implications if the modern banking managers are to use their supply chain management efficiency as a strategy for recovering from the unfolding crisis.

MANAGERIAL IMPLICATIONS

To improve the efficiency of supply chain management during crisis recovery situations, it is suggested that banking managers must consider adopting Liker's (2020) "Lean-Digital Hybrid Supply Chain Model". Derived from how the Toyota Production System (TPS) works, Liker's (2020) "Lean-Digital Hybrid Supply Chain Model" has been modernized in the era of the Fourth Industrial Revolution. Liker's (2020) "Lean-Digital Hybrid Supply Chain Model" argues that digital supply chain management can only influence improved operational excellence if the use of digital technologies is integrated with the adherence to the essential TPS principles.

While ensuring lean operation, the motive of introducing various supply chain technologies should be to improve operational efficiency, minimise wastes and costs. Such an approach would be more suitable for banks that often focus on a more aggressive cost minimisation approach. Supply chain digitisation must also strive to improve global responsiveness by automating various business processes and improving the global bank's business scalability, flexibility and agility to quickly respond to emerging new needs.

To achieve that, Liker (2020) proposes the creation of a "Lean-Digital Hybrid Supply Chain Model" that integrates the use of lean principles with the application of digital supply chain technologies like robotics to improve process automation and artificial intelligence to improve inventory management. A Digital Kanban System is used to improve JIT (Just-in-Time) production, Internet-of-Things and AI to improve predictive maintenance of supply chain equipment, machines and technology. In that process, Digital Dashboards are used for real-time analysis and tracking performance, and an Integrated ERP (Enterprise Resource Planning) System is used for automating supplier scheduling.

When these digital supply chain technologies are being used, Liker's (2020) "Lean-Digital Hybrid Supply Chain Model" suggests that all activities must be accomplished within the framework that strongly adheres to Lean/Toyota Production System (TPS) principles of cost minimisation, waste elimination, continuous improvement, JIT production, efficiency and value-stream mapping. These would leverage a global supply chain operational excellence by improving delivery efficiency, delivery speed, cost reductions, reliability, product availability, quality, responsiveness, waste minimisation, integratedness, collaboration and seamless interface of the internal and external supply chain ecosystems.

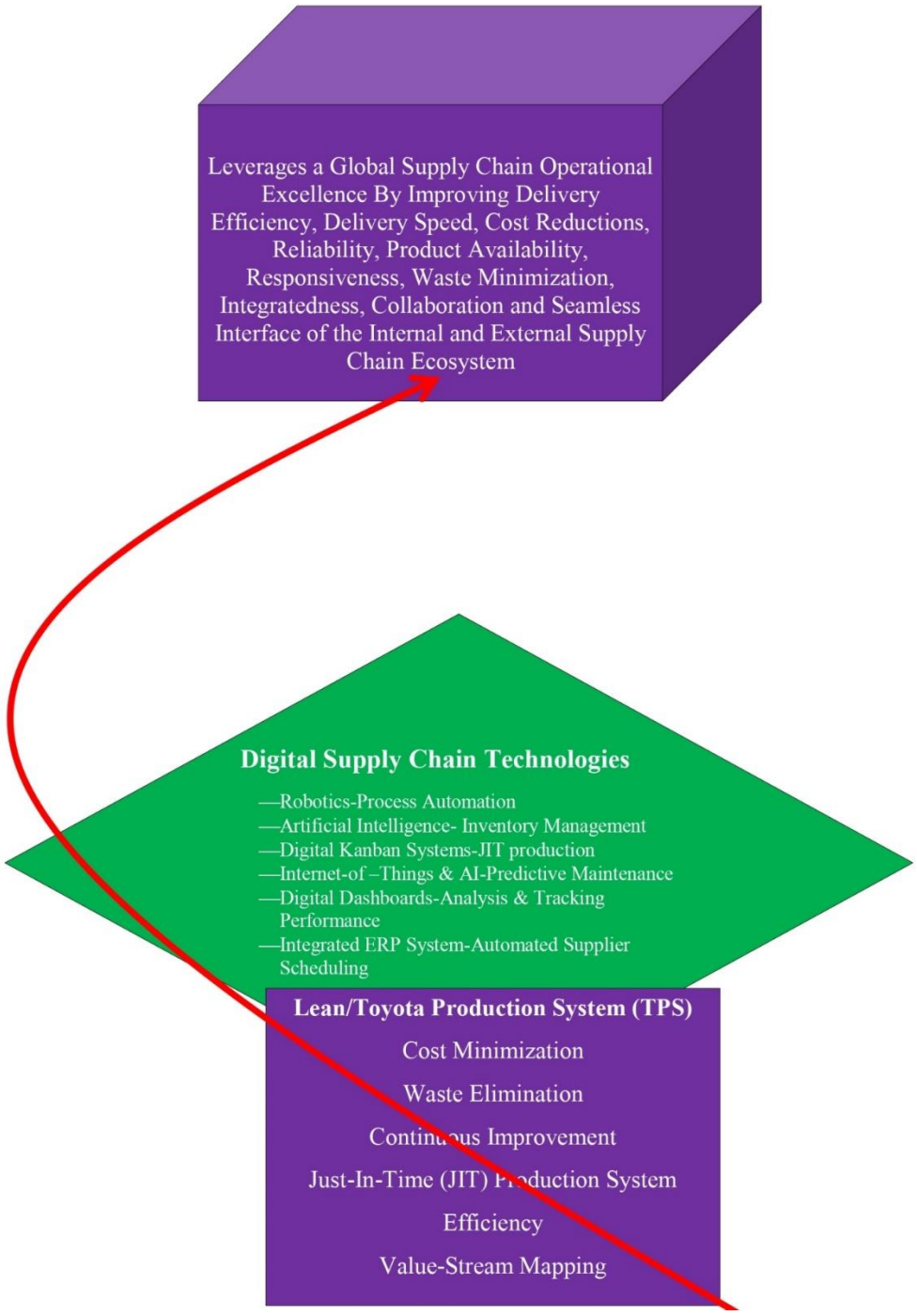

Figure 1: Liker's (2020) "Lean-Digital Hybrid Supply Chain Model"

Even if Liker's (2020) "Lean-Digital Hybrid Supply Chain Model" offers a more accurate insight on how 4IR digital supply chain technologies can improve operational excellence, it still does not elucidate how the five core supply chain activities of plan, source, make, deliver and return can be digitised to influence attainment of the desired cost and efficiency advantages. Yet, as the SCOR (Supply Chain Operations Reference) Model indicates, the integration of digital technologies' usage like Internet-of-Things, Artificial Intelligence, Cloud Computing and Blockchain throughout the supply chain processes of plan, source, make, deliver and return influences real-time tracking, forecasting and production scheduling, automation and operational efficiency. Such insight also accentuates the view in the Digital Twin Supply Chain Model that states that usage of digital twin, which is one of the digital technologies ignored in Liker's (2020) "Lean-Digital Hybrid Supply Chain Model", influences the simulation of activities from the points-of-sourcing to points-of-sale. By comparing the virtual with the physical supply chain system, bank managers can identify and mitigate operational glitches that undermine operational efficiency.

CONCLUSION

As the increasing proliferation of new 4IR digital technologies changes and revolutionises the nature of business operations, this study becomes important for discerning how such new 4IR digital technologies impact the global supply chain system. During crisis

recovery processes, this study is important for discerning the most suitable model that can be adopted for optimising the existing 4IR digital supply chain technologies in the improvement of a bank's operational excellence. Some studies have proposed digital supply chain models like Liker's (2020) "Lean-Digital Hybrid Supply Chain Model", SCOR (Supply Chain Operations Reference) Model and Digital Twin Supply Chain Model. But such models are still limited by the fact that they just focus on using just one or a few of the available 4IR digital supply chain technologies. This affects discerning how a combination of the emerging new 4IR digital technologies can be optimised to improve supply chain operational excellence. During crisis recovery processes, it also affects discerning how the existing 4IR digital technologies link up with each other to bolster the supply chain operational excellence. To respond to such a gap, this research was of significant importance for exploring the kinds of the modern 4IR digital supply chain technologies that are used for improving the multinational banking corporations' operational excellence. The study will also examine the techniques used for optimising the existing 4IR digital supply chain technologies in the improvement of the multinational banking corporations' operational excellence. Besides evaluating how the use of 4IR digital supply chain technologies has impacted the multinational banking corporations' operational excellence and competitiveness, the study is also important for assessing the management, organisational, resource, strategy and technology-related challenges affecting the optimisation of the modern 4IR digital supply chain technologies in the way that improves the multinational banking corporations' operational excellence and competitiveness. Through such analysis, this study emerged with the 4IR digital global supply chain management model that can be adopted going forward into the increasingly technologically driven business era of the Fourth Industrial Revolution. While usage of such a model will improve supply chain operational efficiency, it will also enrich the existing theories and literature on digital supply chain management. But given the increasingly more instrumental roles of 4IR digital technologies, it is suggested that future studies must still continue exploring the best models for optimising 4IR digital technologies in the global supply chain management processes.

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