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# Relief Distribution in Humanitarian Logistics: A Literature Review

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## ABSTRACT

This study undertakes a review of the literature on relief distribution, which is a part of humanitarian logistics. Researchers' interest in relief distribution has grown over the previous two decades, as indicated by the growing number of studies on the subject, both in the pre-disaster and post-disaster phases. The initial step in humanitarian logistics is determining the site of the distribution center, health care facility, and shelter, as well as allocating resources to that place. The second step is to determine the transportation route for commodity/resource relief delivery in the disaster logistics network. Transportation issues are inextricably linked to the evacuation of disaster victims and inventory management. As a result, the difficulties addressed in this study include location/allocation, routing, distribution and evacuation, and integration issue, which is integration of location/allocation, routing, inventory, and others. The type of data modelling, objective function, time period, commodity type number, and solution method for each problem will be examined. Topics that can be developed for additional investigation will be discussed in the final section.

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## Keywords:

relief distribution; humanitarian logistics; literature review; integrated approach

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## 1. Introduction

Disaster is an unavoidable occurrence, and its incidence is frequently unpredictable. Disasters cause costs not just in terms of fatalities, but also in terms of injured, displaced people, material losses, environmental damage, and the psychological impact on victims. Between 2003 and 2012, there were an average of 388 natural disasters every year around the world, resulting in 106,654 deaths and 156.7 million USD in financial losses. In 2013, the number of catastrophes reduced to 330 occurrences, resulting in 21,610 fatalities and 118.6 million dollars in financial losses ([Guha-sapir et al., 2014](#)).

A disaster, according to the International Federation of Red Cross and Red Crescent Societies (IFRC), is a sudden event, a catastrophe that seriously disrupts the functioning of a community or institution and causes human, material, economic, or environmental losses that exceed the community's or institution's ability to cope using existing resources. Disasters can be caused by humans as well as natural causes. According to IFRC data from 2004 to 2013, the average number of natural disasters was 388 per year, accounting for 59% of total catastrophe events and the other 41% being man-made disasters, resulting in an average of 267 incidents per year.

The enormous number of deaths and financial losses that occur indicate the necessity for catastrophe prevention and management; thus, researchers are currently focused on emergency management and humanitarian logistics. Humanitarian logistics is frequently used to assess disaster management success. Logistics distribution in the proper amount, timing, and target will reduce the number of casualties, therefore logistics planning will become the

foundation of every aid distribution operation ([Ahmadi et al., 2015](#)). [Altay and Green \(2006\)](#) examined the research on emergency management in the OR/MS community. They found that researchers are most interested in mathematical programming. This was corroborated by [Hoyos, et al. \(2015\)](#), who found that 47% of the publications evaluated are about mathematical programming, and that research on mathematical programming with stochastic parameters has increased from 2006 to 2012.

Humanitarian logistics is the process of planning, implementing, and controlling the efficient and cost-effective flow and storage of products and commodities, as well as related information, from point of origin to point of consumption in order to fulfill the needs of the end beneficiary ([Thomas and Mizushima, 2005](#)). Disaster logistics research is becoming increasingly relevant as the threat of natural catastrophes grows ([Whybark, 2007](#)). Many literature reviews on research on humanitarian logistics have been conducted ([Tomasini and Van Wassenhove \(2009\)](#), [Kovács and Spens \(2009\)](#), [Costa, et al. \(2012\)](#), [Caunhye, et al. \(2012\)](#), [Leiras et al. \(2014\)](#), [Gutjahr and Nolz, \(2016\)](#) and [Habib et al \(2016\)](#) ).

[Caunhye, et al. \(2012\)](#) classified disaster logistics into two categories: (1) facility location and (2) relief distribution and casualty transportation. Each category is further subdivided depending on objective (single, multi-objective), data type (deterministic, stochastic), and each paper's objective function and limitations. [Gutjahr and Nolz \(2016\)](#) go into greater detail on research with multi-criteria objectives. [Hoyos, et al. \(2015\)](#) classify mathematical programming research in the same way that [Caunhye, et al. \(2012\)](#), classifies it, namely facility location, resource allocation, relief distribution, and casualty transportation. Meanwhile, [Leiras, et al. \(2014\)](#) classified humanitarian logistics difficulties into three categories: facility location, inventory management, and routing.

[Boonmee, et al. \(2017\)](#) go into greater detail on the facility location study, specifically reviewing the mathematical model for optimizing facility location. This research divides facility location problems into four categories based on data modelling: deterministic facility location problems, stochastic facility location problems, dynamic facility location difficulties, and robust facility location problems.

[Safer et al. \(2014\)](#) conducted a transportation and distribution analysis in emergency humanitarian logistics. [Safer, et al. \(2014\)](#) divide the research into two parts: (1) casualty transportation and evacuation and (2) distribution, with each subdivided further based on its model parameters and objective function. [Anaya-Arenas, et al. \(2014\)](#) reviewed the relief distribution network and classified relief distribution problems into four categories: (1) location/allocation and network design issues, (2) transportation issues, (3) combined location and transportation issues, and (4) other less popular but still important relief distribution topics.

The most recent literature review on facility location was completed in 2017, whereas the most recent literature review on relief distribution was conducted in 2014; so, in this study, the researcher did a literature review on the current state of the relief distribution in humanitarian logistics as additional updates on the research field. It is expected that the findings could give an insight on the potential future research.

## 2. Methodology

The phases of performing a literature review in this work are based on the processes outlined by [Seuring and Gold \(2012\)](#), which are roughly separated into four stages: data collection, descriptive analysis, category selection, and analysis.

### 2.1 Data collection

The literatures included in this work were discovered through research on Science Direct and Google Scholar. The material used in this paper is restricted to material published between 2004 and 2017. Because the topic of discussion is humanitarian logistics, the first step is to search for paper review literature that discusses humanitarian logistics using the keywords review, humanitarian, logistics, disaster, and emergency. Because the literature review study is centered on discussing aid distribution in humanitarian logistics, we are seeking for works that explore relief distribution. Relief, distribution, route, transportation, allocation, humanitarian, logistics, disaster, and emergency are the keywords utilized.

The material collected is filtered again, and papers that are not relevant to the issue are removed. The material excludes papers on the issues of routing, transportation, distribution, and allocation in the context of commercial logistics. Similarly, articles that simply describe disaster victim transportation or evacuation but not logistical distribution will be eliminated from the content. Only papers from scientific publications and conferences were used. Project papers, doctoral reports, and magazine articles are not accepted as material. This analysis relied on 92 publications published in journals and conferences, not including literature reviews.

## 2.2 Analysis

There are three parts of analysis used, namely, descriptive analysis, category selection, and content analysis. Descriptive analysis is used to provide an overview of current publication trends. Descriptive analysis provides information on the number of publications each year and articles per category of topic handled. A histogram will be used to display this analysis.

In the category selection, the collected paper content will be categorized in this study based on the type of problem. Furthermore, each problem category will be subdivided further based on the type of data modelling, objective function, time horizon, commodity changes, and methods utilized to address the problem.

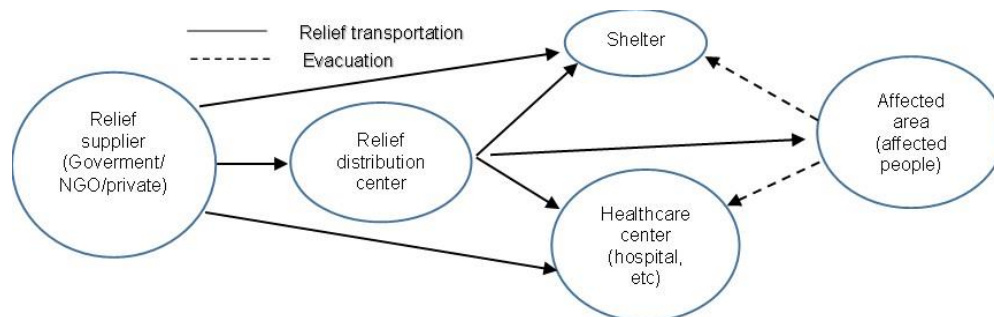
Material that has been categorized is read again to determine if the classification is correct. Another writer double-checked the content to prevent partiality in categorizing it. Furthermore, material that has not been widely explored yet is crucial stuff to discuss is evaluated. This material is a study topic that can be expanded upon.

## 3. Results

### 3.1 Research themes

The issues covered in this paper are all about relief distribution. In general, relief distribution consists of a number of decision sequences. The first decision is to construct the distribution network, which includes identifying the shelters and distribution hubs that will be used to support relief activities. The second option is the logistics deployment, which involves allocating available resources to distribution centers based on the needs of the people who will be served. The third decision concerns distribution routes ([Anaya-Arenas, et al., 2014](#)).

[Sheu \(2007\)](#) described a disaster logistics network made up of relief suppliers, distribution centers, and disaster-affected locations. Aid givers, both organizations and individuals, are referred to as relief suppliers. Relief distribution centers can be divided into levels, such as central distribution centers and local/regional distribution centers. Relief providers will send assistance to the central distribution center, and the central distribution center will send assistance to local/regional distribution centers. Relief organizations can also supply directly to local/regional distribution hubs. Shelters, healthcare centers, and affected areas can all be used to provide relief. Communities in the impacted region will be evacuated to shelters, but injured people will be transported to medical facilities. The disaster logistics network is depicted in Figure 1.



**Figure 1.** Disaster logistics network

Evacuation can take the form of transporting residents from disaster-affected areas to evacuation shelters or transporting injured victims to hospitals, which is commonly referred to as casualty transportation.

The following issues exist in the logistics network:

- Identifying and allocating resources at relief distribution sites, healthcare facilities, and shelters (location/allocation).
- Determining resource distribution routes to high-demand areas (routing).
- Integration of distribution and evacuation with location/allocation or route.
- Integration of location/allocation, routing, inventory and others

### 3.2 Literature Analysis

This section examines the 91 papers utilized as source material; 28 papers address location/allocation issues, 22 papers address routing issues, 12 papers address distribution concerns, and the remaining 29 papers address integration issues. Figure 2 depicts the distribution of papers from 2004 to 2017. Figure 2 illustrates that the number

of relief distribution papers increases from year to year. Prior to 2010, the concerns discussed were dominated by location/allocation and routing, but beginning in 2010, integrated papers began to be explored, and the quantity tended to increase. Location/allocation paper and integrated paper currently dominate in relief distribution paper.

Aside from the issues raised, publications can be divided into two categories: deterministic and uncertain data modelling. Deterministic studies comprise single period (static) and multi period (dynamic) publications in which all model parameters are deterministic. Meanwhile, publications with stochastic and robust model parameters are included in the uncertainty category. However, there are works that create two models in one study, namely one with deterministic parameters and one with uncertainty (Verma and Gaukler (2015), Marcelin et al. (2016) and Ahmadi, et al (2015)).

Figure 3 depicts the distribution of papers based on the type of data modelling per category of problem. There are more publications with uncertain data types than papers with deterministic data types for location/allocation problems, but more papers with deterministic data types for the other three problems; even for distribution and evacuation difficulties, only four studies mention uncertainty.

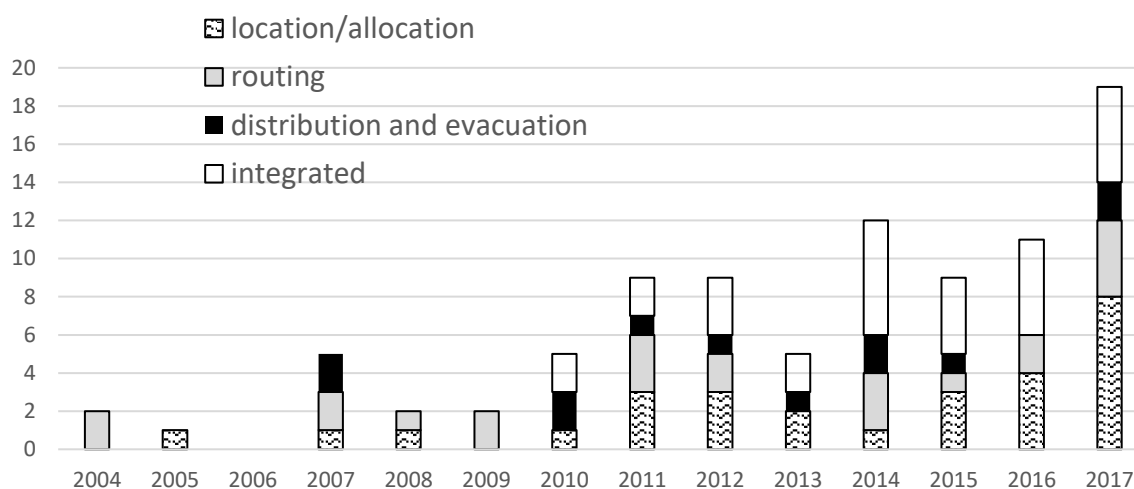


Figure 2. Distribution based on the themes

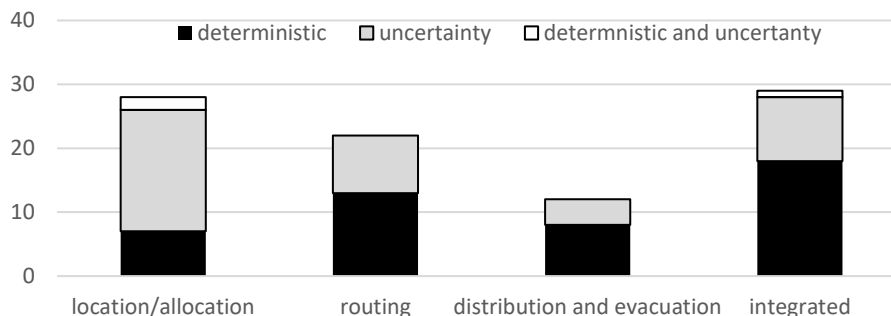
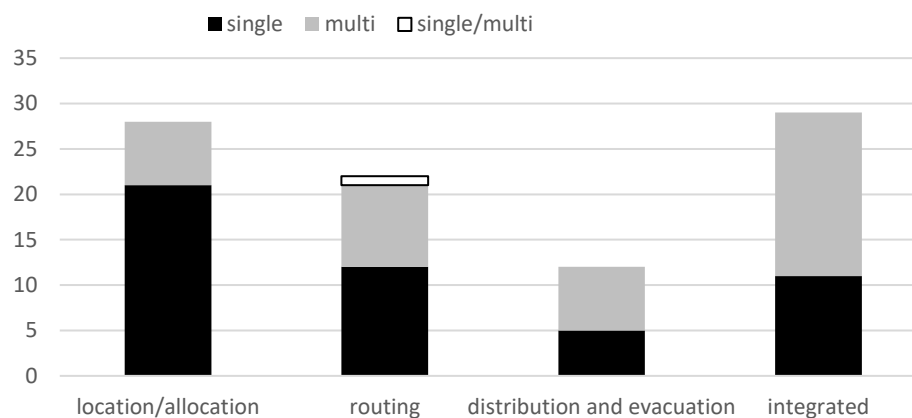


Figure 3. Paper distribution based on modelling approach

Another classification is based on its objective function, which is either single or multi objective (Figure 4). It is shown that 49 of the 91 studies are single objective papers, 41 are multi objective papers, and 1 study develops both single and multi objective at the same time. Location/allocation and routing problems have fewer single objectives, whereas distribution and evacuation difficulties and integrated problems have more. Another classification is the amount of variance in the commodity/resource/relief item transported and the solution approach.

Based on the number of commodity variations, there are two categories: single commodity and multi commodity. The number of papers containing multiple commodities is nearly equal to the number of papers containing a single commodity. It is classified as precise or heuristic based on the solution approach (Genetic Algorithm, Ant Colony Optimization, Tabu search, Simulated Annealing, and others). Capacity is one of the model's

constraints. Vehicle capacity, as well as relief distribution center or healthcare center capacity (facility capacity), are often limited. Furthermore, the number of commodities sent and the expenditure may be limited too. The amount of time available for a single trip can also constrain the model.



**Figure 4.** Paper distribution based on objective function

### 3.3 Location/Allocation

The location/allocation dilemma entails deciding where to locate a distribution center, health care center, or shelter among multiple existing options. The choice variable in question is a binary variable with a value of one if an existing candidate is chosen and a value of zero if the existing candidate is not chosen as a distribution facility, health care center, or shelter. Aside from establishing the location, another issue is determining the quantity of commodity to be supplied from suppliers to the distribution center or the health care center, as well as the quantity of commodity to be sent from the distribution center to the demand point (shelter or impacted area). The route taken is ignored in this situation.

Articles in Table 1 discuss location/allocation in relief distribution. Several studies have been written about multi-echelon distribution. Horner and Downs (2010) replace distribution centers with the terms Logistical Staging Areas (LSA), Points of Distribution (POD), and Break of Bulk Points (BOB). LSA functions as a central distribution center, whereas POD and BOB function as regional/local distribution centers. LSA delivers needed products to populations in need via POD and BOB. POD and BOB perform the identical functions, although BOB has a smaller capacity than POD. In addition to analyzing the uncertainty of roadway failure, [Horner and Widener \(2011\)](#) utilize the same concept and analyze multi-echelon distribution. [Charles and Laurus \(2011\)](#), who are global and regional warehouses, also perform multi-echelon distribution. Products from global and regional suppliers will be sent to regional warehouses, and products from regional warehouses will be delivered to local warehouses. Local warehouses will receive commodities from local suppliers in addition to getting things from regional warehouses. Products are delivered to the impacted region from nearby warehouses.

Four of the publications with type uncertainty are robust models, including [Bozorgi-Amiri, et al. \(2013\)](#), [Jabbarzadeh, et al. \(2014\)](#), [Zokaei, et al. \(2016\)](#) and [Kasemsri et al. \(2017\)](#). Stochastic data types are used in papers with other data types ([Chang, et al. \(2007\)](#), [Balcik and Beamon \(2008\)](#), [Horner and Widener \(2011\)](#), [Zhan and Liu \(2011\)](#), [Paul and Hariharan \(2012\)](#), [Davis, et al \(2013\)](#), [Salman and Yücel \(2015\)](#), [Verma and Gaukler \(2015\)](#), [Lu et al. \(2016\)](#), [Marcelin et al. \(2016\)](#), [Paul and MacDonald \(2016\)](#), [Rath, et al. \(2016\)](#), [Condeixa et al \(2017\)](#), [Cook and Lodree \(2017\)](#), [Sahebjamnia, et al \(2017\)](#) and [Wang, et al \(2017\)](#)).

The solution method for the location/allocation problem is exact and heuristic. [Salman and Yücel \(2015\)](#) use Tabu Search, while [Zhang, et al. \(2012\)](#), [Verma and Gaukler \(2015\)](#), [Paul and MacDonald \(2016\)](#) and [Mishra, et al. \(2017\)](#) developed a heuristic algorithm to solve the model they created. [Marcelin et al. \(2016\)](#) considered the uncertainty parameter, namely transportation time, because transportation time is affected by road conditions and congestion. Aside from transit time, aid demand is also unpredictable due to the refugees' age. Refugees aged 65 and up are unlikely to have been relocated to shelters and are likely to remain in the affected area.

**Table 1.** Location/allocation problem in relief distribution.

Author	Data type	Obj.	Obj function	Period	commodity	Capacity limit	Solution method
Sheu, et al. (2005)	deterministic	multi	Total number of fatalities, total distance cost	single	single	facility	Exact
Chang, et al. (2007)	uncertainty	multi	Expected shipping distance, total cost	single	multi	facility	Exact
Balcik & Beamon (2008)	uncertainty	single	Expected covered demand	single	multi	facility	Exact
Horner & Downs (2010)	deterministic	single	Distribution cost	single	single	facility	Exact
Charles & Luras (2011)	deterministic	single	Cost	multi	multi	facility	Exact
Horner & Widener (2011)	uncertainty	single	Total cost	single	single	facility	Exact
Zhan & Liu (2011)	uncertainty	multi	Travel time, unmet demand	single	multi	vehicle, commodity	Exact
Ji & Zhu (2012)	deterministic	multi	Demand fill rate, distribution time	multi	multi	facility	Exact
Paul & Hariharan (2012)	uncertainty	single	Sum of fatality cost and maintaining stockpile cost	single	single	-	Exact
Zhang, et al. (2012)	deterministic	single	Resorce allocation cost	single	multi	resource	Heuristic
Bozorgi-Amiri, et al. (2013)	uncertainty	multi	Expected total cost, sum of maximum shortage	single	multi	facility	Exact
Davis, et al. (2013)	uncertainty	single	Expected total cost	single	single	time	Exact
Jabbarzadeh, et al. (2014)	uncertainty	single	Total cost	multi	single	facility	Exact
Khayal et al. (2015)	deterministic	Single	Social cost	multi	multi	facility	Exact
Salman & Yücel (2015)	uncertainty	single	Expected demand coverage	single	single	-	Heuristic
Verma & Gaukler (2015)	deterministic uncertainty	single	Transportation cost	single	single	facility	exact, heuristic
Lu et al. (2016)	uncertainty	single	Total distribution time	multi	multi	Commodity, facility, vehicle	Exact
Marcelin et al. (2016)	deterministic uncertainty	single	Total transportation cost	single	single	-	Exact
Paul & MacDonald (2016)	uncertainty	single	Total expected cost	single	single	facility	Heuristic
Rath, et al. (2016)	uncertainty	multi	Expected demand coverage, total cost	single	single	vehicle	Exact
Zokaee, et al., (2016)	uncertainty	single	Total cost	single	multi	facility	Exact
Babaei & Shahanaghi (2017)	uncertainty	Multi	Logistic cost, demand satisfaction	multi	multi	Facility, budget	Heuristic
Condeixa et al. (2017)	uncertainty	single	Total cost	single	multi	commodity	Exact
Cook & Lodree (2017)	uncertainty	single	Expected shortage	multi	single	vehicle	Exact
Kasemsri et al. (2017)	uncertainty	single	Total delivery cost	single	single	Vehicle, facility, time	Exact
Mishra, et al. (2017)	deterministic	multi	Unmet demand, travel distance	single	multi	facility	Heuristic
Sahebjamnia, et al. (2017)	uncertainty	multi	Coverage, total cost, response time	multi	multi	Facility, vehicle	Simulation
Wang, et al. (2017)	uncertainty	multi	Reliability, transportation cost	single	single	time	Exact

### 3.4 Routing

In a disaster logistics network, routing is concerned with resource/commodity distribution routes. If the distribution network is shown as a network model, distribution suppliers, distribution centers, shelters, health care centers, and affected areas are nodes, while arcs indicate possible transportation routes. The decision variable in the routing problem is determining the selected arc for resource/commodity transportation and determining the number of commodities that can be transferred to the specified arc. Each arc has criteria for transit expenses, travel time, and the lowest and maximum allowable limits. The node that gets assistance (demand node) contains a parameter for the number of requests required at that node, whereas the parameter for the supply node is the amount that can be delivered. The capacity parameter is associated with the transshipment node (distribution center). Other factors are frequently associated with the mode of transportation.

There are 22 routing articles, 13 of which use deterministic modelling data while the other 9 use uncertain data. There are 12 studies in the form of a single objective function, 9 papers in the form of a multi-objective function, and 1 study developing a single objective model and a multi-objective model, namely by [Yuan and Wang \(2009\)](#).

The solution method is both exact and heuristic. Greedy Heuristic, Ant Coloni Optimization, Genetic Algorithm, and Simulated Annealing are the heuristic methods employed in this routing problem. Solution based on the Greedy Heuristic proposed by [Özdamar, et al. \(2004\)](#) and [Chang et al. \(2014\)](#). by [Yuan and Wang \(2009\)](#) apply Ant Colony Optimization to finish the multi-objective model they created. [Berkoune et al. \(2012\)](#) and [Hamed, et al. \(2012\)](#) employed a Genetic Algorithm as a model solution approach, whereas [Yang \(2017\)](#) used Simulated Annealing. [Fontem et al. \(2016\)](#) created a decomposition-based heuristic for stochastic emergency routing situations. [Ortuño, et al. \(2011\)](#) devised a two-phase solution method based on lexicographical goal programming. [Babaei, et al. \(2017\)](#) conducted another investigation integrating lexicographical goal programming with a weighted sum technique.

### 3.5 Distribution and evacuation

Distribution and evacuation problems are a combination of location/allocation problems and evacuation, or routing problems and evacuation. [Salmeron and Apte \(2010\)](#), [Liu and Guo \(2014\)](#), [Sheu and Pan \(2014\)](#), [Widener, et al. \(2015\)](#), and [Mollah et al. \(2017\)](#) are publications that examine the integration of location/allocation with evacuation. Meanwhile, [Yi and Kumar \(2007\)](#), [Yi and Özdamar \(2007\)](#), [Chern, et al. \(2010\)](#), [Ozdamar \(2011\)](#), [Özdamar and Demir \(2012\)](#), [Najafi, et al. \(2013\)](#), and [Al Theeb and Murray \(2017\)](#) studied the integration of routing problem and evacuation.

To solve this challenge, heuristic methods are commonly used. Ant Coloni Optimization was applied by [Yi and Kumar \(2007\)](#). [Chern, et al. \(2010\)](#) created the ERTPA (Emergency Relief Transportation Planning Algorithm) heuristic algorithm. Meanwhile, [Özdamar and Demir \(2012\)](#) created the HOGCR heuristic approach, which is a hierarchical cluster and route procedure that uses cluster first, route second.

[Najafi, et al. \(2013\)](#) developed a multi-objective resilient optimization model. SMSRM (Solution Methodology of the Structured Robust Model) is the recommended solution approach. A bi-objective stochastic model was constructed by [Liu and Guo \(2014\)](#). The model is completed in two-stages: the first stage employs a lexicographic approach to convert the bi-objective stochastic programming model into a series of single objective stochastic programming models, and the second employs scenario-decomposition-based heuristic algorithms developed to complete the model as a result of the first stage's changes.

[Al Theeb and Murray \(2017\)](#) developed a model called the humanitarian logistics vehicle routing problem (HLVRP). The solution for this model uses the heuristic method which consists of 4 phases, namely phase 1: construct vehicle routes, phase 2: determine distribution quantities, phase 3: improvement via local search, and phase 4: save elite route. Iteration using 4 phases of the heuristic method is carried out, starting with doing phase 1, phase 2, phase 3, phase 4 and returning to phase 1 and so on. The iteration stops for example until a certain time or until there is no improvement in the next iteration.

### 3.6 Integrated approach

The problem of integrating location selection and routing is discussed in [Nolz, et al. \(2010\)](#), [Han, et al. \(2011\)](#), [Nolz, et al. \(2011\)](#), [Afshar and Haghani \(2012\)](#), [Abounacer, et al. \(2014\)](#), [Rath and Gutjahr \(2014\)](#), [Wang, et al. \(2014\)](#), [Ahmadi, et al \(2015\)](#), [Caunhye et al. \(2016\)](#), [Fikar, et al. \(2016\)](#), [Ai and Wigati \(2017\)](#), [Chang et al. \(2017\)](#), [Cheraghi and Hosseini-Motlagh \(2017\)](#). Meanwhile, the problem of integration of resource allocation and routing is discussed by [Huang et al. \(2015\)](#) and [Sharif and Salari \(2015\)](#).

[Nolz, et al. \(2010\)](#) developed an adaptation of the non-dominated genetic sorting algorithm II (NSGA-II) including variable neighborhood search (VNS) and path relinking. [Han, et al. \(2011\)](#) developed a new method based on the successive subproblem solving approach (SSS) in the Lagrangian relaxation (LR) framework. Nolz, et al. (2011) used 2 phases as the solution method. In phase 1, a memetic solution approach is developed to generate a set of potentially Pareto-optimal solutions for multi-objective covering tour problems. This method is based on the Nondominated Genetic Sorting Algorithm II (NSGA-II) including variable neighborhood search (VNS) and path relinking, while phase 2 is the Enrichment phase using Martins' algorithm for multi-objective shortest paths. [Afshar and Haghani \(2012\)](#), [Abounacer, et al. \(2014\)](#), [Wang, et al. \(2014\)](#), [Caunhye et al. \(2016\)](#), [Ai and Wigati \(2017\)](#) use the

exact method as a solution method. Ahmadi, et al (2015) used the heuristic variable neighborhood search (VNS) method. [Chang et al. \(2017\)](#) applied a robust optimization method to overcome uncertainty parameters and a solution method using a Genetic Algorithm. [Cheraghi and Hosseini-Motlagh \(2017\)](#) developed a fuzzy-stochastic mixed integer linear programming model for designing blood supply chain networks. The model solution uses the exact method.

**Table 2.** Routing problems in relief distribution.

Author	data type	Obj.	Obj function	period	commodity	Capacity limits	solution method
Barbarosoğlu & Arda (2004)	uncertainty	single	Total transportation cost and expected resource cost	single	multi	vehicle, link	exact
Özdamar, et al. (2004)	deterministic	single	Sum of unsatisfied demand	multi	multi	vehicle	exact, heuristic
Sheu (2007)	deterministic	multi	Transportation cost, coverage	multi	multi	facility, vehicle	exact
Tzeng, et al. (2007)	deterministic	multi	Total cost, total travel time, satisfaction	multi	multi	Commodity	exact
Balcik, et al. (2008)	deterministic	single	sum of routing cost and penalty cost	multi	multi	Vehicle	exact
Yan & Shih (2009)	deterministic	multi	Length of time for repair, distribution time	single	single	-	exact
Yuan & Wang (2009)	deterministic	single/ multi	Total travel time/ Total travel time, path complexity	multi	single	-	Exact/ heuristic
Ortuño, et al. (2011)	uncertainty	multi	Cost, travel time, ransack probability, reliability, equitable distribution, priority status	single	single	Vehicle	exact
Vitoriano et al. (2011)	uncertainty	multi	Cost, operation time, equity, priority, reliability, security	single	single	Facility, vehicle, link	exact
Chen, et al. (2011)	deterministic	single	Travel time	single	single	Vehicle, commodity	Exact
Berkoune et al. (2012)	deterministic	single	Total transportation duration	single	multi	Facility, vehicle	Heuristic
Hamed, et al. (2012)	uncertainty	single	Sum travel time cost and reliability cost	multi	single	-	Heuristic
Battini et al. (2014)	deterministic	single	Cost	multi	multi	Vehicle, available time	exact
Chang et al. (2014)	deterministic	multi	Unsatisfied demand, time to delivery, transportation cost	single	single	vehicle	heuristic
Liberatore et al. (2014)	uncertainty	multi	Demand satisfaction, time, security, reliability	single	single	-	exact
Camacho-Vallejo et al. (2015)	deterministic	single	Response time	single	multi	facility	exact
Fontem et al. (2016)	uncertainty	single	Relief delivery value	single	single	time	heuristic
Huang & Song (2018)	uncertainty	single	Expected value total arrival times	single	single	Vehicle, facility	-
Babaei, et al. (2017)	uncertainty	multi	Total travel time, total network length, total path link	single	single	vehicle	exact
Setak, et al. (2017)	deterministic	single	Total travel time and number of vehicles	single	single	vehicle	exact
Yang (2017)	deterministic	multi	Rescue time, rescue effect	single	single	-	heuristic
Uslu, et al. (2017)	uncertainty	single	Total distance	single	single	facility, vehicle	exact

**Table 3.** Distribution and evacuation problem in relief distribution.

Author	Data type	Obj.	Objective function	Period	commodity	Capacity limit	Solution method
Yi & Kumar (2007)	deterministic	multi	Weighted sum of unsatisfied demand and unserved wounded people	multi	multi	vehicle	heuristic
Yi & Özdamar (2007)	deterministic	multi	Expected shipping distance, total cost	multi	multi	vehicle	exact
Chern, et al. (2010)	deterministic	multi	Traveling time, distribution cost	multi	multi	vehicle	heuristic
Salmeron & Apte (2010)	uncertainty	multi	expected number of casualties, expected unmet transfer population	single	single	vehicle, facility, time	exact
Ozdamar (2011)	deterministic	single	Total mission time	single	multi	vehicle, facility, commodity	heuristic
Özdamar & Demir (2012)	deterministic	single	Travel time	single	multi	vehicle, commodity	heuristic
Najafi, et al. (2013)	uncertainty	multi	Total unserved injured people, total unsatisfied demand, total vehicle utilization	multi	multi	vehicle, facility	exact
Liu & Guo (2014)	uncertainty	multi	Expected minimal fill rate, expected total cost	single	multi	vehicle	heuristic
Sheu & Pan (2014)	deterministic	multi	Travel distance, operational cost, psychological cost	multi	multi	facility	exact
Widener, et al. (2015)	uncertainty	single	Distance	multi	single	-	simulation, exact
Al Theeb & Murray (2017)	deterministic	single	Sum of unsatisfied demand, unserved wounded, nontransfer worker	multi	multi	Commodity, vehicle	heuristic
Mollah et al. (2017)	deterministic	single	Total cost	single	single	Facility, vehicle, time	Exact, heuristic

[Mete and Zabinsky \(2010\)](#) , [Lin et al. \(2012\)](#) , [Noyan \(2012\)](#), [Rezaei-Malek and Tavakkoli-Moghaddam \(2014\)](#) , [Bozorgi-Amiri and Khorsi \(2016\)](#), [Tavana et al. \(2017\)](#) discussed the integration of location/allocation, routing and inventory. [Mete and Zabinsky \(2010\)](#) developed a two-stage stochastic programming model to solve storage and distribution problems for emergency medical supplies. Stage 1 solves the problem of warehouse selection and inventory decisions, while stage 2 solves transportation plans and demand satisfaction decisions.

A two-phase heuristic approach developed by [Lin et al. \(2012\)](#) to solve the problem. Phase 1 is to place temporary depots and allocate covered demand points, Phase 2 uses two iterative procedures for replenishment of items, assignment of vehicles and delivery of items. Replenishment of items and assignment of vehicles were completed first using Dantzig's Greedy Algorithms and Random Re-Starts Hill Climbing Algorithm, and continued solving the problem of delivery of items using the Decomposition and Assignment Heuristics approach (DAH).

The model developed by [Noyan \(2012\)](#) considers the risk-averse two-stage stochastic programming model, where it is determined conditional-value-at-risk (CVaR) as a measure of risk. [Noyan \(2012\)](#) uses two decomposition algorithms based on the generic Benders-decomposition approach to solve the problem. Robust models in the integration of location selection, routing and inventory problems were developed by [Rezaei-Malek and Tavakkoli-Moghaddam \(2014\)](#) using the Reservation Level Tchebycheff Procedure (RLTP) method to solve the bi-objective model.

The solution method proposed by [Tavana et al. \(2017\)](#) is an epsilon-constraint method, non-dominated genetic sorting algorithm (NSGA-II), and a modification of NSGA-II called reference point based non-dominated genetic sorting algorithm-II (RPBNSGA-II). Analysis of variance (ANOVA) is used to analyze the performance of using the epsilon-constraint method, NSGA-II and RPBNSGA-II. The results of the ANOVA show that NSGA-II is better than the other two methods for problems with small sizes, whereas for problems with large sizes, RPBNSGA-II is better.

**Table 4.** Integrated problem in relief distribution

Author	Data type	Obj.	Objective function	Period	commodity	Capacity limit	Solution method
Mete & Zabinsky (2010)	uncertainty	Single	Total cost operating ware house (stage 1), transportation time (stage 2 )	single	multi	vehicle	exact
Nolz, et al. (2010)	deterministic	Multi	Distance, coverage, travel times	single	single	vehicle	exact, heuristic
Han, et al. (2011)	deterministic	Single	Total transportation distance (time)	multi	multi	link, facility	exact
Nolz, et al. (2011)	deterministic	Multi	Risk, coverage, total travel time	single	single	facility, vehicle	heuristic
Afshar & Haghani (2012)	deterministic	Single	Unsatisfied demand	multi	multi	facility, vehicle	exact
Lin et al. (2012)	deterministic	Single	Operational cost	multi	multi	vehicle, facility	heuristic
Noyan (2012)	uncertainty	Multi	Total cost, satisfy realized demand	single	multi	facility	heuristic
Khorsi, et al. (2013)	uncertainty	Multi	Expected total cost, sum of max shortage	multi	multi	facility	exact
Rottkemper & Fischer (2013)	deterministic	Multi	Unmet demand, operational cost	multi	single	-	exact
Abounacer, et al. (2014)	deterministic	Multi	Transportation duration, number of agent, uncovered demand	single	multi	facility, vehicle	exact
Barzinpour & Esmaili (2014)	deterministic	Multi	Coverage population, facility setup cost, transportation cost	single	multi	commodity	exact
Esmail & Barzinpour (2014)	deterministic	Multi	Coverage inside and outside the municipal region, cost	single	multi	facility	heuristic
Rath & Gutjahr (2014)	deterministic	Multi	Cost, coverage demand	single	single	vehicle	heuristic
Rezaei-Malek & Tavakkoli-Moghaddam (2014)	uncertainty	Multi	Weighted response time, total cost	single	multi	vehicle, commodity	exact
Wang, et al. (2014)	deterministic	Multi	Travel time, distribution cost, reliability	single	multi	link	heuristic
Ahmadi, et al (2015)	deterministic, uncertainty	Single	Sum of distribution time, penalty cost and fixed cost	single	multi	vehicle, facility	exact, heuristic
Huang et al. (2015)	deterministic	Multi	Lifesaving utility, delay cost, quality of demand fill rate	multi	single	vehicle	exact
Pérez-Rodríguez & Holguin-Veras (2015)	deterministic	Single	Social cost	multi	multi	vehicle	heuristic
Sharif and Salari (2015)	deterministic	Single	Total cost	single	single	vehicle	heuristic
Bozorgi-Amiri & Khorsi (2016)	uncertainty	Multi	Sum of maximum shortage, travel time, total cost	multi	multi	facility	Heuristic
Caunhye et al. (2016)	uncertainty	Single	Cost and time	single	single	facility, vehicle	exact
Fikar, et al. (2016)	uncertainty	Single	Lead time	multi	single	facility	simulation, heuristic
Ransikarbum & Mason (2016a)	deterministic	Multi	Equity, unsatisfied demand, total network cost, deviational variable based on fairness, unsatisfied demand and cost	single	single	facility, commodity, budget	exact
Ransikarbum & Mason (2016b)	deterministic	Multi	Equity, unsatisfied demand, total network cost	single	single	facility, commodity, budget	exact
Ai and Wigati (2017)	deterministic	Single	Unmet demand	single	single	Vehicle, available time	exact
Chang et al. (2017)	uncertainty	Multi	Total cost, demand satisfaction, vehicle velocity	single	single	vehicle	heuristic
Cheraghi & Hosseini-Motlagh (2017)	uncertainty	Single	Total cost	multi	single	facility	exact
Manopiniwes & Irohara (2017)	uncertainty	Multi	Total cost, response time	single	single	facility, vehicle, commodity	exact
Tavana et al. (2017)	deterministic	Multi	Total procurement and preparation cost, operational cost, relief responcw	single	multi	vehicle	heuristic

The problem of location/allocation and inventory integration is discussed by [Khorsi, et al. \(2013\)](#), [Rottkemper and Fischer \(2013\)](#), [Barzinpour and Esmaili \(2014\)](#), [Esmail and Barzinpour \(2014\)](#), [Pérez-Rodríguez and Holguin-Veras \(2015\)](#). The model solution on [Khorsi, et al. \(2013\)](#), [Rottkemper and Fischer \(2013\)](#), [Barzinpour and Esmaili \(2014\)](#) use the exact method, while [Esmail and Barzinpour \(2014\)](#) use a genetic algorithm. [Pérez-Rodríguez and Holguin-Veras \(2015\)](#) developed models for single commodities and multiple commodities. The model solution uses a heuristic method, first using Inventory Allocation with Point-to-Point Distribution (IA-PTP) for a single commodity, Inventory Allocation with Point-to-Point Distribution and Multiple Commodities (IA-PTP-MC) for multiple commodities and so on using VRP.

[Ransikarbum and Mason \(2016b\)](#) developed a multiple objective integrated response and recovery (MOIRR) model, which is an integrated aspect of distribution and restoration of distribution system. This research discusses distribution issues for delivery of aid and restoration in disrupted supply ports, disrupted relief warehouses, disrupted arcs between supply ports and relief warehouses and disrupted arcs between relief warehouses and demand. [Ransikarbum and Mason \(2016a\)](#) developed a GP-based MOIRR model. MOIRR is modeled in A Mathematical Programming Language (AMPL) and analyzed using the CPLEX solver ([Ransikarbum and Mason \(2016b\)](#), [Ransikarbum and Mason \(2016a\)](#)).

[Manopiniwes and Irohara \(2017\)](#) discuss the integration of location/allocation, routing and evacuation. The developed model integrates the pre-disaster and post-disaster phases. In the pre-disaster phase, a relief distribution center (DC) location will be selected and the amount of relief supply stored in the DC will be determined. Evacuations from affected communities to shelters and relief supply distribution routes from DCs to shelters and from DCs to affected communities are carried out in the post-disaster phase. The model solution uses the exact method.

#### 4. Conclusion and Future Research

This study undertakes a review of the literature on relief distribution, which is a part of humanitarian logistics. This study examines 91 papers published in journals and conference proceedings between 2004 and 2017 in addition to literature review publications. From the analysis, there are four categories of difficulties were identified: location/allocation, routing, distribution and evacuation, and integration of location/allocation, routing, inventory, and others (integrated). Prior to 2010, the challenges discussed were dominated by location/allocation and routing, but beginning in 2010, integrated papers began to be explored, and the quantity increased. Relief distribution paper is currently dominated by location/allocation paper and integrated paper.

Each type of problem is further classified based on the type of data modelling (deterministic/uncertainty), objective function (single/multi), time period (single period/multi period), commodity (single commodity/multiple commodity), and solution approach (exact/heuristic). The uncertainty data type is more commonly used in the location/allocation problem, but the deterministic data type is more commonly utilized in the other three situations. Travel time, demand in the impacted area, supply relief, and travel costs are among the uncertainty parameters considered. Models with a single objective function are explored more in papers that develop multi-objective function models, whereas distribution and evacuation problems and integrated problems are studied more in papers that build multi-objective function models. The exact technique is more often employed as a solution method than the heuristic method. The genetic algorithm and its variants are the most extensively used heuristic methods.

On integrated issues, the integration discussed are integration of location selection and routing (13 papers), integration of resource allocation and routing (2 papers), integration of location/allocation, routing and inventory (6 papers), location/allocation and inventory integration (5 papers), distribution and restoration integration (2 papers), integration of location/allocation, routing and evacuation (1 paper).

In terms of distribution and evacuation integration, the most often discussed evacuation is causality evacuation, which involves transporting the injured from the impacted region to a medical center or a shelter. Because there may still be populations that cannot or do not want to be evacuated, the number of healthy victims evacuated to the shelter will affect the demand for commodity relief such as food, water, medicine, and others at the shelter, as well as the demand for the affected area. Because population behavior and culture strongly influence the amount of healthy victims in the shelter, the need for the shelter is unpredictable. The demand for affected areas and shelters in the paper that discusses healthy victims is deterministic and unrelated to the number of people evacuated. Hence the aspect of uncertainty in all aspects of humanitarian logistics process, both in pre-disaster or post disaster is

potentially to be explored. Consequently, the solution method must also adapt to these conditions, such as the use of simulation which is still rarely used as a tool for helping the stakeholders in making decision.

Aside from the aforementioned conclusions, this study still lacks comprehensive analysis of implementation, as the aid distribution is potentially to be unique in different areas and disasters. Therefore the four difficulties explored will have different characteristics on each site. Furthermore, the coordination and social aspect have not been adequately investigated, despite the fact that they may have a considerable impact on relief distribution. Because of the existence of this gap, it could be used as a future research topic.

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