Supplementary file number 1

Supplement to: Humanitarian aid distribution logistics with accessibility constraints: A systematic literature review

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Section 1. Extraction matrix part 1 of 3.

Author(s)/Year	Type of Problem	Title	Abstract	Purpose	Future work	Main results found	Limitations of the study
Maya-Duque et al., (2016)	Access Restoration	Network repair crew scheduling and routing for emergency relief distribution problem	Every year, hundreds of thousands of people are affected by natural disasters. The number of casualties is usually increased by lack of clean water, food, shelter, and adequate medical care during the aftermath. One of the main problems influencing relief distribution is the state of the post-disaster road network. In this paper, we consider the problem of scheduling the emergency repair of a rural road network that has been damaged by the occurrence of a natural disaster. This problem, which we call the Network Repair Crew Scheduling and Routing Problem addresses the scheduling and routing of a repair crew optimizing accessibility to the towns and villages that demand humanitarian relief by repairing roads. We develop both an exact dynamic programming (DP) algorithm and an iterated greedy-randomized constructive procedure to solve the problem and compare the performance of both approaches on small- to medium-scale instances. Our numerical analysis of the solution structure validates the optimization model and provides managerial insights into the problem and its solutions.	Analyze the problem of emergency repair of a rural road network that has been damaged by the occurrence of a natural disaster.	Extend this problem to more than one repair team and more than one depot node. Model real-life situations where different relief organizations or entities are involved in emergency reconstruction operations of the region's road network. Consider the limited amount of resources available at each depot, and repair decisions are constrained by the need to meet the demand for relief from the cities that become accessible.	Feasible repair programs, where a damaged node cannot be repaired until the team has repaired all damaged nodes on a path between a node and the repository.	Coordination of two or more teams in the repair of a single damaged node. Failure to consider multiple depots in distribution allocation decisions. In such cases, the limited amount of resources available at each depot must be considered, and repair decisions are constrained by the need to meet relief demand from accessible cities.
Rodríguez et al., (2018)	Relief Distribution	Dynamic formulation for humanitarian response operations incorporating multiple organisations	The logistical deployment of resources to provide relief to disaster victims and the appropriate planning of these activities are critical to reduce the suffering caused. Disaster management attracts many organisations working alongside each other and sharing resources to cope with an emergency. Consequently, successful operations rely heavily on the collaboration of different organisations. Despite this, there is little research considering the appropriate management of resources from multiple organisations, and none optimising the number of actors required to avoid shortages or convergence. This research introduces a disaster preparedness system based on a combination of multi-objective optimisation and geographical information systems to aid multi-organisational decision-making. A cartographic model is used to avoid the selection of floodable facilities, informing a bi-objective optimisation model used to determine the location of emergency facilities, stock prepositioning, resource allocation and relief distribution, along with the number of actors required to perform these activities. The real conditions of the flood of 2013 in Acapulco, Mexico, provided evidence of the inability of any single organisation to cope with the situation independently. Moreover, data collected showed the unavailability of enough resources to manage a disaster of that magnitude at the time. The results highlighted that the number of government organisations deployed to handle the situation was excessive, leading to high cost without achieving the best possible level of satisfaction. The system proposed showed the potential to achieve better performance in terms of cost and level of service than the approach currently employed by the authorities.	Propose the first dynamic response model for resource allocation and relief distribution that also considers optimization of the number of organizations involved. This research contributes to a larger body of research that emphasizes the importance of coordination. The analysis presented here demonstrates the importance of improving the involvement of different organizations to provide better support, as no one agency has the resources to completely handle disaster situations alone. Optimization can be a valuable tool to create an environment that allows different participants to work together and achieve better results.	Future challenges and opportunities include introducing a routing and scheduling plan, managing the hierarchy of organizations involved, and expanding this system to introduce casualty transport. Integrating the response phase with recovery.	Ignoring interdependency between organizations can result in suboptimal solutions, even using optimization models. Comparison of individual agency performance with coordinated response performance shows a high level of noncompliance and excessive cost. Interoperability in the actual activities was critical in reducing the level of noncompliance compared to the independent agency cases. The ability to decide which institutions are required rather than sending all potential participants to the affected area can drive efficient use of resources and improve operations.	Not considering the hierarchy of the organizations involved and not extending this system to introduce victim transport. Another aspect is the adaptation of the model to work with real-time information and modifying it to provide real-time results. The introduction of collaborative models for disaster recovery and the development of integrated systems for disaster response and recovery.
Nurre and Sharkey, (2018)	Access Restoration	Online scheduling problems with flexible release dates: Applications to infrastructure restoration	We consider scheduling problems with the new concept of flexible release dates under an online optimization framework. A flexible release date is one where the traditional release date of a specific operation can be moved earlier in time, specifically to the completion time of an associated supplementary operation. In this context, we examine two classes of parallel identical machines: those that perform supplementary operations to alter release dates and those that perform installation operations to change the network characteristics. We further consider multi-function machines that can perform both supplementary and installation operations. The release date of an operation is often determined by events outside the knowledge of the decision-maker. Therefore, we consider scheduling problems in an online setting to model the lack of- and evolution of information about the release dates of tasks. Motivated by infrastructure restoration after an extreme event, we consider flexible release dates for an integrated network design and scheduling problem that seeks to improve the performance of a network over time by selecting and scheduling operations that will change the network characteristics. To solve these problems, we propose heuristic dispatching rules whose solutions are benchmarked against the solutions of a mixed integer programming formulation. Using a realistic infrastructure network, we perform computational tests; the results of these tests demonstrate the ability of the dispatching rule to find high-quality solutions in real time and quickly adapt to the arrival of new information. From the analysis of these results, we deduce policy insights regarding the role of flexible release dates and the machine fleet configuration.	Select and schedule the restoration of damaged network components over time to increase peak flow in the network or, equivalently, satisfied demand. Model when external factors, such as debris and flooding, prohibit access to network components with a release date.	Further examine the interdependent nature of infrastructure restoration.	Release dates associated with tasks represent the earliest time at which processing can begin. By adding supplemental machines or specialized multifunctional machines, release dates are relaxed or become flexible and can be moved earlier, specifically to the completion time of a supplemental operation.	Develop general theoretical results, distribution rules and policy knowledge for a wide range of programming problems.
Iloglu and Albert, (2020)	Access Restoration	A maximal multiple coverage and network restoration problem for disaster recovery	The recovery of physically damaged infrastructure after disasters is critical to efficiently deliver disaster relief supplies and emergency services. The physical damage to road infrastructure from disasters can result in decreased road link capacities and an inability to meet the community's emergency demand. This paper provides an infrastructure restoration plan for delivering critical services after disasters. We present a maximal multiple coverage and network recovery problem for the recovery and restoration of infrastructure systems after disasters. In the model, recovery crews make damaged arcs available by repairing components over a time horizon in a disrupted network. The model relocates emergency responders using the available arcs in the network to maximize multiple coverage of emergency service demand over the time horizon. We present two heuristics for the model. The first uses the Lagrangian and the linear programming relaxation solutions of the problem, and the second uses an integer rounding procedure applied to the linear programming relaxation solution. We test the model using a real-world example representing the road infrastructure and emergency services of the Bronx Borough in New York, NY during Hurricane Sandy. The results demonstrate that the integer rounding heuristic is effective in identifying near-optimal solutions. Our computational study suggests that our model can aid emergency managers in achieving their goals by scheduling effective restoration activities for real-time disaster recovery and long-term recovery planning.	Contribute to the effective coverage of the demand for emergency services and the recovery of the network after a sudden natural disaster.	Consider the interdependence between road infrastructure and emergency services.	Computational experiments suggest that the best recovery strategy is to install components that are connected to the most critical open facility locations. Contribute to decision makers in the relocation of emergency services and the timing of recovery equipment to improve coverage of emergency service demand during the disaster recovery process.	While solutions to the problem provide a plan to restore the most critical components of the network, the problem also relocates emergency responders using available arcs to improve cumulative multiple coverage of the demand for emergency services.
Maya-Duque et al., (2013)	Access Restoration	The accessibility arc upgrading problem	The accessibility arc upgrading problem (AAUP) is a network upgrading problem that arises in real-life decision processes such as rural network planning. In this paper, we propose a linear integer programming formulation and two solution approaches for this problem. The first approach is based on the knapsack problem and uses the knowledge gathered from an analytical study of some special cases of the AAUP. The second approach is a variable neighbourhood search with strategic oscillation. The excellent performance of both approaches is demonstrated using a large set of randomly generated instances. Finally, we stress the importance of a proper allocation of scarce resources in accessibility improvement.	Define the arc accessibility update problem.	Adequate allocation of scarce resources	Major improvements in accessibility can be achieved by allocating scarce resources appropriately.	Little flexibility to deal with additional restrictions.

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Celik, (2016)	Access Restoration	Network restoration and recovery in humanitarian operations: Framework, literature review, and research directions	In the aftermath of large-scale events requiring humanitarian action, critical infrastructure networks in the affected areas, such as electrical power, transportation, telecommunications, water supply, and waste water networks, may be disrupted by the devastating impact of the event. In the short and long term following the event, activities to return these networks to the pre-disaster working state include debris clearance and disposal, infrastructure repair, network reconstruction, road repair and rehabilitation, and snow removal. The costly and complicated nature of these activities has led to an increased level of interest regarding this field in the OR/MS literature over the recent years. In this study, we present the results of a comprehensive overview of the literature on network restoration and recovery in humanitarian operations, and provide a framework to consider this body of literature. We classify the studies in terms of the problems addressed, main decisions, objectives, models, and solution methods for these problems. Based on ongoing work, we also underline potential directions for future research by pointing to the gaps between the needs in the field and the existing body of literature.	The main emphasis of the work is on network restoration and recovery. In the short and long term post-event, activities to return these networks to pre-disaster working order include debris removal and disposal, infrastructure repair, network reconstruction, road repair and rehabilitation, and snow removal. A comprehensive review of recent papers on network restoration and recovery in the context of humanitarian operations.	Inventory prepositioning problem, where pre-disaster decisions of facility location and inventory prepositioning may be affected by post-disaster network vulnerability and repair, as this also affects relief transportation decisions.	We provide a comprehensive overview of the literature on network restoration and recovery in humanitarian operations, and provide a framework for considering this body of literature. We categorize the studies according to the problems addressed, major decisions, objectives, models, and methods of solving these problems. Possible directions for future research by pointing out gaps between needs in the field and the existing body of literature.	New developments for seemingly unrelated problems and methods (particularly in network optimization) that can be applied directly or with minor modifications to network restoration problems in humanitarian operations.
Sabbaghtorkan et al. (2020)	Relief Distribution	Prepositioning of assets and supplies in disaster operations management: Review and research gap identification	Prepositioning of assets and supplies prior to a disaster strike accelerates the response activities as it reduces the supply chain burden associated with humanitarian relief items. Unlike prior survey papers on pre-disaster and post-disaster humanitarian logistics, our paper has a specific focus on prepositioning of assets and supplies in the domain of natural disasters. The first aim of our paper is to review the main Operations Research and Management Science (OR/MS) journal papers published between 2000 and 2018 on this topic. We have statistically analyzed these papers based on contributions in different journals, number of papers per year, and type of disaster. We have also categorized the papers based on their decision variables into three categories: Allocation papers ("A"), Location papers ("L"), and Location-Allocation papers ("LA"). After that, we have assessed our current literature based on some of the methodological issues in Humanitarian Operations that gathered by Kovacs and Moshtari (2018). The second aim of our paper is research gap identification. Our key findings in this domain are that there is a lack of papers that: consider demand-side costs in their proposed model objectives; deal with uncertainty in funding, budget, asset and supply quantities, and infrastructure; considering prepositioning as a risk mitigation strategy; take reliability into account for reducing the risk of loss; consider prepositioning of medical staff and emergency crew; discuss the best time to start prepositioning of supplies and assets in confronting a foreseen disaster; use social media to better prepare for upcoming disasters.	Prepositioning assets and supplies prior to a disaster attack accelerates response activities by reducing the supply chain burden associated with humanitarian relief items.	Lack of documents that: consider demand-side costs in their proposed model objectives; deal with uncertainty in funding, budget, asset and supply quantities, and infrastructure; consider prepositioning as a risk mitigation strategy; consider reliability to reduce risk of loss; consider prepositioning of medical personnel and emergency equipment; discuss the best time to begin prepositioning supplies and assets to address an anticipated disaster. Tailored models for specific disasters, consider priorities among supplies for different types of disasters, Lack of papers that consider demand-side costs, i.e., a significant gap we note is that most model objectives are built from supply-side costs and rarely include demand-side costs (unmet demand penalty, deprivation, utility social welfare). Very few reviewed articles address reliability by resorting to risk measures. Prepositioning of medical personnel and emergency crews is a common practice in severe hurricane events, however, to our knowledge, there is no study of this in the current reviewed academic literature. Consider the limitation on the number of products that can be procured. Infrastructure uncertainty (such as uncertainty in the availability of the transportation network and uncertainty in the level of damage to facilities). Finding the best time to begin placing supplies is a challenge for emergency managers when dealing with a predicted disaster.	Prepositioning of assets and supplies prior to a disaster. Specific review for prepositioning of assets and supplies in LH.	Consider demand-side costs in the model's objectives. Considering supply priorities can help local and national agencies manage their time and budget effectively to achieve better results for both demand and supply. Consider the limitation on the quantity of products that can be procured.
Yan & Shih, (2009)	Access Restoration and Relief Distribution	Optimal scheduling of emergency roadway repair and subsequent relief distribution	The completion of every disaster rescue task performed by repair work teams relies on the in-time supply of materials to the rescue workers. Up to now, logistical support planning for emergency repair work in Taiwan has been done manually, which is neither effective nor efficient. To remedy the problem, this study presents a logistical support scheduling model for the given emergency repair work schedule. The objective is to minimize the short-term operating cost subject to time constraints and other related operating constraints. This model is formulated as an integer multiple-commodity network flow problem which is characterized as NP-hard. A heuristic algorithm, based on the problem decomposition and variable fixing techniques, is also proposed to efficiently solve this problem. Computational tests are performed using data from Taiwan's 1999 Chi-Chi earthquake. The results show that the model and the solution algorithm would be useful for the logistical support scheduling.	Simultaneously plan emergency road repair for subsequent relief distribution on a road network.	The integration of the work team and the scheduling of logistical support can be investigated in the future. Certainly, if more than one mode of transportation is to be considered, a multimodal network may be investigated in the future. In practice, work crews do not return to their work stations and other support units supply rescue machinery, fuel, and other resources to the work crews; therefore, this logistical support is not included.	Planning for emergency road repair and relief distribution after a natural disaster.	In practice work crews do not return to their work stations and rescue machinery, fuel and other resources are supplied to work crews by other support units; therefore, such logistical support is not included in our model. Consider more than one mode of transportation, then a multi-mode network may be investigated in the future.
Tuzun & Ozdamar, (2014)	Access Restoration	A mathematical model for post-disaster road restoration: Enabling accessibility and evacuation	This paper focuses on the planning of road restoration efforts during disaster response and recovery. The primary objective is to maximize network accessibility for all locations in the area during the restoration process so that survivors are evacuated and road side debris is removed as soon as possible. We propose a dynamic path based mathematical model that identifies criticality of blockages and clears them with limited resources. This model is more efficient than link based models and can solve restoration problems for realistic size networks within reasonable time. Algorithm performance is demonstrated using two instances based on districts in Istanbul.	Planning for road restoration efforts during disaster response and recovery. The primary goal is to maximize network accessibility for all locations in the area during the restoration process.	It does not include detailed travel routes for the restoration teams in each district, thus avoiding the solution of the multiple vehicle routing problem.	Make all locations in the affected area accessible for relief and evacuation. The restoration process is carried out with a limited number of teams during the first 3 days of response to maximize the survival rate.	They do not include detailed travel routes for the restoration teams in each district, thus avoiding the solution of the multiple vehicle routing problem.
Al ted & Murray (2017)	Relief Distribution	Vehicle routing and resource distribution in postdisaster humanitarian relief operations	After a disaster, supplies must be efficiently and equitably distributed to those in need, wounded persons must be evacuated to triage centers, and relief workers must be transported to affected areas. This complex humanitarian relief problem requires the coordination of numerous vehicles of varying capacities to transport goods, disaster victims, and volunteer workers through a network of roads, some of which may be impassable. To address this problem, a detailed mathematical programming model is presented. Owing to the complexity of this formulation, only small-scale problem instances may be solved optimally via commercial solver software. Therefore, a new heuristic approach is proposed to solve problems of practical size within acceptable time restrictions. The performance of the heuristic is evaluated for numerous representative test instances.	Coordination of heterogeneous type vehicles to facilitate three logistical operations, including commodity delivery, casualty evacuation and personnel transfer.	Incorporate additional practical logistical operations, such as the allocation of vehicles and work crews for debris removal. Evaluate the stochastic nature of relief operations.	Coordination of multiple heterogeneous vehicles to facilitate three logistical operations, including the delivery of commodities, evacuation of the wounded, and transfer of personnel.	Assignment of vehicles and work equipment for debris removal.

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Victoria et al., (2016)	Relief Distribution	Column Generation based heuristic for the Vehicle Routing Problem with Time-Dependent Demand	This paper presents a novel Capacitated Vehicle Routing Problem with Time-Dependent Demand (CVRP-TDD) applied to humanitarian logistics. This is a problem where the demand is time dependent and the objective is to maximize the total satisfied demand. When a disaster strikes a territory, the people go directly to shelters. If they do not receive the first aid, water, food, etc. They tend to flee out of the shelters looking for the aid outside of the affected area. This mobilization of people generates an increase in the chaos already caused by the disaster. The aid must arrive at shelters as quickly as possible to stop this mobilization. We developed a mixed integer linear program (MILP) and a column generation (CG) algorithm where the promising columns are generated using dynamic programming (DP). In CG algorithm, two dominance rules and one heuristic are proposed to solve the problem. The algorithm is tested on small and medium instances. CG gives good bounds and find more optimal solutions than those reported by MILP in less than one hour. Also, we show that the heuristic improves significantly the solution time.	Presents a new capacitated vehicle routing problem with time-dependent demand (CVRP-TDD) applied to humanitarian logistics. This is a problem where the demand is time-dependent and the objective is to maximize the total satisfied demand.	Limited resources	A novel problem in humanitarian logistics is proposed where demand is time-dependent due to the movement of people trying to flee the nodes.	Heterogeneous fleet of vehicles and elements of uncertainty in the model.
Lu et al., (2016)	Access Restoration	An optimal schedule for urban road network repair based on the greedy algorithm	This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The schedule of urban road network recovery caused by rainstorms, snow, and other bad weather conditions, traffic incidents, and other daily events is essential. However, limited studies have been conducted to investigate this problem. We fill this research gap by proposing an optimal schedule for urban road network repair with limited repair resources based on the greedy algorithm. Critical links will be given priority in repair according to the basic concept of the greedy algorithm. In this study, the link whose restoration produces the ratio of the system-wide travel time of the current network to the worst network is the minimum. We define such a link as the critical link for the current network. We will re-evaluate the importance of damaged links after each repair process is completed. That is, the critical link ranking will be changed along with the repair process because of the interaction among links. We repair the most critical link for the specific network state based on the greedy algorithm to obtain the optimal schedule. The algorithm can still quickly obtain an optimal schedule even if the scale of the road network is large because the greedy algorithm can reduce computational complexity. We prove that the problem can obtain the optimal solution using the greedy algorithm in theory. The algorithm is also demonstrated in the Sioux Falls network. The problem discussed in this paper is highly significant in dealing with urban road network restoration.	Propose an optimal schedule for the repair of the urban road network with limited repair resources. The classification of critical links will be changed along with the repair process due to the interaction between links. We repair the most critical link for the specific network state based on the greedy algorithm to obtain the optimal schedule. The research focuses on how much link restoration can contribute to the road network performance by evaluating the critical link.	Use more than one repair kit.	Allocation of limited resources to minimize the cumulative travel cost of the entire road network along with the restoration of the damaged link. Timing of urban road network recovery caused by storms, snow and other adverse weather conditions, traffic incidents and other daily events.	The specific repair time of the different damaged links and the time the crew travels from one damaged link to another is not considered.
Ahmadi et al., (2015)	Relief Distribution	A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: A case study on San Francisco district	We propose a multi-depot location-routing model considering network failure, multiple uses of vehicles, and standard relief time. The model determines the locations of local depots and routing for last mile distribution after an earthquake. The model is extended to a two-stage stochastic program with random travel time to ascertain the locations of distribution centers. Small instances have been solved to optimality in GAMS. A variable neighborhood search algorithm is devised to solve the deterministic model. Computational results of our case study show that the unsatisfied demands can be significantly reduced at the cost of higher number of local depots and vehicles.	They propose a multiple depot location routing model considering network failure, multiple vehicle uses, and standard relief time. The model determines local depot locations and routes for last mile distribution after an earthquake. Consider the possibility of road destruction in a real transportation network using GIS data, multiple vehicle uses, and some penalty costs for unmet demand. The contribution of this paper is to provide a mathematical model for humanitarian logistics operations considering the possibility of road destruction in a real transportation network using GIS data, standard relief time constraints, and a standard quantity of relief items needed for each person and a penalty cost for unmet demand.	Network repair	Determination of local depot locations and routing for last mile distribution after an earthquake.	It does not involve operations or decisions to restore the failure of the transport network.
Iloglu and Albert, (2018)	Access Restoration	An integrated network design and scheduling problem for network recovery and emergency response	Effective recovery and restoration of infrastructure systems play a crucial role in recovery after disasters. This issue is particularly critical when delivering time-sensitive services and commodities. Damage to infrastructure can lead to disruptions and diminished capacity to respond to emergencies. We model the interdependencies between infrastructure systems and service providers as a network model, where emergency responders deliver critical services while network recovery crews repair damage to critical infrastructure. We present a novel extension to the P-median problem, where the objective is to minimize the cumulative weighted distance between the emergency responders and the calls for service over the time horizon by coordinating the activities of two types of service providers. We locate emergency responders (facilities) on a network over a finite time horizon while network recovery crews install arcs. The installation part of the models is modeled as a scheduling problem with identical parallel servers (the repair crews), where an arc can be used by the emergency responders when installation is completed. We propose Lagrangian relaxation formulations of the models, which we solve using subgradient optimization. A feasible solution is obtained using the Lagrangian relaxation, which provides an upper bound to the original models. We test our models with both real-world data and data sets from Beasley's OR Library to demonstrate the effectiveness of the algorithm in solving large-scale models. The results give insight into the optimal schedule for restoring critical arcs in a network when delivering critical services and commodities after a disruptive event.	They present an integrated restoration and placement problem, modeling the interdependencies between critical infrastructure systems and service providers.	Consideration of transportation restrictions, where emergency responders and recovery teams can only move to "adjacent" facilities or components in sequential time periods.	Minimize the cumulative weighted distance between first responders and demand nodes over a time horizon.	No consideration of transportation restrictions, where both emergency responders and recovery teams can only move to "adjacent" facilities or components in sequential time periods.
Karakoc et al., (2019)	Access Restoration	Community resilience-driven restoration model for interdependent infrastructure networks	Critical interdependent infrastructure networks such as water distribution, natural gas pipeline, electricity power, communication and transportation systems provide the essential necessities for societies and their utilization is the backbone of everyday processes such as production, health, convenience and many more. Often cascading dysfunctionality or disruption in these critical infrastructure networks triggers chain reactions of blackouts or blockages through the system of highly interconnected infrastructure networks, and the disruption of surrounding societies. For the planning of restoration processes and resilience of these, social aspects and demographics should also be considered to assign and mitigate the possible social risks associated with these disruptions. In this work, we study the restoration planning of critical interdependent infrastructure networks after a possible disruptive event by mainly emphasizing on the vulnerability indices of interacting society. We integrate (i) a resilience-driven multi-objective mixed-integer programming formulation to schedule the restoration process of disrupted network components in each network with (ii) an index of social vulnerability that is geographically distributed. We present an illustrative example of the proposed integrated model that focuses on studying the community resilience in Shelby County, TN, United States.	Restoration planning of critical interdependent infrastructure networks after a potential disruptive event, emphasizing primarily the vulnerability indices of the interacting society (community impact), as measured by socioeconomic and demographic information describing the affected communities. They make use of social vulnerability indices and population densities of service areas to represent community impact, thus guiding the restoration process to areas of potential community need.	Consider partial outages, so that the system can operate with reduced capabilities. In addition, partial physical dependencies could be included in the proposed model, where a component could be partially functional, if the components on which it depends are partially operational. The dynamic nature of socioeconomic characteristics and population densities, along with uncertainties related to their varying existing levels, could also be included in future studies. The dynamic nature of socioeconomic characteristics and population densities, together with uncertainties related to their varying existing levels, could also be included in future studies. Naturally, a centralized decision-making environment is assumed here, where a lone, Central Decision Maker determines schedules across all networks, and future work will address a decentralized decision-making process where network utilities make restoration decisions with their own information. In addition, the proposed community resilience-based prioritization and scheduling process could be combined with geographic hazard metrics to account for spatial risks associated with the specific location of grid components.	Planning for the restoration of critical networks of interdependent infrastructure after a possible disruptive event, emphasizing mainly on the vulnerability indexes of the interacting society.	Partial physical dependencies, where a component could be partially functional, if the components on which it depends are partially operational. Other interdependent infrastructure networks that are important for completing and coordinating recovery activities (e.g., transportation, communications) could be included. The dynamic nature of socioeconomic characteristics and population densities.

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Hemakumar et al., (2017)	Access Restoration	Fuzzy Based Approach for Restoration of Distribution System during Post Natural Disasters	Distribution systems are inevitably vulnerable to natural disasters, which causes multiple damages within or outside the system. The disruption of supply demands microgrid formation, where the objective is to maximize the restoration of critical loads. The complete restoration requires repair of damaged regions which brings the need for an efficient crew selection, repair time estimation, and crew dispatch. Ranking of load points and location are important considerations for strategic placement of distributed generation units. Prioritization of damaged regions is required for efficient crew dispatch. These ranking depends on multiple criteria based on subjective opinions of the experts. However, the existing methods fail to take account of the same. This paper presents fuzzy approaches which fill the gap present in the existing methods by explaining the theoretical solutions to ranking of load points, locations, crew selection, estimation of repair times, and prioritization of the damaged regions.	Prioritize damaged regions for efficient crew dispatch. This ranking depends on multiple criteria based on subjective expert opinions.	Involve various repair resources	A fuzzy rule-based system for repair time estimation considering the available linguistic information about the severity of the system damage. The ability of the crew to repair a damage is determined by considering the repair skills of the crew, the required resources and the resource management capability of the crew. The severity of diffuse damage in a damaged region is assessed considering the damage severity information.	It is not considered a resource constraint.
Kim el al., (2018)	Access Restoration	Network repair crew scheduling for short-term disasters	Casualties and damages caused by disasters occur every year. To reduce further damages in the post disaster period, many types of research have been conducted. The repair crew problem is one of these efforts, and it is used for deciding ways to manage repairs to destroyed roads that connect members of supply chain networks. Especially in rural areas where road networks are sparse and supply chains are limited, road-network repair is particularly important because road destruction can contribute to high rates of rural isolation. In addition, the unpredictable nature of disasters creates concerns for those effecting post-disaster management. Especially in the short-term after a disaster, damage characteristics can dramatically change. Therefore, we considered a repair crew problem in which aspects of damage vary at certain times. A mathematical formulation on the basis of mixed integer programming is introduced to minimize the weighted sum of total damages caused in isolated areas and completion time of a repair crew. To overcome the complexity issue, an ant colony system algorithm was developed. It can be used to solve a multiple repair crew problem. Our study gives new insights into ways to manage problems in the post-disaster period.	We considered a repair team problem in which the damage aspects vary at certain times. To describe the dynamic damage aspects over time, we considered the timing of additional disasters caused by the initial event and changes in the damage rate.	This study was based on dynamic conditions in isolated areas, but did not take into account aspects that may worsen in non-isolated areas during a post-disaster period. For example, a repaired node may be destroyed again by additional disasters.	Minimization of the weighted sum of total damage caused by isolation and direct (and additional) disasters and the completion time of a repair team.	It is assumed that a single repair team starts from a single node of origin. It was not contemplated that a repaired node may be destroyed again by additional disasters.
Tavana et al., (2018)	Relief Distribution	An integrated location-inventory-routing humanitarian supply chain network with pre- and post-disaster management considerations	Efficiency is a key success factor in complex supply chain networks. It is imperative to ensure proper flow of goods and services in humanitarian supply chains in response to a disaster. To this end, we propose a multi-echelon humanitarian logistic network that considers the location of central warehouses, managing the inventory of perishable products in the pre-disaster phase, and routing the relief vehicles in the post-disaster phase. An epsilon-constraint method, a non-dominated sorting genetic algorithm (NSGA-II), and a modified NSGA-II called reference point based non-dominated sorting genetic algorithm-II (RPBNSGA-II) are proposed to solve this mixed integer linear programming (MILP) problem. The analysis of variance (ANOVA) is used to analyze the results showing that NSGA-II performs better than the other algorithms with small size problems while RPBNSGA-II outperforms the other algorithms with large size problems.	Propose a new multilevel logistics network with central warehouse location scouting and inventory planning and control in the pre-disaster phase, as well as routing of relief transport vehicles to provide damaged areas with needed products in the post-disaster phase.	Simultaneously obtain optimal pre-positioning of warehouses and minimize storage and transportation costs of relief goods.	Pre-disaster planning to prevent or reduce the effects of these events, as well as post-disaster planning for relief actions.	Relief commodities are not prioritized and consider these priorities when planning the transportation of commodities to hospitals and damaged areas.
Grass and Fischer, (2016)	Relief Distribution	Two-stage stochastic programming in disaster management: A literature survey	In the humanitarian context, two-stage stochastic programming is of special interest as it allows for modeling uncertainties and time-dependent decisions. Since natural disasters are highly unpredictable, the magnitude of the damage that will result cannot be determined in advance and hence, modeling uncertainties is a major challenge in the humanitarian decision making process. Two-stage programming is an issue, as some decisions have to be made before uncertainty is realized, and some can be made only afterwards. This paper reviews the state-of-the-art literature of the last decade on this topic with a special emphasis on modeling and solution approaches. In particular, the survey compares and classifies the respective models according to the disaster phase in which they are applied and to their objectives, underlying assumptions and special features. A variety of solution techniques are presented in the relevant literature; also these are discussed and critically evaluated in this work. Moreover, future research directions with respect to modeling and solution approaches, especially for large-scale problems, are recommended.	In the humanitarian context, two-stage stochastic programming is of particular interest as it allows modeling uncertainties and time-dependent decisions. Since natural disasters are highly unpredictable, the magnitude of the damage that will result cannot be determined in advance and, therefore, modeling uncertainties is a major challenge in the humanitarian decision-making process. Two-stage programming is a problem, as some decisions must be made before realizing the uncertainty, and some can only be made afterwards.	Fuzzy programming could be an alternative for modeling uncertainties whenever probability distributions cannot be easily obtained. This is often the case in emergency situations where expert knowledge, experience and data may not be sufficient to derive appropriate probabilities of occurrence. Assumptions, such as the integrity of transport links, are often made to simplify the complexity of the model, leading at the same time to limited utility of the proposed model. Due to the widespread destruction resulting from disasters, Assuming undamaged links and facilities is rather unrealistic. Taking into account multiple disasters and multiple periods represents another avenue of investigation. Conflicting objectives, such as minimizing costs on the one hand and maximizing satisfied demand on the other, are common in disaster management and deserve special attention. Since relief chains generally contain more than two participants, more realistic models can be achieved by considering multilevel supply chains. Almost no work within the context of two-stage stochastic programming has been devoted to integrating different actors in humanitarian supply chains into the model building and decision making process.	This paper provides an overview of the state-of-the-art literature on two-stage stochastic programming models in disaster management of the last decade, highlighting their special features and practical relevance. It compares and classifies the respective models according to the disaster phase in which they are applied and their objectives, underlying assumptions, and special features.	Consideration of multi-stakeholder coordination elements and multi-objective approaches.
Faiz et al., (2019)	Relief Distribution	A column generation algorithm for vehicle scheduling and routing problems	In this paper, we consider a variant of a truckload open vehicle routing problem with time windows, which is suitable for modeling vehicle routing operations during a humanitarian crisis. We present two integer linear programming models to formulate the problem. The first one is an arc-based mixed integer linear programming model that can be solved using a general purpose solver. For the second formulation, we first devise a task adjacency graph, that we use to develop a path-based integer linear program. We then propose a column generation framework to solve large-scale instances. Finally, we perform numerical experiments to compare the performance of the two models. Our computational results show that the path-based formulation solved using our proposed column generation framework outperforms the arc-based mixed integer linear program in solution time, without sacrificing solution quality.	A vehicle scheduling and routing problem of truckloads with target delivery times is studied from the perspective of a central resource coordinator. They consider (i) vehicle acquisition decisions : how many vehicles to acquire from dedicated contracted carriers and for how long each truck should be leased , (ii) scheduling decisions : at what time each acquired truck should start its trip and when it should return to the carrier, and (iii) routing decisions : grouping orders and assigning a truck to each group. The supplier's objective is to minimize the total transportation cost by minimizing the number of vehicles purchased and the total empty trip distance.	Priority consideration in route development (task combinations), delivery times have been used as the driving factor in route generation, but can easily be replaced by other priority rules: for example, disaster-affected areas with a higher percentage of children, elderly and injured people may have higher priorities, and vehicles may be routed through these areas first. The inclusion of uncertainty in (i) vehicle availability, (ii) vehicle travel time, and (iii) target delivery time in the decision model is another potential extension of our model. To accommodate this uncertainty, we will have it redesign our route generation algorithms to obtain routes with probabilistic durations. integration of vehicle GPS location data with the model; re-solving the model with current vehicle positions and states will provide more efficient and time-effective decisions.	A variant of the open vehicle pickup and delivery problem is solved from the perspective of a resource provider. The supplier must rent vehicles from a contracted supplier with rental period restrictions to complete a set of pickup and delivery tasks within a target delivery time.	Consideration of priority rules: e.g., disaster-affected areas with a higher percentage of children, elderly and injured people may have higher priorities and vehicles may be routed through these areas first. Include uncertainty in (i) vehicle availability, (ii) vehicle travel time, and (iii) delivery time.

Author(s)/Year	Type of Problem	Title	Abstract	Purpose	Future work	Main results found	Limitations of the study
Moreno et al., (2019)	Relief Distribution	A branch-and-Benders-cut algorithm for the Crew Scheduling and Routing Problem in road restoration	Extreme events such as disasters cause partial or total disruption of basic services such as water, energy, communication and transportation. In particular, roads can be damaged or blocked by debris, thereby obstructing access to certain affected areas. Thus, restoration of the damaged roads is necessary to evacuate victims and distribute emergency commodities to relief centers or affected areas. The Crew Scheduling and Routing Problem (CSRP) addresses decisions in post-disaster situations with the aim of minimizing the time that affected areas remain inaccessible. The integration of crew scheduling and routing decisions makes this problem too complicated to be effectively solved for practical instances using mixed integer programming (MIP) formulations recently proposed in the literature. Therefore, we propose a branch-and-Benders-cut (BBC) algorithm that decomposes the integrated problem into a master problem (MP) with scheduling decisions and subproblems with routing decisions. Computational tests based on instances from the literature show that the proposed exact method improves the results of MIP formulations and other exact and metaheuristic methods proposed in literature. The BBC algorithm provides feasible solutions and optimality gaps for instances that thus far have not been possible to solve by exact methods in the literature.	The integration of crew routing and scheduling decisions makes this problem too complicated to solve effectively in practical cases using mixed-integer programming (MIP) formulations recently proposed in the literature. Therefore, we propose a Benders branch-and-cut (BBC) algorithm that decomposes the integrated problem into a master problem (MP) with scheduling decisions and subproblems with routing decisions.	Investigate particular properties and characteristics of the problem to derive new valid inequalities and different ways to decompose the IPM formulation. Finally, it would be interesting to improve the lower bounds of the current solutions and to develop hybrid methods combining exact and metaheuristic strategies to obtain tighter solutions.	Crew planning and routing, in the context of road restoration. As a key contribution, he developed the first exact solution approach that is able to obtain feasible solutions and lower bounds for all cases in the literature, including large-scale cases. The problem addressed is typically encountered in post-disaster situations where the damaged network must be repaired as quickly as possible to promote an effective response.	Mono-objective nature
Alinaghian et al., (2019)	Relief Distribution	A mathematical model for location of temporary relief centers and dynamic routing of aerial rescue vehicles	This paper presents a new mathematical model for location of temporary relief centers and dynamic routing of aerial rescue vehicles distributing basic supplies in relief operations. The objective function of the proposed model minimizes the arrival time at the last designated temporary relief center. The proposed model seeks to locate the temporary relief centers in a way that all affected areas get covered by at least one temporary relief center. Considering the importance of quick action amid a post-disaster environment with characteristics such as uncertain demand for relief supplies, inaccurate information regarding victims, aftershocks, and extensively damaged road networks, in the proposed model, location and level of demand are considered to be dynamic, and relief supplies are assumed to be distributed by aerial transport vehicles. According to NP-Hardness of proposed problem, in this paper an improved hybrid metaheuristic algorithm based on scatter search combined with variable neighborhood search is presented. To evaluate the performance of the proposed algorithm, it is tested and compared with an exact method, basic scatter search and genetic algorithm. Results show the good performance of the proposed algorithm.	Location of temporary relief centers and dynamic routing of air rescue vehicles distributing basic supplies in relief operations. The proposed model seeks to locate temporary relief centers so that all affected areas are covered by at least one temporary relief center. Considering the importance of rapid action in the midst of a post-disaster environment with characteristics such as uncertain demand for relief supplies, inaccurate casualty information, aftershocks, and heavily damaged road networks, in the proposed model, the location and level of demand are considered dynamic. In the proposed model, the location and level of demand are considered dynamic, and relief supplies are assumed to be distributed by air transport vehicles. In the proposed model, the location and level of demand were considered dynamic.	Assume multiple vehicle paths and develop a mathematical formulation and an effective solution method for this problem.	Location of temporary relief centers and dynamic routing of air rescue vehicles that distribute basic supplies in relief operations while minimizing overall travel time.	Do not assume multiple vehicle routes.
Li et al., (2019)	Relief Distribution	A model for assignment of rescuers considering multiple disaster areas	Due to the severity of natural disasters, multiple areas can be affected simultaneously. Thus, the rescuers need to be assigned to multiple disaster areas to carry out the relief effort. In the process of the assignment of the rescuers, the rescuers usually have different professional skills and subjective preferences for the rescue tasks. Because of the differences of disaster situations, each disaster area has its rescue time requirement for the rescue tasks. This paper develops a model for the assignment of the rescuers considering multiple disaster areas in which the task fitness degrees and the time fitness degrees are introduced. Firstly, the satisfaction degree of each rescuer is calculated according to the intention list provided by each rescuer for the rescue tasks, and the competence degree of each rescuer is calculated according to the evaluation values of the rescuer with respect to the capability evaluation criteria. Then, according to satisfaction degrees and competence degrees of the rescuers, the task fitness degrees between the rescuers and the rescue tasks are obtained. Further, the time fitness degrees of the travel times are calculated based on the actual travel times and the time requirements of different disaster areas, and the matching degrees between each rescuer and the rescue tasks of different disaster areas are obtained by aggregating the task fitness degrees and the time fitness degrees. Afterwards, to maximize the sum of the matching degrees between the rescuers and the rescue tasks, an optimization model is constructed, and the optimal assignment result can be obtained by solving the model. Finally, an example on the assignment of the rescuers after earthquake is given to illustrate the use of the proposed model.	Develop a model for the assignment of rescuers considering multiple disaster areas in which task fitness grades and time fitness grades are introduced. Build a new model for the assignment of rescuers with multiple disaster areas in the case of considering rescue time, subjective preferences, and rescuers' degrees of competence.	Consider the complexity of rescue tasks and the collaborative effect between rescuers. In addition, the problem of rescuer assignment should also be considered when the total number of rescuers is not sufficient.	Assignment of rescue crews based on the degree of competence of the rescuers for rescue tasks.	Do not consider collaboration between rescuers.
Zhou et al., (2017)	Relief Distribution	A multi-objective evolutionary algorithm for multi-period dynamic emergency resource scheduling problems	The resource distribution in post-disaster is an important part of emergency resource scheduling. In this paper, we first design a multi-objective optimization model for multi-period dynamic emergency resource scheduling (ERS) problems. Then, using the framework of multi-objective evolutionary algorithm based on decomposition (MOEA/D), an MOEA is proposed to solve this model. In the proposed algorithm, new evolutionary operators are designed with the intrinsic properties of multi-period dynamic ERS problems in mind. The experimental results show that the proposed algorithm can get a set of better candidate solutions than the non-dominated sorting genetic algorithm II (NSGA-II).	Developed a multi-objective optimization model for multi-period dynamic ERS problems with uncertainty in road availability. Multiple-period dynamic ERS with uncertainty in road availability. The first objective is to minimize the unsatisfied demand of the affected points with the purpose of satisfying the demand of people in disaster areas as much as possible. The second objective is to minimize the risk of choosing the damaged road. They assume that the number of trucks and the carrying capacity of each truck are unlimited.	The rational arrangement of limited emergency trucks can also be analyzed according to the obtained scheduling schemes. They assume that the demand and resource storage in each period are known in advance and many factors in multi-period dynamic ERS problems have not been considered in this paper, such as actual road networks.	Set of resource distribution schemes for emergency rescue, and we assume that the number of trucks and the transport capacity of each truck are unlimited.	There are enough trucks available. There is only one service from each emergency supply point to each affected area in each rescue period.
Edrissi et al., (2015)	Relief Distribution	Transportation network reliability in emergency response	Distribution of humanitarian supplies is vital in saving lives during disasters. Investment in retrofitting critical transportation links reduces casualties as intact links improve flow of relief supplies. In finding critical links, link importance values are derived using the concept of network reliability. A network improvement problem is then solved to minimize death toll. To increase practicality, a heuristic algorithm is proposed to solve real size problems. Results show that initial incremental investments in network improvement are more profound in reducing the death toll than higher budget increments. Moreover, higher relief inventories reduce the death toll when the network is reliable.	This paper presents a new reliability measure based on the efficiency of rescue operations to assess network performance. This measure is an important and meaningful performance index as it is a direct indication of the efficiency of rescue operations.	Include the joint failure probability of multiple links. Integrating the facility location problem and the reliable transport network improvement problem would also improve the applicability of the model.	A new reliability measure based on the efficiency of relief operations is presented to evaluate network performance.	No probability of joint failure of multiple links is included, since active faults in an earthquake can affect multiple links simultaneously.

Author(s)/Year	Type of Problem	Title	Abstract	Purpose	Future work	Main results found	Limitations of the study
Sanci and Daskin, (2019)	Access Restoration and Relief Distribution	Integrating location and network restoration decisions in relief networks under uncertainty	Prepositioning emergency relief items in emergency response facilities before an anticipated disaster is a common strategy to increase the effectiveness of relief distribution. In this paper, we assume that relief distribution activities are hampered due to damaged roads, which can be restored by repair teams using restoration equipment. We propose a two-stage stochastic programming model integrating facility location and network restoration decisions. Our integrated model decides on the location of restoration equipment prior to the disaster in addition to the facility location decisions. Moreover, decisions related to relief item distribution and network restoration are made jointly after the disaster for each disaster scenario. We capture uncertainty in the network availability by incorporating the repair times required to restore the damaged roads. To solve our integrated model efficiently, we develop a sample average approximation method with concentration sets motivated by Rosing and ReVelle's (1997) Heuristic Concentration. These concentration sets are comprised of promising locations identified by information obtained from disaster scenarios. We limit our solution space in the first stage to concentration sets to reduce the problem size without sacrificing the solution quality significantly. Our computational results show significant improvement in unmet demand and cost measures by integrating location and network restoration models.	They propose a two-stage stochastic programming model to locate emergency response facilities and road restoration equipment prior to a disaster. They assume that demand occurs only once immediately after the disaster. They assume that the time to repair a damaged arch is the time required to make it available for emergency response activities. They assume that operating arcs can carry flow in both directions. They assume that the flow of relief elements (also the flow of restoration equipment) from a source node to a destination node arrives within the same time period since transport times are negligible compared to repair times.	An important extension could be to recognize that the timing of the disaster is also uncertain. Analyze food distribution by mobile kitchens after disasters.	Locating emergency response facilities and road restoration equipment prior to a disaster. Integration of facility location decisions with network restoration decisions so that routes between facilities and inaccessible demand nodes are available throughout the time horizon.	Conditions of transport and storage of food aids.
Habib et al., (2016)	Relief Distribution	Mathematical Models in Humanitarian Supply Chain Management: A Systematic Literature Review	In the past decade the humanitarian supply chain (HSC) has attracted the attention of researchers due to the increasing frequency of disasters. The uncertainty in time, location, and severity of disaster during predisaster phase and poor conditions of available infrastructure during postdisaster phase make HSC operations difficult to handle. In order to overcome the difficulties during these phases, we need to assure that HSC operations are designed in an efficient manner to minimize human and economic losses. In the recent times, several mathematical optimization techniques and algorithms have been developed to increase the efficiency of HSC operations. These techniques and algorithms developed for the field of HSC motivate the need of a systematic literature review. Owing to the importance of mathematical modelling techniques, this paper presents the review of the mathematical contributions made in the last decade in the field of HSC. A systematic literature review methodology is used for this paper due to its transparent procedure. There are two objectives of this study: the first one is to conduct an up-to-date survey of mathematical models developed in HSC area and the second one is to highlight the potential research areas which require attention of the researchers.	They conducted a systematic review of the literature in order to describe the different developments in terms of mathematical modeling applied in the context of humanitarian logistics, highlighting elements such as objective functions, constraints, nature of the model and solution algorithms.	Emergency operations involve different aid organizations or entities. In addition, collaboration and coordination aspects must also be taken into account, such as how to deal with the situation when two or more vehicles may be working simultaneously to serve the same destination.	Optimizing the scheduling and routing of vehicles during each period to improve accessibility of the road network; maximizing the satisfaction of relief material allocation and minimizing the total time required to transfer relief materials to affected areas.	Failure to consider collaborative aspects in humanitarian operations.
Shin et al., (2019)	Access Restoration and Relief Distribution	Integrated optimal scheduling of repair crew and relief vehicle after disaster	When catastrophes occur, certain areas could be isolated and have more hardship in being provided with the relief goods because of the destruction of roads. Additional damages will occur if isolated areas cannot be supplied relief goods quickly. Therefore, to provide adequate relief goods to the demand area in time, it is essential to recover the destroyed roads and make the isolated areas accessible. In addition, relief goods should be distributed on the basis of optimal scheduling. If the order for repairing destroyed roads and supplying relief goods to an isolated area is established from the respective viewpoints, a delay will occur compared to optimal schedule considering both of them simultaneously. Thus, this study proposes a mathematical model based on Mixed Integer Linear Programming (MILP) and an Ant Colony Optimization (ACO) algorithm providing optimal scheduling by taking into account both reconstruction and delivery. By conducting various numerical experiments, the solution from the MILP and ACO could lead to more effective results than decisions based on two points of view that are not synchronized. Some meaningful findings are also found by numerous computational experiments. This research can help to make the optimal decision for scheduling of recovery and supply that thus reduces any additional damage after a major disaster.	Determine the order of repairing destroyed roads and transporting relief items to demand areas after a disaster occurs in a rural area with a limited number of connected roads. It is assumed that the repair team and relief vehicle start from the same depot. A relief vehicle has sufficient capacity for the supply of goods during a single run. The demands for relief goods at the nodes are deterministic. A relief vehicle can visit the nodes and traverse the edges several times.	Uncertainties, driven by various factors, such as the amount of demand and supply goods, would be worthwhile in a disaster study. Model with multiple repair teams and relief vehicles would adequately expand the study.	Timeline that simultaneously integrates repair and relief efforts.	Failure to consider several repair teams and relief vehicles would adequately expand the study.
Yan et al., (2012)	Access Restoration	Optimal scheduling of logistical support for an emergency roadway repair work schedule	The completion of every disaster rescue task performed by repair work teams relies on the in-time supply of materials to the rescue workers. Up to now, logistical support planning for emergency repair work in Taiwan has been done manually, which is neither effective nor efficient. To remedy the problem, this study presents a logistical support scheduling model for the given emergency repair work schedule. The objective is to minimize the short-term operating cost subject to time constraints and other related operating constraints. This model is formulated as an integer multiple-commodity network flow problem which is characterized as NP-hard. A heuristic algorithm, based on the problem decomposition and variable fixing techniques, is also proposed to efficiently solve this problem. Computational tests are performed using data from Taiwan's 1999 Chi-Chi earthquake. The results show that the model and the solution algorithm would be useful for the logistical support scheduling.	They present a logistical support scheduling model for a given emergency road repair work schedule, as well as a solution algorithm to solve the model for large realistic problems. The objective of the proposed model is to minimize the total short-term operating cost for logistical support, subject to time constraints based on an emergency repair schedule, as well as other related operational constraints.	Future research can investigate how to incorporate stochastic vehicle travel times into the logistics support scheduling model to make the schedule more reliable.	Efficiently and effectively plan a good logistical support program for an emergency repair program prepared in the aftermath of a major disaster.	Stochastic vehicle travel times need to be incorporated into the logistical support scheduling model.
Aslan and Celik, (2019)	Access Restoration and Relief Distribution	Pre-positioning of relief items under road/facility vulnerability with concurrent restoration and relief transportation	Planning for response to sudden-onset disasters such as earthquakes, hurricanes, or floods needs to take into account the inherent uncertainties regarding the disaster and its impacts on the affected people as well as the logistics network. This article focuses on the design of a multi-ech- elon humanitarian response network, where the pre-disaster decisions of warehouse location and item pre-positioning are subject to uncertainties in relief item demand and vulnerability of roads and facilities following the disaster. Once the disaster strikes, relief transportation is accompanied by simultaneous repair of blocked roads, which delays the transportation process, but gradually increases the connectivity of the network at the same time. A two-stage stochastic program is for- mulated to model this system and a Sample Average Approximation (SAA) scheme is proposed for its heuristic solution. To enhance the efficiency of the SAA algorithm, we introduce a number of valid inequalities and bounds on the objective value. Computational experiments on a potential earthquake scenario in Istanbul, Turkey show that the SAA scheme is able to provide an accurate approximation of the objective function in reasonable time, and can help drive policy-based impli- cations that may be applicable in preparation for similar potential disasters.	This article focuses on the design of a multi-tiered humanitarian response network, where pre-disaster decisions of warehouse location and pre-positioning of items are subject to uncertainties in the demand for relief items and the vulnerability of roads and facilities post-disaster.	They assume that a sufficient number of repair resources exist, thus ignoring any potential scheduling issues. Second, they assume that resources can initiate repair activities at the same time. Although significantly increasing the complexity of the problem environment, relaxing these assumptions is important for future work to better represent the real-life situation. Coordination between repair and relief transportation entities is another challenge, which points to a separate area for future research. Finally, the assumption of deterministic repair times can also be relaxed without substantial changes to the modeling and solution approach.	Design a humanitarian inventory prepositioning network in vulnerable situations by considering pre-disaster decisions of facility location and pre-positioning of items, as well as post-disaster relief transport and road repair activities simultaneously.	Assume that there is a sufficient amount of repair resources, thus ignoring any potential scheduling issues. Second, assuming that resources can initiate repair activities at the same time. Failure to consider coordination between repair and relief transportation entities is another challenge.

Author(s)/Year	Type of Problem	Title	Abstract	Purpose	Future work	Main results found	Limitations of the study
Coco et al., (2020)	Relief Distribution	Modeling and solving the multi-period disruptions scheduling problem on urban networks	In the last decades, the urban mobility has become a critical issue with several social, economic and ecological challenges. This is a consequence of the fast and unplanned cities growth and of the high population density in urban areas. In this context, we focus on the Disruption Scheduling problem on Urban Networks (DSUN) which consists in scheduling a set of planned disruptions in an urban road network while ensuring a path between all points of this network (strong connectivity in graph theory). Disruptions can break the urban network connection, requiring then to modify the routes direction (arcs reversals). Such situations may disturb the users' habits. The goal of DSUN is (1) to minimize the number of arcs reversals and (2) the sum of the starting times to all disruptions simultaneously. DSUN is formalized in this study by means of a mathematical formulation. Moreover, since it is a bi-objective problem, we propose an exact algorithm based on the ϵ-constraint method. Computational experiments are performed on theoretical instances, as well as on realistic instances built from the road network map of Troyes city in France. The numerical results show that the exact algorithm can prove optimality for instances with up to 100 vertices and 20 disruptions.	They focused on the DSUN problem which consists of scheduling a set of planned outages in an urban road network while guaranteeing a path between all points of this network (strong connectivity in graph theory). Interruptions can break the urban network connection, which requires modifying the direction of the routes (arc reversal). This problem combines features of the resource constraint scheduling problem and a network design problem, closely related to URND. We propose a strong formulation in terms of linear relaxation and an extension, DSUN-P, which includes precedence constraints between interruptions.	Consider unpredictable outages. Unpredictable outages can have cascading effects on planned decisions, requiring modifications to the solution currently in use.	Schedule a set of planned interruptions in an urban road network while ensuring a path between all points on the road network.	No consideration of unpredictable interruptions.
Chen et al., (2020)	Relief Distribution	Supply allocation: bi-level programming and differential evolution algorithm for Natural Disaster Relief	Delivering relief supplies to victims of natural disasters is a very complicated process faced with many challenges: damaged road network, high demand for various materials, scarcity of resources, multi-supply and multi-demand sites, limited transport capacity, etc. Traditionally, outreach maximization is the focus of emergency relief. In this research, we propose a bi-level programming model which takes the aforementioned challenges into full account. We consider two objectives: minimizing the distribution time, and maximizing the allocation fairness. Because the problem is NP-hard, we design an improved differential evolution (IDE) algorithm and numerically compare it with several conventional differential evolution algorithms, including CoDE, SaDE, JADE and JDE. We found that the proposed IDE outperforms the existing algorithms. The feasibility and validity of the proposed model and the IDE algorithm are verified by applying them to the 2008 Wenchuan earthquake in western China.	They derive a two-level programming model that fully considers post-catastrophe situations, e.g., congested road network, supply and demand imbalance, and mode mix.	Incorporate dynamic information of victims and trapped victims in real time. We would continue our research and study dynamic optimization of the relief material allocation problem. Finally, distribution units and emergency centers are often owned and operated by different agencies, the best possible disaster relief outcome can only be achieved through effective and efficient coordination.	Two-tier scheduling that fully considers post-disaster situations, e.g., congested road network, supply-demand imbalance, and mode mix.	Inter-organizational coordination aspects are not considered.
Morshedlou et al., (2018)	Access Restoration	Work crew routing problem for infrastructure network restoration	This paper introduces a synchronized routing problem for planning and scheduling restorative efforts for infrastructure networks in the aftermath of a disruptive event. In this problem, a set of restoration crews are dispatched from depots to a road network to restore the disrupted infrastructure network. Two mathematical formulations are presented to scheduling and sequencing disrupted network components to restoration crews and route the crews towards disrupted components to maximize network resilience progress in any given time horizon. In the first formulation, the number of restoration crews assigned to each disrupted component, the arrival time of each assigned crew to each disrupted component and consequently the restoration rate associated with each disrupted component are considered as variables to increase the flexibility of the model in the presence of different disruptive events. Along with the contributions applies in the first formulation, in the second formulation, each disrupted component can be partially active during its restoration process. To find the coordinated routes, we propose a relaxed mixed integer program as well as a set of valid inequalities which relates the planning and scheduling efforts to decision makers policies. The integration of the relaxed formulation and valid inequalities results in a lower bound for the original formulations. We further introduce a feasibility algorithm to derive a strong initial solution for the routing restorative capacity problem. Computational results on gas, water, and electric power infrastructure network instances from Shelby County, TN data, demonstrates both the effectiveness of the proposed model formulation, in solving small to medium scale problems, the strength of the initial solution procedure, especially for large scale problems.	An integration of a vehicle routing generation problem and an infrastructure network restoration equipment scheduling problem is proposed.	An important (and realistic) direction for future work is to consider the effects of outages (and subsequent recovery) on the routing network itself and to analyze the behavior of both infrastructure and routing networks in terms of restoration equipment sharing, rerouting, and restoration interdependencies. . Another relevant direction in this area is to consider multiple restoration tasks associated with each component. In this case, crews that were assigned to a given disrupted component may finish their restoration tasks before others working on the same component and, consequently, may leave before the entire component restoration process is completed.	Integrate routing and restoration problems by formulating restoration equipment routing problems.	No consideration of the effects of disruptions in the routing network and analysis of infrastructure behavior.
Nurre et al., (2012)	Access Restoration	Restoring infrastructure systems: An integrated network design and scheduling (INDS) problem	We consider the problem of restoring services provided by infrastructure systems after an extreme event disrupts them. This research proposes a novel integrated network design and scheduling problem that models these restoration efforts. In this problem, work groups must be allocated to build nodes and arcs into a network in order to maximize the cumulative weighted flow in the network over a horizon. We develop a novel heuristic dispatching rule that selects the next set of tasks to be processed by the work groups. We further propose families of valid inequalities for an integer programming formulation of the problem, one of which specifically links the network design and scheduling decisions. Our methods are tested on realistic data sets representing the infrastructure systems of New Hanover County, North Carolina in the United States and lower Manhattan in New York City. These results indicate that our methods can be used in both real-time restoration activities and long-term scenario planning activities. Our models are also applied to explore the effects on the restoration activities of aligning them with the goals of an emergency manager and to benchmark existing restoration procedures.	This paper proposes an integrated network design and scheduling problem that can be applied to restoration efforts for a variety of infrastructure systems. This problem focuses on selecting a set of nodes and arcs for installation in a network and then scheduling them into a set of identical parallel workgroups. Once a node or arc is processed by one of these workgroups, it becomes operational in the network and flow can be routed through or over it. In each time period, network performance is evaluated by determining the maximum amount of (weighted) demand that can be sent from a set of supply nodes to a set of demand nodes through the operational network (i.e., the original network plus those nodes and arcs completed by the workgroups at this time). The objective function of this problem focuses on maximizing the cumulative network throughput over a finite horizon.	Examine the effects of infrastructure restoration efforts when aligned with county emergency manager priorities. Determine customized large-scale integer programming methods that can be used to determine the optimal solution for large case studies. Examine different methods for evaluating network performance to capture different infrastructure considerations. For example, it may be more appropriate to model the operations of a road network by determining the shortest routes from a set of critical origin nodes to a set of critical destination nodes.	Programming that can be applied to the restoration efforts of a variety of infrastructure systems.	No consideration of coordination aspects.
Shanshan et al., (2015)	Access Restoration	Collaborative dynamic optimization on post-earthquake emergency supply and road rehabilitation based on road network connectivity	Earthquakes often cause road damage, so the earthquake relief needs cooperative road rehabilitation and postearthquake emergency supply. In the thesis, the definition of connectivity degree on post-earthquake road network is proposed, and the rehabilitation order for road network is resolved according to its extended meaning. Then, the multistage dynamic problem is decomposed to multiple single phase problems. For each single one, the mathematical model, which balances between efficiency and fairness, is established, and a simulated annealing algorithm is adopted for solving the model, at last its feasibility is verified by a numerical example.	Dynamic integration between post-earthquake road rehabilitation and emergency material distribution, from the perspective of road network connectivity.	Enrich the connotation of theoretical research through access to real data, to make it more realistic.	The connectivity of the road network after the earthquake is defined, and the rehabilitation order is solved by extending the average connectivity.	Resources are assumed to be unlimited. The start and completion times of each restoration operation are not taken into account. Resources are assumed to come from a single centralized agency.

Author(s)/Year	Type of Problem	Title	Abstract	Purpose	Future work	Main results found	Limitations of the study
Oruc et al., (2018)	Relief Distribution	Post-disaster assessment routing problem	In this study, we propose a post-disaster assessment strategy as part of response operations in which effective and fast relief routing are of utmost importance. In particular, the road segments and the population points to perform assessment activities on are selected based on the value they add to the consecutive response operations. To this end, we develop a bi-objective mathematical model that provides damage information in the affected region by considering both the importance of population centers and road segments on the transportation network through using aerial and ground vehicles (drones and motorcycles). The first objective aims to maximize the total value added by the assessment of the road segments (arcs) whereas the second maximizes the total profit generated by assessing points of interests (nodes). Bi-objectivity of the problem is studied with the ϵ-constraint method. Since obtaining solutions as fast as possible is crucial in the post-disaster condition, heuristic methods are also proposed. To test the mathematical model and the heuristic methods, a data set belonging to Kartal district of Istanbul is used. Computational experiments demonstrate that the use of drones in post-disaster assessment contributes to the assessment of a larger area due to its angular point of view. Also, the proposed heuristic methods not only can find a high-quality approximation of the Pareto front but also mitigates the solution time difficulties of the mathematical model.	Develop a biobjective mathematical model that provides information on damage in the affected region considering both the importance of population centers and road sections in the transportation network through the use of aerial and ground vehicles (drones and motorcycles).	Consider associated vehicle and transportation costs.	Computational experiments show that the use of drones in post-disaster assessment contributes to the assessment of a larger area due to their angled viewpoint. Post-disaster damage assessment.	Unlimited resources are assumed.
Liu et al., (2019)	Relief Distribution	A branch-and-price algorithm for the home-caregiver scheduling and routing problem with stochastic travel and service times	This paper addresses the solution methods for the stochastic home-caregiver scheduling and routing problem which arises in many service industries such as home care and home health care. In the problem, the caregiver's travel times and service times for customers are stochastic. A chance constraint is introduced to ensure the on-time service probability for the customers. Such stochastic travelling and service time and the chance constraint further complicate the problem. In this paper, a route-based mathematical model is introduced. A branch-and-price (B&P) algorithm and a discrete approximation method are combined to solve the problem. Herein, effective label algorithms are designed to generate negative reduced cost routes. The efficiency of the algorithm are improved by employing three acceleration strategies. The experiments on test instances validate the performances of the proposed B&P algorithm and demonstrate the necessity of considering the stochasticity of travel times of home-caregiver and service times to the customers.	Addressing a chance-constrained home caregiver scheduling and routing problem with stochastic service and travel times.	Consider accessibility constraints in humanitarian assistance.	Generation of optimal care routes.	Unlimited resources will be considered.
Yan et al., (2020)	Access Restoration	Post-disaster power system restoration planning considering sequence dependent repairing period	In this paper, a post-disaster restoration planning (PDRP) model for critical power system infrastructure is proposed. The model intends to find the optimal repair and activation schedule for damaged components so that the system load accommodation capability is maximized and the makespan of restoration process is minimized. The model takes into account the effect of adverse weather on the component repair process and a time-varying repair velocity function model is proposed to obtain the time-varying repair duration (TVRD) of the damaged component. The sequence-dependent repairing period (SDRP) of damaged components can be formed by combining TVRD and the transportation time of resources, and embedded into the PDRP model. The proposed model also allows the repair units to perform repair work on arbitrary damage component, not just the damage components in their routine service area. As a result, the maintenance efficiency is maximized. A two-stage bi-pheromone heuristic method is developed to efficiently solve the proposed PDRP model. The sequence position adherence information of each repair task and the relationship between two adjacent tasks are used in the search so that the solution time of the PDRP model is avoided from increasing exponentially with the problem size. The IEEE-118 and IEEE-30 bus test system are used for case studies to validate the proposed model and method. In addition, advantages of considering the sequence dependent repairing period are presented.	Propose a power system restoration model with a sequence-dependent repair period, so as to maximize the load accommodation capacity of the system and minimize the duration of the restoration process.	Sequence-dependent repair period can be extended in roadblock care in transportation networks. Development of a dispatching rule that can guarantee robust performance under sequence dependency and stochastic nature of the repair period.	The dependence of the duration of repairs on the repair schedule (sequence) itself, caused by several factors, such as adverse weather conditions and crew en-route logistics.	Lack of consideration of multiple resources.
Barrera et al., (2012)	Access Restoration	A network-based approach to the multi-activity combined timetabling and crew scheduling problem: Workforce scheduling for public health policy implementation	This paper introduces the multi-activity combined timetabling and crew scheduling problem. The goal of this problem is to schedule the minimum number of workers required in order to successfully visit a set of customers characterized by services needed matched against schedule availability. Two solution strategies are proposed. The first is based on mathematical programming whilst the second uses a heuristic procedure in order to reduce computational time. The proposed model combines timetabling with crew scheduling decisions in one mixed integer programming model which considers multiple activities. The algorithms are tested on randomly generated and real instances provided by the Health to School Initiative, a program based at Bogotá's local Health Department. The results show that the Initiative can increase its coverage by up to 68% using the proposed heuristic approach as a planning process tool.	Maximize network accessibility to all locations in the area during the restoration process so that survivors are evacuated and road debris is removed as soon as possible.	Consider transportation of humanitarian aid.	Route-based tactical resource planning introduced for post-disaster road restoration scheduling.	It assumes the participation of a single organization supplying the repair resources.
Qin et al., (2010)	Access Restoration	Evaluation model for damage extent of roads in Wenchuan earthquake-stricken areas based on remote sensing information	A low-altitude remote sensing data-based evaluation model for damage extent of roads was proposed for rapid assessment of transport facilities in Wenchuan earthquake-stricken areas. Spatial information about roads, bridges, tunnel portals and spatial distributional information about landslides, collapses and barrier lakes were extracted from large-scale true-color images of Wenchuan earthquake-stricken areas gained from low-altitude remote sensing platforms, and the corresponding thematic maps were drawn. Spatial coupling of a road and disaster bodies was taken as the criterion to judge whether this road is damaged. The road damage coefficient was get from the damage level of road structures due to individual disaster body, and the damage scale factor was obtained from the length of individual damaged road. Based on the above parameters, an evaluation model was established for the damage extent of roads in Wenchuan earthquake-stricken areas. The damage extent of Baisha-Xiajiaping section of Dujiangyan-Wenchuan highway was obtained using this evaluation model. The obtained result is consistent with the actual situation.	Scheduling of road repair work troops in order to increase accessibility to the population as quickly as possible after a major earthquake.	For future works, optimizations will be considered in terms of algorithm complexity, together with smart ways to improve solutions for real instances within a reasonable computational time.	Optimal repair program	Consideration of a single actor.
Liberatore et al., (2014)	Access Restoration	A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics	The distribution of emergency goods to a population affected by a disaster is one of the most fundamental operations in Humanitarian Logistics. In the case of a particularly disruptive event, parts of the distribution infrastructure (e.g., bridges, roads) can be damaged. This damage would make it impossible and/or unsafe for the vehicles to reach all the centers of demand (e.g., towns and villages). In this paper, we propose and solve the problem of planning for recovery of damaged elements of the distribution network, so that the consequent distribution planning would benefit the most. We apply the model, called RecHADS, to a case study based on the 2010 Haiti earthquake. We also show empirically the importance of coordinating recovery and distribution operations optimization.	Model the interdependencies between infrastructure systems and service providers as a network model, where emergency services provide critical services while network recovery teams repair damage to critical infrastructure.	First, other objectives, such as coverage, are often used to model quality of service in disaster situations. Second, consider transportation constraints, where both emergency responders and recovery teams can only move to "adjacent" facilities or components in sequential time periods.	Generate a plan to restore the most critical network components in the models and provide information on how to provide essential services during recovery.	Consideration of unlimited resources and single-actor.
Wu and Wang, (2020)	Access Restoration	Post-disruption performance recovery to enhance resilience of interconnected network systems	Mitigating the effect of disruptive events at the operating phase of complex systems therefore improving the systems' resilience is an important yet challenging task. To improve the resilience, one way is to enhance the failure restoration capability with appropriate performance recovery strategies. However, considering different characteristics of disruptive events, the challenge is to develop a generally applicable framework to optimally coordinate different recovery strategies within a given budget. In order to tackle the challenge, this paper presents a post-disruption recovery framework for networked systems to optimize the performance. In this study, coordination of different recovery agents is achieved by using mathematical programming technique, while the assignment of the required resource for restoration is found by a heuristic algorithm. Case studies based on IEEE test feeders are used to demonstrate the feasibility of the developed framework, as well as the effects of optimal resource allocation nested in the restoration framework.	Solve the problems of restoring the distribution system after natural disasters by prioritizing damaged regions.	Consider multiple remediation resources.	Finding the optimal network restoration plan.	Consideration of unlimited resources.

Section 2. Extraction matrix part 2 of 3.

Author(s)/Year	Type of Problem	Title	DRUTA	TRED	TAREA	ND	PND	DUM	DEC	DVT	FD	FV	DI	ACT	MODO	MR	TRANS	TT	DEPRR	TRR	LRR	PRR	RRR	PRD	TMRR	TPRR	CPP	TAH	PAH	LRAH	DDAH	TFT	DINV	VTAH	TP	TPOBJ
Maya-Duque et al., (2016)	Access Restoration	Network repair crew scheduling and routing for emergency relief distribution problem	NODC	RND	AR	X	X		CP		RES	X		UA	UM		TC		MDRR	MRR		X	X		TRC	MRUD									P	OBJ
Rodriguez et al., (2018)	Relief Distribution	Dynamic formulation for humanitarian response operations incorporating multiple organisations	NODNC	RD		X			LP		RES	X		MA	UM		TC										MLP	AL y ANL	X	X		FTHT	X		VP	MOBJ
Nurre and Sharkey, (2018)	Access Restoration	Online scheduling problems with flexible release dates: Applications to infrastructure restoration	NODNC	RD					CP		RES	X		UA	UM					MRR					TRC	MRUD									P	OBJ
Iloglu and Albert, (2020)	Access Restoration	A maximal multiple coverage and network restoration problem for disaster recovery	NODNC	RD		X			CP		RES	X		UA	UM					MLRR				X	TRC		MP	AL			MDAH				VP	OBJ
Maya-Duque et al., (2013)	Access Restoration	The accessibility arc upgrading problem	NODC	RD	AR	X			CP		RES	X		UA	UM		TC		MDRR	MRR	X	X	X		TRC	MRUD									P	OBJ
Sakuraba et al., (2016a)	Access Restoration	Road network emergency accessibility planning after a major earthquake	NODC	RD	AU	X			CP		RES	X		UA	UM		TC	Satellite images in graphics	MDRR	MRR	X	X	X		TRC	MRUD		AL y ANL							VP	OBJ
Vahdani et al., (2018b)	Access Restoration and Relief Distribution	Multi-objective, multi-period location-routing model to distribute relief after earthquake by considering emergency roadway repair	NODC	RD		X			CP		PREP, RES	X		UA	UM		TC			MRR	X	X			TRC		MLP	AL y ANL			MDAH	FTHT			VP	MOBJ
Ozdamar et al., (2014)	Access Restoration	Coordinating debris cleanup operations in post disaster road networks	NODNC	RD					CP		RES	X		UA	UM					MRR		X		X	TRC, TRV		MP								VP	MOBJ
Sakuraba et al., (2016b)	Access Restoration	Work-troop scheduling for road network accessibility after a major earthquake	NODNC	RND					CP		RES	X		UA	UM					MRR		X			TRC	MRUD									VP	OBJ
Averbakh, (2012)	Access Restoration	Emergency path restoration problems	NODC	RD					CP		RES	X		UA	UM				MDRR	MRR					TRC										VP	OBJ
Rezai-Malek et al (2016)	Relief Distribution	An approximation approach to a trade-off among efficiency, efficacy, and balance for relief pre-positioning in disaster management	NODNC	RD		X			CP		PREP, RES			UA	MM	X	TC, TA, TF										MLP	AL y ANL	X	X	MDAH	FTHT	X		VP	MOBJ
Vahdani et al. (2018a)	Relief Distribution	Two-stage multi-objective location-routing-inventory model for humanitarian logistics network design under uncertainty	NODC	RD		X			CP		PREP, RES			UA	UM		TC										MLP	AL y ANL			MDAH	FTHT	X	X	VP	MOBJ
Celik, (2016)	Access Restoration	Network restoration and recovery in humanitarian operations: Framework, literature review, and research directions	NODC	RD		X	X		CP, MP,LP	X	PREP, RES, REC	X	X	UA	UM	X	TC, TA	X	MDRR	MRR		X	X	X	TRC, TRV			AL y ANL			DAH, MDAH		X		P, VP	OBJ, MOBJ
Sabbaghtorkan et al. (2020)	Relief Distribution	Prepositioning of assets and supplies in disaster operations management: Review and research gap identification	NODNC	RD		X	X	X	LP		PREP		X	UA	UM		TC	X			X						MLP	AL y ANL					X		VP	OBJ
Yan and Shih, (2009)	Access Restoration and Relief Distribution	Optimal scheduling of emergency roadway repair and subsequent relief distribution	NODNC	RD	AR	X			CP		RES	X		UA	UM		TC			MRR		X			TRC	MRUD	MLP	AL y ANL				FTHG			P	MOBJ
Tuzun and Ozdamar, (2014)	Access Restoration	A mathematical model for post-disaster road restoration: Enabling accessibility and evacuation	NODNC	RD		X			CP		RES	X		UA	UM		TC		MDRR		X			X	TRC										VP	OBJ
Al ted and Murray (2017)	Relief Distribution	Vehicle routing and resource distribution in postdisaster humanitarian relief operations	NODC	RD					CP		RES			UA	UM		TC										MLP	AL y ANL	X		MDAH	FTHT			VP	OBJ
Victoria et al., (2016)	Relief Distribution	Column Generation based heuristic for the Vehicle Routing Problem with Time-Dependent Demand	NODC	RND		X			CP		PREP, RES			UA	MM		TC										MP	ANL		X		FTHG			VP	OBJ
Lu et al., (2016)	Access Restoration	An optimal schedule for urban road network repair based on the greedy algorithm	NODNC	RND	AU				CP		RES	X		UA	UM		TC		MDRR	MRR	X	X		X	TRC	MRUD									P	OBJ
Ahmadi et al., (2015)	Relief Distribution	A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: A case study on San Francisco district	NODC	RD		X		X	CP		PREP, RES	X		UA	UM		TC	Geographic Information Systems (GIS)									MLP	AL y ANL		X	MDAH				P	OBJ

Author(s)/Year	Type of Problem	Title	DRUTA	TRED	TAREA	ND	PND	DUM	DEC	DVT	FD	FV	DI	ACT	MODO	MR	TRANS	TT	DEPRR	TRR	LRR	PRR	RRR	PRD	TMRR	TPRR	CPP	TAH	PAH	LRAH	DDAH	TFT	DINV	VTAH	TP	TPOBJ
Iloglu and Albert, (2018)	Access Restoration	An integrated network design and scheduling problem for network recovery and emergency response	NODNC	RD		X			CP		RES	X		UA	UM		TC			MRR		X	X		TRC										VP	OBJ
Karakoc et al., (2019)	Access Restoration	Community resilience-driven restoration model for interdependent infrastructure networks	NODNC	RD			X		LP		RES, REC	X	X	UA	UM		TC			MRR	X	X		X	TRC	MRUD									VP	MOBJ
Hemakumar et al., (2017)	Access Restoration	Fuzzy Based Approach for Restoration of Distribution System during Post Natural Disasters	NODC	RD					LP		RES			UA	UM					MRR				X	TRV										P	OBJ
Kim el al., (2018)	Access Restoration	Network repair crew scheduling for short-term disasters	NODC	RND					CP		RES	X		UA	UM				MDRR	MRR		X	X	X	TRC	MRUD									VP	OBJ
Tavana et al., (2018)	Relief Distribution	An integrated location-inventory-routing humanitarian supply chain network with pre- and post-disaster management considerations	NODC	RD					CP		PREP, RES			UA	UM	X	TC										MP	AL			MDAH	FTHT	X		VP	MOBJ
Grass and Fischer, (2016)	Relief Distribution	Two-stage stochastic programming in disaster management: A literature survey	NODC	RD		X			CP		PREP, RES			UA	UM													AL y ANL		X	MDAH				VP	OBJ
Faiz et al., (2019)	Relief Distribution	A column generation algorithm for vehicle scheduling and routing problems	NODC	RD					CP		RES			UA	UM																	FTHG		X	P	OBJ
Moreno et al., (2019)	Relief Distribution	A branch-and-Benders-cut algorithm for the Crew Scheduling and Routing Problem in road restoration	NODC	RND		X			CP		RES	X		UA	UM		TC		MDRR	MRR					TRC	MRUD									P	OBJ
Alinaghian et al., (2019)	Relief Distribution	A mathematical model for location of temporary relief centers and dynamic routing of aerial rescue vehicles	NODC	RD		X			LP		RES			UA	MM		TA										MP	AL y ANL			DAH	FTHG			VP	OBJ
Li et al., (2019)	Relief Distribution	A model for assignment of rescuers considering multiple disaster areas	NODC	RD					CP		REC			UA	UM																				VP	OBJ
Zhou et al., (2017)	Relief Distribution	A multi-objective evolutionary algorithm for multi-period dynamic emergency resource scheduling problems	NODNC	RD		X		X	CP		RES	X		UA	UM		TC										MLP	AL y ANL		X	MDAH	FTHT			VP	MOBJ
Edrissi et al., (2015)	Relief Distribution	Transportation network reliability in emergency response	NODNC	RD		X	X		CP		RES	X		UA	UM		TC							X			MLP	AL y ANL			DAH				P	OBJ
Sanci and Daskin, (2019)	Access Restoration and Relief Distribution	Integrating location and network restoration decisions in relief networks under uncertainty	NODNC	RND		X		X	CP		PREP, RES	X		UA	UM		TC			MRR			X			MLRUD	MP	AL y ANL			MDAH				P, VP	OBJ
Habib et al., (2016)	Relief Distribution	Mathematical Models in Humanitarian Supply Chain Management: A Systematic Literature Review	NODC	RND		X			CP		RES	X		UA	UM		TC		MDRR	MRR		X			TRC	MRUD			X	X					VP	OBJ
Shin et al., (2019)	Access Restoration and Relief Distribution	Integrated optimal scheduling of repair crew and relief vehicle after disaster	NODC	RND	AR	X		X	CP		RES	X		UA	UM		TC		MDRR	MRR		X	X		TRC	MRUD	MP	AL y ANL			DAH				P	OBJ
Yan et al., (2012)	Access Restoration	Optimal scheduling of logistical support for an emergency roadway repair work schedule	NODNC	RD					CP		RES	X		UA	MM		TC			MLRR		X	X		TRC	MLRUD						FTHT			P	OBJ
Aslan and Celik, (2019)	Access Restoration and Relief Distribution	Pre-positioning of relief items under road/facility vulnerability with concurrent restoration and relief transportation	NODNC	RD					LP		PREP, RES	X		UA	UM		TC			MRR											MDAH	FTHG	X		P	OBJ
Coco et al., (2020)	Relief Distribution	Modeling and solving the multi-period disruptions scheduling problem on urban networks	NODNC	RD		X			CP		RES			UA	UM		TC										MLP	AL y ANL	X	X	MDAH		X		VP	MOBJ
Chen et al., (2020)	Relief Distribution	Supply allocation: bi-level programming and differential evolution algorithm for Natural Disaster Relief	NODNC	RD		X			CP		RES	X		UA	UM		TC, TA, TF										MLP				MDAH				P	OBJ
Morshedlou et al., (2018)	Access Restoration	Work crew routing problem for infrastructure network restoration	NODC	RD					CP		RES	X		UA	UM		TC			MRR	X	X	X		TRV										VP	OBJ

Author(s)/Year	Type of Problem	Title	DRUTA	TRED	TAREA	ND	PND	DUM	DEC	DVT	FD	FV	DI	ACT	MODO	MR	TRANS	TT	DEPRR	TRR	LRR	PRR	RRR	PRD	TMRR	TPRR	CPP	TAH	PAH	LRAH	DDAH	TFT	DINV	VTAH	TP	TPOBJ
Nurre et al., (2012)	Access Restoration	Restoring infrastructure systems: An integrated network design and scheduling (INDS) problem	NODNC	RD		X			LP		RES	X		UA	UM									X											VP	OBJ
Shanshan et al., (2015)	Access Restoration	Collaborative dynamic optimization on post-earthquake emergency supply and road rehabilitation based on road network connectivity	NODNC	RD		X			CP		RES	X		UA	UM		TC			MRR															P	OBJ
Oruc et al., (2018)	Relief Distribution	Post-disaster assessment routing problem	NODC	RD					CP		RES			UA	MM		TC, TA																		P	OBJ
Liu et al., (2019)	Relief Distribution	A branch-and-price algorithm for the home-caregiver scheduling and routing problem with stochastic travel and service times	NODC	RD		X	X	X	LP		RES			UA	MM		TC, TA										MP		X		MDAH	FTHG			P	OBJ
Yan et al., (2020)	Access Restoration	Post-disaster power system restoration planning considering sequence dependent repairing period	NODC	RD		X			LP		RES, REC		X	UA	UM		TC		MDRR	MRR				X	TRC	MRUD									VP	OBJ
Barrera et al., (2012)	Access Restoration	A network-based approach to the multi-activity combined timetabling and crew scheduling problem: Workforce scheduling for public health policy implementation	NODC	RND					CP		RES			UA	UM				MDRR	MRR					TRC										P	OBJ
Qin et al., (2010)	Access Restoration	Evaluation model for damage extent of roads in Wenchuan earthquake-stricken areas based on remote sensing information	NODC	RND					CP		RES			UA	UM				MDRR	MRR					TRC										P	OBJ
Liberatore et al., (2014)	Access Restoration	A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics	NODC	RND					CP		RES			UA	UM				MDRR	MRR					TRC										P	OBJ
Wu and Wang, (2020)	Access Restoration	Post-disruption performance recovery to enhance resilience of interconnected network systems	NODC	RND					CP		RES			UA	UM				MDRR	MRR					TRC										P	OBJ

Item	Description	Response Options
DRUTAS	Route determination	NODC (Matching source and destination nodes)
		NODNC (Matching source and destination nodes)
TRED	Type of network	RD (Directed Network)
		RND (Red No Directed)
TAREA	Area Type	AR (Rural Area)
		AU (Urban Area)
ND	Demand nodes (areas demanding humanitarian aid)	
PND	Priority, importance (weighting) demand nodes	
DUM	Exclusive decisions in last mile distribution	
DEC	Decision Horizon	CP (Short-term Disaster Decisions)
		MP (Medium-term Disaster Decisions)
		LP (Long-term Disaster Decisions)
DVT	Damage or impact generated by the disaster at various points in time	
FD	Phase(s) of the disaster	
FV	Consideration of road failures (roadblocks or interruptions)	
DI	Damage to facilities	
ACT	Participation of one or more stakeholders	UA (Single Actor Participation)
		MA (Multi-stakeholder participation)
MODO	Unimodal or Multimodal Problem (Transportation)	UM (Unimodal Problem)
		MM (Multimodal Problem)
MR	Multiple routes	
TRANS	Type of transport	TC (Road transportation)
		TA (Air Transportation)
		TF (River Transportation)
TT	Type of technology	
DEPRR	Type of decision deposit of remedies	MDRR (Mono Depot Repair Resources)
		MLDRR (Multiple Repository Repair Resources)
TRR	Type of remedy	MRR (Mono Repair Resource)
		MLRR (Multiple Remediation Resources)
LRR	Limitation on availability of remedies	
PRR	Programming and allocation of repair resources	
RRR	Routing repair resources	
PRD	Prioritization of damaged nodes, zones or routes	
TMRR	Repair times	TRC (constant repair (cleaning) times)
		TRV (Fuzzy or stochastic repair (cleaning) times)
TPRR:	Single or Multi repair on the same node	MRUD (Mono repair at the same node)
		MLRUD (Multiple repairs on the same node)
TAH	Type of humanitarian aid	AL (Food Aid)
		ANL (Non Food Aid)
CPP	Single or Multi humanitarian aid product or service	MP (Mono product or service of humanitarian aid)
		MLP (Multiple humanitarian aid products or services)
PAH	Priority type humanitarian aid	
LRAH	Limitation of resources for the delivery of humanitarian aid	
DDAH	Mono or Multi - humanitarian aid depot	DAH (Mono-deposit of humanitarian aid)
		MDAH (Multi Depot for Humanitarian Aid)
TFT	Type Transportation fleet	FTHG (homogeneous transport fleet)
		FTHT (Heterogeneous Transportation Fleet)
DINV	Consideration of inventory levels	
VTAH	Humanitarian aid delivery time windows	
TP	Mono or Multi-period	P (Single-period)
		VP (Multi-period)
TPOBJ	Single or Multi-target or performance function	OBJ (single-objective or single-performance function)
		MOBJ (Multi-objective or multiple performance functions)

Section 3. Extraction matrix part 3 of 3.

Author(s)/Year	Type of Problem	Title	FDESEM	Dimension	EQUID	PRZA	TMOD	NMOD	ALG	DECET	LDEP	LREP	CAPLOC	CAPTRAN	DEMAN	TPAIS	DLEVEL	OTHER	Type of sensitivity analysis or scenarios
Maya-Duque et al., (2016)	Access Restoration	Network repair crew scheduling and routing for emergency relief distribution problem	Summative minimization of the times at which each demand node becomes accessible weighted by demand	Efficacy		X	Dynamic Programming	Deterministic	Exact	ETAPA						PVD	OPER		Analysis of the percentage of repaired nodes vs. accessibility of the entire network.
Rodríguez et al., (2018)	Relief Distribution	Dynamic formulation for humanitarian response operations incorporating multiple organisations	Minimization of total non-compliance for shelter care, medical care and relief distribution in all areas of demand. Minimization of cost of organizations involved, acquisition cost and transportation cost across all organizations and all time periods.	Efficiency			Integer Linear Programming	Deterministic	Exact	ETAPA			X	X	X		OPER		Two scenarios were developed, the first one considering the independent participation of all the organizations involved, while the second one assumes coordination among the participants.
Nurre and Sharkey, (2018)	Access Restoration	Online scheduling problems with flexible release dates: Applications to infrastructure restoration	Maximize the sum of peak flow	Efficacy			Mixed Integer Linear Programming	Deterministic	Exact, Heuristic	ETAPA							OPER		Analysis of the change in peak flow in the network over time in the face of flood events.
Iloglu and Albert, (2020)	Access Restoration	A maximal multiple coverage and network restoration problem for disaster recovery	Maximize multiple coverage of the demand for emergency services over a time horizon.	Efficacy			Integer Linear Programming	Deterministic	Heuristic	ETAPA	X				X		OPER		Analysis coverage in terms of total number of emergency response relocations and total distances associated with these relocations (in miles)
Maya-Duque et al., (2013)	Access Restoration	The accessibility arc upgrading problem	Minimize total cost of flow	Efficiency			Integer Linear Programming	Deterministic	Exact	ETAPA			X		X		OPER		Analysis of average percentage improvement in accessibility for each combination of budget level and number of vertices.
Sakuraba et al., (2016a)	Access Restoration	Road network emergency accessibility planning after a major earthquake	Minimization of the time required to serve the affected population, Minimization of the weighted sum of the SP distances to each destination in all time periods.	Efficacy			Integer Linear Programming	Deterministic	Heuristic	METAPA							OPER		Analysis of accessibility improvement before and after repairs.
Vahdani et al., (2018b)	Access Restoration and Relief Distribution	Multi-objective, multi-period location-routing model to distribute relief after earthquake by considering emergency roadway repair	Minimize fixed costs for setting up distribution centers, vehicle travel cost and the cost of repairing roads on damaged roads; Minimize maximum travel time on the route; Maximize route reliability for equipment maintenance in this process.	Efficiency, Efficacy			Nonlinear Integer Programming	Deterministic	Metaheuristics: non-dominated sorting genetic algorithm II (NSGAII) and multiobjective particle swarm optimization (MOPSO)	ETAPA	X			X	X	PVD	EST, OPER	Assignment of disaster areas and vehicles to distribution centers; each disaster point can be served more than once by different vehicles.	An analysis was performed on the change in the value of inter-location distances as a function of route time, and the increase in route cost and reliability.
Ozdamar et al., (2014)	Access Restoration	Coordinating debris cleanup operations in post disaster road networks	Maximize the cumulative accessibility of the network during the cleaning operation; Minimize the time it takes to complete the cleaning (the makespan)	Efficacy			Mixed Integer Linear Programming		Heuristic	ETAPA							OPER		From an ANOVA it was determined that the variability in the performance of the four rules (maximum number of blocked edges, accessible blocked with the shortest working time, accessible blocked that is closest to the first available busy crew, accessible blocked edge and whose cleanup results in the maximum proportion of their total savings) that we have discussed so far are statistically significant. The analysis also indicates that the performance of each rule varies significantly depending on the scenario solved.
Sakuraba et al., (2016b)	Access Restoration	Work-troop scheduling for road network accessibility after a major earthquake	Minimize the weighted sum of the distances to each destination over all time periods	Efficacy			Integer Linear Programming		Heuristic	ETAPA							OPER	Aggregate Unit of Remedial Resources	Experiments were addressed using a set of 80 simulated instances and a real instance. The time period from which all population becomes accessible was used to measure the quality of the solutions obtained. This metric is referred henceforth as "accessibility", and its average value obtained by CPLEX and by the heuristics for each instance set.
Averbakh, (2012)	Access Restoration	Emergency path restoration problems	Minimize total recovery time of all nodes	Efficacy						ETAPA									Time-to-repair analysis was performed for problems with fixed initial server locations and flexible initial locations.

Author(s)/Year	Type of Problem	Title	FDESEM	Dimension	EQUID	PRZA	TMOD	NMOD	ALG	DECET	LDEP	LREP	CAPLOC	CAPTRAN	DEMAN	TPAIS	DLEVEL	OTHER	Type of sensitivity analysis or scenarios
Rezai-Malek et al (2016)	Relief Distribution	An approximation approach to a trade-off among efficiency, efficacy, and balance for relief pre-positioning in disaster management	Minimize the total cost in the pre-disaster phase consisting of the sum of the fixed cost of establishing warehouses, the fixed cost of prepositioning humanitarian relief items, and the total cost in the post-disaster phase, including the cost of transportation and the additional cost of holding penalties for unused items; Maximize the expected level of time-, demand-, and priority-weighted utility of the aid delivered; Minimize the maximum expected difference in the utility levels of the aid to alleviate suffering in the affected areas.	Efficiency, Efficacy			Multiobjective Nonlinear Programming	Stochastic	Exact (Separable Programming to Linearize the Model and Epsilon Constraints to Solve the Multiobjective Problem)	METAPA	X		X		X		EST, OPER	Stochastic model	Sensitivity of the model with respect to the important parameters used in the RM utility level through four indices that measure the expected time-weighted demand satisfaction, the expected satisfied demand index for PD, the network attention as a function of demand, and the expected time-weighted quantity delivered.
Vahdani et al. (2018a)	Relief Distribution	Two-stage multi-objective location-routing-inventory model for humanitarian logistics network design under uncertainty	Model 1: Minimize the cost of establishing warehouses and distribution centers and storing products in the warehouses and distribution centers (Obj.1); Model 2: Minimize the vehicle travel cost; the first part indicates the travel cost between the distribution center for the customer and the customer for the distribution center and the second part represents the transportation cost between the affected areas. The second objective function minimizes the vehicle travel time (Obj.2). The third function maximizes the route reliability in which the first part represents the reliability of the routes between the circulated customers and the reliability of the routes from the distribution centers to the customer and vice versa (Obj.3).	Efficiency, Efficacy			Multiobjective Linear Programming Model	Deterministic	metaheuristics : NSGAII and MOPSO	METAPA	X				X		EST, OPER	Reliability of routing, each zone can be served by only one vehicle, No consideration of arc capacity for relief supply, inventory decisions only at Warehouses (distribution center) and not at local distribution points or immediate relief.	Sensitivity of the parameters to changes in their values in each objective function. The parameters considered are travel time between locations and demand for disaster areas.
Celik, (2016)	Access Restoration	Network restoration and recovery in humanitarian operations: Framework, literature review, and research directions				X	Integer Linear Programming, Mixed Integer, Dynamic Programming and Discrete-Event Simulation	Deterministic	Accuracy, Metaheuristics, Heuristics	ETAPA, METAPA	X	X			X	PVD, PDD	EST, OPER	Review Article (2000-2016)	Most studies consider a two-stage scenario, where all uncertainty is revealed at one point in time.
Sabbaghtorkan et al. (2020)	Relief Distribution	Prepositioning of assets and supplies in disaster operations management: Review and research gap identification					Integer Linear Programming, Mixed Integer and Discrete Event Simulation	Stochastic	Accuracy, Metaheuristics, Heuristics	ETAPA	X				X		TAC	Review Article (2000-2018)	Tailor-made models for specific types of disasters.
Yan and Shih, (2009)	Access Restoration and Relief Distribution	Optimal scheduling of emergency roadway repair and subsequent relief distribution	Minimize total repair time; Minimize total product delivery or distribution time	Efficacy			Integer Linear Programming	Deterministic	Exact	ETAPA				X			OPER	Certainly, if more than one mode of transportation is to be considered, a multimodal network may be investigated in the future.	A sensitivity analysis of the total number of work teams, the number of work teams in each job and the weighting of each FO.
Tuzun and Ozdamar, (2014)	Access Restoration	A mathematical model for post-disaster road restoration: Enabling accessibility and evacuation	Maximize the dynamic accessibility of the network	Efficacy			Integer Linear Programming	Deterministic		METAPA							TAC	The model proposed here is a dynamic path-based model (the first one we know of).	Analysis of the impact on repair equipment allocation and on the objective function from variations in the availability of repair equipment.
Al ted and Murray (2017)	Relief Distribution	Vehicle routing and resource distribution in postdisaster humanitarian relief operations	Minimize the amount of unmet demand, unattended casualties and untransferred workers.	Social welfare and equity		X	Integer Linear Programming	Deterministic	Heuristic	ETAPA				X	X		OPER	Evacuation Decisions	Four classifications of small-, medium- and large-scale test problems were used to evaluate el rendimiento de las variantes heurísticas propuestas.
Victoria et al., (2016)	Relief Distribution	Column Generation based heuristic for the Vehicle Routing Problem with Time-Dependent Demand	Maximize total satisfied demand	Efficacy			Integer Linear Programming	Deterministic	Heuristic	ETAPA				X	X		OPER		Evaluation of solution time and performance function value for different instance sizes.

Author(s)/Year	Type of Problem	Title	FDESEM	Dimension	EQUID	PRZA	TMOD	NMOD	ALG	DECET	LDEP	LREP	CAPLOC	CAPTRAN	DEMAN	TPAIS	DLEVEL	OTHER	Type of sensitivity analysis or scenarios
Lu et al., (2016)	Access Restoration	An optimal schedule for urban road network repair based on the greedy algorithm	Minimizing the cumulative travel cost of the entire network	Efficacy			Integer Linear Programming	Deterministic	Heuristic	ETAPA							OPER	No travel time consideration, the same repair time is assumed for all damage.	An analysis of experiments varying the number of damaged links and their impact on the objective function.
Ahmadi et al., (2015)	Relief Distribution	A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: A case study on San Francisco district	Minimize Total distribution time, penalty cost of unsatisfied demand and fixed costs of opening LD	Efficacy			Mixed integer nonlinear programming model	Deterministic	Heuristic	METAPA	X		X	X	X		EST, OPER	Standard relief time limitations. Homogeneous capacity facilities and vehicles. VNS Algorithm	Comparison between commercial and humanitarian logistics based on the variation of the maximum relief time in both contexts and its impact on the objective function.
Iloglu and Albert, (2018)	Access Restoration	An integrated network design and scheduling problem for network recovery and emergency response	Minimize the cumulative weighted distance between demands and the nearest open facilities on the time horizon	Efficacy			Integer Linear Programming	Deterministic	Heuristic	ETAPA	X		X				OPER	Identical crews	Analysis of objective function value and computation time using different instance sizes.
Karakoc et al., (2019)	Access Restoration	Community resilience-driven restoration model for interdependent infrastructure networks	Maximize the resilience of interdependent infrastructure networks; Minimize the total cost associated with the restoration process.	Efficiency			Mixed Integer Linear Programming			ETAPA								Restoration programming of interdependent critical infrastructure networks is modeled from a community resilience perspective.	Behavioral analysis of unsatisfied demand considering different recovery times.
Hemakumar et al., (2017)	Access Restoration	Fuzzy Based Approach for Restoration of Distribution System during Post Natural Disasters								ETAPA							PREP	The repair time depends on the severity of the damage and the number of damages in a damaged region. A fuzzy rule-based system is developed for repair time estimation considering the available linguistic information about the severity of the system damage.	Evaluation of resource requirements and people capable of repairing damage for different minimum and maximum levels of severity.
Kim el al., (2018)	Access Restoration	Network repair crew scheduling for short-term disasters	Minimize the weighted sum of the total damage in isolation and the time to complete a repair kit	Efficacy			Mixed Integer Linear Programming		Metaheuristics	ETAPA						PVD, PDD	OPER	Short-term disasters in the post-disaster period. Ant colony. Isolated nodes.	Optimal ratios and computation times for normal distributions with different numbers of repair teams.
Tavana et al., (2018)	Relief Distribution	An integrated location-inventory-routing humanitarian supply chain network with pre- and post-disaster management considerations	Minimize the total cost of acquisition and preparation before the disaster occurs. Minimize the total OPER cost of assistance in the action (confrontation) phase after the disaster occurs. Minimize the total time of operational assistance in the action phase after the disaster occurs.	Efficiency, Efficacy			Mixed Integer Linear Programming		Metaheuristics: the non-dominated sorting genetic algorithm II (NSGA-II) and the benchmark-based non-dominated sorting genetic algorithm II (RPBNSGA-II).	METAPA	X				X		EST, OPER	Central warehouse location decisions. Perishable products	Due to the high complexity of the problem, the Epsilon-Constraint method, coded with Lingo software, could not produce a solution to the problem. Therefore, the problem was coded and solved in NSGA-II and RPBNSGA-II. The results and information obtained from the analysis of variance (ANOVA) concluded that NSGA-II performs better than RPBNSGA-II on small problem sizes. At the same time, RPBNSGA-II outperforms NSGA-II on large problems.
Grass and Fischer, (2016)	Relief Distribution	Two-stage stochastic programming in disaster management: A literature survey	Minimize the total cost of the trip. Maximize total demand satisfied	Efficiency, Efficacy			Mixed Integer Linear Programming	Stochastic		METAPA	X			X	X		EST, OPER		

Author(s)/Year	Type of Problem	Title	FDESEM	Dimension	EQUID	PRZA	TMOD	NMOD	ALG	DECET	LDEP	LREP	CAPLOC	CAPTRAN	DEMAN	TPAIS	DLEVEL	OTHER	Type of sensitivity analysis or scenarios
Faiz et al., (2019)	Relief Distribution	A column generation algorithm for vehicle scheduling and routing problems	Minimize the total cost of transportation to carry out all necessary operations.	Efficiency			Mixed Integer Linear Programming	Deterministic	Exact (Column generation)	ETAPA				X			OPER		Performance function impact analysis based on the variation of parameters of interest.
Moreno et al., (2019)	Relief Distribution	A branch-and-Benders-cut algorithm for the Crew Scheduling and Routing Problem in road restoration	Minimize the time that demand nodes remain inaccessible from the repository weighted by their corresponding demands	Efficacy				Deterministic	Exact (Branch cutting algorithm and Benders (BBC))	ETAPA								Branch Cutting Algorithm and Benders (BBC)	Performance analysis of heuristic methods based on objective value.
Alinaghian et al., (2019)	Relief Distribution	A mathematical model for location of temporary relief centers and dynamic routing of aerial rescue vehicles	Minimize arrival time at the last aid center	Efficacy			Mixed Integer Linear Programming	Deterministic	Metaheuristic (scatter search and neighborhood search; Genetic algorithm)	ETAPA	X				X		OPER		Comparative GAP analysis of each solution provided by three algorithms.
Li et al., (2019)	Relief Distribution	A model for assignment of rescuers considering multiple disaster areas	Minimize total network repair time	Efficacy			Integer Linear Programming	Deterministic	Metaheuristic (ant colony)	ETAPA									Analysis of the results of assigning rescuers to different rescuers with varying degrees of competence.
Zhou et al., (2017)	Relief Distribution	A multi-objective evolutionary algorithm for multi-period dynamic emergency resource scheduling problems	Minimize the unsatisfied demand of the affected points with the purpose of satisfying the demand of people in disaster areas. Minimize the risk of choosing the damaged road, and aims to guide the rescue team to select appropriate and efficient roads.	Social welfare and equity						ETAPA								Multi-period dynamic emergency resource scheduling (ERS)	Test model performance on different road networks.
Edrissi et al., (2015)	Relief Distribution	Transportation network reliability in emergency response	Maximizes the updating of links that are important and have a high probability of failure.	Efficacy			Integer Linear Programming	X	Exact	ETAPA								Limited budget for network restoration	To illustrate the role of relief inventory on the number of deaths, a sensitivity analysis is performed at different levels of relief supplies.
Sanci and Daskin, (2019)	Access Restoration and Relief Distribution	Integrating location and network restoration decisions in relief networks under uncertainty	The objective function (1) minimizes the total cost consisting of facility location costs, restoration equipment costs. The objective function (2) minimizes the transportation costs for emergency relief items and catering equipment, and the unmet demand costs.	Efficiency			Mixed Integer Linear Programming	Stochastic	Heuristic	METAPA	X	X	X		X		EST, OPER	Single aid claim at the beginning of the period	Percentage analysis of expected satisfied demand for various budget levels.
Habib et al., (2016)	Relief Distribution	Mathematical Models in Humanitarian Supply Chain Management: A Systematic Literature Review	Maximize network accessibility	Efficacy			Mixed Integer Linear Programming		Metaheuristic (Genetic Algorithm)	METAPA					X				Percentage repaired at damaged nodes based on the variation in the number of repair crews in urban areas.
Shin et al., (2019)	Access Restoration and Relief Distribution	Integrated optimal scheduling of repair crew and relief vehicle after disaster	Minimize the last transport time of all demand nodes.	Efficacy		X	Mixed Integer Linear Programming	Deterministic	Metaheuristic (ant colony)	ETAPA					X		OPER	The repair team and the support vehicle are supposed to start from the same depot.	Computational experiments performed by varying the number of edges.
Yan et al., (2012)	Access Restoration	Optimal scheduling of logistical support for an emergency roadway repair work schedule	Minimize the short-term OPER cost for logistics support, which includes a sum of the OPER cost of the vehicle, the cost of external use of the vehicle and the transportation cost de material.	Efficiency		X	Mixed Integer Linear Programming	Deterministic	Exact (CPLEX)	ETAPA									Two sensitivity analyses of the essential model parameters (number of vehicles and material demand) are performed to examine their influence on the solution.

Author(s)/Year	Type of Problem	Title	FDESEM	Dimension	EQUID	PRZA	TMOD	NMOD	ALG	DECET	LDEP	LREP	CAPLOC	CAPTRAN	DEMAN	TPAIS	DLEVEL	OTHER	Type of sensitivity analysis or scenarios
Aslan and Celik, (2019)	Access Restoration and Relief Distribution	Pre-positioning of relief items under road/facility vulnerability with concurrent restoration and relief transportation	Minimize total time to deliver aid, Minimize unsatisfied demand.	Efficacy				Stochastic	Heuristic (a heuristic approach based on an SAA scheme)	METAPA			X		X		TAC, OPER	A given DL can be served a given product from a single DC to avoid coordination problems.	Analysis of expected percentages of total weighted demand satisfied for half-hourly intervals under the three objectives with no repair and with repair immediately available.
Coco et al., (2020)	Relief Distribution	Modeling and solving the multi-period disruptions scheduling problem on urban networks	Minimize the total cost of deprivation. Minimize the total OPER cost.	Social welfare and equity			Mixed Integer Linear Programming	Deterministic	Metaheuristic (Simulated Annealing)	ETAPA			X	X	X		OPER	In the distribution of relief goods, one should try to move essential goods from warehouses to points of demand. Then, decision makers may decide to transfer goods from one affected region to another to achieve the optimal use of available goods. Therefore, one of the challenges in disaster management is to redistribute relief goods to avoid severe shortages in some areas, while excess inventory in other areas.	
Chen et al., (2020)	Relief Distribution	Supply allocation: bi-level programming and differential evolution algorithm for Natural Disaster Relief	Minimize the weighted distribution time to deliver all relief materials. Maximize the minimum compliance rate of all affected sites required for each type of relief material.	Efficacy			Mixed Integer Linear Programming	Deterministic	Metaheuristics	METAPA			X						Convergence analysis genetic algorithm vs. generation number for each objective function.
Morshedlou et al., (2018)	Access Restoration	Work crew routing problem for infrastructure network restoration	Maximize network accessibility	Efficacy			Integer Linear Programming	Deterministic	Metaheuristics	ETAPA									Scenario analysis for different levels or degrees of track disruption.
Nurre et al., (2012)	Access Restoration	Restoring infrastructure systems: An integrated network design and scheduling (INDS) problem	Maximize the cumulative weighted flow reaching the demand nodes over the horizon of the problem.	Efficacy			Integer Linear Programming	Deterministic	Heuristics (dispatch rules)	ETAPA									Comparison of different resource dispatch rules.
Shanshan et al., (2015)	Access Restoration	Collaborative dynamic optimization on post-earthquake emergency supply and road rehabilitation based on road network connectivity	Maximize network accessibility	Efficacy			Mixed Integer Linear Programming	Deterministic	Heuristic	ETAPA									Scenario analysis on unmet distribution variation, delayed time and distribution routes for different stages.
Oruc et al., (2018)	Relief Distribution	Post-disaster assessment routing problem	Maximize network accessibility. Minimize OPER cost	Efficiency, Efficacy			Integer Linear Programming	Deterministic	Metaheuristics	ETAPA								Damage assessment operations. Use of drones and motorcycles	A scenario analysis is performed considering different numbers of drones and motorcycles
Liu et al., (2019)	Relief Distribution	A branch-and-price algorithm for the home-caregiver scheduling and routing problem with stochastic travel and service times	Maximizing relief equity	Social welfare and equity	X		Integer Linear Programming	Deterministic	Exact	ETAPA	X				X			Use of helicopters	Comparative analysis of "soft time windows" and "hard time windows" to analyze the impact on the objective function.

Author(s)/Year	Type of Problem	Title	FDESEM	Dimension	EQUID	PRZA	TMOD	NMOD	ALG	DECET	LDEP	LREP	CAPLOC	CAPTRAN	DEMAN	TPAIS	DLEVEL	OTHER	Type of sensitivity analysis or scenarios
Yan et al., (2020)	Access Restoration	Post-disaster power system restoration planning considering sequence dependent repairing period	Maximize network accessibility	Efficacy			Integer Linear Programming	Deterministic	Exact	ETAPA								Sequence-dependent repair periods	Sensitivity analysis of the repair speed model, i.e., the repair period is directly affected by the repair speed model.
Barrera et al., (2012)	Access Restoration	A network-based approach to the multi-activity combined timetabling and crew scheduling problem: Workforce scheduling for public health policy implementation	Maximize network accessibility	Efficacy			Integer Linear Programming	Deterministic	Exact	ETAPA									Scenario analysis for different number of damaged links and their impact on the performance function.
Qin et al., (2010)	Access Restoration	Evaluation model for damage extent of roads in Wenchuan earthquake-stricken areas based on remote sensing information	Maximize network accessibility	Efficacy			Integer Linear Programming	Deterministic	Exact	ETAPA									A scenario analysis was performed evaluating different instance sizes and their impact on the performance function.
Liberatore et al., (2014)	Access Restoration	A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics	Maximize network accessibility	Efficacy			Integer Linear Programming	Deterministic	Exact	ETAPA									Analysis of various instance sizes and their impact on the objective function.
Wu and Wang, (2020)	Access Restoration	Post-disruption performance recovery to enhance resilience of interconnected network systems	Maximize network accessibility	Efficacy			Integer Linear Programming	Deterministic	Exact	ETAPA									

Item	Description	
FDESEM	Description function(s) performance	
Dimension	Performance measure dimension	
EQUID	Consideration Equity in attention to affected are	
PRZA	Priority affected areas	
TMOD	Type of model	
NMOD	Nature of the model	
ALG	Solution algorithm	
DECET	Single-stage or multi-stage solution approach	ETAPA (Single-stage solution approach)
		METAPA (Multi-Stage Solution Approach)
LDEP	Decisions to locate humanitarian aid depots	
LREP	Spare parts warehouse location decisions	
CAPLOC	Facility capacity	
CAPTRAN	Transport fleet capacity	
DEMAN	Consideration Demand for humanitarian aid	
TPAIS	Country characteristics	PVD (Application in developing or low-income countries)
		PDD (Application in developed or high-income countries)
DLEVEL	Decision level	OPER (Operational Level)
		TACT (Tactical Level)
		EST (Strategic Level)
OTHER	Other limitations or considerations	