# Humanitarian Logistics: Addressing Challenges and Improving Relief Operations

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## Abstract

To address challenges faced by humanitarian logistician and improve future relief efforts, the purpose of this research is twofold. First, we aim to characterise the key challenges in humanitarian supply chains that hinders disaster relief efforts to respond effectively to diverse humanitarian logistics requirements. Second, we seek to adapt and apply the evaluation criteria of commercial supply chains to the humanitarian context to aid practitioners in evaluating the effectiveness and efficiency of humanitarian logistics and supply chain management operations. We make use of both primary data that include survey questionnaires and interviews and secondary data including archival reports/records of past humanitarian relief cases to address the research aims. Based on the data collected from 30 valid survey responses, we identified the different key players in the Humanitarian Relationship Model, their roles and the key challenges they faced when responding to natural disasters. Three key challenges that the respondents faced included issues related to poor and unpredictable operating conditions, supply and demand uncertainty, lacking in communications and information. Further, we made use of an adapted SCOR framework and Analytical Hierarchy Process (AHP) methodology to help respondents in selecting and prioritizing performance metrics based on their priority and feasibility weightages. We also highlighted several best practices that aim to improve the effectiveness and efficiency of future humanitarian logistics and disaster relief efforts.

**Keywords**: Humanitarian logistics, Disaster operations, SCOR, AHP, Stakeholders management

## 1. Introduction

Unlike commercial logistics supply chains, the effectiveness of humanitarian logistics affects not just money or economics, but the innocent lives of many. There is an increasing trend of disasters happening around the world and this warrants more focus and attention to be put on the humanitarian logistics domain. Major disasters such as the 2004 Thailand tsunami and 2010 Haiti earthquake have taught us how unprepared we may still be when responding to large scales disasters and the criticality of having efficient and effective humanitarian relief operations to ensure as many lives as possible are saved.

This research study recognizes the lack of knowledge and performance analysis to conduct evaluation and improvements on current humanitarian logistics processes. To tackle these issues, we employed a systematic approach to better understand the types and roles of stakeholders in humanitarian logistics, the key challenges faced in their relief operations and propose methods to evaluate and enhance humanitarian relief operations.

The following Research Questions and Research Objectives were formulated:

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Research Question #1:
Who are the different groups of key players involved in humanitarian logistics and what types of services/products do they offer in their contributions to disaster relief efforts?

Research Question #2:
What are the key challenges faced when conducting humanitarian relief operations in natural disasters?

Research Question #3:
How do we enhance humanitarian logistics processes to enable more effective and efficient disaster relief operations?

The first phase of the research was primarily focused on identifying and validating the key groups of stakeholders involved in humanitarian logistics, their respective roles and interactions. Part of the first phase also involved surfacing the key challenges that they faced, validate these pieces of information through deeper correlation and analysis with literatures reviews and interviews; before providing suggestions and recommendations in the second phase of the study that inform on the possible implementations that can be helpful in overcoming these challenges and further enhance current humanitarian relief operations.

To address the three research questions, we collected primary data through surveys administered to expert informants in the humanitarian logistics and relief operations domains and conducted interviews with stakeholders to gain relevant and useful insights that helped us in the formulation of relevant recommendations in response to research question 3.

## 2. Literature Review

Despite its significance, performance measures and measurement systems have not been widely developed and systematically implemented in the relief chain (Beamon and Balcik, 2008). This was the main issue that Lu, Goh, & Souza (2016) wanted to address. As the number of global disasters increase over the years, the need for greater effectiveness and efficiency in humanitarian logistics increases as well. Lu, Goh, & Souza (2016) discussed on the difficulty in creating performance measurements for relief chains due to the inherent unique characteristics involved in a disaster relief environment. They include factors such as the involvement of multiple stakeholders and difficulties in data collection on the ground.

***Performance Measurement in Commercial Logistics vs. Humanitarian Logistics***
While humanitarian logistics may share certain similarities with its commercial counterparts in activities such as planning and transportation, they differ in demand pattern, objective, stakeholders, structure, complexity, and operating environment (Van Wassenhove, 2006; Erten *et al*., 2010). Figure 2.1 and 2.2 provides a visual comparison on the different stakeholders involved between humanitarian logistics and commercial logistics.

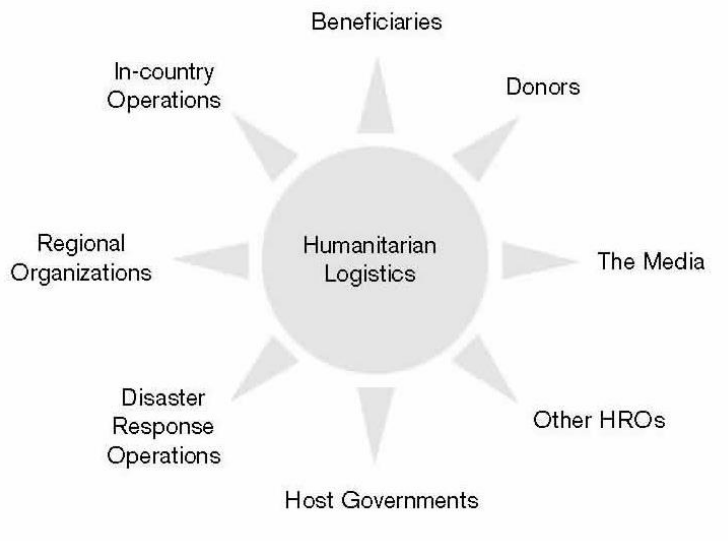



**Figure 2.1: Stakeholders Involved in Humanitarian Logistics (Source: A. Thomas, 2003)**

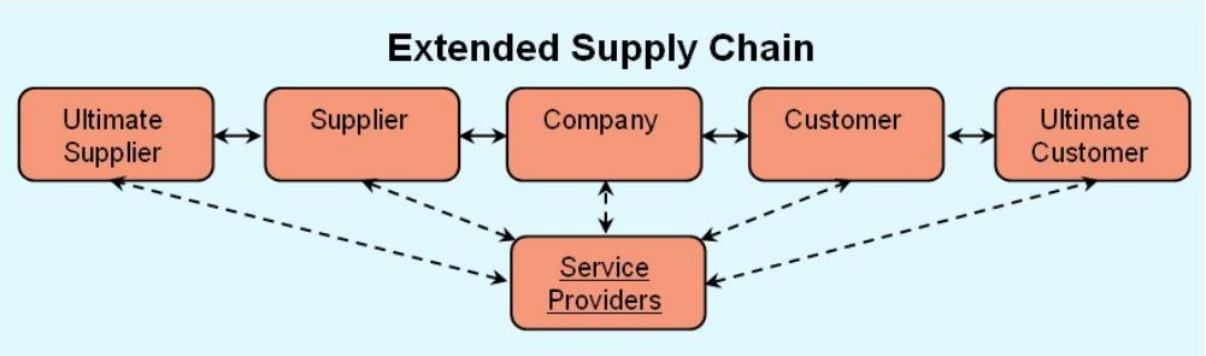



**Figure 2.2: Stakeholders in Commercial Logistics (Source: Hugos, 2018)**

It can be observed there is a larger number and variety of stakeholders involved in a humanitarian chain than a commercial chain. This translates to more complications and difficulties in data gathering, workflow evaluations and performance measurements. With the involvement of different types of stakeholders, the strategic, tactical and operational planning and objectives of the two chains will thus differ vastly.

***Developing a Performance Measurement Framework in Humanitarian Relief Organizations***

There are many studies on supply chain performance measurement, using various approaches and targeting different objectives (Garcia *et al.*, 2012). Over the past few decades, different logistics experts have come forward and proposed different types of frameworks, with different focuses on a variety of components and performance indicators. During the early stages, the Balanced Scorecard (BSC) Approach was a common tool practiced in the humanitarian domain because of its ease of usage and ability to balance various performance components (Schiffling and Piecyk, 2014). In 2006, Davidson (2006) proposed a framework which focused on four performance indicators: appeal coverage, donation to delivery time, financial efficiency, and assessment accuracy. Two years later, Beamon and Balcik (2008) proposed a performance measurement framework focused on three components: resource performance, output performance, and flexibility. On the other hand, the Supply Chain Operations Reference (SCOR) model, which this research article focused and proposed on in the later paragraphs, was more widely used in the commercial supply chains. This was probably due to the difficulty in data gathering for HROs, as compared to data gathering in commercial supply chains, where information is more readily available.

Performance measurement in the humanitarian domain is much less developed as compared to the commercial world and that there has yet to be a universally accepted performance measurement framework for the HROs (Tatham and Hughes, 2011). Moreover, research also showed that most existing measures in the industry are results-based and may not be very helpful to improve HRO relief operations, which biggest issues include uncertainty due to a variety of factors beyond the control of one organization. Other complications also include differences in organization strategies and operating procedures, communication barriers and even geo-political factors. This research article was thus initiated to address these issues by choosing the Supply Chain Operations Reference (SCOR) model as the key framework, seeing it is a comprehensive supply chain process model covering multiple levels of supply chain operations with ready-made KPIs generated from its extensive application in the commercial world (Lu, Goh, & Souza, 2016).

***Supply Chain Operations Reference (SCOR) Framework and Performance Metrics***

When developing the performance metrics, Lu, Goh, & Souza (2016) explored both performance attributes and industry logistics processes. There are five performance attributes in the original SCOR model. They include: Reliability, Responsiveness, Agility, Cost, and Asset Management. However, in the context of humanitarian logistics, all attributes except for asset management are deemed important (Lu, Goh, & Souza, 2016). This is because HROs are normally resource-light with few assets; and rely heavily on external resources and capabilities for emergency relief operations (Oloruntoba and Kovacs, 2015). Thus, to make the SCOR more applicable and accurate for our research study, we shall omit Asset Management during our conduct of SCOR metrics development. Shown below in table 2.3 is how Lu, Goh, & Souza (2016) classified the four performance attributes and the SCOR metrics they adopted to measure the efficiency of the critical processes in their case study organization.

| Metric | SCOR metric | SCOR no. | Performance attribute and process | Formula |
|---|---|---|---|---|
| A1.1 | Perfect order fulfilment | RL 1.1 | Reliability and all processes | (Total perfect orders)/(Total number of orders) × 100%<br>Note: an order is perfect if the individual items making up that order are all perfect |
| A2.1 | Percentage of orders delivered in full | RL 2.1 | Reliability and delivery process | (Total number of orders delivered in full)/(Total number of orders) × 100% |
| A2.2 | Delivery performance to customer commit date | RL 2.2 | Reliability and delivery process | (Total number of orders delivered within scheduled date)/(Total number of orders) × 100% |
| A2.3 | Documentation accuracy | RL 2.3 | Reliability and delivery process | (Total number of orders delivered with accurate documentation)/(Total number of orders) × 100% |
| A2.4 | Perfect condition percentage | RL 2.4 | Reliability and delivery process | (Total number of orders delivered in perfect condition)/(Total number of orders) × 100% |
| A3.1 | Store documentation accuracy | RL 3.43 | Reliability and store process | (Total number of orders delivered with accurate store documentation)/(Total number of orders) × 100% |
| A3.2 | Delivery documentation accuracy | RL 3.50 | Reliability and final delivery process | (Total number of orders delivered with accurate delivery documentation)/(Total number of orders) × 100% |
| A3.3 | Risk mitigation plan | RL 3.48 | Reliability and all processes | (Total number of items with alternative sources)/(Total number of items) × 100% |
| B1.1 | Order fulfilment cycle time | RS 1.1 | Responsiveness and all processes | (Total actual cycle times for all orders delivered)/(Total number of orders delivered) |
| B2.1 | Source cycle time | RS 2.1 | Responsiveness and source process | For all supply items ordered, the maximum value of ((The payment date)–(Date of informal sourcing request)) |
| B2.2 | Assembly cycle time | RS 2.2 | Responsiveness and store process | (Total number of kits in active assembling) (Average daily kits outputs) |
| B2.3 | Delivery fulfilment cycle time | RS 2.3 | Responsiveness and delivery process | (Total actual delivery cycle times for all orders delivered)/(Total number of orders delivered) |
| B3.1 | In-stock percentage | RS 3.47 | Responsiveness and store process | (Total number of essential items where the stock level falls below its minimum stock level during emergency event)/(Total number of essential items) × 100% |
| B3.2 | External event response | RS 3.31 | Responsiveness and all processes | For all items delivered for an emergency events, the average value of ((Date when a specific resource is delivered to victim)–(Onset date of a particular humanitarian event)) |
| C1.1 | Upside supply chain flexibility | AG 1.1 | Agility and all processes | Total elapsed days between the occurrence of the unplanned event and the achievement of sustained plan, source, make, deliver and return performance |
| C2.1 | Upside source flexibility | AG 2.1 | Agility and source process | For all supply items ordered, the maximum value of ((Receipt date of order in which quantity increases by 100%)–(PO date of order in which quantity increases by 100%)) |
| C2.2 | Upside delivery flexibility | AG 2.3 | Agility and delivery process | For all delivery items, the maximum value of ((order delivery date in which quantity increases by 100%)–(The date of ordered items ready for delivery in which quantity increases by 100%)) |
| C3.1 | Current on-hand inventories | AG 3.39 | Agility and store process | The amount of all items currently in warehouses |
| C3.2 | Current purchase order cycle time | AG 3.40 | Agility and source process | For all supply items ordered, the maximum value of ((goods receipt date)–(Date of purchase request)) |
| D1.1 | Supply chain management cost | CO 1.1 | Supply chain and all processes costs | The sum of the costs associated with the Level 2 processes to plan, source, store, and deliver |
| D2.1 | Cost to plan | CO.2.1 | Supply chain costs and plan process | The sum of all costs associated with the plan process such as plan to source, and plan to delivery |
| D2.2 | Cost to source | CO.2.2 | Supply chain costs and source process | The sum of all costs related to sourcing such as material planning, planning procurement staff, supplier negotiation, bidding, and quotations |
| D2.3 | Cost to manage product inventory | CO.3.82 | Supply chain costs and store process | The sum of all costs on activities for store, including warehousing operating cost, rental cost, and manpower cost |
| D2.4 | Cost to deliver | CO.2.4 | Supply chain costs and delivery process | The sum of all costs associated with the delivery process such as outbound transportation costs |
| D2.5 | Supply chain risk mitigation cost | CO.2.7 | Supply chain costs and all processes | The sum of the costs associated with supply chain risk mitigation activities in plan, source, and deliver processes |
| D3.1 | Cost to manage supply chain performance | CO.3.78 | Supply chain costs and all processes | The sum of all costs on activities for supply chain performance management, including both manpower and documentation costs |

**Figure 2.3: Proposed SCOR Metrics for HROs (Source: Lu, Goh, & Souza, 2016)**

***KPI Validation***

With these 26 metrics developed based on their case study organization, Lu, Goh, & Souza, (2016) proceeded to conduct validation on these metrics with the participation of seven other HROs. Lu, Goh, & Souza, 2016 conducted the validation on these 26 KPIs by focusing on two aspects, its level of importance and feasibility. The level of importance of a KPI refers to its relevance of the mentioned KPI in humanitarian operations, and the degree of potential improvement achievable by using this metric in operations. The feasibility of a KPI refers to the level of difficulty it is to implement measurement of the mentioned metric from ground operations based on the subject's current processes and existing data. To better quantify and present the data gatherable from this validation, Lu, Goh, & Souza, (2016) used a coupled five-point Likert Scale, where ((1,1) = not important at all, not difficult at all) and (5,5) = very important, very difficult to implement)). A metric scoring of more than 3 in importance would mean that it should be implemented. Similarly, a metric scoring of more than 3 in difficulty indicates that the metric would face significant difficulty to implement. Figure 2.4 shows the strategy of how Lu, Goh, & Souza, (2016) intended to propose the implementation of adopted KPIs.

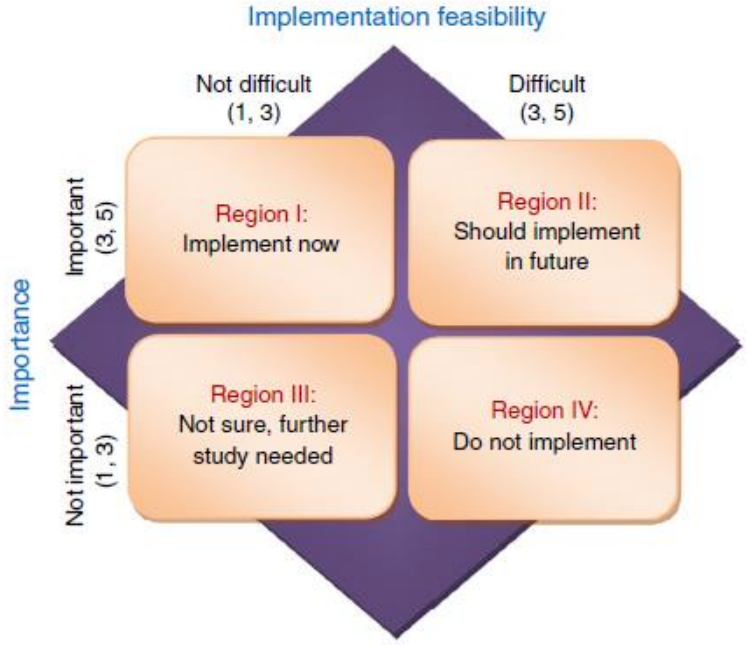



**Figure 2.4: Strategy for KPI Implementation (Source: Lu, Goh, & Souza, 2016)**

Lu, Goh, & Souza, (2016) classified all the 26 KPIs into four quadrants of a 2x2 matrix of importance as shown in Figure 2.4.4. Following which, Lu, Goh, & Souza, (2016) adopted the different strategies for each of the respective quadrant. KPIs falling in Region 1 and 4 are simpler to handle, with KPIs in Region 1 to be implemented as soon as possible to enhance current processes as the KPIs are both important and yet not difficult to implement. On the other hand, KPIs falling into Region 4 should not be implemented, simply because they are deemed unimportant and difficult to implement. Regions 2 and 3 are the trickier ones, where organizations must do their own internal prioritization and reviews before making their own strategic decisions. In general, KPIs falling into Region 2 are those that are important but difficult to measure. Thus, if organizations are to focus on these KPIs, they should consider making adjustments or improvements to their current processes to enable better data collection so that these KPIs will be easier to measure. KPIs falling into Region 3 can also seem unclear, as they are deemed not important but yet relatively easy to implement. Thus, HROs should consider pursuing or remove these KPIs based on the potential value to each of their own unique organizations. This research study acknowledges and adopts this ideology in the later stages.

***Analytical Hierarchy Process (AHP) and SCOR Model to support Supply Chain Re-design***

Palma-Mendoza (2014) provided a somewhat similar aspect as Lu, Goh, & Souza, (2016) in their proposed solutions to improve and re-design supply chains. Both articles discussed on the possibilities and capabilities of the SCOR model, where they identified relevant logistics processes and proposed viable key performance metrics (KPIs) to enable more effective and efficient measurement of relief chain processes. However, going further, Palma-Mendoza (2014) introduced the Analytical Hierarchy Process (AHP) for the selection of a target to focus the re-designing efforts on. Essentially, Palma-Mendoza (2014) proposed to use the SCOR model to identify relevant processes and to use the SCOR model performance attributes and metrics as the evaluation criteria to conduct an AHP analysis for the selection of a target for re-design. This approach was also adopted and experimented in the later stages of this research study.

***Selection of Key Supply Chain Process for Re-design***

Palma-Mendoza (2014) recognized that some processes in a supply chain are more critical than others. Thus, in order to effectively identify and differentiate the degree of importance among

other supply chain process, Palma-Mendoza (2014) proposed to utilize a multi-criteria decision analysis tool such as the Analytical Hierarchy Process (AHP), as a decision support tool for process selection. The AHP methodology was introduced by Thomas Saaty (1980) and is an effective tool for dealing with complex decision making. The AHP methodology assumes that the decision problems can be structured by translating its goals to into measurable criteria, which in turn can be linked to alternative decisions. Essentially, the AHP provides a priority number at each level of the hierarchy; then priorities of the alternatives are weighted against those of the criteria so that the eventual importance of the alternatives related to the goal are quantified (Saaty & Vargas, 2012). The AHP structure proposed by Palma-Mendoza (2014) consists of a two-level criterion composed by the SCOR model performance attributes and level 1 metrics. Figure 2.5 shows the AHP structure proposed by Palma-Mendoza (2014).

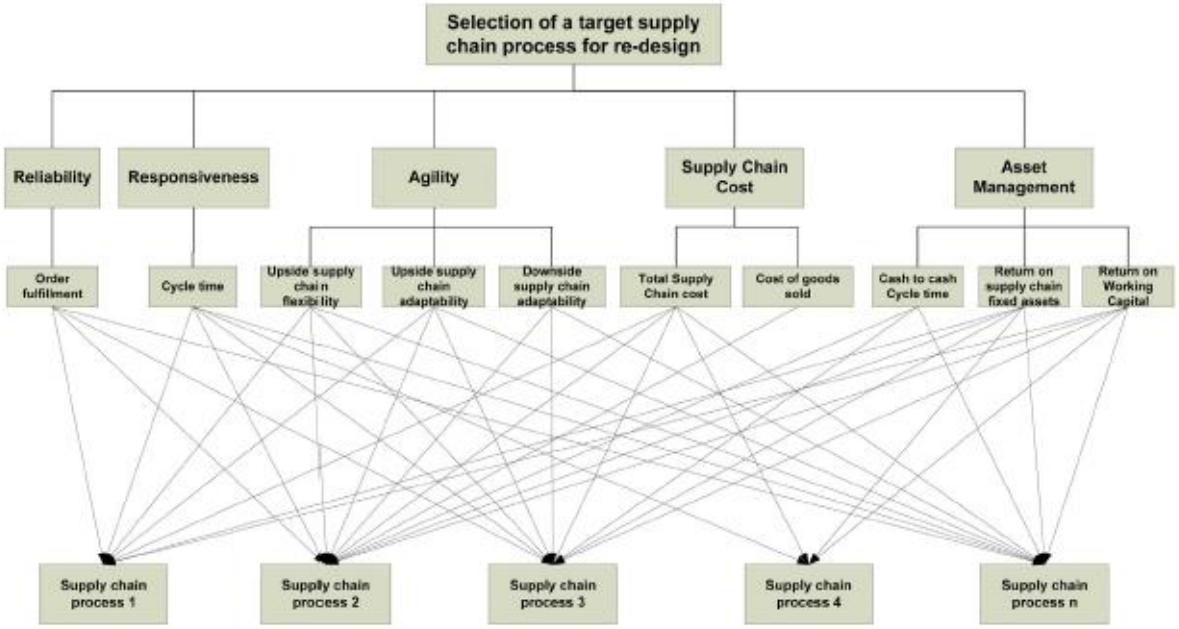



**Figure 2.5: AHP Structure for Selection of a Target Supply Chain Process for Re-design (Source: Palma-Mendoza et al., 2014)**

The top level of the figure shows the overall objective to select a target supply chain process for re-design. The next level shows the SCOR model performance attributes criteria, followed by the third level showing level 1 metrics. And at the bottom are the decision alternatives, which are to be represented by relevant supply chain process previously identified through Palma-Mendoza (2014)'s SCOR model mapping. These alternatives will be compared using the two-level criteria which consists of SCOR model performance attributes and level 1 metrics. Once the structure is confirmed, the AHP analysis will follow the following steps:

1. Pair-wise comparison
- *To determine the relative importance of the elements in each level of the hierarchy.*

2. Weightage calculation
- *To normalize and calculate the priority vector from a comparison matrix constructed from the pair-wise comparisons.*

3. Consistency check
- *Consistency ratio calculated to check for consistency in making the pair-wise comparisons.*

4. Hierarchical synthesis
- *Allow overall evaluation of the alternatives.*

5. Determine priority for all alternatives
- *The alternative with the highest overall priority weight will be chosen.*

Finally, the AHP analysis provides a priority numerical order for the supply chain processes considered for the selection. From this priority numerical order, users are able to decide with greater confidence and ease on which supply chain process to focus our re-designing or improvement efforts on.

## 3. Methods

The aim of this study is to provide useful insights on the criticality of delivering efficient and effective disaster relief operations. The information and data used for this study will be obtained from primary and secondary sources. Primary sources shall consist of avenues such as surveys and interviews with related entities and stakeholders involved in humanitarian logistics. Secondary sources include various documented online sources such as ReliefWeb, UN Statistics Division (UNSD), published humanitarian relief chains study papers and etc; as well as offline sources such as published humanitarian logistics textbooks, logistics domain academic textbooks and from interaction with various subject matter experts from Human Relief Organisations (HROs) etc. The research methodology to obtaining the required project data and information will be discussed further under the method section.

***Survey Questionnaires***
Two sets of surveys were constructed in total. The Humanitarian Logistics Survey consists of 4 sections; Section 1: Organization Information, Section 2: Workflow Information, Section 3: Performance Measure and Section 4: Performance Metrics and comprises a total of ten questions. This survey questionnaire was designed to gather relevant data for further analysis and assessments focused on Research Questions #1 and #2. The AHP Pair-wise Comparison Survey was designed as an AHP pair-wise comparison study and was only conducted with a selected group of survey respondents for further analysis focused on Research Question #3. Data provided by the selected respondents were used to facilitate the proposed approach discussed in the Section 4.5. Essentially, these questionnaires served well to collect both quantitative and qualitative data required in the context of this study to provide applicable and beneficial recommendations.

***Interviews***
During the data collection phase, multiple face-to-face interviews were conducted with selected respondents. Through the face-to-face interviews, this study was able to validate the data collected from the Humanitarian Logistics Survey and gather more value-adding qualitative data through the experiences and knowledge shared by this selected group of interviewees. The interviews also served as a good platform to share and validate the proposed approach to answer Research Question #3.

***SCOR Framework***
There are five performance attributes in the original SCOR model: reliability, responsiveness, agility, cost, and asset management (Lu, Goh and De Souza, 2016). However, as discussed in Section 2.4, in the context of humanitarian logistics, all attributes except for asset management are deemed important (Lu, Goh and De Souza, 2016). This is because HROs are normally resource-light with few assets and rely heavily on external resources and capabilities for emergency relief organisations (Oloruntoba and Kovacs, 2015). Therefore, this project will only focus on the other four performance attributes in the SCOR model: reliability, responsiveness, agility and cost. To apply the SCOR model effectively, this study adopted a systematic approach

to introduce the twenty-six performance attributes and metrics identified in the literature review section, thereafter validate them based on the respondents' inputs from the surveys and interviews using the SCOR Validation Matrix, before selecting focused data to facilitate further analysis through the AHP methodology.

***AHP Methodology***

Introduced by Thomas Saaty in 1980, an Analytical Hierarchy Process (AHP) is a multi-criteria decision-making tool that can deal with complex decision making, while providing aid to the decision maker to set priorities and making the best decision. The project has chosen AHP as one of the proposed analysis tools as it is able to incorporate judgements with qualitative criteria, along with tangible qualitative criteria, to provide a holistic approach to evaluate all chosen criteria and therefore providing carefully weighted and implementable solutions in the later part of this project.

Overall, a systematic approach was taken to ensure effective data collection, data integrity and accuracy so that the findings can from this study may present applicable and beneficial contributions to the humanitarian domain. Figure 3.1 presents an overview on the research design and methodologies employed to answer the three research objectives discussed.

| **Research Objective #1:**<br>**Similar to a commercial logistic supply chain, there are also various players involved in a humanitarian relief supply chain. Research Question 1 seeks to identify these key players, the roles they play and types of services/products they offer in disaster relief operations.** |
|---|
| (i) Case Study Method: Article 1,2 Reviews<br>(ii) Data Collection and Validation: Humanitarian Logistics Survey, Face-to-face interviews<br>(iii) Tools and Methodologies: Pie Charts, Bar Charts |

↓

| **Research Objective #2:**<br>**Research Question 2 seeks to define disasters, provide general knowledge on the types of disasters, and to identify the key challenges involved when reacting to natural disasters.** |
|---|
| (i) Case Study Method: Article 1,2,3 Reviews<br>(ii) Data Collection and Validation: Humanitarian Logistics Survey, Face-to-face interviews<br>(iii) Tools and Methodologies: Pie Charts, Bar Charts |

↓

| **Research Objective #3:**<br>**Research Question 3 seeks to propose solutions to evaluate and improve current humanitarian logistics processes to enable more efficient and effective disaster relief operations.** |
|---|
| (i) Case Study Method: Article 4,5,6 Reviews<br>(ii) Data Collection and Validation: Humanitarian Logistics Survey, Face-to-face Interviews, AHP Pair-wise Comparison Survey<br>(iii) Tools and Methodologies: SCOR Framework, AHP Methodology |

**Figure 3.1: Research Design and Methodology**

## 4. Findings and Discussions

With these three research objectives in mind, a survey was constructed and disseminated to professionals in the humanitarian logistics domain. The surveys were disseminated physically through referrals, and through online avenues such as the Qualtric online survey platform. This initiative was also fortunate to have gained the attention of the Humanitarian Logistics Association as the online survey invitation was shared and disseminated in their #40 Issue Newsletter. Comprising of ten questions across four sections, the Humanitarian Logistics Survey yielded 30 valid responses and the findings are discussed in the following sections. This paper also takes into consideration that across the literature reviews and online researches conducted prior to the data gathering phase, there seems to be a lack of conformity and clear definitions or categorizations on certain data groups that are essential to this research project. Thus, data gathered from the survey conducted thereafter was referred to, correlated and synchronized as best possible, to information obtained from other sources, before the final discussions and presentations on the findings seen below. This approach also allowed maximum participation and diversity of relevant data collection.

### *4.1 Key players in disaster relief efforts*

Cozzolino (2012) introduced the Humanitarian Relationships Model that identified seven main groups of key players in the humanitarian logistics domain. The seven main groups include: governments, military, aid agencies, donors, non-governmental organizations (NGOs), logistics companies and other companies. Apart from identifying the types of key player that the respondents played, data was also collected on the types of operations or services that their organizations provided. This information was correlated and presented in the following paragraphs. Figure 4.1 shows a pie chart on the respondents' inputs on the roles they perform in the humanitarian logistics domain.

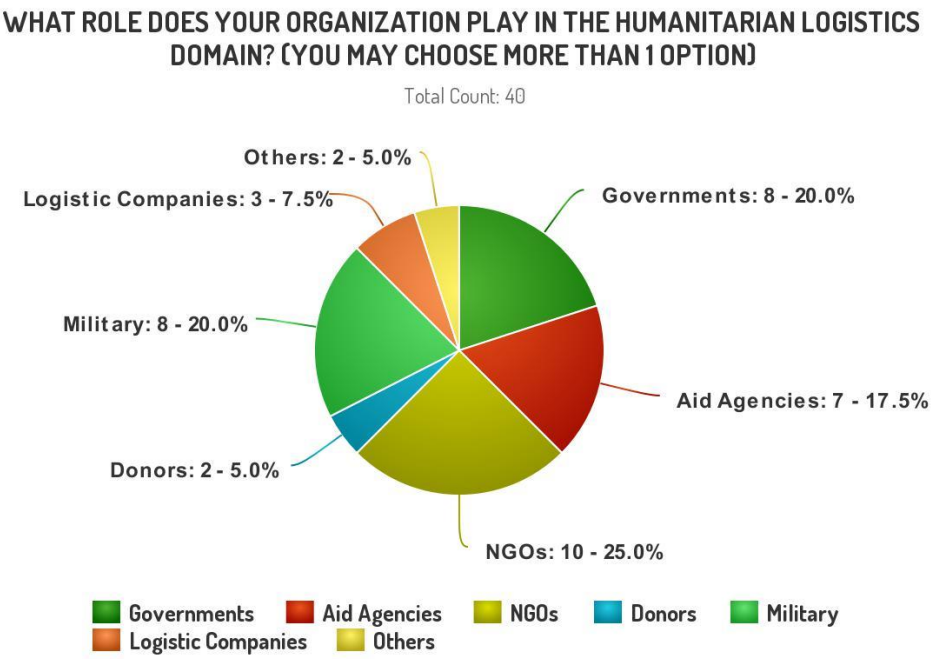



**Figure 4.1: Pie Chart on Organizations and their Roles**

***Non-governmental Organizations (NGOs)***

The NGOs groups was the strongest represented group (25%). It is important to note that the survey allows the respondents to select more than 1 option. This factor considers the multiple roles some organizations may undertake, in their contributions toward humanitarian operations.

NGOs can be defined as any non-profit, voluntary citizens' group organized at a local, national, or international level, and can be temporary setups or permanent establishments (Cozzolino, 2012). NGOs are an essential group of key players in the Humanitarian Relationships Model as they perform a variety of services and functions in contributions to humanitarian efforts. Through data collected from the surveys, it was observed that the common types of operations the NGOs provided include:

- Disaster management teams
- Disaster preparation, trainings and technical assistance
- Food and shelter support
- Materials provision and support
- Key installation and infrastructure support
- Medical and livelihood support
- Financial support
- Logistics support
- Procurement

***Military***

The second highest represented group were the Government and Military group (each accounted for 20% of total respondents). Strongly affiliated to Governments, militaries are essential in supporting humanitarian relief operations as soldiers are called upon to provide emergency assistance such as hospital and camp installation, telecommunications set up, and providing route repairs (Cozzolino, 2012). The military also serves as important actors in the Disaster Management Cycle (DMC) thanks to their high planning and logistic capabilities. Common types of operations provided include:

- Food and shelter support
- Medical and livelihood support
- Key installation and infrastructure support
- Transportation support

***Government***

Tied to second place as well is the Government group (20%). Governments include host governments, neighboring country governments, and other country governments within the international community. The group can be defined as the activators of the humanitarian logistics stream after a disaster occurrence as they have the power and authority to sanction operations and mobilize resources. Identical to the Military group, common types of operations provided include:

- Food and shelter support
- Medical and livelihood support
- Key installation and infrastructure support
- Transportation support

***Aid Agencies***

The third highest represented group by the respondents was Aid Agencies (17.5%). Aid Agencies can be defined as actors through which governments are able to alleviate the suffering caused by disasters (Cozzolino, 2012). Some examples of large aid agencies recognized by the United Nations (UN) include United Office for the Coordination of Humanitarian Affairs (OCHA), World Food Programme (WFP) and (World Health Organization (WHO), among many others (Tradecommissioner.gc.ca, 2018). Common types of operations provided include:

- Food and shelter support
- Medical and livelihood support
- Key installation and infrastructure support
- Materials provision and support
- Disaster preparation, trainings and technical assistance

***Logistics companies***
Only 3 out of the 30 respondents indicated themselves as Logistics Companies (7.5%). Logistics companies are also essential key players in the relationship model as they provide logistical support at each stage of the disaster-relief operation through their logistics and supply chain management core capabilities (Cozzolino, 2012). Operations provided include:

- Transportation support
- Goods and supplies support
- Supply chain services support

***Donors***
Donors can generally be identified as entities who provide donations by means of giving financial means (in-cash donations) to support humanitarian operations; or provide goods and/or services for free (in-kind donations) while performing logistics operations (Cozzolino, 2012). However, since each player within its own specific role can provide in-kind donations, we shall refer to the term "Donors" in the model as those who exclusively give financial means to fund aid operations. Only 2 out of the 30 respondents (5%) represented themselves as a donor. Operations provided include:

- Cash provision to aid relief distribution

***Others***
Lastly, also represented by 2 out of the total 30 respondents (5%) is the Others group. Cozzolino (2012) discussed that these other companies can include a wide range of service providers, such as providing engineering support, banking support , postal services and etc. Essentially, these companies normally contributed to the humanitarain efforts because of the economic impacts observed and they work to allievate these losses. However, there is also another form of "Others" companies that was captured by the survey data. The two "Others" respondents were identified to support mainly in the education and consultancy services of disaster relief and operations. Operations provided included:

- Consultancy/training to stakeholders in humanitarian logistics domain
- Education services to enhance disaster preparedness
- Goods and supplies donation

## *4.2 Key players in the Disaster Management Cycle (DMC)*
Data was also collected to gather information on the phases that the respondents played in the Disaster Management Cycle (DMC). Figure 4.2 provides an insight on the share of participation in each of the four phases.

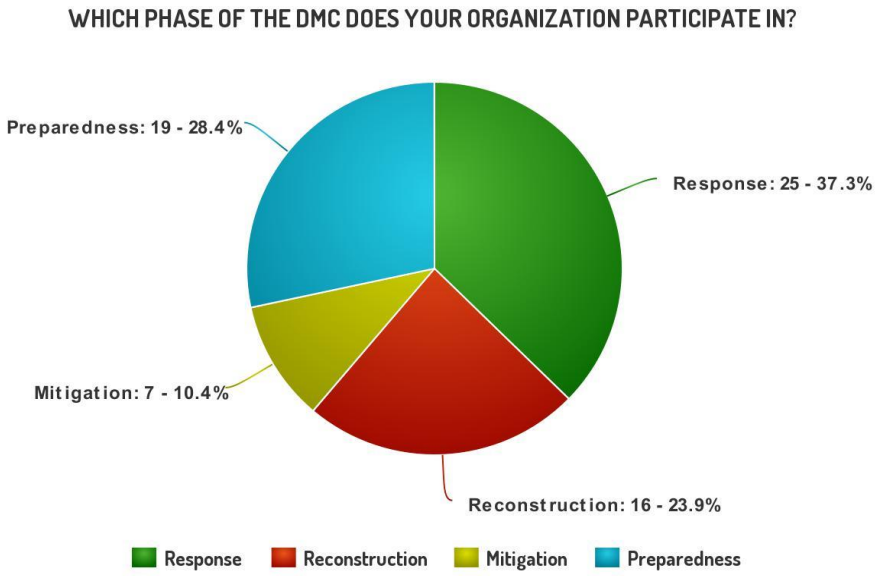



**Figure 4.2: Pie Chart on Key Players in the DMC**

***Response Phase***

The response phase refers to the various types of operations that are instantly implemented or conducted after a disaster occurs. This phase may be split into two sub-phases namely: Immediate Response and Restore. Immediate Response refers to the immediate response based on temporary structures or processes, while Restore refers to the restoration of basic services and delivery of goods to as many beneficiaries as possible in the quickest time possible. Coordination and collaboration between key players are critical in this phase. Shown in Figure 4.2, the response phase is the highest participated phase by the respondents (37.3%). Correlating with data gathered from Question 1 of the survey, it was observed that the most represented key player group in this phase was the NGOs.

***Reconstruction Phase***

The reconstruction phase refers to the various operations involved in the aftermath of a disaster. This phase involves rehabilitation aspects and aims to address issues or problems from the disaster from a long-term perspective. Data gathered showed that 23.9% of the respondents participate in the reconstruction phase. Correlating with data gathered from Question 1 of the survey, it was observed that NGOs was also the highest key player group represented in this phase.

***Mitigation Phase***

The mitigation phase refers to the laws and mechanisms in place to reduce social vulnerability from disasters. These processes are also known to be related to the responsibilities of governments. Data gathered showed that only 10.4% of the respondents indicated that they participate in the mitigation phase. Correlating with data gathered from Question 1 of the survey, it was observed that both Aid Agencies and NGOs represented the highest groups in this phase.

***Preparedness Phase***

The preparedness phase refers to operations that occur during the period before a disaster strike, with the aim of avoiding the gravest possible consequences of a disaster. This phase is crucial because it is the phase in which the physical network design, information and communications technology systems, and the bases for collaboration are developed to ensure successful operational responses (Cozzolino, 2012). The preparedness phase also incorporates efforts made between disasters in learning and adapting from past experiences to meet new possible challenges. Data gathered showed that this phase was the second highest participated phase (28.4%), with the NGOs as the highest represented group in this phase.

### *4.3 Challenges faced in humanitarian relief operations*

During the data collection phase, it was observed that there was a wide range of challenges faced across the various types of relief operations provided by the seven identified groups of key players in the Humanitarian Relationships Model. In efforts to enable a more concise and focused data presentation, the consolidated raw data was correlated and validated with both primary and secondary sources, before subsequently categorized into the eight types of common challenges faced in conducting humanitarian relief operations as presented in Figure 4.3.

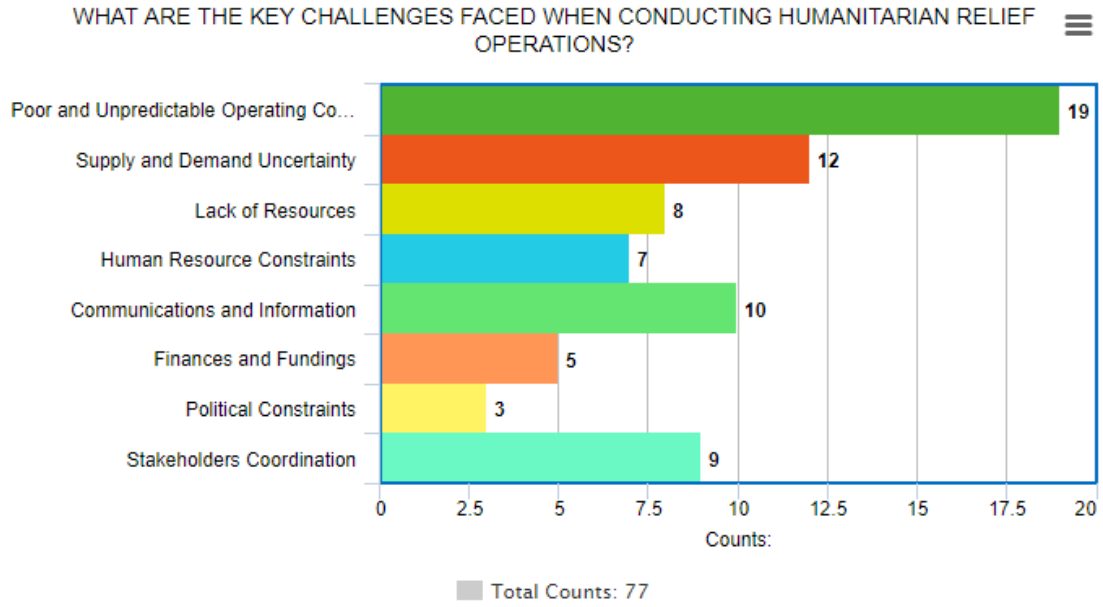



**Figure 4.3: Bar Chart on Key Challenges Faced in Relief Operations**

Further analysis was conducted on the top three key challenges highlighted by the thirty survey respondents. They include: Poor and Unpredictable Operating Conditions (26%), Supply and Demand Uncertainty (16%), and Communications and Information (14%).

***Challenge #1: Poor and Unpredictable Operating Conditions***

With a total of 19 counts, poor and unpredictable operating conditions account for the highest challenge faced in humanitarian relief operations (26%). Poor operating conditions can often be referred to as operation challenges due to poor infrastructure support due to damaged roads, facilities, airports, ports etc. These causes problems when conducting relief operations as it hinders logistical processes such as transportation routes and even more severe cases such as inaccessibility to resources and equipment. For example, shipments may be inaccessible due to lack of receiving ports or damaged roads, which contributes to shortage of critical relief aids reaching the crisis site. Unpredictable operating conditions could also mean that relief workers cannot be fully prepared to answer to the disaster as they may be unsure on the types of equipment, aids and assets to bring or ident. They may also have difficulty strategizing their operation processes as different disasters carry along different types of damages, destructions and consequences. Coordination among the different stakeholders may mean even more crucial under such circumstances as last-minute plans or preparations may need to be activated in order to work around these unpredictable operating conditions, in order to adequately meet relief timelines.

***Suggested Methods to Overcome Challenge #1***

One potential method of overcoming this challenge is to provide adequate training for the humanitarian workers and organizations. With platforms to enable sharing, experiences and best practices can be shared by experts who have worked in disaster relief operations on what to expect when responding to the different types of disasters. This helps to enhance disaster preparedness

across the entire humanitarian relationship model. Another possible method is to conduct vulnerability assessments, which supports information sharing and forecast preparations. To conduct vulnerability assessments, organizations can send assessment teams into an affected region with known vulnerabilities to record the state of infrastructures, local response capabilities, and current status of the affected population. These assessments can also be value-added by technologies such as building overlays in a Geographic Information System (GIS), or even through advanced technology such as imagery support from satellite imagery. This valuable information can also guide the humanitarian agencies in planning alternate transportation routes and setting up of warehouses and aid facilities.

***Challenge #2: Supply and Demand Uncertainty***

Supply and demand uncertainty rank as the second most common challenge faced in relief efforts (16%). Much alike to commercial supply chains, supply and demand uncertainty can cause fluctuations such as bullwhip effects, in both the upstream as well as downstream supply chain efficiency levels. However, in the context of humanitarian logistics, supply and demand uncertainty causes even larger problems as they can be decisive factors to critical life and death situations. Uncertain or unpredictable supply can cause issues such as inconsistency in quantity and quality of relief aids, as well as inconsistent lead time which also leads to late distribution of aids or resources. Uncertainty in demand may be caused by the unknowns as to the what, where, when or how much aid is required in response to a specific crisis or disaster. Even with algorithms aided forecasting and assessments, demand uncertainty still poses challenges in humanitarian relief efforts today if organizations lack adequate disaster preparedness such as safety stock management, flexibility and agility measures.

***Suggested Methods to Overcome Challenge #2:***

One key method to overcoming supply and demand uncertainty in any supply chains is to achieve a good balance of the push and pull strategy within the relief chain. Figure 4.4 shows an illustration on how we can use the push/pull strategy to predict the unpredictable.

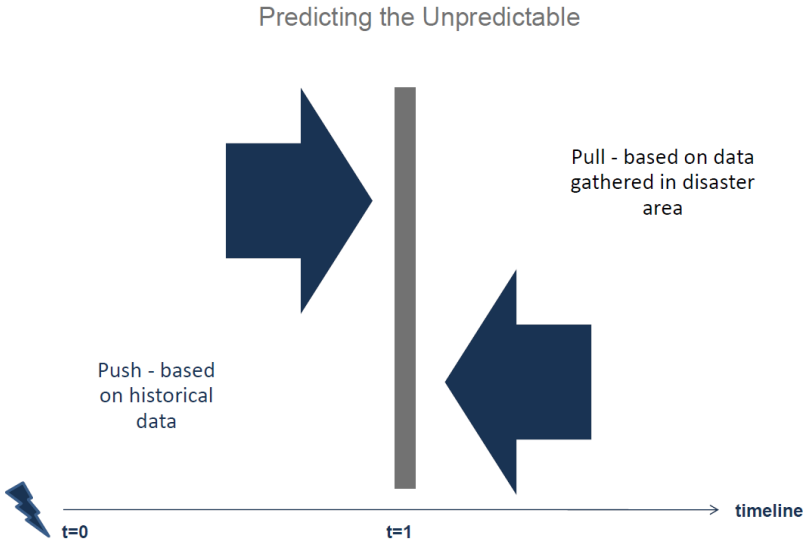



**Figure 4.4: Using the Push/Pull Strategy to Predict the Unpredictable (Souce: Everywhere et al., 2011)**

A push-based supply chain strategy works by having production or distribution based on historical data. In humanitarian logistics, this may mean that upon a disaster reaction, relief supplies are pushed to consumers without the needs clearly defined and met. Relying too much of a push-based supply chain strategy may also cause problems such as the inability to meet changes in demand patterns, inefficient deployment of relief efforts and higher inventory needs. A pull-based

supply chain strategy works when production and distribution are demand driven, where quantities are determined at the point of consumption and the needs are more clearly defined and met. With a pull-based strategy, HROs can achieve higher levels of efficiency as there are less wastages, lower inventory needs and more effective efforts to meet the clearer defined needs of the consumers. However, relying too much on a pull-based strategy also presents problems such as inability to meet sudden demand surges and longer lead times, which are critical to humanitarian relief efforts.

It is therefore recommended that HROs adopt a push/pull based supply chain strategy. This strategy recognizes the need for both push and pull, with the push system employed upon immediate disaster response due to the need for assumptions on the types and quantities of aid that should be applied. Thereafter, once the response teams are in place at the disaster site, the supply chain strategy can then be transited from a push to pull system based on more accurate needs assessments on ground. With the essential information and data available for the on-ground crew as well as the manufacturers, the supply chain can now be managed in a more synchronized manner to achieve a good balance between the push and pull strategies. Essentially, the concepts of Supply Chain Management (SCM) methods can help to minimize the effects of uncertainty through the focus on reducing performance variability of the functions involved in a relief supply chain. This can be achieved through information sharing to enable more accurate forecast of supply and demand, and though strong collaborations among the partners and key players in the humanitarian logistics domain.

***Challenge #3: Communications and Information***

Challenges related to Communications and Information present itself as the third common challenge faced in relief efforts (14%). Challenges in this category often include communication problems such as differences in communications or culture, lack of information sharing or accessibility, and poor reliability of information. These issues are also often interlinked with other categories of challenges. For example, the lack of a synchronized and interlinked electronic data interchange may cause inconsistencies in terminologies or references used, resulting in accuracy of information which ultimately leads to stakeholder coordination issues. The lack of information sharing also restricts different stakeholders or agencies to have a common "big picture", so different agencies may work at different paces or even worse, performing their roles with misaligned objectives or references. The lack or inaccessibility of information also causes supply and demand uncertainty, which in turn leads to unnecessary delays along the humanitarian supply chain and ineffective disaster relief operations.

***Suggested Methods to Overcome Challenge #3:***

The employment of Logistics Information Systems (LIS) and frameworks such as the Collaborative, Planning, Forecasting and Replenishment (CPFR) can be employed to tighten the gaps in communications and sharing of information within the humanitarian key players. The effective utilization of LIS such as the Disaster Resource Network operated by the World Economic Forum (WEF) and the Relief Web operated by the United Nations (UN) are some good examples of employing technology to enable effective communications and information sharing. These platforms can help in humanitarian efforts by serving as electronic data interchanges (EDI) to provide benefits such as: improved accuracy due to less manual processing, increased speed of information transfer, reduced administrative manpower requirements, reduced paperwork, reduced ordering costs, increased employee productivity, better inventory accuracy and order response leading to reduced inventory levels (Stock and Lambert, 2001). Players in the CPFR participate in demand planning using shared data, execute unified production or service response outlined during joint capacity planning, and finally fulfil consumer need in a coordinated and comprehensive response (Coyle and others, 2003). With the key players exercising CPFR, they can better anticipate a demand and form a unified reaction because the doctrine and implantation tools are readily understood and accessible (Rodman, 2004). This ideology is very similarly aligned to the objectives of HROs and should be explored to create a form of information sharing

platform between the key players in the Humanitarian Relationship Model to enable collaboration and create more synergy by aligning their strategic goals and objectives to provide swift, efficient and effective relief operations. The exploration of LIS and CPFR in humanitarian logistics can also help to enhance information management across the agencies involved in the humanitarian clusters. Through more effective information sharing, the agencies will be able to strengthen their workflows and interoperability to enable comprehensive and effective disaster relief operations.

## *4.4 SCOR and AHP approach*

During data collection phase, data was gathered to validate the SCOR metrics discussed in our review, based on the respondents' insights and experiences in the humanitarian logistics domain. Respondents were required to provide their inputs on two judging factors regarding the 26 identified performance metrics. The first factor was the Level of Importance, and the second factor was the Difficulty of Implementation. This allowed us to gather ground-up sensing on the users' priorities as to how much they value each of the performance metrics in terms of importance and feasibility using the coupled five-point Likert Scale also previously discussed in literature review.

**Individual approach**

The SCOR and AHP methodology approach was first conducted using an individual approach on Subject A. This meant that the initial 26 performance metrics were first filtered and selected, based on the inputs of an individual respondent. Thereafter, the selected performance metrics were constructed into pair-wise comparison survey, where the subject indicated his priorities necessary for the AHP analysis. Figure 4.5 shows how the 26 performance metrics were grouped into the SCOR Validation Matrix.

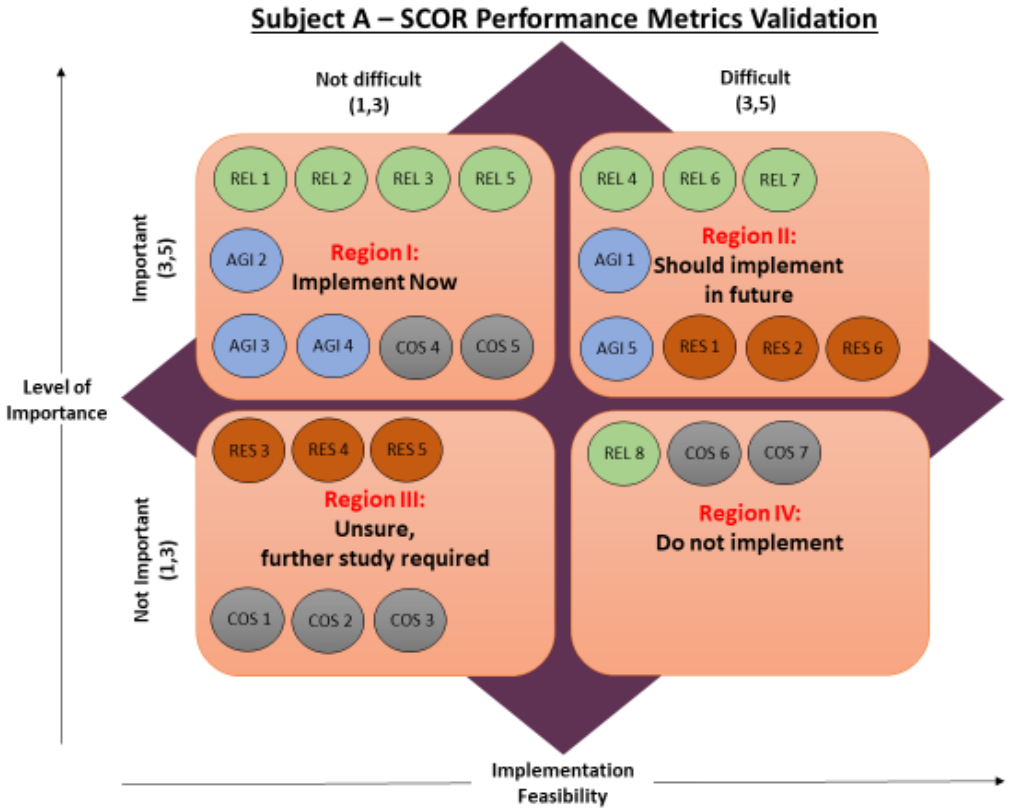



**Figure 4.5: SCOR Validation Matrix**

As shown in the validation matrix, the 26 performance metrics discussed in the survey were categorized into the four regions based on the two factors, level of importance and implementation

feasibility. The significance of each factor was discussed in literature review. For the context of this research project, only the performance metrics filtered into Region I: Implement Now, were focused on to conduct further analysis using the Analytical Hierarchy Process (AHP) methodology. Performance metrics filtered into this region are identified as important but not difficult to implement and thus, should be implemented as soon as possible, considering the possible immediate benefits it could bring to the organization's current operations. Table 4.1 shows the definition of the selected performance metrics and the main criteria category they fall under.

**Table 4.1: Selected SCOR Criteria and Sub-criteria**

| SCOR Metric Criteria | SCOR Metric Sub-criteria | Definition | Formula |
|---|---|---|---|
| **Reliability** | REL 1: Percentage Order Fulfilment | Measures overall reliability of the relief supply chain by measuring the percentage of orders fully consistent to requirements with complete and accurate documentation. | (Total perfect orders) / (Total number of orders) X 100% |
| | REL 2: Orders Delivered in Full Percentage | Measures chain reliability by percentage of orders which meet customer requirements on quantity and accuracy. | (Total number of orders delivered in full) / (Total number of orders) X 100% |
| | REL 3: Delivery performance to customer commit date | Measures the timeliness of the relief supply chain by the percentage of orders fulfilled on the customers' committed date. | (Total number of orders delivered within scheduled date) / (Total number of orders) X 100% |
| | REL 5: Perfect Condition of Orders Percentage | Measures chain reliability by the percentage of orders delivered in full undamaged state that meets specifications and accepted by customers. | (Total number of orders delivered in perfect condition) / (Total number of orders) X 100% |
| **Agility** | AGI 2: Upside Source Flexibility | Measures chain agility of the sourcing process by the number of days required to achieve an unplanned sustainable 100% (general benchmark) increase in quantity supplied. | Maximum value of (Receipt date of order in which quantity increases by 100%) – (PO date of order in which quantity increases by 100%) |
| | AGI 3: Upside Delivery Flexibility | Measures chain agility of the delivery process by the number of days required to achieve an unplanned 100% increase in quantity delivered. | Maximum value of (Order delivery date in which quantity increases by 100%) – (Date of ordered items ready for delivery in which quantity increases by 100%) |
| | AGI 4: Current On-hand Inventories | Measures chain agility by defining all current on-hand inventories, including safety stock required to sustain current order fulfilments. | Sum of all items currently in warehouses |

| | | | |
|---|---|---|---|
| **Cost** | COS 4: Cost to Manage Product Inventory | Measures the balance between costs associated with inventory keeping while achieving agility and responsiveness. | Sum of all costs on activities for store, including warehousing operating cost, rental cost, and manpower cost |
| | COS 5: Cost to Deliver | Measures the total costs to manage the delivery process. | Sum of all costs associated with the delivery process such as outbound transportation costs |

Following which, a face-to-face interview was conducted with Subject A to validate the findings obtained so far, before moving on the next phase of analysis using the AHP methodology.

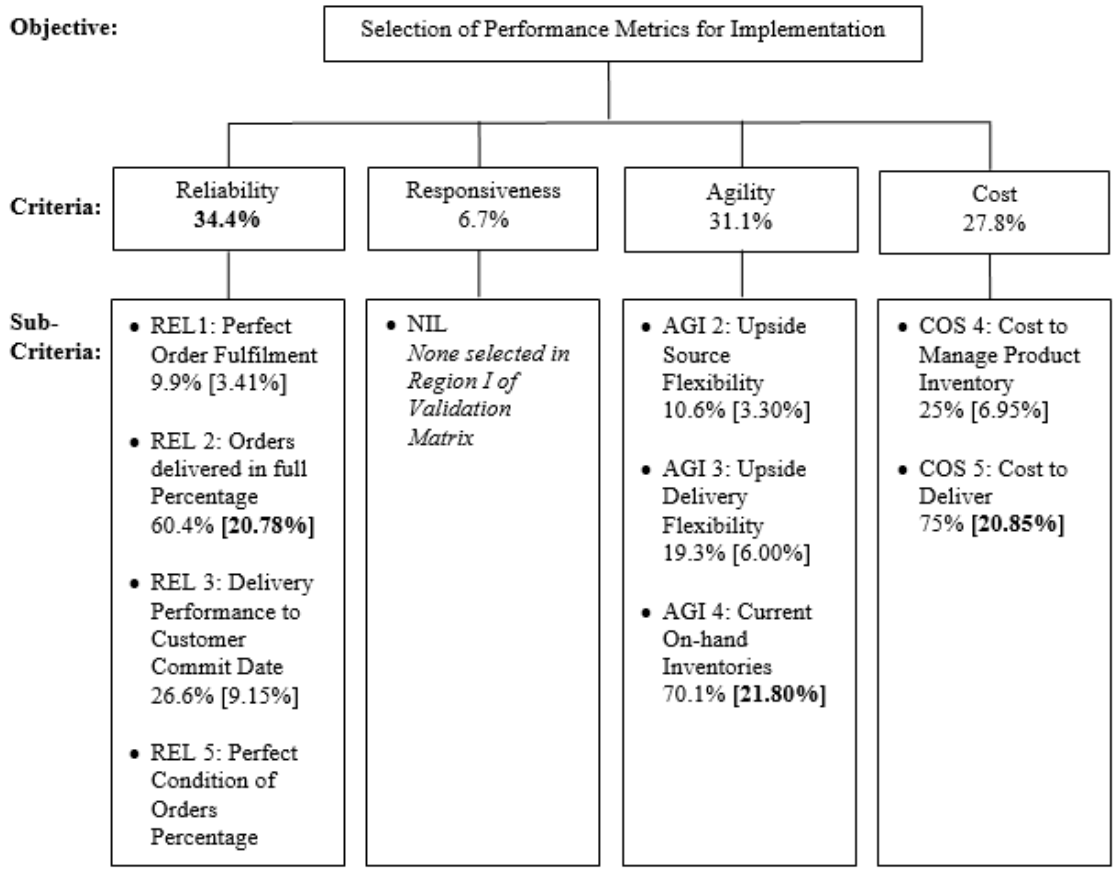
***Application of the AHP Model***

AHP methodology is a multi-criteria decision-making tool that allowed the decision maker to set priorities before selection of the best decision. In this research paper, the decision was to select the appropriate performance metrics for implementation, so that current relief supply chain processes can be evaluated to identify short comings for further improvements to ultimately enable more efficient and effective disaster relief operations.

After the pair-wise comparisons were completed, the relative weights for each element were determined. The final derived weights for the four criteria are: Reliability (34.39%), Responsiveness (6.65%), Agility (31.12%) and Cost (27.85%). In the AHP methodology, consistency is also key to ensure sound decisions are made. This consistency is measured by calculating a consistency ratio (CR) and comparing it with the consistency index (CI) of the subject matrix versus the consistency index of a random-like matrix. In this case, the CR was calculated to be 2.5% at CI value of 0.9 (n=4). As the CR of 2.5% is less than 10% (alpha 0.1), it can be assumed that the judgements matrix in question is reasonably consistent and acceptable to continue the AHP analysis.

***Pair-wise Comparisons and Computation of Weights (Sub-criteria)***

The pair-wise comparisons and computation of weights were repeated for the selected nine performance indicators (sub-criteria), with the pair-wise comparison input by Subject A. After successful calculations for the weights of all nine sub-criteria, the values were adjusted according to the weights of the main criteria. Figure 4.6 shows the suggested decision-making model to select the appropriate performance metrics.




*Note: Weights displayed in square brackets have been adjusted in proportion to weights of respective main criteria.*

**Figure 4.7: Final weights for Decision-making Model**

As shown in the decision-making model, Reliability carried the highest weight among the four criteria (34.4%), followed by Agility (31.1%), Cost (27.8%) and finally Responsiveness (6.7%). Among the sub-criteria, REL 2: Orders delivered in Full Percentage carried the highest weight under the Reliability criteria category (20.78%), while AGI 4: Current On-hand Inventories was the highest under Agility criteria (21.80%) and COS 5: Cost to Deliver as the highest under Cost criteria (20.85%). Ultimately, this allows the decision maker to have a clearer idea on his preferences and priorities among the considered alternatives and make the best possible decision with the help of these values. Depending on the organization's current capabilities, the decision could be made to focus on the highest weight among the sub-criteria performance metric (AGI 4: Current On-hand Inventories); or to focus on the top weighted sub-criteria under each main criteria category (REL 2: Orders Delivered in Full Percentage, AGI 4: Current On-hand Inventories and COS 5: Cost to Deliver), if the organization was confident they have the resources and capabilities to cope with the expected workload required.

Based on the calculations, it was observed that Reliability was weighted the highest (44%), followed by Responsiveness (29.4%), Agility (17.7%) and lastly, Cost (8.9%). This result helps to represent the overall sentiments and preference based on a sample group of 3 participants on the four main SCOR criteria discussed. It was also observed that the results presented a 5.6% CR which was less than 10% (alpha 0.1), so that the values can be assumed to be reasonably consistent and acceptable to continue the AHP analysis. Based on interviews conducted with the three Military participants, we could assess that Reliability was commonly weighted the highest due to the culture of an armed force, where protocols, standard of operations and safety are highly

regarded. This also signifies the high expectations on operations reliability that the participants have for their involvement in humanitarian relief operations to achieve overall mission success. On the other hand, Cost was weighted the least and this is probably because the usual mission focus was not on providing or procuring the relief aids or materials; and that the costs to manage inventory are normally kept low with inhouse manpower and resources available. Instead, these aids are understood to be normally donated or sourced via other Government agencies. Thus, the focus from this group of participants would revolve around more on the types of operations they could provide using their own equipment, vehicles or expertise to ensure that right quantity and quality of relief aids reach the crisis site on time.

## 5. Conclusion

With the data collected from 30 valid responses, the study was able to better understand the different types of key players in the Humanitarian Relationship Model, their roles and the key challenges they faced when responding to natural disasters around the world. It was observed that the top three key challenges that the respondents faced included issues related to poor and unpredictable operating conditions, supply and demand uncertainty, communications and information. With the data gathered, the study was also able to propose and conduct the SCOR framework and AHP methodology to help respondents prioritize their current processes, before making decisions to evaluate and improve upon selected performance metrics based on their priority weightages.

Based on the experiences from this research project, the SCOR validation and AHP methodology approach have proved to be a systematic approach to multi-criteria decision-making problems; and is applicable for both individual as well as sample group initiatives. Having the participants provide their inputs on the criteria and sub-criteria considerations, the approach was able to scrutinize, identify and propose ideal alternatives for an organization to make sound decisions. In this case, for organizations to make decisions on the performance metric(s) to focus their evaluation and efforts on, so that current processes can be evaluated and enhanced to achieve improvements in the quickest possible time. The consistency ratio also helps organizations to serve as a guide to ensure acceptable consistency readings before proceeding with more in-dept comparisons or final decision makings.

In summary, the research project was able to better identify the types of key players and their roles in humanitarian logistics, understand the key challenges they faced, validate these pieces of information through deeper correlation and analysis with literatures reviews and interviews; before providing suggestions and recommendations on how to overcome these challenges and further enhance current humanitarian relief operations.

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