

Review of intermodal freight transportation in humanitarian logistics

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Abstract

Purpose Using intermodal transportation is vital for the delivery of relief supplies when single mode alternative becomes unusable or infeasible. The objective of this paper is to investigate the use of intermodal freight transportation in humanitarian logistics.

Methods This paper first identifies the differences between multimodal and intermodal transportation. Then, we examine the use of each transportation mode for specific disaster types and phases. When combinations of transportation modes (i.e. air, road, rail and sea) for intermodal transportation are considered together with different disaster types (e.g. earthquake, flood and famine), the feasible decision space becomes rather large. To explore this decision space, we have reviewed the academic and practitioner studies as well as several non-governmental organizations (NGO)' disaster archives.

Results From this exploration, we developed a transportation mode/disaster-type combination matrix and a transportation mode/disaster-phase combination matrix. We then discuss examples of real life usage of intermodal transportation in humanitarian logistics and share our findings and analyses. Of

369 academic humanitarian logistics articles, only 20 have mentioned transportation mode changes. In practitioner studies, we found a decreasing percentage of the usage of slower modes (e.g. sea and rail) in the disaster response phase over time. We were not able to find a significant relationship between a specific transportation mode and a specific disaster-type or -phase. Road transportation seems to cover most of the disaster operations regardless of the disaster-type or -phase.

Conclusions We can conclude that intermodality and the transportation unit concept is not being studied extensively in humanitarian logistics. Most of the relief organizations do not share transported freight amounts in their reports and those that do share transported freight amounts in their reports do not explicitly mention mode changes. We discuss the enablers of and obstacles to the effective use of intermodal transportation in humanitarian logistics and propose future research directions. We anticipate that intermodal transportation in humanitarian logistics will garner greater research attention and increased utilization in coming years.

Keywords Humanitarian logistics · OR in disaster relief · Literature review · Freight transportation

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1 Introduction

The number of natural and man-made disasters has been increasing in recent years and these disasters have affected many people. To prevent the loss of lives and help the victims of a disaster, response times must be minimized. Disaster operations management can be divided into four phases: mitigation, preparedness, response and recovery [1]. In the mitigation phase, a risk analysis of the settlements and public education is performed. Resource planning and the advance purchase of

supplies is carried out in the preparedness phase. The response phase includes activities related to needs assessment, resource mobilization and the transportation of relief aids. Finally, the recovery phase entails the removal of all debris and rebuilding essential infrastructure. After the onset of any disaster, the current situation is assessed, and then resources are mobilized for transport to the disaster area. If required, relief aid is also procured and transportation operations are managed. Logistics operations are important in the humanitarian relief chain and account for around 80% of all disaster relief activities [2].

Because of the critical importance of speed, especially in the response phase, many alternatives should be considered to deliver relief items as quickly as possible within the available budget and resources. This can be accomplished by the utilization of various transportation modes (i.e. road, rail, air and water), which can increase the range of options for the decision maker. Moreover, using alternative transportation modes depending on the characteristics of the disaster might be the only option to reach affected people because of the extent of damage to the transportation infrastructure.

Three main types of transportation systems are defined in the utilization of multiple transportation modes. *Multimodal transportation* refers to passenger or freight transportation from an origin to a destination using two or more transportation modes. *Intermodal transportation* is a type of multimodal freight transportation that uses an intermodal transport unit (ITU) (e.g. container) with no handling of the goods themselves between mode changes. *Combined transportation* is a type of multimodal freight transportation that excludes air transport and where most the trip occurs by rail or on waterways with only the initial and final legs of the trip occurring on road. The reader is referred to [3] for a compilation of these definitions. It should also be noted here that air and sea transport do not lend themselves to *unimodal* (i.e. *single-mode*) transportation of freight. Air and sea transport are almost always coupled with either rail/road transport or both. On the other hand, rail and road transport could be used as unimodal and possibly interchangeably. Choice between rail and road transport depends mostly on economic matters and the availability of the required infrastructure (i.e. rail ramp, crane, etc.) and qualified human resource at the transshipment hubs.

Humanitarian relief activities are vital, and even a very small improvement in the process can yield great impacts on people's lives. That's why academicians and practitioners are continuously in search of new methods to improve these activities, especially in recent years due to the increasing number of massive disasters. Investigating alternative ways to transport relief supplies using multiple modes and decreasing transportation times by utilizing a transportation unit can yield remarkable results for the beneficiaries. On the other hand, considering that logistics systems are highly dependent on human effort (e.g. drivers, carriers, warehouse employees, etc.) and the disaster environment is subject to change in

subsequent phases of disaster management, transportation operations are inherently difficult to coordinate. If not coordinated wisely, the expected advantages of utilizing multiple modes may not be obtained. Thus, investigating the use of intermodal freight transportation in humanitarian logistics, in both research and practice, is the main objective of this study.

The rest of this paper is organized as follows: In the second section, we explain our methodology used to find academic studies and practical usage examples, as well as our strategy for choosing those to investigate. In section 3, we present our analyses of studies in emergency management, humanitarian logistics and disaster relief distribution, in particular. We then discuss the utilization of multiple modes both in academic research and real life disasters. In section 4, we analyse our findings and suggest future research directions. Finally, we draw our conclusions in section 5.

2 Literature review methodology

In this section, we present our methodologies for identifying relevant studies, for selecting some for further examination and for analysing the features of the relevant studies. We considered both academic and practitioner studies, but the approaches we used to investigate each type differed in several ways.

2.1 Academic studies

While the transportation aspect of disaster operations management is the focus of this paper, it is important to have an overall perspective of the main topics in this field. We selected the seven literature review studies most related to disaster operations management, humanitarian logistics and transportation in humanitarian logistics, including those by Altay and Green [1], Galindo and Batta [4], Caunhye et al. [5], Natarajathinam et al. [6], Apte [7], Anaya-Arenas et al. [8] and de la Torre et al. [9].

Altay and Green [1] conducted a survey of literature published between 1980 and 2004 that focused on the use of operations research in emergency management. Studies were analysed with respect to the phases and disaster types, suggestions were made for future research in some of these papers and explanations were given regarding problems in emergency management. Inspired by the work of Altay and Green [1], Galindo and Batta [4] continued their analysis by considering articles published between 2005 and 2010, to determine whether any of the gaps identified by Altay and Green [1] had been addressed in new research efforts. Galindo and Batta [4] compared the new studies with those investigated by Altay and Green [1], with respect to their methodology, disaster phase and type. Future research directions were also updated in Galindo and Batta [4]. Similarly, Caunhye et al. [5]

studied the role of optimization models in emergency management by classifying the literature into two main categories—facility location and relief distribution.

In addition to the above three reviews focused on operations research, Natarajathinam et al. [6] focused on the supply chain management literature in emergency management. In their paper, the authors classified the literature reviewed according to the scale, stage and source of the crisis and made future research suggestions in consideration of the gaps identified. Apte [7] compared humanitarian logistics with military and commercial logistics, and discussed the role of the supply chain during preparation, response phases and relief operations as well as other issues in humanitarian logistics, including information flow and risk management. Anaya-Arenas et al. [8] and de la Torre et al. [9] specifically surveyed relief item distribution. While the former paper gave special attention to the response phase and investigated transportation, location and network design problems, the latter evaluated resource allocation, needs assessment and uncertainty in demand and supply and vehicle routing. Both studies investigated how these issues were handled in the literature and ended their papers by recommending future research directions. The reference lists of these seven literature reviews enabled us to capture a broad range of studies in emergency management and humanitarian logistics. Table 1 displays the number of studies reviewed in each article.

The first and third columns of the table list the names of the seven reviewed studies, and the second and fourth columns show the number of articles referenced in each paper reviewed. We captured 726 studies from the reference lists of the seven literature review articles and reduced this number to 391 by eliminating poster presentations, white papers, magazine articles and duplicates. Later, we found 29 of them to be irrelevant to emergency management. We categorized the remaining 362 studies with respect to several criteria, including their models, methods and disaster phases considered, multimodality–intermodality, transportation modes used, geographical region and the data sets on which the models were tested.

These 362 studies include academic articles, book chapters, conference proceedings, M.Sc. theses, Ph.D. dissertations and case studies. The distribution of these publications by year is

Table 1 Number of studies reached via seven literature review articles

Review article	# of articles in the reference list	Review article	# of articles in the reference list
Altay and Green [1]	151	de la Torre et al. [9]	58
Anaya-Arenas et al. [8]	73	Galindo and Batta [4]	69
Apte [7]	168	Natarajathinam et al. [6]	133
Caunhye et al. [5]	74		

given in Fig. 1. An ascending slope, especially after the 1990s, indicates the increasing interest in this research area.

Since these seven literature review articles do not cover all the literature to date, in addition to the reference lists of these articles, we searched three scientific databases (EBSCO, Web of Science and IEEE) to reach multimodal and/or intermodal studies in humanitarian logistics. By searching the keywords ‘humanitarian logistics’ OR ‘emergency management’ OR ‘emergency transportation’ AND ‘intermodal transportation’ OR ‘multimodal transportation’ OR ‘intermodal freight transportation’, we found seven recent studies related to multimodal and/or intermodal transportation. Thus, we minimized the chances of missing any studies relevant to our review.

2.2 State of practice

Since transportation is vital in humanitarian logistics, applications of intermodal freight transportation in humanitarian logistics in real life situations are of particular interest. Regardless of the existence of academic studies on multimodal and/or intermodal transportation in humanitarian logistics, we claim that practitioners should already have been benefiting from multiple modes when transporting relief supplies. We examined several international and national organization websites and databases to assess the validity of this claim.

Of the many international humanitarian organizations, we first investigated those with large databases. Later, we selected other major organizations that deliver aid to many places and some database websites. Besides searching their reports—both annual and related to specific events—we also filtered their databases using keywords such as ‘transportation,’ ‘mode,’ ‘logistics,’ and ‘vehicle’ to capture any information about the volume of relief supplies sent and the type of transportation network used.

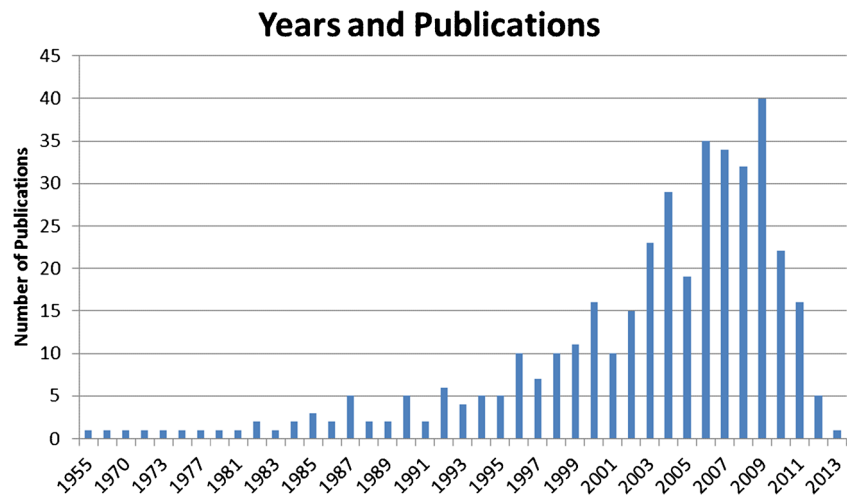
3 Usage of multiple modes in humanitarian logistics

In this section, we analyse the reviewed studies in detail, present the findings of practitioner studies and report the results of the database search with specific keywords.

3.1 Academic studies

Forty of the 362 studies cover issues related to evacuation, while 49 address the distribution of relief supplies. Other main research topics include facility location, relief item prepositioning, resource allocation and risk assessment. Evacuation and relief item distribution may be considered as subtopics of transportation. Figure 2 shows a categorization summary of these 89 (i.e. $89 = 40 + 49$) transportation-related articles, which reveals that only 13 studies can be considered to address multimodal

Fig. 1 Number of publications with respect to years



transportation and seven of these also include the transshipment point between multiple transportation modes.

Intermodal transportation occurs when a transshipment point enables mode changes of the freight being carried in a transportation unit without any handling of the relief supplies. We made detailed investigations of 13 papers with multimodal features, which are summarized in Table 2. Two of the papers studied transportation with a multimodal feature for the purposes of evacuation. The rest focused on relief supplies distribution. The third column in Table 2 shows that most used integer programming, while stochastic programming and linear programming were also utilized. None of these studies mention the concept of intermodality; however, Hu [15], Özdamar et al. [17] and Abdelgawad and Abdulhai [10] supported the usage of a transportation unit. Hu [15] and Özdamar et al. [17] constructed their models such that mode change is possible on a single journey. Even though cost can be considered to be less important than speed in humanitarian logistics, the fifth column reveals that the most widely used objective function is cost minimization (in nine of 13 articles). Besides minimizing cost, increasing service quality is addressed by using several objective functions such as minimizing delivery time, expected casualties, unmet demand for evacuees, service delay and maximizing survival rate, delivery and credibility. The seventh and eighth columns in Table 2 show that road–rail (in seven of 13 articles) and road–air (in six of 13 articles) are the most common transportation mode combinations. We also analysed the disaster types considered, however we found no specific relationship between disaster

type and the modes used. On the other hand, of the articles that specify disaster type, earthquake seems to be the most studied type when multimodal transportation is utilized.

In addition to the studies captured from references lists, our database search using keywords yielded studies by Zhang et al. [23], Goel [24], di Gangi [25], Verma et al. [26], Abdelgawad and Abdulhai [27], Abdelgawad et al. [28] and Miller-Hooks et al. [29]. Zhang et al. [23] investigated the role of intermodal transportation in humanitarian supply chains mainly through interviews and surveys of relief organizations, non-profit organizations and government agencies. These authors assessed the utilization of different modes in humanitarian activities and identified ways to make intermodal transportation more attractive to relief organizations. Goel [24] studied the visibility of rail and road transportation systems that offer shipment and route choices to adjust transportation plans as situations change when supplies are in transit to minimize the total transportation and stock out costs. Di Gangi [25] developed a dynamic traffic assignment (DTA) model to study demand, supply and loading models in order to determine the quantitative indicators of exposed risk in a multimodal transport network that introduces bimodal arcs in a specified road. To minimize shipment costs and exposure risks, Verma et al. [26] used a tabu search algorithm in proposing a bi-objective optimization model for scheduling rail–truck intermodal shipments transporting hazardous materials. To minimize travel costs, Abdelgawad and Abdulhai [10] studied the scheduling and routing of transit vehicles and subways during emergency evacuation. Abdelgawad et al. [28] proposed a multi-objective

Fig. 2 Classification of the papers related to evacuation and distribution

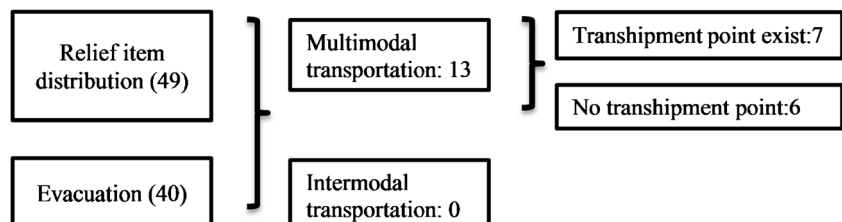


Table 2 Analysis of 13 papers according to multimodality feature

Short Name	Model	Method	Transshipment point (i.e. mode changes) exist	Objective	Multicommodity transportation	First transportation mode	Second transportation mode	Disaster type
Abdelgawad and Abdulhai [10]	Evacuation	LP, MIP	No	Min cost	No	Road	Rail	not mentioned
Adivar and Mert [11]	Relief supplies routing	LP	Yes	Min waiting time	Yes	Not mentioned	Not mentioned	Flood
Barbarosoglu and Arda [12]	Relief supplies routing	Stochastic Programming	Yes	Min cost	Yes	Air	Road	Earthquake
Clark and Cullkin [13]	Relief supplies routing	MIP	No	Min cost	Yes	Air	Road, rail, sea	Earthquake
Haghani and Oh [14]	Relief supplies routing	Heuristic	Yes	Min cost	Yes	Not mentioned	Not mentioned	All
Hu [15]	Relief supplies routing	MIP	Yes	Min cost	No	Road	Rail, sea	Not mentioned
Oh and Haghani [16]	Relief supplies routing	MIP	Yes	Min cost	Yes	Not mentioned	Not mentioned	All
Ozdamar et al. [17]	Relief supplies routing	LP, MIP	Yes	Max delivery	Yes	Air	Road, rail, sea	Natural disasters
Salmerón and Apte [18]	Relief supplies routing	Stochastic Programming, MIP	No	Min expected casualties	No	Air	Road	Not mentioned
	Evacuation			Min expected unmet transfer population				
Tean [19]	Relief supplies routing	Stochastic Programming, MIP Simulation	No	Max survival rate	No	Air	Road, rail, sea	Earthquake, hurricane
Vitoriano et al. [20]	Relief supplies routing	Goal Programming	Yes	Min cost	No	Air	Road, rail, sea	Food crisis
Yi and Kumar [21]	Relief supplies routing	MIP	No	Min service delay	Yes	Road	Not mentioned	All
Zhu et al. [22]	Relief supplies routing	IP	No	Min cost	Yes	Road	Rail	Earthquake, flood, typhoon

model for minimizing in-vehicle travel time, at-origin waiting time and fleet costs in transit evacuations, based on a multi-depot time-constrained pick-up and delivery vehicle routing problem (VRP) framework. Miller-Hooks et al. [29] measured the performance of intermodal freight transportation to maximize network resilience and optimally allocate the budget between preparedness and recovery activities. The authors considered cost parameters and proposed a two-stage stochastic programming model using rail and road modes.

Tables 3 and 4 combine the reference lists and keyword searches to illustrate the relationships among transportation modes, disaster phases and disaster types. The disaster phases are listed as column headings in Table 3, and the transportation modes and mode combinations comprise the table rows. As seen in Table 3, 70 of 95 articles consider only single modes and road stand out with 62 related studies, while air is considered as the single mode in only six studies. Rail is used as a single mode in only one paper with respect to mitigation, as it is a relatively slow transportation type. The remaining 25 articles mention more than one mode. Mitigation, preparedness, response and recovery phases are studied in 3, 7, 22 and 3 of the articles, respectively. Additionally, air is combined with road and sea, while rail is studied only with road. Road is the most widely used transportation mode, especially in the preparedness and response phases.

Most of the 95 articles discuss models for the response phase, and very few combine mitigation/preparedness/response. Three of 95 papers did not mention a specific disaster type. Table 3 also reveals that of the 77 articles addressing road as the transportation mode, many consider the response phase since transportation operations usually take place during this phase. The second most commonly used transportation mode is air, which was studied with respect to the response phase in 12 papers. This is expected due to the importance of speed in response. Rail and sea modes were studied only with respect to the mitigation and response phases.

Table 4 categorizes 95 articles according to the combinations of transportation modes used for different disaster types. As in Table 3, the rows indicate the transportation modes and the columns the disaster types. The categorizations follow the definitions used in the EM-DAT Annual Disaster Statistical Review [30]. The first column indicates studies that either do not distinguish between disaster types or mention more than one type of disaster. Among those focusing on a particular disaster type, earthquakes (categorized as geological in EM-DAT) have attracted the most attention. On the other hand, 24 of the papers do not mention disaster type. As depicted in Table 4, road is the most widely used transportation mode—as a single mode—of all disaster types, whereas rail and sea are used the least. When more than one mode is considered, those with road is usually preferred as well. With seven articles, the most widely studied transportation mode combination is road-air. Three of these seven articles involve

Table 3 Modes of transportation handled in literature review according to disaster phases (i.e. transportation mode/disaster-phase matrix)

Mode	Mitigation	Preparedness	Response	Recovery	Mitigation-Preparedness-Response	Preparedness-Response	Response-Recovery	Not Mentioned	Total
Air			4			2			6
Road	1	2	41	1		12	2	3	62
Rail	1								1
Sea						1			1
Air-Road		1	2			2	1		6
Air-Sea			1						1
Road-Rail	1		5		1	1	1		9
More than 3 modes	1		5			2	1		9
Total	4	3	58	1	1	20	5	3	95

earthquake as the disaster type. Moreover, the lack of studies on transportation mode combinations such as road–sea and air–rail is a clear indication that more work is needed in this field.

3.2 State of practice

We reviewed the disaster archives of 12 international and three national (Turkish) organizations in relation to humanitarian relief activities. These international and national organizations are listed in Table 5.

Unfortunately, we could find no information relating to transportation and transportation modes in many of these archives. In some (European Commission Humanitarian Office) ECHO reports, references were made to the availability of transportation modes for different operations, but there was no mention of the volumes of freight transported [32]. Logistics Clusters, activated by the World Food Programme (WFP) [40], is a mechanism that enables humanitarian organizations to work together to share scarce logistics resources during missions. The Logistics Clusters website [41] has a good archive containing 11 types of documents. We found more than 50 documents by searching ‘transportation mode’

as a keyword on the webpage. These documents have no standard format, so they provide different details regarding transportation processes. Some provide information about the volume of freight transported via different modes for the subject operation in a specified time interval. Others provide only percentages of the usage of modes, while a few provide detailed information via ‘Cargo Moving Requests’ [41]. Reports were available with respect to wars in Darfur, Congo, Somalia and Sudan; floods in Mozambique and Haiti; a typhoon in the Philippines and an earthquake in Pakistan. We could calculate mode changes with respect to disaster timelines by combining situation reports for the Pakistan earthquake operations. Figure 3 depicts the air and ground (i.e. road or rail) transportation mode usage following the Pakistan earthquake from 22 December 2005 to 11 January 2006. We can infer from Fig. 3 that air mode usage was greater than ground mode shortly after the earthquake. As time passed, air mode usage decreased while ground mode usage increased. While this was a reasonable assumption, due to the importance of speed in the early stages of disaster response, finding evidence for this claim was only possible after synthesizing several situation reports.

Table 4 Modes of transportation handled in literature review according to disaster types (i.e. transportation mode/disaster-type combination matrix)

Mode	Multiple Disasters	Biological	Earthquake (Geological)	Hydrological	Man made	Meteorological	Not mentioned	Total
Air	1		2		3			6
Road	18	2	14	2	5	6	15	62
Rail					1			1
Sea							1	1
Air-Road		1	3			1	1	6
Air-Sea							1	1
Road-Rail	3		1		1		4	9
More than 3 modes	3		2		2		2	9
Total	25	3	22	2	12	7	24	95

Table 5 Disaster archives reviewed in this study

Abbreviation	Name
EM-DAT	International Disaster Database [30]
UNOPS	United Nations Office for Project Services [31]
ECHO	European Community Humanitarian Office [32]
FEMA	Federal Emergency Management Agency [33]
USAID	United States Agency for International Development [34]
UNICEF	United Nations Children’s Fund [35]
FAO	Food and Agriculture Organization of the United Nations [36]
IFRC	International Federation of Red Cross and Red Descent Societies [37]
CARE	Cooperative for Assistance and Relief Everywhere [38]
Reliefweb	United Nations Office for the Coordination of Humanitarian Affairs (OCHA) [39]
WFP	World Food Program [40]
LogCluster	Logistics Clusters [41]
DEMP	Disaster and Emergency Management Presidency [42]
Kızılay	Turkish Red Crescent Society (a member of IFRC) [43]
TABB	Turkish Disaster Data Bank [44]

By combining several logistics clusters and WFP situation reports, we confirmed the use of multimodal transportation after the typhoon in the Philippines (8 November 2013) and the flood in Haiti (12 September 2008). We can see in Fig. 4a and b respectively that different locations and disaster types require the use of different transportation modes, thus resulting in different multimodal transportation percentages, ranging from 1.4% to 7.9%.

A country-specific example can be drawn from the Turkish disaster archives. The main governmental humanitarian organization in Turkey, the Disaster and Emergency Management Presidency (DEMP) [42], provides relief aid following any disaster or emergency situation. Disaster statistics provide the number of deaths and the number of injured and affected people for each region, each city and each year according to disaster type. Disaster reports are not publicly available for each disaster. Information about relief aid transportation for

the city of Van (a national mission) and Somalia (an international mission) is given in the disaster reports. For the Van earthquake, relief aid was transported by planes from closer supply points and by trains from supplier points farther away. In total, 40,000 mt of freight were transported by 19 planes and ten ships to Somalia [42].

The largest nongovernmental humanitarian organization in Turkey, the Turkish Red Crescent Society (a member of IFRC), also provides emergency relief to beneficiaries following disasters [43]. On their webpage, there are several reports on missions for Gaza, Iran, Kyrgyzstan, Uzbekistan, Myanmar, Bangladesh, West Africa, Syria and the Van earthquake, regarding the provision of supplies as well as costs and transportation mode. Some of these details are given in Table 6.

As seen in the fourth and fifth columns of Table 6, data related to cost and mode type are not available in some reports. For example, while details about the type of relief items and dispatch dates can be found in the Van earthquake reports, only the number of trailers and planes and the delivered item types are provided [43]. In addition, there is a ‘Turkish Disaster Data Bank’, which can be reached via DEMP’s web page [44], but unfortunately, this database does not provide any transportation details of past disasters.

4 Discussion

4.1 Analysis of findings in literature and practice review

Based on our examination of academic and practitioner studies, we can make several observations. We found that 145 of the 369 academic articles related to humanitarian logistics addressed topics such as evacuation, relief supplies distribution, resource allocation, facility location and inventory. Very few of these 145 articles (e.g. Özdamar et al. [17], Abdelgawad and Abdulhai [10], Hu [15]) addressed the concept of the usage of a transportation unit and making changes

Fig. 3 Percentage of the relief supplies transported by air or ground in Pakistan earthquake

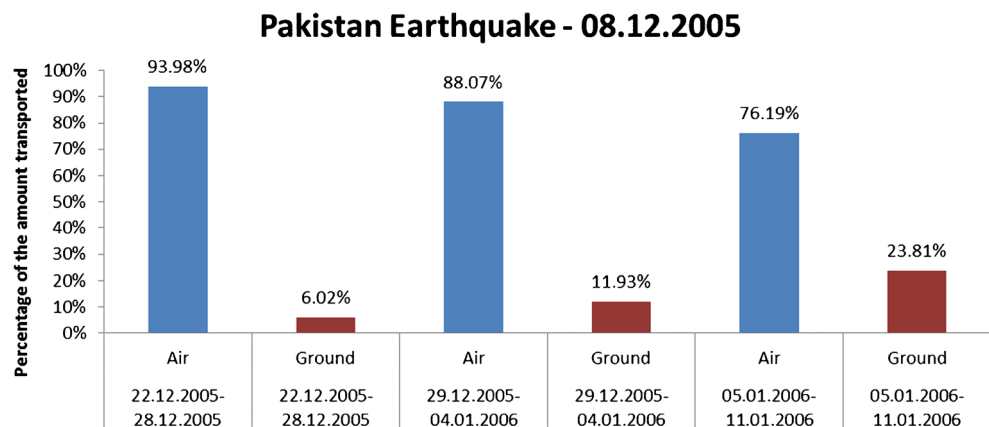
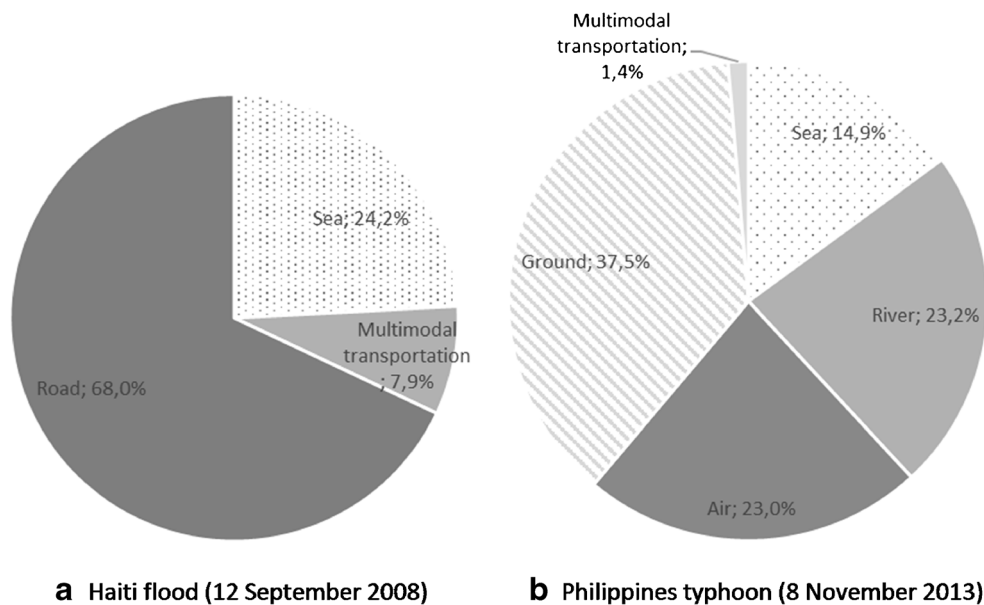


Fig. 4 Percentage of the freight (metric ton) transported by different transportation modes



in transportation modes. Among those mentioning the transportation modes used, 70 studies used a single transportation mode, 20 used more than one mode and six addressed the usage of all modes. This finding confirms that intermodality and the transportation unit concept is not being studied extensively in humanitarian logistics. Based on the literature review, few articles discussed the utilization of rail, sea, or air modes; most focused on road. The most studied transportation mode is road (by trucks), with air (by helicopters) coming second.

Based on the transportation mode/disaster-phase combination matrix, we know that most articles addressed the response phase, and the preparedness/response phase combination coming second. Although each phase has unique characteristics that might be suitable for different transportation modes, we were not able to deduce a correlation between a single transportation mode and different disaster phases. Road transportation seems to cover most of the disaster operations regardless of the disaster phase.

Based on the transportation mode/disaster-type combination matrix the majority of the models focus on earthquake response. The categorizations given in Table 4, regarding the number of people affected by natural disasters, was retrieved from the EM-DAT database [30]. Fig. 5 displays the percentages of people affected between the years 1990 and 2014. Since transportation activities play an important role in all types of disasters, we might expect academic studies to reflect real-life needs. However, despite hydrological disasters seeming to have impacted more people, earthquakes and man-made disasters are the two most studied types of disasters in academic research. Although each disaster type has unique characteristics that might only be suitable for specific transportation modes, we were not able to deduce a correlation between a single transportation mode and a different disaster types. Road transportation seems to cover most of the disaster operations regardless of the disaster type.

Practitioner studies have produced reports relating to disaster types, dates and locations and the number of people

Table 6 Relief aid made by Turkish Red Crescent Society [43]

Disaster location	Type of disaster	Delivered item	Total cost (TL)	Transportation mode
Gaza	Air strike	3000 food packages	Not available	Sea
Iran	Earthquake	21178 food packages	69119.09	Road
	Earthquake	34 prefabricated house and 2 containers	33035.22	Road
Kyrgyzstan-Uzbekistan	Internal conflicting	3218 relief item packages	512480.65	Not available
Myanmar/Bangladesh	Internal conflicting	1546 relief item packages	Not available	Air-sea
West Africa	Poverty situation	Not available	Not available	Not available
Syria	Political crisis	1400 trailer flour	Not available	Not available
Van	Earthquake	1127 trailers and 78 planes	Not available	Road-air

Percentage of affected people

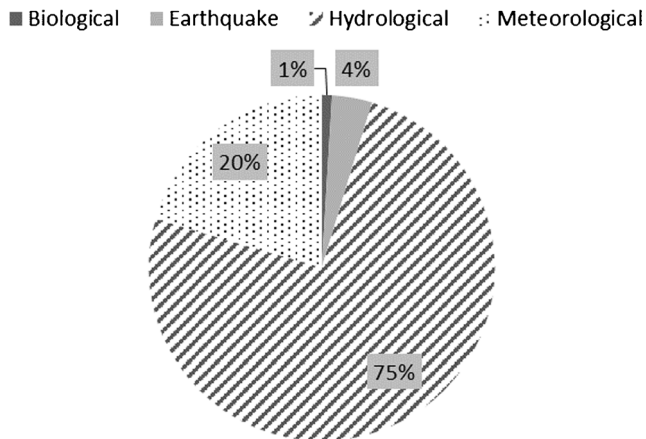


Fig. 5 Percentage of the number of affected people from natural disasters

affected, injured and killed. Rarely do they provide data about the type and quantity of relief items transported. The transportation modes utilized do not appear in most of the reports, although this subject might enlighten academic researchers on the real-world challenges and implications. International NGOs, logistics clusters and other coordinating platforms should provide operational details such as transportation modes and transported amount by each transportation mode in their mission reports.

4.2 Implications for practice

Transshipment points enable mode changes of the freight being carried in a transportation unit. Various types of containers can be used as transportation units, but to qualify as intermodal transportation, they must be handled as a single unit of equipment throughout the trip. Compared to bulk transportation, containers offer several benefits, including less product packaging, higher efficiency and less damage *en route*. Container dimensions have been standardized over the years, and sea transport primarily utilizes containers on ships [45]. However, there is no standardized container type designed specifically for humanitarian logistics. Nevertheless, a promising intermodal transportation unit (ITU) design was funded under EU 7th Framework Programme (Tellibox [46]) for commercial setting combined transportation (i.e. road, rail, and sea). For smaller ITUs that are suitable for all transportation modes, AKE prefixed loading units [47] determined by International Air Transport Association (IATA) can be used.

The use of intermodal transportation is advantageous if there is more than one available transportation mode and there are associated cost benefits, i.e. if long distances are being covered in the whole transportation network. Zhang et al. [23] found distance to be the most important factor in making transportation mode choices. The existence of many hubs (i.e. referred as stops in Zhang et al. [23]) is also important for

creating more alternatives; however, when combined with a large network, complexity also increases significantly. Intermodal transportation requires the presence of qualified employees (i.e. drayage, terminal, network, and intermodal operators (Macharis and Bontekoning [48])) at the hub locations and the proper synchronization of schedules for inbound and outbound transportation, which also increases complexity. For instance, dwell times at hub locations may be very high due to unexpected vehicle delays. Similarly, roads might collapse during the response phase, thus requiring an immediate change of moving vehicle routes. For this reason, the availability of each mode, the locations of vehicles and the locations of available containers must be monitored and updated frequently (Giannopoulos [49]). To achieve the desired advantages over multimodal or unimodal transportation, a properly working decision support system is essential for the effective management of the intermodal transportation of relief supplies.

Not all the disasters destroy the regions of the disaster area. When relief supplies are sufficient and are positioned nearby in advance of the disaster, then intermodal transportation is not necessary for nearby areas. On the other hand, Zhang et al. [23] point out that large organizations covering greater geographical areas are utilizing intermodal transportation more frequently. Zhang et al. [23] also state that large organizations usually preposition supplies in different warehouses around the world, thus requiring long distance intermodal transportation. While fires, contagious diseases, and oil spills do not require special effort to transport relief items from afar, natural disasters usually do. Although intermodal transportation cannot be efficiently used for all disaster types, it provides a vital alternative to reach beneficiaries during most disaster responses.

4.3 Directions for future research

By skimming 362 academic papers, we identified only 13 multimodal studies. Later, searching related keywords led us to seven more studies published after 2009. So, while the advantages of multiple mode utilization are attracting more attention, especially since the year 2000, containerization and hub usage have not yet been studied thoroughly in humanitarian logistics. Zhang et al. [23] reported that, while transporting items, relief agencies benefit from a change in transportation mode 40% of the time. That the ratio of academic studies is well below this value indicates that practitioners have not received enough support from academic research in this area. Pedraza-Martinez and Van Wassenhove [50] provide a three-step closed loop to build trust between practitioners and academics working on humanitarian operations. Three steps are listed as (1) working with practitioners on problems, then (2) validating results with real data, and finally (3) helping practitioners to implement research results

in practice. This closed loop might be useful in filling the gap between academics and practitioners for future work.

NGOs consider several factors such as cost, time, type and amount of supplies and availability of roads and routes. A decision support system and routine updates to these data might help to overcome coordination challenges in intermodal transportation. Giannopoulos [49] also highlight the need for such intelligent transport systems for intermodal operations by reviewing the EU funded research. Macharis et al. [51] provide a good example of such decision support systems for intermodal transport on a commercial setting. Future studies might focus on developing decision support systems for intermodal transportation in humanitarian settings.

Moreover, we can conclude from a comparison of Fig. 5 and Table 4 that academic research does not presently reflect practitioner needs. Different disasters require different response plans in terms of road availabilities, duration and predictability. As the main purpose of all these studies is to better help beneficiaries, we can claim here that there is a need for more academic research on transportation with respect to hydrological- and meteorological-type disasters.

Different disaster types might result in blocked usage of various transportation modes. In earthquakes, ground transportation might be unavailable. The lack of research on transportation mode combinations, such as road–sea and air–rail might shed light to future work in this field. In the future, transportation mode combinations can be assessed in terms of their ‘link-and-node criticalities’ [52] for an undisrupted delivery of relief items. Some of the papers we reviewed that were related to intermodal freight transportation introduced models to facilitate mode changes under some circumstances; however, they did not address coordination challenges. Future studies should address the inherent coordination challenges of intermodal transportation.

5 Conclusions

In this study, we investigated the usage of intermodal freight transportation in humanitarian logistics. We reviewed the transportation modes addressed in the humanitarian logistics literature and relate these to their disaster types and phases. Studies ranging from emergency management to disaster relief distribution were considered and those more related to transportation were analysed in detail. We searched for evidence of any mode changes and transportation unit usage in the academic research literature. We can conclude that intermodality and the transportation unit concept is not being studied extensively in humanitarian logistics. In addition, we examined relief agencies’ web sites and reports and recorded all information relevant to transportation. Consequently, we captured 20 academic studies and three practical examples of different mode usages in humanitarian logistics.

We noted a decreasing usage ratio in the response phase of the slower modes (e.g. sea, rail) as time has passed in one of the practitioner reports that we reviewed. Nevertheless, we were not able to find a strong relationship between a single transportation mode based on neither different disaster-types nor -phases. Road transportation seems to cover most of the disaster operations regardless of the disaster type or disaster phase. This result might stem from the fact that road transportation does not require special infrastructure investments.

Intermodal transportation can be a solution when transportation resources are scarce during the immediate aftermath of a disaster. The quantity of demand is usually high and required lead time is almost zero. Alternative transportation modes such as rail can carry relief supplies in higher amounts on a single trip as a cure for fleet size constraints of road transportation in the short term. Rail can cover the longer distance and final miles can be covered using tours with trucks on road.

We believe that international aid requires the availability of intermodal transportation more than national and local aid operations. This is true especially for large organizations such as international NGOs, UN organizations, ECHO, and USAID. These organizations preposition their relief supplies around the world at certain locations and ship these supplies from their warehouses to the disaster area when needed. These shipments are usually long distance and require intermodal transportation.

Recordkeeping by humanitarian logisticians is a challenge yet to be overcome. Most agencies do not share the volume of goods transported, and even if they do, mode changes are not explicitly mentioned. On the other hand, there is increasing attention to this area in academic research. As multimodality has been the subject of increasing research attention in recent years and transportation unit usage has been considered in a few recent studies, we anticipate that intermodal transportation will garner greater research attention and increased utilization in coming years. We hope this study will serve as a basis for promoting future research on intermodal freight transportation in humanitarian logistics.

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