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Research Article

Mitigating Risks in the Disaster Management Cycle

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Purpose. The disaster management cycle (DMC) is often considered part of the essential efforts to handle disaster risk and consists of four key phases, namely preparedness, response, recovery, and mitigation. The purpose of this conceptual article is two-fold. The first is to identify dominant risks, and the second is to propose risk mitigation strategies for these four phases in the DMC. *Design/Methodology/Approach*. The study uses primary and secondary data to identify the dominant risks in each DMC phase. The primary data sources include responses from an online questionnaire and transcripts from three semi-structured interviews with stakeholders in the humanitarian supply chain. The secondary data sources include practitioner reports and archival data triangulation. *Findings*. The findings reveal five dominant risk factors in the DMC and classify them within the DMC phases, which are (1) demand risk, (2) supply risk, (3) operational risk, (4) infrastructure risk, and (5) disruption risk. The severity and frequency of each risk vary in each DMC phase. We found that several supply chain strategies (SCSs), such as raising risk awareness and horizontal and vertical collaboration and coordination among the key stakeholders in the DMC, can be essential risk mitigation strategies that apply across the four DMC phases. *Research Limitations/Implications*. The study highlighted dominant risks and the appropriate SCSs for mitigating the risk factors within each DMC phase. These findings are encapsulated in a conceptual framework for guiding risk prioritisation, decision-making, and policy-making. Our study has several limitations. First, although we followed a systematic process in computing the risk scores based on the likelihood of occurrences and impacts, the scores are nonetheless considered subjective perceptions of the respondents. Second, the number of respondents was limited. Broader coverage of respondents across geographical regions will provide further insights into the perspectives on the relevant risk factors in the DMC phases. This leaves possibilities for future research, comparison with other risk computation methods, and evaluation. *Originality/Value*. This study is one of the few that collected multiple data to extend the knowledge of risk identification and mitigation within the DMC.

1. Introduction

Disasters bring about adverse economic, physical, and environmental impacts. They also threaten the sustainable development goals of the affected country [1]. While disaster risks can hardly be eliminated, it is possible to mitigate risks by minimising the adverse impacts they bring. Risks can be mitigated and managed to enhance the effectiveness of humanitarian operations while increasing the credibility of the humanitarian sector. These, in turn, will lead to increased fund-raising potential and support for humanitarian operations (Mizushima et al., 2008).

The disaster management cycle (DMC) is a recognised framework for managing disaster events and their impacts in pre-disaster, during, and post-disaster activities ([2]; Baird et al., 1975). Pre-disaster activities involve prevention, mitigation, and preparedness, whereas response activities usually include rescue and relief activities. Post-disaster activities include recovery and development [5]. All these activities collectively help to manage a disaster and reduce the risk of human and physical losses.

While there have been several risk categorisation frameworks (e.g., [6–11]), insights into the sources of risks and appropriate risk mitigation strategies in the DMC

phases seem to be lacking. Moreover, extant literature mostly explored the various risk categorisation approaches in the humanitarian contexts without providing insights into the risk categories present in the different phases of the DMC (e.g., [6–11]). In particular, [11] links humanitarian logistics (HL) and supply chain risk management (SCRM) to understand risk mitigation strategies that humanitarian organisations use or could use to improve their logistics preparedness. Based on systematic reviews of risk mitigation strategies (RMS) in supply chain risk management (SCRM) and supply chain strategies (SCSs) in the HL literature,11 developed a framework that links SCSs in the HL literature. However, there seem to be limited discussions and empirical studies that attempt to adapt supply chain risk management and SCSs within the DMC. Our research attempts to fill this knowledge gap by addressing the following research questions using empirical data collected from humanitarian practitioners:

RQ 1: What are the dominant risks in each DMC phase?

RQ 2: How can SCSs be used to mitigate dominant risks in each DMC phase?

Our study contributes to the literature by integrating two bodies of literature—the disaster management cycle (DMC) and supply chain risk mitigation strategies (SCSs)—to develop a theoretical framework for the study. We collected empirical evidence from a web-based questionnaire and semi-structured interviews (online or face-to-face) with humanitarian operation practitioners and academics within this domain to identify the dominant sources of risks and appropriate SCSs for risk mitigation in the DMC.

The rest of the article is organised as follows: Section 2 discusses the literature related to the DMC, risk assessment, and mitigation strategies and provides the significance of the research. Section 3 explains the research method and proposes a conceptual framework for risk assessment and management in the DMC. Section 4 presents the findings and a modified DMC framework highlighting the dominant risks in the DMC phases and the appropriate risk mitigation strategies. Section 5 discusses research and managerial and policy implications. Section 6 concludes the article with the limitations of this research and opportunities for future research.

2. Literature Review

2.1. Humanitarian Supply Chains and Disaster Management. Humanitarian supply chains are characteristically involved in large-scale operations, addressing high magnitude risks to life and the need to coordinate speedy delivery of rescue and relief goods and services to disaster zones (Jabbour et al., 2017; [10, 11]). Humanitarian supply chains are often emergent, with short lives, responding to specific disasters, uncertainty, and mostly unforeseen situations [12]. Supply chain activities linked to disasters are classified into four key phases. Pre-disaster, the focus is on "mitigation" and "preparedness." Post-disaster, the focus is on "response" and "recovery" [13]. The supply chain activities operate within the DMC and focus on saving, preserving life, building, and maintaining standard life quality in disaster zones.

Kapucu [14] argued that disaster management is the organisation and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, particularly preparedness, response, and recovery, to lessen the impact of disasters [12]. The management of disasters is achieved in the form of disaster operations management and emergency planning [16].

Disaster operations represent activities performed before, during, and after a sudden, devastating incidence that seriously disturbs the functioning of a population and causes human, material, economic, or environmental damages beyond the coping capacity of the affected population using its resources [17].

2.1.1. The Disaster Management Cycle (DMC). According to Martinho and Reis [18], the United Nations' perspective of disaster risk reduction aims at reducing vulnerabilities and disaster risks, preventing the loss of human lives as well as increasing communities' resilience throughout society, public, and private. Martinho and Reis [18] further noted that disaster risk reduction requires managing risk beyond disaster responses to prevention and mitigation.

From the perspective of humanitarian supply chains, disaster risk reduction involves activities carried out before, during, and after disasters to reduce their impact, avoid losses, and save lives [11, 19]. With strategic process design, disaster management is key to successful disaster responses and relief efforts [20]. At an operational level, disaster management can be described as a process through several cyclical and overlapping stages [10]. However, in general, the literature concurs that disaster management has four phases, namely (1) preparedness, (2) response, (3) recovery, and (4) mitigation [10, 21, 22], which are described below.

(1) Preparedness. The preparation phase refers to activities taken before a disaster occurs to avoid possible consequences and prepare all relevant organisations and communities by learning from the past [10]. The literature suggests common preparedness activities, namely developing information and communication, developing collaboration and coordination between relevant organisations and people, training and practicing relief services with communities, designing physical networks, and stockpiling supplies and equipment [10, 11, 23].

(2) Response. The response phase refers to activities immediately implemented after a disaster [10]. Relief efforts are carried out to rescue and delivery basic supplies to the highest possible number of beneficiaries as well as to restore the essential services and infrastructures in the shortest time possible [10, 11]. In this phase, it is also important to assess the disaster situation and keep relevant people (e.g., beneficiaries and relief staff) updated on the disaster situation and the current relief efforts [23]. Therefore, coordination and collaboration among all organisations and actors involved is key to successful relief efforts [10, 24].

(3) Recovery. The recovery phase refers to activities involving reconstructions and rehabilitations operated in the aftermath of a disaster and carried out to recover the situation back to the default state [10, 23]. Therefore, activities are undertaken in this phase to address the problems from a long-term perspective [10].

(4) Mitigation. The mitigation phase refers to actions taken after and before a disaster to reduce the effects of disasters [25]. These actions often involve revising strategies, procedures, mechanisms, regulations, measures, and policies that aim to reduce social vulnerability [10, 23]. The key difference between mitigation and preparation is that mitigation is the application of measures that aim to prevent a disaster and reduce its impact, while preparation includes activities that prepare for an effective and efficient response [22, 25].

To summarise, DMC aims to determine the underlying risk factors and prepare for and initiate an immediate response to disasters to reduce and mitigate disaster risks. Accordingly, the DMC that incorporates risk management and performance outcomes into a single model as shown in Figure 1 was proposed by [10]. This study makes use of this adapted DMC model as the theoretical basis to examine the dominant risk factors and appropriate risk mitigation strategies in our empirical research design.

2.2. Supply Chain Risks. Supply chain risk (SCR) is defined as the "divergence in the distribution of potential outcomes of the supply chain, their probability, and their subjective values" [26]. Goh et al. [27] and Kull & Closs [37] defined SCR as the appearance of an accident with the disability of the influenced firms to deal with consequences. Furthermore, Jüttner et al. [38] described SCR as the potential and influence of a mismatch between supply and demand. It is also defined as anything that disrupts the information, materials, or product flow from original suppliers to end users [39].

SCR has been classified by scholars using various perspectives. One classification of supply chain risks is based on internal and external risks—external risks are such as natural disasters, and internal risks are such as quality problems of suppliers. Supply chain risks are also classified as strategic, tactical, and operational. Daultani et al. (2005) viewed disruption risks as those resulting from man-made or natural disasters and categorised supply chain risks as operational risks and disruption risks. Operational risks are further classified into supply, process, and demand risks. Supply risks are associated with the unforeseeable performance of upstream suppliers regarding quantity, quality, time, and cost. Process risks are usually caused by substandard processes in manufacturing systems, and this will lead to inconsistent quality, target yield, and production time. Demand risk is associated with sales fluctuations resulting from forecast errors, leading to negative consequences like shortage or excessive inventory. This form of risk categorisation (i.e., supply risk, process risk, demand risk, and disruption risk) was reflected in Samvedi et al. [37], except that Samvedi et al. [37] classify disruption risk as an environmental risk.

Tang and Musa [38] offered an alternative supply chain risk categorisation based on three types of flows, namely material flow, financial flow, and information flow. Risks at the source stage are related to purchasing and sourcing physical goods and services. Risks in the make stage may occur during product development, while risks in the delivery stage are those influenced by forecasting challenges. Financial flow risk is associated with "the inability to settle payment and improper investments" [38]. These may include credit terms and payment schedules. Information risk is associated with information flows like inventory status, product and process design changes, and capacity status [38]. Information flow binds supply chain elements and is typically used to link material flow and financial flow. A comprehensive classification of supply chain risks and the main characteristics of supply chain risks closely related to the organisations' objectives in the supply chain can be found in [39].

2.3. Risk Mitigation Strategies

2.3.1. Application of Supply Chain Strategies (SCSs) in Disaster Management. Supply chain risk management is the application of strategies to manage daily and extraordinary risks in the supply chain. Relative to commercial supply chains, supply chain risk management is crucial in the humanitarian context. Supply chain disruptions can add to the challenges in relief and recovery efforts, leading to worsened conditions during humanitarian crises (McLachin et al., 2009). In the humanitarian context, the risk is "the combined susceptibility and vulnerability of the community to potential damage caused by a particular hazard within a specified future time period" [1], p.7).

Supply chain strategies (SCSs) are often used in commercial supply chains and are based on continued risk estimation, aiming to minimise vulnerability and guarantee continuity [36]. Studies have attempted to adapt commercial supply chain risk management practices and risk mitigation strategies to address risks in the humanitarian supply chains (Jabbour et al., 2019).

In particular, Jahre [11] developed a humanitarian SCS framework that connects risk factors and supply chain risk mitigation strategies that could aid in counteracting risks in the humanitarian supply chain. The more common mitigation strategies were found to be strategic stock pre-positioning, postponement, collaboration, flexible transportation, and flexible supply base. However, there seems to be limited research on how SCSs can aid in managing specific risk factors in disaster management. Because of these, this paper seeks to extend the literature on disaster risk management and supply chain management strategies by building on the knowledge based on the humanitarian supply chain strategies framework by [11] and the DMC, to inform on the applicable mitigation strategies in phases and activities of the DMC.

Apart from traditional risk management strategies like risk assessment and continuity planning, resilience is

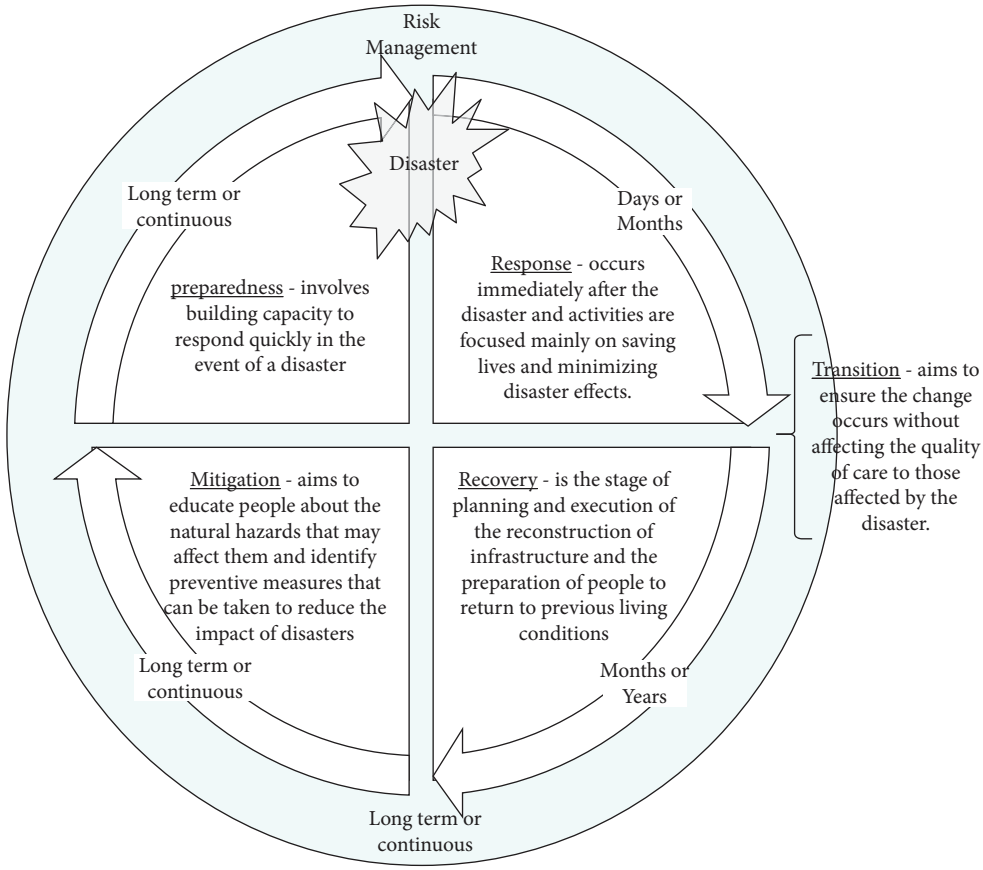

Figure 1: A model integrating risk management in the DMC used in this study (based on [10]).

another approach that can be adopted as "supply chain resilience can deal with unforeseeable disruptions and events" [22]. According to Scholten et al. [22], there are four elements of supply chain resilience, namely supply chain re-engineering, collaboration, agility, and risk awareness/knowledge management. In the humanitarian supply chain, where numerous stakeholders are involved, collaboration and cooperation among diverse stakeholders are core to ensure effective risk management and successful relief operations when disasters occur.

Based on our literature review, the common types of supply chain risks that resonate in extant literature can be summarised into five broad categories as listed in Table 1. These five key risk categories were deployed in this study.

Table 2 lists the SCSs (A to J) that were identified based on a review of prior research and literature in risk mitigation, such as Jahre [11] and Scholten et al. [22], as well as by practitioners and archival reports from international humanitarian organisations.

On the whole, while researchers have studied supply chain risks and mitigation strategies in humanitarian supply chains, studies that focus on understanding how the different sources of risk play out in the various phases of the DMC and the appropriate mitigation strategies that can aid in effective disaster management seem to be scarce. Moreover, most extant literature focused on an individual or a few phases of the DMC [49, 43]. This article serves as an initial step to filling this gap.

We seek to integrate three main research streams and identify the dominant risks and the appropriate risk mitigation strategies in the different DMC phases to aid humanitarian organisations focusing on different disaster stages in prioritising risk and taking effective risk mitigation actions. Figure 2 presents our research approach that integrates the streams of literature adapted from the three main research streams, namely supply chain risk, disaster management cycle, and risk mitigation strategies. The empirical data collection instruments, including questionnaires and semi-structured interview protocols, were then developed for this research.

3. Methodology

3.1. Research Design and Data Collection. We took an exploratory approach in addressing the research questions and adopted a mixed method by collecting primary data through questionnaires and interviews. The primary data included responses from web-based questionnaires and semi-structured interviews with selected key informants involved in disaster management operations. Table 3 presents an overview of the empirical data sources, consisting of key stakeholders and practitioners involved in the DMC.

Table 1: Definitions and examples of the risk categories.

Risk categories	Definition	Source	Examples of risks
Demand risk	Demand risk refers to adverse events at the downstream partners of a firm	[37, 38]	(i) Shifting demand across time (ii) Shifting demand across markets (iii) Shifting demand across products
Supply risk	Supply risk refers to adverse events at the upstream partners of a firm	[37, 38]	(i) Uncertain supply yields (ii) Uncertain supply lead times (iii) Uncertain supply costs
Operational risk	Operational risk was conceived as the operational risk that affects HO's internal processes or operations that affect their ability to produce services, quality, and timeliness of their service provision to meet the needs of the beneficiaries effectively	(Wu et al.) [40]	Unanticipated changes in the volume requirements and mix of items needed, price increases, product unavailability, and product quality problems, lacking personnel, knowledge, and ability to manage new processes
Infrastructure risk (information, transport, finance)	To ensure the healthy functioning of a supply chain, information technology transportation and financial systems are also of critical importance. Any disruptions in these systems can also lead to serious problems in the supply chain. The risks relating to these three systems are classified as infrastructural risks	Information technology [39], transportation [40], and financial systems (Chopra et al. [39, 40]	Lockout or shutdown of transportation hubs such as docks, impacts of conflicts between employer management and labour groups, and the reaction of employers in the form of work slowdowns to changes such as the deployment of information technology. Incompatible IT system and financing mechanism
Disruption risk	Disruption or macro risks refer to adverse and relatively rare external events or situations that might have negative impacts on companies	Sodhi et al. [48];	Natural risks (e.g., earthquakes and weather-related disasters) and man-made risks (e.g., war and terrorism and political instability)

Table 2: Proposed supply chain strategies for mitigating risk in the DMC (adapted from [11]).

	Proposed risk mitigation strategies
A	Having a mobile logistics hub (assuming the chosen location is safe and accessible)
B	Having a centralised propositioned stock
C	Having a joint or bulk procurement system
D	Having a flexible supply base
E	Logistics outsourcing—use of a third-party logistics provider
F	Horizontal collaboration and coordination among players involved in the same phase of the DMC for joint planning and information sharing
G	Vertical collaboration and coordination among players involved in the different phases of the DMC for joint planning and information sharing
H	Pre-position vehicles and having a fleet management program
I	Having flexible transportation with an operational mix of vehicles and transport mode, depending on the location and accessibility of disaster site
J	Risk awareness

3.1.1. Web-Based Questionnaires. Web-based questionnaires are a convenient way to gather data relevant to the project, allowing respondents to answer the questionnaire at their own pace. The questionnaire was developed based on extant literature on DMC risks and supply chain risk mitigation strategies. The questionnaire consisted of close-ended and open-ended questions designed to gather responses to the two research questions.

The research employed a purposive sampling approach [44] in the respondent selection and focused on recruiting participants from the key stakeholders and practitioners involved in the DMC. An essential inclusion criterion is that a respondent must assume a professional role in a humanitarian organisation or carry out work in humanitarian operations. To recruit respondents, we posted calls for research participation on the LinkedIn sites of various humanitarian logistics groups and humanitarian logistician networks. In total, 25 valid responses were gathered from the questionnaire.

(1) Questionnaire Development. The questionnaire comprises three sections of questions. The questions in the first section focused on the general information of the respondents, such as gender and designation. The questions in the second section relate to the risk factors that may be present. Respondents were asked to rate the importance of the risk

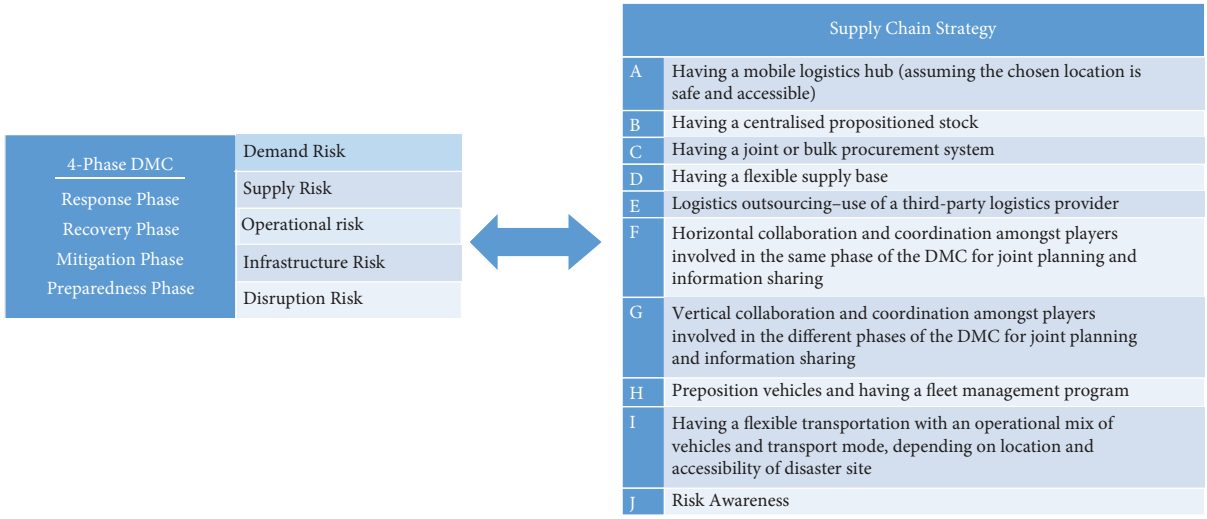

Figure 2: Research framework—integration of the literature relating to the source of risks, disaster management cycle, and supply chain risk mitigation strategies.

Table 3: Empirical data sources.

Primary sources		
Source	Brief description	Value to the study
Questionnaires	A total of 25 valid responses were gathered. Respondents are players of the DMC, including nongovernmental organisations (NGOs), aid agencies, and logistic companies	(i) Risk identification (ii) Risk analysis (iii) Strategies to manage risks
Interviews	3 semi-structured interviews were conducted	(i) Confirmation and validation of questionnaire results

factors (refer to Table 1). The third section covered the relevance of the SCSs in each DMC phase. Respondents were asked to select SCSs that they deemed relevant to mitigate the risks in each DMC phase.

The three sections in the questionnaire:

(1) Professional profile and information about the involvement of the respondents in the DMC. These include years of experience in the humanitarian sector, affiliated organisations, and region.

(2) Risk factors in each DMC phase. Respondents are to rate the risk factors on a Likert scale of 1–7.

(3) Supply chain strategies (SCSs) for each DMC phase. Respondents are to select the relevant SCSs they deem relevant and helpful for mitigating risks in each DMC phase.

3.1.2. Interviews. Semi-structured interviews were also conducted with three key informants, and the informants were involved in the four phases of the DMC. The interviews were focused on issues identifying dominant risks in the DMC and how those risks can be managed by stakeholders involved in risk management decisions. On average, the interviews spanned 30 to 45 minutes and were all transcribed. The interviews provided qualitative insights relating to the experiences and knowledge of the key stakeholders. Table 4 shows the profile of the interviewees.

3.2. Data Analysis

3.2.1. Questionnaire and Interview Data. Qualitative and quantitative data collected from the questionnaires and interviews were examined. We analysed the responses relating to the risk rating using a Likert scale and conducted descriptive statistical analyses of the data using central tendency, and mean and mode were computed. The quantitative data will be analysed using graphical techniques whenever appropriate and relevant. Qualitative data from interviews and secondary data sources were analysed using a thematic approach where key themes were categorised and grouped accordingly.

3.2.2. Risk Assessment and Impact Analysis. A critical element of risk management is identifying and evaluating the impact of the relevant risk factors [37]. Several scholars have characterised risks based on the likelihood and impact (or consequences) of each risk factor (e.g., [45]; Tummala and Schoenherr, 2011). In this study, we use these two measures to evaluate the risk scores for each risk factor and their relative dominance in each DMC phase.

The risk scores were computed based on the combined ranking scores for each risk type based on a rating scale of 1 to 7 on the likelihood of occurrence and consequence for each risk. Specifically, the participants were asked to rate each of the five risk types (demand risk, supply risk,

Table 4: Profile of interviewees.

Informants	Roles and designations
Interviewee 1	A regional director of a nonprofit organisation. He oversaw the execution of operational activities and programmes in the Asia-Pacific region and was also responsible for engaging with his organisation's clients and/or partner organisation
Interviewee 2	A co-founder of a non-profit NGO. He oversees the activities and programmes his organisation provides in humanitarian assistance and disaster relief through new and innovative ways.
Interviewee 3	An independent researcher in humanitarian logistics and is active in Syrian relief operations since 2013

operational risk, infrastructure risk, and disruption risk) in terms of the likelihood of occurrence and consequences based on a rating scale of 1 to 7. Each risk factor is then weighted and averaged based on the ratings by the respondents for each DMC phase. The risk scores were standardised and rounded to 2 decimal places. The derived risk scores would enable stakeholders in the DMC to rank and better prioritise critical risks and plan effective measures to optimise humanitarian resources.

3.2.3. Data Analysis on SCSs. We used a two-step approach to analyse the data relating to SCSs to identify the relevant SCSs that could be useful for the phases and activities in the DMC.

Step 1. Computing average index and relative importance index

The relative importance index (R) is a type of comparative importance analysis. R was used to determine the relative importance of the SCSs in each phase of the DMC based on the respondents' perspectives.

The average index is first computed as follows:

$$\text{Averageindex} = \frac{\sum a_{i \times x_i}}{\sum x_i}, \quad (1)$$

where a_i is the constant (weighing factor), and x_i are the variables representing the response frequency of respondents.

Step 2. Computing average frequency of SCSs selected in each DMC phase

The frequency analysis described the distribution and average frequency of the SCSs selected in each DMC phase. The average frequency is computed based on the selection and ranking of the respondents accordingly to determine the relative importance index for the SCSs. The SCSs with the higher relative importance index values are deemed more important for the DMC phase.

4. Findings

4.1. Professional Profiles and Roles of Respondents. There are many types of stakeholders in the DMC, and some organisations can play different roles in the DMC. Respondents could choose more than one option that best represents their organisation's role in the DMC. Figure 3 illustrates the roles played by respondents' organisations. "Others" refer to organisations that provide consultancy and advisory services to other players such as NGOs and governments. They are often in the education domain and coordinate with different players for fundraising and advocacy. Figure 4 shows the respondent's participation in the four phases of DMC by Viagi et al. (2016). As an organisation can be involved in more than one phase of the DMC, respondents can choose more than one option if it applies to them.

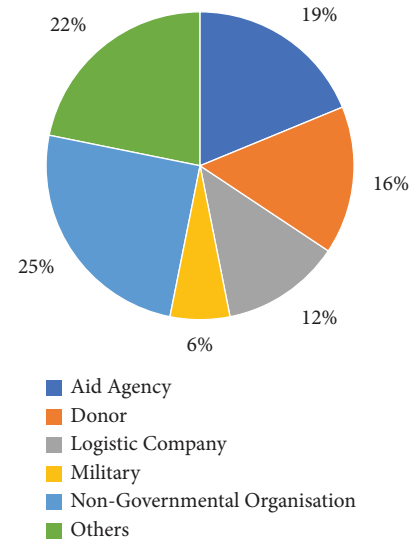

Figure 3: Professional profiles of respondents.

4.2. Risks in the DMC. The risk scores measure each risk's relative importance based on relative frequency and severity (e.g., [45] and Tummala, and Schoenherr, 2011). The risk scores for each risk factor (listed in Table 1) in the preparedness, response, recovery, and mitigation phases were computed based on their likelihood of occurrence and consequences.

Based on the risk scores, we can derive the risk ranking in each DMC phase. The top two dominant risks in each phase were identified to aid in risk prioritisation. Table 5 shows the risks ranking, and the highlighted cells show the dominant risks in the preparedness phase, response phase, recovery phase, and mitigation phase of the DMC.

Based on Table 5, demand risk is ranked the highest in the response phase. Further, operational risk is evident in the response phase but is not as apparent in the recovery phase. This finding is supported by the interviews, where interviewees unanimously agreed that the five risks apply to the DMC, though they are not consistent across all phases. As quoted by one interviewee: "*there are higher levels of risks in some phases, and certain risks pose bigger risks as well.*"

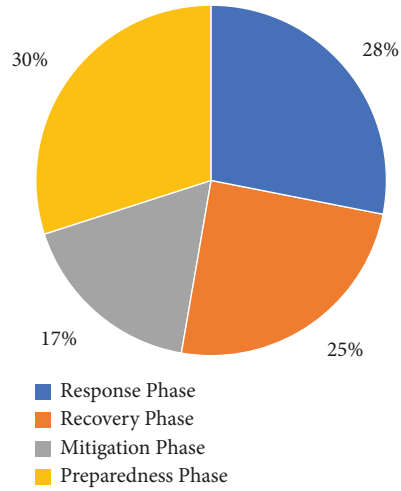

Figure 4: Participation of respondents in the DMC.

Table 5: Risk ranking in the DMC phases.

Risk ranking (based on risk likelihood and impact analysis)	Preparedness phase	Response phase	Recovery phase	Mitigation phase
Demand risk	5	**1**	**2**	**2**
Supply risk	3	5	**1**	**1**
Operational risk	**2**	4	5	3
Infrastructure risk	4	3	3	Not present
Disruption risk	**1**	**2**	4	4

Based on the distinctly higher risk score values, the top two dominant risks were then identified in each phase in the DMC. Table 6 shows a summary of the top two risks that must be prioritised for each phase.

4.3. Risk Mitigation Strategies in the DMC. The second phase of our data analysis seeks to identify the appropriate SCSs that can be deployed in the respective DMC phases. Respondents from both the web-based survey and interviews were asked to select the strategy or strategies listed in Table 2, which they deemed helpful in mitigating the dominant risks in each DMC phase, considering the strategy effectiveness and practicality of implementation in each DMC phase.

Table 7 shows the summary of the top strategies selected by respondents. Figure 5 presents a conceptual framework that encapsulates the findings presented above. It shows the dominant risks and supply chain risk mitigating strategies in each DMC phase.

The conceptual framework encapsulates the key findings that resonated with the verbatims of the three semi-structured interviews. In general, collaboration and coordination among players in the DMC, be it horizontal or vertical cooperation, and raising risk awareness are deemed essential in mitigating risks in the DMC.

4.3.1. Risk Mitigation in Preparedness Phase. The preparedness phase occurs in the pre-disaster stage. The preparedness phase aims to decide on operations to be carried out before a disaster strikes to support response operations effectively [48]. This phase is critical as information and communications technology systems, physical network design, and bases for collaboration are developed in this phase [10]. From Table 5, the dominant risks in the preparedness phase are *operational risk* and *disruption risk*. The appropriate risk mitigation strategies deemed relevant in mitigating these two dominant risks are raising risk awareness and fostering *horizontal collaboration* and *coordination* among stakeholders in the DMC.

In building the resilience and capacity of the community to respond to potential disasters, the most fundamental step is to be conscious of probable disaster risks. Risk awareness can also come from the lessons learned from past disasters and how one can be better prepared for potential ones in the future. Awareness of these risks in the preparedness phase will allow organisations to be more mindful of the perils and hazards in disaster-prone areas and those associated with operational processes. In turn, they will understand how to better prepare for them. The community also needs to be aware of the risks and the negative impacts they bring. Risk awareness will significantly help implement operational plans or strategies as the community understands and recognises the significance of managing the risks.

Horizontal collaboration and coordination among stakeholders in the DMC are also instrumental in managing *disruption risk* and *operational risks*. Strategies developed in the mitigation phase may translate into actionable and operational plans in the preparedness phase. Thus, it is pivotal that stakeholders are aware of their respective roles and responsibilities so that relevant parties can respond effectively in the fastest possible time when disaster strikes. Horizontal collaboration and coordination are even more

Table 6: Summary of the top two dominant risks in each DMC phase.

Top risks	Preparedness phase	Response phase	Recovery phase	Mitigation phase
1	Disruption risk	Demand risk	Supply risk	Supply risk
2	Operational risk	Disruption risk	Demand risk	Demand risk

Table 7: Summary of top strategies for the dominant risks in each phase in the DMC.

Strategy		Preparedness phase		Response phase		Recovery phase		Mitigation phase	
		Disruption risk	Operational risk	Demand risk	Disruption risk	Supply risk	Demand risk	Supply risk	Demand risk
A	Having a mobile logistics hub (assuming the chosen location is safe and accessible)				√				
B	Having a centralised propositioned stock								
C	Having a joint or bulk procurement system								
D	Having a flexible supply base			√	√		√	√	
E	Logistics outsourcing—use of a third-party logistics provider								
F	Horizontal collaboration and coordination among players involved in the same phase of the DMC for joint planning and information sharing	√	√	√		√	√		√
G	Vertical collaboration and coordination among players involved in the different phases of the DMC for joint planning and information sharing					√	√		√
H	Pre-position vehicles and having a fleet management program								
I	Having flexible transportation with an operational mix of vehicles and transport mode, depending on the location and accessibility of disaster site								
J	Risk awareness	√	√		√	√		√	√

crucial since time is important after a disaster. Knowing one's role well will also help one make more informed decisions, especially when the situation is highly critical, and there is little time for decision-making.

4.3.2. Risk Mitigation in Response Phase. The response phase occurs immediately after a disaster strikes. Activities focus on saving lives and minimising disaster impacts and suffering of the impacted community [10, 48]. Based on Table 7, it was found that the top risks in the response phase are *demand risk* and *disruption risk*.

Demand risk occurs when disruptions arise from demand volatility. There is a gap between forecasted demand and the actual demand required. The projected demand is insufficient to fulfil the needs of affected beneficiaries. As a result, beneficiaries may not receive the required aid in time. The response phase is the most life-critical phase in the DMC and is time-bound as dire consequences may occur when food and medical supplies are not delivered promptly. In the first 72 hours of disaster response, operation relief teams must be deployed to the ground to ascertain the relief needs to effectively obtain and deliver the required supplies to the beneficiaries [10]. This view was echoed by the informants in the interviews, as seen in the following quote,

Hence, considering the aforementioned, demand risk is the top risk that is highly likely to occur and has severe repercussions if it is not managed well.

Disruption risks are typically caused by natural and man-made disasters such as floods, earthquakes, and terrorist attacks. In the response phase, humanitarian relief operations are carried out in areas where the disaster occurred, and there may be high casualty numbers, coupled with improper conditions and limited constraints. This is made

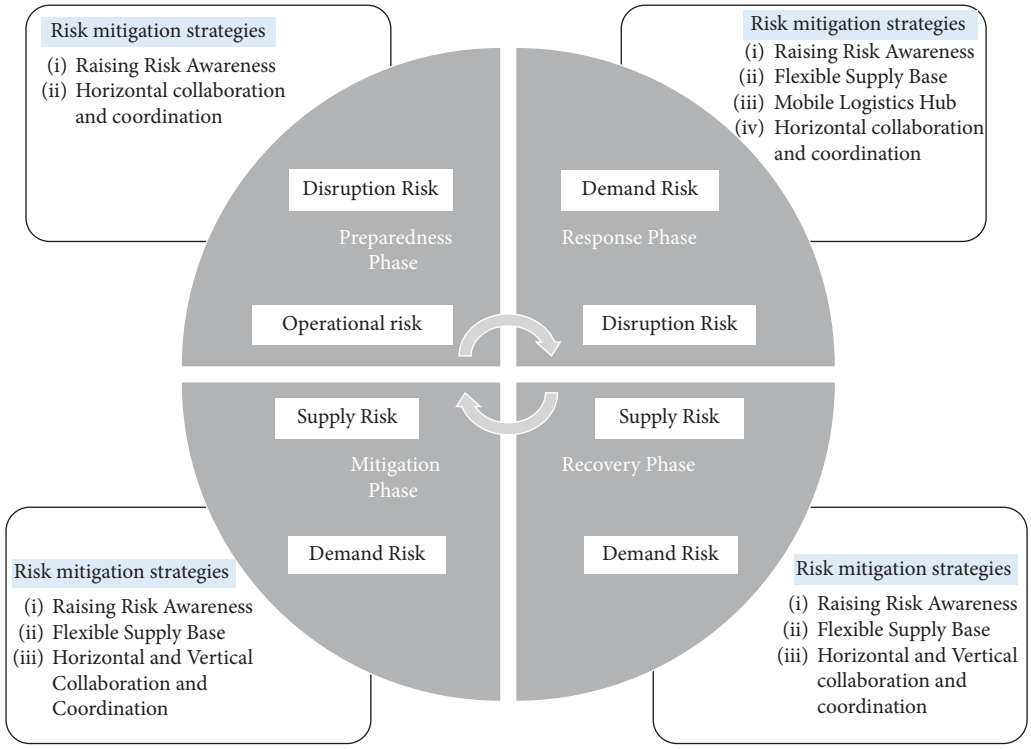

Figure 5: A conceptual framework identifying the dominant risks and supply chain risk mitigating strategies in the DMC phases.

worse when another disaster strikes after the initial one, such as aftershocks and landslides which are triggered by earthquakes and floods. Thus, it is inevitable that disruption risk is evident in the response phase and efforts need to be made to manage it well to reduce the repercussions.

To manage *demand risk*, organisations can adopt a flexible supply base. This includes having decentralised decision-making to allow for local adaptations. Decisions may be made on a smaller scale, possibly between smaller supply chain groups that manage their operations. Decisions can also be adapted to the local demand conditions of each area. This is unlike centralised decision-making, where decisions must account for the various operating structures and conditions different supply chain groups face. As organisations make decisions on a smaller scale, they may be better able to forecast the projected demand in different areas of a disaster-prone region and reduce demand volatility in the long term.

Other than having a flexible supply base, it is crucial to have horizontal collaboration and coordination among players in the response phase. Adopting horizontal collaboration capabilities enhances communication among the different stakeholders, which will help in the exchange of information sharing. This will facilitate information flow between the local communities and relevant stakeholders who deliver emergency supplies and enable effective disaster response management [6]. Even on occasions when projected demand is lower than the actual demand, the affected beneficiaries may still be able to receive aid in the fastest possible time as there is proper communication and coordination among stakeholders. Hence, the two identified strategies will significantly manage demand fluctuations and risk in the response phase.

Three strategies are highly favoured to manage *disruption risk*. First, risk awareness should be advocated among stakeholders in the response phase. Relevant stakeholders must be aware of and understand disruption risk in the response phase. Stakeholders can only realise the urgency and need to collaborate to manage the disruption risk by first establishing awareness and understanding. The other strategy that can be adopted is locating mobile logistics hub (MLH) in affected regions. MLHs are "pre-designated for storing emergency logistics and telecommunication equipment" (see p.2 in [49]). One important consideration when locating an MLH is that the chosen location must be safe, yet still accessible and close to the disaster regions. The MLH serves as an operation centre where disaster relief supplies are managed and consolidated. If successfully implemented, the MLH can enhance the effectiveness and responsiveness of humanitarian supply chains, improving disaster response efforts.

Lastly, organisations can adopt a flexible supply base. It is a good practice that organisations have alternative sources. This view resonated with the interviewees in this study based on their rating of the appropriateness of the risk mitigation strategies. For instance, there can be various suppliers for an item, and organisations may consider different variations of the same item, as long as the item serves its intended

purpose. Such consideration will ensure that supplies can continue to reach vulnerable groups and affected communities in time of need, albeit from a different supplier or of a different variation.

4.3.3. Risk Mitigation in Recovery Phase. The recovery phase focuses on rehabilitation for the long term as the main objective is to restore the system as much as possible, reconstruct infrastructure, and rebuild the livelihoods of the impacted community [10, 24]. From Table 7, the top risks in the recovery phase are *supply risk* and *demand risk*.

Supply risk occurs due to the inconsistent performance from upstream supplies as a result of uncertainties associated with inbound supply, and this may, in turn, hinder product flow. Hence, this affects the number of supplies delivered to the impacted community and the corresponding time and cost required to transport the supplies. These supplies are crucial in helping the affected beneficiaries rebuild their houses and restore infrastructure in the community. More so, when another disaster hits during the rehabilitation period. The livelihoods of the impacted community are severely affected as they are constantly trapped in the cycle of rebuilding and rehabilitating infrastructure.

Supply and demand risk usually coexist. Thus, demand risk is also present in the recovery phase apart from supply risk. Delivering supplies and goods is paramount in the recovery phase, where the main objective is the rehabilitation of affected beneficiaries. Demand risks typically occur due to demand fluctuations that result from gaps between the actual and forecasted demand. These gaps exist due to the lack or breakdown of information sharing between the relevant stakeholders. As a result, information on required necessities and goods may not be communicated or relayed properly from affected beneficiaries to stakeholders like aid agencies, international NGOs, and donors. They all play an instrumental role in providing relief supplies in the recovery phase. Hence, this lack or breakdown of information flow will inevitably lead to the existence of demand risk in the recovery phase.

One important strategy in managing *supply risk* is risk awareness. Organisations that participate in the recovery phase have two main tasks on hand. They must ensure adequate support is given to the team for rehabilitative operations and proper resilience management [22]. However, these tasks can only be executed well if knowledge of the risk is present among stakeholders and they are aware of what to do during a product flow disruption.

Stakeholders would also be more prepared to provide the necessary support when they have adequate knowledge and awareness of the risk. Hence, this illustrates the importance of risk awareness in managing supply risk in the recovery phase. It is also essential to have horizontal collaboration and coordination among players in the recovery phase and vertical collaboration and coordination among other stakeholders in the DMC.

Such cooperation allows for joint planning among the stakeholders. This will significantly aid in integrating the efforts and actions of the various players, especially when upstream product flow is disrupted. Apart from that, there would also be a deeper understanding of the community's vulnerabilities, which will go a long way in channelling the appropriate efforts in rebuilding and rehabilitation works.

One identified strategy to manage demand risk is to have flexible supply bases. Organisations can have separate cooperation agreements with various suppliers or service providers. This ensures that if high demand spikes and one supplier does not have sufficient supplies, alternative sources of relief goods are available from other supplies to fulfil the demand for necessities and other relief supplies.

Horizontal collaboration and coordination among players in the recovery phase and vertical collaboration and coordination among stakeholders in the DMC are also critical in managing demand risk. This will ensure accurate risk information sharing among all relevant stakeholders at different levels, aiding in effective recovery efforts. These collaboration and coordination capabilities will also allow stakeholders to have greater knowledge of each player's resources and skills. They may utilise resources and potential complementary skills most efficiently and effectively.

4.3.4. Risk Mitigation in Mitigation Phase. The objective of the mitigation phase is to deter potential hazards from becoming disasters and minimise any potential adverse disaster impacts through adopting preventive measures [10]. One important consideration when planning mitigation strategies is the demand and supply of goods and emergency supplies needed when disasters strike. Activities range from strategic-level decisions like policy determination to operational-level ones like discerning the most appropriate transportation route for hazardous materials [48]. Based on Table 6, it is found that *supply risk* and *demand risk* are the top risks in the mitigation phase. This requires considerable coordination and collaboration among stakeholders to ensure that disruptions from demand volatility and inbound flow of supplies are minimised. Thus, relevant stakeholders must consider supply and demand risks when planning mitigation strategies to reduce the community's vulnerability in disaster-prone regions and limit the damages caused by disasters.

Risk awareness is central to managing *supply risk* and *demand risk*. In the mitigation phase, various stakeholders like governments and local NGOs must develop a collective strategy to reduce negative disaster impacts. Such strategies are crucial in preventing disaster hazards. However, developing these strategies requires significant understanding and knowledge of the risks faced by the affected community. Thus, risk awareness is crucial so that appropriate mitigation strategies can be planned and developed to target critical risks.

A flexible supply base also helps in managing *supply risk*. In this regard, organisations can discern suppliers who pose the most significant risk or are likely to have operations disrupted and those whose operations are least likely to be interrupted. Thereafter, organisations can initiate cooperation agreements with the latter group and other suppliers

who can provide supplies to minimise the risk of operational disruptions. Organisations may also diversify the supplies of the various types of items to mitigate supply risk.

To manage *demand risk*, other than risk awareness, it is also necessary to have horizontal collaboration and coordination among players in the mitigation phase and vertical collaboration and coordination among stakeholders in the DMC. Apart from driving information sharing, establishing partnerships will also allow for programme activities to be integrated and carried out at different levels, such as the national and state levels. It would also help to ensure that there will not be any overlap of plans for the same group of beneficiaries, which will help save resources for other purposes.

5. Concluding remarks and Future Research

The findings from this study revealed specific risks in the DMC's preparedness, response, recovery, and mitigation phases and suggested appropriate risk mitigation strategies for each phase. Overall, we found several risk factors resonate strongly in each DMC phase. They are demand risk, supply risk, operational risk, infrastructure risk, and disruption risk, with only the infrastructure risk absent in the mitigation phase.

From the study, it appears that risk awareness and horizontal collaboration and coordination among players involved in the same phase of the DMC and vertical collaboration and coordination among players involved in different phases of the DMC are essential and fundamental for risk mitigation in the DMC. These strategies were found in separate frameworks in Jahre [11] and Scholten et al. [22]. Yet, the above discussion showed that there are overlapping themes in the frameworks which resonated with each other.

Risk awareness is crucial, and actionable plans such as close and strategic collaboration and coordination are essential components of risk mitigation. This study highlighted that all stakeholders must be wary of the five risks in the DMC. More importantly, there should be collaboration and coordination among stakeholders across levels and at different levels to better manage risks in the DMC, as reflected succinctly by the informants in the interviews:

> "*. . . horizontal and vertical collaboration and coordination. They go hand-in-hand with each other and one cannot do without another*"

These cooperation capabilities will go a long way in enabling effective and efficient disaster responses and preparedness plans.

5.1. Theoretical and Practical Implications. In our research, we have focused on providing granularity to the knowledge in the DMC by integrating theories from conventional supply chain risk management and mitigation strategies. This article contributes in three ways. First, we provide a theoretical linking of supply chain risk management literature with the DMC by using two bodies of literature, the DMC and supply chain risk mitigation strategies (SCSs), in developing a conceptual framework for the study. Second, we identified the dominant risk factors in the four phases of the DMC. Third, we add to the extant literature by developing a conceptual framework that links the risk factors, SCSs, and DMC that are expected to aid risk mitigation in humanitarian supply chain and disaster management. The conceptual framework presented in Figure 5 can be used to prioritise risks, guide decision-making, and develop risk mitigation policies in the DMC.

Overall, the findings from this study offer valuable insights and deepen the understanding of risk management strategies in the DMC. The findings could be extended to different types of humanitarian organisations and NGOs. Nonetheless, it is vital to accord attention to variant contextual needs in distinct humanitarian circumstances in each phase of the DMC so that optimal actions can be taken to meet the needs of the beneficiaries.

5.2. Limitations and Future Research. While the study addressed salient issues pertinent to risk management in the DMC, our research has several limitations that can be explored in future studies. First, though our research primarily targeted representative humanitarian operations and DMC stakeholders, we only managed to gather 25 valid questionnaire responses that were corroborated by three independent semi-structured interviews due to the limited data collection time frame. Although the computed risk scores are relative values based on the informants' perceptions, it nonetheless enables the identification of the dominant risks in each DMC phase. Further research can collect quantitative data to validate the conceptual framework. Longitudinal data over an extended period of disaster management could help generate deeper insights across a more extensive network of respondents in the DMC that is lacking in this study.

Second, this study focused on identifying the top risks in each disaster phase. Further studies can examine other risk factors to shed insights into areas that humanitarian practitioners may overlook. Lastly, the risk score values were averaged from the respondents' inputs, and the identified strategies were weighted based on the general responses from respondents. Future studies can explore other research approaches, such as case analyses of exemplary scenarios, to deepen the understanding of recurrent and common scenarios among the DMC phases. Overall, the findings from this article can be used as a basis for future studies to deepen the knowledge of supply chain risk management and resiliency in the HLSCM context.

Data Availability

The questionnaire responses and interview transcripts used to support the findings of this study have not been made available to protect the interest and confidentiality of the research informants and organisational identities that were studied. Public archival data and the literature used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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