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Overcoming Barriers in Healthcare Supply Chain: An ISM Approach to Logistics Challenges

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1. INTRODUCTION

The supply chain relies heavily on logistic activities, which carry out several tasks like customs clearance, trade, transportation infrastructure, international shipments, logistics expertise, tracking and tracing, and meeting delivery deadlines (Çelebi, 2019; Gani, 2017). The green supply chain approach helps economies transition to clean logistics by improving environmental quality and lowering healthcare expenses(Alhawari et al., 2021)

Managing medical supplies, equipment, and data across the supply chain to boost efficiency and cut costs is known as healthcare logistics. Addressing issues like security, transparency, and fake goods in medical supply chains has been easier by integrating technologies like Blockchain and IoT(Nanda et al., 2023). To maintain inventory and guarantee the timely delivery of consumables, hospitals must engage in an ongoing cycle of planning, purchasing, and distribution(Rachel Karimah et al., 2022). Supply chain management (SCM) can potentially improve healthcare, but many organizations find it challenging to apply, affecting care quality and cost(Mittal and Mantri, 2023a). Technology integration and strategic management techniques are two components of a comprehensive strategy needed to optimize healthcare logistics (Normasari et al., 2023). A Markov chain model that optimizes stock management in France shows how necessary efficient logistics are for hospitals, especially regarding inventory control and forecasting medication demand(Vélez et al., 2023). To guarantee accessibility to primary healthcare facilities, the aging population also calls for strategically planning facility location using Geographic Information Systems (GIS)(Amchang and Suraraksa, 2023). As it highlights ethical and legal issues and enables distant patient care, telemedicine is becoming an increasingly important part of healthcare logistics(Kuntardjo, 2020).

2. LITERATURE REVIEW

2.1. SUSTAINABLE SUPPLY CHAIN IN HEALTH CARE

It is becoming more widely acknowledged that improving public health while reducing environmental effects requires sustainable supply chain management, or SSCM, in the healthcare industry. By combining economic, social, and environmental factors, this strategy encourages cooperation among stakeholders to boost productivity and patient care. For the healthcare industry to improve public health while reducing environmental effects, sustainable supply chain management, or SSCM, is becoming increasingly important. Maximizing resource use and minimizing emissions includes waste recycling, green manufacturing, and green procurement(Li, n.d.). A comprehensive literature assessment emphasizes adopting sustainable practices throughout the healthcare supply chain, focusing on demand management and staff welfare as crucial elements that enhance organizational performance (Simwita and Salema, 2023).

Achieving sustainability in hospital supply chains also requires the integration of cutting-edge technologies and efficient stakeholder collaboration, especially in the post-pandemic context where there is a greater need for effective service delivery(Islam and Habib, 2023a). All things considered, implementing sustainable practices improves operational effectiveness, public health results, and environmental issues. In the healthcare industry, sustainable supply chain management (SSCM) is becoming increasingly important, especially during a pandemic when patient safety and environmental considerations are paramount. According to the literature, which highlights the importance of Hospital Infrastructure Development (HID) in maximizing resource use and cutting waste, improving stakeholder collaboration and information flow is one of the key strategies for attaining sustainability(Islam and Habib, 2023b). Furthermore, a new model that emphasizes the safety of patients incorporates technological, social, environmental, and economic aspects, demonstrating the necessity of an all-encompassing approach to healthcare supply chains(Kanokphanvanich et al., 2023). According to empirical research, implementing sustainable practices promotes long-term sustainability by enhancing healthcare performance and aiding in the shift to a circular economy(Vishwakarma et al., 2022) In healthcare contexts, efficient supply chain management can significantly improve operational effectiveness and the standard of patient care(Mittal and Mantri, 2023a).

2.2. SUSTAINABLE SUPPLY CHAIN LOGISTICS

Various tactics are used in sustainable supply chain logistics to reduce environmental impact and increase economic efficiency. Green Supply Chain Management (GSCM) incorporates eco-friendly techniques across the supply chain to address financial and environmental issues, from sourcing raw materials to recycling trash (Li, 2024). To achieve sustainability, reverse and green logistics concepts are essential; nevertheless, there are obstacles to their application, including a lack of commitment among managers and strategic planning(Álvaro et al., n.d.). Additionally, the connection between GSCM and the Circular Economy (CE) emphasizes the necessity of a comprehensive strategy that encourages waste minimization and resource efficiency(Aroonsrimorakot and Laiphrakpam, 2023).Furthermore, utilizing Free Trade Agreements (FTAs) might reduce expenses and carbon emissions; however, cautious handling is necessary to avoid carbon leakage(Kinoshita et al., 2023).

Additionally, enhancing supply chain efficiency and advancing sustainability requires the integration of digital technologies and performance monitoring frameworks (Kumar et al., 2023). According to Karmakar et al. (2023), models that integrate remanufacturing by manufacturers and suppliers also emphasize the significance of green investments and cautious production management to increase profitability while lowering emissions. Finally, resource usage can be optimized and conflicting plans can be efficiently balanced by employing multi-agent systems to manage sustainable supply chains (Göbel, 2023). These revelations highlight how difficult and essential it is for supply chain logistics to implement sustainable standards.

3. METHODOLOGY

3.1. Expert Mining

We adopted an intensive expert mining procedure to carry out this study. We selected medical professionals, physicians, consultants, representatives of pharmaceutical companies, and policymakers to serve on our expert panel. We had fifteen experts in all. After discussing with experts, we created a questionnaire for them based on all the barriers in the Google Scholar search. All 15 members received the questionnaire via email. Although the number of experts selected may seem small, a comparable number of experts have been employed in earlier research using a similar methodology (Singh & Misra, 2021).

We extracted prior research from 2005 to 2024. We utilized keywords like "hospital supply chain barriers," "healthcare supply chain barriers," or "healthcare logistics barriers" to identify the barriers associated with healthcare supply chains. The analysis, which focused on the Web of Science and Scopus databases, was carried out in October 2024. A total of 65 articles were found after a thorough review. Only 38 of the 65 thoroughly examined papers were deemed appropriate for this investigation. Twelve barriers were found in these 38 studies, listed in Table 1.

We performed expert mining to validate each of the twelve hurdles. To get a score on every obstacle, 15 experts were contacted. Experts answered on a Likert scale from 1 to 5. Only barriers that had a mean score of 3.5 or above from experts were selected. Our investigation revealed no obstacles to a mean score lower than 3.5.

Table 1: Identified Barriers associated with healthcare supply chains

Sl. No.	Barriers to Sustainable Logistics	References	Expert Mean Score
1.	Health Emergencies and Pandemics	(Bak et al., 2023), (Sathiya et al., 2023), (Moridu et al., 2023)(Syahrir et al., 2018), (Iyengar et al., 2020)	4.6
2.	Sudden Shutdowns	(Mekonen et al., 2024) (Rastogi, 2023) (Singh & Parida, 2022) (Joshi et al., 2022) (Sharma et al., 2020)	3.6
3.	Supply Chain Fragmentation	(Latif, 2024) (Samreen et al., 2024) (Mittal & Mantri, 2023) (Bandhu et al., 2022) (Rastogi, 2023)	4.13

4.	Inadequate Transportation	(Neugebauer, 2024) (Chen et al., 2021) (Varela et al., 2019) (Rastogi, 2023) (Mashiri et al., 2009)	3.75
5.	Demand Variability	(Rastogi, 2023)(Mekonen et al., 2024) (Rehman et al., 2023)	3.8
6.	Stockouts	(Neugebauer, 2024) (Ballard, 2022) (Bam et al., 2017) (Karimi et al., 2021) (Emmett, 2019)	4.13
7.	Supplier Relationships	(Alfina et al., 2022) (Setiawati et al., 2023) (Paul et al., 2024)(Adebayo et al., 2024) (Achimba & (PhD), 2022)	4.27
8.	Negligence of respective personnel	(Şeker & Aydın, 2024), (Mekonen et al., 2024) (Dai et al., 2021) (Bateman, 2015) (Tucker & Spear, 2006)	3.6
9.	Vendor Management	(Settanni, 2020)), (Sathiya et al., 2023) (Lotfi et al., 2022) (Abdulsalam & Schneller, 2021)	4.5
10.	Inventory Management	(Khatib et al., 2024) (Suryaputri et al., 2022) (Balkhi et al., 2022) (Friday et al., 2021)	4.36
11.	Cost constraints	(Bozzani et al., 2018), (Baal et al., 2018), (Brekke et al., 2012)(Bialas et al., 2023; Mittal and Mantri, 2023b)	4.13
12.	Safety Standards (Accidents leading to the destruction of inventories)	(Khatib et al., 2024) (Bandhu et al., 2022) (Skowron-Grabowska et al., 2022) (Karimi & Ardalan, 2019) (Kapp, 2018)	3.75

3.2. Model development

In the second phase, we implemented ISM modeling to ascertain the contextual link between barriers (Bag & Anand, 2014; Singh, Kazi, et al., 2019). The ISM approach helps examine the relationships between criteria and create a structural model of specific enablers and barriers. With a process flow chart, the suggested methodology's steps are shown in Fig. 1. Any intricate association structure can be adequately explained by the structural model built using the ISM technique since it uses flow charts to produce a clear structure that helps decision-makers.

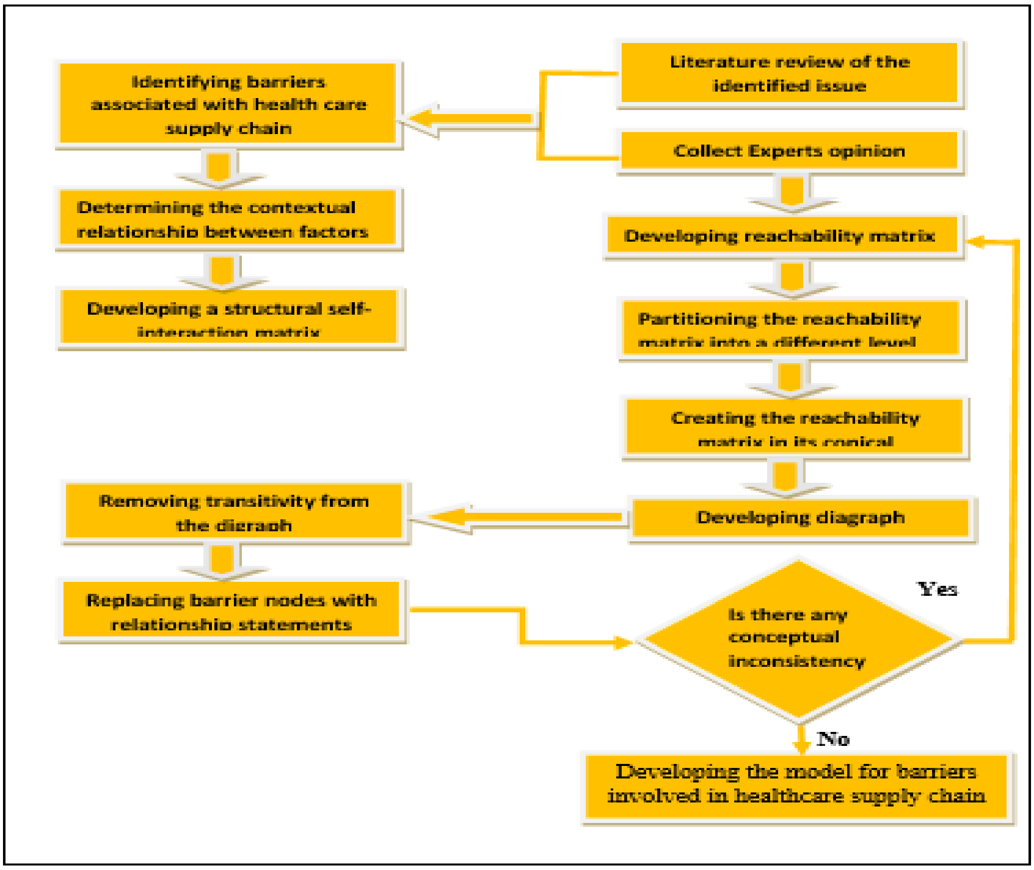

Figure 1: ISM framework for practical barriers in sustainable healthcare supply chain logistics
Source: Author

3.3. ISM and structural self-interaction matrix

The 12 barriers were identified to develop a model. The process flowchart (Fig. 1 above) illustrates the several matrices developed by identifying barriers and their relationships. Academics and industry specialists were consulted to determine which barrier relates to another and the path of the relationship. The correlations between barriers were found using the self-structured interaction matrix (SSIM). The relationship is explained using four symbols. Previous ISM studies have also employed comparable symbols.

Let i and j be barriers under consideration,
Then the symbol 'V means that the i barrier will help to achieve the j barrier;
'A' means that the j barrier will help to achieve the i barrier;
'X' means that the both i and j help each other;
'O means that the neither i nor j is related to the other.
Based on the V, A, X, and O methodology, the self-structured interaction matrix (SSIM) was developed to address the 12 barriers related to healthcare supply chains. The SSIM is depicted in Table 2

3.4. Reachability Matrix

From SSIM, the reachability matrix is obtained. The relationship between the barriers is represented in binary form in this matrix. In the previous SSIM, four symbols—V, A, X, and O—represent different interrelations between variables. The binary numbers 0 and 1 have now replaced all the symbols. According to Table 3, the reachability matrix is obtained by substituting the SSIM's V, A, X, and O using the following principles. The original reachability matrix, displayed in Table 4, was produced by substituting binary numbers for V, A, X, and O. To arrive at the final reachability matrix, we also included transitivity analysis. Suppose the first variable has a connection with the second, and the second has a relation with the third. In that case, the first variable likewise has a relationship with the third, considering transitivity. Transitivity is represented by 1* in the final reachability matrix (Table 5). Five cycles were carried out to identify each barrier positioned in the hierarchy following the acquisition of the final reachability matrix. We acquired the reachability and antecedent sets for every variable in the five iterations (Warfeld, 1974). The intersection of the antecedent and reachability sets was then determined. The junction of the reachability and the antecedent set determined the barriers' highest priority. Subsequent iterations were eliminated if a priority was established. Until the last iteration was finished, the precise procedure was adhered to. Table 6 below displays the entire iterative process. Figure 2 illustrates the elements at different levels identified following the completion of the iterative method.

Table 2- SSIM for Barriers to Sustainable Logistics

Sl No.	Barriers to Sustainable Logistics	12	11	10	9	8	7	6	5	4	3	2	1
1	Health Emergencies and Pandemics	O	O	A	A	V	V	O	O	V	V	V	
2	Sudden Shutdowns	V	O	A	A	O	V	A	A	V	X		
3	Supply Chain Fragmentation	V	V	V	X	O	V	A	A	V			
4	Inadequate Transportation	X	O	A	A	O	O	A	A				
5	Demand Variability	V	V	V	V	O	V	V					
6	Stockouts	V	V	V	V	V	V						
7	Supplier Relationships	O	O	A	A	A							
8	Negligence of respective personnel	O	O	A	A								
9	Vendor Management	V	V	V									
10	Inventory Management	O	V										
11	Cost constraints	O											
12	Safety Standards												

The blue diagonal highlights the inherent self-association of variables

Table 3: Rules to replace VAXO to get the Reachability Matrix

SSIM matrix	Reachability matrix	Reachability matrix
If The matrix is V	The i, j entry becomes 1	The j, i entry becomes 0
If The matrix is A	The i, j entry becomes 0	The j, i entry becomes 1

If The matrix is X	The i, j entry becomes 1	The j, i entry becomes 1
If The matrix is O	The i, j entry becomes 0	The j, i entry becomes 0

Table 4- Initial Reachability Matrix for Barriers of Sustainable Logistics.

Sl No.	Barriers to Sustainable Logistics	1	2	3	4	5	6	7	8	9	10	11	12
1	Health Emergencies and Pandemics	1	1	1	1	0	0	1	1	0	0	0	0
2	Sudden Shutdowns	0	1	1	1	0	0	1	0	0	0	0	1
3	Supply Chain Fragmentation	0	1	1	1	0	0	1	0	1	1	1	1
4	Inadequate Transportation	0	0	0	1	0	0	0	0	0	0	0	1
5	Demand Variability	0	1	1	1	1	1	1	0	1	1	1	1
6	Stockouts	0	1	1	1	0	1	1	1	1	1	1	1
7	Supplier Relationships	0	0	0	0	0	0	1	0	0	0	0	0
8	Negligence of respective personnel	0	0	0	0	0	0	1	1	0	0	0	0
9	Vendor Management	1	1	1	1	0	0	1	1	1	1	1	0
10	Inventory Management	1	1	0	1	0	0	1	1	0	1	0	0
11	Cost constraints	0	0	0	0	0	0	0	0	0	0	1	0
12	Safety Standards	0	0	0	1	0	0	0	0	0	0	0	1

Table 5- Final Reachability Matrix for Barriers to Sustainable Logistics

Sl No.	Barriers to Sustainable Logistics	1	2	3	4	5	6	7	8	9	10	11	12	Driving power
1	Health Emergencies and Pandemics	1	1	1	1	0	0	1	1	1*	1*	1*	1*	10
2	Sudden Shutdowns	1*	1	1	1	0	0	1	1*	1*	1*	1*	1	10
3	Supply Chain Fragmentation	1*	1	1	1	0	0	1	1*	1	1	1	1	10
4	Inadequate Transportation	0	0	0	1	0	0	0	0	0	0	0	1	2
5	Demand Variability	1*	1	1	1	1	1	1	1	1	1	1	1	12
6	Stockouts	1*	1	1	1	0	1	1	1	1	1	1	1	11
7	Supplier Relationships	0	0	0	0	0	0	1	0	0	0	0	0	1
8	Negligence of respective personnel	0	0	0	0	0	0	1	1	0	0	0	0	2
9	Vendor Management	1	1	1	1	0	0	1	1	1	1	1	1*	10
10	Inventory Management	1	1	1*	1	0	0	1	1	1*	1	1*	1*	10
11	Cost constraints	0	0	0	0	0	0	0	0	0	0	1	0	1
12	Safety Standards	0	0	0	1	0	0	0	0	0	0	0	1	2
	Dependence power	7	7	7	9	1	2	9	8	7	7	8	9	81

Table 6: Final Iteration to achieve the level of barriers

Barriers	Reachability set	Antecedent Set	Intersection Set	Level
1st Iteration				
F1	1,2,3,4,7,8,9,10,11,12	1,2,3,5,6,9,10	1,2,3,9,10	
F2	1,2,3,4,7,8,9,10,11,12	1,2,3,5,6,9,10	1,2,3,9,10	
F3	1,2,3,4,7,8,9,10,11,12	1,2,3,5,6,9,10	1,2,3,9,10	
F4	4,12	1,2,3,4,5,6,9,10,12	4,12	1
F5	1,2,3,4,5,6,7,8,9,10,11,12	5	5	
F6	1,2,3,4,6,7,8,9,10,11,12	5,6	6	
F7	7	1,2,3,5,6,7,8,9,10	7	1
F8	7,8	1,2,3,5,6,8,9,10	8	
F9	1,2,3,4,7,8,9,10,11,12	1,2,3,5,6,9,10	1,2,3,9,10	

F10	1,2,3,4,7,8,9,10,11,12	1,2,3,5,6,9,10	1,2,3,9,10	
F11	11	1,2,3,5,6,9,10,11	11	1
F12	4,12	1,2,3,4,5,6,9,10,12	4,12	1
2nd Iteration				
F1	1,2,3,8,9,10	1,2,3,5,6,9,10		
F2	1,2,3,8,9,10	1,2,3,5,6,9,10		
F3	1,2,3,8,9,10	1,2,3,5,6,9,10		
F5	1,2,3,5,6,8,9,10	5		
F6	1,2,3,6,8,9,10,11,12	5,6		
F8	8	1,2,3,5,6,8,9,10	8	2
F9	1,2,3,8,9,10	1,2,3,5,6,9,10		
F10	1,2,3,8,9,10	1,2,3,5,6,9,10		
3rd Iteration				
F1	1,2,3,9,10	1,2,3,5,6,9,10	1,2,3,9,10	3
F2	1,2,3,9,10	1,2,3,5,6,9,10	1,2,3,9,10	3
F3	1,2,3,9,10	1,2,3,5,6,9,10	1,2,3,9,10	3
F5	1,2,3,5,6,9,10	5		
F6	1,2,3,6,9,10,11,12	5,6		
F9	1,2,3,9,10	1,2,3,5,6,9,10	1,2,3,9,10	3
F10	1,2,3,9,10	1,2,3,5,6,9,10	1,2,3,9,10	3
4th Iteration				
F5	5,6	5		
F6	6	5,6	6	4
5th Iteration				
F5	5	5	5	5

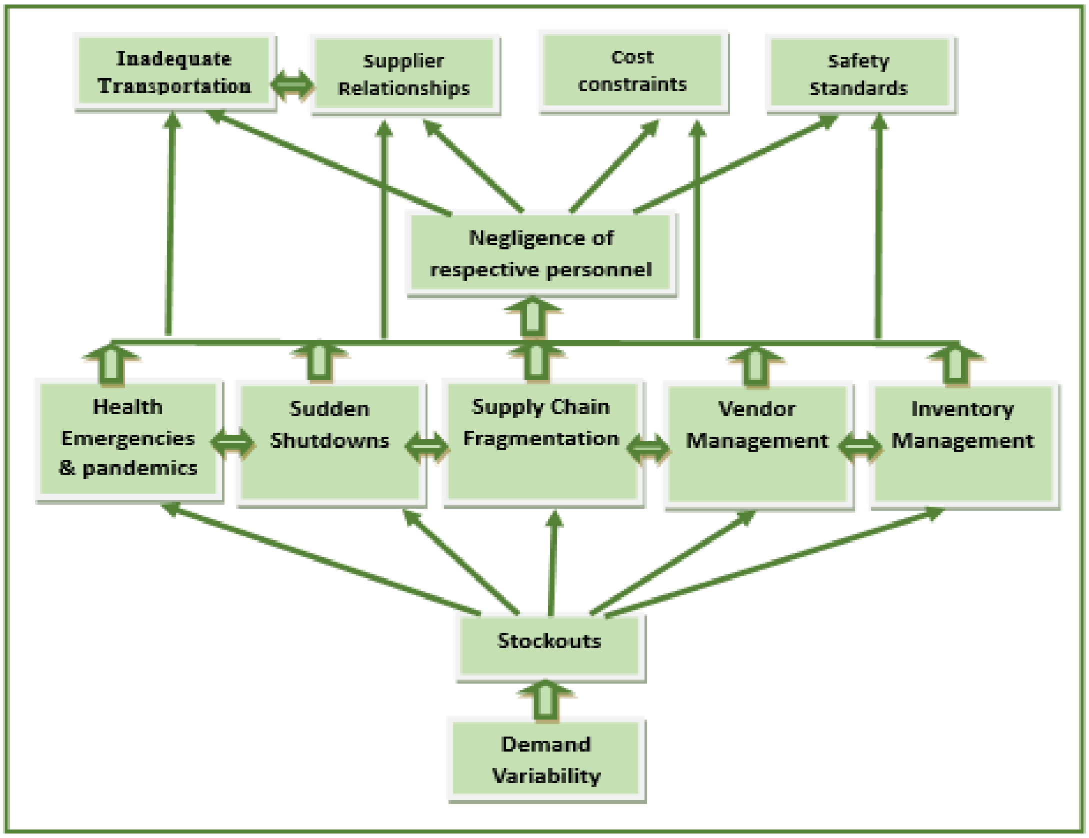

Fig 2: Sustainable Healthcare Supply Chains Logistics Barrier model.
Source: Author

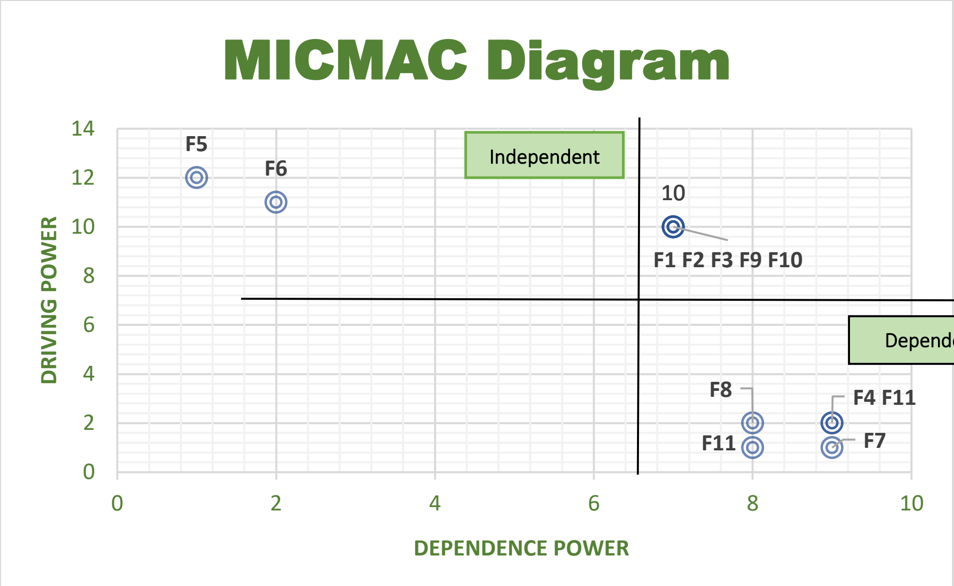

Fig. 3 MICMAC diagram of Healthcare Supply Chains Logistics Barrier.
Source: Author

4. FINDINGS AND RESULTS

The matrix of Cross Impacts-Multiplication Applied to a Classification (MICMAC) was chosen to describe the study's outcomes. MICMAC was first presented by Duperrin and Godet (1975) as an operational technique to assign a rank to the components of a system. The dependent, independent, autonomous, and connection criteria are the four groups into which this analysis divides the critical variables. The barriers' driving force and dependence power are the basis for their identification and classification (see Fig. 4).

One of the main instances of such a dynamic economic scenario where people require supply chain and logistical support that must be sustained sustainably is the healthcare industry. Recent challenges facing the healthcare logistics supply chain include rising public awareness of high standards for pharmaceuticals, pricing volatility, integrating social behaviors, and complying with environmental policies, government regulations, and health and safety standards. Thus, implementing sustainable practices at all levels can give such an industry the boost it needs to overcome these obstacles.
The barriers in this research have been divided into four groups according to their drive and reliance powers (Mathiyazhagan et al., 2013):
1. Autonomous Quadrant: This quadrant exhibits poor reliance and driving power in Quadrant I. Due to their limited links, they are comparatively detached from the system. The connections, nevertheless, can be pretty substantial.
2. Dependent Quadrant: Barriers with significant reliance power but weak driving strength fall into this category. Their location is in Quadrant II.
3. Linkage Quadrant: These fall into Quadrant III and have a high driving and reliance power. Because of their instability, taking action will impact others and involve feedback.
4. Independent Quadrant: These have poor reliance but significant driving power. Their location is in Quadrant IV. It is noted that a significant variable—a variable with extremely high driving power—fits into the independent or linkage criterion group. Table 5 displays the current study's 12 components' driver and reliant power. Figure 3 provides further information on the ultimate comprehensive ISM model for the 12 barriers.

5. DISCUSSIONS

The analysis results of the barriers affecting sustainable supply chain logistics (SCL) in healthcare centers are summarized in Figures 1 and 2. Figure 2 illustrates the ISM considered for the 12 barriers influencing healthcare centers' sustainable SCL. There are also five levels in this model. Using Table 6, agents' power and dependency graphs were drawn for each factor. This graph concerns microscopic-macroscopic (MICMAC) analysis, which was obtained through valuable insights into the relative importance and interdependence between the 12 barriers in the sustainable SCL. The results of this study can be summarized in four categories:

- **There is no Autonomous Factor (Domain I):** In general, the autonomous factors have poor dependence and driving powers and do not impact the system much. Moreover, the lack of such factors within the autonomous domain shows that all the identified factors within the sustainable SCL in healthcare centers are of utmost importance.
- **Dependent Factors (Domain II):** Four factors fall into this category, characterized by low driving power but high dependency. Among these, Factor 1 (HE&P) demonstrates the greatest level of dependence within the sustainable supply chain logistics (SCL) of healthcare centers. Additionally, Factors 4 (IT) and 5 (DV) share similar attributes, each possessing a driving power of 3 and the highest dependency score of 11.
- **Linkage Factors (Domain III):** This domain comprises five factors that exhibit both high driving and high dependence powers, indicating their dynamic role in the system. Factor 2 (SS) holds a balanced driving and dependence power score of 9, making it a central element in the sustainable electronic supply chain within healthcare facilities. Meanwhile, Factors 3 (SCF), 7 (SR), and 10 (IM) each possess a driving power of 10 and a dependence power of 7, highlighting their interconnected influence.
- **Independent Factors (Domain IV):** This domain includes three factors with strong driving power and minimal dependence, making them pivotal in influencing the system while being less affected by others. Factor 9 leads with a driving power of 12 and the lowest dependence score of 2, underscoring its primary role in shaping the sustainable electronic supply chain. Factor 6 (SO) also resides in this category, both being positioned at the topmost level of influence in the healthcare center's sustainable electronic supply chain framework.

6. CONCLUSION

Supply chain logistics (SCL) is one of the most crucial areas where cost reduction is anticipated, as determined by healthcare system analysis. In light of the healthcare industry's past, the advantages of re-engineering the SCL are distinct from those of other sectors. The current study sought to identify barriers to healthcare facilities' sustainable SCL. With the assistance of subject-matter experts, 12 barriers influencing the sustainable SCL were identified for the current study. The correlations between the elements above were also assessed using the ISM approach. Notably, the ISM method was used to build the correlations between barriers based on expert viewpoints and various management strategies, including brainstorming and the nominal group technique. According to the current study findings, Inadequate Transportation and Supplier Relationship issues were the most crucial elements and the mainstay of research on SCL in healthcare facilities.

However, the MICMAC analysis's findings showed that SCL management is one of the most crucial elements. The ISM model did not ascertain the impact of each barrier on a sustainable SCL in healthcare facilities, although it showed a valuable understanding of the connections between barriers. Therefore, it is advised that future research assess the magnitude of each barrier relationship's impact. Lack of equitable access to all healthcare facilities and the inability to gather the views of all medical professionals regarding the elements influencing sustainable supply chains in healthcare facilities were two of the study's main shortcomings. The present study's research methodology and societal population were restricted to the ISM method. Consequently, more research should be conducted to assess the sustainable SCL model in additional service sectors.

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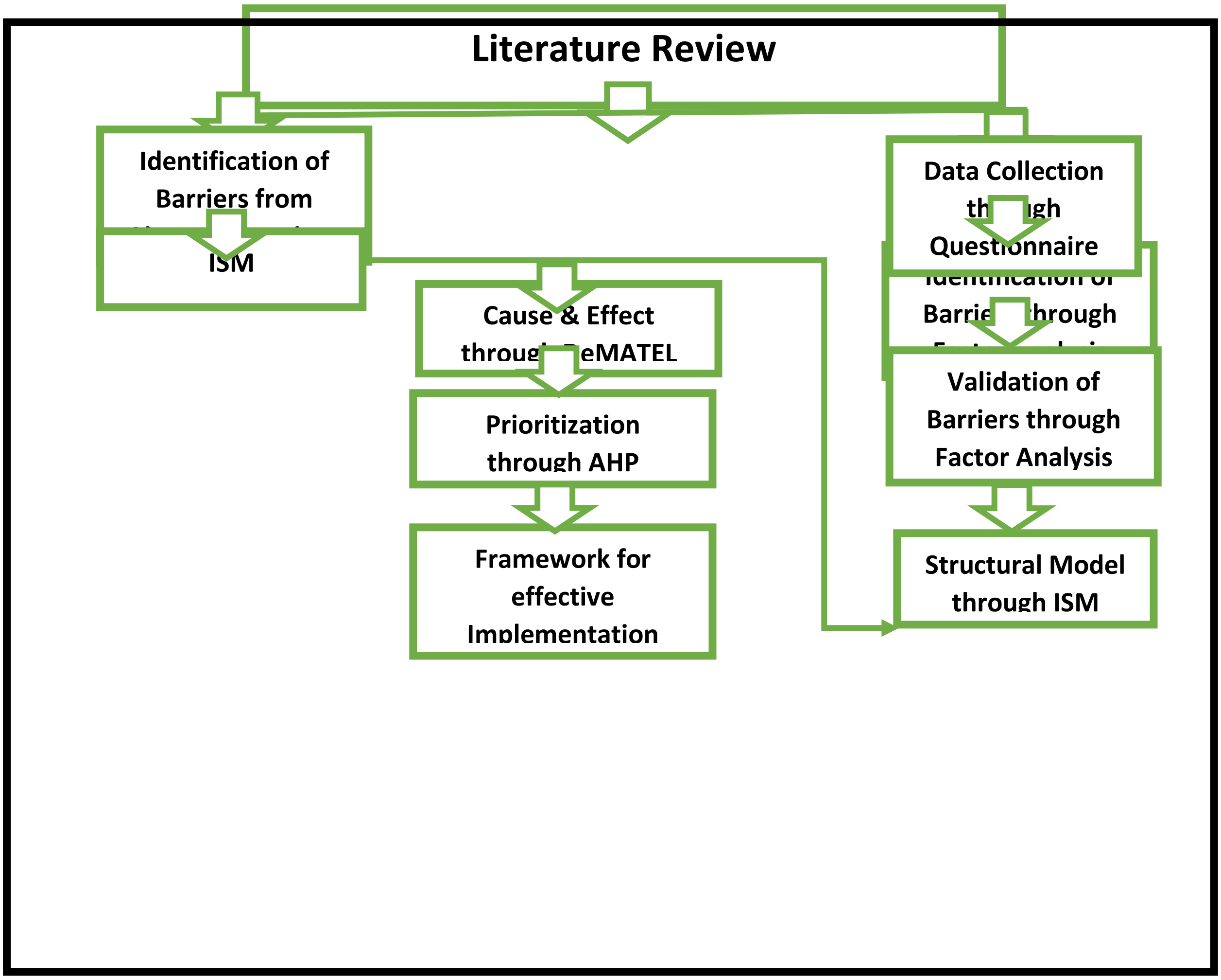

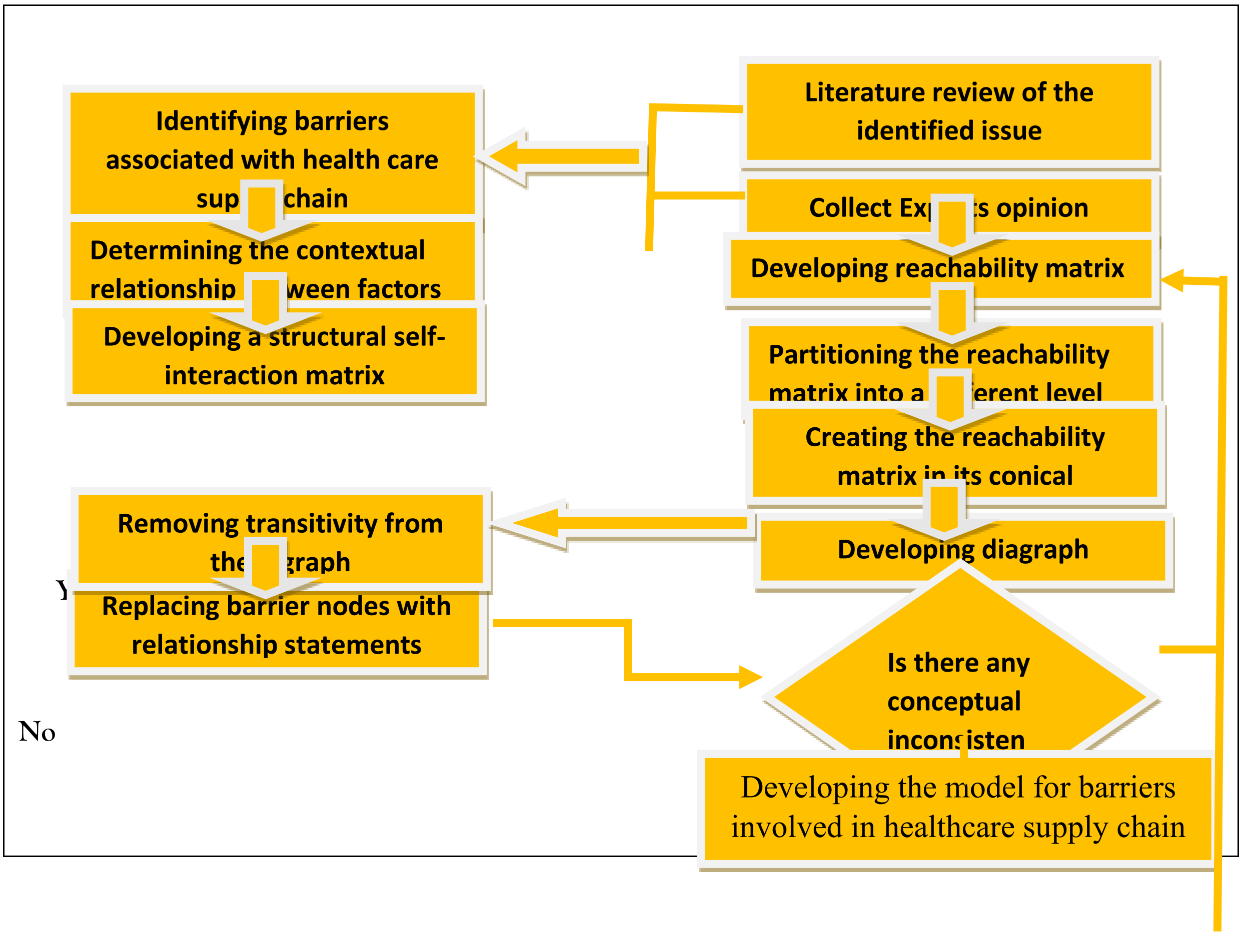
Literature review of the identified issue
Collect Exp s opinion
Developing reachability matrix
Partitioning the reachability matrix into a erent level
Creating the reachability matrix in its conical
Developing diagraph
Identifying barriers associated with health care sup chain
Determining the contextual relationship ween factors
Developing a structural self-interaction matrix
Removing transitivity from the graph
Replacing barrier nodes with relationship statements
Is there any conceptual incons isten
Y
No
Developing the model for barriers involved in healthcare supply chain