Review on Model and Algorithms of the Post-Disaster Relief Distribution Problem

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Abstract. With the global economic development and the instability of the political structure, in recent years, the occurrence of major disasters around the world has shown an intensified trend. This paper reviews on the model and algorithm of relief distribution in emergency logistics. Systematically analyzing the present academic research on relief distribution, this paper classified researchers into four categories: Vehicle Routing Problems; Inventory Routing Problems; Location Problems; Location Routing Problems. Finally, we draw a conclusion of emergency logistics and propose a new study direction of relief distribution in the future research.

1. Introduction
In the past century, various types of disasters have occurred frequently in the world, and their destructiveness and scale have increased significantly. The population affected by disasters has also increased dramatically. According to the statistics of relevant UN departments, about 235 million people have been affected by disasters every year since the 1990s. The impact of this number is increasing every year. Due to the current imbalance in global economic development, emerging economies are developing rapidly, especially in the BRICS, Brazil, Russia, India, China and South Africa. So how to mitigate the loss of calamity after disaster happened is really important to these countries.

Admittedly, there are many scholars study a large amount of different type of relief distribution problems. For instance, Aakil M. Caunhye. et al (2012) [1] proposed that optimization modeling can be an effective tool for solving emergency logistics problems and the process can be divided into three parts: pre-disaster, mid-disaster and post-disaster. Additionally, ChawisBoonmee.et al (2017) [2] also pointed out the importance of solving the major humanitarian relief activities through the combination of precise algorithms and heuristic algorithms. Throughout these researches on emergency logistics, I found that although these former papers give us some wise advises when we deal with the post-disaster problem, we lack the systematic study to relief distribution in post-disaster.

The rest of the paper is arranged as follows: the second part mainly deals with vehicle routing problems; the third part will distribute the inventory routing problems; the fourth part mainly deals with the location problems; the fifth part will focus on location routing problems; the sixth part is conclusion.

2. Vehicle Routing Problems
In recent years, many researchers have a huge emphasis on vehicle routing problems and this question mainly solves how to send the emergency goods to victims immediately when the disaster happened. For instance, Sheu, JiuhBiing (2014)[3] purposed a conceptual model based on survival psychology...
and cognition theories to pursue disaster relief–service distribution to maximize survivor resilience. The author gives us a new field to research the emergency logistics. ZhiHua Hu et al (2014)[4] built a novel mixed-integer linear program based on minimization of panic-induced psychological penalty cost, psychological intervention cost, and costs associated with transportation and building shelters in order to solve multi-step evacuation and temporary resettlement. DilekTuzun Aksu et al (2014) [5] proposed a mathematical model to maximum network accessibility for enabling identifies criticality of blockages and clears them with limited resources within a reasonable time. Furthermore, Linet Özdamar et al (2011) [6] described multi-level clustering algorithm called HOGCR and it was always used to solve coordinating vehicle routing in large-scale post-disaster distribution and evacuation activities, as well as finding the satisfactory vehicle routing results. In addition, Mehdi Najaf (2013) [7] designed a dynamic model to dispatch vehicle in response to an earthquake and it aimed to minimum the time of delivery the necessary goods to the disaster area and send the injured people to the hospital. Additionally, Yawen Zhou et al (2017) [8] designed a multi-objective optimization model for multi-period dynamic ERS problems with the uncertainty in the roadway availability and it aimed to minimize the unsatisfied demand of affected points with the purpose of satisfying the demand of people in disaster areas as much as possible and minimize the risk of choosing the damaged road, and aims at guiding the rescue team to choose appropriate and efficient roads. B.Zahiri (2018) [9] presented a novel bi-objective mixed-integer model and a novel hybrid multi-objective self-adaptive differential evolution algorithm to deal with blood transportation in emergency vehicle routing problem and achieved simultaneously optimize the total cost and freshness of transported blood products to hospitals. In this way, Qiang Zhang (2018) [10] proposed a mixed algorithm based on combining artificial immune and ant colony optimization (ACO) algorithms to solve three different targets in emergency grain vehicle routing problem, including maximizing satisfaction of the needs at the emergency grain demand points, minimizing total cost of grain distribution and minimizing the distribution time respectively. So we make a table to list these relevant academic papers.

Table 1. List of Vehicle Routing Problem

| Reference | Author | Objective | Problem | Method |
|-----------|--------|-----------|---------|--------|
| [3]       | Sheu, JiuhBiing | Maximum survivors’ resilience | Stochastic single goal in vehicle routing problem | Conceptual model |
| [4]       | ZhiHua Hu et al | multi-step evacuation and temporary resettlement minimization time | mixed-integer linear program |
| [5]       | DilekTuzun Aksu et al (2014) | satisfactory vehicle routing results | mathematical model multi-level clustering algorithm called HOGCR |
| [6]       | Linet Özdamar et al | minimum the time of delivery | single goal in vehicle routing problem | dynamic model |
| [7]       | Mehdi Najaf | minimize the unsatisfied demand and risk and guiding the rescue team to choose appropriate and efficient roads | a multi-objective optimization model |
| [8]       | Yawen Zhou et al (2017) | achieved simultaneously optimize the total cost and freshness of transported blood products to hospitals | a novel bi-objective mixed-integer model and a novel hybrid multi-objective self-adaptive differential evolution algorithm |
| [9]       | B.Zahiri (2018) | maximizing satisfaction of the needs, minimizing total cost of grain distribution and minimizing the distribution time | mixed algorithm based on combining artificial immune and ant colony optimization (ACO) algorithms |
| [10]      | Qiang Zhang (2018) | | | |
3. Inventory Routing Problem

In this section, we would consider a different range of related literatures. Previous papers and latest research in the field of emergency logistics are examined focusing on emergency inventory-routing problem and we would divide this problem into two aspects: stochastic and certainty respectively. For instance, Aakil M.Caunhye et al (2016) [11] propose a two-stage location-routing model with recourse for integrated preparedness and response emergency accidents planning under uncertainty. Additionally, Emre Çankaya et al (2018)[12] developed a Cluster-Route-Improve Heuristic (CRI) to achieve equitable distribution of these supplies to the affected areas over a planning horizon.

| Reference | Author | Objective | Method | Problem |
|-----------|--------|-----------|--------|---------|
| [11]      | Aakil M.Caunhye et al (2016) | integrated preparedness and response emergency accidents planning under uncertainty | two-stage location-routing model | Stochastic inventory-routing problem |
| [12]      | Emre Çankaya et al (2018) | equitable distribution of these supplies to the affected areas over a planning horizon | Cluster-Route-Improve Heuristic (CRI) | Certainty inventory-routing problem |

4. Location Problems

| Reference | Author | Objective | Problem | Method |
|-----------|--------|-----------|---------|--------|
| [13]      | Fatih Cavdur et al (2016) | Minimum the total distance traveled, the unmet demand and the total number of facilities | Stochastic emergency location problem | a two-stage stochastic program |
|          | Nathalie Cotes et al (2019) | Minimization the global social costs minimize total amount of value at risk and total cost of network | facility location model |  |
| [15]      | Vahidreza Ghezavati et al (2018) | Certainty emergency location problem | (\(\varepsilon\)) – constraint; NSGA-II; MOPSO |  |
| [16]      | Chawis Boonmee et al (2018) | minimize the financial effects through assessment of the fixed costs and variable costs | a mathematical model of mixed-integer linear programming |  |
| [17]      | Mahmoud Golabi et al(2017) Rajali Maharjan et al (2017) | minimizes the aggregate traveling time improvement response and efficiency and decreasing cost minimizing the expected total cost. | a mathematical model simplex algorithm with branch and bound |  |
| [19]      | Kanglin Liu et al (2019) |  | distributionally robust model[4] |  |
In this section, we would think about a different variety of related papers on emergency material distribution location problems and also divide this part into two sections: stochastic and certainty respectively, such as Fatih Cavdur et al (2016) [13] developed a two-stage stochastic program to solve the problem of temporary disaster response facility allocation for temporary or short-term disaster relief operations and achieved to minimize the total distance traveled, the unmet demand and the total number of facilities (considering the potential difficulties to access the facilities). Nathalie Cotes et al (2019) [14] develops a facility location model for prepositioning supplies in preparation for disasters. Meanwhile, Vahidreza Ghezavati et al (2018 [3]) [15] used three different algorithms to solve bi-objective hub facility location problem and it aims to minimize total amount of value at risk and total cost of network. Chawis Boonmee et al (2018) [16] developed a mathematical model of mixed-integer linear programming to minimize the financial effects through assessment of the fixed costs and variable costs on post-disaster waste management. Furthermore, Mahmoud Golabi et al (2017) [17] developed a mathematical model and metaheuristic algorithms to minimizes the aggregate traveling time for both people and UAVs over a set of feasible scenarios for choosing the best location of relief distribution centers. Additionally, Rajali Maharjan et al (2017) [18] using simplex algorithm with branch and bound to deal with a humanitarian relief chain that would respond to sudden-onset disasters in order to improvement overall responsiveness, efficiency and effectiveness of the humanitarian supply chain while decreasing the cost incurred in the process. Kanglin Liu et al (2019) [19] a distributionally robust model for optimizing the location, number of ambulances and demand assignment in an EMS system by minimizing the expected total cost.

5. Location-Routing Problem

In this section, we would research a wide range of academic papers on emergency material distribution location-routing problem and classified these papers into two sections: stochastic and certainty. For instance, A. Bozorgi-Amiri et al (2015) [20] proposed a multi-objective dynamic stochastic programming model to solve three goals in humanitarian relief logistics, including minimizing the maximum amount of shortages among the affected areas in all periods, the total travel time, and sum pre- and post-disaster costs. Bo Zhang et al (2018) [21] propose the uncertain multi-objective model can be rebuilt as an uncertain single-objective optimization model by implementing the main-objective method to achieve minimization of emergency relief costs and carbon dioxide emissions. N Herazo-Padilla et al (2015) [22] propose a hybrid solution procedure based on ACO and DES to solve location routing problem with stochastic transportation cost and vehicle travel speeds. A. Bozorgi-Amiri et al (2016) [23] propose a multi-objective dynamic stochastic programming model to deal with a humanitarian relief logistics problem where decisions are reached for pre- and post-disaster. Additionally, Mohammad Moshef Javadi et al (2016) [24] used the Memetic Algorithm (MA) and the Recursive Granular Algorithm (RGA) to solve Latency Location-Routing Problem (LLRP) and minimized waiting time of recipients by optimally determining both the locations of depots and the routes of vehicles. Finally, Ying Zhang et al (2015) [25] designed a scenario-based mixed-integer programming model to optimize depot location, outbound delivery routing in a depots are randomly disrupted condition and backup plans and used a metaheuristic algorithm to verify this model. Xianhua Wu et al (2018) [26] constructed the location-routing problem model of urban emergency logistics in the situation of rainstorm and waterlogging disaster, and found out the dynamic emergency distribution path of Nanjing in the situation of waterlogging disaster. Haijun Wang et al (2014) [27] constructs a nonlinear integer open location-routing model for relief distribution problem considering travel time, the total cost, and reliability with split delivery. Aakil M. Caunhye et al (2016) [28] propose a two-stage location-routing model with recourse for integrated preparedness and response planning under uncertainty. Behnam Vahdani et al (2018) [29] suggest a new mathematical integer nonlinear multi-objective, multi-period, multi-commodity model to locate the distribution centers, for timely distribution of vital relief to the damaged areas, vehicles routing and emergency roadway repair operations. Hao Hu et al (2019) [30] present a novel multi-objective optimization method for finding the optimal routes in hazardous material logistics under the constraint of traffic restrictions in inter-city roads.
| Reference | Author | Objective | Problem | Method |
|-----------|--------|-----------|---------|--------|
| [20]      | A. Bozorgi-Amiri et al (2015) | minimizing the maximum amount of shortages among the affected areas in all periods, the total travel time, and sum pre- and post-disaster costs | Stochastic emergency location-routing problem | multi-objective dynamic stochastic programming model |
| [21]      | BoZhang et al (2018) | minimizing the maximum amount of shortages, total travel time and cost | uncertain multi-objective location-routing programming model | |
| [22]      | N Herazo-Padilla et al (2015) | minimizing the maximum amount of shortages among the affected areas in all periods, the total travel time, and sum pre- and post-disaster costs | a hybrid solution procedure based on ACO and DES | |
| [23]      | A. Bozorgi-Amiri et al (2016) | minimizing the maximum amount of shortages among the affected areas in all periods, the total travel time, and sum pre- and post-disaster costs | a multi-objective dynamic stochastic programming model | |
| [24]      | Mohammad Moshref-Javadi et al (2016) | minimized waiting time of recipients | Certainty emergency location-routing problem | Memetic Algorithm (MA) and the Recursive Granular Algorithm (RGA) |
| [25]      | Ying Zhang et al (2015) | a metaheuristic algorithm to verify this model | a nonlinear integer open location-routing model | |
| [26]      | Xianhua Wu et al (2018) | found out the dynamic emergency distribution path of Nanjing in the situation of waterlogging disaster considering travel time, the total cost, and reliability with split delivery integrated preparedness and response planning under uncertainty | a multi-objective dynamic stochastic programming model | |
| [27]      | Haijun Wang et al (2014) | minimizing the travel time and total cost | two-stage location-routing model | |
| [28]      | Aakil M.Caunhye et al (2016) | minimization risk, cost, and maximization customer satisfaction | a new mathematical integer nonlinear multi-objective, multi-period, multi-commodity model | |
| [29]      | Behnam Vahdani et al (2018) | | multi-objective optimization method | |
| [30]      | HaoHu et al (2019) | | | |
6. Conclusion
The primary of this paper is to present a literature review over-viewing the problem and challenges encountered in emergency response operations, at the level of relief distribution. The article also presents the modeling techniques and paradigms employed to overcome the challenge with, and improvement of relief distribution activities. Those models are grouped into two subtopics, namely stochastic and certainty. Under these topics, four categories are analyzed: vehicle routing problem, inventory routing problem, location problem and location-routing problem.

The first aspect involves vehicle routing problem of relief distribution. This part considers a variety of different situations, such as the single goal, multi-objectives, single period, multi-period, time window, damaged road, traffic network disruption, split delivery and so on. Furthermore, this research seeks to diminish the cost of post-disaster and finding the time-saving routes. Researchers also use multiple methods and optimal algorithms to achieve the minimization unsatisfied demand and maximization victims’ satisfaction. Emergency vehicle is used to rescue critical population (in need of emergency accidents) and provide transportation to the injured by the disaster.

The second aspect relates to consider location of inventory pots and send the emergency goods to the disaster area under uncertain demand. Meanwhile, the literatures relate to this field is rarely at present and researches usually divide inventory routing problem into three stages, including pre-disaster, responses and post-disaster and think the fairness of distribution.

The third aspect concerns the location of emergency facilities, including distribution center, shelter center, hospital, medical center and temporary housing, in the case of disaster. The article in this part shows the necessary of optimal positioning as it permits more economic delivery plan and better emergency goods satisfaction. Those designed models serve as a guide in the decision making process and are employed to implement adequate emergency facilities positioning.

Finally, the location-routing problem is covered considering two different issues, including relief distribution center location and optimal delivery routes from distribution center to disaster areas under the situations of uncertain and certainty. The studies in this realm point prefer to maximization reduction unmet demand of victims’ and raising the effective of relief distribution activities. Here too, researchers also apply optimal models, in order to send required aid supply to disaster area. All of the research indentified in this paper is classified in terms of methodology and focus. The paper suggests a categorization of research problems into two groups: stochastic and certainty. Subgroups can then be created for an illustration more exactly. Table 1, Table 2, Table 3 and Table 4 provides information as to which method is more widely used and which is more appropriate for a certain purpose. Taken individually, the method of Mathematical modeling is the most used, considering the vehicle routing problem and location-routing problem. It is an indication of the adequacy and appropriateness of the method these specific areas. The higher proportion of those types of models mirrors a higher likelihood of output accuracy. For location problem, researchers also use math models to achieve their goals, as well as use optimal algorithms or set some critical constrains to achieve multi-objectives optimal. As for inventory routing problem, researches always focus on the knowledge of supply chain to solve the currently issues and propose some novel theoretical concept to deal new issue in inventory routing operations. From the management/reader point of view, these methods appear to be the most satisfactory. Case studies are also common though they mostly focus on a single situation.

Overall, the descriptive analysis of the literature reveals some similarities in the approaches addressing relief distribution issues in emergency situations. However, the perspective of researchers has changed from single stage to three stages, including pre-disaster, fast responses and post-disaster.

For the goals, the multi-period and multi-objectives optimal have considered more frequently instead of thinking single goal and single period. In term of focus content, more scholars begin to concern issues which stand on the perspective of victims and not to only stand on decision makers’ perspective. Furthermore, The implementation of optimization models minimize the rescue time, optimize the resource use and improve the effectiveness/efficiency of the rescue plan. That is, the terms effectiveness and efficiency used in this paper reflect the nature of the solution proposed by the models cited. Depending on the purpose or objective function, these models can provide either effective or efficient alternatives. Effectiveness is defined as accomplishing desired results and efficiency is accomplishing results in the best possible manner with the least waste of resources.
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