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**Strategies to overcome barriers to innovative digitalisation technologies for
supply chain logistics resilience during pandemic**

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Abstract

Logistics is a crucial function for any organisation. In the scenario of a pandemic or other disruptions, the role of logistics becomes even more important. Digitalisation of logistics and the supply chain is seen as an important tool for logistics resilience in such situations, but for developing countries digitalisation poses certain challenges. This study identifies barriers to innovative digitalisation technology that hinder the digital elevation of supply chain logistics during a pandemic. Strategies to deal with and overcome these barriers are proposed. The multi-criteria decision analysis method (Bayesian best-worst method) is used to prioritise such barriers within the context of the Indian logistics sector of manufacturing organisations. The strategies are also prioritised according to their impact on the barriers, for which the additive value function is used. The results show that "high cost of investment", "lack of monetary resources", "inadequate internet connectivity", "lack of IT (Information Technology) infrastructure" and "unclear economic benefit of digital investment" are the top five barriers to implementing innovative digitalisation technologies in developing countries like India, during a pandemic situation. The findings reveal an insight into digitalisation barriers during a pandemic that can be of value to managers and researchers.

Keywords: Logistics; resilience; pandemic; COVID-19; Bayesian best-worst method

1. Introduction

Logistics is a crucial function of every business (Stephen et al., 2000). For a company, the logistics cost makes up around 9–10% of the final price of goods during the period of 2005 (Ghiani et al., 2004), currently this cost is estimated to be around 20–25%, and also the logistics cost in developing countries such as India is around 14%, which is quite large compared to developed countries, where it is approximately 7% of the GDP (McKinsey, 2019). Companies always try to cut this cost, and cost reduction is possible in many ways such as by reducing the level of services (Ghiani et al., 2004) or increasing the performance of the logistics system (NITI Aayog and Rocky Mountain Institute, 2018). An increase in the performance of the logistics system reduces the logistics cost and also increases the level of customer satisfaction (Ramachandran et al., 2015). The performance of the logistics system can be improved by operational and technical improvement of the processes associated with it (NITI Aayog and Rocky Mountain Institute, 2018). The Internet of Things (IoT), artificial intelligence (AI), cloud computing, blockchain and augmented reality (AR) are new and emerging digitisation technologies used in different areas such as the smart grid, smart home, manufacturing, etc. for process improvement and efficiency (Güvercin, 2022). Using these innovative digitisation technologies can immensely benefit organisations in terms of efficiency and customer satisfaction. Logistics is one such sector that has tremendous scope for digitisation (Burroughs and Burroughs, 2020), as especially in developing countries like

India this sector relies mostly on manual systems, causing a loss of material and time and hence unsatisfied customers. With rapid penetration of the internet, the digital customer base has increased in India, which is now next only to China in terms of internet subscribers. With the scope for digitisation in the logistics sector, investments increased by more than 80% from \$161 million in 2013 to over \$3 billion in 2019 (McKinsey, 2019). Widespread disruptions occurring over the course of the last few decades have also necessitated the digitisation of the logistics sector. Disruptions such as pandemic outbreaks, like the Spanish flu, swine influenza, avian flu and recently the COVID-19 virus, have a severe and widespread impact on the economy as well as the supply chain (Amankwah-Amoah, 2020; Barbieri et al., 2020; Choi, 2020; Seddighi and Baharmand, 2020). The COVID-19 virus was first reported in the city of Wuhan in China (NCB, 2020a). Wuhan city is a major Chinese business hub. It seemed a local problem at the initial stage, but, as time passed, it assumed global dimensions. Tier 1 suppliers or direct suppliers of about 51,000 (163 Fortune 1000) companies from all over the world are located in Wuhan. First- or second-tier suppliers of about 5 million companies (938 Fortune 1000) from all over the world are located in Wuhan (DNB, 2020). However, the number of containers held in Chinese ports dropped by 10.1% in the first months of 2020 (IFC, 2020). Globally, companies that operate in the gift and toys industries suffered from both a supply shortage from China and demand disruption round the world, which was severely affected by the Coronavirus (NCB, 2020b). The supply chains of different markets of the world have been disrupted. This generates a spillover effect throughout different levels of supplier networks (Ozdemir et al., 2022). The US Institute for Supply Management has said that the lead-time has doubled for many companies and 75% of companies are affected by supply chain disruption (Fernandes, 2020). Coronavirus is a type of LFHI (Low-frequency-high-impact) event that comes as a high-risk event because we did not prepare for it in advance (Ivanov, 2020; Ivanov & Das, 2020). The supply chain is also under tremendous pressure in India ever since the government-imposed lockdown restrictions (Chaudhry, 2020). Large Indian companies have either halted or reduced operations temporarily due to supply-chain logistics disruption (Singh, 2020). Fast moving consumer goods (FMCG) companies also stopped manufacturing, except for essential items (Mudgill, 2020). During the first phase of lockdown, interstate logistics was banned; this hampered the supply chain of medical supplies also (Biswas et al., 2020). To manage these disruptions in future and to prepare our supply chains and logistics sector for these high-risk events, digitisation of the supply chain and logistics sector is necessary. Our primary focus is on supply chain logistics resilience, which can be improved by using the futuristic technology discussed above such as IOT, AI, blockchain, cloud computing, Industry 4.0, and AR. These technologies improve the visibility of the supply chain, which can help to understand the impact of a pandemic. Records can be digitised to avoid future shocks, making the supply-chain more resilient. Tracking and tracing play a significant role in the management of goods and products. Industry 4.0, along with other applications in the logistics sector, can reduce manual practices within the logistics system, improve system performance and reduce overall costs (Borgia, 2014; Oracle, 2020). However, for emerging economies like India,

digitisation of the supply chain and logistics sector for resilience is an uphill task and is often marred by a number of issues. Past literature regarding these is scant: Al-Talib et al. (2020) worked on IoT as a tool for supply chain resilience; Golan et al. (2020) worked on a literature review for supply chain resilience; Marusak et al. (2021) studied supply chain resilience in the food industry and Sharma et al. (2021) studied mitigation strategies for supply chain resilience. Studies exploring the challenges and strategies for adopting digitisation technologies in the supply chain and logistics sector have not been undertaken yet.

Based on this background, the inherent issues and disruptions existing in the supply chain and logistics sector, which have been even more exacerbated due to the COVID-19 pandemic, this study tries to answer the following research questions:

- What are the barriers to the adoption of digitisation technologies for achieving supply chain and logistics resilience?
- What strategies can be identified to overcome the challenges/barriers to the adoption of digitisation technologies for achieving supply chain and logistics resilience?
- Which are the most prominent of the barriers identified to the adoption of digitisation technologies for achieving supply chain and logistics resilience?

The structure of this paper is as follows. The literature is reviewed in Section 2 and research gaps are highlighted. The methodology is discussed in Section 3. Section 4 discusses the case and expert background. Section 5 presents the results of the analysis. Section 6 discusses the results of the study. Section 7 highlights the implications of the study and the last section presents conclusions.

2. Literature Review

2.1 Supply chain management, logistics resilience and digitisation technologies

Supply chain management is a crucial part of improving an organisation's productivity, profitability and competitive success (Verma et al., 2011). It is the basic requirement of any company for the movement of goods from the point of origin to the customer, or from the supplier to the company. With globalisation, many multinational companies try to manufacture their products in a developing country because of the availability of resources and cheap labour; they then sell their products to different countries, the management of which requires efficient, effective and very complex logistics management. The components of the supply chain are planning, marketing, procurement, operation and logistics. Logistics management is an important part of supply chain management, which includes inventory setting and transportation. Logistics deals with the flow of items and their storage (Mentzer, 2004). Perfect logistics is that which can deliver goods to the right person in the right quantity at the right time at the right place and with the goods in the original condition. Digitisation technologies are helping supply chain and logistics organisations to efficiently manage their operations and provide resilience to enable them to manage disruptions.

Supply chain and logistics resilience can be defined as “The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function” (Ponomarov and Holcomb, 2009). Some of the important digitisation technologies for supply chain and logistics resilience are discussed in next section.

2.2 Digitisation technologies for supply chain and logistics resilience

There are many digitisation technologies that are gaining traction in the supply chain and logistics sector, one of which is the Internet of Things (IoT). The term IoT was first coined by Kevin Ashton in 1999. Computers are being empowered to gather real-time data by themselves –, that is, without human intervention – on the physical environment, thus creating what is termed as the IoT. The IoT is an interconnected system of devices or products embedded with different types of sensors, actuators, and software, with the help of which they can communicate among themselves or with humans, for exchanging status information or surrounding information, with much less human involvement, over the internet (Tadejko, 2015; Rose et al., 2015; Meola, 2019). For the implementation of IoT, two things are essential: one is Radio Frequency Identification (RFID) and the other is sensor technology. RFID is a technique used for the identification of objects and electronic labelling, using radio waves (Srivastava, 2004). Sensors are used to collect, comprehend and specify real-world data (Marinagi et al., 2013). Due to its pervasive and ubiquitous nature, IoT is being used widely (Gubbi et al., 2013). IoT can be used for different purposes in different sectors, such as the health sector (Ahmadi et al., 2019); sustainable energy sector (Khatua et al., 2020); volcano monitoring (Awadallah et al., 2019); intelligent automobile systems for smart cities (Menon et al., 2020); lean manufacturing (Anosike et al., 2021); sustainability in manufacturing organisations (Yadav et al., 2020); agri-food supply chain (Kumar et al., 2020). According to Radivojevića et al. (2017), in the Internet of Things concept, objects become smart in terms of identification, communication and interaction. The architecture of IoT includes all elements from sensors/actuators, interconnection to applications and services in IoT, and consists of four layers: the “perception”, “network”, “middleware” and “application” layers (Khan et al., 2012; Al-Fuqaha et al., 2015). The perception layer contains all such sensors/actuators that are embedded in the object, and are used to collect data on its status or surroundings. This layer actually interconnects the physical world with the virtual world. This layer's smart objects send and receive data from their surroundings, identify themselves and also interact among themselves or with end-users or other entities in the network (Miorandi et al., 2012; Kamble et al., 2019).

Other important digitisation technology is Industry 4.0. Industry 4.0 refers to the fourth Industrial Revolution. The term was first used in Germany when the new economic policy was introduced. It has a focus on the evolution of revolutionary Advanced Technology such as the Internet of Things, cloud computing, artificial intelligence, augmented reality and 3D printing (Tang et al., 2019; Sindhwani et al., 2022). In this system, the production process is fully automated, and communication is also autonomous. Data and information are

updated on the cloud in real time so that the top official can monitor any information in real time while sitting in the office. The system is fully integrated vertically and horizontally, which significantly helps in improving the efficiency and productivity of the whole system (Chen et al., 2017). Industry 4.0 collects a lot of data through the IoT sensors that is used in the analytics supporting equipment servicing, product quality and sales prediction. In this way, decision-making becomes very easy, and the whole process becomes very efficient and productive.

There has been a lot of positive change in the industry due to the use of cloud computing. The price is also decent because of the availability of cloud solutions and competition in the market. Thus, it is easier and cheaper than conventional data storage methods. Cloud computing is nothing but a simple data storage point. Apart from storage, different companies also provide several web-based tools which make data analysis easy. The user does not require any type of software installation for this web application (Cámara et al., 2015; Namasudra et al., 2017). National cloud service providers create cloud facilities, keeping in mind its use by industry. They also provide knowledge processing engines that can handle big data. Extending knowledge from the collected data and using it in decision-making due to this efficient data, it can improve the service sector supply chain (Singh et al., 2015).

Blockchain technology is also gaining momentum in the supply chain and logistics sector. Blockchain is a digital ledger that stores information in such a way that it becomes impossible to change or hack the information. A blockchain is a chain of blocks that is connected by a hash. This hash is based on cryptography technology that stores the information of previous blocks. Changing any block without changing the subsequent block becomes impossible. Satoshi Nakamoto (a pseudonym) started blockchain, which is used in data privacy, banking and virtual currency such as bitcoin, ethereum. It can also be used for data privacy in industry (Tasatanattakool et al., 2018). Whenever the user makes a new transaction, a verification note is generated, and a new block is added to the blockchain after being verified through predefined rules (Narayanan et al., 2016).

2.3 Recent related studies

Moktadir et al. (2019) reported that Big Data are extensively used in different sectors today. Big Data can help in decision-making within the manufacturing supply chain. But there are many barriers to the implementation of Big Data. In this paper, the author has identified these barriers and analysed them based on their criticality. Data from five Bangladeshi companies were taken for analysis, and the Delphi-based AHP method was used for that analysis. Sensitivity analysis was also done to verify the robustness of the model. Its findings can help researchers and industrial managers to understand the potential barriers in the manufacturing supply chain and their nature. Singh et al. (2020) argued that the worldwide spread of COVID-19 has resulted in all manufacturing and logistic activities being greatly affected. An action plan is proposed in this paper, which tackles the effects of the pandemic on food supply, handling of medicine, grains and medical safety-related items such as PPE

(Personal Protective Equipment) kits and masks, enabling them to reach their consumption points. In this system, trucks and drones can deliver food and grain to high-rise buildings with the help of a synchronisation system. A simulated study of the PDS (Public Distribution System) system has also been done, in which the supply chain was disrupted due to the lack of labour and truck drivers in the pandemic situation. In another study, Choi et al. (2020) found that the service sector has been affected more than the manufacturing sector by the pandemic. A piano class was taken as a case study in this paper, and the study is situated in Hong Kong, a crowded city. The author developed a model with the help of which piano classes can be converted to mobile operations from static operations. In this, a fully-equipped van will accompany the piano to the student's home and serve there. In this model, government institutions at the initial stage will have to provide subsidies in different ways such as fixed cost subsidies and operational cost subsidies. The author has a greater preference for operational cost subsidies. This model will also become financially viable in the long term. The author also discusses the transition of static service operations to mobile service operations. Končar et al. (2020), in their paper, explored setbacks that inhibit the deployment of technologies such as IoT, in an FMCG company located in the Western Balkan region in a pandemic situation. They analysed the setbacks and found that the supply system should be less dependent on humans. IoT should not only be engaged in logistics but also in all production and service operations. It is not easy to predict such type of pandemic situation and its economic impact; so, FMCG companies should also change their philosophy and promote digitisation. Biswas et al. (2020) pointed out that Coronavirus had a profound effect on the supply chain, and the supply of most products was stalled, whether raw materials or finished products. Food supplies, medicines and essential everyday items were also affected. Due to the manufacturing sector being affected, the cost of essential items also increased. In such a situation, it becomes necessary to revive the manufacturing supply chain. In this paper, the author has identified the barriers in the Indian manufacturing supply chain. The author also proposes a method for pairwise comparison based on the fuzzy AHP method. Al-Talib et al. (2020) studied how IoT helps in achieving resilience in the supply chain. They found that 'visibility', 'flexibility', 'control' and 'collaboration' are key attributes of supply chain resilience and these can be effectively achieved by the adoption of IoT technologies in supply chains. Golan et al. (2020) carried out a systematic literature review of resilience analytics in supply chain modelling in the context of the COVID-19 pandemic. They found that, although there are numerous studies related to supply chain resilience, there is a dearth of studies related to the uncertainty arising from the threats of conditions arising out of 'unknown unknowns' like COVID-19. More emphasis is required on this context. Marusak et al. (2021) studied resilient food supply chains in the United States in the context of COVID-19, using a case study approach to identify how the food supply chain in regional parts of the US can improve its resilience during the time of pandemic. The results indicate that the adoption of new innovative distribution and logistics strategies along with collaboration among food supply chain partners and proper communication and information sharing helped the regional food supply chains to improve their resilience. Sharma et al.

(2021) studied resilient strategies to mitigate the long-term effects of the pandemic on retail supply chains. The study utilised a full consistency model and best-worst method (BWM) for the analysis. The study identified that efficient collaboration among stakeholders is the most important criterion for enhancing the performance of the retail supply chain and also determined that digitisation of the supply chain along with order fulfilment are the most important resilient strategies for overcoming the long-term effects of the pandemic.

2.4 Research gap and highlights

As soon as the pandemic broke out, the attention of many scholars was drawn to this and they researched the impact of the pandemic on supply chains and logistics. For example, some research papers focus on the impact of the pandemic on logistics and discuss the commercial aspect of the supply chain (for example, Choi et al., 2020; Queiroz et al., 2020; Wiley, 2020; Haren & Simchi-Levi, 2020). Choi (2020) analysed the model of logistics for mobile service operation during the Coronavirus outbreak. Ivanov (2020) developed a model of a viable supply chain (VSC), which focused on the redesign of the structure of the supply chain and planning economic performance. Biswas et al. (2020) found barriers to supply chain management in the manufacturing sector and also discussed the impact of COVID-19. Not only scholars, but many industry experts have also done research work and published reports on this topic. Singh et al. (2020) discussed the ways and technologies that can quickly help overcome the effects of the pandemic. Marusak et al. (2021) discussed the resilient food supply chain in the US. Sharma et al. (2021) discussed resilient strategies to mitigate the effects of the pandemic. Deloitte (2020) discussed the short-term plan for supply chain disruption due to the pandemic and also discussed how to mitigate the effect of a pandemic. Forbes (2020) studied the impact of the pandemic on the global automotive supply chain and mainly discussed the effect of Chinese industries on the global supply chain. Dubey et al. (2020) published a report mainly focused on the application of blockchain on supply chain transparency, but did not work on other technical aspects such as the IOT, cloud computing, AI and AR. DNB (2020) is an analytics firm that published a report on the impact of Coronavirus and how industries should mitigate the risk and further disruption to business. WEF (World Economic Forum) published an article on past instances and compared these with the current pandemic situation (WEF, 2020a) and suggested how to recover from the current situation. WEF also published many other articles and discussed the impact of Coronavirus on the supply chain and logistics (WEF, 2020b). The Institute for Supply Chain Management discussed the impact of a pandemic on supply chain ISM (2020).

From the above discussion, it is clear that the majority of studies focused on the impact of a pandemic on supply chains and logistics, and some of the research proposed revival strategies to address it. Other studies focused on finding the barriers to supply chain management. No one has conducted a study of the barriers to supply chain logistic resilience improvement in terms of technological transformation, or found strategies to address it and help to establish a resilient logistics system. These innovative technologies can solve the

issues arising due to the pandemic in organisations (Golan et al., 2020). Thus it becomes clear that we can use the new technology to build a resilient logistics environment. In this paper, we are integrating technology and supply chain logistics to propose the idea of a resilient logistics system during the pandemic. We study different barriers to technological transformation in the logistics system and try to find a strategy to deal with such barriers.

3. Research Methodology

A multi-case study methodology is utilised in this study. The Bayesian best-worst method (BBWM) is used to prioritise the barriers and strategies for innovative technologies.

3.1 The Bayesian Best-Worst Method (BBWM)

As mentioned above, BBWM is used to prioritise the barriers and strategies for innovative technologies. The simple BWM is comparable to the Analytical Hierarchy Process (AHP) in that it uses the same 9-point scale for pairwise comparison among the criteria, and calculation of criteria weights. However, BWM first identifies the best and worst criteria among the set of criteria, and then performs comparisons among the best-to-others and others-to-worst criteria. It is also better than AHP in that it provides more consistent results using fewer pairwise comparisons than are required for AHP (Rezaei, 2015). Over time, BWM has gained importance among researchers across the world, and more and more researchers have started applying BWM in their works. Some important studies mentioning applications of BWM include Gupta and Barua (2017) on green innovation supplier selection, Kheybari et al. (2019) on bioethanol facility selection, Malek and Desai (2019) on sustainable manufacturing barriers prioritisation, Yadav et al. (2019) on smart cities framework evaluation, Govindan et al. (2020) on barriers to industrial sharing economy analysis, Moktadir et al. (2019) on the analysis of circular economy practices, Kaushik et al. (2020) on online apparel return factors analysis, Orji et al. (2020b) on the analysis of social media success factors for sustainability, and Gupta et al. (2020) on supply chain sustainability innovation-related barriers and their mitigation strategies. Mohammadi and Rezaei (2020) proposed BBWM for determining group weights on the basis of statistical probability distribution. Steps for BWM are listed below:

Step 1: Select relevant criteria for the study.

Step 2: Once the criteria are finalised, choose, from amongst the main and sub-criteria, the best and worst criteria.

Step 3: The next step is to get a rating of the best criterion over all other criteria. For this purpose, a scale of 1 to 9 is used. This will result in vector $A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$.

Step 4: Similarly, the next step is to obtain ratings of all other criteria with the worst criterion. All the experts are required to follow steps 3 and 4. This will also result in vector $A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T$.

Step 5: Next is to obtain optimised weights $(w_1^*, w_2^*, \dots, w_n^*)$ for all the criteria.

The A_B and A_W vectors mentioned above can be converted into a multinomial probability distribution. The probability mass density function of a multinomial distribution of A_W can be written as

$$P(A_W|w) = \frac{(\sum_{j=1}^n a_{jw})!}{\prod_{j=1}^n a_{jw}!} \prod_{j=1}^n w_j^{a_{jw}} \quad (1)$$

where the probability distribution is represented by w . The number of experiments has a direct impact on the probability of event j as per the multinomial distribution:

$$w_j \propto \frac{a_{jw}}{\sum_{i=1}^n a_{iw}}, \forall j = 1, \dots, n. \quad (2)$$

In a similar manner, the worst criterion equation can be obtained as

$$w_W \propto \frac{a_{WW}}{\sum_{i=1}^n a_{iw}} = \frac{1}{\sum_{i=1}^n a_{iw}} \quad (3)$$

Combining Equations (2) and (3), one can obtain the following:

$$\frac{w_j}{w_W} \propto a_{jw}, \forall j = 1, \dots, n. \quad (4)$$

Equation (4) is similar to the concept followed in the original BWM.

Similar to the above, the multinomial distribution can be used to model A_B . However, the vectors A_B and A_W are different from each other, as the former is a vector representation of the best-to-other criteria and A_W is a representation of the other-to-worst criteria. Thus, A_B can be denoted as the inverse of the earlier weight as follows:

$$A_B \sim \text{multinomial}(1/w) \quad (5)$$

which can be further written as

$$\begin{aligned} \frac{1}{w_j} &\propto \frac{a_{Bj}}{\sum_{i=1}^n a_{Bi}}, \frac{1}{w_B} \propto \frac{a_{BB}}{\sum_{i=1}^n a_{Bi}} = \frac{1}{\sum_{i=1}^n a_{Bi}} \\ \Rightarrow \frac{w_B}{w_j} &\propto a_{Bj}, \quad \forall j = 1, \dots, n, \end{aligned} \quad (6)$$

The weight vector can now be determined using the statistical distribution, provided it satisfies a non-negative constraint and sums to one property. The Dirichlet distribution can be used for the same as mentioned below

$$\text{Dir}(w|\alpha) = \frac{1}{B(\alpha)} \prod_{j=1}^n w_j^{\alpha_j - 1} \quad (7)$$

Next, BBWM is used instead of the maximum likelihood method for approximating the parameters. The posterior distribution model can be represented as below:

$$\begin{aligned} \mu_j &= \frac{\alpha_{post_j} - 1}{\sum_{i=1}^n \alpha_{post_i} - n} \\ &= \frac{1 + a_{jw} - 1}{\sum_{i=1}^n (a_{iw} + 1) - n} \\ &= \frac{a_{jw}}{\sum_{i=1}^n a_{iw}}, \forall j = 1, \dots, n. \end{aligned} \quad (8)$$

The next step is to estimate the joint probability distribution for vectors A_B and A_W for group decision-making.

Let us assume that we have k decision makers and n criteria; w^k represents the individual optimal weight related to each expert, w^{agg} represents the group weight, $A_B^{1:K}$ a vector indicating all experts' best-to-other criteria evaluation, and $A_W^{1:K}$ represents a vector indicating all experts' other-to-worst criteria evaluation. The joint probability distribution for group decision-making can be represented as

$$P(w^{agg}, w^{1:K} | A_B^{1:K}, A_W^{1:K}) \quad (9)$$

The following marginal probability rule can be used to obtain the individual probability of any arbitrary variables x and y as

$$P(x) = \sum_y P(x, y) \quad (10)$$

The next step is the development of the Bayesian hierarchy model. This is based on the iterative method, which means that the A_B^K and A_W^K vectors will generate weight w^K after each expert's evaluation, which, in turn, will generate the optimal group weight w^{agg} . This indicates that there is conditional independence between variables. Thus, the joint probability of the Bayesian model considering conditional independence can be represented as

$$\begin{aligned} P(w^{agg}, w^{1:K} | A_B^{1:K}, A_W^{1:K}) &\propto P(A_B^{1:K}, A_W^{1:K} | w^{agg}, w^{1:K}) P(w^{agg}, w^{1:K}) \\ &= P(w^{agg}) \prod_{k=1}^K P(A_W^k | w^k) P(A_B^k | w^k) P(w^k | w^{agg}) \end{aligned} \quad (11)$$

The next step is to specify the distributions of each element. The above elements can also be specified as a multinomial distribution as per the inferences drawn in Equations (2) –(8).

$$\begin{aligned} A_B^k | w^k &\sim \text{multinomial}(1/w^k), \quad \forall k = 1, \dots, K, \\ A_W^k | w^k &\sim \text{multinomial}(w^k), \quad \forall k = 1, \dots, K. \end{aligned} \quad (12)$$

Here, w^K and w^{agg} can be modelled as a Dirichlet distribution as

$$w^k | w^{agg} \sim \text{Dir}(\gamma \times w^{agg}), \quad \forall k = 1, \dots, K, \quad (13)$$

where w^{agg} is the average of the distribution and γ is the concentration parameter.

The concentration parameter can be modelled using a gamma distribution to satisfy the non-negativity constraints.

$$\gamma \sim \text{gamma}(a, b) \quad (14)$$

Finally, the Dirichlet distribution is used to model the optimal weight w^{agg} as

$$w^{agg} \sim \text{Dir}(\alpha) \quad (15)$$

Here $\alpha = 1$.

Once all the parameters have been represented with their probability distributions, Markov Chain Monte Carlo (MCMC) simulation is used to solve the posterior distribution and thus obtain the group optimal weight w^{agg} based on expert preference ratings.

The next step is the ranking confidence test. Here, credal ranking is used to determine the confidence of the consistency of group weights. Thus, the probability that a criterion c_i is better than c_j will be

$$P(c_i > c_j) = \int I(w_i^{agg} > w_j^{agg}) P(w^{agg}) \quad (16)$$

Here, $P(w^{agg})$ is the posterior distribution of w^{agg} . I will be 1 if the condition $(w_i^{agg} > w_j^{agg})$ holds, otherwise it will be 0. Q samples obtained by MCMC will be used for calculating the confidence as

$$P(c_i > c_j) = \frac{1}{Q} \sum_{q=1}^Q I(w_i^{aggq} > w_j^{aggq})$$

$$P(c_j > c_i) = \frac{1}{Q} \sum_{q=1}^Q I(w_j^{aggq} > w_i^{aggq}) \quad (17)$$

where the q^{th} sample of w^{agg} obtained from MCMC is represented as w^{aggq} . When $P(c_i > c_j) > 0.5$, it represents that criterion i is more significant than criterion j , and the confidence is represented by the corresponding probability. Also, the total probability should be equal to 1, i.e., $P(c_i > c_j) + P(c_j > c_i) = 1$.

The additive value function given by (Keeney and Raiffa, 1976) is used to evaluate alternatives.

$$V_i = \sum_{j=1}^n w_j n_{ij} \quad (18)$$

where i is the index of any alternative, n_{ij} is the normalised score of the alternative i with respect to criterion j . The value of n_{ij} can be calculated by using expressions (19) and (20), where Equation (19) is used when the criterion value is supposed to increase and we label it as a profit or positive criterion, and Equation (20) is used when criteria value is supposed to decrease and it is labelled as a cost or negative criterion.

$$n_{ij} = \frac{y_{ij}}{\sum_i y_{ij}} \text{ for all } j \quad (19)$$

$$n_{ij} = \frac{\frac{1}{y_{ij}}}{\sum_i \frac{1}{y_{ij}}} \text{ for all } j \quad (20)$$

where y_{ij} is the actual score of alternative i with respect to criterion j .

4. Case analysis

4.1. Information related to experts and about the case

With the aim of achieving the objectives, twelve different experts with similar or related profiles, but from different organisations, were selected. The experts involved in the study have different levels of experience, with a minimum of 10 years' experience. We deliberately included experts from different backgrounds in our study to make the result more homogeneous and generalisable for the organisation and for different industrial contexts. The information on these twelve experts is provided in Table 1.

4.2. Identification of barriers to innovative digitalisation

In this phase of the study, the authors identified the 22 barriers from the literature and presented these barriers to the experts for their opinions and suggestions regarding the addition or elimination of any barrier. The experts agreed with the 22 identified barriers and found them relevant for our study. After that, these barriers were categorised and put into 5 main categories, namely: Technological, Organisational, Economic and Financial, Cultural, and Regulatory and Institutional barriers. The final list of barriers categorised into these 5 main categories is presented in Table 2.

4.3. Strategies for overcoming barriers to innovative digitalisation

This pandemic has exposed the weaknesses of the classical logistics system, and it made us think again about how we can use innovative technology to create a better logistics system. As discussed above, there are many barriers to the implementation of these innovative technologies, so it is essential further that we find strategies to overcome these barriers. Each barrier is quite complicated and different from the others, and they cannot be tackled with only one strategy, so we need more than one strategy to overcome them all. After an in-depth literature review, we made a list of nine crucial strategies to overcome the barriers to innovative digitalisation, as shown in Table 3.

In the next step, we ranked the barriers using the Bayesian BWM methodology. We asked each expert to select one best and one worst barrier for the main category and all sub-categories. After this, we asked the experts to rate the best-to-others and others-to-worst barriers on a scale of 1–9 for the main category and all sub-categories. We consolidated all the expert pairwise comparison sheets and made a Table (Table 4). The pairwise ratings for all the sub-category barriers are given in Appendix A (Tables A1–A5).

In the next step, we calculated the weight of the main category barriers and all sub-category barriers by using the Bayesian BWM methodology with the help of pairwise rating sheets. We then calculated their global weight. The weight of a main category barrier becomes its global weight, whereas, in order to calculate the global weight of a barrier in a sub-category, the local weight of that barrier in the sub-category has to be multiplied with the weight of the barrier of the respective main category. The global weights of all the main- and sub-category barriers are presented in Table 5. After identifying the strategy, we need to analyse

the strategy's impact on the barrier. Every strategy was analysed with the main-category and all sub-category barriers. Rating of the strategies on a Likert scale of 1–9, corresponding to their power to resolve the respective barrier, was required. So, we asked the experts to rate the strategy for the main-category and all sub-category barriers, where 1 means very low, and 9 means very high. The rated strategies are presented in Table A6 attached in the Appendix. We collected the ratings from all 12 experts and extracted the average using Equation (19), and then found the normalised value (U_{ij}) of the score using Equation (4). We obtained the V_{ij} value for all strategies by multiplying U_{ij} with the global weight of the main criterion corresponding to every barrier. To obtain the V_i value of the strategy, we added the V_{ij} value of all barriers for each strategy within the main category using Equation (18).

The V_i values and the corresponding ranks are displayed in Table 6 for the main category and also all sub-categories.

5. Results

In the classical BWM method, we use two criteria to determine the confidence superiority, whereas with the Bayesian BWM the concept of credal ranking is introduced, which gives the confidence of each credal ranking. When this principle is applied to a real-world scenario, the confidence superiority between different pairs of criteria can be determined.

As shown in Figure 1, "Technological Barriers" prove to be the most important of all the main criteria barriers. This is due to the fact that, in the implementation of innovative technologies in logistics, the technological barrier plays a major role. Although "Technological Barriers" is considered more important than the other four criteria, a confidence of 0.76 between it and the "Economic Barriers" shows that a few experts believe "Economic Barriers" to be more important. Other than that, all experts believe technological barriers to be more important than the other three barriers, with a confidence of 1. Similarly, "Organisational Barriers" is considered more important than "Cultural Barriers" and "Regulatory & Institutional Barriers", but the confidence of 0.99 between "Cultural Barriers" and "Regulatory & Institutional Barriers" shows that some experts believe "Social & Cultural Barriers" to be more important than "Regulatory & Institutional Barriers".

The credal ranking of the main criteria and all sub-criteria along with their confidence is shown in Figures 1–6.

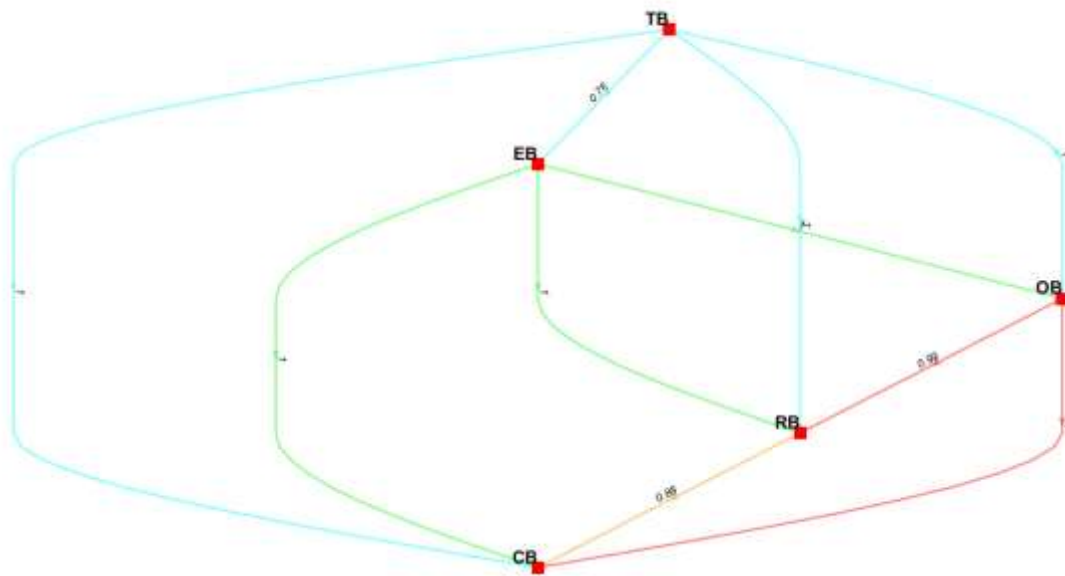


Figure 1 Main criteria barrier credal ranking

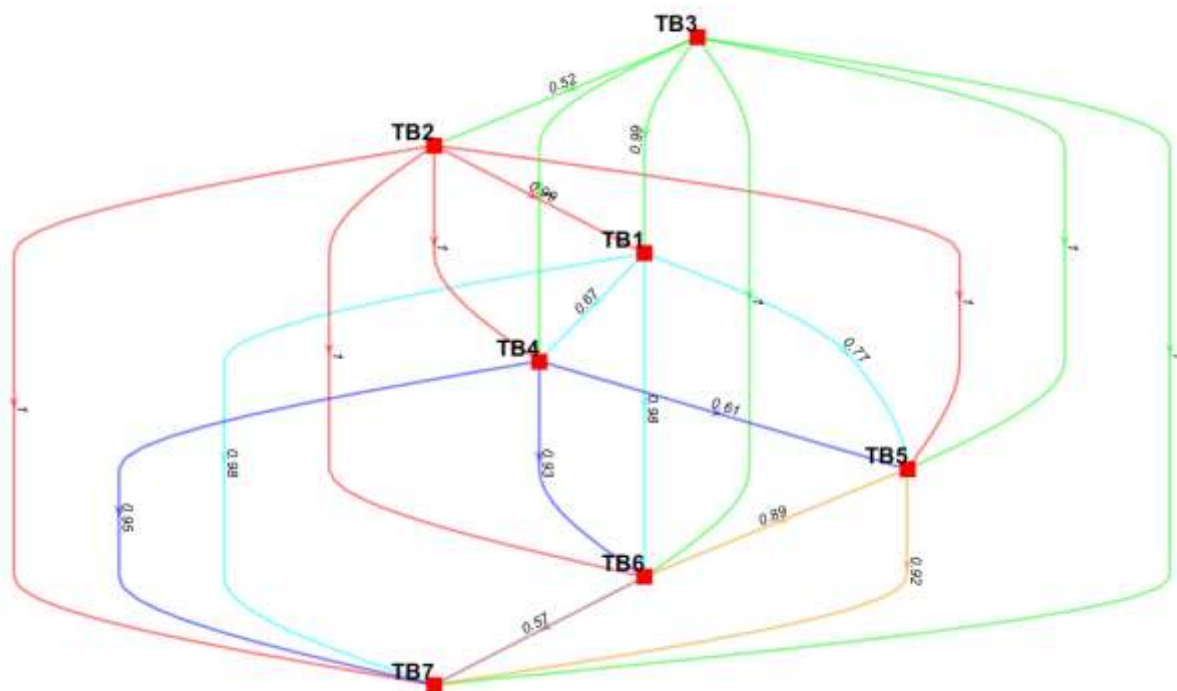


Figure 2 Technological credal ranking

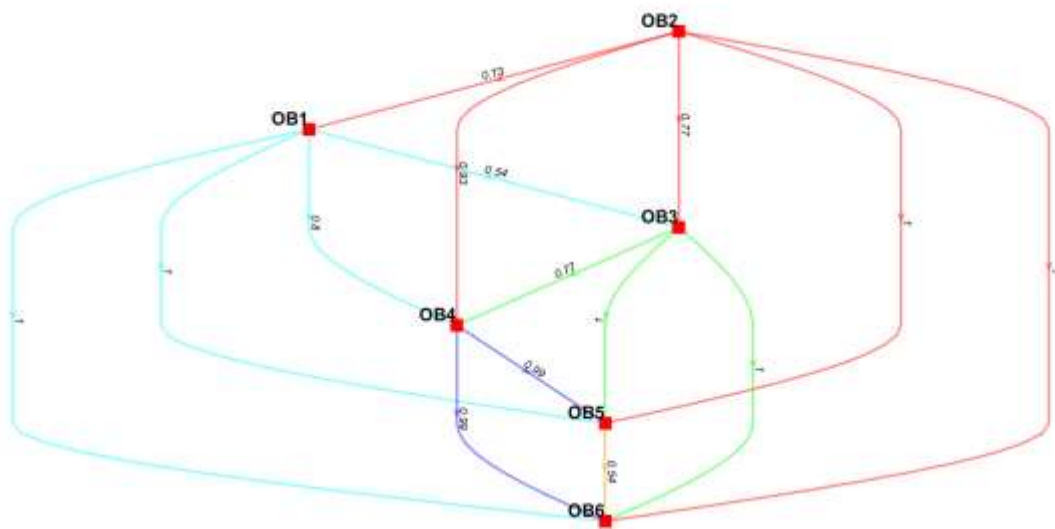


Figure 3 Organisational barriers credal ranking

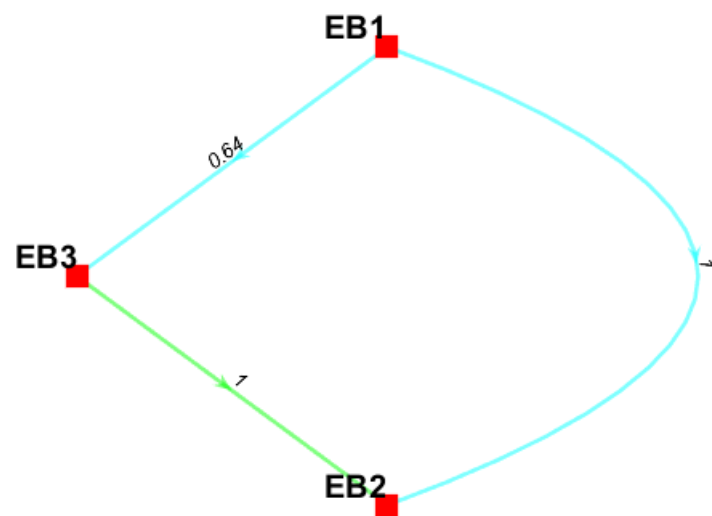


Figure 4 Economic and financial barriers credal ranking

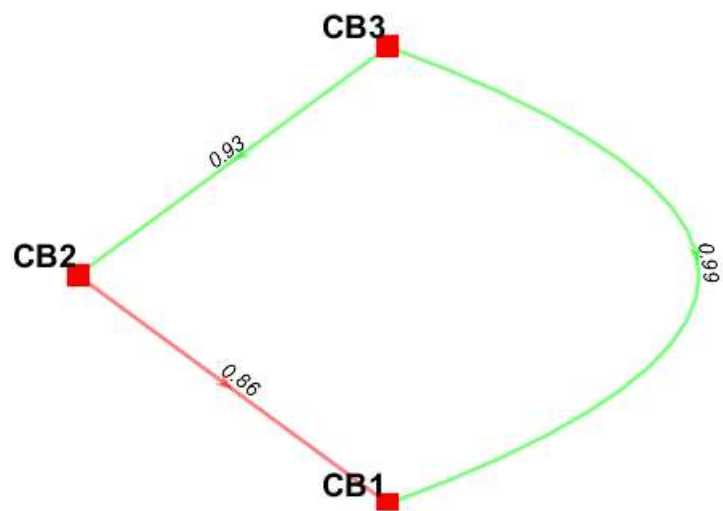


Figure 5 Cultural barriers credal ranking

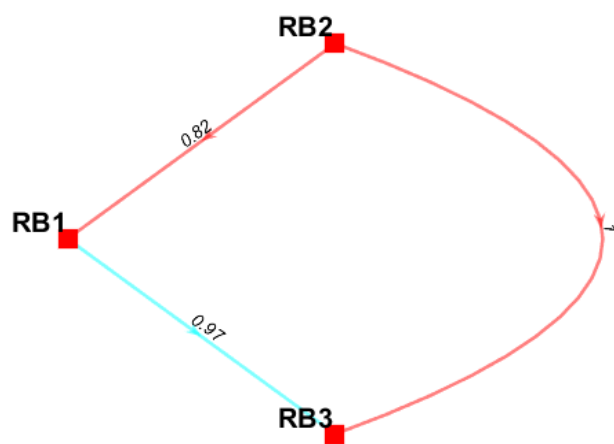


Figure 6 Regulatory and institutional barriers credal ranking

Table 1. Details of respondents.

Expert	Expertise	Experience (Years)	Education	Industry/Organisation
Expert-1	Manager- Operations	11	M.Tech	Food
Expert-2	Analyst	12	M.Tech	Automobile
Expert-3	Manager- Operations	11	MBA	Manufacturing
Expert-4	Asst. Manager- Operations	10	MBA	Steel
Expert-5	Manager- Operations	12	MBA	Power
Expert-6	Asst. Manager- Process Control	10	B.Tech.	Steel
Expert-7	Deputy Manager- Operations	10	BE.	Steel
Expert-8	Asst. Manager- Operations	10	B.Tech.	Steel
Expert-9	Data Scientist	11	M.Tech	Core Compete
Expert-10	Manager - Logistics and Supply Chain Management	11	MBA	Logistics
Expert-11	Asst. Manager- Operations	12	B.Tech.	Steel
Expert-12	Senior Manager - Procurement	13	B.Tech.	Automobile

Table 2. Barriers to innovative digitalisation in logistics.

Main Category	Barriers	Description	References
Technological barriers (TB)	The need for unique, faster, and cheap identification process	Many items going from origin to the consumption point and their receiving, storing, and sorting should be done quickly and with highly accurate unique identifications.	Miorandi et al., 2012; Azevedo et al., 2012; Karakostas, 2013; Ginters et al., 2013; Tadejko, 2015; Stoltz et al., 2017.
	Lack of IT infrastructure	IT infrastructure (hardware, software, and network) needs to be improved to support technological	Trelles et al., 2011; Malaka & Brown, 2015; Alharthi et al., 2017; Kankanhalli et al., 2019; Moktadir et al., 2019;

	transformation in the industries, which will improve the resilience of logistics during pandemic situations when information and instructions are transferred through the IT network.	Sharma et al., 2020; Idwan et al., 2020.
Inadequate internet connectivity	Internet connectivity is poor in 3 rd tier cities and rural areas, which needs to be addressed for improving real-time data transfer to the cloud visibility across the entire supply chain, and work from home experience. There is less mobility of employees, so we need adequate internet facilities for better connectivity, which is required for resilience during pandemics.	Azevedo et al., 2012; Luthra et al., 2018; Bruneo et al., 2019; Zeb et al., 2019; Sharma et al., 2020; Abdul-Hamid et al., 2020.
Lack of integration among IT networks	During a pandemic, the logistics system relies on automation, which needs integration among IT networks and legacy systems, which is a big issue in implementing IOT and cloud computing in logistics.	Pang et al., 2015; Lokshina et al., 2017; Kamble et al., 2019; Horváth & Szabó, 2019; Deore et al., 2019; Sharma et al., 2020; Abdul-Hamid et al., 2020.
Security and privacy concerns	During a pandemic exchange of information is mostly online, the security	Mukhopadhyay et al., 2014; Richey Jr et al., 2016; Alharthi et al., 2017;

		of this critical information is our prime concern.	Luthra et al., 2018; Sfar et al., 2019; Wirtz et al., 2019; Emami-Naeini et al., 2020.
	Complexity of data	In logistics, a variety of data is generated from different sources, which creates problems with data storage and data integration.	Johnson, 2012; Douglas, 2013; Chen et al., 2015; Alharthi et al., 2017; Luthra et al., 2018; Arunachalam et al., 2018; Moktadir et al., 2019.
	Scalability	For better resilience during a pandemic, scalability is a big issue in adopting artificial intelligence and big data analysis, which are necessary tools for building a scalable logistics model.	Mukhopadhyay et al., 2014; Malaka & Brown, 2015; Richey Jr et al., 2016; Arunachalam et al., 2018; Moktadir et al., 2019; Sharma et al., 2020.
Organisational barriers (OB)	Resistance from employees due to fear of job loss	Digitalisation during a pandemic in the logistics firm requires significantly fewer employees, so there will be layoffs and retained employees who need to learn new skills, which creates uncertainty among employees.	Hoti, 2015; Tomic, 2017; Doan, 2018.
	Lack of technical knowledge/skill	Lack of technical skills hinders the adoption of such complicated technologies to develop a resilient logistics system	Douglas, 2013; Mukhopadhyay et al., 2014; Alharthi et al., 2017; Luthra, et al., 2018;

	during a pandemic situation.	Arunachalam et al., 2018; Orzes et al., 2018; Umachandran et al., 2019; Moktadir et al., 2019.
Lack of training facilities	There are insufficient training facilities to provide a new skill to the employee.	Malaka & Brown, 2015; Moktadir et al., 2019.
Lack of support by top management	A resilient logistics system requires high-level commitment from top-level management for working culture transformation, which is required to implement these technologies.	Orzes et al., 2018; Luthra et al., 2018; Arunachalam et al., 2018; Horváth & Szabó, 2019; Abdul-Hamid et al., 2020.
Need to find a suitable research partner	SMEs lack support from research institutes compared to the large industries, which is required to develop new products/ services and new business models in the digital world to counter pandemic problems and develop a resilient logistics system.	Hall et al., 2001; Issa et al., 2017; Orzes et al., 2018.

	E-waste management	The generation of E-waste from millions of sensors, batteries, and old computers increases day by day, and contains hazardous and toxic materials. For a sustainable and resilient supply chain, it is necessary to adopt a waste management system; organisations face the problem of disposing of E-waste because the workforce is already insufficient during a pandemic situation.	Mukhopadhyay et al., 2014; Sharma et al., 2020; Lofti et al., 2021; Ali et al., 2020; 2021.
Economic and financial barriers (EFB)	The high cost of investment	The cost associated with smart sensors and IOT devices and its implementation plays a significant role in adopting these technologies. The cost of sensors and IOT devices is high during a pandemic because of poor supply chain management between cross-border organisations.	Mukhopadhyay et al., 2014; Al-Momani et al., 2018 Orzes et al., 2018; Moktadir et al., 2019.
	Unclear economic benefit of digital investments	Return on investment is not clearly defined, which discourages investment in these high investment technologies.	Kiel et al., 2017; Marques et al., 2017; Luthra, et al., 2018; Arunachalam et al., 2018; Horváth & Szabó, 2019; Abdul-Hamid et al., 2020.
	Lack of monetary resources	If a pandemic is long-lasting, it leads to economic crises among small and medium	Hoti, 2015; Erol et al., 2016; Luthra et al., 2018; Doan, 2018;

		enterprises, as the implementation of new technologies requires immense financial resources.	Moktadir et al., 2019; Horváth & Szabó, 2019.
Cultural barriers (CB)	Lack of trust among partners	Trust among the partners is necessary for critical information sharing and buying on credit without any fear of misuse of data they entrust to each other; trust leads to a seamless flow of data and items from suppliers to customers during pandemic situations, which makes a resilient supply chain.	Kwon & Suh., 2004; Ustundag et al., 2017; Orzes et al., 2018; Nagy et al., 2018.
	Lack of support from supplier/ customer	Supplier/customer needs to be ready to support new systems and improve coordination and communication among partners and suppliers for better performance during a pandemic.	Ngai et al., 2014; Yazdani et al., 2017; Orzes et al., 2018; Horváth & Szabó, 2019.
	Acceptance of new technologies	Acceptance of wearable devices such as cameras and microphones is a big concern for employees due to privacy and confidentiality issues.	Stoltz et al., 2017; Ustundag et al., 2017; Al-Momani et al., 2018; Orzes et al., 2018.
Regulatory and institutional barriers (RIB)	Lack of standards and regulation	Standardisation is essential for sharing information among smart devices, and information-sharing plays a crucial role in building smart and resilient supply-chain, smart objects, and	Ustundag et al., 2017; Doan, 2018; Lee, 2018; Nagy et al., 2018; Arunachalam et al., 2018; Orzes et al., 2018; Horváth & Szabó, 2019;

	environments. Integration between smart devices is difficult because each country has different rules and regulations.	Sharma et al., 2020; Abdul-Hamid et al., 2020.
Lack of financial supports in govt policies.	During a pandemic, financial crises faced by the organisation, along with the lack of incentives by the government and professional organisations to promote the adoption of new technologies in logistics, create a double setback for the organisation.	Ustundag et al., 2017; BRICS Business Council, 2017; Luthra et al., 2018; Nagy et al., 2018; Gupta et al., 2020; Emami-Naeini et al., 2020.
Lack of rewards and recognition	Rewards and recognition motivate the employee to perform well in pandemic type difficult situations.	Luthra et al., 2016; Kouhizadeh et al., 2020.

Table 3. Strategies for achieving innovative digitalisation in logistics.

Strategy	Description
Focus on research, development, and innovation (S1)	These strategies are essential for achieving a resilient logistics system during a pandemic situation. They also help with cost reduction of technological equipment, improvement of system effectiveness, and improvement of the deliverable product and services.
Provide financial support (S2)	During a pandemic situation, small businesses face economic crises. So big organisations in the supply chain should provide monetary support to small stakeholders such as suppliers and retailers for adopting these technologies to overcome the financial problems and develop trust and relationships, which is most important for building a resilient supply chain.

Enhance training facilities and conduct awareness programs (S3)	Provide training to employees to understand these technologies and organise seminars and awareness programs to think about new technologies that can help build a resilient logistics system, and impart awareness and knowledge from top-level management to lower-level management.
Enhance security and privacy (S4)	Cyber-attacks have risen during COVID-19 (ISACA Survey), so improved security and privacy are needed by using new era technology such as blockchain and artificial intelligence. This also builds confidence among customers and suppliers to use technology-driven logistics systems.
Automation strategy (S5)	There is a lack of skilled workforce during a pandemic situation, so replacing the workforce by robots can help tackle this situation and increase the precision and accuracy of the processes involved in logistics like the sorting and loading of packages.
Adoption of new and alternative technology (S6)	The adoption of new technology is very critical. Under this strategy, the cost of adopting new technology and its alternatives needs to be analysed. Also, there is a need to check the scalability and feasibility of that technology.
Create or hire an organisation to monitor the complete supply chain (S7)	Several types of problems arise, such as trust and relationship problems, financial problems, and credit dispute problems during a pandemic. Such an organisation can solve the problems between different stakeholders and create a system under which all stakeholders operate seamlessly. If any concern arises, stakeholders may approach this organisation for support.
Use satellite internet access (S8)	Internet connectivity is poor in remote areas, so we can use satellite internet access, which can also help during natural disasters such as floods, earthquakes, and tsunamis.
Collaboration with technical institutes (S9)	Several new industrial problems arise during a pandemic, so technical institutes can also support research and innovation as per the industry requirements. This is also a crucial strategy for training young minds and developing relevant skills required by the industry.

Table 4. Pairwise comparison for main category barriers.

Best-to-others for 12 respondents.

	Best to others	TB	OB	EFB	CB	RIB
Expert-1	TB	1	6	2	9	5
Expert-2	TB	1	9	2	6	7
Expert-3	TB	1	6	2	7	9
Expert-4	EFB	3	4	1	9	7
Expert-5	EFB	2	3	1	8	9
Expert-6	TB	1	6	2	9	4
Expert-7	TB	1	7	3	9	5
Expert-8	TB	1	5	2	9	4
Expert-9	EFB	2	4	1	9	7
Expert-10	TB	1	4	3	9	7
Expert-11	OB	5	1	3	6	9
Expert-12	TB	1	4	2	6	9

Others-to-worst

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Expert 11	Expert 12
Experts→ Worst Criterion →	CB	OB	RIB	CB	RIB	CB	CB	CB	CB	CB	RIB	RIB
TB	9	9	9	7	8	9	9	9	8	9	3	9
OB	3	1	4	5	7	3	3	4	5	5	9	5
EFB	8	8	8	9	9	7	6	7	9	5	6	7
CB	1	3	3	1	2	1	1	1	1	1	2	3
RIB	4	2	1	2	1	5	4	5	3	2	1	1

Table 5. Criteria weights and rankings of the barriers.

Main Criteria	Main Criteria Weight	Sub-criteria	Sub-criteria Local Weights	Sub-criteria Global Weights	Ranks
Technological barriers	0.344	TB1	0.137	0.047	6
		TB2	0.216	0.074	4
		TB3	0.218	0.075	3
		TB4	0.126	0.043	8
		TB5	0.119	0.041	9
		TB6	0.092	0.031	13
		TB7	0.088	0.030	16
Organisational barriers	0.157	OB1	0.201	0.031	14
		OB2	0.22	0.035	12
		OB3	0.197	0.031	15
		OB4	0.170	0.026	17
		OB5	0.103	0.016	21
		OB6	0.100	0.015	22
Economic and financial barriers	0.310	EFB1	0.431	0.134	1
		EFB2	0.170	0.053	5
		EFB3	0.397	0.123	2
Cultural barriers	0.084	CB1	0.224	0.018	20
		CB2	0.307	0.025	18
		CB3	0.467	0.039	10
Regulatory and institutional barriers	0.103	RIB1	0.352	0.036	11
		RIB2	0.445	0.045	7
		RIB3	0.202	0.020	19

Table 6. Ranking of strategies.

Strategies	Main Category Barriers		Technological Barriers		Organisational Barriers		Economic Barriers		Cultural Barriers		Institutional Barriers	
	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank
S1	0.120	2	0.049	1	0.016	7	0.034	5	0.007	8	0.012	2
S2	0.127	1	0.042	3	0.019	2	0.049	1	0.009	6	0.012	4
S3	0.110	6	0.030	7	0.023	1	0.033	7	0.013	1	0.011	7
S4	0.107	7	0.029	8	0.016	8	0.035	4	0.011	2	0.012	3
S5	0.096	9	0.042	4	0.018	4	0.025	9	0.008	7	0.010	9
S6	0.112	4	0.047	2	0.016	6	0.038	2	0.010	4	0.010	8
S7	0.105	8	0.025	9	0.017	5	0.034	6	0.011	3	0.011	5
S8	0.111	5	0.040	6	0.013	9	0.026	8	0.006	9	0.011	6
S9	0.112	3	0.041	5	0.019	3	0.036	3	0.009	5	0.014	1

6 Discussion of results related to barriers and identified strategies

6.1. Discussion of the ranking of the barriers

In this study, after an in-depth literature review, the first barrier was identified, and the second strategy that tackles barriers to the implementation of innovative technologies was also identified. Subsequently, the responses concerning the barrier and the strategy were separately analysed, based on discussions with supply chain and logistics experts. The barriers were analysed with the help of the Bayesian BWM methodology, and the results are presented in Table 5.

After analysis, it becomes clear that the technological barrier (TB) is a very significant one for implementation of the new innovative technologies that can make supply chain logistics more resilient and minimise the hindrances caused by the pandemic. It is often seen in developing countries that the technological barrier becomes very important as technology penetration and implementation cannot be achieved easily (Zemin, 2008). The lack of IT infrastructure is also a massive problem in a developing country, hindering the implementation of new technology (Sharma et al., 2020; Hald and Coslugeanu, 2021). Technology reduces operational costs and also increases the delivery performance and customer satisfaction levels, making the company more competitive in terms of cost, quality, delivery and flexibility (Ramachandran et al., 2015). The technological factor plays a significant role, perhaps because the unique identification made possible by devices improves the tracking and location of items (Tadejko, 2015; Shen et al., 2020). An enormous amount of data can be used for forecasting future sales and customer behaviour. Interconnected devices reduce human work, which ultimately reduces causes of damage due to direct human intervention. Compatibility with other hardware and software enhances usability (Abdul-Hamid et al., 2020). The faster and cheaper identification process reduces costs incurred by the company. These things ultimately affect the adoption of these new technologies. The data provided by a person or firm when placing an order contains sensitive information like the name of the consumer, address, and bank details. The information given by the consumer can be used for tracking the user and monitoring the purchase behaviour (Doan, 2018). The use of consumer data without the consent of the consumer comes under

the privacy issue (Miorandi et al., 2012). This becomes a core issue when data analytics tools are used to infer knowledge about the customer and create a digital picture of the customer without the customer knowing that their private information is being used (Marjani et al., 2017).

As seen in the analysis results list, economic and financial barriers (EFB) are in second place. For many developing countries, these have been significant barriers to the implementation of new technology. The costs associated with sensors, cameras, other digital devices, and the implementation of such technology play a significant role (Al-Momani et al., 2018). A firm or company not only incurs the costs of the sensors and IoT devices and the implementation of these devices, but also incurs the cost of training employees. The initial investment needed for the adoption of IoT is very high (Moktadir et al., 2019), which prevents small and medium-sized organisations implementing such technologies in their firms due to limited funds and resources (Hoti, 2015; Doan, 2018).

Organisational barriers (OB) are also significant because of the lack of training facilities, lack of digital knowledge and lack of awareness of new technologies (Umachandran et al., 2019). The lack of technological skill limits the harnessing of the adopted technology, which ultimately reduces the expected benefit to the organisation. Small firms are reluctant to implement these technologies due to their great complexity, which requires highly skilled professionals. The wages of highly skilled professionals are high, as is the cost of training employees (Doan, 2018). The adoption, implementation and operation or use of these technologies in an organisation requires experienced and knowledgeable professionals (Kamble et al., 2019). Thus, we can say that organisational barriers play an essential role in the adoption and implementation of innovative technology in the organisation.

Among the sub-category barriers, "High cost of investment (EFB1)" emerged as the most critical issue related to the implementation of innovative technologies. These technologies need very high investment as the cameras, goggles, UID chips, IOT devices and sensors used in them are quite expensive (Moktadir et al., 2019). The high cost of investment in these innovative technologies in the initial stage makes it difficult for any SME or small organisation to implement such innovative technologies (Al-Momani et al., 2018). "Lack of monetary resources (EFB3)" also comes out as an essential barrier that needs attention. As discussed above, these technologies require very high-cost investments and huge monetary resources to implement them (Al-Momani et al., 2018). If the pandemic is long-lasting, this can lead to economic crises. Developing countries are very fragile in any financial crisis (Gurtner, 2010), so the financial institutions of a developing country such as NBFCs and banks may find themselves unable to fulfil the financial requirements of the organisation (Moktadir et al., 2019). As concerns "Inadequate internet connectivity (TB3)", this becomes critical in pandemic situations as the mobility of human resources is low, and logistics professionals have to work remotely, so they have the problem of connecting to the shared server without internet connectivity. In rural and remote areas, there is an Internet connectivity problem that hampers the adoption of new and innovative technologies in the field of logistics (Luthra

et al., 2019). The internet is a medium for the sharing of real-time data for the company; if there is poor internet connection, then the company cannot get real-time data and the is not able to derive benefits from the data. The connectivity in remote areas is insufficient, thus reducing the efficiency and productivity of employees (Sharma et al., 2020). To use innovative and new technologies like IOT and cloud computing, we need to have good internet connectivity (Abdul-Hamid et al., 2020). "Lack of IT infrastructure (TB2)" comes out at number four in our study, if we look at this barrier from the impact point of view. Efficient software, a fast network and hardware are needed extensively to implement these new and innovative technologies, but a developing country like India still does not have an IT infrastructure on that scale (Idwan et al., 2020; Sindhvani et al., 2022). These technologies should work in connection with various software packages to utilise the knowledge extracted from the data gathered by the sensors. IoT devices and sensors are used in connection with application software such as WMS, ITS, and TMS used by many companies (Barreto et al., 2017), so we need software and hardware which are compatible with many platforms and devices. "Unclear economic benefit of digital investments (TB2)" is another critical barrier to implementing these innovative technologies (Arunachalam et al., 2018). These technologies require high investments, but exactly when the returns on that investment will materialise, and in which form it will come, are unstructured. For these reasons, investors still avoid investing in these new technologies (Luthra et al., 2018).

6.2. Discussion of the strategies

The second phase of the analysis is a strategic analysis to overcome the barriers to the implementation of these new innovative technologies. The strategic analysis suggests that no single strategy alone can overcome these barriers. This becomes clear by looking at the total weight of each study (see Table 6 for these results). To overcome the main category barriers (overall barrier) "Provide financial support (ST2)" emerges as the most crucial strategy for tackling the main category barriers. "Technological barriers (TB)" and "Economic and financial barriers (EFB)" are the top two barriers in the main category and "Provide financial support (ST2)" can be the most useful strategy for overcoming these barriers. If a small organisation is given financial support from the bank and NBFCs, then it will be able to improve its research and development. This funding can help to further reduce the technological and economic barriers. The organisation can also build its IT infrastructure. Focusing on research, development, and innovation (ST1) also helps to improve the research work to implement these technologies.

To overcome the technological barriers (TB), an essential strategy emerges to be "Focus on research, development and innovation (ST1)". Research development can improve the use of inexpensive and fast identification chips such as inkjet-printed chips. It can also solve problems such as internet connectivity through innovations; a project like Sterling can revolutionise this field. Further modification of the blockchain technology through

innovation can be used to strengthen data security and privacy and avoid data breaches. "Adoption of new and alternative technology (ST6)" strategies also help to overcome the technological barriers. These technologies are quite new so there is not much exploration of these technologies; if a chip or device is too expensive, then we can explore secondary alternatives.

For overcoming organisational barriers (OB), the most crucial strategy proves to be to "Enhance training facilities and conduct awareness programs (ST3)", because these technologies are very complex and the adoption of such technology is not easy for a company if there are no employees who can understand it. For overcoming economic and financial barriers (EFB), providing financial support (ST2) emerges as the most important strategy. Financial support from governments to various logistics and manufacturing organisations can help build resilience and also help them build innovative digital technologies so that these organisations can better cope with pandemic and other disruptions.

7 Implications

7.1 Managerial implications

The study has some significant implications for organisations and their managers in their adoption of digitisation technologies in the supply chain and logistics sector for resilience. Logistics and supply chain organisations often face uncertainties due to the disruptions occurring in this sector, which have been further compounded due to the recent COVID crisis. Organisations are looking to become more resilient to overcome these disruptions. but this is an uphill task for the managers of the organisations, especially in developing countries. They face a lot of challenges and need first of all to overcome the economic and financial challenges in adopting digitisation technologies for building resilience. Implementing digitisation technologies requires a high initial investment and many organisations lack the necessary monetary resources. Managers of these organisations need to focus on acquiring funds from government and other regulatory bodies for digitisation of their supply chains, and large organisations in the chain should provide monetary support to small stakeholders such as suppliers and retailers for adopting these technologies to overcome the financial problems and develop trust and relationships, which is most important for building a resilient supply chain. Collaboration with technical institutes is also necessary for developing low-cost digitisation technologies for the supply chain and logistics sector. Technology complexity and non-availability is also a major challenge for the managers of these organisations to adopt digitisation technologies for resilience. Often the technology is complex and not easily understandable or is simply not available. Managers need to focus on providing training for their employees related to these digitisation technologies and also to seek technological support from other larger industries or regulatory bodies. Large organisations in the supply chain again have their role in providing technological support to the other supply chain partners for the adoption of digitisation technologies for supply chain

and logistics resilience. In a broader sense, organisations need to focus more on providing financial support, and research & development, for adopting innovative technologies in their domain. Government participation throughout the process is very critical, and they need to provide incentives and other help to encourage it.

7.2 Theoretical and academic implications

The current study has significant theoretical and academic implications also as it tries to fill the gap by providing results related to barriers to the adoption of digitisation technologies for supply chain and logistics resilience. This study identified the challenges to supply chain logistics resilience from the perspective of an emerging economy like India. The major contribution is the identification of 22 challenges related to digitisation for supply chain logistics resilience. This study also contributes with the identification of nine strategies to overcome these challenges. Thus, a comprehensive framework is developed for researchers, policy makers and academics for further study of the challenges to digitisation for resilience in other industry contexts also. Academics and policy makers need to work together to develop policies to facilitate organisations' adoption of digitisation technologies for supply chain and logistics resilience, especially in these times of extreme uncertainty and turbulence.

8 Conclusions and future research directions

The outbreak of the pandemic has completely exposed the weaknesses of the classical logistics system and now requires that the logistics system be reformed. The whole logistics system, especially for organisations operating their logistics in the traditional manner, has been facing numerous challenges during the pandemic. Innovative technologies play an important role in this reform, and without them, reform cannot be achieved. However, these reforms are often inhibited by many challenges, as discussed in the above sections. This study focused first on identifying the barriers/ challenges to the adoption of innovative digitisation technologies and then on identifying and ranking resilient strategies to overcome these challenges. The BBWM methodology was used for the analysis of the barriers and strategies. The results identified technological, economic, and organisational barriers as the most significant barriers to the adoption of innovative digitisation technologies in the logistics sector. Technological and economic barriers are the two major problems. More than one strategy is needed to tackle these barriers and no single strategy is sufficient. In this context, an analysis of resilient strategies with respect to each barrier was carried out for both the main and sub-category barriers. To overcome the major technological and economic barriers, focusing on research, development and innovation, providing financial support, and collaboration with technical institutes are the most important resilient strategies. Enhancing training facilities and conducting awareness programs is essential also since it helps workers and managers to learn technical skills so that they can easily apply these technologies and make them operational. Organisations need to focus more on

research and development of innovative technologies so that these technologies can be adopted through some innovative projects in the context of the logistics sector. Bigger budgets need to be allocated by organisations for innovation, research and development, and the adoption of innovative technologies in order to improve resilience to unknown-unknowns like the current pandemic. Government also needs to pitch in and provide financial as well as other support in terms of incentives to the logistics sector to enable them to become resilient.

As with the other research works, this work also suffers from certain limitations. This study is based on the opinions of experts from the logistics sector as well as government and academics. The sample of experts chosen is limited, but future studies can carry out a statistical analysis of the factors identified using techniques like structural equation modelling. Future studies can also explore the interdependencies among the various barriers to logistics resilience through digitisation. Future studies related to the pandemic can also include other related fields like studying the relationships with respect to inventory management, transportation and the energy sector as well. Studies related to resilience in the logistics sector can include more complex mathematical models like the one discussed by (Khalilpourazari et al., 2019; 2020; 2021a; 2021b; Tirkolaee et al., 2021; Goli et al., 2020; Graczyk-Kucharska et al., 2020). These methodologies can help to develop more strategies for resilient logistics during uncertain times like a pandemic. Future studies can focus on studying the impact of one specific technology like Industry 4.0 or Artificial Intelligence for supply chain logistics and resilience.

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Appendix A

Table-A1

Pairwise comparison for technological barriers

Best to others for 12 respondents

Experts	Best to Others	TB1	TB2	TB3	TB4	TB5	TB6	TB7
Expert-1	TB3	3	2	1	7	5	8	9
Expert-2	TB1	1	7	2	5	3	9	6
Expert-3	TB3	8	6	1	3	4	9	7

Expert-4	TB1	1	6	4	7	3	6	9
Expert-5	TB2	9	1	2	4	5	5	7
Expert-6	TB2	5	1	3	9	7	6	8
Expert-7	TB3	5	2	1	4	8	9	7
Expert-8	TB2	4	1	2	7	6	8	9
Expert-9	TB2	3	1	2	9	4	6	7
Expert-10	TB4	9	3	6	1	7	5	4
Expert-11	TB2	7	1	6	2	9	3	5
Expert-12	TB2	3	1	2	5	6	7	9

Others to the Worst

Experts→	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6	Expert-7	Expert-8	Expert-9	Expert-10	Expert-11	Expert-12
Worst Criterion →	TB7	TB6	TB6	TB7	TB1	TB4	TB6	TB7	TB4	TB1	TB5	TB7
TB1	6	9	2	9	1	4	4	5	7	1	2	7
TB2	7	2	4	3	9	9	8	9	9	5	9	9
TB3	9	8	9	5	8	7	9	8	8	2	3	7
TB4	3	4	6	2	5	1	6	3	1	9	7	4
TB5	4	7	5	7	4	3	2	4	5	2	1	3
TB6	2	1	1	2	4	3	1	2	3	3	5	2
TB7	1	3	3	1	3	2	3	1	3	5	4	1

Table A2

Pairwise comparison for organisational barriers

Best to others for 12 respondents

Experts	Best to Others	OB1	OB2	OB3	OB4	OB5	OB6
Expert-1	OB4	7	2	3	1	8	9
Expert-2	OB2	5	1	3	6	8	9

Expert-3	OB1	1	5	6	3	8	8
Expert-4	OB1	1	5	7	2	9	5
Expert-5	OB3	5	3	1	4	8	9
Expert-6	OB2	7	1	2	9	5	6
Expert-7	OB1	1	4	7	3	6	9
Expert-8	OB1	1	6	7	3	9	5
Expert-9	OB1	1	8	4	5	6	7
Expert-10	OB2	5	1	3	4	7	9
Expert-11	OB2	4	1	2	6	9	7
Expert-12	OB3	6	2	1	9	5	6

Others to the Worst

Experts→	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6	Expert-7	Expert-8	Expert-9	Expert-10	Expert-11	Expert-12
Worst Criterion →	OB6	OB6	OB6	OB5	OB6	OB4	OB6	OB5	OB2	OB6	OB5	OB4
OB1	3	4	9	9	4	3	9	9	9	3	3	3
OB2	8	9	4	3	7	9	5	3	2	9	9	7
OB3	6	7	3	2	9	8	3	2	5	5	7	9
OB4	9	3	7	8	5	1	6	6	4	5	3	1
OB5	2	2	2	1	2	4	4	1	3	2	1	4
OB6	1	1	1	4	1	3	1	4	3	1	2	3

Table A3

Pairwise comparison for economical barriers

Best to others for 12 respondents

Experts	Best to Others	EB1	EB2	EB3
Expert-1	EB2	3	1	7
Expert-2	EB1	1	9	4

Expert-3	EB3	3	9	2
Expert-4	EB1	1	9	4
Expert-5	EB3	7	4	1
Expert-6	EB1	1	9	3
Expert-7	EB3	3	9	1
Expert-8	EB1	1	9	4
Expert-9	EB3	8	6	1
Expert-10	EB1	1	8	3
Expert-11	EB3	2	9	1
Expert-12	EB1	1	8	4

Others to the Worst

Experts→	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6	Expert-7	Expert-8	Expert-9	Expert-10	Expert-11	Expert-12
Worst Criterion →	EB3	EB2	EB2	EB2	EB1	EB2	EB2	EB2	EB1	EB2	EB2	EB2
EB1	7	9	7	9	1	9	7	9	2	8	5	9
EB2	9	1	1	1	5	1	1	1	3	1	1	2
EB3	1	5	8	5	9	7	9	5	8	4	9	5

Table A4

Pairwise comparison for cultural barriers

Best to others for 12 respondents

Experts	Best to Others	CB1	CB2	CB3
Expert-1	CB3	9	7	1
Expert-2	CB3	8	6	1
Expert-3	CB3	6	9	1
Expert-4	CB3	9	7	1

Expert-5	CB1	1	5	9
Expert-6	CB3	8	5	1
Expert-7	CB2	4	1	8
Expert-8	CB3	9	6	1
Expert-9	CB3	9	7	1
Expert-10	CB3	9	4	1
Expert-11	CB2	8	1	3
Expert-12	CB2	4	1	8

Others to the Worst

Experts→	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6	Expert-7	Expert-8	Expert-9	Expert-10	Expert-11	Expert-12
Worst Criterion →	CB1	CB1	CB2	CB1	CB3	CB1	CB3	CB1	CB2	CB1	CB1	CB3
CB1	1	1	3	1	9	1	5	1	1	1	1	5
CB2	3	3	1	2	4	3	9	3	2	3	8	9
CB3	8	9	9	9	1	9	1	9	9	9	4	2

Table A5

Pairwise comparison for regulatory & institutional barriers

Best to others for 12 respondents

Experts	Best to Others	RB1	RB2	RB3
Expert-1	RB3	9	4	1
Expert-2	RB2	3	1	9
Expert-3	RB1	1	8	6
Expert-4	RB2	2	1	9

Expert-5	RB2	4	1	8
Expert-6	RB1	1	9	5
Expert-7	RB2	3	1	9
Expert-8	RB2	3	1	9
Expert-9	RB2	4	1	9
Expert-10	RB2	3	1	9
Expert-11	RB3	8	3	1
Expert-12	RB2	5	1	9

Others to the Worst

Experts→	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6	Expert-7	Expert-8	Expert-9	Expert-10	Expert-11	Expert-12
Worst Criterion →	RB3	RB2	RB2	RB3	RB3	RB2	RB3	RB3	RB3	RB3	RB1	RB3
RB1	1	7	9	8	5	9	7	7	5	4	1	4
RB2	5	9	1	9	9	1	9	9	9	9	4	9
RB3	9	1	3	1	1	4	1	1	1	1	8	1

Appendix B

Sample Survey Questionnaire

Reference: Survey for research work

Dear Respondent,

I am working on a research paper regarding “**Strategies to overcome barriers of innovative digitalisation technologies for supply chain logistics resilience during pandemic**”. Our research has the following objective:

- Identification and ranking of barriers to digitization for supply chain and Logistics resilience during pandemics.
- Identification and ranking of strategies to overcome barriers to digitization for supply chain and Logistics resilience during pandemics.

Considering your expertise in this field, we require your opinion on the identified barriers of the study.

Using the scale as mentioned in Table 2 below please rate the barriers presented in Table 1.

Table 1 Barriers to advancing supply chain logistics resilience during pandemic

Category	Criteria
Technological barriers (TB)	Need of Unique, Faster and Cheap Identification Process (TB_1) Lack of IT infrastructure (TB_2) Inadequate internet connectivity (TB_3) Lack of integration among IT networks (TB_4) Security and Privacy Concerns (TB_5) Complexity of data (TB_6) Scalability (TB_7)
Organisational barriers (OB)	Resistance from employee due to fear of job loss (OB_1) Lack of technical knowledge/skill (OB_2) Lack of training facilities (OB_3) Lack of support by top management (OB_4) Need to find suitable research partner (OB_5) E-waste management (OB_6)
Economical and Financial Barriers (EFB)	High cost of investment (EFB_1) Unclear economic benefit of digital investments (EFB_2) Lack of monetary Resources (EFB_3)
Cultural barriers (CB)	Lack of trust among partners (CB_1) Lack of Support from supplier/ Customer (CB_2) Acceptance of new Technologies (CB_3)
Regulatory and Institutional barriers (RIB)	Lack of standard and regulation (RIB_1) Lack of financial supports in gov polices (RIB_2) Lack of rewards and recognition (RIB_3)

Table 2 Linguistic scale for pairwise comparison for best worst methodology

Scale for Best worst methodology								
Equally important	Equal to moderately more important	Moderately more important	Moderately to strongly more important	Strongly more important	Strongly to very strongly more important	Very strongly more important	Very strongly to extremely more important	Extremely more important
1	2	3	4	5	6	7	8	9

Example for Rating

If Best Main category barrier is TB and worst is EB then

Main category barriers comparison

BO	TB	OB	EFB	OB	EB
Best barriers: TB	1	Relative to TB	Relative to TB	Relative to TB	9

OW	Worst barriers: EB
TB	9
CB	Relative to EB
IB	Relative to EB
OB	Relative to EB
EB	1

Score for ranking of barriers (Expert 1)

Among the four main category barriers, identify which is the best and which is the worst among given (You can use codes only as mentioned in Table 1).

Best Main Barriers:

Worst main Barriers:

Using 9-point scale mentioned in Table 2, rate the Best to Other and Other to Worst barriers in format mentioned below:

Main category barriers comparison

BO	TB	OB	EFB	CB	RIB
Best barriers:					

OW	Worst barriers:
TB	
OB	
EFB	
CB	
RIB	

Part 2

This part deals with ranking the strategies with respect to main category barriers as well as each of sub category barriers.

Table 3 supply chain logistics resilience during pandemic strategies

Category	Criteria
supply chain logistics resilience during pandemic strategies	<p>Focus on research, development and Innovation strategy (S₁)</p> <p>Provide Financial Support strategy (S₂)</p> <p>Enhance Training facilities and conduct awareness programs strategy(S₃)</p> <p>Enhance security and privacy strategy(S₄)</p> <p>Automation strategy (S₅)</p> <p>Adoption of new technology Strategies (S₆)</p> <p>Create or hire an organisation for monitor complete supply chain strategy (S₇)</p> <p>Use Satellite Internet Access (S₈)</p> <p>Collaborations with Technical institute (S₉)</p>

Rate the Strategies for SSL with respect to barriers using a scale of 1-9 where 1 represents minimum influence and 9 represents maximum influence.

Strategies	Barriers				
	TB	OB	EFB	CB	RIB
S_1					
S_2					
S_3					
S_4					
S_5					
S_6					
S_7					
S_8					
S_9					