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ABSTRACT

Purpose: The aim of this study is to identify and prioritize a list of key digitization enablers that can improve Supply Chain Management (SCM). SCM is an important driver for organization's competitive advantage. The fierce competition in the market has forced companies to look past the conventional decision-making process which is based on intuition and previous experience. The swift evolution of information technologies (IT) and digitization tools has changed the scenario for many industries, including those involved in SCM.

Design/methodology/approach: The Best Worst Method (BWM) has been applied to evaluate and rank and prioritize the key digitization and IT enablers beneficial for the improvement of SC performance. The study also used additive value function to rank the organizations on their supply chain performance with respect to digitization enablers.

Findings: Twenty-five key enablers have been identified and ranked. The results revealed that "Big data/data science skills", "Tracking and localization of products" and "Appropriate and feasibility study for aiding the selection and adoption of big data technologies and techniques " are the top three digitization and IT enablers that organizations need to focus much on them in order to improve their supply chain performance. The study also ranked the supply chain performance of the organizations based on digitization enablers.

Originality: This study seems to be the first of its kind in which twenty-five digitization enablers categorized in four main categories are ranked using a multi criteria decision making (MCDM) tool. This study is also first of its kind in ranking the organizations in their supply chain performance based on weights/ranks of digitization enablers.

Practical implications: The findings of this study will help the organizations to focus on certain digitization technologies in order to improve their supply chain performance. This study also provides an original framework for organizations to rank the key digitization enablers according to enablers relevant in their context and also to compare their performance with their counterparts.

Keywords**:** Supply Chain Management, Digitization tools, Big Data Analysis, Internet of Things, Blockchain Technology, Industry 4.0, Best Worst Method.

1. Introduction

In today's complex supply chain, which also covers a widely distributed geographical area, Information Technology (IT) and digitization are pre-requisites for efficient control of product and information flow (Fasanghari et al., 2008). According to a study conducted by Forrester Research on the adoption of digitization, it was concluded that, American manufacturers are reaping the benefits digitization including reduction in cycle time, timely delivery of products to the customers, achieving higher efficiency, and improvement in supply chain agility (Radjou, 2003; Hennelly et al., 2020). With adoption in digitization and IT in supply chain management (SCM), firms can improve their performance by developing and storing data regarding customers, suppliers, and markets (Tippins et al., 2003; Huo et al., 2019; Jabbour et al., 2020). Digitization can improve the operations of companies, strengthen distant links of their SC, and can very well interconnect companies and their customers (Carr, 2003). In modern times, an individual business cannot succeed as an independent organization but as an active member of an extensive supply chain network involving diverse activities and relationships (Lambert et al., 2000). Customers have become more aware of and are continuously asking for customized products, enhanced service level, and lesser price (Christopher, 2016). Also, the external environment is ever-changing due to both natural and economic factors like extreme weather conditions, currency exchange rates, cost of energy, etc. Digitization tools are important for managing the supply chains and enhancing their performance in this dynamic environment (Ross et al., 2010; Jabbour et al., 2020).

Digitization tools can significantly improve the agility of the supply chains (Kittipanya-Ngam and Tan, 2020). The most well-known use of digitization tools in SCM is the management of transport. Monitoring of pickups at a local delivery point through digitization tools will help the organization to track shipments to local depots, which in turn helps the organization to collect reliability performance data of the carriers. These tools also help to unify all the entities involved in the coordination of all the processes essential to complete customer orders like order cycle, trading partners, manufacturers, and merchandisers (Fasanghari, 2008; Hennelly et al., 2020).

The adoption of digitization tools in supply chain management will open more and more opportunities when business partners, suppliers, and customers work together to co-produce and co-create value (Wamba et al., 2015). Santagate et al. (2013) stated that synchronization between technological innovation (service quality, system quality, and information quality) and operational performance (cost, reliability, flexibility, quality, and speed) enhances operational efficiency of companies.

With the adoption of digitization tools like big data analytics, the traceability and visibility of the product flow can be improved thus enhancing the supply chain performance (Barratt and Oke, 2007), strength & flexibility (Brandon-Jones et al., 2014), and organizational performance (Schoenherr & Speier-Pero, 2015). Big data analysis has allowed new techniques for arranging and evaluating SC processes to enhance SC performance (Hazen et al. 2014), develop production capacity and efficiency and enhance the satisfaction level of customers (Anwar et al., 2018). Available literature has also revealed that the implementation of big data analysis has a positive effect on the performance of supply chains (Gunasekaran et al., 2017; Wamba et al., 2017), developing competitive edge (Chen et al., 2015) by the reduction in total cost, better decision making, and upgradation in products and services (Matthias et al., 2017). Further, PwC in their study in 2019 found out that almost 67% of the organizations today “consider digital supply chains disruptive and important for performance improvement”. They concluded that digitization of supply chains will help Indian organizations with significant cost reductions thereby increasing their annual revenues apart from other benefits of enhancing traceability and visibility throughout the supply chain.

Internet of things can influence the entire supply chain performance by various means including: (i) reliability of the supply chain can be enhanced by permitting visibility of object and live sharing of data and information; (ii) responsiveness of the supply chain can be enhanced and reduce operational costs for the functioning of the supply chain; (iii) better management of resources of the supply chain by tracking real-time data exchange; and (iv) agility of the supply chain can be improved by facilitating the easier process of information flow (Dweekat et al., 2016). The implementation of blockchain technologies in the supply chain also improves the supply chain performance: (i) by permitting availability, consistency, and immutability of information regarding supply chains (Appelbaum and Smith, 2018); (ii) by enhancing supply chain visibility, coordination and traceability (Kshetri, 2018); (iii) by enabling the reduction in errors and attacks (Appelbaum and Smith, 2018); (iv) by making it easy to govern supply chain and contract management (Appelbaum and Smith, 2018); (v) by reducing the complexity of structure (Subramanian, 2017); and (vi) by contributing in innovations and radical restructuring of the supply chain (Subramanian, 2017).

Industry 4.0 has also led to improved performance of the supply chains. Due to the implementation of Industry 4.0, supply chain gains flexibility, quality standards get improved, and efficiency and productivity increases. This will lead to mass customization of products and services, permitting companies to satisfy varying demands of customers. This also leads to the constant introduction of new and innovative products in the market. Cooperation between humans and machines optimizes the decision-making process resulting in better decisions and lesser errors (Tjahjono et al., 2017). The advantages of the implementation of digitization tools in operations and supply chain are many including: reduction in cost; improvement in the process as well as its efficiency (i.e., increased efficiency; improved resource management; more and more flexibility and agility); better quality, accuracy, and reliability of information; unification and cooperation (improved coordination); new innovative products and services (de Barros et al., 2015). In reality, the unification of different organizations involved in the supply chain can be a very cumbersome process and can be difficult to handle. Digitization tools can provide several methods to assist and enhance the efficiency and reliability of the communication process and the transfer of data between different organizations (de Barros et al., 2015).

Despite substantial investments in digitization and the evidence of positive effects of the adoption, many organizations are unable to achieve expected improvements in the performance of their supply chains (Fawcett et al., 2011). One reason may be that, organizations may be adopting these tools without considering the enablers for digitization transformation (Schallmo et al., 2017). Consequently, the authors review the mechanisms and enablers through which digitization influences supply chain performance. Therefore, this study aims to address the following objectives:

- To identify the key enablers/practices of digitization transformation for improving supply chain management performance
- To rank the identified key enablers with the help of a suitable MCDM method.

- To evaluate organizations' supply chain performance based on these enablers.

The rest of the manuscript is laid out as follows: the next section discusses supply chain performance and digitization enablers. The third section discusses steps in methodology, and the case analysis and results are presented in the four section., In the fifth section, the results are discussed, and the last section presents implications and future research scope.

2. Literature Review

2.1 Supply Chain Performance

A supply chain can be understood as a network of companies and its various suppliers who come together to form a unified process where raw materials, natural resources, or components are processed into end products and then dispatched to its intended users (Autry et al., 2010). Performance measurement can be defined as the method to quantify the efficiency & effectiveness of any process (Rehman et al., 2018). The level of customer satisfaction is a measure of effectiveness, whereas efficiency is how cost-effective resources of a company are being exploited while achieving a pre-determined satisfaction level of users (Paulraj, 2004).

Globalization of market, escalating competition, and prime focus of organizations to cater to what customers demand are the reasons behind emphasis on effective supply chain management (Gunasekaran et al., 2004). There is a large pool of benefits that can be attributed to better supply chain management, like reduction in costs, an increase of market shares as well as sales, and very strong bonding with the customer (Ferguson, 2000). It can be stated that measurement of performance of the supply chain can assist in the progress of a better understanding of the supply chain network, and can also positively impact the entity's behavior, and advance the overall performance of the supply chains (Paulraj, 2004). The following can be attributed as supply chain performance measures according to (i) Applicability of such measures to the five broad supply chain processes, namely planning, sourcing, making, delivering, and return or customer satisfaction (Neely et al., 1995); (ii) Their ability to measure time, cost, innovation and flexibility, (Schonsleben, 2004), and (iii) Whether they are of qualitative or quantitative nature (Beamon 1999; Chan 2003).

It is imperative to distinguish between non-cost & cost metrics (quality, flexibility, time, and innovation) because depending only upon indicators reflecting cost component, can result in a vague result for the supply chain performance (Paulraj et al., 2004). Measurement of quality & time indicates the capability of a supply chain to provide better customer service, whereas innovativeness & flexibility reflect the capability to handle quick variation in supply or demand. When the agility of the supply chain is considered, innovativeness & flexibility are said to be essential factors of SC development (Morgan, 2004; Lee, 2004). Therefore, the supply chain and organizations performance can be enhanced through the application of digitization and IT tools (Jiang et al., 2020).

2.2 Digitization practices and tools in supply chain

He et al. (2014) stated that digitization tools, notably IoT connects the cyber world and physical world, which may result in a significant change in the business model (Schallmo et al., 2017) as well as everyday life. They proposed a model that can describe the impact of IoT on the various flow of SC like material, capital, and information flow. The model can also help to analyze the carbon footprint generated due to various flow in the supply chains. Witkowski (2016) tried to give some smart solutions which can be identified as a novel idea in both organizational as well as technological area. These solutions, when executed by logistics, can play a key role in the era of globalization. This can not only help to different business entities but also the economy of any country or world economy as a whole. Competition is not only among different companies but also at every stage of the supply chain (Christopher, 2011). Developed countries are developing at a faster pace, which also means that companies must incorporate more and more novel solutions to remain in the competition, which also leads to innovation and progress in the market.

Lai et al. (2018) investigated the factors that determine the intention of organizations to adopt big data analysis in their operations. They classified the potential factors into four main categories namely: organizational, technological, environmental, and Supply Chain characteristics. The result of the analysis indicated that, expected advantages and support of higher authority affect the intention of IT tools adoption in organizations. Also, factors like government policy and adoption of competitor and supply chain connectivity can remarkably moderate the relationship between adoption intention and driving factors. Tu (2018) argued that the Internet of Things provides radical transparency to SCM due to the global network of physical objects. Despite clear gains by adopting the Internet of things, a large number of industries and organizations have still not accepted IoT enabled supply chain and logistic systems. Tu (2018) studied the determining factors affecting the use of IoT in SCM and logistic and identified uncertainties, and intention of the organization to implement the IoT in SCM and logistics. Tu (2018) also did a cost-benefit analysis of implementing IoT technology. The quantitative model showed the possible gains, expected cost, and external pressure as important determinants of intention to accept IoT in logistics and supply chain management.

Ben-Daya et al. (2017) studied various IoT enablers in SCM as well as different applications of IoT in SCM. They found that, most of the studies have been focusing on conceptualization on the effects of IoT with few analytical models or empirical studies. Also, most of the studies on IoT has been confined to the delivery supply chain process or manufacturing or food supply chain. They concluded that, IoT will help to remotely manage the supply chain, help to provide more accurate information, and better coordination among different entities so that effective decisions can be made. Tiwari et al. (2018) pointed out that, data produced from SCM has increased exponentially in recent years. In today's competitive environment, SCM professionals are finding it difficult to handle such a big amount of data. So, to understand and analyze how the data is being produced, captured, and analyzed, these professionals are exploring various and new techniques. Some authors have stated that big data analysis is one of the best solutions for SCM professionals (Schoenherr and Speier-Pero, 2015). Lamba and Singh (2018) identified and analyzed the interaction of different enablers which are very necessary for the adoption of big data analytics in SCM. They selected fourteen enablers of big data analytics in operations and supply chain management. Commitments of top management, financial support, organizational structure, skills related to big data/data science are the most influential enablers. They also underlined the importance of interrelationships among all enablers for the success of big data.

Govindan et al. (2018) have explored big data analytics and the application of supply chain management and logistics by carefully examining new opportunities, methods, and practices. They analyzed a variety of opportunities that can significantly improve big data analytics and its application in supply chain management and logistics. The study identified that, a recent in-depth study of big data analytics has come up with various tools and techniques which can efficiently make data-driven supply chain decisions. Analysis and interpretation of results in real-time can help to make faster and better decisions that can satisfy the needs of customers. The study also pointed out that big data analytics will improve supply chain design and its management by a significant reduction in cost and alleviate the involved risks. Treiblmaier (2018) attempted to determine the potential implications of blockchain technology on SCM by suggesting a framework. The study showed how frequently used theories in supply chain management can also be adapted for blockchain technology. The study further made a recommendation on how blockchain technology can be integrated with the theories widely used in supply chain management and logistics. Manavalan et al. (2018) stated that sustainable SC is inevitable to satisfy the requirements of customers which are aggressively dynamic. It is stated that manufacturing entities should shift their focus towards making use of IoT (Internet of Things) to achieve the goal of the organization. Manavalan et al. (2018) studied various aspects that affect the sustainability of SCs, then these factors were analyzed, and the results were noted. Based on these reviews, a framework for the supply chain entities to adopt the fourth industrial revolution was suggested. This framework is a combination of five important perspectives of SCs namely Technology, Collaboration, Business, Management Strategy, and Sustainable development.

Rajput et al. (2018) identified and analyzed enablers of IoT which are important for the success of Industry4.0. The enablers were identified with the help of available literature and discussions with the industry experts. They found that IoT big data and IoT ecosystems are the most important enablers. Interchangeability, consumer IoT, the robustness of interface of IoT, and network capability were found as the most dependent enablers for industries to adopt Industry 4.0. Luthra et al. (2020) stated that Industry 4.0 can radically improve the business system by completely transforming the way any product is designed, produced, delivered, and rejected. Industry 4.0 is a relatively new idea to developing nations, so a clear definition is very important for adoption in business. They further stated that Industry 4.0 can help business house and manufacturing units to integrate environmental protection to the processes as well as to incorporate process safety actions towards a sustainable supply chain. Their study identified 18 important challenges for developing supply chains to incorporate Industry 4.0. The result depicts that organizational challenges were the topmost challenge followed by technological challenges, strategic challenges, and ethical and legal challenges. Hald et al. (2019) focused on constraining and enabling roles of blockchain technology in work practices to conceptualize performance-technology relations in SCM. They found that, three constraining and four enabling BCT which reveals how the BCT can either improve or degrade the performance of the supply chain. With the help of blockchain technology existing resources and competencies of the supply chain can be better exploited. Traceability of data with the help of BCT is core innovation that provides immutability to the data. But the limitation of this study is that it is conceptual in nature only.

Blossey et al. (2019) stated that blockchain technology has started receiving attention outside its starting region i.e. the financial sector (e.g. cryptocurrencies). Various application of blockchain technology in SCM is being found out both in industries as well as the academic community. Blossey et al. (2019) tried to combine industrial and academic aspects of blockchain technology and supply chain management to summarize the current state of the situation. Blossey et al. (2019) identified five emerging enablers of blockchain technology in supply chain management which can enhance its scope beyond tracing and tracking. Daxböck et al. (2019) in their study concluded that organizations have already started adopting digitization tools for revolutionizing their supply chains and in near future, organizations won't be able to function without digital tools. They further concluded that, digitization of supply chain revolutionizes the way supply chains perform and help them become more responsive, thus enhancing their competitive advantage and performance. Ali et al. (2020) studied the moderating role of digitization technologies between supply chain finance and organizations performance in SMEs. They found out that digitization of supply chain enhances the visibility of financial transactions and thus improve the performance of the organizations in a supply chain. Bag et al. (2020) analyzed the impact of big data analytics as one of the tools of digitization on sustainable supply chain performance. They found that digitization tools like big data analytics significantly improves the learning and innovative performance and also overall performance of sustainable supply chains. Chandak and Kumar (2020) in their research analyzed e-business and sustainability enablers for improving supply chain performance. They found 'development of supply chain web system’ as most critical enabler for enhancing the performance of supply chain thus justifying the adoption of digitization technologies. Luthra et al. (2020) studied the connection between sustainability and Industry 4.0. They identified that manufacturing systems are greatly influenced by IT and its quick advancement. They examined the enablers of Industry 4.0 which can be infused into sustainability on SC. The enablers were finalized by a discussion with the industry experts and then DEMATEL was used to examine the relative strength of enablers as well as relationships among different enablers. Their study further examines the key enablers of Industry 4.0 to achieve ecological, social, and economic gains in supply chains using the case study in India.

2.3 Key digitization tools/enablers for supply chain management

2.3.1 Big Data Analytics

The term big data analytics can be defined as computational analysis that can uncover trends or patterns from a set of large datasets including predictive analytics, statistical analysis, data mining, etc. for the benefit of businesses (Russom, 2011). It is a process of examining and analyzing big datasets with a large variance in its types to draw some useful results by revealing invisible patterns and mathematical inter-relations, and other information valuable for the business so that to enhance gains in business, efficiency enhancement, and exploration of new potential customers and opportunities (Kruschwitz et al., 2013). McAfee and Brynjolfsson (2012) found that “companies in the top three of their industries in the use of data-driven decision making were, on average, 5% more productive and 6% more profitable than their competitors”.

2.3.2 Internet of Things (IoT)

Internet of Things (IoT) is a new IT revolution that has improved supply chain communication by another level. Internet of Things is a network formed by connecting a very large number of things into the internet with the help of wireless communication (Citation). IoT improves visibility, adaptability, and agility to cope with various supply chain management challenges (Santagate et al., 2015). The main enablers of IoT in Supply chain management are Radio Frequency Identification (RFID) and sensors (Bahroun et al., 2019). RFID technology helps in tracking and monitoring of the products by real time scanning of products and sharing of the information through wireless networks (López et al., 2011). Wireless Sensor Networks (WSN) is a network of sensors that can track and monitor live data from different devices (Salam et al., 2016).

2.3.3 Blockchain Technology

Blockchain technology can be defined as "a shared ledger that allows for unchangeable storage of data via a verified transaction" (Pilkington, 2016). *The Economist* stated that blockchain technology can be understood as the 'trust machine' because basically a ledger represents a reliable record of business activity (Economist, 2015). Trust in business relationships is one of the foremost criteria for inter-company SC partnership (Kwon and Suh, 2004). As a consequence, SCM is usually viewed as a major area for the application of Blockchain technology which also has been confirmed by recent articles (See et al., 2017). Most particularly, Maersk and IBM have entered into a joint venture for commercialization of Blockchain technology in the shipping of containers as well as for activities related to global trade (IBM, 2018). Blockchain technology has been hailed as "the most important invention since the internet" (Tapscott and Tapscott, 2016). So, there is an exponential rise in academic as well as practitioner interest in blockchain technology from a supply chain management (SCM) viewpoint (Kshetri, 2018).

2.3.4 Industry 4.0

'Industry 4.0' represents the fourth industrial revolution. Industry 4.0 is one of the most important phrases in the industry. Industry 4.0 expresses an exemplar shift in production technology. The shift indicates that focus is on product, its tracing and its production requirements. The product is monitored through cyber physical systems, that track its progress through various stages in production and also guides as to where the product needs to be shipped. This shift empowers processes so that there can be mass customization of products, production can be taken to service level, and feedback can be received from products in the market (Valdez et al., 2015). Because of an increase in digital processes and very high growth of sensible data, SC is set to be impacted by the Industry 4.0 revolution. A better and transparent understanding of available technologies as well as current concepts are required for the strategic management of the supply chains. Since the supply is set to go through an organizational change due to the ever-expanding digital world, a theoretical framework is very important to understand which activity is going to be impacted and how Industry 4.0 technologies can improve the supply chains (Vogel-Heuser, 2014).

3. Methodology

The Best-Worst Methodology (BWM) has been used in this study to analyze and rank the key digitization enablers/practices that can improve supply chain management performance. The BWM developed by Rezaei (2015,2016) is very widely used multi criteria decision analysis technique due to its advantage of more consistent results and lesser pairwise data requirements. BWM requires lesser pairwise comparisons than AHP or other ranking techniques, thus requiring considerably lesser time and resources for getting the desired results, that's why it is preferred over them. The recent applications of BWM includes Nawaz et al., 2018 (cloud service selection); van de Kaa et al., 2018 (standard dominance success factors); Wang and Jin, 2019 (project financing risk); Ecer and Pamucar, 2020 (sustainable supplier selection); Kusi-Sarpong et al., 2019 and Gupta et al., 2020 (sustainability innovation and barriers); Kujlu et al., 2020 (solidification method for oil treatment); Palanisamy et al., 2020 (additive manufacturing machine selection).

3.1 Steps in BWM

Step 1: Identification of criteria through literature review and expert opinion.

Step 2: Next step is to select the best (B) criteria and also worst (W) criteria among the finalized set of criteria.

Step 3: The experts are asked to rate best to other criteria on a scale of 1 to 9. The ratings will be obtained in the form a resultant vector $A_B = (a_{B1}, a_{B2}, \dots a_{Bn})$.

Step 4: Further, experts are also asked to rate others to worst criteria and the resultant vector in this case will be vector $A_w = (a_{1w}, a_{2w}, \dots a_{nw})^T$.

Step 5: The last step is to obtain the ranking through optimized weights. Model (2) mentioned below is used to obtain optimized weights (w_1*, w_2*, …….,w_n*) for all the criteria.

Here the aim is to minimize the maximum absolute difference as mentioned here for all j {$|w_B - a_{Bj}w_j|$, $|w_j - a_{jW}w_W|$}. The following minimax model will be obtained:

min max $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$,

s.t.$\sum_j w_j = 1$,

$w_j \geq 0$, for all . (1)

Model (1) is transformed to a linear model and is shown as:

minξ^L,

s.t.

$|w_B - a_{Bj}w_j| \leq \xi^{L^*}$, for all j,

$|w_j - a_{jW}w_W| \leq \xi^{L^*}$, for all j,

$\sum_j w_j = 1$,

$w_j \geq 0$, for all j. (2)

Model (2) can be solved to obtain optimal weights $(w_1^*, w_2^*, \dots \dots . w_n^*)$ and optimal value ξ^{L^*}.

Consistency (ξ^{L^*}) of attribute comparisons close to "0" is desired (Rezaei, 2016).

Next phase of the analysis involves, obtaining the ranks of alternatives. The additive value function mentioned in equation (3) is used for the same.

$$V_i = \sum_{j=1}^{n} w_j u_{ij} \quad (3)$$

Here u_{ij} is the normalized score of alternatives which can be obtained using equations (4) and (5), where equation (4) is used for benefit criteria and equation (5) is used for cost criteria.

$$u_{ij} = \frac{x_{ij}}{\sum_j x_{ij}} \quad \text{for all j} \quad (4)$$

$$u_{ij} = \frac{\frac{1}{x_{ij}}}{\sum_j \frac{1}{x_{ij}}} \quad \text{for all } j \quad (5)$$

Where, x_{ij} is the actual score of alternative i in criterion j.

4. Case analysis and results

4.1 Case explanation and experts background

This study involved nine experts from both industry and academia for the purpose of achieving research objectives. The experts involved were mainly working in the area of digitization, IT implementation in organizations and their supply chains. All the experts involved in the study have at least ten years of experience in the field. The details of the nine experts involved in the study are mentioned in Table 1.

Table 1 Expert information and background

Expert	Designation/Expertise	Experience (Years)	Qualification	Department/Organization
Expert 1	Deputy Manager	13	B.Tech.	Materials Management
Expert 2	Associate General Manager	17	MBA	Supply Chain
Expert 3	Manager	11	MBA	Procurement Management
Expert 4	Senior Manager	16	B.Tech.	Vendor Development
Expert 5	Senior Manager	13	MBA	Supply Chain Management
Expert 6	Manager	12	B.Tech.	Supply Chain and Procurement
Expert 7	Senior Manager	14	MBA	Production Planning
Expert 8	Professor	15	Ph.D.	University
Expert 9	Professor	19	Ph.D.	University

4.2 Digitization enablers/practices identification

In this phase, the practices/enablers of digitization of supply chains for performance improvement were identified through literature review. First the main categories of enablers were identified and then the sub- category enablers were further identified through literature review. A total of twenty- five sub- category enablers were finally identified under these four categories and were presented to experts for validation and for any possible addition or deletion. All the sub- category enablers were finalized by the experts. These are presented in Table 2.

Table 2 Digitization enablers for supply chain performance improvement

Main category enablers	Sub- category enablers	Description	Supporting Literature
Big Data Analytics (BDA)	Big data quality management (BDA1)	Data being used must be of good quality, complete and should also be reliable	Hazen et al., 2014 ; Batini et al., 2009
	Data capturing and storage (BDA2)	Smart filters are required so that useful information can be separated from inconsistent and ambiguous data	Sivarajah et al., 2017; Khayer et al., 2020
	Data security and privacy (BDA3)	Privacy of data is needed to be maintained	Mengke, 2016
	Data and information technology Integration (BDA4)	This refers to collecting data at each and every process in supply chain network and integrating the data for better utilization	Asri, 2015
	Top management commitment and Change Management Program (BDA5)	People who understand the root problem should be employed by the top management	Lamba and Singh, 2018
	Big data/data science skills (BDA6)	Organizations need to have trained people in big data skills so that these technologies can be implemented easily within the network	Davenport and Patil, 2012
	Appropriate and feasibility study for aiding the selection and adoption of big data techniques (BDA7)	Big data tools are expensive and may not be even appropriate in the context of the organization. A feasibility study should be done before the implementation of big data.	Lamba and Singh, 2018 Auschitzky et al., 2014 Sivarajah et al 2017
Internet of Things (IOT)	Big data supported manufacturing and industrial systems (IOT1)	The adoption of IoT will enhance productivity and decrease downtime of the manufacturing facility. Big data helps to improve the industrial systems by gaining insights from data generated.	Wang et al., 2015 ; Voss et al., 2017 ; Lim et al., 2020
	Cloud-centric IoT for Logistics and manufacturing systems (IOT2)	Cloud and Internet of Things fuse with information systems easily. It can be used in logistics as well as in the automobile industry. It gives rise to the machine to machine interaction leading to an intelligent system and cloud manufacturing.	Botta et al., 2014 ; Tao et al., 2014; Khayer et al., 2020
	Enterprise modeling (Manufacturing) (IOT3)	Internet of Things (IoT) has helped Enterprise System to be developed as a modern manufacturing system consisting of live data that has been collected from different processes and machines.	Bi et al., 2014; Lim et al., 2020

	Radio Frequency Identification (RFID) (IOT4)	With help from RFID it is easy to track and transfer data via a wireless network.	López et al. 2011
	Wireless Sensor Network (IOT5)	It is a network of sensors which can track and monitor live data from various devices	Rayes and Salam, 2017
Blockchain Technology (BCT)	Transparency and visibility (BCT1)	Blockchain permits peer to peer transfer of live data with each transaction forming a new block which can be stored thus, providing high transparency and visibility	Babich and Hilary, 2018
	Validation (BCT2)	The perpetuation of transaction details as well as verification and validation of data	Christidis and Devetsikiotis, 2016
	Automation (BCT3)	On the basis of available information, smart contracts can be executed	Chen, 2018
	Integrity (BCT4)	Resources and assets can be tracked from their origin. With the help of this, fraudulent transactions can easily be detected	Babich and Hilary, 2018
	Orchestration (BCT5)	A supply chain can be made to operate as highly automated based on pre-specified rules by the unification of transparency & automation	Diedrich and Ethereum, 2016
	Virtualization (BCT6)	Physical systems can be recreated into logical software for their better utilization and flexibility in usage	Laudon and Laudon, 2017
	Exploration technology (BCT7)	Innovations & restructuring is possible in the supply chain by implementing blockchain tools	Kewell et al., 2017; Anderson, 2018
Industry 4.0 (IDY)	E-Supply Chain Management (IDY1)	Use of technologies like E-business; Extranet; Web portal for digitization of supply chain	Cheng et al., 2010
	Tracking and Localization of products (IDY2)	Tracking of the products throughout the supply chain network using Geographical Information Systems (GIS) RFID technologies	Young et al., 2010
	Building Information Modeling (BIM) (IDY3)	This refers to monitoring the activities of supply chain network though building of information integration decision support system	London and Singh, 2013
	Additive manufacturing and 3D Printing (IDY4)	3D printing helps to improve the process which includes a reduction in lead times	Kothman and Faber, 2016

		and unification of functions and permits reduction in the usage of material.	
	Improved information transfer, resource development, and better cost-efficiency (IDY5)	A better system for easier transfer of information and development of resources are important members of the supply chain during the adoption of Industry 4.0	Wan et al. 2016; Tavana et al., 2016
	Implementation of innovative business models (IDY6)	Industries are required to improve themselves. Innovations concerning processes and implementation of innovative models to achieve global demand.	Stock and Seliger, 2016; Gottge et al., 2020

4.3 Ranking of digitization enablers

In order to improve the supply chain performance with the help of digitization and information technology (IT) implementation, first enablers were identified and finalized with the help of available research and discussions with the experts. In the next step, BWM is used to obtain priority ranks of these enablers. Nine experts were requested to identify the most desirable (best) enabler and least desirable (worst) criteria among main category as well as sub-category enablers. The best and worst enablers recognized by experts for main category are presented in Table 3 and table 4 respectively.

After each expert identified the best and worst enablers, they were requested to give preference order of 'best to others' and 'other to worst' enablers for main category enablers as well as sub-categories enablers. The preference rating for the sub-categories by all the experts has been shown in Tables A1-A8. (Supplementary File).

Table 3 Responses from experts for the best to others for the main category enablers

Respondents	**Best criteria**	**Big Data Analytics (BDA)**	**Internet of Things (IOT)**	**Blockchain Technology (BCT)**	**Industry 4.0 (IDY)**
Respondent 1	IDY	8	6	3	1
Respondent 2	BCT	5	8	1	3
Respondent 3	BDA	1	9	5	4
Respondent 4	BDA	1	6	8	3
Respondent 5	IDY	3	8	5	1
Respondent 6	BDA	1	6	3	9

Respondent 7	BDA	1	9	4	6
Respondent 8	IDY	8	6	3	1
Respondent 9	BDA	1	9	4	3

Table 4 Responses from experts for others to worst for the main criteria

Respondents	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**	**Expert 6**	**Expert 7**	**Expert 8**	**Expert 9**
Worst criteria	BDA	IOT	IOT	BCT	IOT	IDY	IOT	BDA	IOT
Big Data Analytics (BDA)	1	2	9	9	4	9	9	1	9
Internet of Things (IOT)	3	1	1	2	1	2	1	2	1
Blockchain Technology (BCT)	4	8	3	1	2	4	2	3	3
Industry 4.0 (IDY)	8	4	4	5	8	1	2	8	3

After obtaining the ratings for all main category enablers as well as for the sub-categories, the next step of BWM is to obtain the weights of all the enablers using equation (2). A simple average was then used to calculate the overall weights and ranks obtained on the basis of the average sum obtained from the data provided by the nine experts. The rank of all the main category enablers as well as of sub-categories along with their weights has been shown in Table 5.

Table 5 Analysis of weights of enablers

Main Category	**Weight of Main Category**	**Sub-Categories**	**Weight of sub-categories**	**Global Weights**	**Ranks**
Big Data Analytics (BDA)	0.394	BDA1	0.108	0.043	10
		BDA2	0.081	0.032	13
		BDA3	0.056	0.022	18
		BDA4	0.144	0.057	7
		BDA5	0.135	0.053	8
		BDA6	0.291	0.115	1

		BDA7	0.185	0.073	3
Internet of Things (IOT)	0.085	IOT1	0.292	0.025	17
		IOT2	0.392	0.034	12
		IOT3	0.133	0.011	23
		IOT4	0.107	0.009	24
		IOT5	0.075	0.006	25
Blockchain Technology (BCT)	0.211	BCT1	0.328	0.069	4
		BCT2	0.130	0.027	16
		BCT3	0.143	0.030	14
		BCT4	0.192	0.041	11
		BCT5	0.066	0.014	21
		BCT6	0.063	0.013	22
		BCT7	0.076	0.016	20
Industry 4.0 (IDY)	0.310	IDY1	0.203	0.063	6
		IDY2	0.304	0.094	2
		IDY3	0.091	0.028	15
		IDY4	0.144	0.045	9
		IDY5	0.206	0.064	5
		IDY6	0.054	0.017	19

Once the criteria weights are obtained, next step is obtaining the ranks of organizations based on their supply chain performance due to digitization of supply chains. The equation (3) is used to obtain the ranks of organizations. This step uses the normalized score obtained using equation (4). Five organizations were chosen for the analysis, all the nine experts were asked to rank the supply chain performance of these organizations with respect to digitization enablers. The average response matrix of all the nine experts is presented in Table 6. The response of all the nine experts is presented in Tables B1 – B9 (Supplementary File).

Table 6 Average responses of nine experts for ranking of supply chain performance

	BDA1	BDA2	BDA3	BDA4	BDA5	BDA6	BDA7	IOT1	IOT2	IOT3	IOT4	IOT5	BCT1	BCT2	BCT3	BCT4	BCT5	BCT6	BCT7	IDY1	IDY2	IDY3	IDY4	IDY5	IDY6
ORG1	5.444	6.222	4.000	4.222	5.333	5.111	6.000	5.333	5.000	6.111	5.222	5.667	4.778	5.111	5.333	6.111	6.556	5.444	6.778	5.556	3.778	3.556	4.778	4.556	5.222
ORG2	5.444	4.667	6.000	3.222	5.222	5.556	5.444	5.889	4.889	4.667	5.889	5.111	4.000	6.667	6.111	5.444	4.778	4.111	4.444	6.556	4.667	7.333	5.556	4.333	5.444

ORG3	5.778	6.667	6.444	6.333	4.778	5.000	4.333	5.444	6.667	3.333	5.444	5.556	4.778	5.000	5.000	5.778	6.667	5.556	5.778	4.556	5.111	7.111	4.444	6.000	5.333
ORG4	5.667	5.444	4.444	6.000	5.556	6.556	5.111	6.000	4.333	4.889	5.778	6.222	6.556	4.778	4.222	5.556	4.889	5.778	5.778	5.556	5.889	5.889	5.444	5.000	4.444
ORG5	6.222	5.556	4.333	6.111	8.111	5.778	5.778	6.000	5.778	4.778	5.000	6.778	5.444	4.667	5.556	5.444	6.222	4.556	6.778	4.889	7.333	5.333	6.000	6.556	5.556

The final ranking of the organizations is presented in Table 7.

Table 7 Ranking of organizations

Organizations	V_i	Ranking
ORG1	0.187	5
ORG2	0.191	4
ORG3	0.197	3
ORG4	0.206	2
ORG5	0.220	1

The results indicate that based on the digitization initiatives, organizations 5 has best supply chain performance followed by ORG4 and ORG3.

5. Findings

The study identified and ranked the key digitization enablers for supply chain performance improvement. The identified enablers were analyzed using BWM with the inputs from industry experts. It is found that 'Big Data Analytics' is the most important enabler among the four key enablers identified namely Big Data Analytics, Internet of Things, Blockchain Technology, and Industry 4.0. 'Industry 4.0' is the second most perceived important main category enabler after Big Data Analytics, which is then followed by 'Blockchain Technology'. In case of global ranking (see Table 5), 'Big data/data science skills (BDA6)', 'Tracking and Localization (IDY2)' using Industry 4.0 and 'Appropriate and feasibility study for aiding the selection and adoption of big data technologies and techniques (BDA7)' are found to be the top three digitization enablers for improvement in supply chain management performance.

'Big Data Analytics' (BDA) emerged as the most important digitization tool for enhancing supply chain performance. Different past researches have also revealed the gains of adopting big data analytics in logistics and SCM. The biggest problem for SCM professionals these days is how to deal with the very large volume of data as well as its variety and velocity, to leverage it for predictive analysis. Predictive analysis is the use of both qualitative as well as quantitative methods for improvement in supply chain design and competitiveness (Waller and Fawcett, 2013). While the majority of companies have started experimenting with big data methods, its application is at the early stages of what the potential it carries. The requirement of a well-qualified and trained data scientist is also highlighted (Dwoskin, 2014). BDA is found to be impacting supply chain in various areas in many past studies which includes, strategic sourcing (Panchmatia, 2015); network design of SC (Wang et al., 2018); product design and development (Jin, et al., 2016); demand Planning (Chase, 2013); procurement (Wang et al., 2016); production (Zhong, et al. 2014; inventory (Wang et al., 2016); logistics and distribution (Ayed et al., 2015; Brouer et al., 2016); sustainability and agility of SC (Zhao et al., 2017).

Second rank among main criteria is obtained by ‘Industry 4.0’, which is regarded as an exemplar shift in production technology. It seeks the transfer of attention and accountability from the production process to the product. Digitization with the help of computers & mass production helps in effectively managing supply chains. Industry 4.0 visions a global network of machines that are capable of automatically share information and can control each other (Tjahjono, et al., 2017). The adoption of Industry 4.0 tools in the manufacturing process has also led to a significant change in the whole supply chain. The most important benefits include the gain in flexibility, productivity, quality standards, and efficiency. The most affected areas when Industry 4.0 is implemented in the supply chain will be order fulfillment and transport logistics thus increasing overall efficiency and performance (Tjahjono et al., 2017).

Third among main criteria is ‘Blockchain Technology’ (BCT). The BCT is a tool used in reliable transactions and improving the traceability of the products. The logistics and supply chain industry can benefit immensely with the adoption of BCT as often many products are lost due to non-sharing of data among supply chain partners and lack of tracing (Babich and Hilary, 2018; Kshetri, 2018).

Among sub-criteria, ‘Big data/data science skills (BDA6)’ is ranked first, qualified data scientists are the key to the successful reaping of the benefits of big data analysis. The supply chain industry is facing a severe shortage of experts who are competent for big data analytic jobs (Davenport and Patil, 2012). People with greater skill set in data analysis can help achieving the full benefits of big data methods in operations and supply chain management. Second among sub-criteria is ‘Tracking and Localization (IDY2)’, an automatic system, which unifies RFID (Radio Frequency Identification) with GPS (Global Positioning System) with the help from the Geographical Information System, can trace resources easily. This can stamp out the labor-intensive collection of data. Also, this will eliminate the limitation of line-of-sight with respect to distance. Geographical Information System maps show the position of resources through the supply chain (Irizarry et al., 2013). Third among sub criteria is ‘Appropriate selection of big data techniques. Feasibility study for big data adoption (BDA7)’, numerous tools and technologies of big data analytics are not only expensive but might not be even suitable in the context of a particular organization. The feasibility study should be done before the implementation of big data analysis. So, it is necessary to first find out the requirement and prospects of big data analysis in the organization before taking big data initiatives (Sivarajah et al., 2017). Next ranked is ‘Transparency and visibility (BCT1)’, one of the major issues of the supply chain network and logistics sector is the exact information of products at various stages in the network. The digitization of supply chain network using BCT greatly enhances the tracking and visibility of product movement in network, thus reducing wastages and effective management (Babich and Hilary, 2018).

6. Final Remarks, Implications and Limitations

6.1 Final Remarks

Digitization is having remarkable effects on how organizations and people associated with them communicate in their network. With digitization of the supply chains the whole supply chain network has undergone a rapid change. Tracking and locating of the products is easier now leading to lower wastages and losses. All the supply chain partners are having access to all the data thus making supply chain more efficient with just in time delivery of right quantity of products at each stage in the supply chain network. This study analyzed and ranked supply chain digitization enablers. Industry 4.0 practices and Big Data Analytics emerged as most important enablers for digitization of supply chain for performance improvement. More prevalent are recruiting people with necessary skills related to digitization and specifically for big data analytics so that successful digitization of whole network can be done to enhance supply chain performance. Other important enabler that emerged is use of RFID and associated technologies with each product so that products can be tracked and located easily by supply chain channel partners.

6.2 Managerial and practical implications

This study is an expansion of the available literature on IT enablers for the improvement of SCM. The study has many managerial and practical implications for supply chain professionals, decision-makers of manufacturing organizations as well as for academicians. This study has identified 25 major IT enablers which will improve the supply chain management after their proper implementation. In addition to this, the ranking of these enablers has also been done with the help of inputs of experts from both industry and academia. As competition in the market is growing exponentially, the use of IT enablers is also gaining prominence in the supply chains. Findings from this study can be helpful in the decision-making process by the top management. The focus of managers and decision-makers should be on the top-ranked 'digitization and IT' enablers so as to achieve the most potential gains. Decision-makers of supply chain and logistic firms should target tracking of these top-ranked IT enablers and make sure that there are adequate mechanisms for proper implementation. Managers can attain better supply chain performance by implementing and integrating 'big data analytics' and 'Industry 4.0' technologies throughout their supply chain. Big data analytics capabilities have revolutionized how organizations work and communicate, these technologies help organizations to hand and process large amount of data thus giving a better overview of the working and flow in the supply chain. Managers and organizations can adopt big data analytics technologies to revolutionize their business and enhance their performance by saving on various resources. Industry 4.0 technologies also has capabilities to substantially enhance the performance of the supply chain by allowing better tracking and monitoring of all the products produced in the organization. As the study suggests that skills related to big data analytics is one of the most important enablers of digitization, managers and organizations can arrange special training and workshop programs to train their workforce in the adoption of IT enablers in their organizations. They can implement technologies for enhancing their tracking capabilities of products and thus can improve the supply chain performance. The policymakers and government agencies can also benefit from this study, as they can gain insight into the key areas to focus on for the betterment of the businesses in the country. Key areas to focus on for policy makers is building capabilities for training and skill development of workforce to make them future ready for adoption of digitization technologies and also focus on technological capabilities through more funding and emphasis on digitization technologies.

6.3 Limitations and future research scope

The study has certain limitations which can be addressed in future studies. As the study has been done based on the judgment of supply chain and logistics experts, the outcome of the study might be biased as they are based on the comprehension of the experts. Also, the results have not been statistically validated. In the study MCDM technique (Best-Worst Method) has been used to evaluate and rank the digitization enablers, future studies can include other methodologies like structural equation modeling (SEM) so that statistical validation of these digitization enablers can be done. The future studies can also include larger pool of experts from different set of organizations and apply Bayesian BWM for probabilistic validation of results.

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