

Evaluation of Risks in Humanitarian Supply Chain and Their Inter-Dependence using ISM and MICMAC Analysis

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Abstract: Risks affecting the effectiveness of humanitarian supply chains are a major issue. Which is why the need to understand and mitigate them is a necessity. The purpose of this study is 1) To understand the inter-relationship and interdependence of significant risks using the ISM methodology. 2) To create a structured framework for prioritising risks using the insights from ISM methodology. 3) To categorize the risks based on their driving power and dependence using MICMAC analysis. For the purpose of fulfilling the objectives, ISM and analysis were implemented. The result was an ISM framework prioritising the significant risks and a MICMAC diagram categorising those risks. The models found that the risks of secondary natural hazards, infrastructure damage and insufficient staffing were among the risks with high driving power at the first level of ISM model and the risk of inadequate healthcare facilities is at level 8 of ISM model, and with high dependence and very low driving power indicating that this risk is impacted most by the other risks. The study helps in understanding the interrelationships of the risks so that the decision makers can make more informed decisions. Since the study identifies which risks have high driving power, it helps in understanding the root cause of the problems. ISM and MICMAC provide a replicable framework for the risk analysis. This study was conducted with the help of group interviews, in which the possibility of one point of view dominating others is a possibility. The existence of expert bias is a possibility.

Keywords: HSC (Humanitarian Supply Chain); HSCR (Humanitarian Supply Chain Risks) Risk Analysis; ISM (Interpretive Structural Modelling) Methodology; MICMAC Analysis;

Introduction

Increasing frequency of natural disasters has been an eye-opener for researchers around the world. Researchers realise that there is a growing need for effective humanitarian supply chains. Humanitarian supply chain management (HSCM) is defined by the IFRC as 'acquiring and delivering requested supplies and services at the places and times they are needed, whilst ensuring best value for money; in the immediate aftermath of any [type of] disaster or reconstruction situation, including items that are vital for survival, such as food, water, temporary shelter and medicine' (IFRC, 2012). But the humanitarian supply chains are prone to experiencing many expected and unexpected risks (Abikova, 2024). Many such risks have been identified by many studies (Yadav & Barve, 2015). In the study by (Abikova, 2024) the author mentions various risks that could materialize. Risks like limited human resources, training of human resources pre-deployment etc... Many times, the HSCs lead to a large dependence on external agencies, and it leads to ignorance towards the actual needs of affected populations (Anjomshoe, Banomyong, Azadnia, Kunz, & Blome, 2025). Authors

emphasize the importance of preparedness and mitigation as it has an impact on the sustainability aspect of the HSCs.

Many studies research the risks and their mitigation, but what is lacking in the research is the cascading effects. The impacts of one risk materialising on another risk. How the risks impact each other. Which is why many studies use tools like ISM and MICMAC to study the interrelationships of factors (Abbas, Asim, Ahmed, & Moosa, 2022) (Singh, Gupta, & Gunasekaran, 2018). ISM methodology is great for creating a multi-hierarchy model for understanding the interrelationships of different factors, complemented by MICMAC analysis which helps in categorising the said factors/risks into categories to understand which are the root causes of the problem that is being faced (Rahman, Tasnim, Mukta, Abedin, & Aryal, 2022).

There are multiple studies regarding the improvement of humanitarian supply chains using different methods. But most authors come to the conclusion that there is a need for incorporating technologies. In this study, research has been done to understand the inter-relationships of the risks in humanitarian supply chains. It is being done to determine how the risks impact each other. Mitigation of which risks would further mitigate which other risks.

Literature Review

Risks in Humanitarian Supply Chain

Humanitarian supply chains have been facing a lot of challenges (Tay, Loh, & Chen, 2025). They talk about risks like expiry of inventory before it can be used, availability of suppliers, and difficulty in forecasting demand for the required products. Another study by (Sun & Liao, 2025) found that the mitigation of risks early on in humanitarian supply chains for relief operations is necessary. Otherwise, things keep getting out of control, and after a threshold, any efforts to mitigate have minimal effects. A paper by (Singh R. K., Transforming humanitarian supply chains with digital twin technology: a study on resilience and agility, 2025) study how the resilience of humanitarian supply chains using the Digital Twins technology. They found that DTT improves the resilience of HSCs. (Singh R. K., 2025) studies how technology adoption can help with the reduction in operational costs and response time. (Quispe, Mamani, Yoshizaki, & Junior, 2025) conducted a literature review and found that a lot of research is still needed on the application of various models and technologies to find solutions to the problems faced by the temporary facilities after a disaster. They found that humanitarian logistics face many problems, like coordination problems and supply chain bottlenecks. Another study by (Parmadia & Ramlib, 2025) talk about use of IoT in Humanitarian Relief Operations. The author found many potential applications for IoT in making the relief operations more effective but suggests that more research is needed in this area. In a study by (Lawal, 2025) the author was trying to study how the industrial engineering methods could be applied to disaster response operation frameworks to improve them. The author states that even after all the technological advancements there is an issue of technology adoption in high-risk operations. Many problems are faced by relief operations such as infrastructure problems, communication issues and resistance to adopt the new technologies, especially AI.

(Léoffel, Schmidt, & Wagner, 2025) also study the risks in relief aid process. The authors talk of multiple risks like resource constraints, security concerns, failure of delivery and many more. The authors also state how there is lack of research in analysis of contingencies. In a study by (Karuppiah, Kandasamy, Lona, Sanchez, & Joshi, 2025) the authors are studied the drivers of incorporating AI in HSC management. (Jayadi, 2025) study and review the existing research on digitization in management of humanitarian operations. The authors say that even though there is an increase in awareness on this issue, there is still a huge gap between actual action and the research. (Guan, Tay, & Zhao, 2025) in their research study the financing in humanitarian supply chains. The authors state that there is a need for transparency in financing, and the integration of innovations in humanitarian operations to optimize them. the study explains the importance of coordination between the different

organizations. In a study by (Delgado, Castillo, Garcia, & Carrillo, 2025) the authors found that insecurity and corruption are major social problems in the disaster affected countries, which receive aid. In all the studies one thing is common, studying, mitigating and understanding risks has become necessary due to the severity of the consequences of those risks materialising. In a study by (Lee, 2024), author found out that budget constraints and security threats are a major problem that are faced in humanitarian logistics, due to which some mitigation strategies cannot be implemented like outsourcing the logistics and centralization.

Risks in HSC can be in various categories. A paper by the author (Gupta, Jain, & Gupta, 2025) various risks pertaining to HSC have been identified, the total no of risks being 126. Using FMEA and risk severity matrix, significant risks were identified and on the basis of risks rating, 18 risks were found to be significant. And the list of Significant Risks is as below:

Table – 1 Significant Risks in Humanitarian Supply Chain

S. No.	Risk	Risk Rating
1	Resource Scarcity	23.03
2	Transportation Disruptions	22.56
3	Secondary Natural hazards	21.62
4	Supply shortages	21.6
5	Supply Disruption	20.7
6	Spread of Diseases	19.8
7	Fraud and Corruption	20.68
8	Security Issues (Logistical)	18.92
9	Infrastructure Damage	18.92
10	Communication breakdown	18.92
11	Inadequate Health Care Facilities	17.808
12	Bureaucracy	17.22
13	Exposure to Hazardous Conditions	17.22
14	Environmental Degradation	15.96
15	Delayed Funding	17.22
16	Lack of Personal Protective Equipment	16.4
17	Misallocation of Resources	16.4
18	Insufficient Staffing	15.99

Source – (Gupta, Jain, & Gupta, 2025)

The authors in the study found the technological solutions to mitigate the risks. For the purpose of this study, this list of significant risks will be considered for further analysis. Further analysis is being done to understand their inter relationships. This will help us understand if mitigation or exaggeration of a risk would have any impact on the rest of the significant risks, or are there any risks that have no or minimal Impact on the rest of them.

ISM Methodology

Interpretive structural modelling (ISM) is a very popular way to create a hierarchical model of factors (Yadav & Sushil, 2014). The model helps in understanding the impact of factors on other factors and the underlying hierarchical relationships (Singh, Panigrahi, Panigrahi, & Shrivastava, 2024) (Zhou, 2019). In a paper by (Ahmad, Tang, Qiu, & Ahmad, 2019) use ISM methodology to study soil liquefaction methods. In another paper (Babu, Bhardwaj, & Agrawal, 2021) study the inter relationships of risks in supply chains for Indian manufacturing SMEs. (Bagherian, Gershon, Kumar,

& Mishra, 2024) study the inter relationships of digital measurements that are a part of energy sustainability in European energy domain.

The first step in ISM methodology is defining contextual relationships between the factors based on expert opinion by applying the parameters of VAXO matrix formulation. The parameters are as follows where $i > j$ (Shibin, Gunasekaran, & Dubey, 2017):

- V- i leads to j , but j doesn't lead to i
- A- j leads to i , but i doesn't lead to j
- X- both i and j lead to each other
- O- i and j are not related to each other

The resultant matrix of this step is Structural Self Interaction Matrix. The second step in ISM is making the reachability matrix (Sushil, 2017), (Shibin, Gunasekaran, & Dubey, 2017). It is done by replacing VAXO with binary numbers 1 and 0. The rules for developing the initial reachability matrix are (Attri, Dev, & Sharma, 2013) (Attri, 2013; Kumar et al., 2013, 2014, 2015; Faisal and Talib, 2017):

- V- value of (i, j) is 1 and value of (j, i) is 0
- A- value of (i, j) is 0 and value of (j, i) is 1
- X- value of (i, j) is 1 and value of (j, i) is also 1
- O- value of (i, j) is 0 and value of (j, i) is also 0

The next step in ISM methodology is level partitioning of factors on reachability matrix by Iteration method. In this step different factors are divided into different levels. The procedure is to start with Level 1, where for every factor reachability set, antecedent set and intersection set are determined from the reachability matrix. The factors whose reachability set and the intersection set are same, occupy the level 1 (Yadav & Sushil, 2014). For level 2 the factors occupying level 1 are removed, and the same procedure is done with the remaining factors to find out which factors occupy level 2 and so on. It is continued until no factors are left to occupy a new level. Based on the result ISM model is developed. From the bottom starting with level 1 moving upwards till the last level (Kumar, Gupta, & Gupta, 2022).

Research Objective

1. To understand the inter-relationship and interdependence of significant risks using ISM methodology.
2. To create a structured framework for prioritising risks using the insights from ISM methodology.
3. To categorize the risks based on their driving power and dependence using MICMAC analysis.

Methodology

The identified risks were analysed with ISM method and MICMAC analysis to identify the inter-relationships among the risks. This was done to understand how the risks impact each other. Mitigation of which risks would further mitigate which other risks. For this purpose, a Multi-level Hierarchy Model was created using ISM.

ISM Method

Interpretive structural modelling (ISM) is a very popular way to create a hierarchical model of factors (Yadav & Sushil, 2014). The model helps in understanding the impact of factors on other factors and the underlying hierarchical relationships (Singh, Panigrahi, Panigrahi, & Shrivastava, 2024) (Zhou, 2019). The first step in ISM methodology is defining contextual relationships between the factors based on expert opinion by applying the parameters of VAXO matrix formulation. The parameters are as follows where $i > j$ (Shibin, Gunasekaran, & Dubey, 2017):

V- i leads to j, but j doesn't lead to i
A- j leads to i, but i doesn't lead to j
X- both i and j lead to each other
O- i and j are not related to each other

The resultant matrix of this step is Structural Self Interaction Matrix (table 2). This was done with the help of a Focus Group Discussion with experts from NGOs, Government agencies. The experts were asked if the risk is impacting the other risk in any way and then the values were allotted according to the agreed upon response. Table 2 shows the structural self-interaction matrix developed from this.

Table – 2 Structural Self Interaction Matrix

STRUCTURAL SELF-INTERACTION MATRIX	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18
	1	1	1	1	1	1	1	1	1	9	8	7	6	5	4	3	2	1
	8	7	6	5	4	3	2	1	0									
R1 (RESOURCE SCARCITY)	V	O	X	A	V	A	V	A	V	V	V	A	V	X	X	V	V	
R2 (TRANSPORTATION DISRUPTIONS)	V	V	X	A	V	V	V	A	V	V	V	O	V	A	A	V		
R3 (SECONDARY NATURAL HAZARDS)	X	O	O	O	O	A	O	A	A	A	O	A	O	A	A			
R4 (SUPPLY SHORTAGES)	V	O	V	A	V	O	V	A	V	V	V	A	V	V				
R5 (SUPPLY DISRUPTIONS)	V	O	O	A	V	V	V	A	V	V	V	A	V					
R6 (FRAUD AND CORRUPTION)	O	O	A	A	A	O	O	A	O	O	O	O						
R7 (SPREAD OF DISEASES)	V	O	O	V	O	V	O	V	O	O	O							
R8 (LOGISTICAL SECURITY ISSUES)	O	O	O	O	O	O	O	O	V	V								
R9 (INFRASTRUCTURE DAMAGE)	V	A	O	O	O	A	O	A	A									
R10 (COMMUNICATION BREAKDOWN)	O	O	O	O	A	V	O	A										
R11 (INADEQUATE HEALTHCARE FACILITIES)	O	V	V	V	V	V	V											
R12 (BUREAUCRACY)	O	A	A	A	A	O												
R13 (EXPOSURE TO HAZARDOUS CONDITIONS)	X	A	O	V	V													
R14 (DELAYED FUNDING)	O	A	A	A														
R15 (LACK OF PPE)	O	A	V															
R16 (MISALLOCATION OF RESOURCES)	O	A																
R17 (INSUFFICIENT STAFFING)	O																	
R18 (ENVIRONMENTAL DEGRADATION)																		

Source: ISM Analysis

The second step in ISM is making the reachability matrix (Sushil, 2017), (Shibin, Gunasekaran, & Dubey, 2017). It is done by replacing VAXO with binary numbers 1 and 0. The rules for developing the initial reachability matrix are (Attri, Dev, & Sharma, 2013) (Attri, 2013; Kumar et al., 2013, 2014, 2015; Faisal and Talib, 2017):

V- value of (i, j) is 1 and value of (j, i) is 0

A- value of (i, j) is 0 and value of (j, i) is 1

X- value of (i, j) is 1 and value of (j, i) is also 1

O- value of (i, j) is 0 and value of (j, i) is also 0

Table – 3 shows the Initial Reachability Matrix developed.

Table – 3 INITIAL REACHABILITY MATRIX

INITIAL REACHABILITY MATRIX	R 18	R 17	R 16	R 15	R 14	R 13	R 12	R 11	R 10	R 9	R 8	R 7	R 6	R 5	R 4	R 3	R 2	R 1
R1 (RESOURCE SCARCITY)	1	0	1	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1
R2 (Transportation Disruptions)	1	1	1	0	1	1	1	0	1	1	1	0	1	0	0	1	1	0
R3 (Secondary Natural Hazards)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
R4 (Supply Shortages)	1	0	1	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1
R5 (Supply Disruptions)	1	0	0	0	1	1	1	0	1	1	1	0	1	1	0	1	1	1
R6 (Fraud And Corruption)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
R7 (Spread Of Diseases)	1	0	0	1	0	1	0	1	0	0	0	1	0	1	1	1	0	1
R8 (Logistical Security Issues)	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
R9 (Infrastructure Damage)	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
R10 (Communication Breakdown)	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0
R11 (Inadequate Healthcare Facilities)	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1
R12 (Bureaucracy)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
R13 (Exposure To Hazardous Conditions)	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	1	0	1
R14 (Delayed Funding)	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0
R15 (Lack Of PPE)	0	0	1	1	1	0	1	0	0	0	0	0	1	1	1	0	1	1
R16 (Misallocation Of Resources)	0	0	1	0	1	0	1	0	0	0	0	0	1	0	0	0	1	1
R17 (Insufficient Staffing)	0	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0
R18 (Environmental Degradation)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0

Source: ISM Analysis

Next step is final reachability matrix. In this transitivity is included. Transitivity is when a risk impacts another risk indirectly. If risk a impacts risk b, and risk b impacts risk c, then risk a impacts risk c indirectly, and this a transitive link. It is depicted by 1* in the final reachability table.

Table-4 Final Reachability Matrix

	R1	R1	R1	R1	R1	R1	R1	R1	R1			R	R					
	8	7	6	5	4	3	2	1	0	R9	R8	7	6	R5	R4	R3	R2	R1
R1 (Resource Scarcity)	1	1*	1	0	1	1*	1	0	1	1	1	1*	1	1	1	1	1	1
R2 (Transportation Disruptions)	1	1	1	1*	1	1	1	0	1	1	1	1*	1	0	0	1	1	1*
R3 (Secondary Natural Hazards)	1	0	0	0	0	1*	0	0	0	0	0	0	0	0	0	1	0	0
R4 (Supply shortages)	1	1*	1	0	1	1*	1	0	1	1	1	1*	1	1	1	1	1	1
R5 (Supply Disruptions)	1	1*	1*	1*	1	1	1	0	1	1	1	1*	1	1	1*	1	1	1
R6 (Fraud and Corruption)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
R7 (Spread of Diseases)	1	1*	1*	1	1*	1	1*	1	1*	1*	1*	1	1*	1	1	1	1*	1
R8 (Logistical Security Issues)	1*	0	0	0	0	1*	0	0	1	1	1	0	0	0	0	1*	0	0
R9 (Infrastructure Damage)	1	0	0	0	0	1*	0	0	0	1	0	0	0	0	0	1	0	0
R10 (Communication Breakdown)	1*	0	0	1*	1*	1	0	0	1	1	0	0	0	0	0	1	0	1*
R11 (Inadequate Healthcare Facilities)	1*	1	1	1	1	1	1	1	1	1	1*	1*	1	1	1	1	1	1
R12 (Bureaucracy)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
R13 (Exposure to Hazardous Conditions)	1	0	1*	1	1	1	1*	0	1*	1	1*	1*	1*	1*	1*	1	1*	1
R14 (Delayed Funding)	1*	0	0	1*	1	1*	1	1*	1	1*	0	1	0	1*	1*	1*	0	1*
R15 (Lack of PPE)	1*	1*	1	1	1	1*	1	0	1*	1*	1*	1*	1	1	1	1*	1	1
R16 (Misallocation of resources)	1*	1*	1	0	1	1*	1	0	1*	1*	1*	1*	1	1*	1*	1*	1	1
R17 (Insufficient Staffing)	1*	1	1	1	1	1	1	0	1*	1	0	1*	1*	0	0	1*	1*	1*
R18 (Environmental Degradation)	1	0	0	1*	1*	1	0	0	0	1*	0	0	0	0	0	1	0	1*

Source: ISM Analysis

The next step in ISM methodology is level partitioning of factors on reachability matrix by Iteration method. In this step different factors are divided into different levels. The procedure is to start with Level 1, where for every factor reachability set, antecedent set and intersection set are determined from the reachability matrix. The factors whose reachability set and the intersection set are same, occupy the level 1 (Yadav & Sushil, 2014). For level 2 the factors occupying level 1 are removed, and the same procedure is done with the remaining factors to find out which factors occupy level 2 and so on. It is continued until no factors are left to occupy a new level (Table - 5). The identified factors are partitioned into eight levels as obtained from the result:

$L1 = \{R7, R11\}$; $L2 = \{R5, R15\}$; $L3 = \{R1, R4, R16\}$; $L4 = \{R2, R17\}$; $L5 = \{R8, R13, R14\}$; $L6 = \{R6, R10, R12\}$; $L7 = \{R9, R18\}$; $L8 = \{R3\}$

TABLE – 5 LEVEL PARTITIONING USING ITERATION METHOD

LEVEL	RISK	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET
1	R1	1,2,4,5,7,10,11,13,14,15,16,17,18	1,2,3,4,5,6,7,8,9,10,12,13,14,16,17,18	1,2,4,5,7,10,13,14,16,17,18
	R2	1,2,4,5,7,11,13,15,16,17	1,2,3,6,7,8,9,10,12,13,14,15,16,17,18	1,2,7,13,15,16,17
	R3	1,2,3,4,5,7,8,9,10,11,13,14,15,16,17,18	3,13,18	3,13,18
	R4	1,4,5,7,11,13,14,15,16	1,2,3,4,5,6,7,8,9,10,12,13,14,16,17,18	1,4,5,7,13,14,16
	R5	1,4,5,7,11,13,14,15,16	1,2,3,4,5,6,7,8,9,10,12,13,14,16,17,18	1,4,5,7,13,14,16
	R6	1,2,4,5,6,7,11,13,15,16,17	6	6
	R7	1,2,4,5,7,11,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,4,5,7,11,13,14,15,16,17
	R8	1,2,4,5,7,8,11,13,15,16	3,8,9,10,13,18	8,13
	R9	1,2,4,5,7,8,9,10,11,13,14,15,16,17,18	3,9,13,18	9,13,18
	R10	1,2,4,5,7,8,10,11,13,14,15,16,17	1,3,9,10,13,14,15,18	1,10,13,14,15
	R11	7,11,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	7,11,14
	R12	1,2,4,5,7,11,12,13,14,15,16,17	12	12
	R13	1,2,3,4,5,7,8,9,10,11,13,14,15,16,17,18	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,18	1,2,3,4,5,7,8,9,10,13,14,15,16,18
	R14	1,2,4,5,7,10,11,13,14,15,16,17,18	1,3,4,5,7,9,10,11,12,13,14,15,18	1,4,5,7,10,11,13,14,15,18
	R15	2,5,7,10,11,13,14,15,17,18	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18	2,5,7,10,13,14,15,17,18
	R16	1,2,4,5,7,11,13,15,16,17	1,2,3,4,5,6,7,8,9,10,12,13,14,16,17,18	1,2,4,5,7,13,16,17
	R17	1,2,4,5,7,11,15,16,17,	1,2,3,6,7,9,10,12,13,14,15,16,17,18	1,2,7,15,16,17

2	R18	1,2,3,4,5,7,8,9,10,11,13,14,15,16,17,18	1,3,9,13,14,15,18	1,3,9,13,14,15,18
	R1	1,2,4,5,10,13,14,15,16,17,18	1,2,3,4,5,6,8,9,10,12,13,14,16,17,18	1,2,4,5,10,13,14,16,17,18
	R2	1,2,4,5,13,15,16,17	1,2,3,6,8,9,10,12,13,14,15,16,17,18	1,2,13,15,16,17
	R3	1,2,3,4,5,8,9,10,13,14,15,16,17,18	3,13,18	3,13,18
	R4	1,4,5,13,14,15,16	1,2,3,4,5,6,8,9,10,12,13,14,16,17,18	1,4,5,13,14,16
	R5	1,4,5,13,14,15,16	1,2,3,4,5,6,8,9,10,12,13,14,15,16,17,18	1,4,5,13,14,15,16
	R6	1,2,4,5,6,13,15,16,17	6	6
	R8	1,2,4,5,8,13,15,16	3,8,9,10,13,18	8,13
	R9	1,2,4,5,8,9,10,13,14,15,16,17,18	3,9,13,18	9,13,18
	R10	1,2,4,5,8,10,13,14,15,16,17	1,3,9,10,13,14,15,18	1,10,13,14,15
	R12	1,2,4,5,12,13,14,15,16,17	12	12
	R13	1,2,3,4,5,8,9,10,13,14,15,16,17,18	1,2,3,4,5,6,8,9,10,12,13,14,15,16,18	1,2,3,4,5,8,9,10,13,14,15,16,18
	R14	1,2,4,5,10,13,14,15,16,17,18	1,3,4,5,9,10,12,13,14,15,18	1,4,5,10,13,14,15,18
	R15	2,5,10,13,14,15,17,18	1,2,3,4,5,6,8,9,10,12,13,14,15,16,17,18	2,5,10,13,14,15,17,18
	R16	1,2,4,5,13,15,16,17	1,2,3,4,5,6,8,9,10,12,13,14,16,17,18	1,2,4,5,13,16,17
	R17	1,2,4,5,15,16,17	1,2,3,6,9,10,12,13,14,15,16,17,18	1,2,15,16,17
3	R18	1,2,3,4,5,8,9,10,13,14,15,16,17,18	1,3,9,13,14,15,18	1,3,9,13,14,15,18
	R1	1,2,4,10,13,14,16,17,18	1,2,3,4,6,8,9,10,12,13,14,16,17,18	1,2,4,10,13,14,16,17,18
	R2	1,2,4,13,16,17	1,2,3,6,8,9,10,12,13,14,16,17,18	1,2,13,16,17
	R3	1,2,3,4,8,9,10,13,14,16,17,18	3,13,18	3,13,18
	R4	1,4,13,14,16	1,2,3,4,6,8,9,10,12,13,14,16,17,18	1,4,13,14,16
	R6	1,2,4,6,13,16,17	6	6
	R8	1,2,4,8,13,16	3,8,9,10,13,18	8,13
	R9	1,2,4,8,9,10,13,14,16,17,18	3,9,13,18	9,13,18
	R10	1,2,4,8,10,13,14,16,17	1,3,9,10,13,14,18	1,10,13,14
	R12	1,2,4,12,13,14,16,17	12	12
	R13	1,2,3,4,8,9,10,13,14,16,17,18	1,2,3,4,6,8,9,10,12,13,14,16,18	1,2,3,4,8,9,10,13,14,16,18
	R14	1,2,4,10,13,14,16,17,18	1,3,4,9,10,12,13,14,18	1,4,10,13,14,18
	R16	1,2,4,13,16,17	1,2,3,4,6,8,9,10,12,13,14,16,17,18	1,2,4,13,16,17
	R17	1,2,4,16,17	1,2,3,6,9,10,12,13,14,16,17,18	1,2,16,17
	R18	1,2,3,4,8,9,10,13,14,16,17,18	1,3,9,13,14,18	1,3,9,13,14,18
4	R2	2,13,17	2,3,6,8,9,10,12,13,14,17,18	2,13,17
	R3	2,3,8,9,10,13,14,17,18	3,13,18	3,13,18
	R6	2,6,13,17	6	6
	R8	2,8,13	3,8,9,10,13,18	8,13
	R9	2,8,9,10,13,14,17,18	3,9,13,18	9,13,18
	R10	2,8,10,13,14,17	3,9,10,13,14,18	10,13,14
	R12	2,12,13,14,17	12	12
	R13	2,3,8,9,10,13,14,17,18	2,3,6,8,9,10,12,13,14,18	2,3,8,9,10,13,14,18
	R14	2,10,13,14,17,18	3,9,10,12,13,14,18	10,13,14,18
	R17	2,17	2,3,6,9,10,12,13,14,17,18	2,17
	R18	2,3,8,9,10,13,14,17,18	3,9,13,14,18	3,9,13,14,18
5	R3	3,8,9,10,13,14,18	3,13,18	3,13,18
	R6	6,13	6	6
	R8	8,13	3,8,9,10,13,18	8,13
	R9	8,9,10,13,14,18	3,9,13,18	9,13,18
	R10	8,10,13,14	3,9,10,13,14,18	10,13,14
	R12	12,13,14	12	12
	R13	3,8,9,10,13,14,18	3,6,8,9,10,12,13,14,18	3,8,9,10,13,14,18
	R14	10,13,14,18	3,9,10,12,13,14,18	10,13,14,18
	R18	3,8,9,10,13,14,18	3,9,13,14,18	3,9,13,14,18
6	R3	3,9,10,18	3,18	3,18
	R6	6	6	6
	R9	9,10,18	3,9,18	9,18
	R10	10	3,9,10,18	10
	R12	12	12	12
	R18	3,9,10,18	3,9,18	3,9,18
7	R3	3,9,18	3,18	3,18
	R9	9,18	3,9,18	9,18
	R18	3,9,18	3,9,18	3,9,18
8	R3	3	3	3

The multi hierarchy model is prepared with the help of the result of level partitioning by Iteration method, which can be seen in Fig 1.

ISM HIERARCHY MODEL

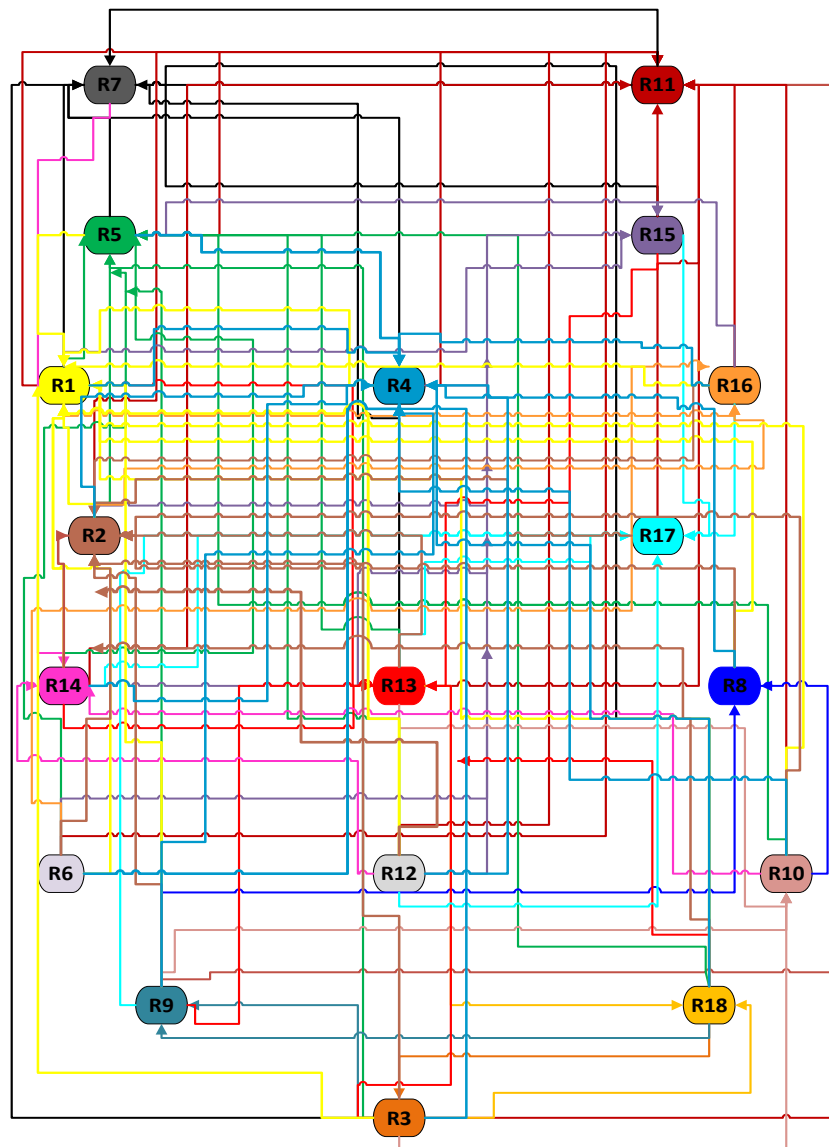


Fig – 1 ISM Model for Risks in Humanitarian Supply Chain

Source – Developed by researcher

As can be seen in the model in fig 1 the risks can be put in 8 hierarchical stages. The model starts from the bottom i.e. level 1 and ends on top i.e. level 8. Level 1 consisting of risks that impact the other levels but are not impacted by them in return, and level 8 consisting of risks that have a very minimal to no impact on other levels but are highly impacted by them. The bottom most stage is 1st level. On this level there is only 1 risk R3 – Secondary Natural Hazards. It means that according to this model R3 is not impacted by the rest of risks but it impacts most of them. This means that if there is any impact on this risk, if it is being mitigated through some measures it will have a similar impact on the risks it is interconnected with either direct connection or transitive connection. For strategic risk mitigation this should be dealt with first (if mitigation is possible), as their mitigation would lead to mitigation of the rest of the factors to some extent. The next level is the one above this 2nd level. There are two risks that are present on this level: R9 – infrastructure damage and R18 – Environmental Degradation. These risks impact the rest of the risks on the other levels and are impacted by the risk

R3. These two risks have high driving powers. They act more like root causes on the second level. They are very influential and only depend on level 1 risk. Level 3 consists of 3 risks R6- Fraud and corruption, R12- Bureaucracy, and R10- communication breakdown. Although R6 and R12 are not impacted by the level 1 and level 2 factors, they are on 3rd level because even though their dependence is lowest (1) their driving powers (11, 12) fall somewhere in the middle. These risks impact many risks on the levels 4-8. If these can be mitigated, they will in turn have a similar impact on the risks on levels 4-8. For example, if risks of fraud and corruption and bureaucracy are mitigated it will lead to mitigation of risk of Delayed funding. If risk of communication breakdown can be mitigated it will lead to better information to healthcare providers which will ensure that people are not exposed to hazardous conditions, and they receive the required help for that sooner rather than later.

MICMAC Analysis

MICMAC (**Matrice d'impacts croisés multiplication appliquée à un classment**) analysis a widely used method for identification of significant factors/ risks. This method was formulated by Two researchers Duperrin and Godet in 1973 (Chandramowli, Transue, & Felder, 2011). (Duperrin & Godet, 1973) (Akpınar & Caylan, 2023) Studies use the method to divide the factors/risks into 4 clusters:

1. Autonomous Features
2. Linkage Features
3. Dependent Features
4. Independent Features

Autonomous are those risks that have a weak driving power as well as weak dependence. Linkage risks are those with high dependence and driving powers. Dependent are those which have a low driving power but high dependence and, Independent are those that have high driving power but low dependence (Foli, 2022).

Table-6 Calculating Driving Power and Dependence with Final Reachability Matrix

	R18	R17	R16	R15	R14	R13	R12	R11	R10	R9	R8	R7	R6	R5	R4	R3	R2	R1	Dependence
R1 (Resource Scarcity)	1	1*	1	0	1	1*	1	0	1	1	1	1*	1	1	1	1	1	1	16
R2 (Transportation Disruptions)	1	1	1	1*	1	1	1	0	1	1	1	1*	1	0	0	1	1	1*	15
R3 (Secondary Natural Hazards)	1	0	0	0	0	1*	0	0	0	0	0	0	0	0	0	1	0	0	3
R4 (Supply shortages)	1	1*	1	0	1	1*	1	0	1	1	1	1*	1	1	1	1	1	1	16
R5 (Supply Disruptions)	1	1*	1*	1*	1	1	1	0	1	1	1	1*	1	1	1*	1	1	1	17
R6 (Fraud and Corruption)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
R7 (Spread of Diseases)	1	1*	1*	1	1*	1	1*	1	1*	1*	1*	1	1*	1	1	1	1*	1	18
R8 (Logistical Security Issues)	1*	0	0	0	0	1*	0	0	1	1	1	0	0	0	0	1*	0	0	6
R9 (Infrastructure Damage)	1	0	0	0	0	1*	0	0	0	1	0	0	0	0	0	1	0	0	4
R10 (Communication Breakdown)	1*	0	0	1*	1*	1	0	0	1	1	0	0	0	0	0	1	0	1*	8
R11 (Inadequate Healthcare Facilities)	1*	1	1	1	1	1	1	1	1	1	1*	1*	1	1	1	1	1	1	18
R12 (Bureaucracy)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
R13 (Exposure to Hazardous Conditions)	1	0	1*	1	1	1	1*	0	1*	1	1*	1*	1*	1*	1*	1	1*	1	16
R14 (Delayed Funding)	1*	0	0	1*	1	1*	1	1*	1	1*	0	1	0	1*	1*	1*	0	1*	13
R15 (Lack of PPE)	1*	1*	1	1	1	1*	1	0	1*	1*	1*	1*	1	1	1	1*	1	1	17
R16 (Misallocation of resources)	1*	1*	1	0	1	1*	1	0	1*	1*	1*	1*	1	1*	1*	1*	1	1	16
R17 (Insufficient Staffing)	1*	1	1	1	1	1	1	0	1*	1	0	1*	1*	0	0	1*	1*	1*	14
R18 (Environmental Degradation)	1	0	0	1*	1*	1	0	0	0	1*	0	0	0	0	0	1	0	1*	7
Driving Power	16	9	10	10	13	16	12	3	13	15	10	11	11	9	9	16	10	13	

MICMAC Analysis Diagram

The Driving power and the dependence are calculated using the Final reachability matrix developed during the ISM methodology. The risks are then plotted on a graph (Fig - 2) with Dependence on X-axis and Driving power on Y-axis.

DRIVING POWER	18																		
	17																		
	16			R3				R18								R13			
	15				R9	IV									III				
	14		In-Dependent							R17			Linkage						
	13								R10					R14			R1		
	12	R12																	
	11	R6																R7	
	10						R8								R2	R16	R15		
	9															R4	R5		
	8																		
	7																		
	6		Autonomous										Dependent						
	5																		
	4					I									II				
	3																	R11	
	2																		
	1																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	DEPENDENCE																		

Fig 2 - Cross-impact matrix multiplication applied to classification (MICMAC) analysis of Risks in Humanitarian Supply Chains

Findings

Since there are no autonomous risks (Cluster I), that means all the risks are relevant to the study. The risks R4-Supply Shortages, R5-Supply Disruptions and R11-inadequate healthcare facilities fall under the cluster of Dependent risks (Cluster II). This means that these risks have high dependence and low driving power (Kumar, Gupta, & Gupta, 2022). They do not impact the other risks as much as they are impacted by them. Any impact good or otherwise towards the mitigation of other risks would similarly impact these.

The 3rd cluster is Linkage (Cluster III). The risks that come under this category have a very high both the Driving Power and the Dependence. It means that these are impacted by some of the risks as well as they impact some of the risks. The risks that fall under this cluster are R1- Resource Scarcity, R2- Transportation Disruptions, R7- Spread of Diseases, R13- Exposure to Hazardous Conditions, R14- Delayed Funding, R15- Lack of PPE, and R16- Misallocation of Resources. It means these impact the risks that have lower dependence and are impacted by risks that have higher driving power than them. These are considered unstable (Jayant & Chhimwal, 2016).

Finally, the independent risks (Cluster IV) that have been identified through analysis are R3- Secondary Natural Hazards, R18-Environmental Degradation, R9- Infrastructure Damage, R17- Insufficient Staffing, R10- Communication Breakdown, R8- Logistical Security Issues, R6- Fraud and Corruption, And R12- Bureaucracy. Independent risks means that these risks have a very high Driving power and a low Dependence. Having high driving power and low dependence means these risks are not impacted that much by other risks but they have an impact on the rest of the risks. In the

ISM model at level 1 and level 2 these risks are at the bottom, which means that R3, R9 and R18 are the risks which are not impacted by other risks a lot, but impact them highly. It means if these risks materialise, this will lead to increased chances of other risks materialising. If these risks are mitigated through some measure, it should have an impact i.e. it should lead to mitigation of the rest of the factors to some extent (Li, Liu, Hu, & Li, 2025). Risks R7 and R11 have highest dependence of 18. That means they are dependent on rest of the factors. R7 and R11 are on the last level of ISM model as well, which also suggests the same thing.

Limitations

This study was conducted by the help of group interview, in which the possibility of one point of view dominating others is possibility. Existence of expert bias is a possibility.

Significance of the study

The study helps in understanding the inter relationships of the risks so that the decision makers can make more informed decisions. Since the study finds out which risks have high driving power, it helps in understanding the root cause of the problems. ISM and MICMAC provide a replicable framework for the risk analysis.

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