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Modelling of Determinants of Logistics 4.0 Adoption: Insights from Developing Countries

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Abstract: With the emergence of industry 4.0, several elements of the supply chain are transforming through the adoption of smart technologies such as blockchain, the internet of things and cyber-physical systems. Logistics is considered one of the important elements of supply chain management and its digital transformation is crucial to the success of industry 4.0. In this circumstance, the existing logistics system needs to be upgraded with industry 4.0 technologies and emerge as logistics 4.0. However, the adoption/transformation of logistics 4.0 is dependent on several determinants that need to be explored. Therefore, this study has the prime objective of investigating the determinants of logistics 4.0 adoption in the context of a developing country, specifically, India. Initially, ten determinants of logistics 4.0 are established after a survey of the relevant literature and the input of industry experts. Further, a four-level structural model is developed among these determinants using the Interpretive Structural Modelling (ISM) approach. In addition, a fuzzy Matrix of Cross-Impact Multiplications Applied to Classification (MICMAC) analysis is also conducted for the categorization of these determinants as per their driving and dependence power. The findings show that top management supports, information technology infrastructure and financial investment are the most significant determinants towards logistics 4.0 adoption. This study facilitates the supply chain partners to focus on these high-level determinants for the effective adoption of logistics 4.0. Moreover, the findings lead to a more in-depth insight into the determinants that influence logistics 4.0 and their significance in logistics 4.0 adoption in emerging economies.

Keywords: determinants; industry 4.0; logistics 4.0; ISM; fuzzy MICMAC

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Citation: Khan, S.; Singh, R.; Sá, J.C.; Santos, G.; Ferreira, L.P. Modelling of Determinants of Logistics 4.0 Adoption: Insights from Developing Countries. *Machines* **2022**, *10*, 1242. https://doi.org/10.3390/machines10121242

Academic Editor: Pingyu Jiang

Received: 28 October 2022
Accepted: 14 December 2022
Published: 19 December 2022

1. Introduction

The pervasiveness of information and communication technologies provides the opportunity to incorporate "smartness" in factories and pushes the industry towards the next industrial revolution, i.e., the fourth industrial revolution. This industrial revolution focuses on the adoption of smart technologies to improve the system and process efficiency in order to achieve sustainability. In the current world, professionals, managers, and government representatives are becoming increasingly interested in Industry 4.0 as its implementation would boost national economies and corporate competitiveness [1–3]. To promote higher automation, industry 4.0 was first implemented in Germany [4,5]. This paradigm shift has been recognized by other countries, including the United States, China, United Kingdom, and India, through the adoption of several initiatives [5,6]. Although industry 4.0 originated in the manufacturing sector, it has significant implications for the supply chain [7]. The goal of industry 4.0 is to develop smart factories and supply chains by incorporating cutting-edge technologies such as analytics, big data, the Internet of Things (IoT) and Cyber-Physical Systems (CPS) [8,9]. These technologies are utilized to advance the many supply chain components, including planning, sourcing, manufacturing and logistics. It is widely recognized that logistics 4.0 is a substantial part of industry 4.0, and its adoption could benefit digitalization throughout the entire supply chain.

Logistics 4.0 is the logistical version of industry 4.0 and focuses on turning logistics activities into more effective activities with improved material and information flow, resulting in smart and intelligent logistics that are more precise, dependable, agile, and sustainable [10]. Some authors have recognized that logistics 4.0 is a new paradigm associated with industry 4.0. The logistics 4.0 concept entails integrating smart technologies with logistics subsystems, such as smart sensors, big data and IoT, and CPS. These technologies provide data-driven ecosystems that more successfully meet the customer's demand for customized products. Timm and Lorig [11] define logistics 4.0 as: " . . . a logistic system which consists of independent subsystems and behaviour of these subsystems depend on other surrounding subsystems". In addition to this, Wang [12] defined logistics 4.0 as " . . . a collective term for technologies and concepts of value chain organization. Within the logistics, CPS monitors physical processes creates a virtual copy of the physical world and makes decentralized decisions. Over the IoT, CPS communicate with machines and humans in real-time. Data mining discovers knowledge to support the decision-making process. Both internal and cross-organizational services are offered and utilized by participants of the value chain through the Internet of Services (IoS)".

In light of the above definitions, the combination of smart technology and logistics is referred to as "logistics 4.0" to address the demand for highly personalized goods and services. To implement logistics 4.0, more initiative and financial resources must be invested in the adoption of these cutting-edge technologies. This transformation is challenging because of the high cost of technology and infrastructure, complicated network of supply chains, global participation, and security and privacy issues.

The adoption of logistics 4.0 faces several challenges from the organizational, cultural and supply chain levels [13]. Despite these challenges, some factors are also present in the system that enable the adoption of logistics 4.0. In order to adopt logistics 4.0, these determinants need to be explored and analyzed in a comprehensive manner. The determinants of logistics 4.0 are the factors that facilitate its adoption. These determinants are the key factors that need to be addressed for the successful adoption of logistics 4.0. In addition, the shift from conventional logistics to logistics 4.0 is dependent on these determinates. To ensure a seamless and effective implementation of logistics 4.0, it is vital to explore these determinants. The adoption of logistics 4.0 is facilitated by several industry 4.0 technologies. The adoption of these technologies depends on external factors, including business environment, technological readiness, working culture and associated uncertainties. These factors differ between developed and developing countries. Therefore, the adoption of logistics 4.0 will not necessarily be identical because of their differing levels of infrastructure and economies of scale [14]. Due to this, the determinants of logistics 4.0 adoption differ for developing and developed countries. It is found that logistics 4.0 faces a wide range of business issues due to the lack of technological development, big data management, and market volatility [15]. In comparison with developed countries, such as the USA, United Kingdom and German, developing countries use relatively fewer sophisticated technological tools and techniques in the logistics sector [15]. Therefore, the adoption of logistics 4.0 needs to be addressed from the perspective of developed and developing countries [16]. The literature review reveals that the majority of current research focuses on logistics 4.0 adoption in developed countries. Only limited research has been conducted on logistics 4.0 adoption in emerging countries [10]. It is also important to note that the adoption of logistics 4.0 implementation has not been fully explored. Therefore, the disproportionate focus on developed countries in comparison to developing countries, the lack of guidance on the determinants of logistics 4.0 adoption, and the lack of sufficient evidence regarding logistics 4.0 adoption constitute compelling gaps in the existing literature. Hence, it is necessary to identify and analyse the determinants of logistics 4.0 in emerging economies in order to fill these research gaps. For efficient and effective adoption, managers also need to be aware of the structural relationships between the identified determinants in the context of developing countries. The structural relationship among the determinants of logistics 4.0 is rarely explored. Therefore, this study was conducted to identify and explore the structural relationship among determinants of logistics 4.0 adoption in the context of developing countries, and specifically, India. This study has the following research objectives to fill the knowledge gaps in the existing literature:

- To identify the key determinant of logistics 4.0 adoption in the context of developing countries
- To develop the structural relationship among the finalized determinant
- To categorize the determinant based on their driving and dependence power

We have identified the determinants to meet the aforementioned study objectives through a literature review and validated this with expert feedback. After the finalization of the logistics 4.0 adoption determinants, the structural relationship is developed between them using the ISM method. The results of this study will assist practitioners in implementing logistics 4.0 for incorporating sustainability into their supply chains. Logistics 4.0 and sustainability have a close relationship by reducing waste and carbon footprints, and creating new job prospects. The implementation of digital technologies in logistics improves the availability of items at the right place, time, and amount, hence reducing waste [17]. This study will also assist policymakers in formulating policies that support the systematic adoption of logistics 4.0. As the majority of the literature suggests, logistics 4.0 is not well adopted in developing countries and required further exploration. Therefore, the uniqueness of this paper lies in the identification of the determinants of logistics 4.0 in developing countries. With the findings of this study, supply chain partners that are located in developing countries will benefit in terms of logistics 4.0 adoption.

The remaining study is organized as follows: Section 2 gives a summary of studies relevant to logistic 4.0; the adopted solution methodology is provided in Section 3; Section 4 provides the data analysis; Section 5 discusses the findings; Section 6 provides the implications of the study and finally, Section 7 concludes the study and provides scope for future research.

2. Background of the Study

Several advancements and enhancements are introduced to the logistics industry under Industry 4.0. For instance, businesses are able to construct hyper-connected supply chains by implementing digital technologies at every stage of the planning process [18], to increase operational and financial limitations by capturing big data and operating at a different level of resilience and responsiveness [19]. In the framework of Industry 4.0, transportation and distribution networks have placed a significant focus on flexibility and resilience [20]. Moreover, as the supply chain partners become more integrated, logistics becomes an increasingly vital element for industry 4.0's success [21]. A digitalized supply chain and smart systems have enabled logistics to propose the name "logistics 4.0" as the equivalent of industry 4.0 [22].

Logistics 4.0's emergence from the industry 4.0 idea is crucial, not just for operational views such as sustainability, effectiveness, and customer responsiveness, but also for allowing advances in all basic business components [23]. Since logistics ensures the timely and appropriate availability of resources for manufacturing systems, logistics is ideally suited to exploring practical applications and reflecting industry 4.0 [24]. Therefore, logistics 4.0 adoption will significantly enhance the efficiency and effectiveness of the entire supply chain by optimizing the operations of logistics services. Tascón et al. [25] determine the logistics 4.0 service quality criteria and assess the impact of developing technologies on logistics sustainability. Their findings show that artificial intelligence, advanced robotics, blockchain and additive manufacturing are the most significant technologies that help in achieving logistics 4.0 sustainability. Similar to this, Parhi et al. [26] also develop a framework for the assessment of enabling factors that are responsible for the implementation of sustainable logistics 4.0 at various digitalization levels. They focused on the management perspective and found that technology infrastructure", "digital solutions", and "top management commitment", are the prime enablers for the adoption of logistics 4.0.

Sun et al. [27] focused on reverse logistics 4.0 and developed an integrated framework for smart reverse logistics by integrating Industry 4.0 enablers to achieve sustainable business objectives. Batz et al. [28] provide an overview of the maturity model developed for the assessment of Logistics 4.0.

The three primary characteristics of logistics 4.0 are vertical integration, horizontal integration and end-to-end engineering integration [23]. In vertical integration, different IT systems are integrated at different levels within a factory, whereas horizontal integration is about collaboration between firms, and end-to-end integration is about cross-linking stakeholders, products, and machines. In logistics 4.0, products are transported, and their information flow is controlled systemically from source to destination. With Logistics 4.0, customers can cost-effectively access logistics services by utilizing frontends and base technologies [29]. It primarily employs IoT, CPS, big data analytics, and cloud computing technologies [30], which help organizations to optimize their resources and provide enhanced value. The schematic diagram of logistics 4.0 is provided in Figure 1. Based on these technologies, advanced systems such as intelligent transportation systems, warehouse management systems, information security, and independent order processing through blockchain technologies and smart contracts are operated [21,24]. As a result of logistics 4.0 initiatives, organizations can reduce the costs of logistics (such as labour costs), boost productivity, and improve customer satisfaction [31–33].

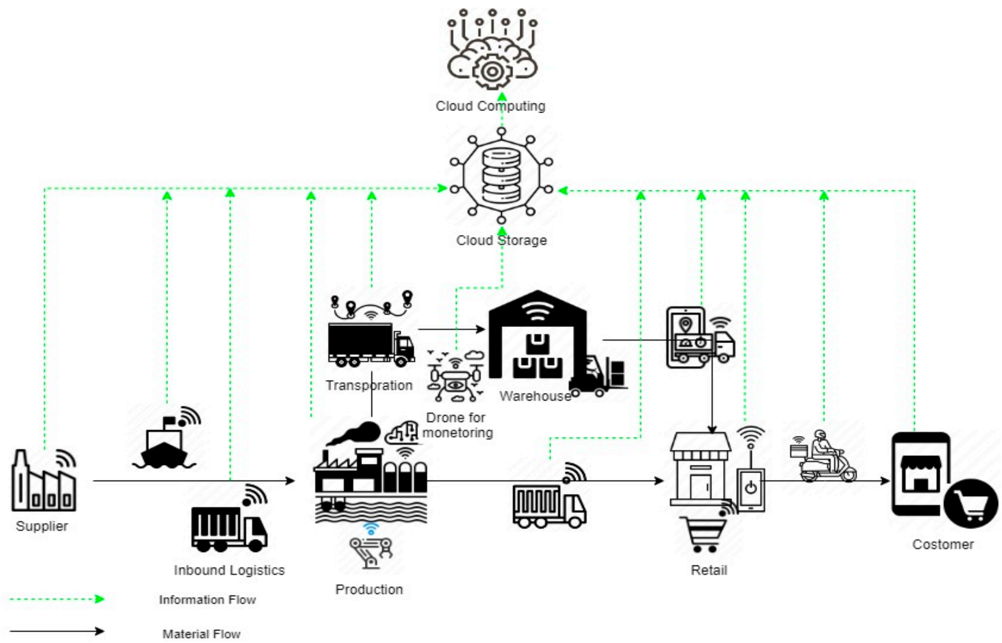

Figure 1. Conceptual structure of Logistics 4.0 (Source: Authors).

Despite these benefits, the adoption of logistics 4.0 is limited, particularly in developing countries. Studies pertaining to the adoption of logistics 4.0 are relatively insufficient. Typically, most of the studies focus on the technological side of logistics 4.0 and how these technologies facilitate adoption. For example, Atzeni et al. [34] claim that a robot is essential to logistics 4.0, assisting with picking, operations and placing a proposed idea of Cobots, or collaborating robots, can be used in logistics 4.0. Additionally, Markov and Vitliemov [35] investigated how blockchain technologies were applied to automobile supply chains and their logistics. They added that blockchain technologies have a significant positive impact on logistics 4.0. Further, they found potential supply chain and logistics 4.0 opportunities for creating sustainable supply chains and logistics.

From the operational perspective, some studies are available related to the adoption of logistics 4.0. A framework for logistics 4.0 was evaluated and purposed by Winkelhaus and Grosse [30]. They examine how this framework might be used to identify future logistics strategies and technological advancements that will enable sustainable logistics operations. They also proposed new technology solutions, such as IoT, CPS, and big data, to address current and future expectations. Kucukaltan et al. [36] observed from a multidimensional perspective to reflect the impact of Industry 4.0 on logistics. It may be impacted by the growth of industries when modifications are made to operational, financial, and human resource factors.

Several studies address the impact of logistics 4.0 on business performance [37,38]. To achieve sustainability, Torbacki and Kijewska [39] investigated the production methods that may be employed in logistics 4.0 in association with the performance characteristics of logistics. Additionally, it concentrated on manufacturing and logistics performance indicators, both of which can be used to gauge a business's performance. Additionally, Nantee and Sureeyatanapas [38] analyzed the impact of logistics 4.0 projects, such as automated warehouse systems, on sustainability performance in various industries. Kodym et al. [40] stated that throughout the logistics and manufacturing process, the supply chain may become more intelligent, efficient, and transparent with the help of digital transformation. They emphasized several cutting-edge technologies, including blockchain, IoT, big data, data mining, and machine learning, which professionals can utilize to identify the risks associated with logistics 4.0. Bag et al. [41] highlight three specific areas in which an organizations' performance is impacted by logistics 4.0 adoption: environmental, organizational, and technological. Planning and scheduling can help to save maintenance costs by utilizing some of these features. Additionally, the logistics 4.0 process can enhance businesses' manufacturing operations through sustained communication and visibility.

Some studies have evaluated the ways in which industry 4.0 technology may affect the operation of logistics [42,43]. Through integrating the lean 4.0 idea, these technologies are enhancing logistical processes by reducing waste. Industry 4.0 is not just a technological term, but rather an amalgamation of social and organizational circumstances [44]. However, Wagner et al. [43] suggested that a lean production system be utilized to estimate the first step in industry 4.0, particularly when a CPS-based Just-in-Time (JIT) method is being used. On the other hand, Rosin et al. [45] advise combining Jidoka and Industry4.0 for optimal results. They claim that IoT and simulation are the two technologies that are most frequently recommended for combining Lean 4.0 and Industry 4.0. For such integration, a cluster with the necessary knowledge base, IT solution expertise, robotics, and automation is required [46–49].

3. Materials and Methods

The three-stage framework is developed to fulfil the research objectives, as shown in Figure 2. An initial literature review, along with validation from multiple experts, has been used to identify the determinants of logistics 4.0. Further, these determinants of logistics 4.0 adoption are modelled using the ISM approach for the exploration of structural relationships. ISM has attracted researchers from different disciplines because it segregates complex relationships between elements of a system into hierarchical structures. It is widely used in the analysis of interrelationships among variables affecting a system, for example, barriers, critical success factors, determinants and drivers. The method has been successfully used in a variety of management studies [50,51]. For example, Khan et al. [52] applied the factors of remanufacturing adoption in the context of emerging economies to the model. Yadav, Luthra and Garg [53] applied the ISM to model the barriers of IoT integration in the agri-food supply chain. In the third stage, the fuzzy MICMAC analysis is used for the validation of the ISM model. The fuzzy MICMAC analysis also classifies the determinants into four groups based on driving and dependence power. The ISM–MICMAC methodology has been applied and recommended for use in management issues such as lean manufacturing [54,55], cold supply chain [56], digital supply chain [57], risk management [58], and industry 4.0 adoption. However, the ISM–MICMAC methodology has not been applied to logistics 4.0. Therefore, the ISM and fuzzy MICMAC is acknowledged by adopting it to solve the problems of logistics 4.0.

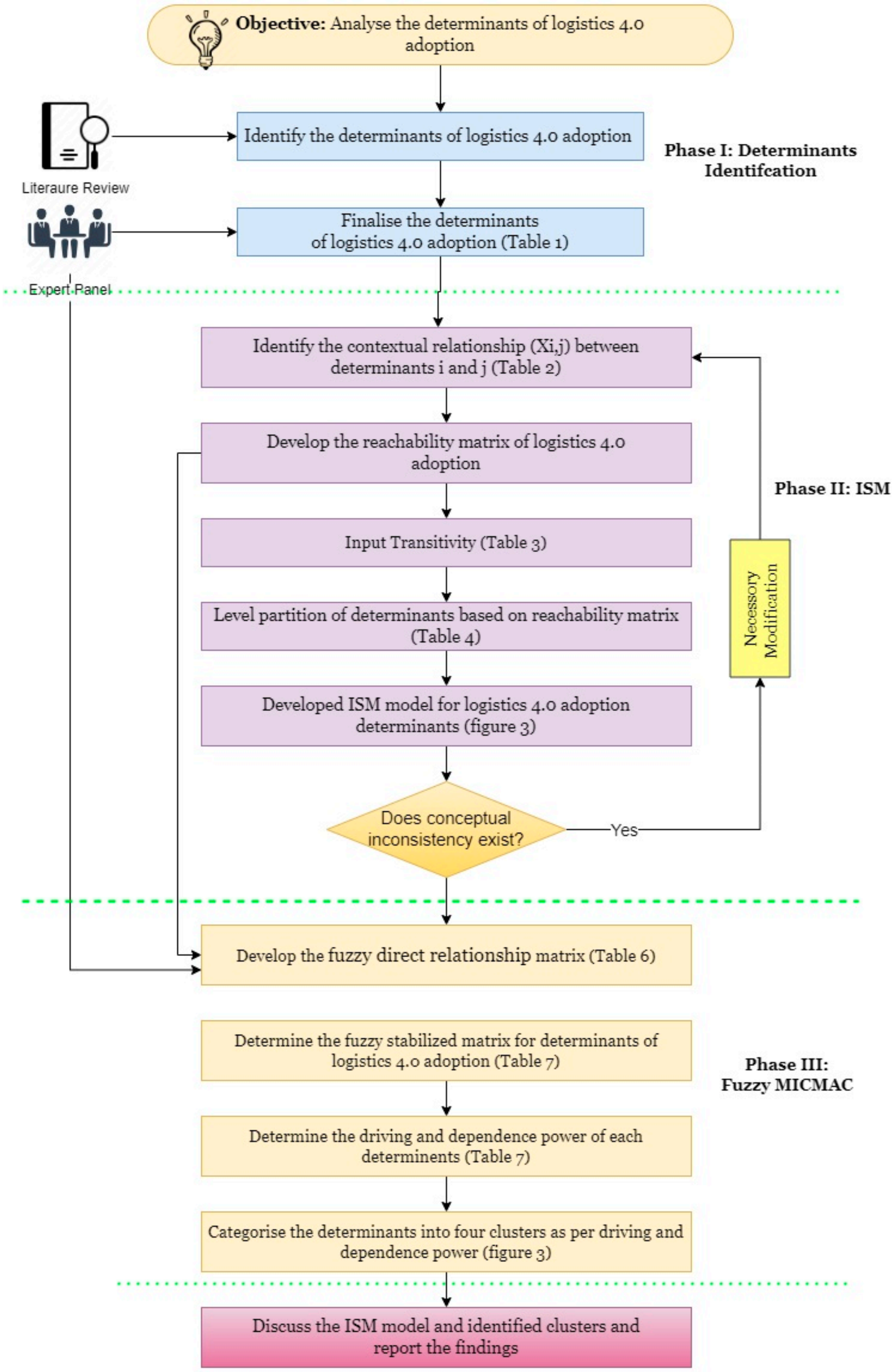

Figure 2. Proposed framework for modelling of determinants of logistics 4.0 adoption (Source: Authors).

3.1. ISM Method

The ISM approach was discovered by Warfield [59]. This approach has been frequently utilized in the past to build structural relationships between identified obstacles/factors/determinants. The steps to the ISM technique are as follows:

Step 1: The first step is to determine the factors that influence the system under study.

Step 2: Analyze the contextual interactions between the elements of the system to create a self-interaction matrix (SSIM).

Step 3: Converting the linguistic characters to binary values to establish an initial reachability matrix.

Step 4: By checking the transitive relationships, obtain the final reachability matrix.

Step 5: To determine the levels of variables, level partitioning is carried out.

Step 6: Create the ISM model by placing each variable at its appropriate level.

Step 7: The developed ISM model is reviewed to ensure that there are no theoretical irregularities, and modifications are made as necessary.

3.2. MICMAC Analysis

MICMAC was developed by Duperrin and Godet [60]. MICMAC enables the determination of the driving power and the dependence power of a variety of elements. The main purpose of MICMAC analysis is to examine how variables affect each other and how they are dependent on each other. Based on their driving and dependency power, these variables can be classified into four groups: autonomous variables, dependent variables, linkage variables, and driving variables. In order to evaluate the sensitivity of MICMAC, the fuzzy theory is combined with traditional MICMAC. Using fuzzy MICMAC, it is possible to measure the direct and indirect effects of relationships between variables. The driving power of a variable can be determined by summing the entries in its row in a fuzzy stabilized matrix. Similarly, the importance of a variable can be calculated by summing the entries in the columns of the fuzzy stabilized matrix.

4. Data Analysis

4.1. Stage 1: Determinants of Logistics 4.0

As a result of the literature review of relevant articles, the initial determinants of logistics 4.0 adoption have been identified. The articles for the literature survey were selected using the Scopus database, which is the largest collection of scientific journals with peer review. Next, the keywords for the literature search were finalized, which included "logistic 4.0", "smart logistics" "digital logistics", "supply chain 4.0", "drivers", and "determinates". The combinations (using a Boolean operator) of these keywords were used for the appropriate article identification. Further, the identified articles were reviewed in order to prepare the initial list of logistics 4.0 adoption determinants. An expert panel of eight members was formed, including five members from industry, two from academia and one policy planner. These industry professionals are well-versed in logistics 4.0 and supply chain digitalization. All the industrial participants in the study have management experience in the logistics industry of more than eight years. These professionals are working in a high-repute logistics company which have a minimum staff strength of 150 and a multinational market base, located in India. Additionally, two academic experts with specialized knowledge of logistics 4.0 operations and an understanding of industry 4.0 have been involved with this study. These two experts are also working in the Indian university at the professor and associate professor level. The details of the experts are provided in Table A1. As a result of the formation of the expert panel, the identified determinants list, which consists of twelve factors, is presented to the panel for its consideration. They were asked to check the relevance of the determinant in the context of the contemporary business environment of developing countries. After the discussion, the expert panel recommended eliminating two determinants due to their irrelevance in the contemporary business environment of developing countries. In this manner, ten determinants of logistics 4.0 adoption are finalized and depicted in Table 1.

Table 1. Determinants of logistics 4.0 adoption.

S. No	Determinants	Description	References
1.	IT Infrastructure	Logistic 4.0 requires IT infrastructure including IoT, big data, and CPS to meet the technological requirement of industry 4.0	[61–63]
2.	Mutual Trust	Logistics 4.0 is a sequence of interconnected activities with the integration of advanced technologies and the realization of logistics 4.0 depend on the mutual trust among the logistics partners	[41,64]
3.	Knowledge Management	Created a training program to foster continual learning which facilitates knowledge transmission, encouraging companies to adopt logistics. 4.0.	[65–67]
4.	Analytical competencies	Data is the main ingredient of Logistics 4.0 and their adoption relies on data analytics, which requires strong analytical skills.	[30,38]
5.	Digital work culture	Logistics 4.0 requires smart environments, new job descriptions, roles, and responsibilities that help to develop a smart work culture.	[63,68]
6.	Organizational strategies for logistics 4.0	Numerous logistics 4.0 initiatives must be integrated with organizational strategies for greater coordination to embrace logistics 4.0.	[69,70]
7.	Top management support	Logistics 4.0 demands several technology integrations, skill development and policy changes therefore, logistics 4.0 adoption requires top management commitment and support.	[6,71]
8.	Collaboration	For logistics 4.0 to succeed, it is essential to cultivate a collaborative relationship with logistics partners	[72]
9.	Financial investment	It is well-known that the adoption of innovative solutions, such as logistics 4.0, is strongly influenced by the amount of investment made into them.	[10,73]
10.	Skill development	As part of the logistics 4.0 initiative, seminars and workshops will be held to assist in the development of the essential analytical and technical capabilities needed	[74,75]

4.2. Stage 2: ISM Modelling

ISM methodology begins with the development of an initial structural self-interaction matrix (SSIM) showing relationships among variables. With the help of expert consultation, contextual relationships are developed between identified factors. To diagnose the interdependencies among the identified determinants of logistics 4.0 adoption, a contextual relationship of the type 'leads to' is considered. For instance, top management support leads to skill development. In the same manner, contextual relationships among determinants are developed, taking into account a determinant's contextual relationship with other determinants, the existence of any relation between two determinants (i and j), and their associated direction of relationship A between determinants (i and j) can be expressed using four symbols:

V: determinant i will lead to determinant j

A: determinant j will lead to determinant i

X: determinant i and j will lead to each other

O: determinant i and j are unrelated.

On the basis of contextual relationships, an SSIM was developed for the determinants of logistics 4.0 adoption and the same is shown in Table 2.

Table 2. SSIM for the determinants of logistic 4.0 adoption.

Determinants	10	9	8	7	6	5	4	3	2	1
1	V	A	V	X	V	O	V	O	O	
2	V	O	X	A	A	V	V	X		
3	V	A	X	A	A	V	V			
4	X	A	A	A	O	X				
5	X	A	A	A	A					
6	V	A	V	A						
7	V	X	V							
8	V	A								
9	V									
10										

By substituting V, A, X, and O with 1 and 0, the SSIM is transformed into a binary matrix, called the initial reachability matrix.

- if the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0
- if the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1
- if the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 1
- if the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 0.

As a result of applying the transitivity principle to the initial reachability matrix, the final reachability matrix can be constructed and is shown in Table 3. Furthermore, this table also depicts the driving and dependence power of each determinant. Driving power is defined as the number of determinants it influences, while dependence is the number of determinants that affect it.

Table 3. Final reachability matrix.

Determinants	1	2	3	4	5	6	7	8	9	10
1	1	1*	1*	1	1*	1	1	1	1*	1
2	0	1	1	1	1	0	0	1	0	1
3	0	1	1	1	1	0	0	1	0	1
4	0	0	0	1	1	0	0	0	0	1
5	0	0	0	1	1	0	0	0	0	1
6	0	1	1	1*	1	1	0	1	0	1
7	1	1	1	1	1	1	1	1	1	1
8	0	1	1	1	1	0	0	1	0	1
9	1	1*	1	1	1	1	1	1	1	1
10	0	0	0	1	1	0	0	0	0	1

1 shows the transitivity.*

The final reachability matrix could be partitioned into different levels with the help of the reachability and antecedent sets for each determinant. Each determinant has a reachability set consisting of the determinant itself and any other determinants that may contribute to achieving it, and an antecedent set consisting of the determinant itself and any other determinants that may support the achievement of it [60]. In other words, the reachability set consists of determinants that have one (row-wise) in the final reachability matrix.

For example, the reachability set of *determinant 2* is calculated as it has 0,1,1,1,1,0,0,1,0,1 (refer to the second row of Table 3) and their reachability set should be 2,3,4,5,8,10 (places where 1 exists). Similar to this, the antecedent set consists of the determinants that have one (column-wise) in the final reachability matrix. For instance, the antecedent set of *determinants 2* can be determined as it has 1,1,1,0,0,1,1,1,1,0 (refer to the second column of Table 3) and their antecedent set should be 1,2,3,6,7,8,9 (places where 1 exists). Further, the intersection (common elements in both sets) of reachability and the antecedent set are identified for all the determinants. Those determinants whose intersection set and reachability set are the same are labelled as Level I, and placed at the highest position in the ISM model. Following this, the top-level determinants are discarded, and subsequent iterations are repeated until all the determinants are placed. A digraph and ISM model were constructed based on the identified levels of variables.

Table 4 present the level partition that is used to construct the structural model of the determinants of logistics 4.0 adoption and based on the level of each determinant the digraph that is generated by removing transitivity in accordance with the ISM methodology. The digraph is transformed into the ISM model by labelling them appropriately, as shown in Figure 3.

Table 4. Shows the level of each determinant of logistics 4.0 adoption.

Factors	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,5,6,7,8,9,10	1,7,9		
2	2,3,4,5,8,10	1,2,3,6,7,8,9		
3	2,3,4,5,8,10	1,2,3,6,7,8,9		
4	4,5,10	1,2,3,4,5,6,7,8,9,10	4,5,10	I
5	4,5,10	1,2,3,4,5,6,7,8,9,10	4,5,10	I
6	2,3,4,5,6,8,10	1,6,7,9		
7	1,2,3,4,5,6,7,8,9,10	1,7,9		
8	2,3,4,5,8,10	1,2,3,6,7,8,9		
9	1,2,3,4,5,6,7,8,9,10	1,7,9		
10	4,5,10	1,2,3,4,5,6,7,8,9,10	4,5,10	I
		Ittiration-2		
1	1,2,3,6,7,8,9,	1,7,9		
2	2,3,8,	1,2,3,6,7,8,9	2,3,8,	II
3	2,3,8,	1,2,3,6,7,8,9	2,3,8,	II
6	2,3,6,8,	1,6,7,9		
7	1,2,3,6,7,8,9,	1,7,9		
8	2,3,8,	1,2,3,6,7,8,9	2,3,8,	II
9	1,2,3,6,7,8,9,	1,7,9		
		Ittiration-3		
1	1,6,7,9,	1,7,9		
6	6,	1,6,7,9	6	III
7	1,6,7,9,	1,7,9		
9	1,6,7,9,	1,7,9		
		Ittiration-4		
1	1,7,9,	1,7,9	1,7,9,	IV
7	1,7,9,	1,7,9	1,7,9,	IV
9	1,7,9,	1,7,9	1,7,9,	IV

4.3. Stage 3: Fuzzy MICMAC Analysis

We used fuzzy MICMAC analysis to examine the driving and dependence power of the determinants of logistics 4.0. To apply fuzzy-MICMAC analysis, the final reachability matrix is used. In the final reachability matrix, binary digits are used, meaning zero or one, so that relationship strength is ignored. The fuzzy MICMAC analysis incorporates the relationship strength among determinants using triangular fuzzy numbers as provided in Table 5.

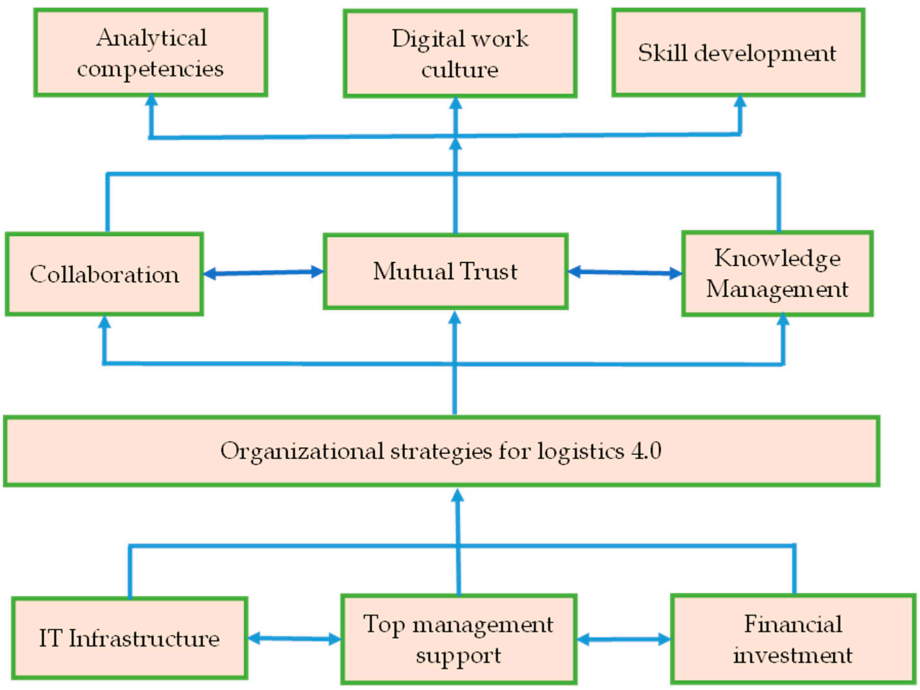

Figure 3. ISM model of determinants of logistics 4.0 adoption.

Table 5. Linguistic Scale and their associated TFNs.

Linguistic Variable	TFNs	Crips Value
No influence	(0, 0, 0)	0
Very low influence	(0, 0.1, 0.2)	0.1
Low influence	(0.2, 0.3, 0.4)	0.3
Medium influence	(0.4, 0.5, 0.6)	0.5
High influence	(0.6, 0.7, 0.8)	0.7
Very high influence	(0.8, 0.9, 1)	0.9
Complete influence	(1, 1, 1)	1

The experts assessed the relationship strength among the determinant using the linguistics scale. The influence of one determinant on the other is assessed by the experts and their linguistic response is converted into TFNs, and the resulting matrix is called the Fuzzy Direct Relationship Matrix (FDRM), as presented in Table 6.

Table 6. FDRM of determinants of logistics 4.0 adoption.

CSFs	1	2	3	4	5	6	7	8	9	10
1	0	0.3	0.3	0.7	0.3	0.7	0.5	0.9	0.3	0.7
2	0	0	0.9	0.7	0.9	0	0	0.5	0	0.9
3	0	0.7	0	0.5	0.7	0	0	0.5	0	0.3
4	0	0	0	0	0.5	0	0	0	0	0.5
5	0	0	0	0.5	0	0	0	0	0	0.3
6	0	0.9	0.7	0.9	0.7	0	0	0.9	0	0.7
7	0.7	0.7	0.3	0.7	0.7	0.7	0.7	0.5	0.3	0.5
8	0	0.7	0.6	0.7	0.3	0	0	0	0	0.3
9	0.7	0.1	0.5	0.1	0.7	0.9	0.7	0.5	0	0.5
10	0	0	0	0.9	0.7	0	0	0	0	0

The FDRM is multiplied repetitively until the driver and dependence power stabilize [51,76]. This stabilization infers that no significant changes in the value driving and dependence power occur if further multiplication is conducted. Through this process, the resultant stabilized matrix is obtained. The driving powers of each determinant are calculated by the row-wise summing of the data, whereas their dependence power is obtained by column-wise summation. Table 7 exhibits the resultant fuzzy stabilized matrix along with the driving and dependence power.

Table 7. Fuzzy stabilized matrix for determinants.

CSFs	1	2	3	4	5	6	7	8	9	10	Driving Power
1	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.3	0.7	5.8
2	0	0.7	0.5	0.7	0.7	0	0	0.5	0	0.5	3.6
3	0	0.5	0.7	0.7	0.7	0	0	0.5	0	0.7	3.8
4	0	0	0	0.5	0.5	0	0	0	0	0.5	1.5
5	0	0	0	0.5	0.5	0	0	0	0	0.5	1.5
6	0	0.7	0.7	0.7	0.7	0	0	0.5	0	0.7	4
7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.7	6.6
8	0	0.6	0.7	0.7	0.7	0	0	0.5	0	0.7	3.9
9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.7	6.6
10	0	0	0	0.5	0.5	0	0	0	0	0.5	1.5
Dependence Power	1.9	4.6	4.7	6.4	6.4	1.9	1.9	3.9	0.9	6.2	

The finalized determinants are classified into four clusters based on their driving and dependence power: autonomous, dependent, linkage, and driving. Figure 4 shows the four clusters of identified determinants of logistics 4.0 adoption.

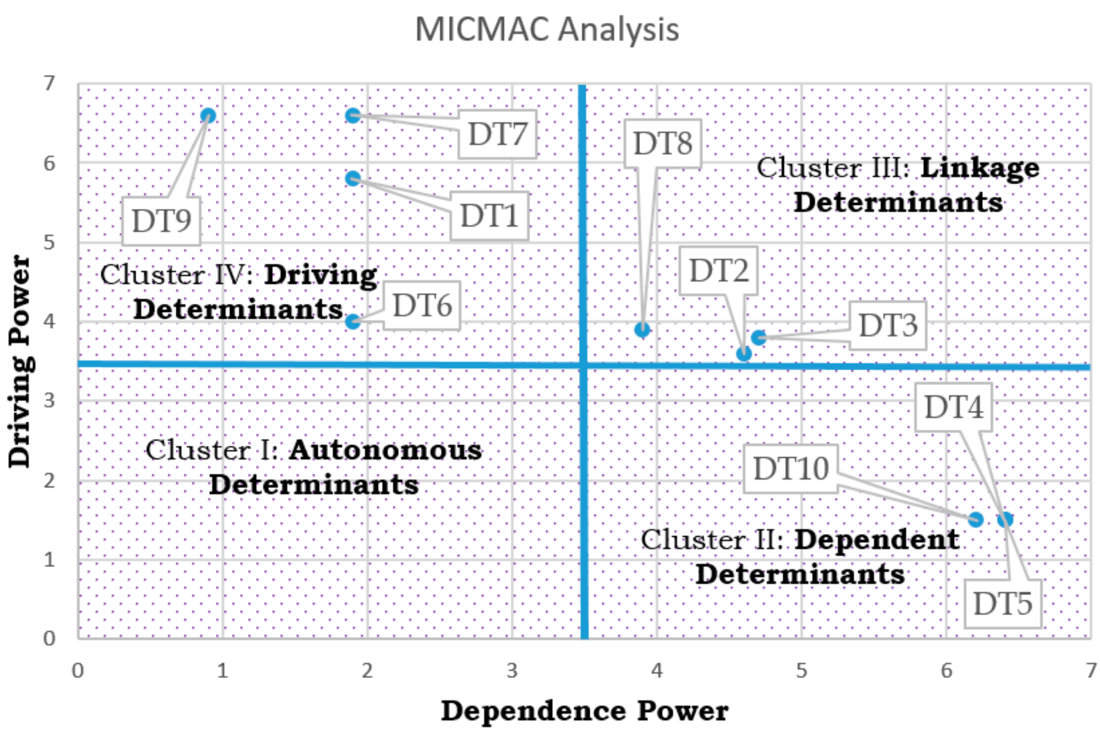

Figure 4. Fuzzy MICMAC analysis of determinants of Logistics 4.0.

5. Discussion

Logistics 4.0 is a relatively new and rapidly emerging topic for both academics and practitioners [10]. Following the literature, supply chain managers are concerned with factors/determinants that help the adoption of logistics 4.0. In this regard, an effort has been made to construct an integrated model for evaluating the linkages between determinants of logistics 4.0, which may be valuable for managers and practitioners. Through this study, ten significant determinants that are responsible for the adoption of logistics 4.0 have been identified. The structural relationship among these determinants is modelled through ISM.

The developed ISM model has four levels, as per their influence on each other. The ISM model reveals that top management support, IT infrastructure and financial investment are the most significant determinants for the adoption of logistics 4.0, asit is placed at the bottom of the model. This could be validated by Bag [41], who stated that dedication is required on a strategic level to implement any novel practices. These three determinants are highly effective for the adoption of logistics 4.0 among all of the identified determinants. As logistics 4.0 requires some strategic and operational transformation in conventional logistics activities, top management support is essential. Logistics 4.0 requires several advanced technological integrations such as big data analytics, IoT-enabled tracking and real-time data transfer. This integration is not possible without a robust IT infrastructure. With the support of top management and their financial investments, the IT infrastructure could be developed. The bottom-level determinants help to achieve the remaining determinants, which results in the effective adoption of logistics 4.0.

The third level of the ISM model contains one determinant: 'organizational strategies for logistics 4.0′. The top management's involvement and the presence of IT infrastructure help in the development of organizational strategies for the adoption of logistics 4.0. The organization could assess the impact of logistics 4.0 on its performance and formulate strategies to adopt logistics 4.0. Establishing a vision and mission to adopt logistics 4.0 help the working personnel to channelize their effort.

The second level of the ISM model contains three determinants, including collaboration, mutual trust, and knowledge management. These factors are influenced by 'organizational strategies for logistics 4.0′. The mutual trust among the logistics partners enables them to share the relevant data with concerned partners and resolve the initial conflict efficiently. This led to the collaboration among logistics/supply chain partners that help them in the long run. Knowledge management is also an essential component for the adoption of any novel practice. Efficient knowledge management helps the logistics partners to understand the logistics 4.0 practices and processes. This will help the organizations to effectively adopt logistics 4.0 in less time. Mutual trust, collaboration and knowledge management depend on the organizational strategies with regard to logistics 4.0 and influence the top-level determinants.

The top level of the ISM model contains three determinants: analytical competencies, digital work culture and skill development. These three determinants could be achieved through the successful adoption of the influential determinants that are placed on levels II, III and IV. The organization receives an outcome in terms of developing its analytical capabilities, digital work culture and skill development by effectively incorporating the above determinants. The analytical capabilities help the organizations to adopt logistics 4.0 and benefit in terms of competitive edge and sustainability. Further, skill development also supports the adoption of logistics 4.0 practices as well as enabling the digital work culture.

Further, the fuzzy MICMAC analysis is conducted to categorize the determinants into four clusters based on their driving and dependence power. Based on this analysis, four clusters of determinates are identified; namely, autonomous, dependent, linkage and driving.

The first cluster of determinates, called autonomous determinants, have weak driving and dependence power. There is not much effect of the autonomous cluster factors on the system due to low driving and dependence power. As there are no determinants that fall into this cluster, it explains that all determinants are related, appropriate, and in control.

In the second cluster, there are dependent determinates that are highly dependent and weakly driven. Three determinants belong to this cluster- analytical competencies, digital work culture and skill development. These three determinants are important because their strong dependence points out that they need all the other determinants to adopt logistics 4.0. The organization's management need to focus on these determinants for the effective adoption of logistics 4.0.

The third cluster is made up of determinates that have both high driving power and high dependence power. These determinates are called linkage determinates and are inherently unstable. Changes in these linkage determinants have a positive or negative effect on the other determinates [60]. Three determinants fall into this cluster, including collaboration, mutual trust, and knowledge management. These determinants are highly unstable, so careful observation is required during the process of logistics 4.0 adoption. It should be noted that, at every stage of logistics 4.0 adoption, managers should continuously observe these determinants.

The fourth cluster is driving determinates that have strong driving power, and weak dependence on others. Four determinants associated with this category include top management support, IT infrastructure, financial investment and organizational strategies for logistics 4.0. Logistics 4.0 implementation relies heavily on these determinants, and logistics partners should give these determinants the highest priority. Any changes in these determinants may have an impact on the other determinants at all levels of the hierarchy. As a result, the highest priority must be given to these four determinants.

6. Implications of Research

This research provided significant implications and useful insights for decision-makers and practitioners to adopt logistics 4.0. As logistics 4.0 is an evolving practice and its adoption is a challenge for the logistics partners, in order to make decisions regarding the adoption of logistic 4.0, organizations are concerned about the factors that are responsible for the logistics 4.0 adoption. The findings of this study show that top management support, IT infrastructure and financial investment are the major component for the adoption of logistics 4.0. The structural changes are required for the adoption of logistics 4.0 are not possible without top management's involvement. Further, the findings claim that IT infrastructure is also an essential component to operationalizing logistics 4.0 practices. The findings of this study corroborate previous research by Khan et al. [10], which indicated that top management involvement has a perceiving influence on the adoption of logistics 4.0. In addition, the organizational strategies need to align with logistics 4.0 to make the adoption process more effective. The current organizational strategies need to be revised and aligned with logistics 4.0 through the incorporation of industry 4.0 technology adoption. Through adopting the determinants of logistics 4.0, organizations can develop its analytical capabilities, digital work culture and skill development. With these characteristics, the organization can smoothly adopt logistics 4.0 and develop a competitive edge. Further, the fuzzy MICMAC analysis also supports the contextual relationship that is established through the ISM model. The fuzzy MICMAC analysis shows that organizations need to primarily focus on the driving determinants that include top management support, IT infrastructure, financial investment and organizational strategies for logistics 4.0. Moreover, it also suggests that the management needs to keep a close look at the linkage factors, collaboration, mutual trust, and knowledge management, at every stage of logistics 4.0 adoption. Based on the interplay among the determinants of logistics 4.0, policy planners could formulate their plans and strategies for the adoption of logistics 4.0.

7. Conclusions, Limitations and Future Scope

As the consequences of the fourth industrial revolution begin to emerge, the necessity for many industries to adopt new technology becomes increasingly evident. Several supply chain solutions are proposed to meet the consumer preferences in the present business environment. Logistics are a crucial component of the supply chain, and supply chain managers gives a lot of attention to them. The customer gains more from the implementation of logistics 4.0 due to enhanced transparency, reduced lead times, traceability, condition monitoring, etc. Therefore, the adoption of logistic 4.0 is the principal focus of this study through the adoption of its determinants. An integrated approach of a literature review and input from experts in the field of logistics is used to first identify the determinants of the adoption of logistics 4.0. These determinants are modelled through ISM for exploring the structural relationships among them. The developed structural model has four levels that show the relationship among these determinants. The structural relationship is helpful for management to align their efforts. Further, fuzzy MICMAC analysis is also used to categorize the determinants into four clusters based on their driving power. The finding shows that top management support, IT infrastructure and financial investment are the most significant determinants towards the adoption of logistics 4.0. It is important to consider that changes to the driving factors leading to improvements in the other determinants. Managers, decision-makers, and experts should instantly concentrate on these aspects to adapt logistics 4.0. Furthermore, based on the driving and dependence power, the MICMAC analysis shows that these three determinants, along with organizational strategies for logistics 4.0 factors, have high driving power. Therefore, the logistics partners should make the strategies for logistics 4.0 at the organizational and supply chain levels.

Similar to other studies, this work has some limitations. The first limitation is that, because there has been so little research conducted on logistics 4.0, it may be possible to overlook some determinants. Second, the expert's input, which is based on the finalization of the uncovered determinants, may be biased in favor of their managerial position, location, and organization. Thirdly, the ISM method is not capable of quantifying the strength of the relationship among the determinants of logistics 4.0. Future research could address these limitations. For identifying the determinants in the subsequent studies, a systematic literature review involving a larger number of documents, along with grey literature, might be conducted. With the help of multiple case studies, the findings of this study will be generalized. Other modelling approaches, such as structural equation modelling, system dynamics, and modified TISM, could be employed to establish the causal link.

Author Contributions: S.K. and R.S. conceived the idea. R.S. surveyed the literature and found determinants. S.K. collected the responses and contributed to the analysis, and J.C.S. and L.P.F. analyzed the results. S.K. and R.S. wrote the paper, and L.P.F. edited the original draft and administration the project. G.S. validated the results. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Details of the participated experts.

S. No	Position	Experience	Qualification	Gender	Specialisation(s)	Country
1.	Professor	28 Years	Doctorate	Male	Industry 4.0, Logistics 4.0, Technology transfer	India
2.	Logistics Manager	16 Years	Postgraduate	Female	Logistics Solution Provider, Logistics 4.0	India
3.	Warehouse managers	12 Years	Graduate	Male	Warehousing	India
4.	Technology Transfer Head	14 Years	Postgraduate	Male	Automation and Industry 4.0 adoption	India
5.	Associate Professor	15 Years	Doctorate	Male	Supply chain management 4.0	India
6.	Research and Development Head	18 Years	Doctorate	Female	Innovation and Technology transfer,	India
7.	Transport Manager	12 Years	Postgraduate	Male	Logistics Management	India
8.	Deputy Director	10 Years	Doctorate	Female	Industrial infrastructure Development	India

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