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Analysis And Management Of Risks In Humanitarian Supply Chain Using Industry 5.0

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ABSTRACT
Increasing natural disasters have led to a drastic increase in the requirement of Humanitarian supply chains (HSCs). But there are a lot of risks that can arise in the humanitarian supply chains. Considering the severity of the impact these risks could pose to human life, significant research is required regarding the mitigation of these risks. For the purpose of this research, only natural disasters are being considered. This study aims to fulfill three objectives: 1) To discern and evaluate risks that impact the HSCs in India. 2) To identify the significant risks in the humanitarian supply chain in India. 3) To identify the strategic solution using Industry 5.0 technologies to subjugate significant risks in the HSC in India. A mixed-method approach and advanced analytical tools were employed to identify significant risks within the HSC. The literature review conducted led to the identification of risks. Based on those risks, a survey was prepared. Significant risks were identified and then prioritized using the Risk Matrix. Then, using Focus group discussion, technological solutions to the significant risks were identified. There are a few limitations of the research: The author conducted surveys to gather the data for analysis, but interviews might have resulted in a more detailed outcome. The responses of the experts could be biased. The risks and solutions identified are based on current knowledge and technologies. However, the rapidly evolving nature of technology and the changing dynamics of global humanitarian crises could render some findings less relevant over time. The significance of the study lies in the fact that there is a need for effective HSCs because of the urgent needs of the affected people from the disasters.
KEYWORDS – Risk; Industry 5.0; Humanitarian Supply Chain; Natural Hazards; Risk Mitigation

INTRODUCTION

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). For the purpose of this research, Humanitarian supply chains in response to natural disasters are being considered. Natural Disaster has been defined as a "sudden and terrible event in nature (such as a hurricane, tornado, or flood) that usually results in serious damage and many deaths" (Natural Disaster. (n.d.) In *Merriam-Webster's collegiate dictionary*). An increase in losses that happened due to the natural disasters occurring since 1980, was identified after studying the data from natural hazards in the U.S. from 1980 to 2016 (Deng, Aminzadeh, & Ji, 2021).

As the frequency and intensity of disasters increase the number of people affected by them has also increased, it has risen to 100.17 million people in 2019 (Chen, Li, Chang, & Zheng, 2021). (Fu, et al., 2021) found that in 2015, over 8000 geological hazards occurred, and about 70% of them were landslides. In a study by (Sithole, Silva, & Kavelj, 2016) the authors mention that the recent surge in Humanitarian Assistance arises from a notable increase in natural disasters, disease outbreaks, and conflict situations, as indicated by a rise in the number of countries rated as "very high risk" according to the Index for Risk Management (INFORM). The (NDMA, 2021) highlights the severe impact of disasters on human lives, infrastructure, transportation, and various other aspects. Humanitarian relief operations (HRO) encompass the activities undertaken during and after a disaster to provide essential support and assistance to the affected individuals. These operations involve addressing crucial needs such as food, water, shelter, and protection for the disaster victims (Narayanan & IBE., 2015). To ensure the effective, efficient, and timely delivery of essential relief items, a well-organized supply chain known as the Humanitarian Supply Chain (HSC) is indispensable. The demand for HSC has significantly increased in recent times due to the heightened frequency of natural disasters. (Das, Das, & Umamahesh, 2021) indicate that there is a noticeable increase in the percentage of drought-affected area.(Gatignon, Wassenhove ,

& Charles , 2010) describe the humanitarian relief operations environment as risky and uncertain. Decentralisation of supply chain, pooling of relief items by determining in advance the requirements, are the capacities of IFRC's (International Federation of the Red Cross) global supply chain restructuring. (McLachlin & Larson, 2011) encourage the idea of humanitarian supply chain relationship building, especially in the context of humanitarian logistics. This would help in mitigating risks in humanitarian supply chains in countries with fewer resources. (Costa, Campos, & Bandeira, 2012) study the logistics issues during three major natural hazards in the decade, i.e., Indian Ocean tsunami (2004), the earthquake in Pakistan (2005), and the tsunami and earthquake in Japan (2011). (Agarwal , Kant, & Shankar, 2021) study and the enablers of HSCM (Humanitarian Supply Chain Management). The authors describe how studying this field is necessary for the successful HSCM.(Pontré, Welter, Malta, Faria, & Chernyshova, 2011) studied the basis of planning for risk management in high-risk operations. The five steps of the cycle are: risk identification, risk assessment, prioritisation, risk management plan, monitoring, and reporting results of the plan. There can be a lot of risks when it comes to the humanitarian supply chain. One of the risks that (Ben-Tal, Chung, Mandala, & Yao, 2011) study in their research is demand uncertainty. The nature of the hazard and the level of people affected by the hazard determine the demand in outbound logistics, which is uncertain and therefore causes interruptions in HSCM.(Peng , Peng, & Chen, 2014) aim to study how the emergency supply in relief operations is affected by the uncertain environmental factors, as compared to standard supply chains. Their research findings suggest that information delay (ID) resulted in poor performance of humanitarian supply chains. (Chan, 2015), in the chapter, studies flood disaster management, as floods are the major and severe disasters in Malaysia. The author also talks about incorporating new technology in the relief operations to make them more effective. (Chari, Ngcamu, & Novukela, 2020) Conducted research on relief efforts in Zimbabwe and found that humanitarian needs are increasing at an alarming rate, and international funding is not keeping up. In 2018, 40% of humanitarian needs were not met because of a funding gap of almost 10 billion dollars in humanitarian response plans. (Miller, 2015) describe how NDRM (National Disaster Response Management) recognizes that risks can be lowered through collaborative approaches, mitigation procedures, and an effective disaster management response. As discussed earlier by (Ben-Tal, Chung, Mandala, & Yao, 2011) (Baharmand, Comes, & Lauras, 2017) study the transportation risks involved in Humanitarian Supply Chains in Nepal. Though the authors encourage studying other risks involved with the humanitarian supply chain other than logistics, so that risk management strategies could be better planned. (Chen & Lin, 2020) study flood vulnerability in Taiwan. The authors found that incomplete disaster mitigation infrastructure might lead to high flood vulnerability and risk. (Nikolopoulos, Petropoulos , Rodrigues, Pettit, & Beresford, 2019) also, study the risk mitigation in disasters, the authors are only studying the most important locations and only associated with earthquakes. Again, the authors encourage the researchers to research and improve upon the ways and technology for predicting all the natural hazards.ISO 31000:2018 defines risk as "effect of uncertainty on objectives." (ISO 31000:2018 Risk management — Guidelines, 2018). (Ammann, 2006) define risk as the probability of damage due to natural events. (DuHadway, Carnovale, & Hazen, 2019) posit that risk mitigation strategies are completely different in both scenarios, as the result of the risks materialising in a humanitarian supply chain would be far trickier to deal with than a normal supply chain. The authors give an example of storing inventory in case of a disaster. Generally, storing will have a positive effect when responding to disasters, but it will be more problematic if the supplier sends ruined product with low shelf life on purpose. The development in technology can be marked in terms of industrial revolutions throughout history. Industry 1.0, or the First Industrial Revolution, started in 1784.

Figure 1 shows the development stages in technology and the industrial revolutions.

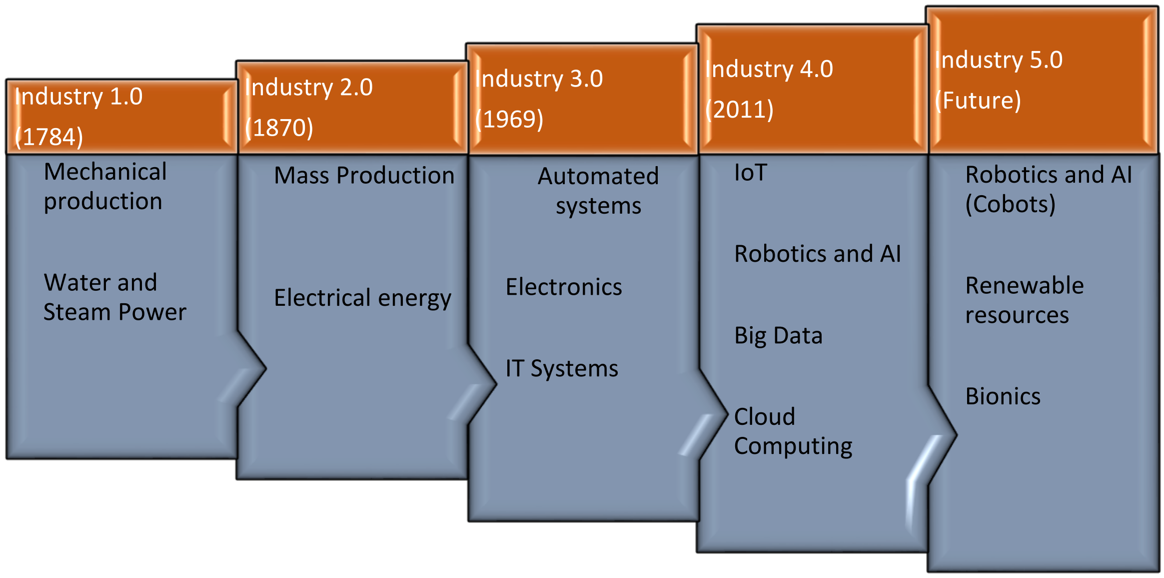


Fig 1 – Industry 1.0 to Industry 5.0
Source - (Demir, Döven, & Sezen, 2019)

Unlike the previous industrial revolutions, Industry 5.0 focuses on the integration of technology under human supervision. It is more human-centric in nature. Unlike Industry 4.0, which focused on the development of technology for the sake of development, Industry 5.0 revolves around the sustainability and the progress of humanity with the development. Rather than excluding humanity from processes, it focuses on the integration, keeping in mind the betterment of humanity (Sharma & Gupta, 2024). Industry 5.0 is a critical topic in academia. Technologies that help interaction between humans and machines will lead to the development of more human-centric technologies (Zeb, et al., 2024).

Problem Statement

A Humanitarian supply chain (HSC) is needed to provide the necessities to affected people effectively, efficiently, and timely manner. Some authors talk about how necessary supplies are not available to the people affected by the hazard. Due to the chaotic atmosphere and all the damage to infrastructure, getting those supplies to the affected populace becomes complicated. (Maddikunta, et al., 2021) talk about how one of the potential industries for Industry 5.0 application could be humanitarian relief operations. (Ertem, Buyurgan, & Rossetti, 2010), (Gatignon, Wassenhove , & Charles , 2010) (Deng et al., 2021), (Chen, Li, Chang, & Zheng, 2021), (Narayanan & IBE., 2015).
Hence, Humanitarian supply chains face significant challenges when natural hazards occur, triggering a range of predicted and unforeseen risks. These events can lead to severe financial losses, with the extent of damage varying based on the disaster's nature, the scale of operations, and organizational preparedness. Additionally, disasters

have led to direct financial losses of USD 79.5 billion globally, with over 76,000 deaths and more than 1 billion people affected. This highlights the critical need for effective risk management strategies in humanitarian supply chains to mitigate these impacts.

LITERATURE REVIEW

1) Humanitarian supply chain

(Gatignon, Wassenhove , & Charles , 2010) describe the humanitarian relief operations environment as risky and uncertain. Decentralisation of supply chain, pooling of relief items by determining in advance the requirements, are the capacities of IFRC's (International Federation of the Red Cross) global supply chain restructuring. (McLachlin & Larson, 2011) encourage the idea of humanitarian supply chain relationship building, especially in the context of humanitarian logistics. (Costa, Campos, & Bandeira, 2012) study the logistics issues during three major natural hazards in the decade, i.e., Indian Ocean tsunami (2004), the earthquake in Pakistan (2005), and the tsunami and earthquake in Japan (2011). (Agarwal , Kant, & Shankar, 2021) study and the enablers of HSCM (Humanitarian Supply Chain Management).

(Pontré, Welter, Malta, Faria, & Chernyshova, 2011) studied the basis of planning for risk management in high-risk operations. The five steps of the cycle are – risk identification, risk assessment, prioritisation, risk management plan, monitoring and reporting results of the plan. One of the risks that (Ben-Tal, Chung, Mandala, & Yao, 2011) study in their research is demand uncertainty.

(Peng , Peng, & Chen, 2014) aim to study how the emergency supply in relief operations is affected by the uncertain environmental factors, as compared to standard supply chains. (Chan, 2015), in the chapter, studies flood disaster management, as floods are the major and severe disasters in Malaysia. The author also talks about incorporating new technology in the relief operations to make them more effective. (Chari, Ngcamu, & Novukela, 2020) conducted research on relief efforts in Zimbabwe and found that humanitarian needs are increasing at an alarming rate, and international funding is not keeping up. In 2018, 40% of humanitarian needs were not met because of a funding gap of almost 10 billion dollars in humanitarian response plans.

(Miller, 2015) describe how NDRM (National Disaster Response Management) recognizes that risks can be lowered through collaborative approaches, mitigation procedures, and an effective disaster management response. Many studies were Studies which led to the identification of transportation risks (Ben-Tal, Chung, Mandala, & Yao, 2011), (Baharmand, Comes, & Lauras, 2017), (Chen & Lin, 2020).

(Nikolopoulos, Petropoulos , Rodrigues, Pettit, & Beresford, 2019) also study the risk mitigation in disasters. Again, the authors encourage the researchers to research and improve upon the ways and technology for predicting all the natural hazards.

(Lowrance, 1976) in his book defines risk in very simple terms. He defines risk as "Risk is a measure of the probability and severity of adverse effects". The Institute of Internal Auditors (IIA) defines risk as the uncertainty of an event occurring that could have an impact on the achievement of objectives (Hopkin, 2018). There can be a lot of risks when it comes to the humanitarian supply chain. (Miller, 2015) describe how NDRM (National Disaster Response Management) recognizes that risks can be lowered through collaborative approaches, mitigation procedures, and an effective disaster management response.

(Jiang, Liua, Lu, Qu, & Yang, 2023) study the risks in the maritime supply chain. (Ammann, 2006) define risk as the probability of damage due to natural events. This paper also tries to identify risks faced by the humanitarian supply chain in the case of natural hazards. The risks that humanitarian supply chains face could be because of the disaster they are responding to, or the risk could be the result of intentional disruptions (DuHadway, Carnovale, & Hazen, 2019). A paper by (Tetteh, Kwateng, & Tani, 2024) mentions the key stakeholders identified by the authors: Humanitarian Organizations: They include both governmental and non-governmental organizations (NGOs). Relief Teams, Supply Chain Partners, Local Communities, Technology Providers.

In a paper by (John & Ramesh, 2012) the actors in HSC identified were: Donors, NGOs and aid agencies, Government, Military, Logistics providers, Inventory and information. The discussion emphasizes the various challenges and gaps in the current HSCM practices. One major issue is the lack of coordination among actors, leading to inefficiencies and duplication of efforts. The paper also points out the simultaneous scarcity and overabundance of resources, where critical supplies are often lacking, while unsolicited donations clog distribution channels.

2) Challenges in Natural Disaster Relief Operations in India

Recent research on natural disasters in India highlights various challenges and shortcomings in relief operations, revealing critical areas that need improvement. One study presents a mathematical model for optimizing disaster relief in the early. The model tested in a real-life case study demonstrates how an integrated approach can reduce vehicle requirements and improve efficiency, yet it underscores the difficulties in large-scale application due to time-consuming exact solution methods (Insani, Taheri, & Abdollahian, 2024). Research on UAVs in disaster scenarios emphasizes the importance of intelligent communication networks for efficient emergency response (Liu, 2023). Another study on man-made disasters in India reveals that poor preparedness, high population density, and environmental conditions exacerbate disaster impacts, necessitating improved disaster management policies and infrastructure (Kumar, 2024).Drones can be designed to deal with issues of response times, resource allocation (Sowmya, Janani, Hussain, Aashica, & Arvindh, 2024) (C & V, 2023). The study on poverty and natural disasters during the Abbasid period in Kurdistan, though historical, provides a comparative perspective on the long-term socio-economic impacts of natural disasters and the importance of historical data in understanding present challenges (Mohammed & Mambakr, 2024). Research on healthcare challenges, significant disruptions in livelihoods and healthcare services, and the need for government and NGO collaboration in disaster prevention and recovery efforts (Hossain, et al., 2024). A comprehensive review of pre- and post-disaster management strategies in organizational contexts identifies a critical research gap in developing mathematical models for disaster management. It proposes an optimization model to minimize overall costs and improve the efficiency of humanitarian logistics within organizations, addressing penalty costs, delays, and waiting times (Aghsami , et al., 2024). A significant study emphasizes that humanitarian relief operations often face severe disruptions due to a lack of accurate and timely information, poor inventory control, and inadequate collaboration among stakeholders. These issues are exacerbated by the chaotic nature of disaster environments, making efficient coordination and logistics extremely challenging (Ganguly & Rai, 2016). Another analysis highlights the gaps in humanitarian supply chains, noting that while organizations recognize the importance of efficient supply chains, they often lack the necessary resources and tools to optimize their operations. Their primary problems identified include insufficient funding, lack of skilled personnel, and inadequate technology (Agostinho, 2013).

3) Overview of risks in the humanitarian supply chain

(Chari, Ngcamu, & Novukela, 2020) examined evidence regarding supply chain risks in the provision of humanitarian aid to individuals affected by Cyclone Idai in Zimbabwe. The authors mentioned these risks: Organizational risks, Resource risks, Technological risks, Manufacturing risks, Warehousing risks, Distribution risks, Retail risks.

(Zhang, Li, & Liu , 2012) emphasize that there is a high likelihood of secondary disasters or a chain of disasters occurring following the initial impact of the primary disaster.

(Warner, Hamza, Smith, Renaud, & Julca , 2010) suggest that Climate change poses a significant risk to the occurrence and impacts of disasters, and there are various factors contributing to this connection.

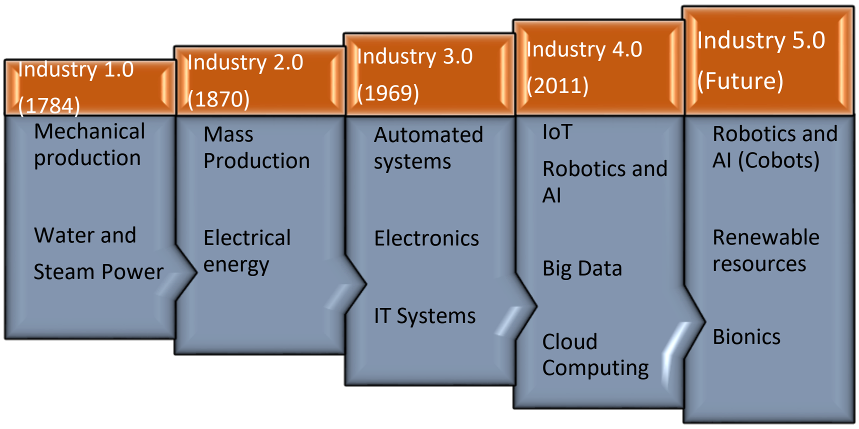
(Jamieson, 2016) mentions a term, shorthand environment. According to the research conducted by (Farber, 2012), an in-depth analysis of risks in the humanitarian supply chain reveals critical challenges that require attention. Proper planning and action are crucial in mitigating these risks.

(John, Gurumurthy, Soni, & Jain, 2019) mention various coordination risks in their study. (Ben-Tal, Chung, Mandala, & Yao, 2011) Emphasize the importance of "outbound logistics. The authors mention various demand risks in the paper. In a study by (Wassenhove, 2006), the author mentions various logistical risks. One human resource risk is the risk of not selecting and adequately training individuals who possess the necessary skills. Carbon footprint is also a risk to humanitarian supply chains (Fuli, Foropon, & Xin, 2022). The authors study the reduction of carbon emissions in the humanitarian supply chain. (L'Hermitte, Tatham, Brooks, & Bowles, 2016) mention several supply risks in their study. (John, Gurumurthy, Mateen, & Narayanamurthy, 2022) mention in their study that achieving operational coordination between different parties in humanitarian relief efforts may have to face certain risks, including slow information flow and delays in resource allocation. The risks also include the Uncertainty of demand. In a study by, (Negi & Negi, 2021), various risks to the HSCs were found by authors like Operational Risks, Legal and Regulatory Risks, Financial Risks, Human Resource Risks: Lack of training and awareness-raising programs(Sahebi, Arab, & Moghadam, 2017) assess the barriers, highlighting the importance of cultural, managerial, and educational barriers in the HSC context. The availability of experienced and skilled humanitarian personnel is insufficient, limiting the capacity to respond effectively. Communication channels are frequently blocked, impeding the flow of crucial information. Many affected individuals lack awareness regarding aftershocks, putting them at risk. Inconsistent and inadequate training systems for humanitarian workers hinder their preparedness and effectiveness.

The above literature review was conducted to identify various risks in the humanitarians supply chain. There are multiple studies, as evident from the review, that identify various risks. Data from all the studies was compiled to create an extensive list of risks in the humanitarian supply chain.

4) Industry 5.0 technologies (Fifth Industrial Revolution)

The development in technology can be marked in the terms of industrial revolutions throughout history. Industry 1.0, or First Industrial Revolution, started in 1784. Fig 1 shows the development stages in technology, and the industrial revolutions.



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Source - (Demir, Döven, & Sezen, 2019)

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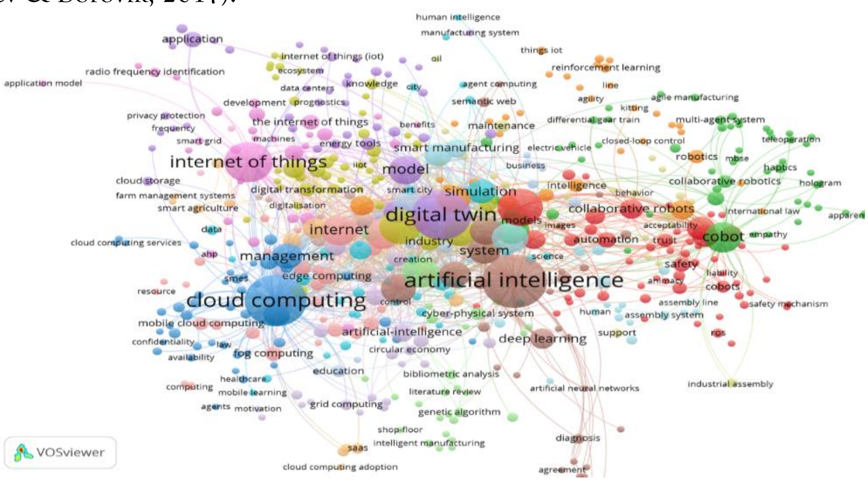

Fig. 2 Major technologies in Industry 5.0

Source – (Gupta, Jain, & Gupta, 2024)

The VOSViewer generated image in Figure 2 shows the major technologies in Industry 5.0.

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5) Existing research on the integration of Industry 5.0 in humanitarian supply chains

(Othmen, 2024) study the influence of technology on transparency in Humanitarian Logistics. The author highlights the growing interest of researchers in studying the potential benefits of the integration of technologies like blockchain, Artificial intelligence, and Internet of Things with Humanitarian logistics. The author suggests, based on their research, that the technologies can help with better collaboration and information flow within the Humanitarian Supply Chain. The author emphasizes the importance of integrating new technologies in Humanitarian Logistics, implying they have the potential to transform Humanitarian Logistics.

(Negi, 2024) study the application of Blockchain technology for managing financial flow in humanitarian supply chains. The author concludes the research by stating the rising problem of trust due to fraud by charities around the world. They suggest that the integration of blockchain technology can increase the traceability and transparency of the financial flows in HSCs. The author talks about the potential application of blockchain in "crowdfunding, documentation, humanitarian financing, data collection, information sharing, and cash programming". The author also states that the features of blockchain technology, like "real-time data sharing, streamlined processes, peer-to-peer financial transactions, transparency, smart contracts, and decentralized ledger technology," can mitigate the risk of fraud, mismanagement of funds, and inclusive financial services in disaster-affected areas. (Patil, Shardeo, Dwivedi, & Paul, 2023) in their study talk about how digitization, across various domains, can improve coordination, increase data collection and retention capacities. The authors mention the challenges faced by the Humanitarian domain. Challenges such as financial funding shortfalls, challenges with the response system. The authors concluded that resource management is the most important for effective and flexible humanitarian operations.

For Research Objective 1
- RQ1 –What are the various risks with respect to HSC?
- RQ2 –What are the associated actors and stakeholders?

For Research Objective 2
- RQ1 – What are the significant risks in HSC?

For Research Objective 3
- RQ1 – What are the specific technologies and tools associated with Industry 5.0 that can be leveraged for risk mitigation of significant risks in HSCs?

The authors suggest that digitally supported applications are necessary to incorporate flexibility in HSCs. (Boeck, et al., 2023) study in their paper the use of technologies like blockchain technology, big data, and AI in the Humanitarian field. They talk about how collaboration between researchers and practitioners is necessary. The authors also stipulate that more research needs to be done on how to improve the accessibility of data, research on the usefulness of data analytics, and stakeholder engagement. (García , Navarro, Chedid, & Mateus, 2021) conduct a bibliometric analysis of research done on the integration of technology in Humanitarian Supply Chains. The authors found many papers worldwide doing research on the integration of technology with HSCs to make it more efficient. The authors analyse what research has been done and in which countries. The authors found that new information technologies (newIT) helped during a disaster response system in Zimbabwe by guaranteeing the supply of medicines, availability of products, and other essential items that are required for the care of disaster victims. In another study done in Singapore, a system was developed called the integrated logistics information system (Setiabudi & Wydiadana, 2019). Similarly, in a symposium in Dublin, a paper was presented that showed how cloud computing helped with communication and information management.

(Kabra, Ramesh, Akhtar , & Dash, 2017) inform that there is limited research focusing on technology adoption in supply chains in the Humanitarian context. The authors extend the UTAUT model in the context of technology adoption in humanitarian supply chains. The authors suggest that the technology should become a routine in daily lives with the help of proper IT and Data mining training.

1. Research Problem

The literature suggests that the need for risk management in humanitarian supply chains is undisputed. Many authors in their studies have suggested that Industry 5.0 technologies can be effectively used for mitigating the risks in HSCs. However, the application of various Industry 5.0 technologies to the Humanitarian Supply Chain as a means of mitigating risks still needs to be investigated.

2. Research Objectives

1) To discern and evaluate risks that impact the HSC in India.
2) To identify the significant risks in the humanitarian supply chain in India.
3) To identify the strategic solutions using Industry 5.0 technologies to subjugate significant risks in the HSC in India.

Research Questions

3. THEORETICAL FRAMEWORK

Unified Theory of acceptance and use of technology (UTAUT) –

UTAUT was articulated in a study "User acceptance of information technology: Toward a unified view," by (Venkatesh, Morris, Davis, & Davis, 2003) Fig. 26. It is an extension of the "Technology Acceptance Model (TAM)" by (Davis, 1989).TAM explains how technology is accepted and used by consumers. UTAUT was created by the amalgamation and analysis of 8 theories (Venkatesh, Morris, Davis, & Davis, 2003) –

- Theory of Reasoned Action
- Technology Acceptance Model
- Motivational Model
- Theory of Planned Behaviour
- A combined theory of planned behaviour/technology acceptance model
- Model of personal computer use
- Diffusion of innovations theory
- social cognitive theory

The research model for UTAUT can be referred to in Figure 1 below:

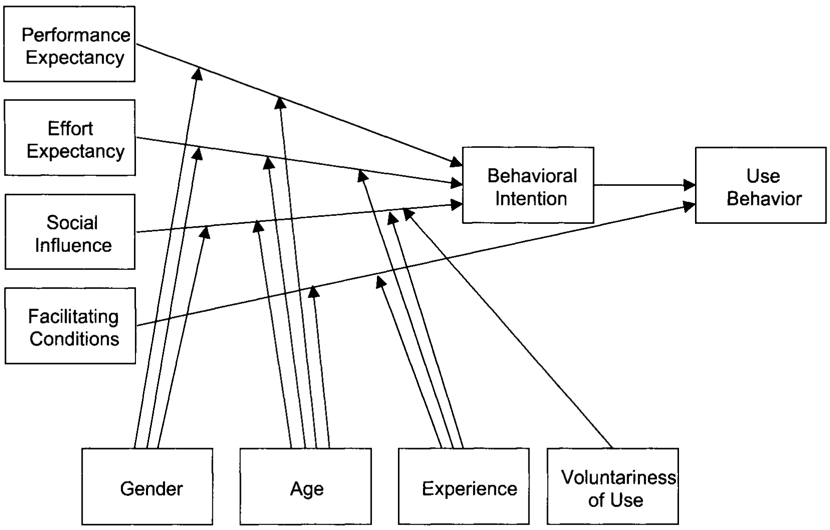

Figure 1 – Research Model of UTAUT
Source - (Venkatesh, Morris, Davis, & Davis, 2003)

UTAUT outlines 3 direct determinants of user acceptance:

1) **Performance expectancy –** the extent to which an individual believes technology would help performance advancement is termed as performance expectancy (Venkatesh, Morris, Davis, & Davis, 2003).
2) **Effort expectancy –** (Venkatesh, Morris, Davis, & Davis, 2003) (Davis, 1989) define effort expectancy as the extent of effort required as perceived by the consumer using the technology/ system.
3) **Social influence -** (AJZEN, 1991) (Davis, 1989) social influence is defined as the social pressure perceived by the individual to use or not use the system/ technology.

UTAUT outlines 1 direct determinant of usage behaviour:

1) **Facilitating conditions –** facilitating conditions have a direct impact on usage behaviour (AJZEN, 1991). Facilitating conditions lose their importance when the constructs for performance expectancy and effort expectancy are both present (AJZEN, 1991).

The four constructs are moderated by age, gender, voluntariness and experience.

4. METHODOLOGY

a. Research approach (e.g., quantitative, qualitative, mixed methods)

For the purpose of fulfilling the objectives, a mixed methodology approach was taken. Some part of the data collection was qualitative and some was quantitative. The flow chart in Fig. 2 explains the methodology followed for the purpose of this research.

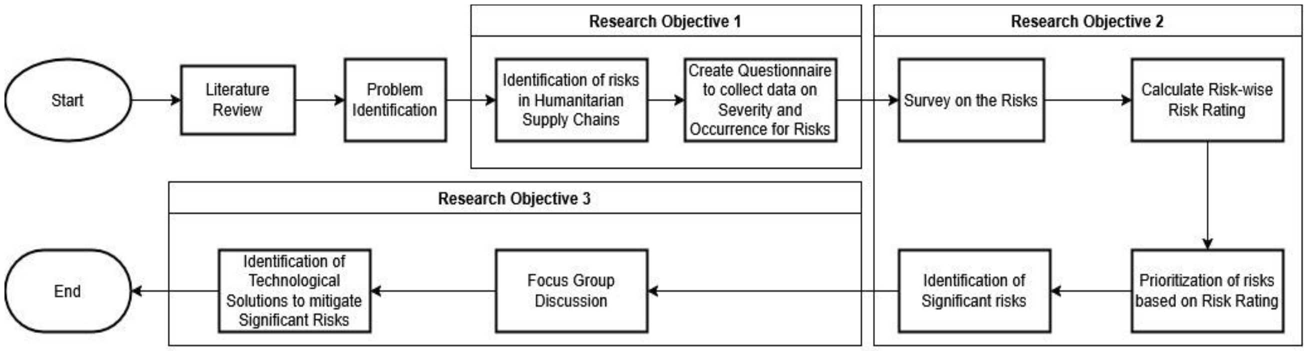

Fig. 2 Flowchart of the research

Source – Developed by Author

b. Data collection methods (e.g., surveys, interviews, case studies)

The literature review conducted led to the identification of risks. Based on those risks, a survey was prepared. A survey was then conducted in which the respondents were asked to rate each risk on three factors: Severity, Probability of occurrence, and Detection on a Likert scale of 1 – 5. Here, the ratings meant:

For Severity (S): (If the risk occurs, how severe would be the impact?)
1: Negligible impact
2: Little impact
3: Moderate impact
4: Significant impact
5: Severe impact

For Occurrence (O): (What is the probability of the risk actually occurring?)
1: Unlikely to occur
2: Low probability
3: Moderate probability
4: High probability
5: Very High Probability

For Detection (D): (How easily detectable is the risk?)
1: Highly detectable
2: Easily Detectable
3: Moderately detectable
4: Difficult to detect
5: Not Detectable

The Sample size was chosen based on purposive sampling. First, a few people from NGOs, the Police department, Government organisations, private sector tech companies, transportation providers, and Non-profit organisations were contacted to do a pilot survey. A total of 12 people responded. The responses of the pilot study were also included in the final data. Reliability analysis was carried out for the data. The Cronbach alpha test yielded the following result.

Reliability Analysis

Scale Reliability Statistics

	Cronbach's α
scale	0.770

The value of Cronbach's alpha came to be 0.770, an acceptable value for a survey questionnaire. So, we proceeded to send the survey questionnaire to organisations that are stakeholders in the HSCs. Many government agencies, NGOs, the Police department, and CSR organisations were contacted.
Government Agencies: NDMA, NIDM, IMD, NDRF, MHA, GSI
NGOs: 497 NGOs were contacted (details accessed through https://ngodarpan.gov.in/index.php/search/)
Police Department: Through MHA, NDMA
Logistic providers: Gati Limited, VRL Logistics, DHL Express, Blue Dart Express Ltd., TCI Freight (Transport Corporation of India)
A total of 72 responses were received.

c. Data analysis techniques

a. FMEA

Failure Modes and Effects Analysis (FMEA) is a strategic process used to identify potential failures in a system or product and understand the implications of these failures. A critical aspect of FMEA is quantifying two key parameters: the severity of the potential failure's impact and the likelihood of the failure's occurrence. These quantifications help in deciding the necessary actions and responses for each identified potential failure. (Bowles, 2003). (Wang W. , Liu, Qin, & Fu, 2018) mention in their study that FMEA is the most widely used and most effective way to analyse and prioritise risks. The FMEA is used to identify potential failures to improve security and reliability (Fan, Wang, & Wu, 2021). Which is why FMEA is used in this research to analyse and prioritise the risks. The risk rating of failure modes (risks in this study) is calculated by RPN (Risk Priority Number). RPN is calculated by multiplying the risk factors: Severity, Occurrence, and Detection. Then the risks can be prioritised on the basis of this RPN. Once the risks have been prioritised, the authors need to categorize the risks into categories to identify the significant risks.

b. Risk Severity Matrix

(Jia, Nwaogazie, & Anyanwu, 2022) describe the Risk severity matrix as the best method for risk assessment. The authors mention Risk Severity Matrix as a qualitative risk assessment. In this method, the risk is assessed using two factors in relation to the risks: Severity and occurrence. And then the risks are rated accordingly. Another study by (Yazdi, 2017) explains that for the use of the risk matrix for the assessment of risks, the values for severity and occurrence are multiplied to get a risk rating for each risk. The risk matrix used by the author is shown in Figure – 3.

	Consequences				Likelihood				
Severity	People	Assets	Environment	Reputation	A 1 Never heard in the industry	B 2 Heard of in the industry	C 3 Has happened in the company or more than once per year in the industry	D 4 Has happened at the location or more than once per year in the company	E 5 Has happened more than once per year at the location
0	No injury or health effect	No damage	No effect	No impact	0	0	0	0	0
1	Slight injury or health effect	Slight damage	Slight effect	Slight impact	1	2	3	4	5
2	Minor injury or health effect	Minor damage	Minor effect	Minor impact	2	4	6	8	10
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate impact	3	6	9	12	15
4	PDT* or up to 3 fatalities	Major damage	Major effect	Moderate impact	4	8	12	16	20
5	More than 3 fatalities	Massive damage	Massive effect	Massive impact	5	10	15	20	25

PDT*: Permanent Disability

Unacceptable risks (25)	In this level the task should not be started till the intolerable risk reach to acceptable level.
Significant risks (15, 16, 20)	In this level the task should not be started till the intolerable risk has been reduced.
Intermediate risks (8, 9, 10, 12)	In this level the preventative actions should be started to reduce the identified risks.
Acceptable risk (2, 3, 4, 5, 6)	No further preventative action is necessary to eliminate the risks. But in this level monitoring is need to ensure that the controls procedure are maintained.
Insignificant risks (0, 1)	No further preventative action is necessary to eliminate the risks.

Fig. 3 Risk Severity Matrix
Source - (Yazdi, 2017)

The same matrix has been explained by another study by (Ahn & Chang, 2016). The authors describe the process as consisting of three steps: risk identification, risk analysis, and decision making. The literature shows that with this method, the risks can be categorised in 5 categories: Insignificant risks, Acceptable risks, Intermediate risks, Significant risks, and Unacceptable risks.

The same risk matrix has been used in this study to assess the risks in the humanitarian supply chain.

c. Focus Group Discussion

Focus group discussions are a qualitative technique to gather insights from experts which is widely used all over the world by researchers. Focus Group Discussion is a structured discussion designed to gather insights, experiences of experts (Susanto, Yuntina, Saribanon, Soehaditama, & Liana, 2024). In a study by (Dedios-Sanguineti1, Guarin1, Torres-Garc´ıa1, & Gómez, 2025), the authors talk about how conducting focus group discussions online is being supported by various researchers in places where it is difficult for people to connect in person, and so connecting online is a must in such cases for the purpose of discussion. A set of pre-prepared questions is used to moderate the discussion. (Susanto, Yuntina, Saribanon, Soehaditama, & Liana, 2024). Another study by (Mishra, 2016) talks about the group size of a focus group discussion. The authors suggest that the study could have as few as 3 participants and as many as possible.

5. Analysis and Findings

- **Risk identification**

Research on healthcare challenges faced by riverine island inhabitants in Bangladesh due to natural disasters reveals significant disruptions in livelihoods and healthcare services, underscoring the need for government and NGO collaboration in disaster prevention and recovery efforts (Hossain, et al., 2024). Recent studies highlight various challenges faced by humanitarian supply chains in India, focusing on strategies to optimize operations and improve resilience. A comprehensive review of pre- and post-disaster management strategies in organizational contexts identifies a critical research gap in developing mathematical models for disaster management. It proposes an optimization model to minimize overall costs and improve the efficiency of humanitarian logistics within organizations, addressing penalty costs, delays, and waiting times (Aghsami , et al., 2024). The literature on humanitarian supply chains in India highlights numerous challenges that impede effective disaster relief operations. A significant study focusing on the Uttarakhand disaster identifies critical issues such as information availability, inventory management, and collaboration. The study emphasizes that humanitarian relief operations often face severe disruptions due to a lack of accurate and timely information, poor inventory control, and inadequate collaboration among stakeholders. Which is why it is necessary to identify the risks and find solutions to mitigate them. Based on the literature review done, a total of 126 risks were identified, shown in Table 1.

Table – 1 Identified Risks

	Risk
1.	Resource Scarcity
2.	Limited Resources
3.	Transportation Disruptions
4.	Natural hazards
5.	Supply shortages
6.	Supply Disruption
7.	Spread of Diseases
8.	Fraud and Corruption
9.	Security Issues (Logistical)
10.	Infrastructure Damage
11.	Civil Unrest
12.	Inadequate Response to Vulnerable Populations
13.	Communication Breakdown
14.	Supplier Reliability
15.	Inadequate Health Care Facilities
16.	Bureaucracy
17.	Exposure to Hazardous Conditions
18.	Environmental Degradation
19.	Communication Gaps

20.	Delayed Funding
21.	Transportation Delays
22.	Lack of Personal Protective Equipment
23.	Misallocation of Resources
24.	Insufficient Staffing
25.	Inefficiency in Aid Delivery
26.	Inadequate Local Resources
27.	Secondary Disasters
28.	Delayed response
29.	Displacement and Migration
30.	Malnutrition
31.	Inefficient Distribution
32.	Technology Failure
33.	Poor Coordination with Other Agencies
34.	Equipment Failure
35.	Data Protection and Privacy Laws
36.	Lack of Security Infrastructure
37.	Information Management Challenges
38.	Violations of Human Rights
39.	Demand Uncertainty
40.	Information Asymmetry
41.	Health and Safety Issues
42.	Carbon Footprint
43.	Inflation
44.	Logistical Challenges
45.	Terrorism and Conflict
46.	Inadequate Training
47.	Limited Accessibility
48.	Warehousing and Storage
49.	Permissions and Licenses
50.	Remote Management
51.	Neglected Areas or Populations
52.	Regulatory Changes
53.	Inadequate Local Knowledge
54.	Inefficient Use of Expertise
55.	Lack of Transparency
56.	Inadequate Local Law Enforcement
57.	Insufficient Funds
58.	Unforeseen Costs
59.	Cybersecurity Threats
60.	Lack of Local Knowledge
61.	Resource Competition
62.	Volunteer Management
63.	Quality Issues
64.	Data Management Risks
65.	Duplication of Efforts
66.	Lack of Technological Training
67.	Different Operational Procedures
68.	Security Issues
69.	Injury or Illness
70.	Lack of Backup Systems
71.	Mismanagement of Funds
72.	Legal and Regulatory Compliance
73.	Negligence in Staff Behaviour
74.	Language and Cultural Barriers

75.	Reliability of Local Partners
76.	Customs and Regulations
77.	Respect for Customs and Traditions
78.	Environmental Regulations
79.	Cultural Misunderstandings
80.	Legal Constraints
81.	High Turnover
82.	Poor Communication
83.	Trade Restrictions
84.	lack of Involvement of Local Communities
85.	Cultural and Language Differences
86.	Inflation or Cost Escalation
87.	Inadequate Technology Infrastructure
88.	Costs of Compliance
89.	Political Influence and Priorities
90.	Jurisdictional Disputes
91.	Security Risks
92.	Import/Export Restrictions
93.	Storage Limitations
94.	Safety and Security
95.	Reliance on Outdated Technology
96.	Gender Inequality
97.	Legal Liability
98.	Geographic Diffusion
99.	Technology Accessibility
100.	Climate Change
101.	Psychological Trauma
102.	Disease or Injury
103.	Dependence on Donors
104.	Biodiversity Loss
105.	Shifts in Needs
106.	Poor Quality Aid
107.	Limited access to Vulnerable Groups
108.	Pollution
109.	Long-Term Financial Sustainability
110.	Burnout and turnover
111.	Compliance Risks
112.	Inadequate Planning and Preparedness
113.	Inadequate Storage Facilities
114.	Staffing Challenges
115.	Fluctuating Demand
116.	Border Disputes
117.	Coordination Among Agencies
118.	Interoperability Issues
119.	Contractual Risks
120.	Government Instability
121.	Target Population Identification
122.	Misalignment of Objectives
123.	Staff Work Permit/Visa Issues
124.	Lack of Cultural Sensitivity
125.	Exchange Rate Fluctuations
126.	Social Tensions

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a. Data collection and Analysis

The FMEA is used to identify potential failures to improve security and reliability (Fan, Wang, & Wu, 2021). Which is why FMEA is used in this research to analyse and prioritise the risks. Risk rating of failure modes (risks in this study) is calculated by multiplying the values of severity and probability of occurrence. So a survey questionnaire was prepared and sent to experts. The experts were asked to then rate all the risks on factors: severity and occurrence. A total of 72 responses was compiled. Mean values of all the responses were then calculated as can be seen in the table - 2.

Table – 2 Mean of collected data of Severity and Occurrence rating on Risks

	Risk	Severity	Probability of Occurrence
1.	Resource Scarcity	4.9	4.7
2.	Limited Resources	4.9	2.4
3.	Transportation Disruptions	4.8	4.7
4.	Natural hazards	4.7	4.6
5.	Supply shortages	4.5	4.8
6.	Supply Disruption	4.5	4.6
7.	Spread of Diseases	4.5	4.4
8.	Fraud and Corruption	4.4	4.7
9.	Security Issues (Logistical)	4.4	4.3
10.	Infrastructure Damage	4.4	4.3
11.	Civil Unrest	4.4	2.3
12.	Inadequate Response to Vulnerable Populations	4.4	2.2
13.	Communication Breakdown	4.3	4.4
14.	Supplier Reliability	4.3	2.2
15.	Inadequate Health Care Facilities	4.2	4.24
16.	Bureaucracy	4.2	4.1
17.	Exposure to Hazardous Conditions	4.2	4.1
18.	Environmental Degradation	4.2	3.8
19.	Communication Gaps	4.2	3.3
20.	Delayed Funding	4.1	4.2
21.	Transportation Delays	4.1	4
22.	Lack of Personal Protective Equipment	4.1	4
23.	Misallocation of Resources	4.1	4
24.	Insufficient Staffing	4.1	3.9
25.	Inefficiency in Aid Delivery	4.1	2.47
26.	Inadequate Local Resources	4.1	2.1
27.	Secondary Disasters	4	2.2
28.	Delayed response	4	2.1
29.	Displacement and Migration	3.8	2.4
30.	Malnutrition	3.8	2.4
31.	Inefficient Distribution	3.73	2.48
32.	Technology Failure	3.6	2.3
33.	Poor Coordination with Other Agencies	3.5	3.6
34.	Equipment Failure	3.4	2.3
35.	Data Protection and Privacy Laws	3.4	2.3
36.	Lack of Security Infrastructure	3.3	2.4
37.	Information Management Challenges	3.3	2.2
38.	Violations of Human Rights	3.3	2.2
39.	Demand Uncertainty	3.2	3.6
40.	Information Asymmetry	3.2	3.5
41.	Health and Safety Issues	3.2	3.1
42.	Carbon Footprint	3.2	2.3
43.	Inflation	3.2	2.1

44.	Logistical Challenges	3.2	2.1
45.	Terrorism and Conflict	2.8	1.4
46.	Inadequate Training	2.62	2.3
47.	Limited Accessibility	2.6	2.4
48.	Warehousing and Storage	2.6	2.4
49.	Permissions and Licenses	2.6	2.4
50.	Remote Management	2.6	2.35
51.	Neglected Areas or Populations	2.6	2.34
52.	Regulatory Changes	2.55	2.13
53.	Inadequate Local Knowledge	2.5	2.4
54.	Inefficient Use of Expertise	2.5	2.4
55.	Lack of Transparency	2.5	2.4
56.	Inadequate Local Law Enforcement	2.5	2.3
57.	Insufficient Funds	2.48	4.6
58.	Unforeseen Costs	2.48	2.7
59.	Cybersecurity Threats	2.48	2.4
60.	Lack of Local Knowledge	2.48	2.35
61.	Resource Competition	2.46	2.3
62.	Volunteer Management	2.45	2.47
63.	Quality Issues	2.45	2.45
64.	Data Management Risks	2.45	2.4
65.	Duplication of Efforts	2.45	2.4
66.	Lack of Technological Training	2.42	2.3
67.	Different Operational Procedures	2.4	3.3
68.	Security Issues	2.4	2.3
69.	Injury or Illness	2.4	2.3
70.	Lack of Backup Systems	2.4	2.3
71.	Mismanagement of Funds	2.4	2.3
72.	Legal and Regulatory Compliance	2.4	2.3
73.	Negligence in Staff Behaviour	2.4	2.3
74.	Language and Cultural Barriers	2.4	2.3
75.	Reliability of Local Partners	2.4	2.3
76.	Customs and Regulations	2.4	2.3
77.	Respect for Customs and Traditions	2.4	2.3
78.	Environmental Regulations	2.4	2.3
79.	Cultural Misunderstandings	2.4	2.3
80.	Legal Constraints	2.4	2.3
81.	High Turnover	2.4	2.26
82.	Poor Communication	2.4	1.4
83.	Trade Restrictions	2.4	1.2
84.	lack of Involvement of Local Communities	2.4	1.2
85.	Cultural and Language Differences	2.4	1.2
86.	Inflation or Cost Escalation	2.4	1.1
87.	Inadequate Technology Infrastructure	2.38	2.4
88.	Costs of Compliance	2.35	2.45
89.	Political Influence and Priorities	2.35	2.24
90.	Jurisdictional Disputes	2.3	2..15
91.	Security Risks	2.3	2.45
92.	Import/Export Restrictions	2.3	2.45
93.	Storage Limitations	2.3	2.4
94.	Safety and Security	2.3	2.2

95.	Reliance on Outdated Technology	2.3	2.2
96.	Gender Inequality	2.3	2.2
97.	Legal Liability	2.3	2.2
98.	Geographic Diffusion	2.3	2.2
99.	Technology Accessibility	2.3	2.1
100.	Climate Change	2.3	2
101.	Psychological Trauma	2.25	2.2
102.	Disease or Injury	2.25	1.8
103.	Dependence on Donors	2.2	4.1
104.	Biodiversity Loss	2.2	3.4
105.	Shifts in Needs	2.2	2.4
106.	Poor Quality Aid	2.2	2.35
107.	Limited access to Vulnerable Groups	2.2	2.1
108.	Pollution	2.2	2.1
109.	Long-Term Financial Sustainability	2.2	1.61
110.	Burnout and turnover	2.2	1.5
111.	Compliance Risks	2.2	1.4
112.	Inadequate Planning and Preparedness	2.18	4
113.	Inadequate Storage Facilities	2.15	2.4
114.	Staffing Challenges	2.14	4
115.	Fluctuating Demand	1.9	2.1
116.	Border Disputes	1.8	1.2
117.	Coordination Among Agencies	1.7	2.28
118.	Interoperability Issues	1.5	2.4
119.	Contractual Risks	1.5	2.4
120.	Government Instability	1.5	1.55
121.	Target Population Identification	1.5	1.4
122.	Misalignment of Objectives	1.5	1.4
123.	Staff Work Permit/Visa Issues	1.5	1
124.	Lack of Cultural Sensitivity	1.4	2.4
125.	Exchange Rate Fluctuations	1.4	1.3
126.	Social Tensions	1.2	2.4

For further analysis of the risks Risk Severity Matrix was utilised.

b. Identification of significant risk

(Jia, Nwaogazie, & Anyanwu, 2022) describe Risk severity matrix as the best method for risk assessment. The authors mention Risk Severity Matrix (Table - 8) as qualitative risk assessment. In this method the risk is assessed using two factors in relation to the risks: Severity and occurrence. And then the risks are rated accordingly. Another study by (Yazdi, 2017) explains that for the use of risk matrix for the assessment of risks, the values for severity and occurrence are multiplied to get a risk rating for each risk. The ratings were then compared to the matrix, and based on that the risks were divided into 5 categories. As can be seen in Table - 3

Table – 3 Classification of risks into categories

Risk	Severity	Probability of Occurrence	Risk Rating
Resource Scarcity	4.9	4.7	23.03
Limited Resources	4.9	2.4	11.76
Transportation Disruptions	4.8	4.7	22.56
Secondary Natural hazards	4.7	4.6	21.62
Supply shortages	4.5	4.8	21.6
Supply Disruption	4.5	4.6	20.7
Spread of Diseases	4.5	4.4	19.8
Fraud and Corruption	4.4	4.7	20.68
Security Issues (Logistical)	4.4	4.3	18.92
Infrastructure Damage	4.4	4.3	18.92
Civil Unrest	4.4	2.3	10.12
Inadequate Response to Vulnerable Populations	4.4	2.2	9.68
Communication Breakdown	4.3	4.4	18.92
Supplier Reliability	4.3	2.2	9.46
Inadequate Health Care Facilities	4.2	4.24	17.808
Bureaucracy	4.2	4.1	17.22
Exposure to Hazardous Conditions	4.2	4.1	17.22
Environmental Degradation	4.2	3.8	15.96
Communication Gaps	4.2	3.3	13.86
Delayed Funding	4.1	4.2	17.22
Transportation Delays	4.1	4	16.4
Lack of Personal Protective Equipment	4.1	4	16.4
Misallocation of Resources	4.1	4	16.4
Insufficient Staffing	4.1	3.9	15.99
Inefficiency in Aid Delivery	4.1	2.47	10.127
Inadequate Local Resources	4.1	2.1	8.61
Delayed response	4	2.1	8.4
Displacement and Migration	3.8	2.4	9.12
Malnutrition	3.8	2.4	9.12
Inefficient Distribution	3.73	2.48	9.2504
Technology Failure	3.6	2.3	8.28
Poor Coordination with Other Agencies	3.5	3.6	12.6
Equipment Failure	3.4	2.3	7.82
Data Protection and Privacy Laws	3.4	2.3	7.82
Lack of Security Infrastructure	3.3	2.4	7.92
Information Management Challenges	3.3	2.2	7.26
Violations of Human Rights	3.3	2.2	7.26
Demand Uncertainty	3.2	3.6	11.52
Information Asymmetry	3.2	3.5	11.2
Health and Safety Issues	3.2	3.1	9.92
Carbon Footprint	3.2	2.3	7.36
Inflation	3.2	2.1	6.72
Logistical Challenges	3.2	2.1	6.72
Terrorism and Conflict	2.8	1.4	3.92

Inadequate Training	2.62	2.3	6.026
Limited Accessibility	2.6	2.4	6.24
Warehousing and Storage	2.6	2.4	6.24
Permissions and Licenses	2.6	2.4	6.24
Remote Management	2.6	2.35	6.11
Neglected Areas or Populations	2.6	2.34	6.084
Regulatory Changes	2.55	2.13	5.4315
Inadequate Local Knowledge	2.5	2.4	6
Inefficient Use of Expertise	2.5	2.4	6
Lack of Transparency	2.5	2.4	6
Inadequate Local Law Enforcement	2.5	2.3	5.75
Insufficient Funds	2.48	4.6	11.408
Unforeseen Costs	2.48	2.7	6.696
Cybersecurity Threats	2.48	2.4	5.952
Lack of Local Knowledge	2.48	2.35	5.828
Resource Competition	2.46	2.3	5.658
Volunteer Management	2.45	2.47	6.0515
Quality Issues	2.45	2.45	6.0025
Data Management Risks	2.45	2.4	5.88
Duplication of Efforts	2.45	2.4	5.88
Lack of Technological Training	2.42	2.3	5.566
Different Operational Procedures	2.4	3.3	7.92
Security Issues	2.4	2.3	5.52
Injury or Illness	2.4	2.3	5.52
Lack of Backup Systems	2.4	2.3	5.52
Mismanagement of Funds	2.4	2.3	5.52
Legal and Regulatory Compliance	2.4	2.3	5.52
Negligence in Staff Behaviour	2.4	2.3	5.52
Language and Cultural Barriers	2.4	2.3	5.52
Reliability of Local Partners	2.4	2.3	5.52
Customs and Regulations	2.4	2.3	5.52
Respect for Customs and Traditions	2.4	2.3	5.52
Environmental Regulations	2.4	2.3	5.52
Cultural Misunderstandings	2.4	2.3	5.52
Legal Constraints	2.4	2.3	5.52
High Turnover	2.4	2.26	5.424
Poor Communication	2.4	1.4	3.36
Trade Restrictions	2.4	1.2	2.88
lack of Involvement of Local Communities	2.4	1.2	2.88
Cultural and Language Differences	2.4	1.2	2.88
Inflation or Cost Escalation	2.4	1.1	2.64
Inadequate Technology Infrastructure	2.38	2.4	5.712
Costs of Compliance	2.35	2.45	5.7575
Political Influence and Priorities	2.35	2.24	5.264
Jurisdictional Disputes	2.3	2.15	4.945
Security Risks	2.3	2.45	5.635

Import/Export Restrictions	2.3	2.45	5.635
Storage Limitations	2.3	2.4	5.52
Safety and Security	2.3	2.2	5.06
Reliance on Outdated Technology	2.3	2.2	5.06
Gender Inequality	2.3	2.2	5.06
Legal Liability	2.3	2.2	5.06
Geographic Diffusion	2.3	2.2	5.06
Technology Accessibility	2.3	2.1	4.83
Climate Change	2.3	2	4.6
Psychological Trauma	2.25	2.2	4.95
Disease or Injury	2.25	1.8	4.05
Dependence on Donors	2.2	4.1	9.02
Biodiversity Loss	2.2	3.4	7.48
Shifts in Needs	2.2	2.4	5.28
Poor Quality Aid	2.2	2.35	5.17
Limited access to Vulnerable Groups	2.2	2.1	4.62
Pollution	2.2	2.1	4.62
Long-Term Financial Sustainability	2.2	1.61	3.542
Burnout and turnover	2.2	1.5	3.3
Compliance Risks	2.2	1.4	3.08
Inadequate Planning and Preparedness	2.18	4	8.72
Inadequate Storage Facilities	2.15	2.4	5.16
Staffing Challenges	2.14	4	8.56
Fluctuating Demand	1.9	2.1	3.99
Border Disputes	1.8	1.2	2.16
Coordination Among Agencies	1.7	2.28	3.876
Interoperability Issues	1.5	2.4	3.6
Contractual Risks	1.5	2.4	3.6
Government Instability	1.5	1.55	2.325
Target Population Identification	1.5	1.4	2.1
Misalignment of Objectives	1.5	1.4	2.1
Staff Work Permit/Visa Issues	1.5	1	1.5
Lack of Cultural Sensitivity	1.4	2.4	3.36
Exchange Rate Fluctuations	1.4	1.3	1.82
Social Tensions	1.2	2.4	2.88

Where:

Unacceptable risks (25)
Significant risks (15,16,20)
Intermediate risks (8,9,10,12)
Acceptable risks (2,3,4,5,6)
Insignificant risks (1)

Source - (Yazdi, 2017)

The identification of significant risks fulfils the second research objective of this study.

- Resource Scarcity
- Transportation Disruptions
- Secondary Natural hazards
- Supply shortages
- Supply Disruption

- Spread of Diseases
- Fraud and Corruption
- Security Issues (Logistical)
- Infrastructure Damage
- Communication breakdown
- Inadequate Health Care Facilities
- Bureaucracy
- Exposure to Hazardous Conditions
- Environmental Degradation
- Delayed Funding
- Transportation Delays
- Lack of Personal Protective Equipment
- Misallocation of Resources
- Insufficient Staffing

6. IDENTIFICATION OF SOLUTION STRATEGIES USING INDUSTRY 5.0 TECHNOLOGIES FOR RISK MITIGATION

Focus Group Technique for Industry 5.0 Solution Strategies

FGT was used in this research to obtain opinions on the technological solutions to significant risks, which were identified using a risk severity matrix. A Focus Group Discussion with 5 experts from the tech industry was carried out. Their responses were collected. The responses received after the first discussion were:

Resource scarcity: A.I. data collection and resource management, Risk Oversight Dashboard

Transportation Disruptions: Telemetric data, Weather Prediction, GPS, Automated notifications to transport providers

Secondary Natural Hazards: ML-driven Data Analytics

Supply Shortages: Machine learning algorithms for past data analysis of demand, Real-time monitoring systems

Supply Disruption: IoT-based supply chain solutions like sensors, RFID tags, and SAP-integrated business planning

Spread of Diseases: no way to mitigate the spread of diseases until after it has already spread

Fraud and corruption: Tokenized Money

Security Issues (Logistical): GPS Tracking on Transport, Weight in Motion (W.I.M.) technology, Robotic Deliveries

Infrastructure damage: Use of Drones for Real-time data

Communication Breakdown: Satellite Phones, Drones working as network providers

Inadequate Healthcare Facilities: Telehealth Technologies, Drones for supply

Bureaucracy: Media, Social Media (IoT)

Exposure to Hazardous conditions: Portable Devices for Toxin Identification, predictive analysis for the quantity of PPE requirement

Environmental Degradation: Tree Transplantation

Misallocation of Resources: AI-driven software to allocate resources

Delayed Funding: Automated relief funds

Lack of PPE: Past data analytics to predict the quantity of PPE

Insufficient staffing: solutions are there, but none are technological. Preparedness based on past data.

One of the risks titled ‘transportation delays’ was removed from the list based on expert opinion that it is the same as transport disruption.

After the first discussion was done, another discussion with 6 tech industry experts was conducted, and their responses were also garnered. And, after conducting 3 focus group discussions it was noted that no new technology was being mentioned at the third Focus Group discussion. So, there was no need to conduct a fourth discussion.

Combining all the risks, their technological solutions, the framework in Fig. – 4 has been created depicting the solution strategies.

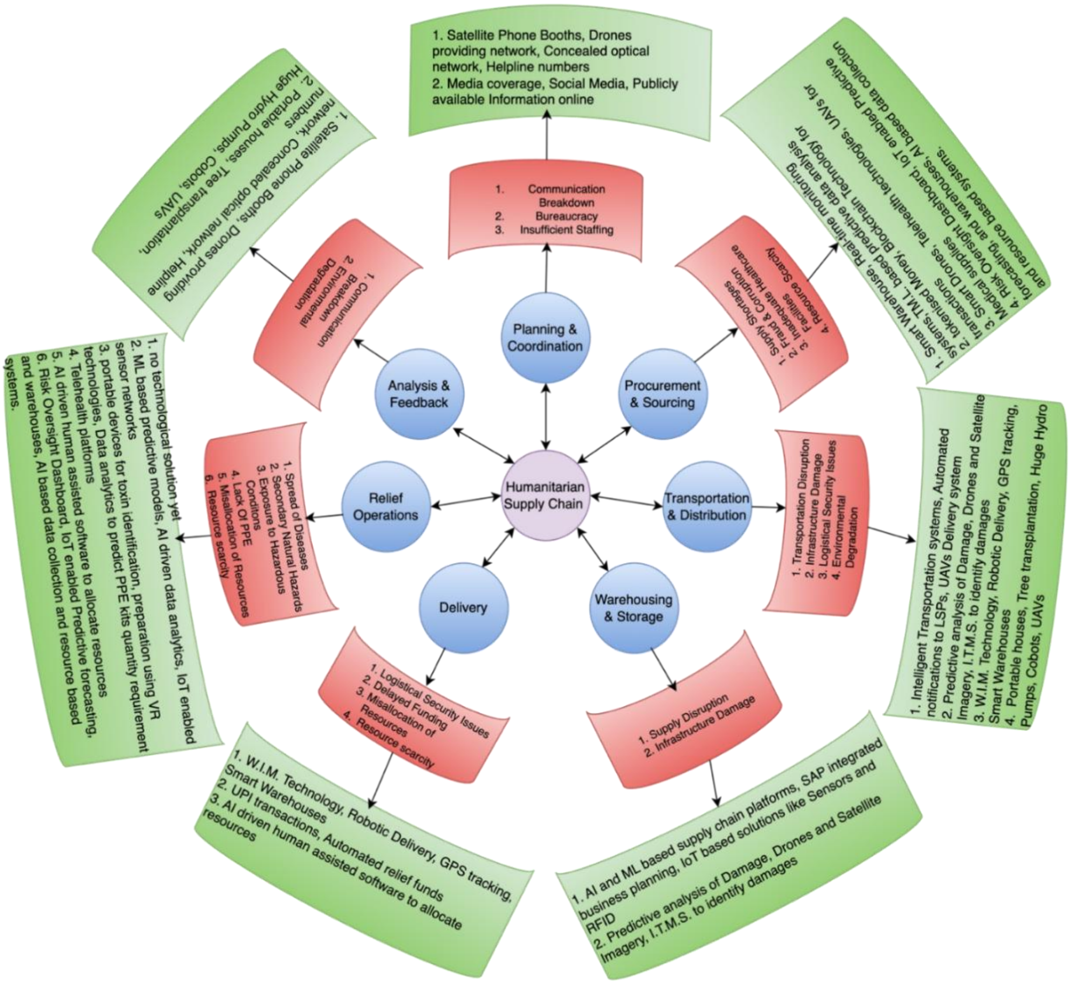

Figure 4 - Humanitarian Supply Chain Process Model
Source – Created by the Author

Practical contributions

The findings of this research have significant implications for the future of HSCs. By integrating advanced technologies into humanitarian operations, organizations can significantly improve their ability to respond to natural disasters. The proposed model provides a practical framework for implementing these technologies, ensuring that they are used effectively to mitigate the most critical risks. Furthermore, the research highlights the importance of continuous innovation and collaboration between the technology and humanitarian sectors.

This research makes several important contributions to the field of humanitarian supply chain management. It provides a comprehensive analysis of the key risks that affect HSCs during natural disasters and offers valuable insights for practitioners and policymakers. The study also identifies and evaluates a range of advanced technologies that can be used to mitigate these risks, providing a practical roadmap for their implementation. The research contributes to the broader field of disaster management by proposing a novel, integrated model for HSCs.

Theoretical contributions

This research draws heavily on established frameworks and empirical studies, which emphasize the significant role that multiple factors play in the adoption and use of technology, especially in high-stress environments such as humanitarian supply chains.

The discussion highlights how the risk of **resource scarcity** is a critical concern in disaster response efforts, driving the adoption of AI-based data collection and IoT-enabled resource management systems.

Similarly, in the face of **transportation disruptions**, the adoption of Intelligent Transportation Systems (ITS) and UAV delivery systems is driven by the need to mitigate perceived risks associated with logistical failures.

Furthermore, the research illustrates how risk perception influences the deployment of **blockchain technology** to combat **fraud and corruption** within humanitarian supply chains.

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The perception of **infrastructure damage** drives the adoption of these technologies to ensure that critical logistics networks remain operational during disasters.
In each of these cases, the research emphasizes that the perceived risk mitigatioshapesociated with humanitarian crises fundamentally shape the adoption and use of technology. The perceived risk mitigation acts as a promoter for integrating advanced technologies into humanitarian operations.
By highlighting the importance of perceived risk mitigation, this research contributes to the understanding of the **Unified Theory of Acceptance and Use of Technology (UTAUT)** in crisis settings. It suggests that while UTAUT's core constructs remain the same but, their interaction with technology adoption is highly influenced by the perceived risk mitigation, which leads to an adaptation of the theory to better predict technology adoption in these settings. So, the research proposes a modification to the UTAUT. The authors propose the addition of *Perceived Risk Mitigation* as another factor that influences the core constructs of the theory – performance expectancy, effort expectancy, and social influence (Figure 5).

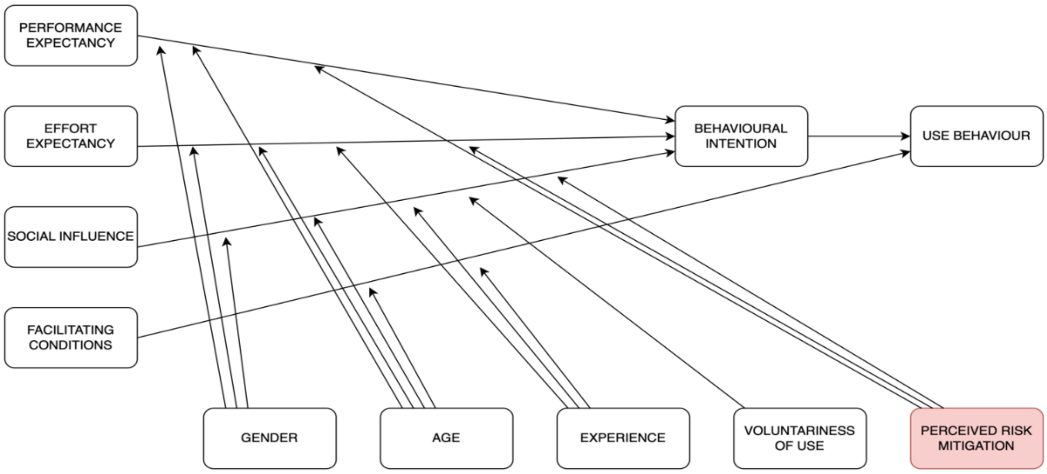

Fig. 5 Contribution to UTAUT Model in context with HSC
Source – Created by the author
Original UTAUT sourced from (Venkatesh, Morris, Davis, & Davis, 2003)

Conclusion

The research provided a comprehensive study of the humanitarian supply chain (HSC) within the Indian context, identifying key risks that impact its efficiency and effectiveness. Through a mixed-methodology approach the study highlighted the critical factors that impede the smooth functioning of HSCs through literature review. A total of 126 risks were found. By employing tools such as FMEA, and Risk Severity Matrix, the study systematically evaluated the severity of these factors. FMEA and then risk severity matrix were used to prioritise and identify the most significant risks. Through Focus Group Discussions experts were contacted to identify the technologies that could be used to mitigate them. A model was created that displays the risks for each stage in the humanitarian supply chain, and the respective technologies that could be used to mitigate them. It was found that the integration of advanced technologies within humanitarian supply chains presents a promising solution to mitigate a wide range of risks that frequently disrupt disaster response efforts. For example, by using the AI-driven data collection and IoT-enabled predictive forecasting, resource management can be significantly improved. For transportation, the deployment of drone delivery systems and GPS-based tracking could play a crucial role in maintaining the flow of goods. To combat supply chain vulnerabilities, the implementation of IoT-based sensors and smart warehousing solutions offers a proactive approach to monitoring inventory levels and anticipating shortages before they occur. Communication breakdowns could be effectively mitigated through the use of satellite communication systems and concealed optical networks. For the risk of Fraud, blockchain technology could be employed to secure transactions and prevent fraud, while robotic deliveries can enhance logistical operations in challenging environments. These suggestions explain the potential of technology to mitigate the risks that challenge the effectiveness of humanitarian supply chains. By implementing these technologies, the resilience and responsiveness of disaster relief operations can be significantly enhanced. Through the research it was found that the perception of risk mitigation furthers the importance and use of technology in the extreme scenarios. This led the authors to propose the addition of another factor "Perceived Risk Mitigation" in the theory UTAUT. The research shows that perceived risk mitigation impacts the three core constructs of the theory i.e., performance expectancy, effort expectancy, and social influence. This was the theoretical contribution of the research.

Concluding Remarks

- This study provided a comprehensive analysis of the humanitarian supply chain (HSC) in India, highlighting key challenges that impede its efficiency.
- A mixed-method approach and advanced analytical tools were employed to identify significant risks within the HSC.
- The research proposed actionable solutions through Industry 5.0 technologies, demonstrating their potential to enhance the resilience and adaptability of supply chains in crisis situations.
- Findings emphasize the critical role of emerging technologies in improving humanitarian operations, making supply chains more robust and responsive.
- The study introduced the concept of "perceived risk mitigation" as an additional factor in the UTAUT framework, reflecting the importance of addressing and managing risks to facilitate the adoption of new technologies in the HSC.
- The research contributes to ongoing discussions on enhancing humanitarian responses by offering a replicable and adaptable model, with a particular focus on integrating risk management into technology adoption strategies.

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