Computers & Industrial Engineering 177 (2023) 109055

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Modeling the artificial intelligence-based imperatives of industry 5.0 towards resilient supply chains: A post-COVID-19 pandemic perspective

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A R T I C L E I N F O

Keywords:
Post-COVID-19 pandemic
Supply chain resilience
Artificial intelligence
Industry 5.0
Bayesian Best-Worst Method

A B S T R A C T

The recent COVID-19 pandemic has significantly affected emerging economies' global supply chains (SCs) by disrupting their manufacturing activities. To ensure business survivability during the current and post-COVID-19 era, it is crucial to adopt artificial intelligence (AI) technologies to renovate traditional manufacturing activities. The fifth industrial revolution, Industry 5.0 (I5.0), and artificial intelligence (AI) offer the overwhelming potential to build an inclusive digital future by ensuring supply chain (SC) resiliency and sustainability. Accordingly, this research aims to identify, assess, and prioritize the AI-based imperatives of I5.0 to improve SC resiliency. An integrated and intelligent approach consisting of Pareto analysis, the Bayesian approach, and the Best-Worst Method (BWM) was developed to fulfill the objectives. Based on the literature review and expert opinions, nine AI-based imperatives were identified and analyzed using Bayesian-BWM to evaluate their potential applicability. The findings reveal that real-time tracking of SC activities using the Internet of Things (IoT) is the most crucial AI-based imperative to improving a manufacturing SC's survivability. The research insights can assist industry leaders, practitioners, and relevant stakeholders in dealing with the impacts of large-scale SC disruptions in the post-COVID-19 era.

1. Introduction

The COVID-19 pandemic imposed several risks and challenges on the SCs over the globe at a large scale and brought the global market to a near standstill (Harjoto & Rossi, 2021; Varriale, Cammarano, Michelino, & Caputo, 2021; Orji & Ojadi, 2021). Undoubtedly, this pandemic is the most devastating disruption, which has caused a toll of death, pushed millions of people into extreme poverty, and depressed the income level for an uncertain period (Moosavi & Hosseini, 2021; Rahman, Taghikhah, Paul, Shukla, & Agarwal, 2021; Moktadir et al., 2022). Now, it is not only a global pandemic and public health crisis but also has depressed global economic activities and financial markets, both in emerging and developed economies.

The challenges faced by developing and emerging economies to deal with damages and disruptions caused by the COVID-19 pandemic, are really different and more acute from those in the developed countries. A huge population characterizes the lack of advanced AI technologies for businesses and broken healthcare systems (Bretas & Alon, 2020; Spieske & Birkel, 2021). Many developed countries have adapted to the new COVID normal, embracing resilient and advanced technologies to mitigate such uncertainties. However, emerging economies face many challenges in continuing their business operations. The uncertain business environment, international travel restrictions, the government imposed tight lockdowns, the shutdown of production plants, and the lack of available advanced AI technologies have accelerated the impacts of disruptions in SCs. Among many sectors, this pandemic has severely stricken the apparel and footwear sectors of emerging economies from multiple directions. Due to the COVID-19 pandemic, foreign buyers canceled nearly US$ 2.9 billion, the value of more than 900 million quantities of Bangladeshi garment products. Consequently, it has led to the suffering of almost 2.27 million workers (Majumdar, Shaw, & Sinha, 2020). Only during the first phase of the COVID-19 pandemic, over US$ 316 million worth of orders been canceled for the footwear industry in Bangladesh (Moktadir et al., 2021).

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https://doi.org/10.1016/j.cie.2023.109055

Available online 31 January 2023

There is no doubt that this pandemic has shown how vulnerable the modern SCs are and, at the same time, increased their strategic importance. This crisis has provided organizations an opportunity to prepare contingency plans for mitigating future uncertainties and improve the resiliency of modern SCs for survivability in the post-COVID-19 era. Amid challenges caused by COVID-19, the positive side of this pandemic is that it has proved that the conventional strategies for SC resiliency are not adequate to tackle disruptions and enable companies to bounce back to the normal state of operations (Chowdhury, Paul, Kaisar, & Moktadir, 2021; Ivanov & Dolgui, 2020; Wu & Olson, 2020). Around 73% of SC professionals have already planned a major transformation toward long-standing resiliency in their chains (Knut, Azcue, & Barribal, 2020).

To enhance the resiliency and sustainability of SC and manufacturing operations, it is important to adopt advanced technologies offered by the fifth-generation industrial revolution (I5.0) (Sharma et al., 2021; Dash Wu, 2020). The AI-based imperatives of I5.0, such as cyber-physical production systems, automation, internet of things (IoT), blockchain technologies, etc., collaborated with human intelligence and profoundly impacted unlocking new possibilities and mitigating future challenges imposed by the COVID-19 pandemic. The idea of I5.0 is still in the embryonic phase. The applications of AI-based imperatives in the context of I5.0 in supply chain management are almost unexplored. Recently, a review of I5.0 and SC has revealed a considerable research gap in this domain that requires further investigation (Frederico, 2021). The advanced AI technologies have the capabilities to ensure more sustainable ways of production, facilitate smarter planning and efficient warehouse management by reducing human error, ensuring timely, and enhancing maximum utilization of resources. Although these AI technologies have charming features to build resilient SCs, they still need more consideration and a rigorous valuation model for analyzing these technologies (Acioli, Scavarda, & Reis, 2021). Again, many developed countries are now approaching I5.0 adoption to make their SCs more resilient. However, companies in emerging economies are trying to apply industry 4.0 technologies to expand their SCs where the human-machine interaction is missing. In this regard, there is a timely purpose of developing a hybrid approach to explaining how AI technologies can establish resilient SCs for companies in emerging economies.

To fill up the research gaps, this study explores the following research questions (RQs):

RQ 1: What are the essential imperatives of I5.0 from the perspective of emerging economies' SCs towards incorporating AI technologies?
RQ 2: How can these AI-based imperatives be evaluated to increase the resiliency of emerging economies' SCs in the post-COVID-19 era?
RQ 3: How can assessing these AI-based imperatives help relevant stakeholders and policymakers implement I5.0 properly?

Exploring the RQs mentioned above, this study intends to sort out, evaluate, and measure the degree of importance of the AI-based imperatives of I5.0 by integrating Pareto analysis, the Bayesian approach, and BWM to ensure the resiliency of the SCs. Firstly, the list of AI-based imperatives was identified to establish resilient SC by reviewing previous literature and relevant reports. Then, experts from Bangladeshi SC disciplines were interviewed to finalize the list of AI-based imperatives.

Further, Pareto analysis was performed to identify the essential AI technologies based on imperatives. Finally, an innovative probabilistic group decision-making approach, Bayesian-BWM (B-BWM), was used to evaluate the priority weights of the imperatives. The conventional BWM provides the optimal weights of any variable of interest incorporating only one experts' preference. While dealing with multiple experts, it fails to calculate the aggregated weights. The B-BWM outperforms the conventional BWM by calculating the aggregated weights of variables from the probabilistic view (Rezaei, 2015). Moreover, due to having many advantages such as easy calculation, less time, and effort, Pareto analysis was considered to reduce the dimensions of the most significant AI-based imperatives. The Pareto-based B-BWM approach is novel and more powerful in decision analysis. To the best of our knowledge, this type of integration has not been explored yet in I5.0 and SC resiliency. It is expected that the integrated method, Pareto-based B-BWM, has made the study unique and more interactive and a new contribution to the literature.

This research has several contributions to the literature. First, it connects AI-based imperatives of I5.0, SC resiliency, and the daunting effects of the COVID-19 pandemic. This type of integration in SC resiliency has not been suggested or explored yet. Another contribution is the integrated Pareto-based B-BWM method to sort out, evaluate, and analyze the AI-based imperatives of I5.0 for establishing a resilient SC. The findings of the research have the potential to guide supply chain decision-makers in shaping strategic decisions amid the COVID-19 pandemic.

To complete the research, this paper is distributed into seven sections. Section 2 presents a brief literature review on SC resiliency, the fifth-generation industrial revolution, and AI-based imperatives of I5.0 for establishing resiliency. Section 3 portrays the proposed research methodology. Section 4 outlines the implementation of the B-BWM. Section 5 presents a discussion of the findings. In Section 6, the implications of the proposed approach are presented. Finally, Section 7 provides the conclusion, limitations of the study and scope for future avenues.

2. Literature review

The devastating impacts of COVID-19 extant had a rampant effect on the global SCs. SCs of emerging economies faced higher challenges. The closure of many farms reminds the necessity of moving from traditional manufacturing processes to the more advanced process with digitization, artificial intelligence, and security advantages aspects of I5.0. Industry 4.0 technologies provide a new world of possibilities for supply chains to efficiently manufacture, deliver, cooperate, and communicate using the least resources possible. This has caused a massive change in today's SCs (Dolgui, Ivanov, Sethi, & Sokolov, 2019; Cheramin, Saha, Cheng, Paul, & Jin, 2021). Today, we are on the threshold of the Fifth Industrial Revolution, known as Industry 5.0, which began in the second decade of the twenty-first century. Unlike I4.0 practices, where the technologies have little or almost no involvement of humans, the I5.0 phenomenon brings human participation back with the technologies to ensure a high level of personalization and increased collaboration. Increasing the interactions between humans, machines, processes, and systems across the SC ensures trust among the stakeholders in delivering data (Cao et al., 2021). With the advantages of different disruptive technologies, human creativity, and robotic precision, the I5.0 offers a more collaborative approach for transitioning to sustainable, human-centric, and resilient production.

As its technologies are quickly adopted and have a favorable influence on every industry, Industry 4.0 has recently become the paradigm for applications. Though these advancements prioritize machines above people, they are still unable to produce the intended results and have disregarded the environment.

2.1. Industry 5.0 and supply chain resilience

The I5.0 appears to be a promising approach for establishing and fostering resilient supply chains. Unlike I4.0 technologies, this initiative has not ignored the environment by highlighting machines over humans. Instead, by effectively integrating human values with disruptive technologies, I5.0 aims to develop a resilient, human-centric SC capable of risk identification, analysis, and accelerated operations to minimize demand variations (Modgil, Gupta, Stekelorum, & Laguir, 2021). Human-machine interaction and collaboration were stressed in I5.0 by adding the missing components of Industry 4.0 – the participation of human intelligence required to create a more customized production environment (Xu et al., 2021). As a result, I5.0 offers the most

Table 1
List of AI-based imperatives of I5.0 toward SC resiliency.

Notation	AI-based imperatives	Description	References
I1	Production flexibility through automation integration	Due to COVID-19′s impact on shifting consumer preferences, emerging markets must include automation to increase industrial flexibility. During the COVID-19 pandemic, the production system's incorporation of automation will allow flexibility in response to changing market conditions.	(Fragapane, Ivanov, Peron, Sgarbossa, & Strandhagen, 2020)
I2	Optimization of SC activities using cloud technologies	During COVID-19, SC activities of emerging markets have been severely disrupted where labor is associated as an important variable. Adopting cloud technologies will help optimize SC activities by connecting the stakeholders.	(Manuel Maqueira, Moyano-Fuentes, & Bruque, 2019)
I3	Decentralization of production system using additive manufacturing	Emerging markets have imposed restrictions and regulations on transportation and movement during the COVID-19 pandemic, eventually affecting the SC. Adopting additive manufacturing supported by industry 5.0 technologies will assist in decentralizing the production system quickly.	(Kurpjuweit, Schmidt, Klöckner, & Wagner, 2021; Liu et al., 2021)
I4	Use of cyber-physical production system (CPPS)	Smooth manufacturing is ensured by CPPS, which has greater operational performance. As a result, this can aid emerging markets in increasing SC sustainability.	(Andronie et al., 2021)
I5	Optimization of warehouse activities using augmented reality	During COVID-19, efficient warehouse management has become a concern for managers in emerging markets. Augmented reality can help plan the optimal warehouse layout and efficiently manage the inventory.	(Rejeb, Keogh, Wamba, & Treiblmaier, 2020)
I6	Cyber immunity for data management	Cyber immunity will help reduce risks and vulnerability during COVID-19.	(Chen, Ramanathan, & Alazab, 2021)
I7	Boosting employee safety and operational continuity through AI	This advanced technology enables remote work and collaboration and maintains self-distinction by eliminating the need for non-critical workers to leave home. Therefore, this will help emerging markets continue operations during the COVID-19 pandemic, ensuring workers' safety.	(Li, Yin, Qiu, & Bai, 2021)
I8	Application of big data and predictive analytics	During the COVID-19 pandemic, SC activities in emerging markets have been disrupted severely. Big data analytics can help in inventory predictions, order fulfillment and real-time tracking, and machine maintenance	(Raut, Yadav, Cheikhrouhou, Narwane, & Narkhede, 2021)
I9	Application of robotics in logistics service	This makes the SC more autonomous and secure. Automated machines and robots ensure safety and improve productivity with almost no human involvement, which is an urgent necessity for managing the impact of the COVID-19 pandemic.	(Attaran, 2020)
I10	Vertical networking and horizontal integration of smart production systems	Vertical networking uses the cyber-physical production system and enables manufacturing plants to react rapidly to changes in demand. This may help to reduce the impact of the COVID-19 pandemic.	(Jamrus, Wang, & Chien, 2020)
I11	Inventory control using RFID	As the market fluctuates unexpectedly during COVID-19, effective inventory control is imperative for emerging markets to ensure SC sustainability. Radiofrequency identification (RFID) can help in real-time inventory control.	(Atkins, Sener, & Russo, 2021)
I12	Real-time tracking of SC activities using IoT	Real-time tracking of SC activities became imperative during COVID-19. It helps to improve data accuracy and demand forecast, collection of data without physical interference, and up-to-the-minute inventory tracking.	(de Vass, Shee, & Miah, 2020)
I13	Application of machine learning in	Machine learning minimizes disruption uncertainties in	(UsugaCadavid, Lamouri, Grabot,

(continued on next page)

significant potential for strategic supply chain optimization and resilience (Fatima et al., 2022).

Over the past few years, scholars and professionals have investigated the missing link between the I4.0 and SC resilience strategies (Saniuk et al., 2022). Thus, some of their findings have identified that the absence of human intelligence is one reason for failing to make the SC resilient, whereas the I5.0 approach can fill this gap (Oliveira-Dias et al., 2022). Belhadi, Kamble, FossoWamba, and Queiroz (2021) stated that AI-based imperatives of I5.0 and machine learning data are curial to promoting SC resilience strategies. I5.0 promotes the benefits of IoT, an information-sharing system to increase collaboration and visibility techniques, which is necessary for SC resiliency for a quick and effective response that keeps operations working and restored to their prior state after a disruption (Al-Talib et al., 2020). I5.0 designs SCs with the ability to react fast to any disturbances in their processes which have a better chance of becoming more stable and gaining a better market position.

2.2. Impacts of COVID-19 on supply chain resilience

Businesses have come across several key outbreaks in the past, though the present COVID-19 pandemic is substantially more acute than earlier outbreaks. As a result, there has been a lack of readiness to handle such an outbreak (Sharma et al., 2021) SCs are expected to fight with executing rapid recovery plans due to inadequate resources and technologies (Paul, Chowdhury, Moktadir, & Lau, 2021; Rahman, Paul, Shukla, Agarwal, & Taghikhah, 2022). Ivanov and Dolgui (2020) demonstrated the influence of this unprecedented pandemic on demand, supply, manufacturing, and other logistics operations. Fluctuating demands and uncoordinated logistic operations were the typical scenarios in this case. A seamless flow of material supply and increased production capacity are critical difficulties for these SCs to overcome because of the outbreak (Paul & Chowdhury, 2021; Paul, Chowdhury, Chakrabortty, Ivanov, & Sallam, 2022). Rapid prototyping is crucial in ramping up certain products and services to ease SC disruption during COVID-19 (Lynch, Hasbrouck, Wilck, Kay, & Manogharan, 2020). Modern AI-based technologies, such as a digital replica of a real system, data-driven decision-making tools, and machine learning, can aid in formulating appropriate strategies. Thus these technologies are vital to overcoming the disruption (UsugaCadavid et al., 2020).

2.3. AI-based imperatives of I5.0

I5.0, with artificial intelligence and blockchain technology, provides cybersecurity, effective virtual management and training systems, faster production and delivery of goods and services, and gain resilient supply chain. AI helps mitigate the post-COVID-19 disruption effect (Liu, Hendalianpour, Hamzehlou, Feylizadeh, & Razmi, 2021). AI-based imperatives of I5.0 can mitigate SC disruption risks related to COVID-19. Real-time information sharing between various SC sectors and digital technologies implementation help build more resilient capabilities (Belhadi et al., 2021). These technologies are intended to speed up the transition to a resilient SC in the COVID-19 era. AI-based imperatives of I5.0 advance supply chain resilience by improving robustness in the context of emergency, abrupt, and large-scale disruptions such as the COVID-19 pandemic.

Significant benefits of such technologies for mitigating the impacts of COVID-19 are faster planning, digital technology usage, automation, flexible working environment, cybersecurity system, and several innovations with the help of advanced manufacturing and digital technologies. SC resiliency is implausible without I5.0 technological assistance, especially after the devastating SC disruption of COVID-19. The adaptation of AI-based imperatives of I.50 can contribute to the successful implementation of immune SC systems and enhance sustainability and resilience. AI, the IoT, Cyber-Physical Systems (CPS), robotics, Big Data Analytics, Augmented Reality and Cloud Manufacturing, are used by organizations to improve risk mitigation strategies, faster production, save costs, and improve customer satisfaction (Belhadi et al., 2021; Wu, Song, Bian, Zheng, & Zhang, 2020).

Table 1 (*continued*)

Notation	AI-based imperatives	Description	References
	production planning and control	COVID-19 through appropriate planning and makes the supply chain more resilient.	Pellerin, & Fortin, 2020)
I14	Advancing SC transparency by implementing the blockchain technologies	Owing to serious circumstances resulting from the COVID-19 pandemic, end-to-end tracking and transparency over the SC are threatened. Emerging markets can adopt blockchain technologies to ensure authentic transactions and monitoring across the SC.	(Kurpjuweit et al., 2021; Nandi et al., 2021)
I15	Rapid prototyping using 3D printing	Rapid prototyping helps ease supply chain disruption during COVID-19. It is critical in ramping up certain products and services in crisis times.	(Lynch et al., 2020)
I16	Creation of digital SC twin	SC digital twin provides a digital replica of a real system, helps data-driven decision-making, and builds a resilient system for disrupted SC situations like COVID-19.	(Ivanov, Dolgui, & Sokolov, 2019)

To improve SC resiliency, essential AI-based imperatives can be collected from present literature and expert response. Consequently, a literature survey has been performed in the initialization phase utilizing numerous fundamental terms, such as “AI-based imperatives and essence for Industry 5.0 improvement/ implementation” OR “AI-based imperatives of industry 5.0 towards resilient supply chain adoption” OR “critical/vital/key indicators/”AND “resilient supply chain essence following COVID-19” OR “identification and examine sustainable industry 5.0 imperatives” OR “scale-up/improving supply chain resiliency” OR “necessary elements of industry 5.0 on resilience and sustainable developments”. Scopus and Google Scholar databases have been employed for the literature search. Finally, the literature survey identified 16 crucial AI-based imperatives of I5.0 on SC resiliency. Table 1 shows the AI-based imperatives identified from the existing literature considering the COVID-19 pandemic.

The conception and implementation ideas of I5.0 are still in the incipient stages. The applications of AI-based imperatives of I5.0 in the SC management context are almost unexplored. These imperatives have enticing qualities that need further rigorous assessment for model development to build a resilient SC (Acioli et al., 2021). A number of knowledge gaps are identified via extant literature on AI-based imperatives of I5.0 on SC resilience as follows.

i. Though current studies recognize I5.0 with AI technologies as a vital topic for research, none of these studies identify the AI-based imperatives of I5.0 in the context of emerging economies’ SCs (Demir, Döven, & Sezen, 2019; Martynov, Shavaleeva, & Zaytseva, 2019).
ii. The literature focuses on applying I5.0 to sustainable development goals (ElFar et al., 2021; Maddikunta et al., 2021).

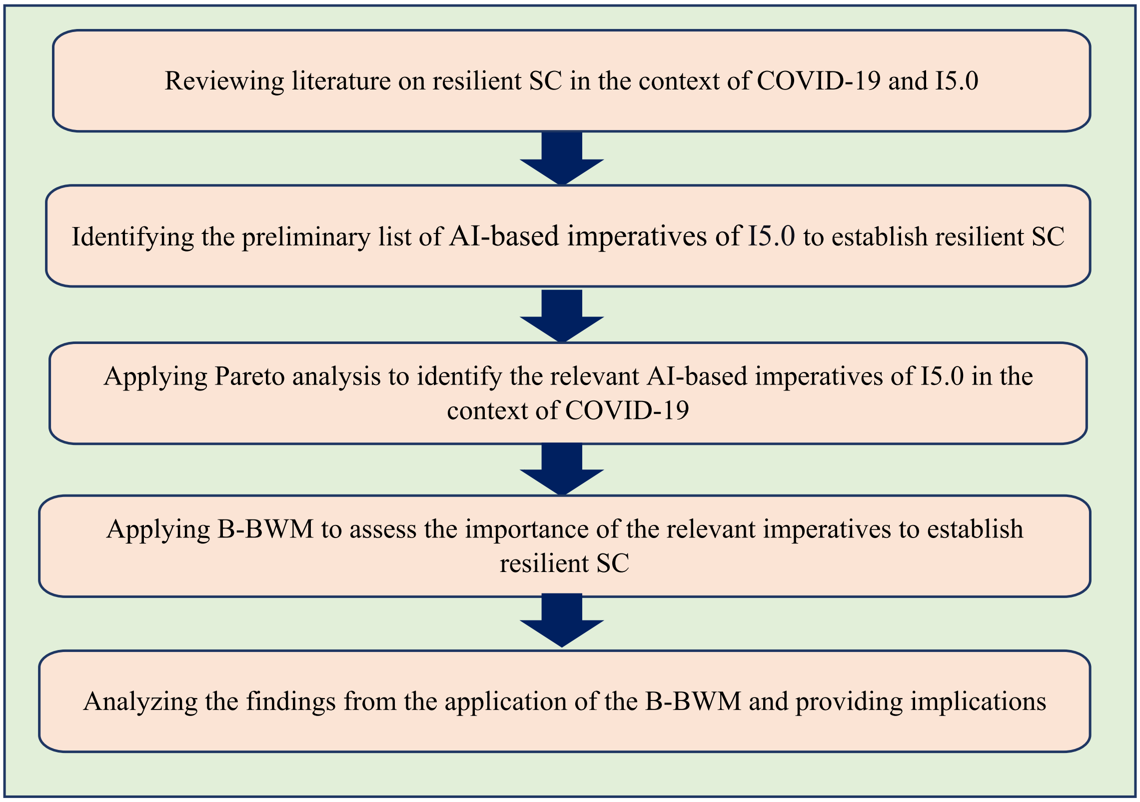

Fig. 1. Proposed research framework.

Table 2
The detailed information of the experts.

Features			Number of experts	Percentage
Evaluators ($m = 40$)	Designation	Managing Director	10	25
		General Manager	10	25
		Manager (Production)	5	12.5
		Supply Chain Manager	10	25
		Academic	5	12.5
	Domain of expertise	Sustainable supply chain	8	20
		Supply chain management	11	27.5
		Environment, health, and safety	7	17.5
		Logistics management	7	17.5
		Production/ Operations	7	17.5
	Experience	Less than 12 years	8	20
		12 to 18 years	18	45
		More than 18 years	14	35

However, none of the literature gives insight into the decision-makers developing strategies for properly implementing AI technologies.

iii. Although a few studies focus on applying technologies during the COVID-19 pandemic (Pillai, Haldorai, Seo, & Kim, 2021), none of these studies focus on analyzing the AI-based imperatives of I5.0 to increase SC resiliency of emerging economies in the post-COVID-19 era.

This study tries to bridge the gaps described above and analyzes the AI-based imperatives of I5.0 toward resilient SCs. The innovation of this research is that it establishes a link between AI-based imperatives of I5.0, SC resiliency, and the impacts of the COVID-19 pandemic. Such integration in SC resiliency has not yet been explored in extant literature. This research offers an innovative and intelligent framework on Pareto and B-BWM to recognize and analyze AI-based imperatives of I5.0 that make SC more resilient. This research provides valuable insights to decision-makers for strategic decision-making to make their SCs more resilient amid the COVID-19 pandemic.

3. Research methodology

This research develops an innovative integrated model for exploring and evaluating the AI-based imperatives of I5.0 that will help organizations make strategic decisions to establish a resilient SC for the post-COVID-19 world. Considering all possible AI-based imperatives of I5.0, the integrated approach was developed with Pareto analysis, Bayesian, and BWM approaches to determine the relationship between pairs of AI-based imperatives of I5.0 and evaluate their priorities. Fig. 1 presents the essential steps for the proposed research framework.

3.1. Data and context of study

A structured framework for assessing the AI-based imperatives of I5.0 was implemented for Bangladesh's apparel and footwear industries as a case study of an emerging economy. Due to the surge of the COVID-19 pandemic, these two industries' SCs are facing a lot of challenges (Acioli et al., 2021). Many manufacturing firms have adopted advanced AI technologies to develop a more sustainable production method and establish a resilient SC. Unfortunately, they have failed to implement them properly due to a lack of understanding of such technologies. In response, we have picked up this topic and proposed a framework that will provide policy-makers valuable insights into measuring which AI-based imperatives they should focus on during the adoption process.

In this research, data were gathered in two phases. In the first phase,

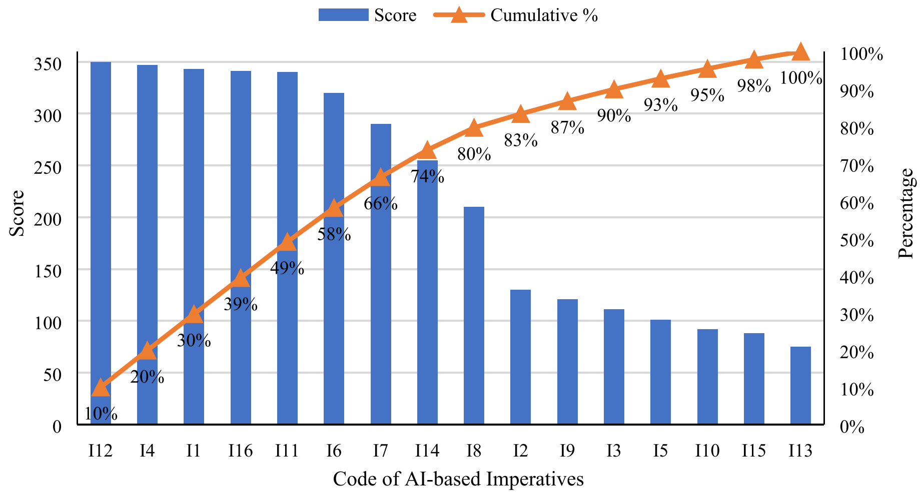

Fig. 2. Pareto diagram of the AI-based imperatives of I5.0 towards resiliency of SCs.

a survey was conducted to finalize the AI-based imperatives with the help of Pareto analysis. For this purpose, this study selected a total of 40 experts using a subjective sampling method (Guarte & Barrios, 2006). The inclusion criteria of experts are having at least ten years of relevant experience and adequate knowledge of I5.0 initiatives. A brief description of expert profiles is shown in Table 2.

Pareto analysis, or the 80/20 rule, introduced by Vilfredo Pareto, is an effective and simple tool for identifying the "vital few" variables from "trivial many". For collecting expert's opinions, a questionnaire with the identified AI-based imperatives was prepared and circulated among experts through email communication (See Table A1 in Appendix-A for the questionnaire). Experts were given the freedom to express their valuable thoughts on the importance (priority weight) of all advanced technologies with the help of a 9-point Likert scale, where a scale of 1 indicates very weakly important, and a scale of 9 indicates very extremely important. After that, the cumulative percentage score of all technologies was calculated, and the most significant ones (comprising 80% score) were finalized, as depicted in Fig. 2. In the second phase, fifteen experts were interviewed to collect the data to investigate the relationships among the AI-based imperatives and determine their final priorities. Here, an integrated approach combining the Bayesian approach and BWM was anticipated to examine the relationships between pairs of imperatives and prioritize them toward SC resiliency. In the following sections, first, the steps of the BWM are explained, then, the details of the B-BWM are described.

3.2. Best-Worst method (BWM)

The BWM, proposed by Professor Jafar Razaei, is a novel and recent tool (Rezaei, 2015). This research selected this method to assess the advanced AI-based imperatives of I5.0 due to its several benefits. First, the best and worst are identified before developing pair-wise comparison vectors. Thus, the decision-makers have a clear view of the priority of evaluation (Fartaj et al., 2020). This action, in turn, increases the consistency of the pair-wise comparisons. Second, the development of pair-wise comparison vectors against two opposite measures helps reduce the biases of expert opinions. Third, it is the most data and time-efficient method compared to other Multi-Criteria Decision Making (MCDM) methods. This method requires a few data which could mitigate the possible biases and, at the same time, provides more reliable and consistent pair-wise comparisons.

3.3. Bayesian-BWM

The original BWM establishes overall weights from a probabilistic perspective and serves as the foundation for the B-BWM (Mohammadi & Rezaei, 2020). The input of the B-BWM, such as two pair-wise comparison vectors, is identical to BWM. In contrast, the output of B-BWM provides a probability distribution as opposed to the BWM's specific value, which is the sole distinction. The definitions of each notation used in this method have been presented in Table A2 (Appendix-A). The followings are the major stages for B-BWM deployed in the current study.

Stage 1: Fixing a set of AI-based imperatives.

$C = \{c_1, c_2, ..., c_n\}$, where n denotes the total number of AI-based imperatives.

Stage 2: Choosing the best (C_B) and the worst (C_w) imperative from a set of C attributes.

Each evaluator now chooses the most crucial and worst imperatives from *a set of C attributes*.

Stage 3: Conduct a pair-wise comparison vector between the best over the other (BO) AI-imperatives.

Each expert uses a rating scale of "1 to 9" to construct the pair-wise comparison vector between the best and the other imperatives. The imperatives have a stronger impact when there are more of them. The resultant vector of BO is written as $A_B = (a_{B1}, a_{B2}, ..., a_{Bn})$. Here, a_{Bj} shows how much more important the best imperative is than the others $c_j \in Cc_j \in C$.

Stage 4: Conduct a pair-wise comparison between the other over the worst imperative (OW).

In the same way, each evaluator rates the impact of the other imperatives on the worst one on a scale from "1 to 9." The following OW vector is shown as $A_w = (a_{w1}, a_{w2}, ..., a_{wn})$. Here, a_{wj} expresses how much more important the other imperatives $c_j \in C$ are than the worst one .

Stage 5: Finding the optimal and the aggregated weight.

This stage determines each optimal weight $z^{1:K}$ as well as the total optimal weight z^{agg} given $A_B^{1:K}$ are identified, which accounts for all the evaluators. Following are the joint probability distribution and the probabilities for each variable.

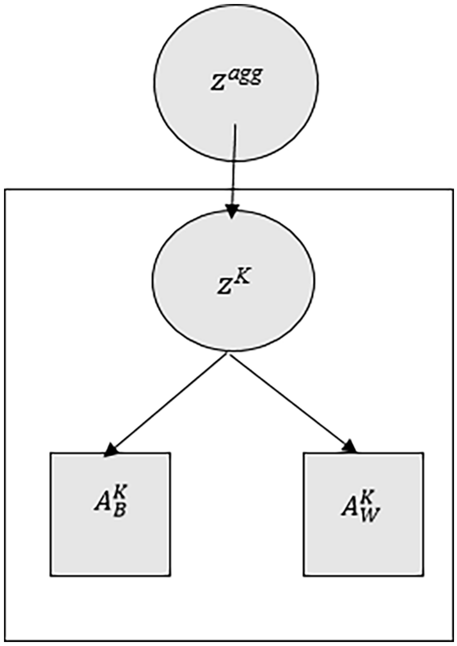

Fig. 3. The probabilistic graphical model of the B-BWM.

Table 3
Aggregated final weights of the AI-based imperatives of I5.0.

AI-based imperatives of I5.0	Final Weight	Rank
Production flexibility through automation integration (I1)	0.1329	4
Use of cyber-physical production system (CPPS) (I4)	0.1699	2
Cyber immunity for data management (I6)	0.1052	5
Boosting employee safety and operational continuity through AI (I7)	0.0607	7
Application of big data and predictive analytics (I8)	0.0598	8
Inventory control using RFID (I11)	0.0924	6
Real-time tracking of SC activities using IoT (I12)	0.1727	1
Advancing SC transparency by implementing the blockchain technologies (I14)	0.0515	9
Creation of digital SC twin (I16)	0.1550	3

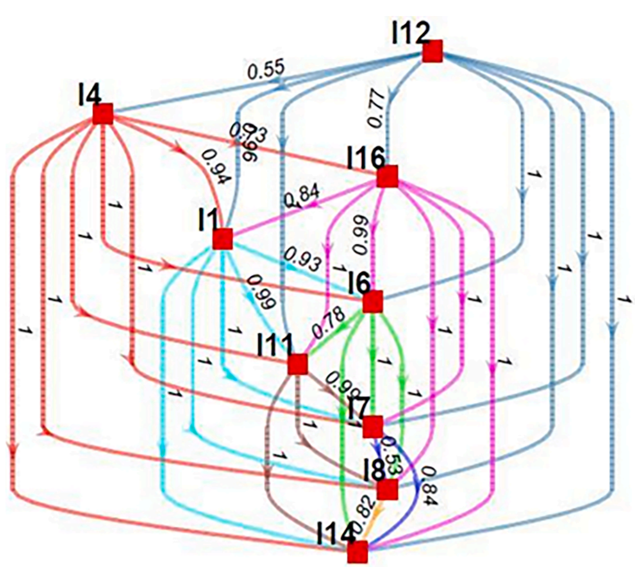

Fig. 4. Hierarchical credal ranking of the AI-based imperatives of I5.0 for establishing resilient SCs.

Table A1
Identified the most relevant AI-based imperatives of I5.0.

No.	List of AI-based imperatives	Code	1: Very weakly important and 9: Highly important				
			1	2	-	-	9
1	Production flexibility through automation integration	I1					
2	Optimization of SC activities using cloud technologies	I2					
3	Decentralization of production system using additive manufacturing	I3					
4	Use of cyber-physical production system (CPPS)	I4					
5	Optimization of warehouse activities using augmented reality	I5					
6	Cyber immunity for data management	I6					
7	Boosting employee safety and operational continuity through AI	I7					
8	Application of big data and predictive analytics	I8					
9	Application of robotics in logistics service	I9					
10	Vertical networking and horizontal integration of smart production systems	I10					
11	Inventory control using RFID	I11					
12	Real-time tracking of SC activities using IoT	I12					
13	Application of machine learning in production planning and control	I13					
14	Advancing SC transparency by implementing the blockchain technologies	I14					
15	Rapid prototyping using 3D printing	I15					
16	Creation of digital SC twin	I16					

Table A2
Definition of notations.

Notation	Definition
C	Alternative to evaluate
C_B	Best alternative
C_w	Worst alternative
A_B	Best -to-Others vector
A_w	Others-to-Worst vector
z	Weight of an alternative by each evaluator
z^{agg}	Aggregated weight of an alternative
K	Number of evaluators
z^K	Weight of an alternative by k^{th} evaluator
O	Credal ordering
R	Relation between the alternatives
d	Confidence in the superiority of the alternatives
M	Sample size

$$P\left(z^{agg}, z^{1:K} \middle| A_B^{1:K}, A_w^{1:K}\right) \tag{1}$$

$$P(x) = \sum_y P(x, y) \tag{2}$$

where x, y are two arbitrary random variables.

3.4. Bayesian hierarchical model

A probabilistic hierarchical model is initially plotted to analyze the relationship between the variables before the Bayesian model is created. Fig. 3 displays a detailed overview of the B-BWM model. In this case, circular and rectangular nodes, respectively, present variables and observed variables. The directed arrows show which nodes are dependent on each other. Therefore, it is evident that the magnitude of z^{agg} depends on z^K and that again depends on A_B^K and A_W^K. The corresponding variables (z^K, A_B^K, A_W^K) in the plate are iterated by each assessor.

Fig. 3 illuminates the conditional independence between the two

Table A3
Best-to-Others vector.

Expert	Best Imperative	I1	I4	I6	I7	I8	I11	I12	I14	I16
E 1	I4	6	1	4	9	7	6	3	8	2
E2	I12	3	2	5	7	6	5	1	9	4
E 3	I4	5	1	3	5	9	7	2	6	3
E 4	I16	4	3	6	6	8	6	4	9	1
E5	I1	1	5	4	9	6	4	3	7	2
E6	I12	3	2	4	9	7	5	1	8	6
E7	I16	4	5	3	8	7	6	2	9	1
E 8	I4	5	1	6	7	8	7	3	9	3
E 9	I1	1	2	4	6	9	3	1	8	2
E10	I4	3	1	5	7	7	6	2	9	4
E11	I12	4	3	6	8	7	5	1	9	2
E12	I1	1	2	3	6	9	4	2	6	2
E13	I4	5	1	4	6	9	3	5	7	5
E14	I12	4	2	5	8	7	9	1	8	3
E15	I16	4	3	4	9	7	6	5	6	1

Table A4
Others-to-Worst vector.

Imperative	Expert														
	E 1	E 2	E 3	E 4	E 5	E 6	E 7	E 8	E 9	E 10	E 11	E 12	E 13	E 14	E 15
	Worst Imperative														
	I7	I14	I8	I14	I7	I7	I14	I14	I8	I14	I14	I8	I8	I11	I7
I1	4	7	5	5	9	7	6	5	9	7	6	9	5	6	7
I4	9	8	9	7	5	8	5	9	8	9	7	8	9	8	6
I6	6	5	7	3	6	4	7	4	6	3	4	7	6	5	6
I7	1	4	5	3	1	1	2	3	4	3	2	4	4	2	1
I8	3	4	1	2	4	3	3	2	1	4	3	1	1	3	3
I11	4	5	3	4	6	5	4	4	7	8	5	6	7	1	4
I12	7	9	8	6	7	9	8	7	8	8	9	8	5	9	5
I14	2	1	4	1	3	2	1	1	2	1	1	4	3	2	8
I16	8	6	7	9	8	5	9	6	8	6	8	8	5	7	9

variables. For example, A_W^K is independent of z^{agg}, given z^K, so,

$$P\left(A_W^K \middle| z^{agg}, z^K\right) = P\left(A_W^K \middle| z^K\right) \tag{3}$$

The resultant equation, combining the Bayes rule with Equation (1), can be rewritten as follows.

$$P\left(z^{agg}, z^{1:K} \middle| A_B^{1:K}, A_W^{1:K}\right) \alpha P\left(A_B^{1:K}, A_W^{1:K} \middle| z^{agg}, z^{1:K}\right) P\left(z^{agg}, z^{1:K}\right)$$
$$= P\left(z^{agg}\right) \prod_{K=1}^{K} P\left(A_B^L \middle| z^K\right) P\left(A_W^K \middle| z^K\right) P\left(z^K \middle| z^{agg}\right) \tag{4}$$

The probability chain rule, the conditional independence of the several variables, and the evaluators' independent assessments of each variable are used to establish the final equality in this case. It is essential to identify all variables in order to compute the posterior distribution. Since every variable in this situation is an integer, a multinomial distribution may be used to represent it. As the two vectors (A_B^K and A_W^K) are just opposite, the opposite weight results from this. The distribution will be as:

$$A_B^K | z^K \text{ multinomial } \left(\frac{1}{z^K}\right) \tag{5}$$

$$A_W^K | z^K \text{ multinomial } \left(\frac{1}{z^K}\right) \tag{6}$$

The MCDM requires a weight vector to satisfy the non-negativity and sum to one property. The Dirichlet distribution is used to determine the weight as a consequence. One way to explain the distribution is as:

$$Dir(a) = \frac{1}{B(a)} \prod_{j=1}^{n} z_j^{a_{i-1}} \tag{7}$$

Here, z is this MCDM's ideal weight and α is the Dirichlet distribution's parameter. The Dirichlet distribution's mean and concentration factor have once again been parameterized for this study's purposes. Here, λ and z^{agg} denote the concentration factor and the distribution consequently.

$$z^K | z^{agg} \; Dir(\lambda \times z^{agg}) \tag{8}$$

Equation (8) shows that each evaluator's weight vector, z^K, must be close to the distribution's mean value, z^{agg}, and that the concentration factor γ gauges this proximity. It is necessary to simulate the concentration parameter, and gamma distribution will be accurate in simulating such a non-negative value.

$$\gamma \text{ gamma } (\mathrm{a}, \mathrm{b}) \tag{9}$$

where a and b represent the model parameters of the gamma distribution.

Finally, z^{agg} as the prior distribution is calculated employing an uninformative Dirichlet distribution with the factor value of $\alpha = 1$ as:

$$z^{agg} \; Dir(1) \tag{10}$$

No closed-form solution exists for the probabilistic model defined by the equations (5–10). A Markov-chain Monte Carlo (MCMC) sampling is necessary to compute the solution. The B-BWM was performed in the free and open-source Just Another Gibbs Sampler (JAGS), one of the most effective available probabilistic languages.

3.5. Credal ranking

In this work, the I5.0 AI-based imperatives were ranked in terms of relevance using the credal ranking approach. Unlike earlier ranking techniques, which determined the significant variable based on two numbers or intervals, this technique employs the Dirichlet distribution to determine the degree of confidence in the criterion's superiority.

These credal ranking and order concepts are utilized to create the probabilistic hierarchical model and determine the confidence level.

Definition 1. The formulation of a credal sorting O for a pair of attribute c_i and c_j, can be explained as follows (Mohammadi & Rezaei, 2020):

$$O = (c_i, c_j, R, d) \tag{11}$$

Where,

R is the relationship among the performance measures c_i and c_j.
$d \in [0, 1]$ represents the relation's degree of confidence.

Definition 2. The credal ranking is a list of credal orderings that contains all pairs (c_i, c_j) for all $c_i, c_j \in C$, upon a given set of criteria $C = \{c_1, c_2, ..., c_n\}$. Now, for every set of criteria c_i and c_j, we just require calculating the credal ordering degree. To achieve this, the S samples from JAGS were utilized and the degree was calculated in the manner specified below: (Mohammadi & Rezaei, 2020).

$$P(c_i > c_j) = \frac{1}{S}\sum_{s=1}^{S} I\left(z_i^{agg_s} > z_j^{agg_s}\right) \tag{12}$$

4. Implementation of Bayesian-BWM

This section presents the findings from implementing the proposed framework to analyze the AI-based imperatives of I5.0 to establish resilient SCs for Bangladeshi RMG and footwear industries in the post-COVID-19 era. The AI-based imperatives were considered the alternatives for assessing the SC resiliency issues in the first phase of the proposed Pareto and B-BWM integrated framework. In the second phase, BO and OW vectors were formed following responses from the purposively selected evaluators. Tables A3 and A4 in **Appendix-A** show the BO and OW vectors, respectively. Then, with the help of multinomial distribution, these two inputs were modeled in Eqs. (5)–(6), and the Dirichlet distribution was used to get the aggregated final weight vector of the imperatives of I5.0 using Eqs. (7)–(8). Table 3 represents the weight vector of the AI-based imperatives of I5.0. This weight vector represents the relative importance of each imperative over the others, along with the ranking.

The credal ranking, which is a weight-driven graph to comprehend the relationship between a pair of imperatives, is one of the main results of the B-BWM. Fig. 4 shows the confidence in choosing one imperative above the others in this investigation, which was achieved using credal ranking.

5. Result and discussions

The proposed framework integrated with Pareto and B-BWM has resulted in the relative importance of AI-based imperatives to achieve SC resiliency for the RMG and footwear industries. As shown in Table 3, "Real-time tracking of SC activities using IoT (I12)" is the most important AI-based imperative for achieving resilient SC with an aggregated weight of 0.1727. Most of the RMG and footwear industries in an emerging economy like Bangladesh lack real-time tracking of SC activities. Hence, optimizing these activities becomes very difficult during the COVID-19 pandemic. IoT can make the SC activities visible to all the stakeholders, and the strategy formulation process regarding selecting optimum routes, energy consumption, inventory policy, and waste elimination becomes very effective. Thus, adopting this AI-based imperative will increase the financial, environmental, and social performance of the SCs of the RMG and footwear industries. Yadav, Luthra, and Garg (2021) also found that integrating IoT can increase resiliency in the case of agri-food SCs in the turbulent business environment resulting from COVID-19. Therefore, "Real-time tracking of SC activities using IoT (I12)" can be a novel implication for Bangladeshi RMG and footwear industries to establish resilient SC. By adopting this strategy, other sectors of emerging economies with similar business characteristics can also make their SCs resilient.

The second most important imperative suggested by the current research is the "Use of cyber-physical production system (I4)" with a weight of 0.1699. Recently, several studies have identified that cyber-physical production systems can tackle the operational disruptions of SCs due to the COVID-19 pandemic and enhance environmental performance (Andronie, Lăzăroiu, Iatagan, Hurloiu, & Dijmărescu, 2021). In an emerging economy like Bangladesh, disruptions in operational and environmental performances of SCs resulting from the COVID-19 pandemic have become a matter of concern for export-oriented industries like the RMG and footwear industries and many local manufacturing industries. Adopting the cyber-physical production system can make the SCs of these industries smooth and efficient by providing a self-monitoring facility that will eventually help to build a resilient SC. In this research, "Real-time tracking of SC activities using IoT (I12)" and "Use of cyber-physical production system (I4)" are found to have almost equal importance in improving SC resiliency. However, IoT needs to be well integrated before establishing the cyber-physical production system.

"Creation of digital SC twin (I16)" will help the RMG and footwear industries simulate the actual SC and collect the real-time data of SC operations. Thus, the uncertainties and risks throughout the SC can be reduced while minimizing human participation in various SC operations during the COVID-19 pandemic. Burgos and Ivanov (2021) stressed the creation of a digital twin to increase SC resiliency during the COVID-19 crisis. The current research has also found the "Creation of digital SC twin (I16)" as the third most important AI-based imperative of I5.0 to increase the resiliency of SCs in RMG and footwear industries. In recent times, the COVID-19 pandemic has made the companies of emerging economies aware of the flexibility in production and SC operations. In Bangladesh, the RMG and footwear industries have also become concerned about SC operations' flexibility that can be achieved through automation integration.

Moreover, the automotive industries of emerging economies with similar production characteristics to RMG have also realized the importance of automation integration during COVID-19. "Production flexibility through automation integration (I1)" is the fourth most significant AI-based imperative suggested by the current research. According to the study by Delic and Eyers (2020), one of the prerequisites for improving SC performance and resiliency is the flexibility of the manufacturing system, which can be achieved through automation. Again, adopting I5.0 initiatives in SC will generate a vast amount of data. Therefore, establishing the "Cyber immunity for data management (I6)" will be imperative for the companies under the COVID-19 crisis. Sobb, Turnbull, and Moustafa (2020) also suggested addressing cybersecurity issues while embedding AI technologies with SCs. Another AI-based imperative for resilient SC found in the current research is "Inventory control using RFID (I11)". Due to the COVID-19 crisis, end-to-end tracking of items and inventory control have become challenging tasks, although they are required for improving SC performances and customer satisfaction. Deploying the RFID to track and control the inventory can solve this problem for most of the SCs of emerging economies. Varriale et al. (2021) found that RFID adoption accelerates achieving SC resiliency.

The recent COVID-19 pandemic has challenged the employee safety of all types of industries. Hence, operational continuity is being hampered because of this safety issue. This eventually has a drastic impact on SC resiliency. "Boosting employee safety and operational continuity through AI (I7)" can be a solution to this problem. AI can automate and manage various SC activities, optimizing human-to-human physical communication (Di Vaio, Boccia, Landriani, & Palladino, 2020). Uncertainty in customer demands and energy consumption has increased dramatically due to the COVID-19 crisis. Forecasting customer demands and energy consumption with greater accuracy during this crisis is imperative to make SC operations smooth and effective. "Application of big data and predictive analytics (I8)" helps companies to make a more accurate prediction on customer demands and energy consumption, even during adverse situations (Tsai et al., 2021). Companies in the emerging economy like Bangladesh are far behind in this regard. Therefore, this AI-based imperative of I5.0 suggested by the current research can be a practical implication for RMG, footwear, and other industries. However, all the imperatives above must be adopted to benefit from the "Application of big data and predictive analytics (I8)". For this reason, this imperative has been ranked *8th* amongst the nine AI-based imperatives. Finally, "Advancing SC transparency by implementing the blockchain technologies (I14)" has been ranked last in the current research. However, Nandi, Sarkis, Hervani, and Helms (2021) found that blockchain can enhance the resilience and sustainability of SC during COVID-19. However, significant investment is necessary to build a blockchain-enabled SC. The current research was conducted in Bangladesh, an emerging economy where investment and legislation are major issues for firms looking to use blockchain technology. Therefore, the current research has found this imperative of I5.0 less important than the others.

The credal ranking in Fig. 4 shows that "Real-time tracking of SC activities using IoT (I12)" is considered the most important AI-based imperative, with a confidence of 0.77 against "Creation of digital SC twin (I16)", with a confidence of 0.96 against "Production flexibility through automation integration (I1)" and with a confidence of 1 against "Cyber immunity for data management (I6)", "Inventory control using RFID (I11)", "Boosting employee safety and operational continuity through AI (I7)", "Application of big data and predictive analytics (I8)" and "Advancing SC transparency by implementing the blockchain technologies (I14)". Again, the confidence of selecting the "Real-time tracking of SC activities using IoT (I12)" against "Use of cyber-physical production system (I4)" is 0.55, indicating that these two AI-based imperatives are equally important to be adopted. Table 3 also shows no discernible difference in the weights of these two imperatives. However, "Real-time tracking of SC activities using IoT (I12)" is preferable to the "Use of cyber-physical production system (I4)" to achieve SC resiliency. Fig. 4 also shows that the other pairs of AI-based imperatives have reasonably high confidence except for the confidence between "Boosting employee safety and operational continuity through AI (I7)" and "Application of big data and predictive analytics (I8)". The confidence level of choosing I7 over I8 is 0.53, which is close to the threshold value (0.50). It indicates that these two AI-based imperatives have almost equal significance for building resilient SC.

For the sustainability of the business, many organizations might consider digitizing their SC with I5.0 technology as a costly undertaking, as introducing such technology in developing countries requires a lot of investment. Most of the costs are associated with the investment in technology purchasing, training, human resources, and maintenance. However, in the long run, it can reduce costs and strengthen the SC against any future disruptions. Therefore, embracing revolution is quite realistic and rational for the emerging economies' companies from the cost and benefit trade-off perspective, with tangible benefits to reduce costs and increase productivity. Although adopting I5.0 technologies by emerging economy companies is still in the embryonic stage, many RMG and footwear have started using I4.0 technologies that might be helpful for the technological transition. For example, many RMG and footwear companies have introduced virtual reality, additive manufacturing, and robotics to make their operations and SC more sustainable.

6. Implications

From a theoretical standpoint, the results of this study provide a wide range of ramifications for the researchers. In order to construct resilient SC in the post-COVID-19 future, the current work has first addressed a set of AI-based imperatives of I5.0 that must be accepted. The majority of the work currently in circulation focuses on detecting and evaluating the effects of COVID-19 on SC resilience (Golan, Jernegan, & Linkov, 2020). This research is a preliminary attempt to pinpoint the answers in light of I5.0 for developing a robust SC in an emerging economy. This study has highlighted the connection between the AI-based technologies of I5.0 and SC resilience that may help the researchers frame more robust solutions in the future. Again, the solutions of I5.0 proposed by this study may be applicable for all the other country contexts where the companies are facing problems establishing resilient SC during the COVID-19 pandemic. Secondly, this study has offered a new and intelligent framework to model the AI-based imperatives of I5.0 to establish resilient SC. This framework integrates Pareto theory with the B-BWM, which may provide future scientists with a different view to utilize such integration with other methods to identify the relevant interest factors.

The findings from applying the proposed framework also have several managerial implications. Due to the uncertain business environment caused by the recent COVID-19 pandemic, companies must rethink what initiatives or strategies they need to take to achieve SC resilience (Ali et al., 2021). This research has shed light on the significance of AI-based imperatives of I5.0 to establish resilient SC. This may help SC professionals and researchers rethink the solution strategies for I5.0 to increase SC resiliency. Operations managers and policymakers may find the suggested solutions, such as real-time SC activity tracking using IoT, setting up cyber-physical production systems, and creating a SC digital twin, helpful in coming up with the best plans to build a resilient SC. The current research has integrated Pareto analysis into the assessment framework that helps identify the relevant AI-based imperatives of I5.0. The proposed framework has integrated the B-BWM for effective group decision that also helps the companies to select the right AI technologies to build resilient SC during the COVID-19 crisis.

7. Conclusions and future research directions

The COVID-19 pandemic affected the global market of many emerging economies by disrupting manufacturing activities. Many manufacturing industries have already shut down their operations, and others face many challenges in continuing their business operations during this pandemic. To enhance the survivability of modern SCs and adopt sustainable ways of production, SCs and manufacturing firms from emerging economies need to build a resilient SC by adopting AI-based imperatives. Many emerging economies' industries have already sought and adopted various technologies. Still, they have failed to get their most advantages due to a lack of in-depth knowledge about these imperatives. A structured framework has been proposed in this study that assists decision-makers and relevant stakeholders of emerging economies in identifying, evaluating, and prioritizing the AI-based imperatives for establishing a resilient SC. This research presented a Pareto-based B-BWM model for assessing AI-based imperatives in an emerging economy context. Based on extant literature, sixteen AI-based imperatives were identified; later, by the Pareto chart, nine were finalized. After applying B-BWM, real-time tracking of SC activities using IoT was found to be the most crucial AI-based imperative, followed by using cyber-physical production systems and creating a digital SC twin.

This research contributes to the literature from multiple directions. First, it connects AI-based imperatives of I5.0, SC resiliency, and the daunting effects of the COVID-19 pandemic. This type of integration in the SC resiliency domain has not been suggested or explored. The second contribution is the integrated method, Pareto-based B-BWM, to sort out, evaluate, and analyze the AI-based imperatives of I5.0 for reducing the difficulties caused by COVID-19 through establishing a resilient SC. The research findings have the potential to guide decision-makers in shaping strategic decisions for increasing resiliency in SCs amid the COVID-19 pandemic. Third, this research has revealed how badly various SC issues, such as production, sourcing, distributions, etc., have been disrupted due to the COVID-19 pandemic. Fourth, the evaluation of AI-based imperatives of I5.0 responds to what technologies-based imperatives should be adopted for which dimension to deal with the 'effects of a large-scale SC disruption such as the COVID-19 pandemic.

Although the research has contributed significantly to SC resiliency and disruption management, it possesses some limitations. Here, the proposed model was developed by collecting data from Bangladeshi RMG and footwear industries; therefore, the findings from the proposed framework may not reveal a clear view of other related industries. Another limitation is that while the results are expected to apply to other industries, they are mostly aligned with the business and operational characteristics of Bangladeshi RMG and footwear industries.

This research provides several avenues for future research. This research has brought the AI-based imperatives of I5.0, the impacts of the COVID-19 pandemic, SC resiliency, and B-BWM into a single platform. The idea of I.50 is still in an embryonic phase. The applications of AI technologies in the SC management context are almost unexplored. The proposed model was developed as an emerging economy based on Bangladeshi RMG and footwear industries. In the future, this work can be performed in other developing and developed economies contexts to generalize the findings.

CRediT authorship contribution statement

Tazim Ahmed: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft. **Chitra Lekha Karmaker:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft. **Sumaiya Benta Nasir:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft. **Md. Abdul Moktadir:** Conceptualization, Resources, Writing – review & editing, Supervision. **Sanjoy Kumar Paul:** Resources, Visualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data has been provided within the manuscript.

Appendix

Primary questionnaires
1. Details of the expert:

(a) Position:
(b) Company Name:
(c) The number of years of service:
(d) Major role:

Q1: Selection of the most relevant AI-based imperatives of I5.0 towards resiliency of the emerging economies' SCs in a post-COVID-19 world. Express your valuable opinions (importance weight) using the 9-point Likert scale (see Tables A1-A4).

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