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Advances in Network Accessibility and Reconstruction after Major Earthquakes

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Introduction

Natural and man-made disasters have a serious impact on populations, environment and urban infrastructures, which is a consequence, among others, of the population density in urban areas. Nowadays, 54% of the world population lives in such areas UN Prospects (2016), increasing the complexity of operations in case of major disasters. Each year different kinds of disasters (floods, fire, earthquakes, hurricanes etc.) leave millions of people dead, injured or homeless and represent billions of dollars in humanitarian aid and reconstruction EMDAT (2016). This explains part of the political, scientific and community interest in improving operations post disasters. This study is a result of co-operation (collaborative project "Optimizing logistics for large scale disasters" (OLIC (2015))) between representative organizations in crisis management, in particular partners from the International Charter on Space and Major Disasters (ICSMD (2015)), and researchers trying to connect theoretical Operations Research (OR)/ Management Science (MS) models and methods with the real problems faced on the ground. The integration of ideas from both members of the International Charter and scientists was mandatory to legitimate the proposed models and approaches. Moreover, it is important to highlight that the members of ICSMD

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involved in the project have provided a support to obtain and to treat real data from major disasters. This has allowed us to define standard inputs to the algorithms, as well as to produce outputs for rescue teams. As a consequence, the problems surveyed here have been tested using real data.

The problems were investigated for major earthquakes, which represent the third most frequent disaster type in the world, and the sixth in terms of damage caused EMDAT (2016). OR/MS foundations have been applied, together with information obtained by satellite images from ICSMD. The results were compiled to add value and produce maps with decision support information. Real data from Port-au-Prince, Haiti, in 2010 and from Kathmandu, Nepal, in 2015 was used to fix the context, define realistic scenarios and treat key points for humanitarian operators. Road accessibility to the population was a relevant issue pointed out in OLIC project. This topic should be considered in its own right and also together with other post-disaster problems, such as relief distribution, reconstruction, etc. (not necessarily in an integrated optimization model). In fact, road networks and buildings can be seriously affected after a major earthquake. The former greatly disrupts accessibility to the population which is very significant to the rescue teams and for routing supplies. The latter is relevant to the rehabilitation of the affected cities, and in some cases becomes an opportunity to improve their urban infrastructures. The earthquake in Port-au-Prince, Haiti, 2010 damaged several buildings and blocked routes, in which the blocked routes appear with different levels of disruption such as light blockage (vehicles can still access routes) and major disruption (a building fell over the route). Port-au-Prince is still suffering the consequences of this disaster in terms of urban infrastructure rehabilitation and private and public building reconstruction. Recently, in 2015, a number of earthquakes hit Nepal and damaged several historic monuments and buildings in Kathmandu. These require particular attention to achieve their restoration, starting with the careful removal of precious debris.

In this chapter, basic and complex problems concerning the accessibility to the population, the road rehabilitation problem, and methods for solving them Sakuraba et al. (2016a, b) are surveyed. For the sake of clarity, "Accessibility to the population" is a generic term used here to indicate if a path exists from starting points (referred also as origins) to destinations and how long they are. A number of trends and opportunities related to this topic are also discussed. In particular the lack of studies dedicated to long-term reconstruction phase, raising new challenges. In addition, it is important to highlight that accessibility issues can also be considered together with other problems (e.g. relief distribution) in a more pragmatic way than in previous studies. Few works considered such an aspect. For instance, authors in Yan and Shih (2009); Liberatore et al. (2014) designed optimization models combining infrastructure recovery decisions with distribution to minimize the time required for the reparation and distribution operations. Work of Liberatore et al. (2014) focuses on this problem, using multi-criteria decisions and optimizes time, cost, reliability, security and demand satisfaction. It is worth mentioning that integrated optimization models are interesting and challenging from a scientific point. However, in the context of crisis management, they do not seem to be an initial good approach to apply in the response phase and in practice, since different decision-makers such as governments, civil safety, nongovernmental organizations (NGO) and Red cross are involved in post-disaster relief operations. Each one has its own tasks, organization, coordination and way of operating. Moreover, some organizations can be even in competition. Huachi et al. (2015a, b) present an acceptable way to handle the network disruption by considering the network changes dynamically and providing vehicle routing solutions for the last mile of distribution.

Several excellent surveys can be entry points to OR/MS applied to disaster operations. For instance, relief distribution, routing and transportation, as well as models and metrics are reviewed in Anaya-Arenas et al. (2014); Caunhye et al. (2012); Huang et al. (2012). Facility location is additionally focused on by Caunhye et al. (2012). The study Diaz et al. (2013) classifies the literature into two categories of problems. The ones dedicated to "emergency management" which includes transportation, routing, supply chain and "emergency procurement logistics, and humanitarian logistics" covering aid, facility locations and resource distribution and allocation. Leiras et al. (2014) propose a systematic way to review the literature on humanitarian logistics both in terms of qualitative and quantitative models and strategies. Work by Altay and Green III (2006) presents a classification and reviews problems based on the well-known phases of disaster operations management: mitigation, preparedness, response and recovery. A number of basic concepts are presented in Ortuño et al. (2013), followed by a literature review also based on disaster phases. Among other issues, it covers problems in mitigation and preparedness phases (assessment, facility location, evacuation, inventory planning, among others), response (e.g. last mile and large-scale distribution) and disaster recovery (e.g. civil infrastructure systems, power system restoration, economic recovery, health care and mental health recovery). Moreover, work by Duhamel et al. (2016) clarifies how OR/MS strategies can improve resilience, and presents models and strategies for solving a location-allocation problem, considering the population dynamics and the type of disaster.

A number of works in the literature do not distinguish between emergency accessibility and medium and long-term accessibility. Nevertheless, accessibility covers different problems according to the time scale of a disaster. Two problems are detailed in this chapter, accessibility in the initial emergency and in the medium term, respectively, the Road Network Accessibility Problem (RNAP) and the Work-troops Scheduling Problem (WSP). RNAP can be solved by polynomial time algorithms, while the WSP appears at the interface between emergency and the beginning of the reconstruction phase, and belongs to the NP-hard class of combinatorial optimization problems. The RNAP consists of providing both an estimation in terms of time periods to make the population accessible, and defining paths to travel to target zones. Some paths can be immediately used, while others are inaccessible depending on the time period. The WSP aims at assigning Work-Troops (WT) to remove debris and improve the overall accessibility. For the sake of clarity, let a WT be composed of bulldozers, excavators, dump trucks and the human resources to pilot these equipments. Several constraints and parameters close to practice are considered by Sakuraba et al. (2016b) such as a limited number of WT, physical road limits (e.g. primary, secondary and tertiary), road blockage level (e.g. partially or complete blocked), time periods and the use of more than one WT to clean a route. The network rehabilitation dynamic is considered to update the accessibility situation per time period.

The remainder of this chapter is organized as follows. Initially, in section “Network Accessibility After Earthquakes”, an overview of accessibility problems found in the literature is provided, together with a description of RNAP and WSP. Then, trends and opportunities are given in section “Trends and Opportunities”. The essential data treatment, which is a key point for applying OR/MS methods in real contexts is discussed in section “Systematic Data Treatment for Network Accessibility” for RNAP and WSP, followed by examples of standard input and output maps. Finally, concluding remarks are done in section “Concluding Remarks”.

Network Accessibility After Earthquakes

In the literature, there are several studies on improving accessibility during mitigation and preparedness phases by defining recommendations to prevent major disruptions, Hu et al. (2012); Faturechi and Miller-Hooks (2015); Fiondella (2013). Furthermore, some authors investigate the emergency accessibility, while others look at scheduling WT to restore the network transportation. An overview on accessibility contributions in the response phase and applying quantitative models and strategies is given below. Then, RNAP and WSP are presented.

Literature Review on Network Accessibility Problems

Network accessibility in the first three days of response is handled by Aksu and Ozdamar (2014). The proposed model assumes a limited number of WT, each WT can restore one route at a time and aims at maximizing the total weighted earliness of all path restoration completion times. The time period in which a road becomes available is defined by the proposed model. Instances based on the road networks of two districts in Istanbul, Turkey are used in the experiments, considering up to 49 blocked roads out of 212, and 4 to 18 WT. Study by Duque and Sorensen (2011) is dedicated to the inter-city accessibility problem and develops a hybrid heuristic (i.e. Greedy Randomized Adaptive Search Procedure with a Variable Neighborhood Descent) to define which roads should be repaired to minimize the weighted sum of the shortest paths for all destinations, with manpower and financial budget constraints. Results and analysis of the budget constraints impact are provided for a realistic instance of three regional centers in Haiti (i.e. Port-au-Prince, Les Cayes, and Cap Haitian) after the quake in 2010.

Highway restoration considered by Yan and Shih (2007) is modeled using a network indexed over time, referred to as time-space network. The authors assume a WT repairs a single road at a time and present a flow-based model which optimizes the repair time. Experiments are addressed using an instance of Nantou County, Taiwan with 24 damaged points and 24 WT. Highways emergency rehabilitation, that is, up to 72 hours is addressed in Feng and Wang (2003). Thus, the authors assume that it is possible to do repairs in the critical and chaotic period of emergency. A multi-objective model is optimized in a given priority order for the following three objectives: maximizing the length of usable roads, maximizing the number of nodes with injured people that can be accessed by roads, referred to by the authors as maximizing the number of lives saved, and minimizing the risk of working in sensitive areas. Experiments have also been carried out in an instance of Nantou County, Taiwan, considering 10 damaged nodes and 3 WT. The restoration of roadways in the main arteries of Taiwan rural areas is modeled using an integer multiple-commodity network flow in Yan et al. (2014). The order of repairs is implicitly handled by the model as the possibility of routing vehicles flow on a specific road. The goal is to minimize the maximum time required to repair all highway segments and the model is tested over the instances from Yan and Shih (2007).

Scheduling problems to improve accessibility in the medium and long term have been investigated by Chen and Tzeng (1999). The authors Chen and Tzeng (1999) propose a bilevel model, where the first level considers the

WT scheduling and the second level addresses the asymmetrical assignment traffic model. The fuzzy multi-objective bi-level model is solved by means of a genetic algorithm, using an instance with 4 WT and 10 blocked routes.

Road Network Accessibility Problem

The main decisions about and answers to RNAP rely on the time required to arrive at points (destinations) on an urban network and the order to repair routes, restoring or improving (i.e. access destinations faster) the network connectivity. However, some characteristics impose specific operations to treat accessibility problems properly. For example, removing debris is very different from doing majors repairs, as illustrated in Fig. 18.1. Here, both RNAP and WSP focus on accessibility and removing debris. The problem of repairs requiring long civil engineering, is discussed in section "Trends and Opportunities".

The RNAP is defined in a graph $G = (V,E)$, where V and E stand respectively for the set of vertices and edges, defining the urban transportation network. The vertex set $V = O \cup D \cup T$, where O, D and T are respectively the origins (network nodes to be defined, e.g. humanitarian aid points, WT origins and others), destinations (nodes to be accessed) and the transshipment nodes. In addition, $t_{ij} \in N$ is the estimated time required to repair an edge $[i,j] \in E$, and p_j is the population at every destination $j \in D$. It should be noted that the volume of debris can be computed using data treatment of satellite images based on the debris volume. Moreover, the population can migrate after an earthquake. Thus, an estimation of population per area based on satellite images, using the habitable surface still available and the spontaneous points of inhabitant grouping can also be computed. Traveling costs (time) are assumed to be irrelevant to available edges, while the number of

Fig. 18.1 Examples of severe route damage, Nepal 2015 (Source: Quanjing, 2016)

time periods required to restore/clean a blocked edge is considered as its costs. Thus, if $[i, j] \in E$ is blocked, c_{ij} is equal to the number of time periods to remove debris in $[i,j]$ using a single WT, otherwise $c_{ij} = 0$. RNAP has been mathematically modeled as a flow-based model by Sakuraba et al. (2016b), where a unit of flow is sent to each destination. Whenever several origins are available, an artificial node is used to connect all origins. The objective is to provide an overview estimation of the number of periods required to arrive at each destination, defined by variables $y_i \geq 0$ associated with every node $i \in D$. Implicitly, the solutions indicate the edges in the path to arrive at large population areas, blocked or not. One may note that, the objective function can be weighted by the number of inhabitants to define a priority on populated regions. It allows us to analyse the impact on repairing/cleaning the blocked routed (modeled by edges) in such paths. Another factor is that if an area is difficult to access in the emergency phase, alternative transportation vehicles can be deployed like helicopters or drones.

Figure 18.2-(a) depicts a simple example of an instance for RNAP, where the gray nodes correspond to destination (D = {5, 6, 8}). There is a single starting point (O = {0}), dashed lines indicate impassable routes, and the number of periods required to repair them are also presented. Available edges cost are set to zero since the traveling times are assumed to be less than a unique repair on the given blocked routes (edges). Fig. 18.2-(b) and (c) show two solutions, where p_i is the number of inhabitants at i and y_i is equal to the number of time periods required to arrive at each destination. The first solution in Fig. 18.2-(b) has a blocked edge, that is [0, 3], while the second one has two disrupted edges [2,3] and [4,8]. However, the second

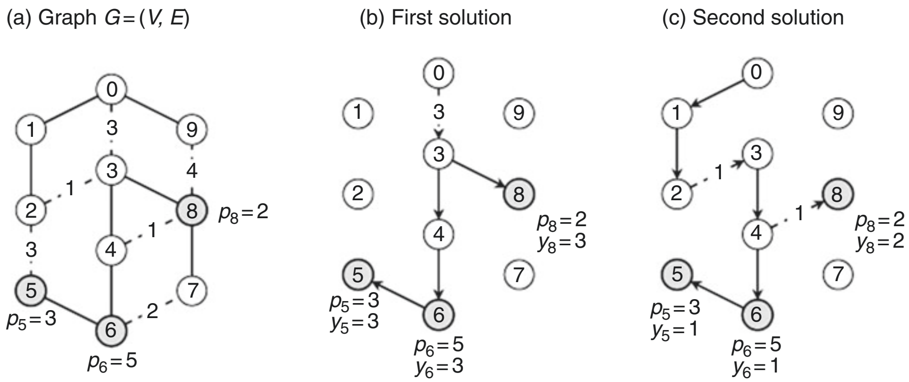

Fig. 18.2 Examples of an instance and solutions to RNAP

Fig. 18.3 Graph for Port-au-Prince, Haiti

solution requires less effort and allows the destinations to be reached in fewer time periods than the first solution, even if two blocked routes are considered in the paths. It is worth mentioning that the destination 8 can be reached faster than in the second solution (see Fig. 18.2-(c)) by using the path {0,1,2,3,8}, that is, $y_8 = 1$.

This problem can be easily solved by a shortest path algorithm, such as Dijkstra or Bellman-Ford, where costs are the number of periods to arrive at each destination. The algorithm complexity is relevant since the urban graphs can be very large. For instance, the Port-au-Prince graph representing its urban transportation network has 16 660 vertices (origins, destinations and transshipment nodes) and 19 866 edges (road segments), as depicted in Fig. 18.3. Djikstra's algorithm can be implemented using a binary heap in $O(m \log n)$ Cormen et al. (2009), where m and n correspond, respectively, to the number of arcs and vertices of a given graph. Note that undirected graphs can be transformed in directed ones. Thus, edges can be represented by arcs.

In spite of the simplicity of this problem, it quickly provides important insights to a decision-maker. A basic example concerns the available resources, whenever they do not allow the proposed routes to be repaired/cleaned, accessibility can be ensured by other kinds of vehicles as mentioned earlier.

Work-Troops Scheduling Problem

Studies Sakuraba et al. (2016a, b) present a cutting edge model for the WSP. In particular, this model allows ground dynamics to be integrated, the mathematical model is indexed per time period with constraints not still handled in the literature, and the heuristic methods are fast which allow new parameters to be updated and solutions to be reoptimized, whenever necessary. Moreover, significant aspects not still treated by previous works have been considered. For example, the road network connectivity constraints together with the WT scheduling are done using a flow model. In addition, more than one WT can work to repair a route according to its physical limitations and relevance to the network connectivity. Furthermore, it considers an overall urban area relying on large-scale graphs. Last but not least, the model and methods have been designed with experts in situation on the ground, and data treatment received as much attention as the model and methods (section "Systematic Data Treatment for Network Accessibility").

The following input parameters are used. The road network is represented by a graph $G = (V, E)$ as previously defined, where the origins and destinations belong to the set of vertices. The origins contain the information about the number of available WT, while destinations have an estimation of population. The edges also have parameters stating their distance and the amount of time periods necessary to repair them, if they are blocked. Without loss of generality, "an edge repair" means the route represented by the corresponding edge will be repaired. A limitation on the number of WT that can work simultaneously on a route is given for each edge according to the type of route (primary, secondary and tertiary), as well as the number of WT is assumed to be known in advance. It is important to mention that the estimation of population and the volume of debris are computed from satellite images. A pro of this data treatment is that it gives the state of the situation, that is, population migration, volume of debris, etc. in real-time and a con is that weather conditions can disturb getting satellite images.

The mathematical model uses two levels of flow: one level to follow the evolution of the shortest paths from origins to destinations and network connectivity, and the second level to ensure WT arrive at the destination if and only if there is a path to route them. Moreover, the objective function is weighted by the number of inhabitants. According to this objective function, priority is given to populated regions. The model selects edges, requiring repairs such that resource constraints are satisfied. It decides the assignation of WT to edges' extremities, how many WT to be sent for blocked edges, and in which time period the repairs will be performed. The goal is to reduce the shortest paths, considering populated areas as priority. The mathematical model gives a formal definition of the problem, which is very relevant in the scientific context. However, it is time consuming for large-scale graphs. Thus, Sakuraba et al. (2016a, b) propose simple and efficient heuristics described below, able to address the problem in real cases.

A relevant result observed in the experiments with the mathematical model is that the allocation of WT in the first time period is determinant to obtain good quality solutions in terms of accessibility to the population. Using this information, the authors in Sakuraba et al. (2016a) propose ranking heuristics which work as follows. Initially, blocked edges are classified to repair in a priority order. The first ranking heuristic (H1) basically classifies edges according to the gain on the objective function used in the mathematical model. The second ranking heuristic (H2) classifies blocked edges according to the number of times they appear in shortest paths to destinations. Once the ranking is done, both heuristics allocate available WT on-the-fly to repair edges (routes) in the order they appear on the classification. This is done without violation of the constraints (e.g. number of WT, route limitations, etc.). In Sakuraba et al. (2016b), more sophisticated heuristics have been proposed, named Lexicographic Classification Heuristic (LCH). LCH uses several criteria to choose edges to be repaired such as time required to repair, the reduction on the shortest paths to destinations and the size of population at destinations. The allocation of WT is done by time period, ensuring constraints are satisfied. LCH performs better than H1 and H2. Moreover, LCH results are close enough to the optimal solutions achieved by CPLEX (i.e. up to 2.7% from optimal solution values) using simulated instances.

The choice of doing simple, but efficient heuristics in Sakuraba et al. (2016a, b) and not metaheuristics is justified by the connection with practice. In fact, operators are constantly receiving radio messages informing them about unexpected events, for example, an apparently intact building finally collapses, earthquake aftershocks frequently occur (especially in the first days), equipment like bulldozers fails, the trucks to evacuate the ruins can be late, a dumping site may become saturated, etc. Thus, several simulations need to be done to answer the many "what if?". In conclusion, metaheuristics and other methods can also be developed, providing that they will not consume much time, which is crucial in this context.

In summary, several points have been overcome in studies Sakuraba et al. (2016a, b) such as a model closer to the ground situation, efficient heuristics able to run in a real context, systematic production of inputs and outputs maps (see section "Systematic Data Treatment for Network Accessibility"), and validation by disaster operators for this kind of problem. Moreover, several interesting problems for further research have emerged during this collaboration.

Trends and Opportunities

Several interesting decision problems that can be solved by means of OR/MS strategies, appear on road accessibility and city reconstruction. Figure 18.4 illustrates a simple classification covering some of these problems, and in particular some problems with lack of methods, mathematical models, etc. The problems are separated according to time scale since this has a major impact on the choice of models and methods to solve them, on the objectives to be targeted, among other aspects. For instance, in an emergency, relevant information for a decision-maker is how quickly one can access population areas and identifying which paths can actually be used according to the situation on the ground (population migration,

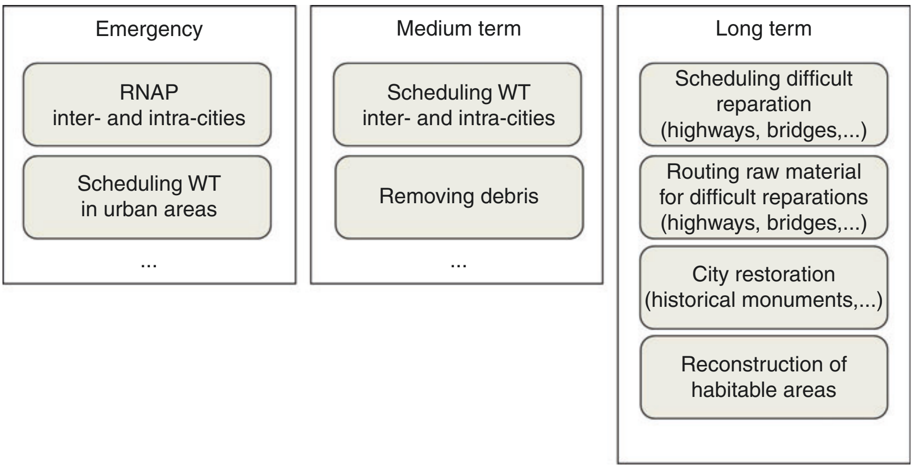

Fig. 18.4 A classification of problems to clean and reconstruct cities after a major earthquake

congestion, blocked roads, etc). For this purpose, RNAP can produce an answer efficiently, providing the data is available. Scheduling emergency WT can also be done for critical tasks like security. A building which is threatening to collapse may have to be secured, and in some cases early demolition may have to be anticipated. In the emergency phase, the important thing to keep in mind is that there is no time for long resolution methods, and that the operators on the ground are essential and, in some cases, more appropriate to get good decisions. In spite of that, maps with decision information such as the ones shown in section "Systematic Data Treatment for Network Accessibility", see Figs. 18.5 and 18.6, can be a very useful support.

In the medium term (covering the frontier between the emergency and the weeks after an earthquake), several combinatorial optimization problems can be properly treated with a global gain on the overall operations. One example is the intra-city WSP presented in this survey. For other problems, such as removing debris, there is clearly a lack of studies. In an emergency, debris is sometimes just pushed to one side of a street. On the contrary, in the medium term, they are removed to specific areas. Debris comes from the road network but also from buildings. Dealing with this situation relies on a vehicle routing problem (VRP) with some interesting characteristics such as multi-trips. This problem can be integrated into WSP in some cases, whenever the responsible for such operations are handled by a co-ordinate team. Otherwise, gains from integrating WSP into the corresponding VRP model in a unique optimization model can be lost in practice due to the lack of coordination between the involved teams. Removing debris of monuments and historical zones is a different problem since each piece needs to be classified and numbered. This allows the puzzle to be put back together in the reconstruction phase.

The reconstruction of a city after a major earthquake can require months/years, and depends on the city: towns with a long history will try to restore their monuments and buildings, while other cities will focus on reconstruction or may seize the opportunity to improve their urban areas. Combinatorial optimization problems are found in this phase for the road network accessibility and reconstruction. For the former, the problems require major and difficult civil engineering work as the routes are completely broken (e.g. Fig. 18.1). The scheduling and the transportation of raw material are examples of problems. In terms of highways and infrastructure reconstruction, there are works in the scientific literature as mentioned in section "Network Accessibility After Earthquakes". For the latter, it can be an opportunity to reorganize urban areas better and also to construct resilient buildings able to resist earthquakes.

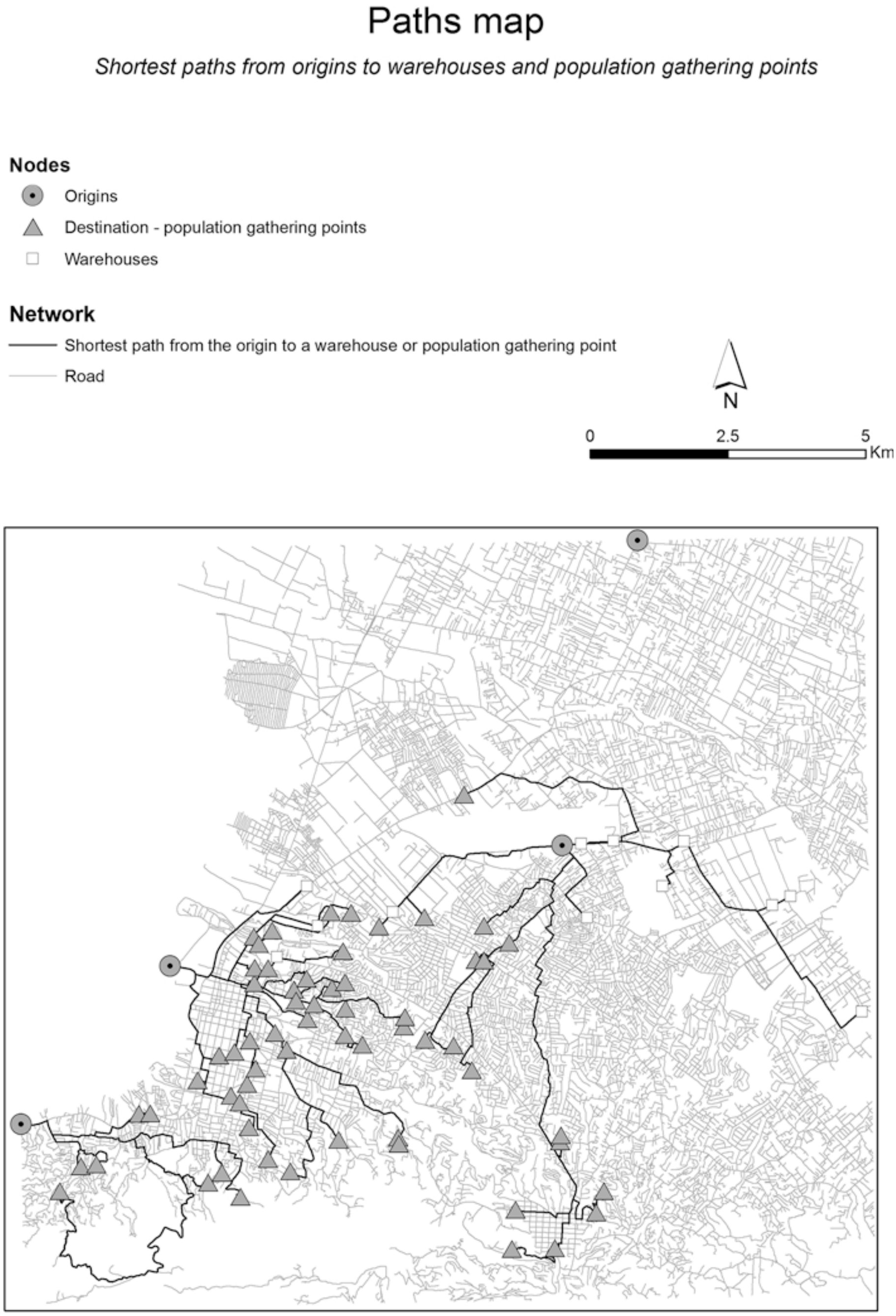

Fig. 18.5 Example of maps with a RNAP solution for Port-au-Prince, Haiti

Fig. 18.6 Example of map with a gradient determining the accessibility of the overall urban network for Port-au-Prince, Haiti

Systematic Data Treatment for Network Accessibility

Many studies in the literature have tested methods using realistic instances, that is, only a part of the data is real. The data and parameters required to solve just-in-time decision problems is still a challenge that was partially overcome in OLIC project. In fact, full-scale test was done in 2015 with the quakes that struck Nepal. Data from several sources was combined: satellites images, real time information from social networks, Geographical Information Systems (GIS), etc. An interesting and prospective study by Bono and Gutiérrez (2011) applies similar ideas to data treatment to handle road network accessibility.

The road network, including the type of routes (primary, secondary and tertiary) was recovered from GIS and database as Google earth and Openstreetmap for RNAP and WSP. Then additional information was added to edges and nodes of the final graph. The blockage levels were computed by the volume of debris and added as a parameters of edges, while the population estimation are attached to the nodes. Relevant information such as hubs, depots, points where spontaneous population gatherings happened, was distinguished from other nodes in the graph. Dimensioning the human and material resources has been done for Port-au-Prince based on past information. The evolution of the network accessibility is then updated according to the dynamics on the ground based on satellites images treated in the ICSMD.

Figs. 18.5 and 18.6 are examples of maps with added decision information produced in OLIC project. Fig. 18.5 illustrates a RNAP solution for Port-au-Prince some hours after the quake in 2010, where the gray circles, the gray triangles and the squares represent respectively the origins (Port, Airport and relevant road entry points), points where spontaneous population gatherings happened, and the depots of supplies. The RNAP solution is given and shows the best paths to arrive at the target gathering points of population. Fig. 18.6 provides an estimation in meters on the accessibility to regions in the city by means of a gradient. The smaller the black circles are, the faster the access (paths from origins to destinations) to the corresponding region is.

Several experts working on disaster operations from different organizations have analysed the maps produce in OLIC project. The feedback from them is that they expect OR/MS methods to remain decision-support information, rather than a tool to replace human decisions. Moreover, it is important to make clear the criteria used to set up solutions. Thus they can choose from the various possible solutions, the ones which seem the most relevant to the context and the so many subjective appreciations.

Concluding Remarks

Post-disaster operations are a very rich topic, both in terms of theoretical and practical issues. In this context, there are many opportunities to apply OR/MS strategies to improve operations on the ground in case of major catastrophes: providing data is available and the decision-making operators trust the solutions generated by the OR/MS methods. Some initiatives have contributed to overcoming these obstacles such as OLIC project, and consortia like the ICSMD.

Road accessibility and reconstruction problems after major earthquakes are crucial for a return to normal life. In this context, an overview of the available literature for road accessibility problems has been done in this chapter. Moreover, two problems, the RNAP and WSP, have been described, together with methods and main results. RNAP and WSP are the initial problems faced on road accessibility and provide a base for studies on this subject.

Data remains a critical factor for producing solutions in the initial response phase of a disaster. Although difficult, it is not an impossible task due to technological advances and available computational tools (GIS, collaborative platform as Openstreetmap, etc). Considerable efforts based on relevant information from satellite images have been made in the past 15 years, which it is now possible to exploit. Other technologies such as sensor networks, drones, etc. can also support information gathered in the field. In any case, parameters required to run methods for decision problems can already be used in the time scale of a disaster.

Finally, a picture of trends and opportunities involving road network accessibility and reconstruction in the emergency, medium term and long term has also been developed. It is easy to see that there is still room for further research on the development of mathematical models and methods for such problems. In particular, it is relevant to investigate how to connect existing OR/MS methods for solving real-life problems. In this context, sometimes less is more and the goal is to provide good, just-in-time solutions using scalable and efficient methods.

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