Guiding Framework for Traffic Management in Disasters

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Abstract

In this paper, the author attempts to highlight a number of disaster related traffic management goals and objectives in a form of a guiding framework. The development of such a framework will serve as an effective decision making tool for a dynamic process of planning, design and implementation of traffic management in disasters. Such a framework will provide a decision support to traffic managers on how to operate a transport system in disasters. This framework would also help in the investigation and development of possible traffic management measures and strategies, which can be directly implemented during disasters.

1. INTRODUCTION

Traffic Management is aimed at influencing traffic and transport with a range of measures to bring traffic demand and transport supply in an optimized balance. Disaster management means a continuous, integrated, multi-sector and multi-disciplinary process of planning and implementation of measures aimed at prevention and mitigation, preparedness, response and recovery in disasters.

Every natural system or engineered system serves at least a purpose within the systems’ hierarchies. In some cases, this purpose can be fairly self-contained and focused on only a small role in the hierarchy. In other cases, a particular system could be an important component in the effective functioning of the other systems. A transport system can be considered for both cases. One perspective of transport system is focused on the transport functions, which aims at providing the mobility and accessibility to the people. Another perspective of transport system is the performance of transport system for supporting other systems or system functions for example security, environment or economy functions including disaster management functions during disasters. Thus, transport system supports the activities of other systems or system functions as well as being itself a source of negative impacts on environment, safety and economy. Transport during disasters can be viewed both as a requirement of the people to sustain mobility and also to fulfill other support functions of disaster management (Fig. 1). The national response plan of the United States Federal Emergency Management Agency (FEMA) identified 14 disaster support

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functions. These functions represent specific response activities that are common to disasters. Logistics and transport is an important function requirement for other disaster support functions.

A fundamental component necessary for achieving sustainable development of urban cities is the existence of a clear and shared vision of cities, which provides both the framework and the impetus for the future development of the cities. Over the last few years, there is a growing concern about the safety of the cities in cases of disasters. The increasing number and intensity of natural and manmade disasters are constantly making difficult for planning, policy and design models to respond effectively. This fact provides serious challenges to stakeholders of disaster management. The issues of disaster management also pose challenges to sustainability of local approaches of urban planning, design and implementation for disasters. Thus, the traffic management in disasters needs to adopt sustainable solutions in addressing issues of transport accessibility and mobility, traffic safety and security, transport economy and impacts of transport on local environment.

The focus of this paper is to present a framework for traffic management operations in disasters. This is achieved by the formulation of well defined vision and mission statements including goals and objectives of traffic management (Fig. 2).
2. TRAFFIC MANAGEMENT FRAMEWORK

2.1 Vision Statement
The statement of vision contributes to the development of a thematic framework by articulating the concept and content of urban sustainability. Urban sustainability considers equity within and between generations in the use of resources, integration of social, economic and environmental requirements, and public participation and acceptance.

One of the original descriptions of sustainable development is credited to the Brundtland Commission: ‘Sustainable development is defined as a development process that provides the needs of the present generation without distracting the needs of future generations’ (World Commission on Environment and Development, 1987). World Commission on Environment and Development
(WCED) was created to address growing concern “about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development.” The process of disaster management promotes the sustainability issues by ensuring the needs of the society in terms of food, housing and medical care among several other societal functions. A vision is generally presented as interaction between the desired states of prosperity, environmental quality and social quality of life. This interaction is mostly observed and presented as a strongest link to sustainable development.

In the city planning context, vision portrays the future imagination of a city. The vision statement of traffic management for most cities supports the city vision concept of enhancing the quality of life and economic prosperity by connecting people, communities, employment, goods, services and amenities. The context of enhancing the quality of life is too general and it encompasses several themes including the city preparedness for disasters. The literature indicates that the vision statements of cities are expressed using different themes to describe the desired end states. Such themes are capable city, ideal city, learning city, livable city, planned city, resilient city, safe city, youth-friendly city, bicycle city, inclusive city etc. (Axworthy, Fallick et al, 2006). These visions are generally the key visionary themes in most of the city planning and development. Vision sometimes encompasses a lot of themes together and yet depicts the specific characteristic or quality of a city. Some planners expressed the vision of a livable city to include more specific visionary themes of the city e.g. motorcycle dependent cities (Khuat, 2006 and Timmer and Seymour, 2006).

The vision of a safe city is generally addressed in many key visionary themes like resilient city, capable city, livable city, crime-free city, disaster-resistant cities, disaster-resilient cities; etc. Traffic management supports disaster management by implementing proactive and reactive strategies in disasters. Thus, traffic management supports the vision of disaster resistant cities by providing the efficient traffic and transport operations to minimize the impact of disaster on the community. One such formulated vision for traffic management is: ‘ensure the safe, quick and efficient movement of people and goods on the transport system, irrespective of any disaster’ (Minhans, 2004).

The vision can consist of general statements of the desired end states or can be as specific as a well-defined scenario. Vision may represent the majority decision of a community, organization or nation’s programs. Many authors use the terms ‘secure city’, ‘safe city’ and ‘resilient city’ in their vision statements to provide similar development concepts for the cities prone to disaster. In
either case, such visions indicate the need to develop city’s resistance to the impact of disasters.

2.2 Mission Statement
The mission statements describe the purpose of a vision for being in existence or in other words the vision supports a certain mission. Also, the mission statement describes the limits or boundaries within which the vision is to be achieved. The formulated mission statements of traffic management in disasters are:

- To preserve the societal values;
- To preserve the natural and built-up environment; and
- To preserve the economics of the disaster-affected region.

The mission statements of disaster traffic management indicate the use of acceptable or compatible traffic measures. The mission statements of traffic management address sustainability issues of society, environment and the economy. In the absence of standardized goals of disaster traffic management, the mission statements must address at least three major areas of consideration; one area of consideration deals in the preservation of societal values. The other areas focus on conservation of natural resources by reducing the environmental impacts and improvement of economic reliability and economic system affected by transport.

2.3 Goals of Traffic Management in Disasters
In order to realize a vision, one must think about mechanisms and procedures available to attain the vision. The goals, objectives, strategies and performance targets are the instruments in achieving a desired vision. Most city authorities initially develop citywide goals from the inputs provided by the Community and the State’s obligation to the community. The vision and mission statements of disaster traffic management thus provide the orientation for the achievement of traffic management goals and objectives.

The traffic management goals and objectives are derived from the shortfalls, issues and problems due to disaster impacts. State of development in transport is deeply influenced by social, technological, economic, environmental and political development in disaster-affected or prone areas also provide inputs in formulation of goals and objectives of traffic management. Literature review on transport in disasters has consistently indicated the need for transport mobility, transport accessibility, transport safety, transport security, traffic education, transport economy and transport environment, as the main requirements of traffic management. In some publications, traffic management goals are formulated,
statements indicating an urgent need to increase the efficiency, integration and productivity of transport. The efficiency, integration and productivity goals of traffic management are well considered in this framework for achieving the mobility and safety goals of traffic management in disasters. In most literature on disaster traffic management, the economy and environment goals are inadequately addressed. This is primarily due to certain degree of trade-offs with the other objectives such as mobility, accessibility, safety, etc. The proposed operational framework in this paper adequately addresses the relevance of both the environment and economy goals of traffic management in disasters. This framework proposes four basic goals of disaster traffic management, which are:

- To ensure the quick accessibility and adequate mobility of transport in disasters;
- To ensure the safety and security of transport in disasters;
- To ensure the economy of the transport system operations in disasters; and
- To reduce the impact of transport on environment in disasters.

This formulation of the goals and objectives served as a guide for the development of traffic management measures.

2.4 Objectives of Traffic Management in Disasters

Descendent TM objectives are specific and measurable statements, which relate to the fulfillment of the set TM goals. The descendent objectives within each goal of traffic management are described in the next sections. The descendent objectives are fully interrelated and do not imply relevance or priority over other objectives. Also, possible conflicts of one objective on other objectives were considered while formulation.

Transport Accessibility and Mobility Objectives of Traffic Management: Accessibility is a term which has been defined and measured in a variety of ways and is often used in the field of transport in various urban, regional and rural contexts. Accessibility is the ability to reach the desired goods, services, activities and destinations. Access is the ultimate goal of transport and transport systems may be evaluated on their ability to provide access. Mobility is the ability to travel and is described with the physical movement, including travel by walking, cycling, public transit, taxi, private automobile and other motorized modes. The mobility refers to the ability to travel and travel is a term used in transport context as the mobility fulfilled. Mobility includes the provision of transport services based on places and time of demand, information required for the trips and the ease and costs involved in using a transport facility. Mobility differs from accessibility in the fact that one can even have mobility
and yet no accessibility for example availability of adequate transport modes or affordability of transport does not mean accessible destinations. The increase of the travel opportunities does not necessarily allow a greater ability to reach destinations beyond the short term because increasing mobility is sometimes associated with deteriorating accessibility (Litman, 2006 and Simpson, 2005).

The impact of disaster is clearly observable on transport as inadequate mobility due to increased congestion, reduced traffic volume, decreased capacity, decreased speed and disintegrated transport modes. The physical damage to the roads following the disaster impacts the accessibility by reducing the capacity and reducing the number of routes to reach destinations including disaster-affected areas. Thus, enhancing mobility means maximizing the transport and travel opportunities whereas improving accessibility is focused on increasing the number of accesses or routes. This objective considers both the accessibility and mobility aspects with respect to traffic management.

**Objective 1: To Provide the Equitable Transport Service**

This objective ensures provision of transport services to:

- Mobility-disadvantaged people;
- Inaccessible and low accessibility areas and the equitable use; and
- Transport modes.

This objective ensures the equity of transport service regardless of physical disabilities, educational disabilities and personal disabilities of different people. Transport equity means the equitableness with which the transport benefits and transport costs are distributed. Equitable transport services need to treat everyone equally, regardless of socio-economic factors as ethnicity, gender or income level among others. This objective deals with vertical equity, which is concerned with the distribution of transport benefits and costs among individuals and groups who differ in abilities and needs due to socio-economic reasons. The measures of the equity objective are oriented towards compensating the inequities of transport so disadvantaged groups do not bear an excessive share of the external costs of traffic pollution, traffic accident risk and transport costs. The experiences from Hurricane Katrina indicated the failure to provide the evacuation for some people such as old people, people with disabilities, African-American people, etc. (Litman, 2006). Hurricane Katrina formed over the Bahamas on Aug 23, 2005 is considered costliest hurricane and one of the five deadliest. The most severe loss of life occurred in New Orleans, Louisiana, which flooded as the levee system catastrophically failed. Thus, the equity objective enhances the mobility by providing equal priorities and opportunities with respect to a particular transport service. The transport equity objective
also deals with the equitable use of transport modes, except for necessary traffic restrictions on individual motorized transport and freight transport at different routes, destinations and times. The equitable transport objective is measurable by indicators such as fare structure, tax burdens due to subsidy, transport service quality, travel opportunities, etc; and are expressed in per capita, per kilometer, per person-kilometer, per trip, per peak period and per tax subsidy. The social costs borne by the transport organizations per person-kilometer and subsidy per person-kilometer are common criteria to measure the equity of transport.

Objective 2: To Increase the Number of Transport Route Options
This objective focuses on increasing the transport route options in order to increase the accessibility to important destinations. The measures of this objective include the development of well connected, safe and efficient pedestrian, bicycle and motorized transport routes for respective transport destinations. This includes the use of secondary transport network to increase the possibilities of reaching the accessibility-threatened disaster area. Although, the fulfillment of this objective requires infrastructure measures, yet this objective is typically confined to the establishment of new routes or to extension of existing routes and the re-routing of flexible transport routes only. The establishment and development of missing links are proposed for the fulfillment of this objective. The criteria to measure this objective are the number of routes or links available per required destination, per travel time, per travel distance and per transport mode.

Objective 3: To Increase the Number of Transport Mode Options
This objective intends to enhance mobility by providing multiple transport modes to create a flexible, demand-responsive transport system in disasters. The objective of increasing transport mode option includes measures which increase the transport fleet of one or more transport modes. In the formulation of this objective, the possibility to fulfill the increased traffic demand in disasters is considered. Thus, the given objective is measured as number of mode choices per trip for different trip purposes.

Objective 4: To Increase the Capacity of the Transport System
Under this objective the increase of the capacity of transport system in disasters is considered. This objective involves the improvement of both transport infrastructure and transport operation in order to enhance the total transport capacity. This includes increasing the infrastructure capacities of roads and ancillary infrastructure such as parking, garages, bus stations and other road transport infrastructure. This objective also includes increasing the operation capacities of a particular transport service by increasing the frequency of
operations, time of operations etc. Under this objective, the increase of infrastructure capacities is limited to existing infrastructure possibilities only. New development in transport is normally not considered due to lengthy time for construction unless temporary construction. Non-availability of funds is also deterrent to a new transport development. In cases where full infrastructure capacity cannot be achieved, this objective will aim to retain the basic infrastructure. This objective could be measured through transport infrastructure capacities e.g. road length, traffic volume, number of serviceable bus stations, holding capacities of parking area, metro stations, bus stations etc. and traffic operation capacities (passenger and freight capacities) e.g. frequency of traffic operations, start and end time of traffic operations etc.

Transport Safety and Security Objectives of Traffic Management: Disasters affect road safety through increased accident risk both in terms of accident frequency and accident severity. Many articles have documented safety issues in disasters, weather events and special events (Cambridge Systematics, 2003; NCHRP, 2003; USDOT, 2003; Litman, 2006). The occurrence of traffic accidents is highly related but not limited to prevalence of poor weather and road conditions during or after disaster and prevalence of secondary disasters following a primary disaster e.g. power grid failures, aftershocks of earthquakes, fires, oil spill etc.

The following section describes the formulated safety and security objectives of disaster traffic management.

Objective 1: To Reduce the Response Time in Traffic and Other Accidents

The objective of reducing the response time is formulated to expedite medical response in traffic-related accidents or in other accidents. This objective is evaluated based on both the response time to reach the accident location and to reach the hospital or safe location. This objective is applicable for all traffic and non-traffic accidents such as fire, explosions among other accidents which may or may not be traffic related. The fulfillment of this objective may involve complimentary measures that improve traffic flow and hence contribute to the response time reduction. The traffic incident management is aimed at reducing the each component of response time viz. detection time, information time, verification time, registration time, decision time and travel time to the accident site. Thus, the measures belonging to this objective are intended to reduce either one or multiple components of response time to minimum.

Objective 2: To Reduce the Number of Traffic Accidents

The objective of accident reduction is aimed at reducing the total number of traffic accidents involving transport modes used in disaster response and recovery
operations. The objective considers all possible factors that cause traffic accidents and propose measures for improving either one or many contributing factors. The factors that cause traffic accidents are:

- Road condition;
- Vehicle condition;
- Driver condition;
- Road users; and
- Environmental conditions.

The accident reduction objective is clearly measured by estimating the reduction in number of accidents, which is expressed as accidents per vehicle population, accidents per unit population and accident density measured as accidents per kilometer of road length.

**Objective 3: To Reduce the Severity of Traffic Accidents**

The objective of accident severity reduction is aimed at reducing the fatality of accidents and thus increasing the chances of the survival of accident victims. The fatality of traffic accidents is also dependent on factors related to driving conditions e.g. speed differentials and heterogeneous traffic flow among other factors given in the earlier objective. The measures belonging to this objective also propose the prior protection of crucial transport properties from damages. This objective is measured by estimating the reduction in fatality of accidents e.g. number of deaths per unit vehicle population, fatalities rates per year, total costs of property damage per accidents, etc.

**Transport Economy Objectives of Traffic Management:** Most disasters cause major damages to transport system components (roads, vehicles and road users) affecting the traffic operations, which lead to significant economic disruption (Chang and Nojima, 1999). On the other hand, disaster response and recovery phases of disaster management demand for additional cost-intensive traffic operations. Thus, the consideration of sustaining the economy of traffic operations during disasters is of paramount importance as disaster traffic operations are cost-intensive and severely impact the overall economy of the disaster affected region. Therefore, traffic management in cases of disasters need to support the economic goals of disaster management by optimizing the traffic operations during disasters. Traffic management implementation bears the potential to reduce the total transport costs (including fixed and variable costs) and to maximize the benefits of the traffic operations. Fixed costs such as depreciation, insurance, and registration do not vary with vehicle use. Variable costs such as fuel, travel time and accident risk are
proportional to vehicle use (Victoria Transport Institute, Online TDM encyclopedia.
This section describes the formulated economic objectives of disaster traffic
management which are:

**Objective 1: To Reduce the Total Transport Costs**
This objective focuses on reducing the total transport costs. The total transport
costs include the cost of the initial facility, cost of maintenance of facility and
the road user costs. The road user cost is composed of the following:

- Vehicle operating costs;
- Travel time costs; and
- Accident costs.

Although this objective is intended to reduce the total transport costs, the
emphasis is required on providing traffic management measures which reduce
the road user costs, especially the vehicle operating costs (both the fixed and
variable costs). This objective considers administrative and organization type
of measures to reduce the fixed costs e.g. charges related to insurance,
maintenance, finance, licensing and registration. In addition, the measures of
the objective are aimed to reduce the variable cost (fuel and oil costs, fuel
taxes, tolls and parking costs, cost of automobile parts and other related costs)
involving promotion of non fuel-based transport (non-motorized), overall
reduction of trips and shift of traffic to public transport among other measures.
This objective is measured generally as operating cost per unit capacity. They
are also expressed as total cost per person-kilometer for passenger transport,
total cost per ton-kilometer for freight transport, total costs per activity, etc.

**Objective 2: To Maximize the Economic Efficiency of Existing Transport
Systems**
This objective focuses on increasing the offered benefits of the existing transport
systems. The objective of maximizing economic efficiency is applicable for
different transport modes e.g. public transport, individual motorized transport
etc. The economic efficiency benefits of a particular transport system are
vehicle operating costs savings, congestion reduction savings, parking costs
savings, road infrastructure maintenance costs savings, accident costs savings,
fuel consumption savings etc. The economic efficiency is generally measured in
cost savings, travel time savings, accident costs savings. Efficiency considers
the time, cost and effort required to produce a certain benefit. This objective
ensures the maximum passenger or freight transport within the minimum
time, costs and capacity limits. Time is one criterion to measure this objective,
which is expressed in average time taken per passenger-kilometer or ton-
kilometer. Others are costs/person-km, costs/ton-km, etc.
Transport Environment Objectives of Traffic Management: It is observed that the ambient environmental quality of disaster-affected area is drastically reduced. The urban transport system includes both the passenger transport and commercial transport. Based on the US Department of Energy estimates, of the total energy used by the transport sector, approximately 65 percent is consumed by gasoline-powered vehicles, primarily individual motorized transport. The commercial transport consists of mostly diesel-powered vehicles (trains, merchant ships, heavy trucks etc.) which consumes about 20 percent and air transport consumes most of the remaining 15 percent (US Department of Energy, ‘Annual Energy Outlook’ (February 2006)). The environmental impacts of transport during disasters are often ignored or are inadequately considered by traffic management. One apparent reason is the relatively higher importance given by transport departments to the other traffic management goals viz. accessibility and mobility, safety etc. Often there are trade-offs between the goals related to transport accessibility and transport safety versus transport economy and transport environment. The following sections explain the formulated environmental objectives of disaster traffic management which are:

Objective 1: To Minimize the Consumption of Energy Resources in Transport

This objective of minimizing consumption of energy resources is mainly aimed to reduce consumption of fossil fuel (mainly gasoline) for traffic operations during disasters. The fulfillment of this objective will not only serve the environmental goal but also the economy goal of disaster-related traffic management. The objective is measurable in many ways as per capita consumption of energy, energy consumption per person-kilometer, energy consumption per vehicle kilometer.

Objective 2: To Reduce the Air Pollution Related to Transport

It is observed that traffic generating activities of disaster management produce negative impacts on the environment by increasing the air pollution levels. This objective of minimizing the air pollution is mainly aimed at reducing the air pollution due to traffic and transport operations. The objective proposes measures which reduce the total amount and rates of traffic-related emissions of polluting transport modes. The air pollution due to traffic operation can be decreased by improving traffic flow conditions in cases of bad weather, accidents, incidents etc. The air pollution due to transport modes can be decreased by improving vehicle conditions and strict prohibition on the operation of unmaintained transport vehicles. This objective is measureable in concentration of pollutants at different times, volume of pollutant (e.g. CO2 emissions) released per person-kilometer, tone-kilometer, vehicle-kilometer, etc.
Objective 3: To Reduce the Noise Pollution Related to Transport

This objective of reducing the noise pollution is aimed at reducing the noise levels and thus supporting the quality of life in disaster-affected areas. Disaster response and recovery activities generate a lot of traffic both individual motorized traffic and freight traffic. Also, such activities are medium to long term activities due to large scale reconstruction and redevelopment after the disaster occurrence. The establishment of work-zones within the disaster-affected areas can generate levels of noise that can severely affect human health. Traffic calming measures are required to be strictly implemented while such activity in work-zones and residential areas. This objective is measurable by noise levels in db (A) at different locations where noise is produced. db (A) is a “A -weighting filter” used to calibrate the frequency to that of a human ear. Sound pressure level on the dBA scale is easy to measure and is therefore widely used. The intensity of the sound and length of exposure of sound are important determining factors to set noise emission standards.

The standards permit the highest noise levels in industrial areas and are more stringent in residential areas. However, it should be also considered that TM measures in disaster response phase are implemented under life-threatening situations demanding special organizational and political framework with major exceptions of jurisdictions and limits of authorities and standards. While different standards may apply in terms of noise levels in disasters, traffic calming measures must still be further investigated and implemented.

3. CONCLUSIONS

A clear framework of traffic operations is necessary towards supporting the disaster management functions. Without the formulated goals and objectives especially for disaster situations, traffic managers operate a transport system under a generic set of goals and objectives, which may be counterproductive. This paper has provided the traffic management framework of operations in disasters by identifying the clear vision and mission statements. The main focus of the framework is to identify the goals and objectives of traffic management viz. accessibility and mobility, safety and security, economy and environment. This paper also has provided overview of probable approaches of traffic management in achieving the traffic management objectives. The indicators to measure the fulfillment of objectives are also briefly indicated. The developed framework of traffic management goals and objectives can be used as an effective assessment tool to assess the traffic management measures for their effectiveness in fulfilling traffic management goals and objectives.