International Journal of Transportation
Vol.2, No.3 (2014), pp.17-32
http://dx.doi.org/10.14257/ijt.2014.2.3.02

Transportation Network Post-Disaster Planning and Management: A Review
Part II: Decision-Making and Planning of Post-Disaster Operations

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Abstract

This is the second part of a two-part survey investigating transportation network post-disaster planning and management. The first part focused on efforts and models for the estimation and assessment of post-disaster network performance (PDNP). This paper addresses the problem of decision-making and planning of post-disaster network operations (Post-Disaster Network Operations Planning – PDNOP). The paper reviews existing work in the field of post-disaster network planning, as realized by the deployment of different operational actions for improving service provision by a surviving network. Three distinct types of operations are considered: evacuation, network design and emergency traffic management. The survey highlights important aspects of PDNOP, offers a detailed discussion on the strategies and parameters found in the literature and indicates potential future research directions.

Keywords: *transportation network post-disaster planning, network operations, evacuation, emergency traffic management, traffic routing, lane-based strategies, demand regulation*

1. Introduction

In cases of disasters, transportation networks act as vital lifelines as they provide physical access to communities and support evacuation, emergency response and emergency logistics operations. However, the surviving network's ability to fulfill its role and satisfy the generated needs in the aftermath of a disaster is dependent on (a) its post-disaster performance and (b) actions undertaken to sustain and improve its operations. The estimation of network performance (PDNP) was the subject of the first part of this review. Existing work was classified with respect to specific characteristics, such as the type of analysis considered and the performance measures used. In this second part of the review, focus is given on post-disaster network planning and management and particularly on the deployment of strategies for managing and operating a surviving transportation network. Such operations are part of the overall post-disaster network management process and the respective decisions are based on post-disaster network performance (PDNP) estimation, a topic already discussed in the first part of the review. This paper offers a systematic classification of operations' planning work; based on the review outcomes, literature gaps and potential future research areas are identified. It should be stressed that a distinction is made between the actual management of the network and to emergency response, logistics and humanitarian operations supported by the network. Indeed, the former addresses the problem of improving service provision to

ISSN: 2287-7940 IJT

all kinds of network users, for example, establishing emergency and evacuation routes, managing traffic and restoring transportation infrastructures. As for the latter, it refers to actual emergency response activities which use the surviving transportation network for their own purposes; while these are also part of an overall disaster planning process, they do not focus on the operation of the transportation network but they rather exploit its services. As such, from a conceptual perspective, they are excluded from this review.

The remainder of this paper is organized as follows. Section 2 analyzes the problem of decision-making and planning of post-disaster network operations (post-disaster network operations planning – PDNOP). Existing work is classified with respect to specific problem characteristics including management tactics followed, the types of operations and actions employed and the analysis tools used. Special emphasis is put on the management strategies, parameters and constraints participating in each problem formulation. Section 3 discusses findings and Section 4 indicates paths for future research.

2. Post-disaster Network Operations Planning (PDNOP)

The first part of this review presented approaches for conceptualizing, modeling and estimating PDNP; these set the basis for decision-making and planning of post-disaster operations. The term *operations* refers to the nature of activities taking place for managing a surviving transportation network. In this context, this review has identified three distinct types of operations: (a) emergency traffic management, (b) network design and (c) evacuation. Each operation comprises a set of *strategies*, which are to be decided upon and deployed for addressing the impacts of a disaster, as part of the *operations*. Furthermore, planning as a process entails specific actions at that level, which would be applied by decision makers in order to produce the desired outcome. A total number of seventy four papers are reviewed. The classification made is based on the framework of Figure 1 and includes the following major categories:

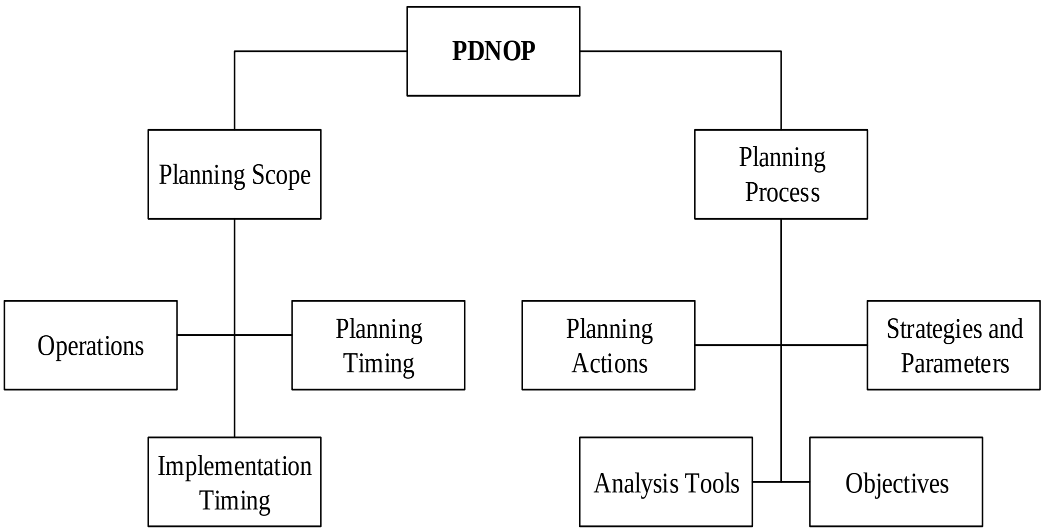

Figure 1. PDNOP Classification Framework

- *Planning Scope:* This category refers (a) to the actual timing of implementing post-disaster operations, (b) to the timing of PDNP and (c) to generalized planning operations identified in the literature.
- *Planning Process:* In this category, focus is given on the actual decision making process, including (a) planning actions, (b) identified strategies and parameters, (c) planning objectives, and (d) analysis methods followed.

Based on this framework, papers are classified according to their planning scope (operations, timing) and process (planning actions, operational strategies, analysis tools, objectives and parameters).

2.1. Planning Scope

This category focuses on the operations level (type of operations considered) and the timing for implementation and planning of post-disaster network operations. It sets general planning requirements for dealing with post-disaster network operations.

2.1.1. Type of Operations: Three generalized operation types are identified in the literature: *emergency traffic management*, *network design* and *evacuation*. Among them, evacuation has been widely investigated by researchers; relevant operations involve the movement of people out of harm zones (evacuation zones) to safety zones. As [5] explain, evacuation is not an "orderly" process, as uncertainties apply to the incident itself as well as demand, supply and other (operational) issues. Despite these uncertainties, a typical characteristic of all evacuation studies is the consideration of single direction of movement; traffic is only heading outbound, moving away from evacuation zones. However, most evacuation studies do not reserve any capacity for some inbound traffic by emergency vehicles.

Emergency traffic management on the contrary, considers bi-directional movement of traffic. According to [32], emergency traffic management aims at maintaining surviving network functionality to the best possible extent and attempts to maximize network performance by considering the needs generated by all network users, including evacuation and emergency response. However, despite its importance, studies focusing on traffic management in disaster situations are scarce: the review revealed only four relevant papers [67, 23, 22, 32].

Network design has also been widely studied in the literature, generally as an underlying planning sub-problem in cases of both evacuation and traffic management studies. This can be attributed to the fact that papers exploiting link change actions (for example lane reversal or contraflow actions) as parts of emergency management strategies, yield changes to the connectivity settings of the network and as such require the design of a new network.

2.1.2. Implementation Timing: When planning and managing a surviving transportation network, the following phases should considered; these may be summarized as: (a) pre-disaster, (b) during-the-disaster and (c) after-the-disaster phases. In fact, the duration of the disaster can be considered negligible in relation to the time extending prior and after it and thus the during-the-disaster phase is often incorporated in the post-disaster phase. For instance, [32] distinguish the post-disaster phase into three sub-phases considering the different characteristics they exhibit. We argue that the value of this time fragmentation lies in the fact that during the different phases, the required operations may differ. Table 1 provides examples of disaster-related operations for each phase.

Table 1. Example Operations with Respect to Implementation Phases

	Pre-disaster Phase	During-the-disaster Phase	Post-disaster Phase
Infrastructure inspection	✓		✓
Network performance enhancement interventions	✓		✓
Critical infrastructure location (hospitals, fire-stations, shelters, warehouses etc)	✓		
Network design	✓		
Districting	✓		
Emergency response (EVs location / allocation / dispatching / routing)		✓	
Evacuation		✓	
Emergency logistics		✓	✓
Traffic management & control		✓	✓
Social media – Information technology		✓	✓
Network re-design		✓	✓

Four operational stages may be distinguished in disaster management; mitigation, preparedness, response and recovery [24]. *Mitigation* refers to the actions taken in order to prevent a disaster strike or decrease its impact. *Preparedness* includes necessary activities for community preparation in the case of a disaster to ensure its best possible response. It is obvious that both these stages refer to the pre-disaster phase. *Response*, on the other hand, refers to the operations undertaken during and shortly after a disaster strike in order to aid humans and protect the environment and the economy. Finally, *recovery* comprises all the activities aiming at community restoration to its normal function and belongs to the post-disaster phase. [81] use a different terminology to describe the above stages in an evacuation context; these are: planning and preparedness, readiness, activation, operations and return-to-readiness. *Planning and preparedness* corresponds to the mitigation and preparedness stages described above. During the *readiness phase*, stakeholders decide upon the need for evacuation and the way to implementation based on the information available. No-notice incidents, as much time is the case with disasters, entail a limited in time or a total lack of a readiness phase, raising thus the importance and the value of *preplanning* operations. The *Activation phase* includes all the necessary, preliminary steps for evacuation while the *operations phase* includes the evacuation itself and the re-entry of evacuees. Finally, during the *return-to-readiness phase*, lessons learned from this incident are exploited for tackling future incidents. Following the framework of [24], a classification of disaster management operations is undertaken using the three phases (pre-, during, and post-disaster phase) and the corresponding operation stages.

2.1.3. Planning Timing: Apart from the actual deployment timing of operations, their related planning activities may also be classified with respect to timing. Indeed, planning may precede the timing of a disaster (pro-active planning) or take place following a disaster (re-active planning). In general, *planning* in disaster management refers to modeling a transportation network, its operations and performance under increased transportation demand and possibly limited capacity [4]. [81] use the term *preplanning* to refer to the planning of activities before an actual incident occurs, as opposed to *advance planning* which takes place based on a priori known, incident-specific information and usually uses the results from the preplanning phase. The role of preplanning becomes more important in the case of no-notice events, such as earthquakes, where it may make up for the limited or non-existing readiness phase (when incident-related information becomes available) and advance planning [81]. Preplanning may refer to any of the phases mentioned above, namely the pre-, during and post-disaster phase, and has the form of a strategy plan for addressing the various aspects of disaster management. Preplanning is in essence the proactive part of disaster management whereas advance planning actually belongs to the reactive part since it is refers to the post-disaster phase. In this context, advance planning is related to *real-time management* which according to [47] can better achieve the maximization of network performance and the minimization of losses in the case of emergencies. This is attributed to the dynamic and stochastic nature of disasters and flow modeling complexity, which cannot be captured in the planning process [47, 14]. Both [47] and [14] agree that real-time management must be "traffic adaptive", meaning the readjustment of the actions implemented based on the prevailing traffic conditions. This is actually the concept of real-time management; as real-time traffic flow data becomes available, it is used as feedback to effectively update dynamically formulated efficient management plans.

Despite being promising, real-time disaster management is still unexplored: a look at Table 2 can reveal a research gap in the field as there are only four published studies attempting an integrated approach by combining planning with real-time management ([19], [14, 27, 47]. [5] and [70] also introduce the concept of real-time management proposing theoretical frameworks for hurricane evacuation. Finally, as [81] note, an important part of the disaster management process is the formulation of contingency plans. These plans should take into account alternative disaster scenarios and the respective changes in network component states and other parameters influencing network operations. In this way, the best possible plan can be devised for each scenario and used in a real time management concept.

2.2. Planning Process

This category refers to details in PDNOP; elements reviewed include those actions typically undertaken for PDNOP, analysis tools employed and particular objectives, strategies and parameters used for planning.

2.2.1. Planning Actions: Action types refer to the specific tasks undertaken as part of general operations. Most papers deal with *traffic routing*, a term that describes the determination of efficient emergency routes. Route identification may differ according to objectives pursued, restrictions imposed and parameters considered. For example, the optimal route between an O-D pair may differ when distance or travel time minimization is considered or when a respective time threshold is assumed. Routes also vary for different types of operations. For instance, emergency response and evacuation will inevitably have routes of opposing direction or even conflicting ones when sharing the same road segments. In addition, post-disaster route establishment depends upon component failures and needs to dynamically alter according to traffic-related feedback [15]. In evacuation operations, the objective of timely and effective transportation of citizens to safety requires satisfactory utilization of the transportation network, which can be achieved by either increasing capacity or spreading demand [62].

[1] point out that in cases of simultaneous evacuation, the sudden surge of traffic may quickly overwhelm the network and lead to congestion phenomena with devastating consequences. On the other hand, a staged evacuation, *i.e.*, an evacuation plan where evacuees are advised on when to evacuate and which route to choose, can better exploit the network's potential and prevent congestion [1]. Such action, where a time component is also involved in the routing process, is denoted as *traffic routing and scheduling*.

Special attention is paid to *evacuation demand estimation,* as trip generation is the first and most crucial step of the four-step transportation planning model, yet the least explored [73]. This may be attributed to the lack of available data, concerns about their accuracy and doubts regarding the applicability of a certain model to a region or disaster type other than the one it was made for [42]. Finally, other actions include the formulation of traffic signal timing plans (*e.g.*, [10]), the estimation of the traffic safety hazards (*e.g.*, [69]) *etc*.

2.2.2. Analysis Tools: As reported by [74], evacuation operations (but also any disaster management operations involving routing) can be modeled using either an optimization-based or a simulation-based approach. An *optimization-based* model typically uses network flow and routing algorithms in order to achieve certain objectives like network clearance time minimization [74]. *Network flow problems* and *traffic assignment* belong to this category and can be formulated in a *dynamic* or a *static* manner. The differentiating parameter between the latter two types of problems is the introduction of time in problem formulation. According to [38], a problem is dynamic in nature if at least one of its variables is “a function of time”. In this context, static traffic assignment uses steady-state traffic information [14] whereas dynamic traffic assignment (DTA) works with time-varying flows aiming at depicting traffic conditions as realistically as possible [58]. In addition, as [38] notes, dynamic network flow problems comprise a wider range of problem formulations than their static counterparts; for example, the quickest flow problem belongs to the dynamic problems whereas the maximum flow problem may be formulated as both static and dynamic. [51] considers static network flow problems to be appropriate for long-term transportation planning while their dynamic counterparts are suitable for real-time operations. He stresses though that in dynamic models, the requirements for a satisfactory representation of flow propagation can yield problems in solution tractability, as an analytical solution is generally impossible [51]. In this context, optimization-based models have been applied to post-disaster, large-scale networks for planning different operations ([6, 49, 9, 68]).

Simulation is an alternative tool for modeling and analyzing PDNOP; as noted by [65], simulation “involves replication of real world transportation system operations through mathematical and logical representations of interactions of the entities present in the system”. Simulation is generally case specific and offers improved analysis capabilities [33]. Depending on the level of detail used for PDNOP, researchers have exploited microscopic simulation (*e.g.*, [69, 41, 34]), *macroscopic* models (*e.g.*, [59, 28]) and *mesoscopic* models (*e.g.*, [53]). Simulation is generally time-consuming compared optimization-based approaches and therefore not appropriate for large-scale networks [74]. [74] also argue that simulation plays more a “what if” experiment role whereas optimization approaches work on a “what to do” basis. This means that simulation could be used to check the adequacy of an already formulated emergency plan whereas optimization would be used for the development of such a plan.

Table 2. Classification of Transportation Network Post-Disaster Management Studies

			Network flow problem		Traffic assignment		Traffic Simulation			Combination & Other
			Dynamic	Static	Dynamic	Static	Micro	Meso	Macro	
Planning	Evacuation	Traffic routing	[68], [56], [52]	[9], [60], [79], [76]	[49], [78], [46], [77], [12], [63]	[40]	[41], [72], [65], [34], [59], [64]	[53]	[43]	[20], [80], [66], [44], [48], [18]
Planning	Evacuation	Traffic routing & scheduling	[6], [45], [54]	[50]	[15]					[55], [37], [1], [62], [13]
Planning	Evacuation	Demand estimation								[25], [42], [73]
Planning	Evacuation	Other		[17]			[69]			[30], [61], [11], [39], [16], [2]
Planning	Network design	Traffic routing	[3], [7], [35], [36]	[31]	[75], [4], [71]				[57], [28]	[21], [26], [74]
Planning	Network design	Traffic routing & scheduling	[8]							
Planning	Network design	Other					[10]			
Planning	Emergency traffic management	Traffic routing	[32], [67]		[23], [22]					
Planning & real-time management	Evacuation	Traffic routing	[19]							[14], [47]
Planning & real-time management	Evacuation	Other								[5], [70]
Planning & real-time management	Network design	Traffic routing					[27]			

2.2.3. Strategies and Parameters: The nature of PDNOP leads to different problem-specific formulations; these depend on the particular operations of the problem under consideration, along with parameters considered and assumptions made. Table 3 provides a summary of major parameters encountered when setting up PDNOP-related problems; these are classified into two categories: (a) network management strategies and (b) other parameters. *Network management strategies* refer to the actions considered to be the problem's decision variables. These may include roadway capacity changes (lane reversal / contraflow, use of shoulder lanes), travel time improvement and traffic safety promotion (uninterrupted flow, merging conflicts limitation, formulation of traffic signal timing plans), population protection (evacuation priority) and demand regulation.

Contraflow refers to shifting direction of traffic to all opposing lanes in an effort to increase capacity. This strategy has been successfully implemented in the US [29]. Lane reversal on the other hand, reserves some lanes for inbound traffic, consisting of emergency vehicles and rescue crews but also civilians. However, the distinction is not always clear and the terms are also used interchangeably. The use of shoulder lanes is another way to add capacity and facilitate traffic by improving capacity along a direction. Crossing conflicts prohibition (uninterrupted flow) and merging conflicts limitation is another category of management strategies. Turning intersections into uninterrupted flow facilities implies the absence of stopping delays at them and can thus reduce total evacuation time [31]. It also limits the number of alternative evacuation routes, providing a more easily comprehensible and manageable evacuation network [31]. Limitation of merging conflicts can further reduce intersection delays while both strategies decrease the potential intersection accident points [18].

The formulation of traffic signal timing plans for controlling the flow appears to be of interest in the literature. A study purely focusing on the subject is that of [10]. Other approaches include that of [44] adopting a pre-defined, long signal cycle for the evacuation routes, [27] making use of pre-timed and actuated signals, [72] combining signal timing with access control and [12] accounting also for the parking rate in their signal timing model. The provision of evacuation priority aims at minimizing human losses. It may take two forms: the prioritization of whole regions on the basis of the risk level they exhibit (*e.g.*, [45, 19]), while the second one focuses more on the flow, giving priority to the evacuation routes or the heaviest loaded road sections (*e.g.*, [72, 64]). Thus, in the first case priority is given to the population most-at-risk while in the second case to the highest demand. Finally, demand regulation can be interpreted as the percentage of vehicles allowed to enter a particular area or a highway (denoted as area- and linear-regulation respectively).

Other parameters include several problem characteristics, which can be summarized as follows:

1. The most common constraint encountered in the literature is that of link capacity. In some evacuation problems, shelter capacities and maximum distances are taken as additional constraints
2. Evacuation studies do not use direct network loading but instead assume different departure rates across time and apply gradual network loads: evacuees are considered to enter the network according to pre-defined, S-shaped loading (response) curves [66].
3. Behavioral characteristics refer to perceptions of evacuees during an impending disaster or in a post-disaster environment ([40, 61, 46]).
4. Route choice is another parameter that remains unexplored in the literature. As [11] note, most papers investigate the development of optimal routing strategies but fail to account for the individuals' perception of risk and how this interferes with their routing decisions. Studies considering a different option than optimal routing include those by [21, 61, 11, 14] and [67].

Other aspects of the problem's environment such as the failure or the degradation of the network's links (e.g. [67]) or the consideration of background traffic are also included in this category. Infrastructure failure, in particular, is critical in transportation network performance since it may render some initially designed routes inoperable. In addition, background traffic, i.e. traffic already on the network at the time of an evacuation order, must be appropriately modeled in order to accurately depict the initial network conditions [34].

2.2.4. Objectives: PDNOP usually aims at minimizing of some performance measure including *network clearance time*, i.e. the time corresponding to the last vehicle / evacuee leaving the impact area ([6], [35], [4]), *total evacuation time* ([8], [75], [56]) or otherwise referenced as *total network travel time*, i.e. the sum of all vehicles' travel times ([46], [47], [15]), *total travel distance* ([66], [18]), *evacuees' total threat exposure* as indicated by exposure duration and severity ([55]), *total cost* expressed in monetary values ([30]) or in a more generic form ([3], [20]) and so on. Other studies pursue the maximization of the *total* *number of evacuees* reaching safety [45, 80, 68, 50]) or explore the *effect of different route-choice behaviors* on performance measures such as the average evacuee travel time ([21]) or the total network travel time ([14]).

Table 3. Strategies and Parameters Involved in the Problem of Post-Disaster Network Management

		[3]	[6]	[21]	[25]	[26]	[30]	[31]	[40]	[42]	[49]	[50]	[53]	[55]	[61]	[69]	[8]	[9]	[11]	[17]	[20]	[45]	[7]	[19]	[37]	[43]	[54]	[68]	[75]	[80]	[41]	[56]	[74]	[78]	[35]	[46]	[60]	[66]
Network management strategies	Lane reversal	*		*				*									*						*						*				*		*			
	Un-interrupted flow							*			*						*	*					*				*		*				*		*			
	Merging conflicts limitation							*									*																					
	Shoulder lanes use																																					
	Evacuation priority		*											*								*		*	*													
	Signal timings formulation																																					
	Demand regulation																							*														
Other parameters	Gradual network loading		*	*			*						*								*				*									*		*		*
	Behavioral patterns								*						*	*																				*		
	Route-choice mechanism			*											*				*																			
	Link failure / Incidents															*							*											*				
	Background traffic			*					*																*									*				
Constraints	Shelter capacity			*		*	*					*								*						*		*									*	
	Distance from shelter																			*																	*	

Table 3. Strategies and Parameters Involved in the Problem of Post-disaster Network Management (Continued)

		[77]	[79]	[1]	[4]	[12]	[14]	[27]	[72]	[10]	[15]	[47]	[63]	[65]	[39]	[44]	[48]	[62]	[67]	[71]	[23]	[36]	[13]	[34]	[52]	[73]	[18]	[22]	[57]	[5]	[16]	[32]	[2]	[28]	[59]	[76]	[70]	[64]
Network management strategies	Lane reversal				*			*		*										*		*							*					*				
	Un-interrupted flow																										*											
	Merging conflicts limitation																										*											
	Shoulder lanes use																*																	*				
	Evacuation priority								*																													*
	Signal timings formulation					*		*	*	*		*				*																						
	Demand regulation													*					*		*							*				*						
Other parameters	Gradual network loading	*			*	*				*		*				*				*									*				*	*				
	Behavioral patterns																																*					*
	Route-choice mechanism						*												*																			*
	Link failure / Incidents									*							*		*		*			*			*	*				*						
	Background traffic																	*						*														
Constraints	Shelter capacity								*							*	*	*																		*		
	Distance from shelter																																					

3. Discussion

The review revealed over seventy papers on PDNOP; these were broadly categorized according to the disaster management phase they refer to and the management tactics they follow, as well as their conceptual approach for addressing PDNOP. In this context, most papers belong to the domain of static operations' planning while only four attempt to integrate real-time management with planning. Indeed, there is a clear trend towards proactive planning as opposed to reactive management, despite arguments on the inability to capture the dynamic nature of disasters and their impacts.

There were three types of operations considered: emergency traffic management, network design and evacuation. Evacuation studies are the largest part of the bibliography followed by the network design studies. Emergency traffic management, on the other hand, is investigated in only four papers, indicating a large research gap in the field. Evacuation is generally treated as a single-direction movement whereas emergency traffic management is more generic. Since its scope is to maintain the functionality of the network in the post-disaster phase, it accounts for the needs generated by all network users, by allowing for bi-directional traffic movements. Network design is addressed by studies that change the connectivity settings of the network.

In each type of operation, the most usual type of planning action investigated is traffic routing, i.e. the specification of a route with respect to some objective measures. It has been observed though, that when evacuation demand is left unmanaged, the sudden surge of traffic may quickly overwhelm the network leading to congestion phenomena. Therefore, in recent years there is a gradual shift towards advising people on both when to evacuate and which route to use, the action denoted as traffic routing and scheduling. The final type of action refers to the estimation of demand in an emergency situation. Demand estimation is certainly less explored than routing actions and its influencing parameters are not captured by this study. The tools used for the analysis purposes can be classified as either optimization-based or simulation-based. Most studies show a preference towards optimization models, including network flow models and traffic assignment. This may be attributed to the fact that optimization models can be used for the development of optimal routing plans even for large-scale networks. Simulation on the other hand is generally more appropriate to check the adequacy of an already formulated plan.

No matter the analysis tools and the specific type of operation considered, all papers considering routing can potentially use different combinations of the strategies, parameters and constraints listed in Table 3 in their problem formulation. Lane reversal, uninterrupted flow and limitation of merging conflicts are the most usually encountered strategies in the evacuation operations literature where capacity augmentation and travel time reduction arise as key issues. Demand regulation on the other hand, is mainly used in emergency traffic management and is defined as the percentage of traffic allowed to enter a region or a road segment at some point in time (area and linear regulation respectively). Other important issues in the disaster management problem concern human behavior during disasters. These problem parameters are generally unexplored due to the lack of data that would enable the understanding of the psychological and other mechanisms involved. In addition, actual network loading is also in need for further investigation. In particular, many researchers decline instantaneous network loading and turn to the use of S-shaped loading curves for gradual network loading. Finally, in optimization-based problems, the objectives used are analogous to the performance measures described in the first part of the survey. Since most studies focus on evacuation operations, the most common objectives include the minimization of network clearance time and total network travel time as well as the maximization of evacuees reaching safety.

4. Conclusions and Future Steps

Efficient decision-making and planning of post-disaster network operations is essential for achieving improved serviceability and functionality of the surviving network. This paper investigated network management in terms of operations and actions employed for the provision of services to network users in a post-disaster environment. In total, seventy four papers were reviewed. Studies were classified according to different planning and conceptual aspects. Post-disaster operations management offers ground for future research. For instance, while literature mostly deals with evacuation operations, there are only four studies focusing on emergency traffic management. Indeed, the consideration of bi-directional traffic raises the problem complexity since it is necessary to find an optimal balance for the satisfaction of contradicting user needs. User behavior has been scarcely investigated; most researchers assume that travelers have perfect knowledge of traffic conditions, they are willing to comply with orders on evacuation routes and timing and make rational trip decisions. Indeed, in a chaotic situation, behaviors deviating from normal may arise: drivers may exhibit changes to their behavior due to panic, try to communicate with their relatives and leave the impact area together, decide to use familiar routes despite not being recommended and so on. Research on such behavioral patterns is still at an early stage but it is expected to be more vivid in the future due to its clear impact on post-disaster routing decisions and network effectiveness. Another aspect that remains unexplored is that of modeling decisions on traveling under post-disaster conditions (implying different trip generation characteristics in a post-disaster environment). In this context, it is acknowledged that modern IT technologies and the social media could play an increasingly important role, influencing the population's post-disaster trip decisions.

Acknowledgements

This work is part of research co-financed by the European Union (European Social Fund – ESF) and the Hellenic National Funds, through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program "Aristeia I".

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