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Structural analysis of the challenges in operating pre-positioned warehouses for humanitarian relief logistics

Saeyeon Roh* · Dong-Wook Kwak**

〈Abstract〉

Purpose : Operating pre-positioned warehouses for humanitarian relief logistics is often considered to be a high-risk strategy despite its advantages regarding the ability to respond to crises more rapidly. This study aims to analyze the critical challenges involved in operating such facilities to understand how such challenges arise, interact, and amplify.

Research design, data, and methodology : An interpretive structural modelling (ISM) method integrated with empirical data collection is adopted to analyze seventeen representative challenges. These are deemed to be isolated as primary threats to the efficient management of pre-positioned warehouses, but are interpreted by examining their interconnectedness in a graphical model.

Results : The ISM-based model shows that the challenges are split into three groups, namely: disturbances in humanitarian relief, issues with logistics decisions, and disruptions by external factors. Elements in the second group are exacerbated by two self-enhancing loops of interactions mainly focused on high transport costs.

Conclusions : This study provides insights into the benefits and disbenefits of operating pre-positioned warehouses, which will improve the effectiveness of the pre-positioning of aid for humanitarian logistics.

Key words : humanitarian logistics, relief logistics, pre-positioned warehouse, interpretive structural modelling

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국제 구호물류창고의 운영 개선을 위한 구조적 분석 연구

노 세 연[*] · 곽 동 욱[**]

〈국문초록〉

인도적 구호물류에서 사전배치창고를 운영하는 것은 재앙적 사건의 발생에 빠르게 대응할 수 있다는 장점에도 불구하고 위험이 높은 전략으로 종종 인식되고 있다. 본 연구에서는 사전배치창고 운영상의 중대한 난맥에 대해 분석함으로써 그러한 난맥이 어떻게 발생하고 상호작용하며 확대되는지 이해하고자 한다. 이를 위해 실증적 자료 분석이 가미된 해석적 구조분석(ISM)을 이용하여 17개의 대표적 운영상 난맥을 분석한다. 17개의 요인은 사전배치창고의 운영을 독립적으로 저해하는 것으로 알려져 있지만, 본 연구는 이들의 연결성을 도식화된 모형을 통해 나타낸다. 분석 결과 운영상 난맥은 3개의 그룹, 즉 인도적 구호의 방해, 물류 결정 관련 문제, 외부적 요인에 의한 차질로 나누어진다. 여기서 물류 결정 관련 문제 그룹은 높은 운송 비용을 중심으로한 두 개의 자기확장적 순환에 의해 악화된다는 것을 보여준다. 본 연구는 사전배치창고 운영의 장점과 단점에 관한 통찰력을 제공하여 구호물자의 사전배치 시 효과성을 증대시키는데 일조할 수 있을 것이다.

주제어 : 인도적 물류, 구호물류, 사전배치창고, 해석적 구조분석

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Ⅰ. Introduction

1. Research Context

The objective of emergency response is to provide assistance in the form of shelter/food/drink, medical supplies and other requisite items or services to the victims of disasters as soon as possible after an emergency occurs. The ultimate goal of humanitarian relief logistics is to deliver the right supplies in the right quantities to the right locations at the right time, so save lives and reduce human suffering within given financial constraints[1]. A particular area of interest, from which this goal can be achieved, is that of the pre-positioning of emergency supplies based on a combination of historical patterns of need and projections of future emergencies.

Pre-positioning is not a new concept, as military organisations have adopted this strategy for a number of years. However, stock pre-positioning is emerging as a focal point of research, especially in the context of emergency response[2]. Pre-positioned warehouses at strategic locations are essential for the purpose of ensuring the availability of supplies when required and to facilitate faster responses. It has been suggested that, in the long run, such an approach leads to the reduction of delivery costs by regular replenishment using relatively inexpensive maritime transport as far as possible[3].

However, some non-governmental organisations (NGOs) might find it difficult to operate pre-positioned warehouses because such approaches are complicated both to organise and to operate, and the expense of funding premises for most NGOs constitutes an additional barrier. Indeed, the operation of pre-positioned warehouses entails important decision-making, especially around the trade-offs between high fixed costs to operate a facility for long-term benefits and high variable costs for emergency transport[4]. Apart from this decision making, the day-to-day operation of pre-positioned warehouses for humanitarian relief faces various challenges associated with, for example, inventory management, transport management, human resource

1) Beamon, B. and Balcik. B., "Performance measurement in humanitarian relief chains", *International Journal of Public Sector Management*, Vol. 21, No. 1, 2008, pp. 4-25.
2) Rawls, C.G. and Turnquist, M.A., "Pre-positioning of emergency supplies for disaster response", *Transportation Research Part B*, Vol. 44, 2010, pp. 521-534.
3) Choi, K.-Y., Beresford A.K.C., Pettit, S.J. and Bayusuf, F., "Humanitarian Aid Distribution in East Africa, A study in supply chain volatility and fragility", *Supply Chain Forum: An International Journal*, Vol. 11, No. 3, 2010, pp. 20-31.
4) Roh, S., Beresford, A.K.C., Pettit, S.J. and Harris, I., "The pre-positioning of warehouses at regional and local levels for a humanitarian relief organisation", *International Journal of Production Economics*, Vol. 170 (B), 2015, pp. 616-628.

management and inter-organisational relationships[5]. These challenges may be similar to those facing management of commercial warehouses, but the unique characteristics of humanitarian logistics, such as non-profit operational motives and extremely unpredictable demand place demands on humanitarian organisations which are often unique to a particular situation.

2. Research Objectives

In consideration of the possible trade-offs involving pre-positioned warehouses, this study aims to investigate the challenges in humanitarian relief operations relating to pre-positioned warehouses from the perspective of humanitarian aid organisations. Specifically, it focuses on how these challenges are generated, amplified and exacerbated by the interactions between various challenges within the management of humanitarian logistics environment. For this purpose, this study explores the main challenges facing pre-positioned humanitarian distribution centres, encompassing a mixed method approach to triangulate a published literature and interviews with the views of practitioners in humanitarian aid organisations. The interactions between identified challenges are mapped with the aid of a directed graph created by Interpretive Structural Modelling (ISM). As a consequence, the results of ISM can potentially help in understanding different groups of challenges and the root causes of the challenges in humanitarian relief logistics. Compared with studies focused on commercial distribution centres, less research has been conducted for humanitarian logistics aid distribution centres. To this end, this research provides a meaningful, valuable and comparatively novel study; it thus represents a significant addition to the literature on humanitarian relief logistics.

II. Literature Review

1. Humanitarian Relief Logistics

Humanitarian relief logistics is defined as "the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people."[6] The comparison between commercial and humanitarian

5) Tatham, P. and Christopher, M., "Introduction", *Humanitarian Logistics*, 2nd Edition, Kogan Page, London, 2014.

6) Thomas, A.S. and Kopczak, L., *From logistics to supply chain management. The path forward in the humanitarian sector*. Fritz Institute, 2005, p. 2.

supply chains has been studied from various perspectives. Humanitarian logistics, as well as business logistics, encompasses a range of activities including preparedness, planning, design, procurement, transportation, inventory, warehousing, tracking and tracing, distribution, recipient satisfaction bidding and reverse bidding, reporting and accountability, and customs clearance[7]. The basic principles of managing the flow of goods, information and finance that have been established by commercial logistics are also valid for humanitarian logistics[8].

However, humanitarian logistics is characterised by large-scale activities, rapid ramp-up, irregular demand and unusual constraints[9]. The problems can range from a lack of electricity supplies to limited transport infrastructure including 'controlled' environment with some minor variability (e.g. traffic congestion)[10]. Furthermore, the lack of support equipment extends beyond transportation-related assets to Information and Communication Technology (ICT) infrastructure[11].

Humanitarian aid organisations often face difficulties in establishing reliable transport routes and implementing effective logistics systems which can be affected by political instability, in-country infrastructure and the difficult terrains in which they often have to operate[12]. Most of the operations are carried out in an environment with destabilised or fragile infrastructure or weather delays to air or sea links[13]. Commercial logistics are usually planned in advance of demand and relatively well established, while relief logistical decisions are made within shorter time frames. Many businesses are driven by customers (demand) in commercial logistics, while humanitarian organisations are mostly accountable to donors (supply)[14]. The customers (aid recipients) have no choice and, therefore, 'true demand' is not created in humanitarian logistics[15].

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7) Widera, A. and Hellingrath, B., "Making performance measurement work in humanitarian logistics: the case of an IT supported balanced-scorecard", Haavisto *et al.* (eds.) *Supply Chain Management for Humanitarians: Tools for Practice*, Kogan Page, London, 2016.
8) Toyasaki, F., Arikan, E., Silbermayr, L. and Sigala, F., "Disaster relief inventory management: horizontal cooperation between humanitarian organisations", *Production and Operations Management*, Vol. 26, No. 6, 2017, pp. 1221-1237.
9) Beamon, B. and Kotleba, S., "Inventory modelling for complex emergencies in humanitarian relief operations", *International Journal of Logistics: Research and Applications*, Vol. 9, No. 1, 2006, pp. 1-18.
10) Kovacs, G. and Spens, K.M., "Identifying challenges in humanitarian logistics", *International Journal of Physical Distribution and Logistics Management*, Vol. 39, No. 6, 2009, pp. 506-528.
11) Widera, A. and Hellingrath, B., 2016, op.cit.
12) Beamon, B. and Balcik. B. 2008, op.cit.
13) Long, D.C. and Wood, D.F., "The logistics of famine relief", *Journal of Business Logistics*, Vol. 16, No. 1, 1995, pp. 213-239.
14) Tomasini, R.M. and Van Wassenhove, L.N., "Pan-American health organisation's humanitarian supply management system: De-politicisation of the humanitarian supply chain by creating accountability", *Journal of Public Procurement*, Vol. 4, 2004, pp. 437-449.
15) Kovacs, G. and Spens, K.M., 2009, op.cit.

2. Challenges of Pre-positioned Warehouse Strategy

In the initial days of the deployment phase, most of the critical supplies arriving at the site of a disaster are sourced from an organisation's global pre-positioned stocks. An important element of disaster response is to increase preparedness by prepositioning goods[16). This could not only secure delivery in the immediate response phase, but it also may reduce cost of transportation because alternative and cheaper transportation means can be employed[17). Cost is one of the reasons for pre-purchasing the supplies as they are able to purchase them at a reasonable price. Once a disaster occurs, demand increases dramatically and suppliers will often raise their prices in response. Relief organisations adapt the in-advance purchase strategy and then store in a pre-positioned warehouse to enable them to react quickly[18). Pre-positioned warehouses can thus be used as a risk-mitigating strategy which provides an emergency response to disaster threats considering uncertainty in demand for the stock supplies, as well as uncertainty regarding transportation network availability after the disaster event[19).

The fundamental difficulties in creating an effective pre-positioning plan follow the 'cascade' principle starting with the fundamental question of whether or not a natural disaster or human-triggered disaster will occur and, if it does, where and with what magnitude[20). Although pre-positioned stocks may be useful, they may be restricted or rationed as they require considerable financial investment. The pre-positioning of relief inventory is problematic because it requires high investment and holding costs due to uncertainty about the timing and location of next disaster[21). In addition, product expiry is a major problem influencing the quality of the relief goods, as there is unlikely to be inventory turnover between crises. Stockpiling time-limited supplies, for example medical supplies, for rare events would thus be expensive[22). In such cases, operating a pre-positioned warehouse could be viewed as financially prohibitive and there are only a handful of relief organisations which could support the expense of operating such 'speculative' distribution centres. Difficulties in finance also occur due to the funding systems in the sector and the costs associated with the operation of distribution centres[23). Donors often insist that their money is spent directly on

16) Roh et al., 2015, op.cit.

17) Jahre, M. and Heigh, I., "Does the current constraints in funding promote failure in humanitarian supply chains?", *Supply Chain Forum: An International Journal*, Vol. 9, No. 2, 2008, pp. 44-54.

18) Roh et al., 2015, op.cit.

19) Rawls and Turnquist, 2010, op.cit.

20) Rawls and Turnquist, 2010, op.cit.

21) Kunz, N., Reiner, G. and Gold, S., "Investing in disaster management capabilities versus pre-positioning inventory: A new approach to disaster preparedness", *International Journal of Production Economics*, Vol. 157, 2014, pp. 261-272.

22) Whybark, D.C., "Issues in managing disaster relief inventories", *International Journal of Production Economics,* Vol. 108, 2007, pp. 228-235.

tangible relief materials and helping victims rather than logistics equipment[24].

A warehouse would be of little or no use if it is damaged, destroyed or rendered inaccessible due to a disaster occurring in an area where strategic stock is held. Thus if strategic stock was held close to a crisis-hit area, the risk of damage or destruction or loss would be significantly increased. In this context, Rawls and Turnquist (2006)[25] and Ukkusuri and Yushimoto (2008)[26] modelled pre-positioned warehouse locations, assuming that the facility would not be destroyed/damaged by the disasters. On the other hand, Verma and Gaukler (2015)[27] provided location models taking the impact a disaster can have on the pre-positioned disaster response facilities into consideration. Including the size of storage facilities can be found in various pre-positioned facility location model s[28] which is a further critical challenge in decision-making process.

Some of the key supply chain elements in a pre-positioning strategy are infrastructure in the form of communications equipment, warehouses, offices and vehicles. Depot-held pre-positioned stocks and coordination procurement and framework contracts for resources and transport are also very important[29]. Not only do disasters themselves impact negatively on the physical infrastructure but inadequate infrastructure is also a common problem in developing countries, often exacerbated by infrastructural damage[30].

These considerations are very persuasive with the result that NGOs often tend to focus on operational disaster relief activities rather than disaster preparedness. Furthermore, Balcik and Beamon (2008)[31] suggest that some NGOs actually consciously avoid using a pre-positioning strategy because it is both complicated and expensive. They also indicate that the proportion of

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23) Balcik, B., Beamon, B., Krejci, C.C., Muramatsu, K.M. and Ramirez, M., "Coordination in humanitarian relief chains: Practices, challenges and opportunities", *International Journal of Production Economics*, Vol. 126, 2010, pp. 22-34.

24) Kovacs, G. and Spens, K.M., "Humanitarian logistics in disaster relief operations", *International Journal of Physical Distribution and Logistics Management*, Vol. 37, No. 2, 2007, pp. 99-114.

25) Rawls, C.G. and Turnquist, M.A., "Pre-positioning of emergency supplies for disaster response", *IEEE International Symposium on Technology and Society* 2006, Quuens, NY, USA, 2006.

26) Ukkusuri, S.V. and Yushimoto, W.F., "Location routing approach for the humanitarian prepositioning problem", *Transportation Research Record: Journal of the Transportation Research Record*, Vol. 2089, 2008, pp. 18-25.

27) Verma, A. and Gaukler, G.M., "Pre-positioning disaster response facilities at safe locations: An evaluation of deterministic and stochastic modelling approaches", *Computers and Operations Research*, Vol. 62, 2015, pp. 197-209.

28) Kelle, P., Schneider, H. and Yi, H., "Decision alternatives between expected cost minimization and worst case scenario in emergency supply – Second revision", *International Journal of Production Economics*, Vol. 157, 2014, pp. 250-260.

29) Jahre and Heigh, 2008, op.cit.

30) Pedersen, P.O., "Development of freight transport and logistics in Sub-Saharan Africa: Taffee, Morrill and Gould revisited", *Transport Reviews*, Vol. 23, No. 3, 2003, pp. 275-297.

31) Balcik, B. and Beamon, B.M., "Facility location in humanitarian relief", *International Journal of Logistics: Research and Application*, Vol. 11, 2008, pp. 101-121.

the demand or need that is actually met via pre-positioned inventory is generally much less than the total volume of supplies sent to the disaster region over the entire relief horizon. However, Cuckow (2006)[32] stated that, even though a changeover to operating a pre-positioned warehouse strategy increased logistics costs every year, more than 50% of the people in need were still reached. This proportion is acknowledged to vary considerably, however, depending on conditions and the detail of the emergency. Shortening logistics chains and response times are nonetheless key benefits of prepositioning[33].

〈Table 1〉 Challenges in operating humanitarian pre-positioned warehouses

Challenges	References
Uncertainty of disaster occurrences	Balcik and Beamon (2008), Balcik et al. (2010), Kunz et al. (2014), Oloruntoba and Gray (2006), Rawls and Turnquist (2010)
Financially prohibitive	Balcik and Beamon (2008), Salisbury (2007)
Needs for considerable financial investment	Chaikan (2003), Kunz et al. (2014), Thomas (2007)
Uncertain demand	Balcik et al. (2008), Barbarosoglu and Arda (2004), Beamon and Kotleba (2006), Cassidy (2003), Lodree and Taskin (2008)
Complicated operations	Balcik and Beamon (2008)
Restricted internal transport capacity	Salisbury (2007)
Funding tendencies	Balcik and Beamon (2008), Balcik et al. (2010), Duran et al. (2011), Kovacs and Spens (2007), Maon et al. (2009), Oloruntoba and Gray (2006), Sandwell (2011), Schulz and Blecken (2010)
Cost associated with operations	Balcik and Beamon (2008), Balcik et al. (2010)
Destroyed by disasters	Akgun et al. (2015), Bozorgi-Amiri et al. (2013), Galindo and Batta (2013), Rawls and Turnquist (2006), Ukkusuri and Yushimoto (2008), Verma and Gaukler (2015)
High inventory cost	Kunz et al. (2014)
Stock out	Kelle et al. (2014), Ozbay and Ozguven (2007)
Poor quality of goods	Whybark (2007)
Local staff quality	Kovacs and Spens (2009)
Instable situation of the country	Kayikci (2010)
High transport cost	Jahre and Heigh (2008), Kelle et al. (2014)
High warehouse management cost	Jia et al. (2007)
Stocking quantities	Balcik and Beamon (2008), Davis et al. (2013), Duran et al. (2011), Rawls and Turnquist (2010), Salmeron and Apte (2010)
Damage of infrastructure	Li et al. (2011), Ozdamar et al. (2004)
Inadequate infrastructure	Bookbinder and Tan (2003), Pedersen (2003)
Size of facility	Balcik and Beamon (2008), Kelle et al. (2014), Rawls and Turnquist (2010)

32) Cuckow, J., *Case study report: The effect of the IFRC regional logistics concept on the efficiency of relief item delivery for the population affected by the Yogyakarta earthquake*, International Federation of the Red Cross and Red Crescent Societies Logistics Department (IFRC Logistics): Geneva, Switzerland, 2006.

33) Roh et al. 2015, op.cit.

The specific challenges in operating pre-positioned warehouses in humanitarian logistics contexts are summarised in Table 1. This list of 20 challenges is not exhaustive, but it represents an attempt to try and integrate extant knowledge. However, as Mason-Jones and Towill (1999)[34] argued, reducing uncertainty is achieved by understanding and tackling the root causes inherent in each of the areas, and, equally importantly, how they interact with each other. This means that, rather than concentrating on individual elements that can lead to an increase in uncertainty, it is more important to understand the holistic picture by analysing the interactions which can take place between challenges. A limited number of studies focused on supply chain risk management have pursued a holistic and comprehensive understanding of supply chain risks, highlighting some of the causes of both short and long-term downtimes[35], and self-enhancing loops generated by information and relationship risks[36]. The same rationale can be applied to analysing the challenges facing the operation of pre-positioned warehouses in order to understand why pre-positioned warehouses are comparatively rare.

III. Methodology

In order to understand the issues pertaining to the location and operation of pre-positioned warehouses for humanitarian aid a series of interviews with practitioners were conducted. The objective was to identify the real challenges that stem from pre-positioned warehouse strategies and to develop a structural model which represented those challenges and helped in understanding the root causes of challenges in humanitarian relief logistics contexts.

This research thus investigated the specifics of the challenges in operating pre-positioned warehouses. It adopts Interpretive Structural Modelling (hereafter, ISM) to identify possible challenges and highlight how such challenges are interrelated, and to identify the root causes of those challenges. The main advantage of the application of

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34) Mason-Jones, R. and Towill, D.R., "Shrinking the supply chain uncertainty cycle", *Control*, September, 1998, pp. 17-22.

35) Pfohl, H.-C., Gallus, P. and Thomas, D., "Interpretive structural modeling of supply chain risks", *International Journal of Physical Distribution and Logistics Management*, Vol. 41, No. 9, 2011, pp. 839-859.

36) Kwak, D.-W., Sanchez-Rodrigues, V., Mason, R., Pettit, S. and Beresford, A., "Risk interaction identification in international supply chain logistics: developing a holistic model", *International Journal of Operations & Production Management*, Vol. 38, No. 2, 2018, pp. 372-389.

the ISM process is that it can effectively transform mental or conceptual models of a system into an analytic and visualised one[37]. Ultimately, the model can generate an understanding of a complex system in a graphical manner with interactions of, and hierarchies within, the elements[38]. In the context of Supply Chain Risk Management (SCRM) research, ISM has been used to identify the structure of risk elements in supply chains[39], risks in international logistics in general[40] and risk mitigation strategies[41]. This method, however, has not generally been applied to humanitarian logistics which often poses unusual strategic and operational challenges, and which thus requires a systematic analysis of the challenges. One exception was Singh et al. (2018)[42], who used ISM to analyse resilience in humanitarian supply chains.

ISM was identified as the appropriate methodology to use because ISM provides a robust method to analyse qualitative data by converting expert discussions into a graphical model after taking several analytic steps. This research will collect interview data to investigate how challenges are generated, interacted and amplified; for this purpose, ISM provides a robust analysis tool. This research used the stepwise ISM process comprising seven steps as suggested by Pfohl et al. (2011)[43] as shown in Figure 1.

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37) Vivek, S.D., Banwet, D.K. and Shankar, R., "Analysis of interactions among core, transaction and relationship-specific investments: the case of offshoring", *Journal of Operations Management*, Vol. 26, No. 2, 2008, pp. 180-197.

38) Sage, A.P., *Interpretive Structural Modeling : Methodology for Large-scale Systems*, New York, McGraw-Hill, 1977.

39) Pfohl et al., 2011, op.cit.

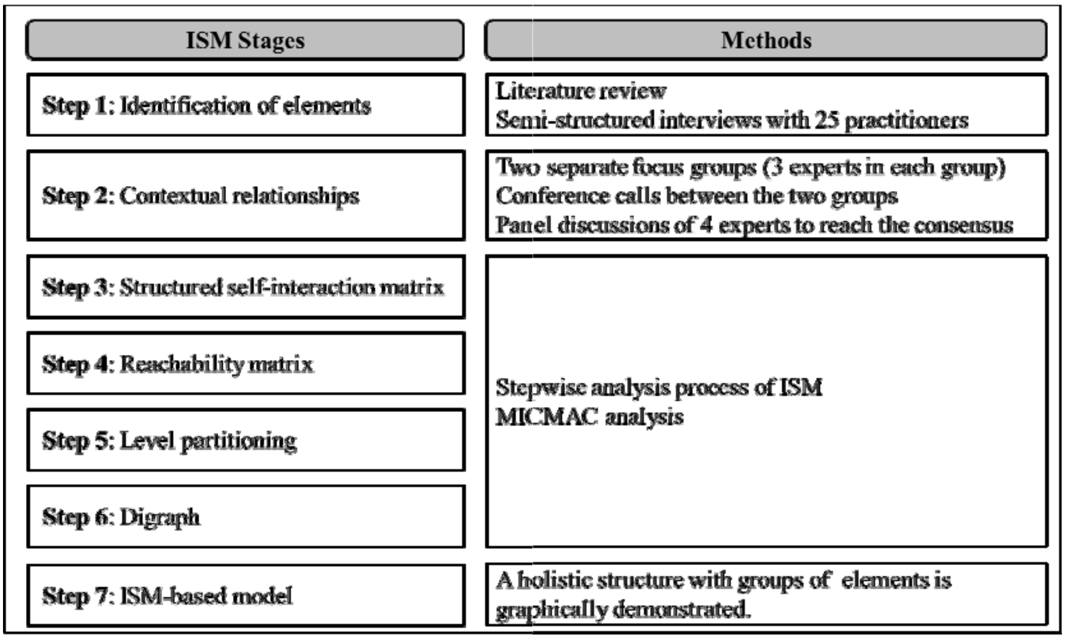
40) Kwak et al., 2018, op.cit.

41) Diabat, A., Govindan, K. and Panicker. V.V., "Supply chain risk management and its mitigation in a food industry", *International Journal of Production Research*, Vol. 50, No. 11, 2012, pp. 3039-3050.

42) Singh, R.K., Gupta, A. and Gunasekaran, A., "Analysing the interaction of factors for resilient humanitarian supply chain", *International Journal of Production Research*, Vol. 56, No. 21, 2018, pp. 6809-6827.

43) Pfohl et al., 2011, op.cit.

〈Figure 1〉 Applications of ISM process



The initial stage of the data collection for the ISM process was an in-depth literature review, conducted to identify any issues arising from the use of distribution centres and warehouses in a logistics system. The optimised number, location, design and operations of distribution centres has been one of the long-debated research topics in supply chain design and operations management research. In addition, there are many studies which reveal issues concerning pre-positioned warehouses for humanitarian aid logistics and from these, a preliminary list of challenges in stock pre-positioning was generated, as shown in Table 1.

For the second stage, semi-structured interviews were carried out with supply chain managers and officers in humanitarian aid organisations to refine and validate the challenges identified from the literature. 25 interviews were conducted, and each lasted around 1-1.5 hours. The objective of the interviews was to better understand the application of the pre-positioning strategy for the humanitarian organisation in broad terms and to confirm the unforeseen issues that may, or do, arise. Opinions of operating or planning officers regarding the pre-positioning warehouse strategy for humanitarian relief logistics were also confirmed or refuted.

For the selection of the interviewees, a snowball sampling method was adopted[44]. The United Nations directory at www.unhcr.org was used to contact experts who provided a list of humanitarian relief organisations operating pre-positioned warehouses. Invitations were sent to the organisations, from among which several logistics managers agreed to be interviewed. These managers recommended experts working in other organisations, thus increasing the number of interviewees. As a result, face-to-face, telephone and email interviews were conducted with 25 personnel at managerial or higher levels who had more than five years' experience in their organisations, as shown in Table 2.

〈Table 2〉 Profile of interview participants

No	Participant	Position	Method	Operating Base
1	United Nations 1	Senior Supply Officer	Face-to-Face	UAE
2	United Nations 2	Senior Supply Officer	Face-to-Face	UAE
3	United Nations 3	Logistics Officer	Email	Iraq
4	United Nations 4	Supply Officer	Email	Philippines
5	United Nations 5	General Manager	Email	Panama
6	United Nations 6	Logistics Manager	Email	Canada
7	United Nations 7	Fund Manager	Email	Ethiopia
8	United Nations 8	Supply Division Officer	Telephone	China
9	Int'l NGOs 1	Logistician	Face-to-Face	Korea
10	Int'l NGOs 2	Assc. Supply Chain Director	Face-to-Face	United Kingdom
11	Int'l NGOs 3	Supply and Logistics Manager	Email	Ireland
12	Int'l NGOs 4	Supply and Logistics Manager	Email	Zimbabwe
13	Int'l NGOs 5	Logistician	Email	Nepal
14	Int'l NGOs 6	Logistician	Email	Uganda
15	Int'l NGOs 7	Logistics Manager	Email	USA
16	Int'l NGOs 8	Senior Logistics Officer	Email	Zimbabwe
17	Int'l NGOs 9	Logistician	Email	Norway
18	Int'l NGOs 10	Logistician	Email	Zimbabwe
19	National NGOs 1	Logistician	Face-to-Face	Korea
20	National NGOs 2	Logistics Manager	Face-to-Face	Korea
21	National NGOs 3	Logistics Manager	Face-to-Face	Korea
22	National NGOs 4	Logistician	Email	Uganda
23	National NGOs 5	Logistician	Email	Zimbabwe
24	Governmental	Assistant Administrator	Face-to-Face	Korea
25	Governmental	Counsellor	Email	Sudan

One interview question related specifically to the objective of this research: "what are the challenges in operating pre-positioned humanitarian warehouses?" This question often led to an adjunct question: "why are some organisations reluctant to employ

44) Salganik, M.J. and Heckathorn, D.D., "Sampling and estimation in hidden populations using respondent-driven sampling", *Sociological Methodology*, Vol. 34, No. 1, 2004, pp. 193-240.

pre-positioning strategy?" The starting point for the interviews was the participants' experience in daily operations. Subsequently, the challenges identified based on the literature were presented to the participants who were asked to give their opinions. They were allowed to refine the challenges in the list, amend titles, add new ones or remove something irrelevant in the context of humanitarian logistics. Further email and video conference calls were made to confirm the factors that were identified, and the respondents were asked to give their opinions on the final list of elements.

For the last stage, contextual relationships between the identified elements were examined by the opinions of the 10 humanitarian logistics experts. These experts were chosen from those who participated in the previous interviews because they were involved in selecting and defining the elements. A three-round process was devised to ensure reliability and validity for deciding the contextual relationships among the elements. In the first round, two focus groups each of which had three participants decided pair-wise relationships between elements by reviewing whether one element directly leads to the other element. In the second round, focus group participants were invited to discuss the relationships where the views of the two groups were different. After sharing their rationale and reasons for their decisions, the discrepancies in the contextual relationships were significantly reduced. The third round asked for the opinions of four additional industry experts about the remaining discrepancies in the nature of the relationships from the previous two stages. Finally, several rounds of email exchange determined the final consensus regarding the status of each relationship.

IV. Analysis

The elements that constitute the challenges in pre-positioned warehousing were identified and then operationalized by means of triangulation. This involved combining the issues identified from the literature with the findings from the semi-structured interviews. The initial findings derived from the literature were validated during the interview process and a number of additional elements not previously highlighted in the literature were also determined. Thus, the interviews acted as a first-stage validation process.

1. Step 1 - Identification of Key Challenges

From the literature review and data collection process 17 key challenges were agreed by the interviewees as highlighted in the discussion below, and these are now discussed in detail. In order to facilitate analysis each element was labelled with a specific number which are used in the analysis, as can be seen in Table 3.

〈Table 3〉 Key challenges

No	Challenges	No	Challenges
1	High warehouse management costs	10	Stock out
2	High inventory costs	11	IT Breakdown
3	Uncertain demand	12	Dependency on Logistics Service Providers (LSPs)
4	Inability to determine stock levels	13	Stock deterioration
5	Lack of confidence in stock determination	14	Poor performance of LSPs
6	High transport costs	15	Local staff competencies
7	Difficulty in justifying funding warehouses	16	Natural disasters
8	Limited space	17	Warehouse security
9	Infrastructure		

2. Step 2 - Contextual Relationships

Once the 17 elements had been identified they were then combined together in pair-wise relationships, e.g. Element 1 with elements 2, 3, 4 …17, element 2 with element 3, 4, 5, …. 17, element 3 with element 1, 4, 5 ….17, and so on. Combining the 17 challenges results in 136 pair-wise relationships as shown. The contextual relationships between the 17 elements were determined from the opinions of the 10 humanitarian logistics experts as explained in Figure 1. Several rounds of discussions were held in order to eliminate any disagreements and inconsistencies in the 136 pair-wise relationships. As part of this process, the contextual type 'leads to' was selected in order to accurately assess the direct effects of one element on another. Participants were asked to use four letter identifiers: V, A, X and O, to describe each relationship. V was used when element i leads to element j, whilst A was used when i is led by j. O was assigned when there is no direct relationship between the two elements. On the other hand, if the two elements have a mutual relationship, i.e. in both directions, X was allocated to the entry.

3. Step 3 - Structural Self-Interaction Matrix (SSIM)

A structural self-interaction matrix provides a comprehensive view of contextual relationships by putting them in one single matrix. This was generated to represent these 136 contextual relationships in (i, j) entries with the identifiers V, A, X and O.

4. Step 4 - Reachability Matrix

There are two reachability matrices used in the ISM process: (1) an initial reachability matrix which shows the influence of one element on the other by binary numbers and (2) a final reachability matrix which further considers any indirect relationships (or transitivity) hidden in the SSIM and an initial reachability matrix.

An initial reachability matrix converted each (i, j) entry of the SSIM into binary numbers. When element i directly leads to element j, number 1 was put into (i, j) entry. If i didn't lead to j at all, 0 was assigned to the entry. Based on the initial matrix as shown in Table 5(a), a final reachability matrix was created by considering any transitivity or indirect relationships in the initial matrix. If there is any indirect relationship between element i and element j mediated by element k, the (i, j) entry was filled with 1* instead of 0 to show transitivity. To take an example from Table 5(b), Element 6 did not have a direct effect on Element 1. However, since Element 6 will lead to Element 5, and in turn to Element 1, transitivity exists in the (6, 1) entry. In this case, 1* was assigned instead of 0.

The final reachability matrix produces a driving power and dependency for each element by counting 1 or 1* in each row and column. Driving power of a specific element can be measured by counting the number of elements that this element affected. On the other hand, dependency can be calculated by counting the number of elements that a specific element was affected. For instance, the sum of 1 and 1* in the first row of the final reachability matrix becomes the driving power of element 1 whilst the sum in the first column is dependency.

〈Table 4〉 Initial and final reachability matrices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
3	1	1	1	1	1	0	1	1	0	1	0	1	0	0	0	0	0
4	1	1	0	1	1	1	1	1	0	1	0	1	0	0	0	0	0
5	1	1	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0
6	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
8	0	1	0	1	1	1	0	1	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
11	0	0	0	1	0	1	1	0	0	1	1	1	0	0	0	0	0
12	1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0
13	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
14	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0
15	1	0	0	1	1	0	0	0	0	1	0	1	0	0	1	0	0
16	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1
17	1	0	0	0	0	1	1	0	1	1	1	1	0	1	1	0	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
3	1	1	1	1	1	1*	1	1	0	1	0	1	1*	1*	0	0	0
4	1	1	0	1	1	1	1	1	0	1	0	1	1*	1*	0	0	0
5	1	1	0	1	1	1*	1	1*	0	1	0	1*	1*	1*	0	0	0
6	1*	1*	0	1*	1	1	1	1*	0	1*	0	1	1*	1*	0	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
8	1*	1	0	1	1	1	1*	1	0	1	0	1*	1*	1*	0	0	0
9	1*	1*	0	1*	1*	1	1*	1*	1	1	0	1	1*	1*	0	0	0
10	1	0	0	0	0	0	1*	0	0	1	0	0	0	0	0	0	0
11	1*	1*	0	1	1*	1	1	1*	0	1	1	1	1*	1*	0	0	0
12	1	1*	0	1*	1*	1	1*	1*	0	1	0	1	1*	1	0	0	0
13	1*	1	0	0	0	0	1*	0	0	1*	0	0	1	0	0	0	0
14	1*	1*	0	1*	1*	1	1*	1*	0	1*	0	1*	1	1	0	0	0
15	1	1*	0	1	1	1*	1*	1*	0	1	0	1	1*	1*	1	0	0
16	1	1	1	1*	1*	1	1*	1*	1	1	1	1	1	1	1	1	1
17	1	1*	1*	1*	1*	1	1	1*	1	1	1	1	1*	1	1	0	1

5. Step 5 - Level Partitioning

Level partitioning aims to determine vertical locations of elements in the final ISM-based model where arrows showing interactions will direct from lower levels to upper levels. Level I elements are located at the top of the model because they are influenced by other elements whilst giving no influences. On the other hand, elements in the final level are placed at the bottom because they are not lead by other elements. Given the reachability matrix, the reachability set (RS), antecedent set (AS) and intersection set of each element were generated. RS means a set of elements where an element affected, whilst AS refers to a set of elements which affected an element. IS is a set of overlapped elements between RS and AS. For the purposes of level partitioning, Table 4 was created to show the reachability, antecedent and intersection sets clearly. The elements whose RS was the same as IS were set aside as Level I (top level) because they are affected by many elements, but their influences are limited. After deciding the elements in Level I, new RS, AS and IS of each element were sought by removing Level I elements from the previous sets. Again, the RS and IS were compared to decide elements in Level II. The same process was continued until all elements were assigned to specific levels, whose results can be seen in the right-hand column of Table 5.

〈Table 5〉 Results of level partitioning

No	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,7	1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17	1	II
2	1,2,7,10	2,3,4,5,6,8,9,11,12,13,14,15,16,17	2	IV
3	1,2,3,4,5,6,7,8,10,12,13,14	3,16,17	3	VII
4	1,2,4,5,6,7,8,10,12,13,14	3,4,5,6,8,9,11,12,14,15,16,17	4,5,6,8,12,14	VI
5	1,2,4,5,6,7,8,10,12,13,14	3,4,5,6,8,9,11,12,14,15,16,17	4,5,6,8,12,14	VI
6	1,2,4,5,6,7,8,10,12,13,14	3,4,5,6,8,9,11,12,14,15,16,17	4,5,6,8,12,14	VI
7	7	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	7	I
8	1,2,4,5,6,7,8,10,12,13,14	3,4,5,6,7,8,11,12,14,15,16,17	4,5,6,8,12,14	VI
9	1,2,4,5,6,7,8,9,10,12,13,14	9,16,17	9	VII
10	1,7,10	2,3,4,5,6,8,9,10,11,12,13,14,15,16,17	10	III
11	1,2,4,5,6,7,8,10,11,12,13,14	11,16,17	11	VII
12	1,2,4,5,6,7,8,10,12,13,14	3,4,5,6,8,9,11,12,14,15,16,17	4,5,6,8,12,14	VI
13	1,2,7,10,13	3,4,5,6,8,9,11,12,13,14,15,16,17	13	V
14	1,2,4,5,6,7,8,10,12,13,14	3,4,5,6,8,9,11,12,14,15,16,17	4,5,6,8,12,14	VI
15	1,2,4,5,6,7,8,10,12,13,14,15	15,16,17	15	VII
16	1,2,3,4,5,6,7,8,9,10,11,12, 13, 14,15,16,17	16	16	IX
17	1,2,3,4,5,6,7,8,9,10,11,12, 13,14,15,17	16,17	17	VIII

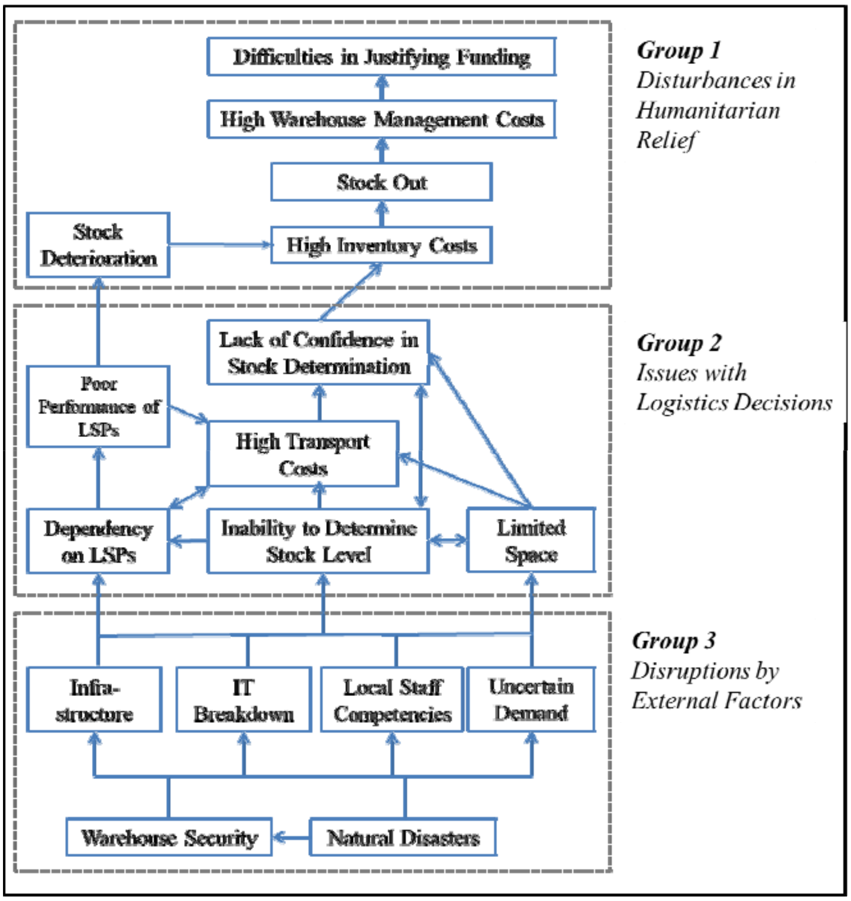
6. Step 6 - Digraph

A directed graph or digraph is a preliminary illustration of the interconnections of the elements by using partitioned levels for deciding vertical locations and the initial reachability matrix for showing interactions. The results of level partitioning indicated a rough location of each element in a digraph. After the elements were vertically assigned according to the levels, the appropriate locations were decided considering interrelationships of elements. Single-headed and double-headed arrows connected two elements based on the binary numbers in the initial reachability matrix to highlight their relationships in the digraph.

7. Step 7 - ISM-based Model

The final ISM-based model was derived from the digraph by replacing node numbers with element titles as well as by illustrating the direct effects which can be fed into a simplified model. As a result, the final ISM-based model can be drawn as shown in Figure 2. Three groups of elements emerged by the dependence and driving power of each elements were also incorporated into the final ISM-based model. These three groups will be further discussed in the following section.

〈Figure 2〉 ISM-based model



V. Discussion

The ISM-based model in Figure 2 showed that the interactions between three groups are uni-directional, where Group 3 leads to Group 2, which in turn leads to Group 1. The elements in each group have commonalities. Group 3 factors can be viewed as the fixed operational platform over which the aid organisation operating in crisis conditions has little or no control. The components of Group 2 are essentially practical problems involved in logistics activities or decisions which exhibit some fragility on a day-to-day basis. Finally, Group 1 represents mainly the consequences of failures in the humanitarian relief supply chain emanating from Groups 2 and 3.

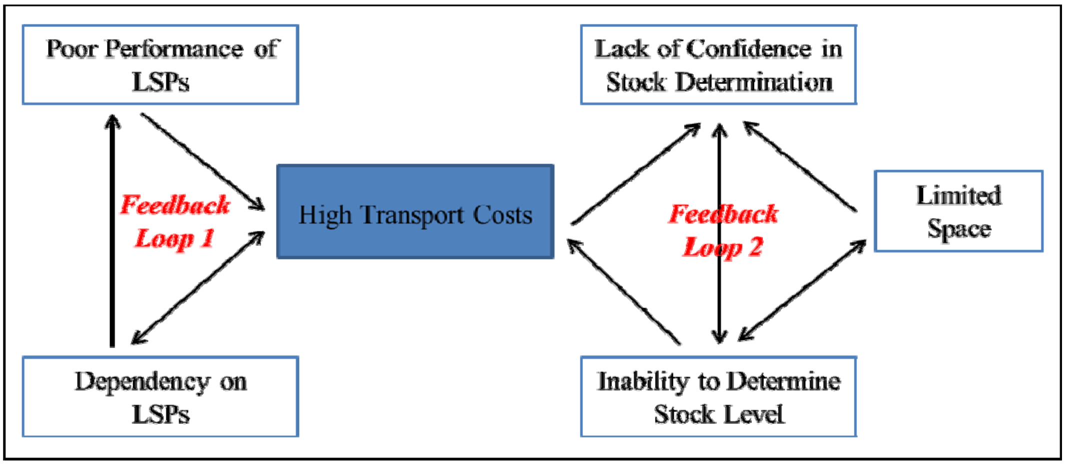
Group 1 consists of the challenges which relate to the main objectives that humanitarian logistics organisations pursue. As these are the outcome of the objectives of the organisation, they are dependent upon other challenges. Among them, for example, difficulties in justifying funding are at the highest level in the structure, which means that organisations feel the pressure from donors once a pre-positioned warehouse malfunctions. This aligns with the characteristics of the funding structure explained by Kent (1987)[45] where support from donors is crucial for a relief organisations' existence. Most donors are not willing to pay for pre-disaster activities as they consider them as a form of insurance policy against the uncertainties surrounding a future disaster[46]. Moreover, donors may even place restrictions on the types of relief activities in which agencies may be involved[47]. Due to funding constraints, the uncertainty of disaster occurrences, and costs associated with operating distribution centres, not many relief organisations use the strategy of pre-positioning that involves, and relies upon, the purchase of relief supplies in advance of disasters. A notable contrast with commercial logistics is that delay or time loss is not captured within this group, which will be partly because pre-positioned warehouse operations clearly aim to reduce the lead time. Nonetheless, they can potentially carry a heavy cash-flow penalty, albeit one that does not necessarily fall entirely on the aid agency. As a consequence, this group can be labelled as 'Disturbances in Humanitarian Relief' because the elements here represent

45) Kent, R.C., *Anatomy of Disaster Relief*, Pinter Publishers: London, 1987.
46) Tatham, P. and Pettit, S., "Transforming humanitarian logistics: The journey to supply network management", *International Journal of Physical Distribution and Logistics Management*, Vol. 40, 2010, pp. 609-622.
47) Stephenson, M. and Schnitzer, M.H., "Interoganizational trust, boundary spanning, and humanitarian relief coordination", *Nonprofit Management and Leadership*, Vol. 17, No. 2, 2006, pp. 211-232.

challenges at the overall humanitarian relief operations.

The challenges in Group 2, on the other hand, are mainly initiated by 'Issues with Logistics Decisions', which encompass forecasting, transport, warehousing and outsourcing. As can be seen in Figure 3, the ISM-based model demonstrates that there are two feedback loops which magnify the level of challenges within Group 2. Interestingly, all these feedback loops are generated around high transport costs. The reason for this can be attributed to the fact that a reduction in transport costs is one of the main purposes of operating pre-positioned warehouses. With the warehouses, the majority of relief items can be transported by the sea where cost is almost invariably cheaper than any other transport mode, given the high volume of items. However, failure in logistics activities both directly and indirectly affects the transport costs by adding transport frequencies and/or by using more expensive transport options[48].

〈Figure 3〉 Self-enhancing loops in the model



For example, dependency on LSPs based on a limited knowledge of logistics often leads to opportunistic behaviours by LSPs, which may result in poor logistics performance. Additional transport cost will be required to rectify this issue, which in turn undermines the bargaining power of humanitarian organisations under budget constraints in the relationships with LSPs (Feedback Loop 1). In order to eliminate this vicious circle, NGOs are advised to pursue tighter cross-sector partnerships with competent LSPs[49].

48) Pettit, S.J. and Beresford, A.K.C., "Humanitarian aid logistics: the Wenchuan and Haiti Earthquakes compared." In Kovacs, G. and Spens, K. (eds.) *Relief Supply Chain Management for Disasters: Humanitarian, Aid and Emergency Logistics*, 2012.

Feedback Loop 2 is closely related to the humanitarian organisations' capability to control and manage the inventory. Inability of forecasting the accurate stock level will result in additional transport costs for urgent delivery of relief items. In the same vein, lack of confidence in selecting items to be stored can lead to forecasting failure and high transport costs[50]. The budget constraints emanating from high transport costs cause jeopardy in the item selection process.

Also, limited space in pre-positioned warehouses is interrelated with failure in forecasting stock level while restricting the range of items to be stocked. Furthermore, acquiring the space for storing is always a critical issue to consider when pre-purchasing relief items. To solve this, several relief organisations collaborate to share warehouse spaces. In the interviews, however, humanitarian organisations find it difficult to make accurate forecasts due to the lack of capability in logistics operations as well as the unpredictability of events requiring humanitarian relief. In this sense, recent research by Yao et al. (2018)[51] suggested the optimal order quantity of pre-positioned inventory while employing proactive or reactive outsourcing strategy depending on item types.

Lastly, Group 3 challenges are external to humanitarian organisations but have significant influences on the challenges clustered into Groups 1 and 2. These challenges are also frequently mentioned in the supply chain risk management literature as environmental risks and uncertainties[52]. Demand uncertainty is a serious challenge faced by humanitarian organisations. Since most natural disasters are unpredictable, the demand for goods in these disasters is also unpredictable. Although external uncertainty is unavoidable, Pedraza-Martinez et al. (2011)[53] suggests that uncertainty can be mitigated with the use of information integration. This also implies that a lack of integrated information systems would increase demand uncertainty. However, the difference is that Group 3 can be considered both as uncertainties in logistics operations and as the events

49) Nurmala, N., de Vries, J. and de Leeuw, S.. "Cross-sector humanitarian–business partnerships in managing humanitarian logistics: an empirical verification", *International Journal of Production Research*, Vol. 56, No. 21, 2018, pp. 6842-6858.

50) Wang, X. and Disney, S.M., "The bullwhip effect: Progress, trends and directions", *European Journal of Operational Research*, Vol. 250, No. 3, 2016, pp. 691-701.

51) Yao, X., Huang, R., Song, M. and Mishra, N., "Pre-positioning inventory and service outsourcing of relief material supply chain", *International Journal of Production* Research, Vol. 56, No. 21, 2018, pp. 6859-6871.

52) Kwak et al., 2018, op.cit.

53) Pedraza-Martinez, A.J., Stapleton, O. and van Wassenhove, L.N., "Field vehicle fleet management in humanitarian operations: A case-based approach", *Journal of Operations Management*, Vol. 29, 2011, pp. 404-421.

where humanitarian relief is required. Therefore, this group of elements can be interpreted as 'Disruptions by External Factors'(for details, see Table 6).

〈Table 6〉 Group 3 challenges: disruptions by external factors

Challenges	Details
Infrastructure	The quality of the infrastructure for pre-positioned warehouses is often a concern for humanitarian organisations as some of the potential warehouses are located in underdeveloped countries or near disaster-prone areas. Such areas also tend to have a lower quality infrastructure and face a greater chance of damage or destruction.
IT Breakdown	IT is a crucial component of communication within and between organisations, especially when a disaster occurs. Accurate information is important to reduce time and cost for efficient relief operations. Humanitarian organisations prefer their pre-positioned warehouses to be located in a country with adequate IT capability as some of them are located in vulnerable countries with poor IT quality.
Local Staff Competencies	The low performance of locally-hired staff can be caused by miscommunication, cultural differences, different working conditions, etc. However, it is considered important for logistics managers to be competent in logistical skills and knowledge. Even though they would be deployed from the humanitarian organisation in many cases, they still have to work with qualified local staff for efficient management.
Uncertain Demand	Most of the demand in humanitarian relief operations is unpredictable which leads to uncertain and variable demand patterns. Not only does uncertainty about the location of where a natural disaster might occur create difficulties in predicting demand, but uncertainties stemming from man-made disasters will also create similar problems. Due to this, humanitarian organisations often have difficulty in identifying the beneficiaries and matching the supply of relief items to demand.
Warehouse Security	The social stability of the country is important for warehouse security to prevent any unexpected theft or pilferage. Some of the relief items stocked in the warehouse are very valuable items; for example, radio telecommunication systems, medicines, armoured vehicles, food, etc. Security of the location is considered to be important.
Natural Disaster	Some humanitarian organisations tend to locate their pre-positioned warehouse closer to disaster vulnerable countries to reduce cost and time. However, some are aware that being close to those areas would put the warehouse in danger from possible natural disasters. To avoid the warehouse being destroyed, some humanitarian organisations prefer an area less influenced, or vulnerable to, such disasters.

Ⅵ. Conclusion

This analytic research identified various challenges in operating pre-positioned warehouses for humanitarian logistics by a mixed method approach and structured their interactions in order to better understand how the challenges are inter-related by the ISM process. As a result, 17 challenges, divided into 3 distinctive groups, as well as into 2 self-enhancing loops, were identified and discussed. This is one of the first studies to have investigated the challenges in humanitarian logistics using a structural model, providing the basis for future research on decision making in humanitarian logistics in consideration of possible challenges and risks.

Given how the groups are formed, and how the feedback loops link the challenges, humanitarian organisations can identify which challenges should be mitigated as a priority in order to reduce the level of overall business risk. In particular, effective management of LSPs and inventory per se appears to be the key to breaking self-enhancing loops. This is mainly because the main aim of pre-positioned warehouse operations is the reduction of transport cost; while breakdowns in their relationships with LSPs and increased inventory will lead to higher transport costs than expected, which will ultimately undermine the purpose of having a pre-positioned warehouse. This implies that organisations will face difficulties in justifying their spending of aid funding. Even though challenges exist in implementing a pre-positioning warehouse strategy, it is nevertheless seen as a net benefit in the overall logistics system and is therefore adopted by some relief organisations.

Strategies for better operations can be derived from three challenge groups, encompassing risk avoidance, risk acceptance, risk reduction and risk transfer strategies[54)55)56)]. Firstly for the Group 1 challenges, strategies to alleviate the burden of high operating costs and the pressure persuading the donors can be done through coordination. For instance, the World Food Programme (WFP) manages the UN Humanitarian Response Depot (UNHRD) and gives support to 75 organisations enhancing

54) Lee, C.B. and Jung, S.-M., "A study on risk management strategies of global supply chain for the electrical and electronic corporations", *Korea International Commerce Review*, Vol. 26, No. 2, 2011, pp. 27-48.

55) Lee, C.B., Lie, Y. and Noh, J.-H., "A study on global supply chain risks management strategies under COVID 19", *Korea International Commerce Review*, Vol. 35, No. 4, 2020, pp. 85-107.

56) Lee, C.B., Park, S.-W. and Kim, H.-C., "A study on the impacts of transport logistics risk factors on risk management strategies", *Korea International Commerce Review*, Vol. 35, No. 2, 2020, pp. 197-219.

its ability to respond efficiently and effectively to a disaster at six depots located across the globe[57]. Secondly for the Group 2 challenges, strong collaboration with competent LSPs and accurate forecasting of what and how much to be stored can be the key strategies. In line with this, humanitarian aid organisations have tended to contract logistics services with global LSPs which can play a lead role in logistics coordination as well as can carry out demand forecasting and management. Lastly for the Group 3 challenges, the selection of proper location for pre-positioned warehouses is a second-to-none strategy. The location decision must take natural disasters, infrastructure, IT stability, local staff competencies and overall security into consideration to avoid or reduce the chance of massive destruction to logistics operations.

The ISM-based model strongly suggests that there may be a chronological sequence in challenges when arranged in a structured form. In general terms therefore, certain challenges can precipitate further challenges in certain circumstances, but in other situations some challenges interact with others in such a way as to act as 'dampers'. This sequencing of challenges opens opportunities for further research especially where some challenges could act with positive feedback (enhancing initial challenge) or with negative feedback (where subsequent challenge is tending to reduce initial challenge) depending on local circumstances.

Similarly, a scale of challenges cannot be assumed to remain constant as both the likelihood and the impact will be dynamic, changing especially over time. Therefore, future research can explore how certain challenges can precipitate further challenges in certain circumstances by focusing on limited knowledge of NGOs about logistics operations as well as on diverse circumstances that NGOs will face. The effectiveness of coordination and collaboration as a main tool of risk management could also prove to be a key area warranting further research.

57) Heaslip, G., Vallaincourt, A., Tatahm, P. and Kovacs, G. (2018), "Supply chain and logistics competencies for the humanitarian logistician", Chapter 9 in Taham, P. and Christopher, M. (eds.), *Humanitarian Logistics*, 3rd Edition, Kogan Page, London.

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