

Research Article

Why IoT Enablement of Agrifood Transportation Disappoints Its Stakeholders: Unravelling Barriers for Enhanced Logistics

Deepika Joshi ¹, Sumit Gupta ², Amit Vishwakarma ³ and Sandeep Jagtap ^{4,5}

¹Operations and Supply Chain Management Department, St. Joseph's Institute of Management, Bangalore 560025, India

²Department of Mechanical Engineering, Amity School of Engineering and Technology, Amity University Uttar Pradesh, Noida 201313, India

³Department of Management Sciences, Indian Institute of Technology, Kanpur 208016, India

⁴Sustainable Manufacturing Systems Centre, Faculty of Engineering & Applied Sciences, Cranfield University, Cranfield MK43 0AL, UK

⁵Division of Engineering Logistics, Department of Mechanical Engineering Sciences, Faculty of Engineering, Ole Romers Vag 1, M-Building, Lund University, Lund 22363, Sweden

Correspondence should be addressed to Sandeep Jagtap; sandeep.jagtap@tlog.lth.se

Received 26 January 2024; Revised 26 July 2024; Accepted 6 August 2024

Academic Editor: Ayon Tarafdar

Copyright © 2024 Deepika Joshi et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The present research work investigates the barriers of weak IoT adoption in agrifood transportation, with special reference to India. It is built on a premise that few barriers upshots from the other more impactful ones. Thus, it is important to identify their linkages and classify them based on their strength of relationship. The data collected from 13 agricultural technology (AgriTech) firms of India were subjected to integrated techniques of M-TISM and Fuzzy MICMAC. As a result, a unique position of autonomous, dependent, linkage, and independent barriers was obtained which revealed that inadequate Internet connectivity, interoperability, and unclear roadmaps are precarious to the use of IoT in agrifood transportation. They are responsible for creating issues like data processing, vehicle tracking, and data privacy. This study offers a contextual phenomenon of barriers that may assist AgriTech stakeholders in developing appropriate strategies to embrace IoT transformation. It extends the theoretical literature by providing critical connections that aspiring researchers can examine through hypothesis testing or building a hierarchical framework. A sensitivity analysis is suggested to optimise decision-making and bring out a robust and reliable set of obstacles.

1. Introduction

Indian agriculture has come a long way in terms of its daily operations. From the congenital procedure of manual farming to present day's smart agricultural (Agri) operations, all are striving to ensure product availability with minimal wastage and hurdles. According to the Food and Agriculture Organization (FAO) of the United Nations, 6 percent of agrifood production and harvest loss takes place postharvest and 18 percent occurs during its distribution and transportation. Moreover, Indian agrifood harvest amounting USD 11.1 billion was lost due to improper management across supply chain phases (ICAR-CIPET, March 2015). Such massive agrifood losses question the

country's stand in meeting Sustainable Development Goal (SDG) 2 which aims to ensure a hunger free nation by 2030. Despite being the third largest contributor to the national Gross Domestic Product (GDP), the pre- and postharvest agrifood supply chain has reported an IoT adoption of merely 10–30 percent [1].

The use of technology has improved food accessibility for common people and agriculture sustainability for global farmers [2–4]. But shorter life of agrifood products requires real-time monitoring and tracking during all stages of agrifood supply chain, namely, procurement, processing, packaging, labelling, loading, unloading, storage, distribution, and sales [5, 6]. Here, the use of IoT constantly captures and updates information. For example, the use of Electronic

Product Code (EPC) and Radio Frequency Identification (RFID) on products and transporting vehicles can help locate vehicles and sort products based on date and place of origin, longevity, usage, season, and quality grades, to name a few attributes. These embedded tags can predict the condition, improve speed, ease logistics, and reduce time and opportunity cost.

Due to the direct benefit of low-cost sensors and devices in the form of quality and yield, the producers and agricultural technology (AgriTech) entrepreneurs are placing a lot of trust on the digitization of preharvest technology. But postharvest digitization which also involves a multilayered distribution network is plagued by many stumbling causes that arise during the transportation of agri-produce from farmers and organized firms. These barriers stem from the number of restrictions like fragmentation, dominance, and inadequacies faced by farmers and organized firms and implementation agencies like the government [7]. Moreover, IoT-based transportation for the farm-to-market ecosystem in India is also challenged by the technological factors related to devices, Internet networks, and data hindrances [6, 8]. Identification of these barriers may lead to low-risk scalable IoT solutions that are easy to replicate at a lower cost. An understanding of current issues in the Agri transportation system forms the basis of this study.

Precisely, the presented research work is conducted with an objective to identify the hindrances faced by AgriTech firms while digitizing the transportation system. This led to the formulation of the first research question—what factors are responsible for a weak adoption of IoT in Indian agrifood transportation system? Moreover, in real-world situations, these barriers do not exert the same dominance. The differential power of their influence led to the formulation of the second research question—what is the influence of these barriers on each other? The academic studies on IoT adoption in various industries like manufacturing are on rise. However, a systematically conducted research work that explores the challenges of AgriTech firms during implementation of IoT in transportation systems are yet to be explored. This creates a substantial research gap to conduct this research work.

The present research work answers these intriguing research questions by utilizing a mixed methodology of Modified Total Interpretive Structural Modelling (M-TISM) and Fuzzy MICMAC. The use of M-TISM synthesized a hierarchical model based on the information shared by 13 AgriTech firms. It explained the nature and direction of power of each barrier. Further, the driving and dependence power of each barrier is identified by using a Fuzzy MICMAC technique. The outcome of this study is typically relevant to the Indian agriculture policy makers and firms that face hurdles while digitizing the transportation of agri-produce. Based on the findings of this research work, they can strengthen supply chain transparency and traceability. In addition, this research work extends possible strategies which are built around agri-transportation to overcome the challenges in achieving SDG 2.

The remainder of the article is organized as follows: the second section highlights the literature review on barriers to

the adoption of IoT-based supply chain management. The third section elaborates the mixed methodology adopted for conducting the research study. The fourth section presents the results and discussion. The fifth section highlights conclusion and future research direction for the research work.

2. Review of Literature

In order to identify the barriers to IoT execution in the agrifood sector, a comprehensive literature review was carried out. At first, reading reports and whitepapers obtained from the Ministry of Agriculture and Farmer Welfare, NASSCOM, and CISCO helped understand the challenges faced by stakeholders during the real-life execution of IoT in agrifood. From this, a long list of barriers was created. For academic literature, the most relevant full-text articles ($n = 50$) from the publishers indexed in the cross-reference were reviewed. This helped ascertain the presence of IoT barriers in academic literature. As a result, 30 barriers were identified. These were discussed with the five senior operations executives from AgriTech firms and five academicians having profound knowledge of IoT in various sectors. The twenty-four barriers which were then carefully chosen and preferred by a minimum of three experts were decided to be used for the present research work.

IoT devices gather a large amount of heterogeneous data to identify gaps in current supply chain and any forthcoming challenges [9]. These data are usually collected through IoT devices which operate on Internet-based networks. Many times, devices are either stolen, replaced, or damaged during transportation of products. The wireless networks are either disconnected or distorted due to unprotected agricultural fields and signal jams [10]. Ultimately, giving rise to the issues related to device and network tampering [11, 12]. Moreover, the data generated by stakeholders comes in various formats which make full-scale interoperability difficult [13, 14]. Nevertheless, a huge digital divide among stakeholders is a key responsible factor [5, 15].

Real-time data collected from various supply chain processes travel under insecure protocol networks. Further, this is stored on cloud or in local databases for the purpose of continuous monitoring [16, 17]. Such voluminous data are challenged by the use of unlicensed spectrum, data deformation, data duplication, and data collection in multiple units and languages [5, 18]. This makes the IoT ecosystem vulnerable and questions the reliability of databases and government procedures [15, 19]. Securing data with generic solutions like tracking the user ID, time, and location of data retrieval are well-thought-out choices to overcome the challenge of data quality and reliability [20]. At advanced level, protection of IoT devices, networks, and data from malware and direct interoperability requires a secured communication and transmission environment, multifactor authentication, common regulatory challenges, policy standardization, institutional fit of global standards, and a common information system [21].

Data latency due to poor Internet connectivity and WiFi-based long-distance networks delays the transmission of

data from farmlands to warehouses and distribution agencies [7]. Similarly, database scalability also becomes a challenge due to the block size of data, network load, and cost issues [22]. It also decreases the computation power and storage capacity on resource-constrained devices [23]. Approaches like increase in block size, optimization of databases, lightning of network, tamperproof transactional record, and protected execution environment should be focused to mitigate the issues of database scalability.

Despite the growing curiosity of IoT implementation, underdeveloped regulatory standards are a mega challenge [24, 25]. In reality, regulatory requirements are industry and geography specific. Thus, standards and protocols which are factored on a common foundation to overcome challenges of interoperability, portability, and manageability are achievable through formalized guidelines [26, 27].

IoT implementation involves huge financial investment in resources and business processes [28]. A clear roadmap or blueprint of implementation strategy is an operative solution [29]. It offers a collaborative multistakeholder approach towards process alignment, system, data accuracy, speed, efficacy, and governance to achieve steady performance. Here, policy standardization can be a key in achieving full potential of digital solutions [30]. It eases interoperability and secures data from vulnerabilities of privacy and security [7, 31]. But the diverse configuration of local and global supply chains has varied requirements. Any oddities in the standards and regulations set by local and global agencies further complicate the process [14].

The potency of an IoT-enabled system requires institutional fit of global standards. It calls for a multi-stakeholder activity that involves public-private partnership (PPP) to mobilize resources and generate value [32]. A distorted role, vague policies, unaligned goals, weak execution framework, inadequate procedure for risk sharing, and weak monitoring and evaluation of partners creates a challenge for PPP [33]. Trust-based governance that executes an agreement with the utmost sense of responsibility is a pressing need of IoT execution [34, 35]. The absence of cooperation among multiple stakeholders due to power and position-related issues hampers the formulation of suitable business models [35].

Supply chain configuration which arises due to IoT leads to fragmented information, supply-demand mismatch, and higher cost of supply chain [36]. A vehicle communication system that enables information sharing between vehicles, warehouses, and clouds strengthens supply chain efficiency [37]. An inadequate infrastructural like inefficient route management, inability to track shipments, underutilization of vehicle capacity, fluctuating transportation costs, unequal information availability to stakeholders, missing information between source and destination, and incorrect traffic prediction limits the vehicle communication and transportation management system [38, 39]. A common information system improves fact-based decision-making by integrating, processing, storing, and disseminating the gathered data [40, 41]. The difference in the structure of obtained data, data handling skills, lack of standard policy and regulation, varied organizational needs, and diverse

types of information systems are hassles to the use of common information systems [15].

While there have been numerous research papers addressing the barriers of IoT, determinants of IoT adoption, technological trends in transportation, and design of transportation systems published in the last few decades. To the best of the author's knowledge, no research work along the lines of investigating the barriers of IoT in agrifood products transportation w.r.t. India exists [5, 6, 18, 42]. The extant summaries on the barriers to IoT adoption in a variety of industries like education, smart cities, intermodal transport, transport infrastructure, public transport, and maritime transport are considered as the base for presented literature review [9, 43–45].

In literature, Modified Total Interpretive Structural Modelling (M-TISM) is considered a deep-rooted interactive technique to explore contextual relationships among a set of variables. It decomposes the experience and knowledge shared by survey respondents to develop comprehensive models which are systematic and word-perfect, thus, can be directly utilized by practitioners struggling with similar problems [46, 47]. This technique is well established among researchers working on similar types of research questions [5, 48–53].

In the agrifood industry, supply chain configuration influences IoT adoption [54]. Thus, the structure of IoT adoption in transportation of agri-products in India may vary from that of the other developed nations like Europe, United States, and Australia. But due to a clear-cut split of members like farmers, processors, distributors, and traders in agrifood supply chain, these barriers can be utilized beyond the Indian boundaries.

3. Research Methodology

In order to answer the two research questions, a two-stage data analysis process was followed. At the first stage, the well-established M-TISM technique was used to develop a framework of barriers. This precise framework exhibits the “to be influenced” and “to influence” relationships among all the barriers. At the second stage, a fuzzy MICMAC analysis was performed to obtain a power diagram. The use of fuzzy enhanced the sensitivity of obtained relationships in four quadrants and precisely clusters the barriers based on driving power and dependence power.

3.1. Modified Total Interpretive Structural Modelling (M-TISM). The M-TISM technique is an upgradation of the Total Interpretive Structural Model (TISM) and Interpretive Structural Model (ISM) [55]. It is a preferred method over TISM and ISM because it conceptualizes the model as well as its proper hierarchical structure. Moreover, TISM and ISM methods check transitivity relations separately, and sometimes, it is iterative in nature. This makes the problem complex. But the M-TISM technique performs reachability and transitivity check in a single step [48]. Moreover, the M-TISM technique finds out “why” and “how” related questions, which the conventional TISM and ISM methods

do not consider. The step used to implement M-TISM technique is discussed as follows:

- (1) Identification of the critical barriers.
- (2) Development of contextual relationships among the identified barriers.
- (3) Interpretation of relation among barriers.
- (4) Development of reachability matrix and transitivity check.
- (5) Level partitioning and development of the model.

STEP 1: In this step, twenty-four barriers were identified from the academic literature. Initially sorting is performed for reducing as well as identifying the critical barriers with the consultation of experts. Their opinion is taken on the five-point Likert scale for every individual barrier. In this study, a total of 13 experts are taken and their response is presented in Table 1. After this, the sum of the opinions is considered and their percentage is calculated. Those barriers which contributed more than 60% were sorted and considered for the next step [5, 51].

From Table 1, eleven barriers which contribute substantially, i.e., 60% and above were separated. These are RST1, RST2, RST4, RST6, RST7, RST11, RST14, RST15, RST17, RST18, and RST23.

STEP 2: During this step, a relationship among individual barriers (out of 11 barriers) was explored. These relationships were called as the contextual relationship. Contextual relationship explains that how one barrier influences the other barrier. The contextual relationships among all identified barriers were represented.

STEP 3: At this step, relationships among challenges were interpreted to find the cause behind relationship. It means the “why” and “how” connection was identified.

STEP 4: This step included the formation of a reachability matrix and simultaneously perform a transitivity check. The relationship between two challenges was explored for their entry into the matrix. If a relationship exists, “Y” (i.e., Yes) was entered, and if no relationship exists, the “N” (i.e. No) was entered in the matrix. This matrix is called as structural self-interaction matrix and is shown in Table 2.

Then, all the “Y” was replaced by 1 and all “N” was replaced by 0. The conversion of structural self-interaction matrix into numbers is shown in Table 3. In the end, transitivity was checked for all the relationships using the law of transitivity. The law of transitivity can be explained as if A is in a relationship with B and B is in a relationship with C, then A is in a relationship with C. The obtained table is called as the final reachability matrix and is shown in Table 4.

STEP 5: This step classified all barriers into different levels based on their influencing power, after which

the development of model takes place. Barrier's classification follows the same methodology as used in ISM and TISM methods. Once the cumulative score of deriving and dependence power of each barrier is calculated, they have been classified into various levels. This process comprised identification of reachability set and antecedent sets. The reachability set consisted of the barrier itself and the other barriers it may impact, whereas the antecedent set consisted of the barrier itself and the other barriers that may affect it. These two common elements are taken, and they are called an intersection set. Fixation of level is done via exact matching of the intersection set with the reachability set, then eliminating those values. This process is repeated continuously until all the levels are decided. After performing all these steps in the final reachability matrix, we get the level of each individual barrier. The same is mentioned in Table 5.

Reachability Set, Antecedent Set, and Intersection Set are obtained by following the aforementioned methods and are shown in Table 5. Following iterations, which involve comparing intersection set elements with reachability set elements, assigning level, and eliminating it. This procedure keeps on until every level is completed. The level of each challenge is presented in Table 6.

After the level partitioning, as shown in Figure 1, a hierarchical model was plotted. For the current set of barriers, we get four levels which sequence the most impactful barrier at the base and least impactful on the top.

3.2. Fuzzy-MICMAC (FMICMAC) Analysis. For the M-TISM method, 0 and 1 were used to indicate the association between the two challenges. This association can be explored in deep by using the Fuzzy-MICMAC (FMICMAC) technique. For example, it can be categorized into very strong, strong, low, and so on. FMICMAC is based on the fuzzy theory which deals with this equivocality and weakness in the decision-making cycle [50]. Here, experts' opinion is considered for converting the linguistic judgments into fuzzy numbers. In present-time research, FMICMAC is preferred over the conventional MICMAC method due to the fact that FMICMAC provides the flexibility to scale challenges into seven values (i.e., 0, 0.1, 0.3, 0.5, 0.7, 0.9, and 1). But a conventional MICMAC categorizes merely into two ways (i.e., 0 and 1). So, the opinion of the experts gets recorded more precisely in FMICMAC, which is not the case with conventional MICMAC. Moreover, during computation, in the FMICMAC method, fuzzy multiplication occurs; in the traditional MICMAC method, normal multiplication occurs.

In this research, scaling of barriers was done by taking 7 values. These are 0, 0.1, 0.3, 0.5, 0.7, 0.9, and 1, and the meaning corresponding to these values is no relationship, negligible relationship, low relationship, medium relationship, high relationship, very high relationship, and full

TABLE 1: Descriptive statistics of expert opinion.

Barriers	Ex1	Ex2	Ex3	Ex4	Ex5	Ex6	Ex7	Ex8	Ex9	Ex10	Ex11	Ex12	Ex13	Sum	%
RST1	4	4	2	2	4	4	4	2	4	4	4	4	4	46	71
RST2	2	2	4	2	4	4	4	2	4	4	2	4	2	40	62
RST3	1	2	2	4	2	3	4	2	4	2	2	4	4	36	55
RST4	4	3	3	4	3	3	4	4	4	4	4	4	4	48	74
RST5	3	3	2	2	4	1	4	1	4	4	1	4	2	35	54
RST6	4	4	4	3	4	4	4	3	4	4	3	4	4	49	75
RST7	4	4	4	3	4	4	4	4	4	4	4	4	4	51	78
RST8	2	1	2	1	2	1	2	1	1	2	1	1	2	19	29
RST9	4	1	2	1	2	2	2	1	1	1	1	1	2	21	32
RST10	2	2	2	2	2	2	2	1	1	1	1	2	1	21	32
RST11	4	4	3	3	4	4	4	3	4	3	4	4	3	47	72
RST12	2	2	2	1	2	2	2	1	1	1	2	1	1	20	31
RST13	2	2	1	1	2	2	2	2	2	2	1	2	1	22	34
RST14	4	5	4	4	5	4	5	4	5	4	5	4	5	58	89
RST15	4	4	5	4	4	4	5	4	4	4	4	4	5	55	85
RST16	3	1	5	2	3	3	2	3	2	3	3	2	2	34	52
RST17	4	5	4	5	5	5	4	5	5	5	5	5	4	61	94
RST18	4	4	5	5	4	4	4	5	4	4	4	4	4	55	85
RST19	3	2	3	3	3	2	3	2	3	4	3	3	3	37	57
RST20	3	1	4	3	3	2	4	3	3	1	3	2	4	36	55
RST21	3	2	3	3	4	2	4	3	3	4	2	2	2	37	57
RST22	3	2	2	2	4	4	1	4	2	4	2	2	3	35	54
RST23	4	5	4	4	5	4	4	4	4	4	4	5	4	55	85
RST24	2	2	4	3	2	4	4	3	3	3	3	2	3	38	58

TABLE 2: Structural self-interaction matrix.

	RST1	RST2	RST4	RST6	RST7	RST11	RST14	RST15	RST17	RST18	RST23
RST1	—	N	N	N	N	N	Y	N	N	Y	N
RST2	N	—	Y	Y	Y	Y	N	Y	Y	Y	N
RST4	N	Y	—	N	Y	Y	N	N	N	N	N
RST6	N	N	N	—	Y	Y	N	N	N	N	N
RST7	N	N	Y	N	—	N	N	N	N	N	N
RST11	N	N	Y	Y	N	—	N	N	N	N	N
RST14	N	Y	N	N	Y	Y	—	Y	Y	Y	N
RST15	N	Y	N	Y	N	Y	N	—	Y	Y	Y
RST17	N	N	Y	Y	Y	Y	Y	Y	—	Y	Y
RST18	N	Y	Y	N	Y	N	N	N	Y	—	N
RST23	N	Y	Y	N	N	N	N	N	Y	Y	—

TABLE 3: Conversion of structural self-interaction matrix.

	RST1	RST2	RST4	RST6	RST7	RST11	RST14	RST15	RST17	RST18	RST23
RST1	—	0	0	0	0	0	1	0	0	1	0
RST2	0	—	1	1	1	1	0	1	1	1	0
RST4	0	1	—	0	1	1	0	0	0	0	0
RST6	0	0	0	—	1	1	0	0	0	0	0
RST7	0	0	1	0	—	0	0	0	0	0	0
RST11	0	0	1	1	0	—	0	0	0	0	0
RST14	0	1	0	0	1	1	—	1	1	1	0
RST15	0	1	0	1	0	1	0	—	1	1	1
RST17	0	0	1	1	1	1	1	1	—	1	1
RST18	0	1	1	0	1	0	0	0	1	—	0
RST23	0	1	1	0	0	0	0	0	1	1	—

relationship, respectively. The values obtained from the expert's opinions were then superimposed on the Binary Direct Reachability Matrix (BDRM) to obtain a Fuzzy Direct Reachability Matrix (FDRM), which is given in Table 7.

In FMICMAC analysis, fuzzy matrix multiplication took place. This multiplication process is quite different from conventional matrix multiplication [50, 52, 53]. According to the fuzzy multiplication rule, the product of two fuzzy

TABLE 4: Final reachability matrix.

	RST1	RST2	RST4	RST6	RST7	RST11	RST14	RST15	RST17	RST18	RST23
RST1	1	1*	1*	0	1*	1*	1	0	0	1	0
RST2	0	1	1	1	1	1	1*	1	1	1	1*
RST4	0	1	1	1*	1	1	0	1*	1*	1*	0
RST6	0	0	1*	1	1	1	0	0	0	0	0
RST7	0	1*	1	0	1	1*	0	0	0	0	0
RST11	0	1*	1	1	0	1	0	0	0	0	0
RST14	0	1	1*	0	1	1	1	1	1	1	1*
RST15	0	1	1*	1	1*	1	1*	1	1	1	1
RST17	0	1*	1	1	1	1	1	1	1	1	1
RST18	0	1	1	1*	1	1*	1*	1*	1	1	1*
RST23	0	1	1	1*	1*	1*	1*	1*	1	1	1

TABLE 5: Final reachability matrix.

Challenges code	Reachability set	Antecedent set	Intersection set
RST1	1, 2, 4, 7, 11, 14, 18	1	1
RST2	2, 4, 6, 7, 11, 14, 15, 17, 18, 23	1, 2, 4, 7, 11, 14, 15, 17, 18, 23	2, 4, 7, 11, 14, 15, 17, 18
RST4	2, 4, 6, 7, 11, 15, 17, 18, 23	1, 2, 4, 6, 7, 11, 14, 15, 17, 18, 23	2, 4, 6, 7, 11, 15, 17, 18, 23
RST6	4, 6, 7, 11	2, 4, 6, 15, 17, 18, 23	4, 6
RST7	2, 4, 7, 11	1, 2, 4, 6, 7, 14, 15, 17, 18, 23	2, 4, 7
RST11	2, 4, 6, 11	1, 2, 4, 6, 7, 11, 14, 15, 17, 18, 23	2, 4, 6, 11
RST14	2, 4, 7, 11, 14, 15, 17, 18, 23	2, 3, 15, 17, 18, 23	2, 15, 17, 18, 23
RST15	2, 4, 6, 7, 11, 14, 15, 17, 18, 23	2, 4, 14, 15, 17, 18, 23	2, 4, 14, 15, 17, 18, 23
RST17	2, 4, 6, 7, 11, 14, 15, 17, 18, 23	2, 4, 14, 15, 17, 18, 23	2, 4, 14, 15, 17, 18, 23
RST18	2, 4, 6, 7, 11, 14, 15, 17, 18, 23	1, 2, 3, 14, 15, 17, 18, 23	2, 14, 15, 17, 18, 23
RST23	2, 4, 6, 7, 11, 14, 15, 17, 18, 23	2, 14, 15, 17, 18, 23	2, 14, 15, 17, 18, 23

TABLE 6: Classification of challenges into different levels.

Challenge code	Name of challenge	Level partitioning
RST1	Inadequate internet connectivity	4
RST2	Device interoperability	4
RST4	Physical tampering	1
RST6	Data governance	3
RST7	Data latency	2
RST11	Data processing	1
RST14	Unclear roadmap	4
RST15	Regulatory standards	3
RST17	Policy standardization	3
RST18	Vehicle tracking systems	3
RST23	Weak data security system	2

matrices is also a fuzzy matrix [49]. This multiplication process is described below in Fuzzy Multiplication Equation in the form of matrices A & B.

Fuzzy Multiplication Equation as shown below in equation in

$$AB = \text{Max}\{\text{Min}(a_{ij}, b_{ij})\}, \quad (1)$$

where

$$\begin{aligned} A &= (a_{ij}), \\ B &= (b_{ij}). \end{aligned} \quad (2)$$

The FDRM was taken as the preliminary matrix to start the procedure. The matrix was repetitively multiplied and iterated. This process continued till the values of driving, and the dependence power stabilizes.

These values were plotted in the form of a table. The dependence and driving power of barriers were found in a similar way as completed earlier. They are obtained by summing up the columns and the rows of the final fuzzy reachability matrix, respectively. Table 8 presents the final fuzzy reachability matrix.

After performing the fuzzy MICMAC analysis, the driving and dependence power of each barrier was obtained in decimal form. Based on the values of dependence and driving power, all barriers were clustered into 4 quadrants (Figure 2).

Figure 2 presents these quadrants as I, II, III, and IV. They were given standard names, i.e., autonomous, dependent, linkage, and independent barriers.

- (i) Autonomous barriers—These are the barriers from the first quadrant having less driving and dependence power. Barriers that arise due to physical tampering, data processing, and data security systems are placed in this quadrant. These barriers have the least influence on the IoT adoption system. In the M-TISM model, these barriers were positioned at top as levels 1 and 2. The stakeholders of IoT adoption should focus more on the barriers which derive autonomous barriers.

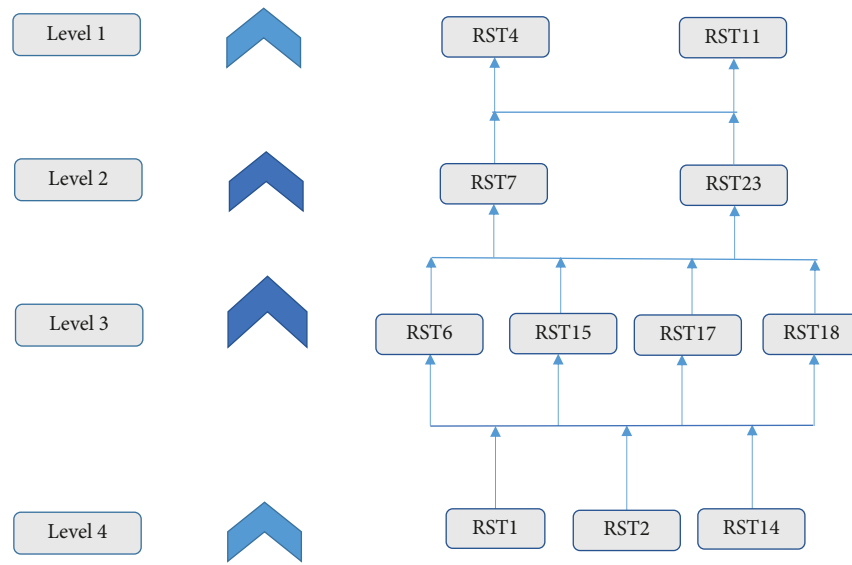


FIGURE 1: Level partitioning model.

TABLE 7: Fuzzy direct reachability matrix (FDRM).

	RST1	RST2	RST4	RST6	RST7	RST11	RST14	RST15	RST17	RST18	RST23
RST1	0.1	0.7	0	0.5	0.7	0.7	0.5	0.5	0.5	0.1	0.1
RST2	0.1	0	0.3	0.3	0.1	0.3	0.3	0.5	0.5	0.3	0.3
RST4	0	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0
RST6	0	0.3	0.3	0	0.3	0.3	0.3	0.5	0.5	0.5	0.3
RST7	0	0.5	0.3	0.5	0	0.9	0.3	0.5	0.3	0.9	0.3
RST11	0.1	0.9	0.7	0.7	0.7	0	0.3	0.3	0.3	0.1	0
RST14	0.1	0.3	0.5	0.1	0.1	0.1	0	0.9	0.9	0.7	0.3
RST15	0.1	0.5	0.5	0.3	0.3	0.3	0.7	0	0.7	0.3	0.3
RST17	0.3	0.5	0.7	0.7	0.7	0.7	0.3	0.9	0	0.7	0.1
RST18	0	0.5	0.7	0.3	0.3	0.3	0.7	0.7	0.7	0	0.3
RST23	0	0.1	0.3	0.3	0.1	0.1	0.5	0.7	0.7	0.5	0

TABLE 8: Fuzzy stabilized matrix.

	RST1	RST2	RST4	RST6	RST7	RST11	RST14	RST15	RST17	RST18	RST23	Driving power
RST1	0.3	0.9	0.7	0.7	0.5	0.5	0.5	0.7	0.7	0.7	0.5	6.7
RST2	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.7	0.7	0.3	7.1
RST4	0.1	0.3	0.3	0.1	0.3	0.1	0.1	0.3	0.3	0.3	0.3	2.5
RST6	0.3	0.7	0.7	0.7	0.7	0.7	0.5	0.7	0.7	0.7	0.3	6.7
RST7	0.3	0.5	0.7	0.5	0.5	0.3	0.7	0.7	0.7	0.5	0.3	5.7
RST11	0.3	0.7	0.3	0.3	0.7	0.1	0.5	0.7	0.9	0.7	0.3	5.5
RST14	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.7	0.7	0.3	7.1
RST15	0.3	0.7	0.7	0.7	0.5	0.5	0.5	0.7	0.7	0.7	0.3	6.3
RST17	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.7	0.5	0.3	6.5
RST18	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	6.9
RST23	0.3	0.5	0.7	0.7	0.7	0.5	0.7	0.3	0.7	0.3	0.3	5.7
Dependence power	3.1	7.1	6.9	6.5	6.7	5.5	6.3	7.1	7.5	6.5	3.5	

(ii) Dependent barriers—These are the second quadrant barriers with high dependence and low driving power. Data latency as a barrier is to be found in this quadrant. In order to reduce its impact, the effect of rest of the barriers that arise due to missing data governance, loose regulatory standards, weak policy

standardization, unclear roadmap, feeble Internet connectivity, and difficult device interoperability should be minimized. Supply chain managers, AgriTech firms, and policy makers should keep these barriers on high priority to stop the third ripple effect.

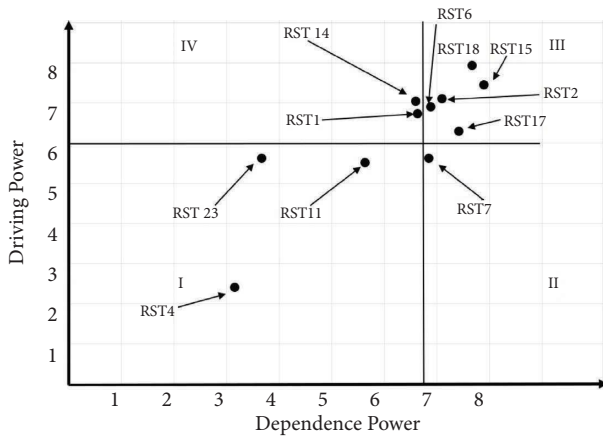


FIGURE 2: Driving-dependence power diagram.

- (iii) Linkage barriers—Linkage elements are the third quadrant elements with high dependence and driving power. Barriers like device interoperability, data governance, regulatory standards, policy standardization, and vehicle tracking system barriers are located in this quadrant. Any effect on these barriers will have a huge impact on barriers like data security systems, physical tampering of devices, and data processing. This supports the result of the M-TISM method as these challenges belong to the higher level, i.e., level 3 and level 4.
- (iv) Independent barriers—These are the fourth quadrant elements with low dependency power and high driving power. Barriers due to inadequate Internet connectivity, device interoperability, and unclear roadmap are listed in this quadrant. These are the barriers with high priority. For the successful adoption of IOT, supply chain managers should primarily work on these barriers. This also supports the result of the M-TISM method as these challenges belong to the higher level, i.e., level 4.

4. Results

The M-TISM model, as shown in Figure 1, arranged the barriers from base to top in an increasing order of criticality. For example, four challenges which were placed at level 4, i.e., inadequate Internet connectivity (RST1), device interoperability (RST2), and unclear roadmap (RST14) are critical barriers to IoT-enabled agrifood transportation. They are responsible for the other top-level barriers. Firm's strategy to reduce the impact of these barriers will reduce the impact of level 1 barriers. Similarly, level 3 consists of 4 barriers, i.e., data governance (RST6), regulatory standard (RST15), policy standardization (RST17), and vehicle tracking system (RST18) which are propelled by level 4 barriers influence the barriers at levels 1 and 2. It means that the barriers located at the base of the model are responsible for barriers at the upper level and the barriers at the top of the model have least criticality [48].

The relationship among barriers explored through M-TISM was further analysed using FMICMAC analysis. The obtained four quadrants show interdependence among the 11 barriers. The autonomous barriers like physical tampering (RST4), data security system (RST23), and data processing (RST11) in the first quadrant do not obstruct IoT adoption [12]. Largely, these barriers are isolated from the system with limited strong connections. They are weak drivers and have weak dependence upon the IoT adoption system of any firm. The dependent barrier—data latency in the second quadrant is weak in its nature and least responsible for occurrence of other variables. This shows that firms engaged in agrifood transportation give less importance to storage, travel, and retrieval time of data during IoT adoption [22]. Linkage barriers in the third quadrant attract the largest number of barriers. It links the barriers in the first and second quadrants with the fourth quadrant. Thus, it transmits the impact of lower level barriers to higher level barriers [48]. Firm's endeavour to eliminate these barriers will take agrifood transportation closer to its easy IoT adoption. Finally, independent barriers, i.e., inadequate Internet connectivity and unclear roadmap in the fourth quadrant, exert strong driving power to intensify the influence of all other barriers. But they are least influenced by the rest of the barriers. In order to reduce the impact of independent barriers, stakeholders of agrifood transportation business should work upon collaborative supply chain strategy [30].

5. Discussion

In the agrifood supply chain, transportation is a critical connection between the point of origin and end consumers [6, 56]. An importance of food safety and quality makes monitoring an invaluable asset for supply chain efficiency. But in the presence of a technology adoption barrier, it becomes hard for firms to utilise the full potential of IoT [43]. Through M-TISM, this research work identifies the impact of these barriers and any relationship between them. Like inadequate availability of Internet on farmlands leads to data latency which create hurdles on-time processing of data. In the same way, an unclear roadmap for IoT implementation questions the data governance system. The dominant barriers which exist at the base of the level partitioning model in Figure 1 put across the system level barriers viz unclear roadmap, inadequate Internet, and device interoperability. Firms need to completely eradicate its supply chain from these three root barriers. In an end-to-end supply chain network, it plainly conveys the organization's vision towards digitization. In order to overcome such barriers, supply chain members can develop common strategies and vision of technology leverage. A collective capital expenditure by firms is required for improving the network connectivity and infrastructure which will ensure real-time connectivity across all phases in the agrifood supply chains [28, 57]. Overall, firms should create an ecosystem wherein all the pain points are tackled effortlessly with benefit to all.

After M-TISM analysis, the FMICMAC technique helped understand the forces of interactions among the considered set of IoT barriers. The resultant four clusters segregated the barriers based upon their magnitude of relatedness and thus separated key barriers from the trivial ones. It is significant to note in Figure 2 on driving-dependence power that barriers of first and second quadrants are driven by barriers of third and fourth quadrants. Such as physical tampering, data processing, weak data security system, and data latency in first and second quadrants drive the barriers like inadequate Internet connectivity, unclear roadmap, device interoperability, data governance, regulatory standards, policy standardization, and vehicle tracking systems located in third and fourth quadrants. The findings of FMICMAC analysis also offer insights from individual clusters. Cluster I exhibits strong connections with very few barriers like inadequate Internet connectivity, device interoperability, and unclear roadmap. But they have negligible driving power. In the second quadrant, data latency as a barrier shows strong dependence on barriers like data governance and policy standardization. This cluster shows weak driving power. The third quadrant having five barriers, viz., governance, regulatory standards, policy standardization, and vehicle tracking systems presents strong dependence Internet connectivity, device interoperability, and unclear roadmap. Its barriers also exhibit strong dependence on other barriers. The fourth quadrant barriers, namely, inadequate Internet connectivity and unclear roadmap, exert strong driving power on other barriers but have weak dependence upon other barriers. The observations made from FMICMAC analysis will help supply chain managers to design appropriate strategies that may lessen the influence of barriers located in third and fourth quadrants.

6. Practical and Policy Implication

Postharvest losses continue to be a top concern among policy makers [1]. Around 13.3 percent of food loss is reported only during transportation. The use of IoT-based technologies in supply chain operations has proved to reduce these losses [6, 17, 58]. On the similar lines, these critical barriers shown in Figure 1 present the hierarchical barriers that require interventions from bodies responsible for creating an IoT ecosystem. Inadequate Internet connectivity which challenges farming operations on the distantly located farmlands of rural India can be addressed by the Department of Telecommunication. In collaboration with Internet service providers, it can design a clear roadmap for supplying a last-mile Internet connectivity to transportation vehicles. This will reduce the impact challenges owing to data interoperability and data latency. Further, the Data Management Office at the local and central level can coordinate with AgriTech firms to secure data when vehicles are transporting the agriproducts. This will ensure a superior data governance system while ensuring no ports or connectors are exposed for data or device tampering. An open discussion on existing data management standards in the light of pain points identified in this research may guide policy makers to set guidelines and develop a mutually agreed framework of IoT adoption.

7. Conclusion

In the existing literature, quite a number of studies have established the difficulties faced by organizations during IoT adoption in supply chain activities. Ascertaining the barriers to IoT implementation w.r.t the transportation of the agrifood sector remains elusive. The presented research work bridges the gap through the comprehensive analysis of possible difficulties by adopting the M-TISM and FMICMAC techniques. It propounds a theoretical model for further development of transportation processes in the agrifood sector. The 24 barriers are clustered into 4 quadrants which reveals the driving and dependence power of each of them. From the results, the three critical hurdles to IoT implementation are inadequate Internet connectivity throughout the transportation, interoperability, and unclear roadmap for the process alignment, system, data accuracy, speed, efficacy, and governance. The causal effect of these driving barriers passes on to another set of barriers which is forwarded to a further level, thus making IoT adoption more complicated. This study is a contribution to the transportation as well as the agrifood sector by addressing such connectedness among barriers so that sustainability in agriproduct transportation can be achieved. The developed M-TISM model can assist AgriTech firms and government agencies to focus on the key driving barriers in IoT adoption. Like, public and private firms can develop Internet infrastructure for better connectivity in vehicles [57]. Supply chain managers of agriproduct transportation firms can adopt a common information system and standard regulations and to reduce interoperability. This research work can be useful for multiple stakeholders in agritransportation to align processes, systems, data accuracy, speed, efficacy, and governance to achieve steady performance. For academic researchers, this research work can act as a base to begin empirical research. In addition, scientists working on developing a technologically smart business ecosystem can build an intelligent decision support system for automated decision-making in the complete value chain of the agrifood industry.

8. Limitations and Future Scope

The current research is based on the hierarchical model which is a theoretical framework and was not based on statistically derived results. In future research work, researchers can fragment the end-to-end transportation into various levels and then can study the barriers exclusive to each level. This may provide a segment that requires relatively more attention for the seamless adoption of IoT in transportation. The developed theoretical model can be statistically tested to establish that the identified barriers and their associations are not by chance, and they are the result of deep knowledge and opinion shared by the researchers.

Data Availability

The original contributions presented in the study are included in the article, and further inquiries can be directed to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

- [1] United Nations, "The sustainable development goals report 2018," 2018, <https://unstats.un.org/sdgs/files/report/2018/the-sustainable-development-goals-report-2018-en.pdf>.
- [2] A. Corallo, M. De Giovanni, M. E. Latino, and M. Menegoli, "Leveraging on technology and sustainability to innovate the supply chain: A proposal of agri-food value chain model," *Supply Chain Management: International Journal*, vol. 29, no. 3, pp. 661–683, 2024.
- [3] W. Martindale, A. Saeidan, F. Tahernezhad-Javazm, T. Æ. Hollands, L. Duong, and S. Jagtap, "Mapping the path to decarbonised agri-food products: A hybrid geographic information system and life cycle inventory methodology for assessing sustainable agriculture," *International Journal of Food Science and Technology*, 2024.
- [4] R. Vinuesa, H. Azizpour, I. Leite et al., "The role of artificial intelligence in achieving the sustainable development goals," *Nature Communications*, vol. 11, no. 1, p. 233, 2020.
- [5] V. S. Narwane, A. Gunasekaran, and B. B. Gardas, "Unlocking adoption challenges of IoT in Indian agricultural and food supply chain," *Smart Agricultural Technology*, vol. 2, 2022.
- [6] S. Yadav, D. Garg, and S. Luthra, "Analysing challenges for internet of things adoption in agriculture supply chain management," *International Journal of Industrial and Systems Engineering*, vol. 36, no. 1, pp. 73–97, 2020.
- [7] R. Vedapradha, D. Joshi, and R. Hariharan, "Prioritizing evaluation criteria of IoT-driven warehousing startups: A silver lining to the unorganized sector in food supply chain," *International Journal of Logistics Management*, 2024.
- [8] S. Jagtap, F. Bader, G. Garcia-Garcia, H. Trollman, T. Fadiji, and K. Salonitis, "Food logistics 4.0: opportunities and challenges," *Logistics*, vol. 5, no. 1, p. 2, 2020.
- [9] C. N. Verdouw, J. Wolfert, A. J. M. Beulens, and A. Rialland, "Virtualization of food supply chains with the internet of things," *Journal of Food Engineering*, vol. 176, pp. 128–136, 2016.
- [10] P. Varga, S. Plosz, G. Soos, and C. Hegedus, "Security threats and issues in automation IoT," in *Proceedings of the 2017 IEEE 13th International Workshop on Factory Communication Systems (WFCS)*, pp. 1–6, Linz, Austria, May 2017.
- [11] H. Pesanhane, W. R. Bezerra, F. Koch, and C. Westphall, "Distributed AgriFood supply chains," *Journal of Network and Systems Management*, vol. 32, no. 3, p. 64, 2024.
- [12] X. Yang, L. Shu, Y. Liu, G. P. Hancke, M. A. Ferrag, and K. Huang, "Physical security and safety of iot equipment: A survey of recent advances and opportunities," *IEEE Transactions on Industrial Informatics*, vol. 18, no. 7, pp. 4319–4330, 2022.
- [13] S. Aydin and M. N. Aydin, "Semantic and syntactic interoperability for agricultural open-data platforms in the context of IoT using crop-specific trait ontologies," *Applied Sciences*, vol. 10, no. 13, p. 4460, 2020.
- [14] C. Brewster, I. Roussaki, N. Kalatzis, K. Doolin, and K. Ellis, "IoT in agriculture: Designing a Europe-wide large-scale pilot," *IEEE Communications Magazine*, vol. 55, no. 9, pp. 26–33, 2017.
- [15] T. Dibbern, L. A. S. Romani, and S. M. F. S. Massruhá, "Main drivers and barriers to the adoption of digital agriculture technologies," *Smart Agricultural Technology*, vol. 8, 2024.
- [16] A. Panghal, S. Pan, P. Vern, R. S. Mor, and S. Jagtap, "Blockchain technology for enhancing sustainable food systems: A consumer perspective," *International Journal of Food Science and Technology*, vol. 59, no. 5, pp. 3461–3468, 2024.
- [17] Y. Zhao, Q. Li, W. Yi, and H. Xiong, "Agricultural IoT data storage optimization and information security method based on blockchain," *Agriculture*, vol. 13, no. 2, p. 274, 2023.
- [18] X. Zhang, Y. Sun, and Y. Sun, "Research on cold chain logistics traceability system of fresh agricultural products based on blockchain," *Computational Intelligence and Neuroscience*, vol. 2022, Article ID 1957957, 12 pages, 2022.
- [19] A. Ometov, V. Petrov, S. Bezzateev, S. Andreev, Y. Koucheryavy, and M. Gerla, "Challenges of multi-factor authentication for securing advanced IoT applications," *IEEE Network*, vol. 33, no. 2, pp. 82–88, 2019.
- [20] Y. Bertrand, R. Van Belle, J. De Weerd, and E. Serral, "Defining data quality issues in process mining with IoT data," in *Process Mining Workshops: ICPM 2022 International Workshops, Bozen-Bolzano, Italy, October 23–28, 2022, Revised Selected Papers*, pp. 422–434, Springer Nature Switzerland, Cham, 2023.
- [21] Y. Song, F. R. Yu, L. Zhou, X. Yang, and Z. He, "Applications of the Internet of things (IoT) in smart logistics: a comprehensive survey," *IEEE Internet of Things Journal*, vol. 8, no. 6, pp. 4250–4274, 2020.
- [22] V. Sahni, S. Srivastava, and R. Khan, "Modelling techniques to improve the quality of food using artificial intelligence," *Journal of Food Quality*, vol. 2021, Article ID 2140010, 10 pages, 2021.
- [23] L. Zhaoliang, W. Huang, and D. Wang, "Functional agricultural monitoring data storage based on sustainable block chain technology," *Journal of Cleaner Production*, vol. 281, 2021.
- [24] S. Chatterjee and A. K. Kar, "Regulation and governance of the internet of things in India. Digital policy," *Regulation and Governance*, vol. 20, no. 5, pp. 399–412, 2018.
- [25] C. Maple, "Security and privacy in the internet of things," *Journal of cyber policy*, vol. 2, no. 2, pp. 155–184, 2017.
- [26] H. F. Atlam and G. B. Wills, "Intersections between IoT and distributed ledger," *Advances in Computers*, vol. 115, pp. 73–113, 2019.
- [27] A. Banafa, "IoT standardization and implementation challenges," *IEEE internet of things newsletter*, vol. 2016, pp. 1–10, 2016.
- [28] S. Hafeez, O. Juszczuk, and J. Takala, "A Roadmap for successful IoT implementation: Empirical evidence from the energy industry," *Issues in Information Systems*, vol. 22, 2021.
- [29] P. Cui, U. Guin, A. Skjellum, and D. Umphress, "Blockchain in IoT: Current trends, challenges, and future roadmap," *Journal of Hardware and Systems Security*, vol. 3, pp. 338–364, 2019.
- [30] M. S. Farooq, S. Riaz, A. Abid, K. Abid, and M. A. Naeem, "A survey on the role of IoT in agriculture for the implementation of smart farming," *IEEE Access*, vol. 7, pp. 156237–156271, 2019.
- [31] Y. Turovets and K. Vishnevskiy, "Standardization in smart manufacturing: evaluation from a supply-side perspective," in *Intelligent Systems in Digital Transformation: Theory and Applications*, pp. 191–218, Springer International Publishing, Cham, Switzerland, 2022.
- [32] T. Liu, S. Mostafa, S. Mohamed, and T. S. Nguyen, "Emerging themes of public-private partnership application in developing smart city projects: A conceptual framework," *Built*

- Environment Project and Asset Management*, vol. 11, no. 1, pp. 138–156, 2021.
- [33] D. W. Brinkerhoff and J. M. Brinkerhoff, “Public-private partnerships: Perspectives on purposes, publicness, and good governance,” *Public Administration and Development*, vol. 31, no. 1, pp. 2–14, 2011.
 - [34] J. Verhoosel, M. van Bekkum, and T. Verwaart, “HortiCube: A platform for transparent, trusted data sharing in the food supply chain,” pp. 384–388, 2016.
 - [35] S. Wolfert, L. Ge, C. Verdouw, and M. J. Bogaardt, “Big data in smart farming—A review,” *Agricultural Systems*, vol. 153, pp. 69–80, 2017.
 - [36] C. Colon, Å. Brännström, E. Rovenskaya, and U. Dieckmann, “Fragmentation of production amplifies systemic risks from extreme events in supply-chain networks,” *PLoS One*, vol. 15, no. 12, 2020.
 - [37] B. Martínez-Rodríguez, S. Bilbao-Arechabala, and F. Jorge-Hernandez, “Security architecture for swarms of autonomous vehicles in smart farming,” *Applied Sciences*, vol. 11, p. 4341, 2021.
 - [38] C. E. Cugnasca, A. M. Saraiva, A. R. Hirakawa, and C. Strauss, “Communication protocols for application in agricultural vehicles,” *Fieldbus Technology: Industrial Network Standards for Real-Time Distributed Control*, pp. 435–450, 2003.
 - [39] A. S. Tomar, M. Singh, G. Sharma, and K. V. Arya, “Traffic management using logistic regression with fuzzy logic,” *Procedia Computer Science*, vol. 132, pp. 451–460, 2018.
 - [40] A. Khanna and S. Kaur, “Internet of things (IoT), applications and challenges: A comprehensive review,” *Wireless Personal Communications*, vol. 114, pp. 1687–1762, 2020.
 - [41] M. J. Sousa, R. Cruz, I. Dias, and C. Caracol, “Information management systems in the supply chain,” in *Handbook of Research on Information Management for Effective Logistics and Supply Chains*, pp. 469–485, IGI Global, Pennsylvania, PA, USA, 2017.
 - [42] J. Chanchaichujit, S. Balasubramanian, and V. Shukla, “Barriers to Industry 4.0 technology adoption in agricultural supply chains: A Fuzzy Delphi-ISM approach,” *International Journal of Quality and Reliability Management*, vol. 41, 2024.
 - [43] A. Iftekhhar, X. Cui, M. Hassan, and W. Afzal, “Application of blockchain and Internet of Things to ensure tamper-proof data availability for food safety,” *Journal of Food Quality*, vol. 2020, Article ID 5385207, 14 pages, 2020.
 - [44] M. Jović, E. Tijan, D. Žgaljić, and S. Aksentijević, “Improving maritime transport sustainability using blockchain-based information exchange,” *Sustainability*, vol. 12, no. 21, p. 8866, 2020.
 - [45] S. Singh, S. Pratap, and S. K. Jauhar, “Unveiling barriers to IoT adoption in the maritime freight industry,” *International Journal of System Assurance Engineering and Management*, vol. 11, 2024.
 - [46] A. P. Sage, *Interpretive Structural Modeling: Methodology for Large-Scale Systems*, McGraw-Hill, New York, NY, USA, 1977.
 - [47] J. W. Warfield, “Developing interconnected matrices in structural modeling,” *IEEE Transactions on Systems, Man and Cybernetics*, vol. 4, no. 1, Article ID 51e81, 1974.
 - [48] S. S. Kamble, A. Gunasekaran, and R. D. Raut, “Analysing the implementation barriers of dual cycling in port container terminal using interpretive structural modeling-Indian context,” *International Journal of Logistics Research and Applications*, vol. 22, no. 2, pp. 119–137, 2019.
 - [49] U. Khan and A. Haleem, “Smart organisations: Modelling of enablers using an integrated ISM and fuzzy-MICMAC approach,” *International Journal of Intelligent Enterprise*, vol. 1, no. 3–4, pp. 248–269, 2012.
 - [50] L. Patidar, V. K. Soni, and P. K. Soni, “Manufacturing wastes analysis in lean environment: An integrated ISM-fuzzy MICMAC approach,” *International Journal of System Assurance Engineering and Management*, vol. 8, no. 2, pp. 1783–1809, 2017.
 - [51] R. Rajesh, “Technological capabilities and supply chain resilience of firms: A relational analysis using Total Interpretive Structural Modeling (TISM),” *Technological Forecasting and Social Change*, vol. 118, pp. 161–169, 2017.
 - [52] A. Vishwakarma, G. S. Dangayach, M. L. Meena, and S. Gupta, “Analysing barriers of sustainable supply chain in apparel and textile sector: A hybrid ISM-MICMAC and DEMATEL approach,” *Cleaner Logistics and Supply Chain*, vol. 5, 2022.
 - [53] A. Vishwakarma, G. S. Dangayach, M. L. Meena, M. K. Jindal, S. Gupta, and S. Jagtap, “Modelling challenges of blockchain technology enabled healthcare sustainable supply chain management: A modified-total interpretive structural modelling approach,” *Operations Management Research*, vol. 16, no. 4, pp. 1781–1790, 2023.
 - [54] L. Cricelli, R. Mauriello, and S. Strazzullo, “Technological innovation in agri-food supply chains,” *British Food Journal*, vol. 126, no. 5, pp. 1852–1869, 2024.
 - [55] Sushil, “Modified ISM/TISM process with simultaneous transitivity checks for reducing direct pair comparisons,” *Global Journal of Flexible Systems Management*, vol. 18, no. 4, pp. 331–351, 2017.
 - [56] S. Jagtap, H. Trollman, F. Trollman, G. Garcia-Garcia, and W. Martindale, “Surviving the storm: navigating the quadruple whammy impact on Europe’s food supply chain,” *International Journal of Food Science and Technology*, vol. 59, no. 6, pp. 3652–3666, 2024.
 - [57] S. Shukla, M. F. Hassan, D. C. Tran, R. Akbar, I. V. Paputungan, and M. K. Khan, “Improving latency in Internet-of-Things and cloud computing for real-time data transmission: A systematic literature review (SLR),” *Cluster Computing*, vol. 24, 2021.
 - [58] S. Jagtap, G. Garcia-Garcia, and S. Rahimifard, “Optimisation of the resource efficiency of food manufacturing via the Internet of Things,” *Computers in Industry*, vol. 127, 2021.



DSPACE

<https://dspace.org/>

Why IoT enablement of agrifood transportation disappoints its stakeholders: unravelling barriers for enhanced logistics

Joshi, Deepika; Gupta, Sumit; Vishwakarma, Amit; Jagtap, Sandeep

2024-01-01

Wiley

<https://doi.org/10.1155/2024/9289098>

Joshi D, Gupta S, Vishwakarma A, Jagtap S. (2024) Why IoT enablement of agrifood transportation disappoints its stakeholders: unravelling barriers for enhanced logistics. Journal of Food Quality, Volume 2024, January 2024, Article number 9289098