# Evaluation of Multi-Modal Transportation Strategies for Emergency Evacuations

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## ABSTRACT

Understanding transportation systems and travel needs is an important consideration in planning for mass evacuations during natural disasters or terrorist attacks. However, current transportation planning processes rarely consider hazards and associated requirements to respond in emergency situations. The objective of this study is to examine the role of transportation planning in evacuations, understand current practices and transportation needs through a case study evaluation, and formulate a list of transportation strategies. The Halifax peninsula, Nova Scotia is selected as the case study. The paper reviews evacuation plans and policy documents to understand the current practices and guidelines. In addition, it investigates demographic profile, travel characteristics and transportation network of the region. During the working hours of the weekday, the population doubles in the Halifax peninsula. Preliminary estimation suggests that it will take approximately twelve hours to evacuate the entire population through five major exit routes of the peninsula. Several strategies may be applied to improve efficiency during evacuation, including promoting multi-modal alternatives, transportation network alterations and public outreach. Particularly, transit should play an important role in mass evacuation during extreme events.

## 1. INTRODUCTION

Understanding transportation systems and travel needs is an important consideration in planning for mass evacuations during natural disasters or terrorist attacks. Evacuations involve rapid physical movement of people from an area to protect them from natural or anthropogenic hazards. By their nature, evacuations are risky, and poor coordination may increase accidents, leading to injury or death. Since mass evacuations are disruptive, expensive and often politically sensitive, they are only chosen when other measures are insufficient to ensure public safety (Wolshon, 2005a). Current transportation planning processes place little emphasis on preparedness for extreme events, and readiness to support suddenly increased travel demand of all types including non-auto dependent population is limited (Litman, 2006). Given the increasing threats (both natural and man-made) and several recent shortfalls in timely and efficient evacuation, strengthening transportation systems for extreme events in advance is required to ensure public safety during emergency evacuations.

The extent of an evacuation depends on the type of hazards. Hazards may be unintentional, stemming from natural occurrences and human error, or may be intentional, stemming from acts of terrorism. A recent study indicated that natural disasters increased threefold and man-made disasters climbed tenfold from 1975 to 2006 (El-Sioufi, 2009). As hazards continue to increase, further emphasis needs to be placed on evacuation planning and preparedness for potential mass evacuation. Since transportation is a key component of mass evacuation, it is important to investigate transportation systems and formulate appropriate strategies to support multi-modal needs for safe evacuation. This paper attempts to examine the role of transportation planning in evacuations, understand current practices and transportation needs for evacuations through a case study, and formulate a list of multi-modal transportation strategies.

The rest of the paper is organized as follows: Section 2 briefly discusses major issues related to the mass evacuation. Section 3 presents a case study evaluation, including policy context, demographic and travel characteristics of the study area, and transportation network analysis. Section 4 outlines transportation strategies to be considered for mass evacuation. Finally, Section 5 concludes the paper with future research directions.

## 2. MASS EVACUATION ISSUES

Mass evacuations often involve complex tradeoffs among various factors, including timing (i.e. when to evacuate) and the perimeter of the evacuation area. Announcing an evacuation earlier will give citizens more time; however, the hazard may subside, negating the need to evacuate. For instance, government officials may be informed about a hurricane few days in advance but do not voice concern immediately as storm conditions may change. Particularly, a false alarm may create a ‘cry wolf’ scenario in which people may be less likely to evacuate in the future (Alsnih and Stopher, 2004). In addition, the costs of an evacuation can exceed one million dollars per mile of coastline from direct and indirect (e.g. losses from commerce, tourism, etc.) sources (Wolshon, 2005a).

A mass evacuation is extremely complex process that requires coordination of many players. No single agency/individual (e.g. the Fire Chief, Emergency Medical Services or the Police Chief) have absolute authority in an emergency situation (Tse, 2005). Elected officials at the municipal level are responsible for disaster response, including the decision to evacuate (Kuban et al., 2001). Several federal, provincial and municipal officials are also involved but capacity varies across municipalities to deal with evacuations. Although representatives of many agencies are involved in preparation and management of mass evacuation, the role of transportation planners are often limited (Lahmer et al. 2006). However, Renne et al. (2008) argues

> "*Disaster response analysis should be considered a normal part of transportation planning. For example, local and regional transportation plans, and transit agency plans, should include analysis of disaster vulnerabilities (the types of disasters that could occur in the service area), risks to the transportation system, emergency response transportation requirements, and how emergency transportation activities will be coordinated.*" (Renne et al., 2008, p.79)

During a large-scale evacuation, many critical issues may affect the evacuation process, particularly transportation arrangements. The municipality needs to assess residents' behaviour (e.g. decision to evacuate, response time, etc.), socio-economic characteristics (e.g. proportion of auto ownership, number of seniors in the area, etc.), travel characteristics (commuter mode choices, trip chains, etc.) to accommodate appropriate modes of transportation and routes assigned for rapid evacuation. Individuals' responses are influenced by their attitudes and personal valuation of the warning (i.e. the level of the perceived threats), effectiveness of information dissemination for evacuation, and the personal/family context in which the warning is received. Figure 1 shows different factors that have significant impacts on individuals' behaviour during an evacuation, which in turn influence travel patterns and needs. Unless properly coordinated, a mass evacuation may result in various scenarios: spontaneous evacuation (i.e. evacuate an area that does not require an evacuation), failure to use allocated transport routes, or failure to respond to an evacuation warning in a timely fashion (Alsnih and Stopher, 2004). Individuals that spontaneously evacuate may create unnecessary congestion, adversely impacting the ability of people in the danger zone to evacuate. On the other hand, individuals may choose undesignated routes or alternative places as their possible destinations (for example, relatives' home). Anticipating residents' travel paths and destinations is important to avoid situations where evacuees could be trapped in the bottlenecks of the transportation network. It may limit emergency personnel's ability to gain access to the people in need or provide sufficient transportation support for safe and quick evacuation. In other circumstances, some individuals may fail to respond to the evacuation because of personal limitations. For example, lower income people may not evacuate because they lack access to a vehicle, and are fearful of conditions in emergency shelters (Litman, 2006).

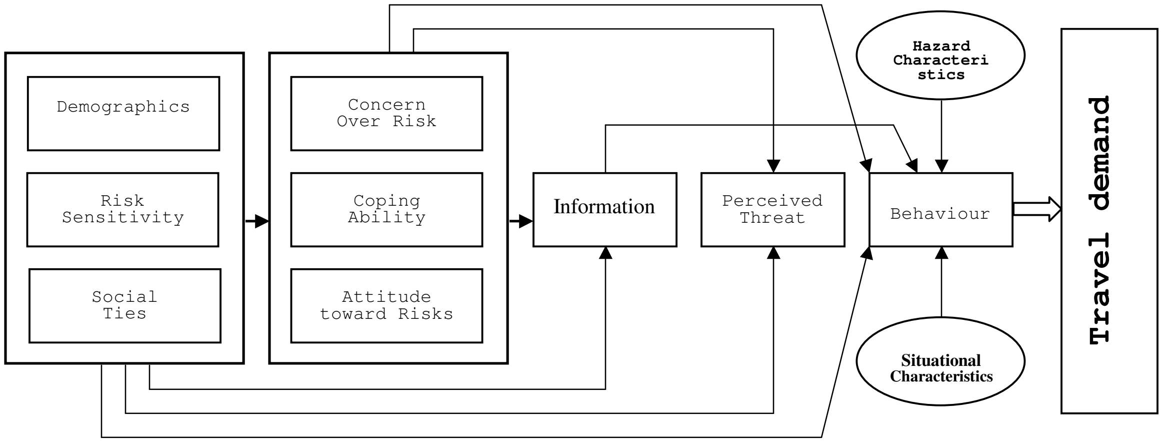


**Figure 1.** Individuals' behaviours to an evacuation depend on multiple factors (adapted from Alsnih and Stopher, 2004).

Predicting individual behavioural responses to an evacuation is often difficult. However, examining the characteristics of the population and travel behaviour may provide important insights into how they will behave during an evacuation, which is essential information in formulating effective strategies. It will also help to focus on travel requirements for particular groups of people (for example, transit-dependent population).

Numerous studies identify the risks and burdens of evacuating transit dependent individuals (see Laws, 2006; Litman, 2006; Renne et al., 2008; Wolshon, 2005a). However, most emergency management plans rely on cars and auto-oriented evacuations, inadequately addressing the needs of a large portion of the population (Renne et al., 2008). Individuals who choose not to drive or lack access to a vehicle are referred to as the carless population (Hess and Gotham, 2007). Again, "special needs" people who are living in institutions require alternative arrangements (Law, 2006). But many cities do not have adequate supply of buses to move all low-mobility evacuees (Wolshon, 2005a). It is estimated that approximately 250,000 residents of New Orleans (not including tourists or "special needs" populations) had no means of private transportation, which significantly exceeded the capacity of available bus fleet. Therefore, it is important to assess the needs of the carless population and provide specific guidelines in evacuation plans regarding how to match sudden demands during extreme events.

On the other hand, transportation network could be deficient to efficiently evacuate all residents in a short duration of time. Traditionally, transportation network design do not adequately address requirements for emergency situations (Law, 2006). However, recent failures in large-scale evacuations due to hurricanes in the United States underscores greater need to anticipate the necessary services for evacuees, including emergency traffic control devices, intelligent transportation system (ITS), etc. (Wolshon, 2007). Alternative detailed functional network design in advance may improve operational efficiency during mass evacuation.

Given the complexity of mass evacuation procedures, numerous issues exist, which require attention. This paper focuses only on transportation issues with particular emphasis on the multi-modal system and road network design. The main purpose of this study is to investigate current practices and transportation needs for mass evacuation. This will be accomplished by examining Halifax peninsula in Nova Scotia as a case study. Specific objectives of this study includes:

- To examine current practices and guidelines outlined in the official evacuation plans and policy documents
- To investigate transportation systems and assess travel needs for mass evacuation at the Halifax peninsula, Nova Scotia
- To develop a list of transportation strategies for an effective and efficient evacuation

## 3 Case study evaluation

### 3.1 Policy and Player Context

In Canada, multiple levels of government (federal, provincial and municipal) are involved in emergency management. When the threat is a national concern, the federal government takes charge of the situation; however, the province is responsible for all matters of local or provincial nature. Local government are generally delegated the control of evacuations. In accordance to the federal *Emergency Management Act*, Nova Scotia's *Emergency Measures Act* and Halifax Regional Municipality's Emergency Evacuation Plan, each level of government is involved with emergency management to establish players and protocols.

At the federal level, legislation governing emergency management is the *Emergency Management Act.* The *Emergency Management Act* assigns the Minister of Public Safety with responsibility for Emergency Management leadership and coordination. However, all Ministers must identify the risks in their areas of responsibility. This includes: preparing emergency plans; implementing those plans; and conducting exercises related to those plans. In terms of transportation, Transport Canada prevents and responds to emergencies that disrupt the national or regional transportation systems or to incidents involving ports.

The *Nova Scotia Emergency Measures Act* sets the guidelines for managing emergencies and requires municipalities to develop emergency plans (Tse, 2005). At the provincial level, the Emergency Management Office (EMO) is responsible for providing coordinated responses to emergencies, in order to ensure the safety of Nova Scotians. EMO conducts many activities, including emergency management training, which is aimed at municipal, provincial and federal officials to ensure that they have the appropriate knowledge to handle an emergency. In Nova Scotia, the elected officials at the municipal level are responsible for responding to disasters within their jurisdiction (Kuban et al., 2001).

The Halifax Regional Municipality developed policy directly related to evacuations. The purpose of the Halifax Regional Municipality Emergency Evacuation Plan (referred to as the Plan hereafter) provides a framework that establishes the players and protocols for emergency evacuation. Section 2 of the Plan establishes the players in Halifax Regional Municipality. Various players that assist with evacuations includes the Metro Transit Services, Public Works and Transportation, Provincial Community Services, Canadian Red Cross society, Salvation Army, Fire Department and Police. The Public Works and Transportation Control Officer coordinates the traffic. This individual is responsible for traffic signage, barricades and other materials needed for the evacuation routes; maintenance of evacuation routes; and traffic system management (HRM, 2003).

Section 3 of the Plan establishes the protocol for deciding when to evacuate, and for creating the tactical plan. The decision to evacuate is at the discretion of elected officials and involves multiple steps. First, the municipality issues a preliminary warning for residents about the hazard. The municipality then conducts a threat and risk assessment to determine the consequences of an evacuation, as well creates an emergency response and best response scenarios to determine the mechanisms for an evacuation. This information assists the municipality with determining whether or not to conduct an evacuation. If the municipality choose to evacuate, they create a tactical plan that is specific to the situation. The tactical plan includes establishing the evacuation perimeter, number of evacuees, population characteristics, duration of the evacuation, communication requirements, evacuation routes, transportation requirements and traffic controls. (HRM, 2003).

Though the Plan establishes the players and protocols, it lacks sufficient details to implement an evacuation. The Plan was developed for all-hazards, which provides only general guidance for different types.[1] Halifax Regional Municipality mainly relies on private automobile, and stipulates that Metro Transit Services will provide transportation for the carless and ambulances for individuals that require assistance of medical staff and life-support equipments. The Plan does not establish connections between the needs of different population groups (e.g. transit-dependent or seniors) and the amount of public transit available (or the pick-up locations). On the other hand, the police services are designated for controlling traffic flows that may involve measures such as contraflow or reverse-laning (HRM, 2003). The plan does not include details regarding tools to implement these strategies (e.g. physical barricade/traffic signalling/ITS) or where these will be implemented. In addition, Halifax Regional Municipality has not established agreements with other municipalities to provide shelter or share public transit resources if required.

### 3.2 SITE CONTEXT

This study selects Halifax peninsula as case study for several reasons. First, this small land mass is densely populated compared to surrounding areas. Second, the peninsula is considered as the financial hub for the region and the Maritimes. Third, Individuals from the surrounding communities (e.g. Dartmouth, Bedford, Halifax County) travel to the peninsula each day to work, and increase the overall population during work hours. Last but not the least, most commuters use two bridge connections, which are vulnerable to extreme events (for example, hurricanes, which are not uncommon threats for the Atlantic Canada). The following subsections discuss demographic profiles, travel characteristics and transportation networks critical for evacuating the peninsula.

[1] According to Section 3.7.4.2, the Plan accompanies information regarding the evacuation route, sector hazard, special population, special circumstances and evacuee shelters

### *3.2.1 Demographic Profile*

In 2007, Halifax Regional Municipality's population was 372,858, of which 58,025 individuals (15% of the total population) lived in the peninsula (HRM, 2009). By 2021, it is forecasted that the population of Halifax Regional Municipality will reach to 406,804. Figure 2 shows projected population increase by age group for the region. Note that elderly population (age over 55 yrs) is growing faster compared to other age groups, which has implications on the planning for emergency evacuation. For instance, the municipality may require accessible transit system, and/or special arrangements to accommodate longer dwell time for senior citizens.

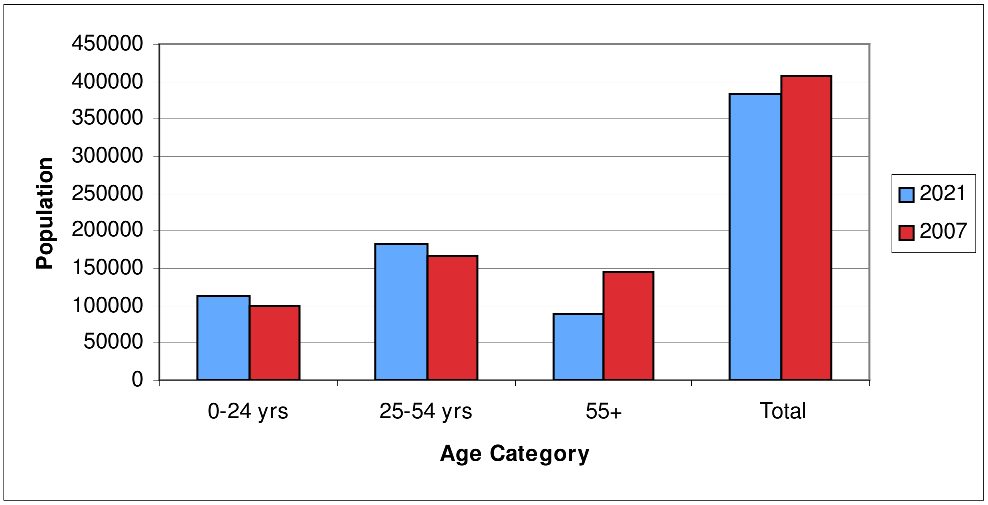


**Figure 2.** Projected population for Halifax Regional Municipality (HRM, 2009)

In addition, the population of the peninsula significantly varies depending on the time of the day. Total population almost doubles on the peninsula to approximately 105,700 individuals during the working hours of the weekday since people commute from surrounding areas for work and other purposes.

### *3.2.2 Travel Characteristics*

Exploration of travel patterns by trip purposes to and from the peninsula is limited due to the lack of household-based travel surveys in the Halifax Regional Municipality. According to the Statistics Canada, 53,000 people commute during the weekday to the peninsula from the surrounding areas. Among the residents of the peninsula (in total 58,025), the majority works within the peninsula (about 22,335) with only 5,325 commuting off the peninsula (Statistics Canada, 2009). As a result during the workday hours, the number of individuals on the Halifax peninsula is 105,700 individuals, of which approximately 75,335 individuals are present for work purposes. This can be summarized as follows:

- Home to Work Trips originated and destined within the Halifax Peninsula: 22,335
- Home to Work Trips originated outside but destined to the Halifax Peninsula: 53,000
- Home to work trips originated from the Peninsula and destined to other areas: 5,325

In terms of the mode split of the workers, the majority takes cars but 23.3% use alternative modes of travel (i.e. public transit, walking or cycling) for commuting (Statistics

Canada, 2008; see Figure 3). Based on annual roadside traffic counts (HRM, 2010), similar trend is observed for the AM and PM peak period (see Table 1).

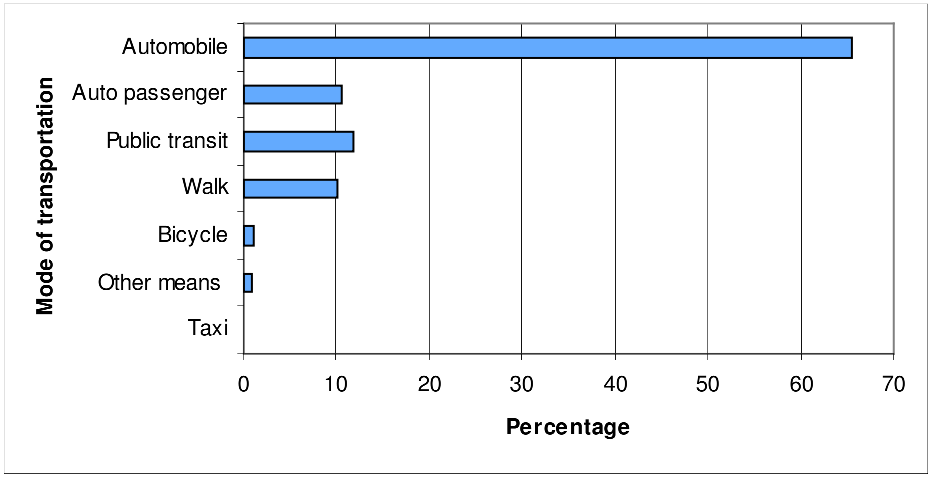


**Figure 3.** Modal share of commuters in Halifax Regional Municipality (Statistic Canada, 2008)

**Table 1.** Estimated mode-spilt of commuters in 2009 traveling to and from the Halifax Peninsula

| **Peninsula Commuters** | | **2-Hour Total** | **Driver** | | **Passenger** | | **Transit** | | **Bicycling** | | **Walking** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Average for 2009** | AM Peak | 43929 | 27884 | 63% | 6798 | 15% | 8729 | 20% | 173 | 0.4% | 346 | 0.8% |
| | PM Peak | 43633 | 26750 | 61% | 8307 | 19% | 7941 | 18% | 179 | 0.4% | 457 | 1.0% |

Again, according to the Statistics Canada vehicle ownership per capita in this region is approximately 0.5, which is very close to the national average. It reflects that approximately 29,000 of the residents of the peninsula and 186,000 residents in Halifax Regional Municipality own a car. This means that some people in this region may not have access to a car, and are entirely captive transit riders. Therefore, it is important to consider comprehensive and detailed evacuation plans for the transit-dependent population in this area.

## 3.3 TRANSPORT NETWORK

### *3.3.1 Critical exit points*

The Halifax peninsula has several routes that link to the major highways. The main evacuation routes off of the peninsula during a mass evacuation are the two bridges that link the peninsula to the sister city, Dartmouth (i.e. Macdonald Bridge and MacKay Bridge), and the land links through the Bedford Highway, Bicentennial Highway and Armdale Rotary (see Figure 4 and 5), which has the following network characteristics:

- *Macdonald Bridge:* 3 lane-bridge that is accessible from Barrington St. (4 lanes near the bridge) and North St. (2 lane), which have maximum speed limit of 50 km/hr;

- *MacKay Bridge:* 4 lane-bridge that is accessible from Barrington St. (2 lanes near the bridge) and Highway 2 (4 lanes) and the maximum speed is 70 km/h;
- *Bedford Highway* (or Highway 2)**:** Two lane highway with a maximum speed of 70 km/h, and is accessible from a number of streets (i.e. Barrington St., Robie St. and Connaught Ave.) that have maximum speed limit of 50 km/hr;
- *Bicentennial Highway* (or Highway 102)**:** Four lane highway but does not start outside of the peninsula boundary. The highway is accessible from Connaught Ave which is a four lane road with a maximum speed of 50 km/h; and
- *Armdale Rotary:* Leads to various roads (i.e. Herring Cove Rd., St. Margaret's Bay Rd. and Joseph Howe Drive). The highway is accessible from Chebucto Rd. (2 lane road) and Quinpool Rd. (4 lane road), which have maximum speed limit of 50 km/hr.

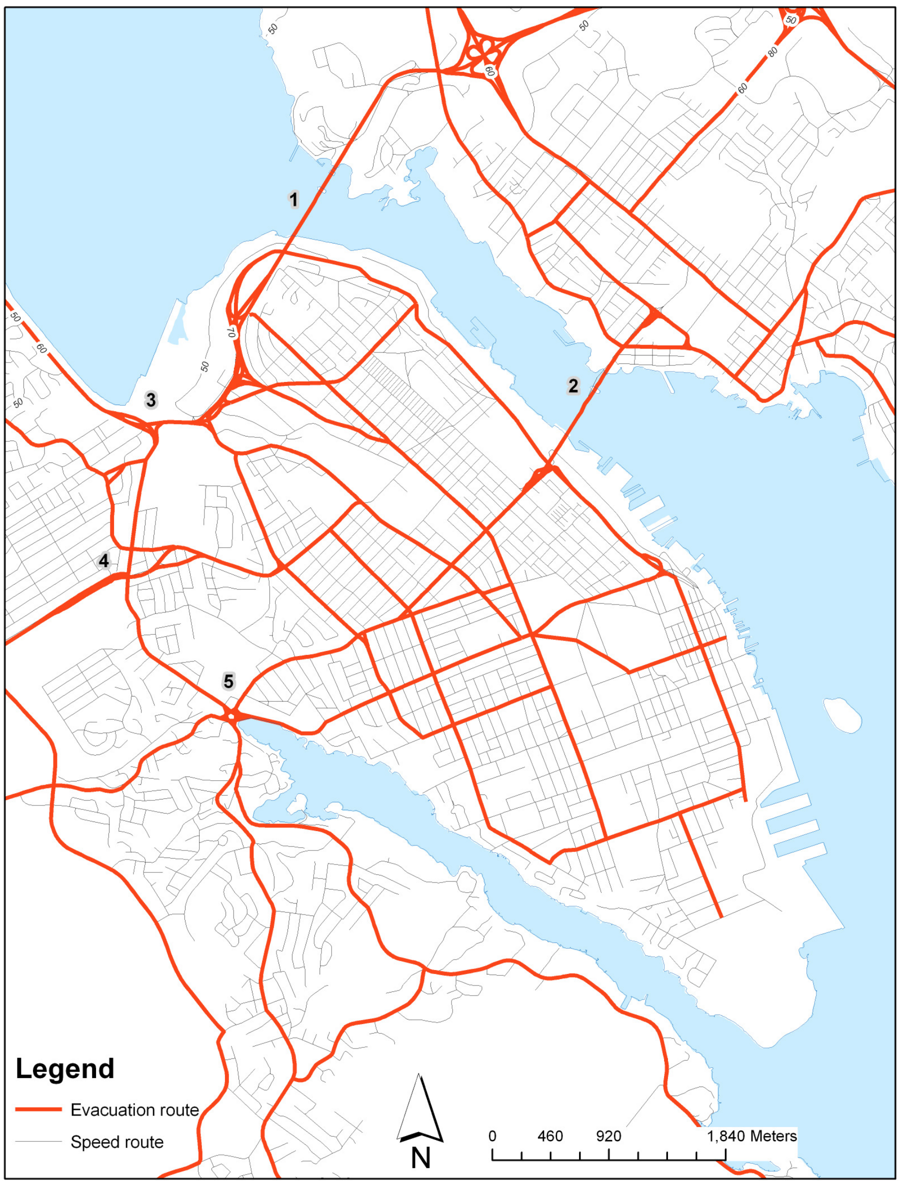


**Figure 4.** Potential evacuation routes off the Halifax peninsula

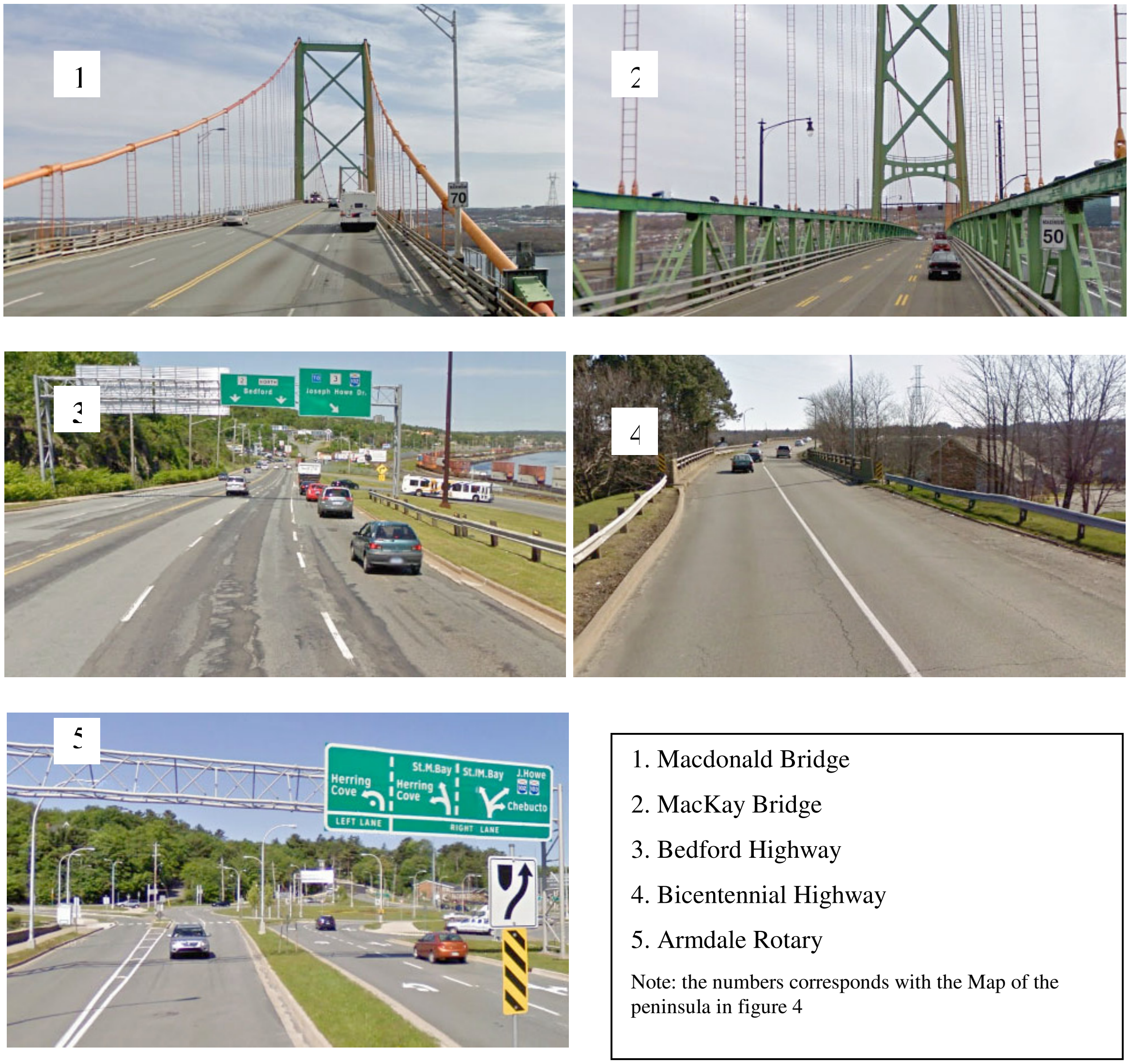


**Figure 5.** The major evacuation routes off the Halifax peninsula

### *3.3.2 Clearance time for an Evacuation*

Predicting minimum clearance time is an important part of transportation planning for mass evacuation. This requires advanced travel demand forecasting models and appropriate travel data. In absence of such models, this study performs a preliminary estimation of total duration required to evacuate the entire peninsula through the aforementioned exit routes based on some strict assumptions. The key assumptions are as follows: all residents have access to vehicles; each car accommodate 2.5 passengers; no congestion condition in the surrounding areas; no reverse-lanes applied; duration does not include the time for picking up family members and packing the car, etc.; and the destination locations are irrelevant. Since the population fluctuates during the time of the day, two separate estimates (for evening and for working hours) are generated. The calculations are based on the population (i.e. number of individuals to be evacuated); road capacity (i.e. the number of cars per hour per lane); and existing network design of the evacuation points (i.e. the number of lanes in the identified exit routes).

It is assumed that only the residents (i.e. 58,025) of the peninsula will need to be evacuated after hours in a weekday (i.e. evening and night). A highway with a speed limit of 100 km/h can accommodate 2000-2200 cars per hour per lane; however, during an evacuation, the capacity may be reduced to half (1000 vehicles per hour) because of congestion, overloaded vehicles, vehicle mechanical problems, crashes, and driver confusion (Litman, 2006). Hence this study assumes a conservative capacity estimate of only 500 vehicles/hour for each exit routes since most streets on the peninsula are 50 km/h (half the speed of a highway). Accordingly, an evacuation of all 58,025 residents through the identified exit routes in figure 4 would take approximately 6 ½ hours. Since the population almost doubles in the peninsula during the working hours of a weekday (about 105, 700 individuals), it would take approximately 12 hours to evacuate. If lanes were reversed, it would reduce the amount of time to evacuate all people from the peninsula. However, this may be limited with the existing network design since many of the streets (connecting the highway and the bridges) provide direct access to the residential units, and residents may require simultaneous access to their homes during emergency situations.

Assessments of minimum clearance time required for a mass evacuation of the Halifax peninsula could provide important insights for planning for a catastrophic event. Better estimates of duration and traffic flows are possible if appropriate data is available (for example, travel surveys, auto ownership survey, etc.), which is not the case for the Halifax Regional Municipality. Due to the limited data and modelling support, the estimated duration of the evacuation in the paper is preliminary in nature. In addition, it does not consider the hazard types and their effects, complex behavioural responses, and ramifications of the surrounding communities (i.e. travel demand, congestions, etc.).

## 4 STRATEGIES FOR MASS EVACUATION

Planning for evacuations requires planning for the 'unexpected'. The Emergency Management Office cannot predict all the issues that will arise during an evacuation; however, creating strategies in advance may improve the responses during emergencies, increasing the municipality's resiliency to hazards (Mileti, 1999). According to VTPI (2010),

> "*Resilience tends to increase if a system has diversity, redundancy, efficiency, autonomy and strength in its critical components. This allows the system to continue functioning if a link is broken, if a particular resource becomes scarce, if a particular decision-maker is unavailable, etc.*"

Transportation strategies are critical since mass evacuations involve rapid physical movements of the population to safe destinations. Given the site analysis, demographic profile, travel characteristics and transportation network analysis of the Halifax peninsula, this study proposes strategies regarding:

- Multi-modal transportation options to evacuate all residents
- Road network alteration to improve efficiency and safety
- Public outreach to inform residents about the protocols and ensure coordination during emergency evacuations

### 4.1 MULTI-MODAL TRANSPORTATION

Different forms of transportation are required for an evacuation of the peninsula since a significant portion of the population is carless, and car-only evacuations could create congestion due to inherent network design problems in the Peninsula. However, the role of transit for evacuation is far from being realized in most urban areas (TRB, 2008). Some evacuation plans suggests that individuals without access to personal vehicles may ask for rides from neighbours (Renne et al., 2008). However, people without cars tend to have neighbours that are also carless. Therefore, the use of public transportation is critical for mass evacuations (Hess and Gotham, 2007). In general, most municipalities do not have enough buses to support the carless and mobility-restricted population. During Hurricane Katrina, New Orleans had approximately 500 transit and school buses, a quarter of the estimated 2,000 buses needed to evacuate residents who wanted transport (Litman, 2006). As a result, individuals were taken to shelters in the city. Public transportation (i.e. buses and ferries) and rail, such as VIA can be used to evacuate the Halifax peninsula. As previously mentioned, the Emergency Evacuation Plan stipulates that Metro Transit will be responsible for evacuating the carless population. Metro Transit fleet consists of approximately 300 buses, including Access a- Bus vehicles (HRM. 2009). It is important to evaluate whether the existing fleet is adequate to transport the carless population to safe destinations. Otherwise, arrangements should be made with other municipalities, the school board and VIA rail authority. This requires prior agreements with these entities to ensure transportation is available for the carless and mobility-restricted population.

Still most evacuations are car dependent, which requires emergency alterations of road network to avoid congestion conditions (see section 4.2). But ensuring availability of alternative modes may assist in minimizing congestion. Table 2 shows possible uses of different modes during evacuations. Note that seamless modal integration from the threat area to the safe destination is an important condition to increase likelihood of taking advantage of multi-modal transportation alternatives.

**Table 2.** Multi-modal transportation for emergency evacuation (adapted from Renne et al., 2008)

| Modes | Typical Uses |
|---|---|
| Automobile | Emergency preparation activities; Evacuations; Delivery of emergency services |
| Ridesharing | May help with evacuations, particularly if arrangement can be made previously |
| Bus | Transport to emergency shelters; Evacuations; Delivery of emergency services, particularly in urban areas; Act as temporary shelters |
| Rail Transit | Evacuations; Delivery of emergency services; Act as temporary shelters (i.e. terminals) |
| Ferry | Evacuations |
| Taxi | Provide automobile transport for non-drivers. Capacity and reliability (number of taxis available) tends to be limited during major disasters |
| Emergency vehicles/ Ambulances | Provide transport for individuals that require medical services |
| Bicycle | Short to medium length trips by physically able people on suitable routes |
| Walking | Shorter trips by physically able people; Access trips to emergency shelters and motorized modes such as bus stops; Delivery of emergency services, particularly in urban areas |

## 4.2 ROAD NETWORK DESIGN

During a mass evacuation, road networks may need to be altered to increase road capacity and lessen congestion. It is also important to provide appropriate signs and guidance to reduce drivers' confusion. As discussed in section 3.3.1, there are five main exit routes from the Halifax peninsula: Macdonald Bridge, MacKay Bridge, Bedford Highway, Bicentennial Highway, Armdale Rotary. In total, there are seven outbound lanes (and six inbound lanes). Many techniques can be applied to increase the capacity of these exit routes, including contra-flow and re-routing of the access roads. Contra-flow is reverse laning (altering the normal flow) on a road segment. Applying contraflow assists to increase capacity by 70% (Wolshon, 2005b). In general, traffic police or physical barriers are applied to re-route and reversing lanes. However, application of Intelligent Transportation Systems (ITS) should be considered for mass evacuation. ITS may also assist in detecting incidents, assessing congestion levels and restoring traffic flows in critical links.

Different types of contra-flow may be implemented (see figure 6), including reversing all inbound lanes. However, many studies suggest that maintaining one lane for emergency vehicles (or returning buses) is vital for an efficient evacuation (Wolshon, 2005b). Sometimes allowing traffic in shoulders could be useful, particularly in highway segments. Priority to the outbound buses and high-occupancy vehicles is another strategy suggested by VTPI (2010), which will encourage people to take the bus or carpool to avoid congestion.

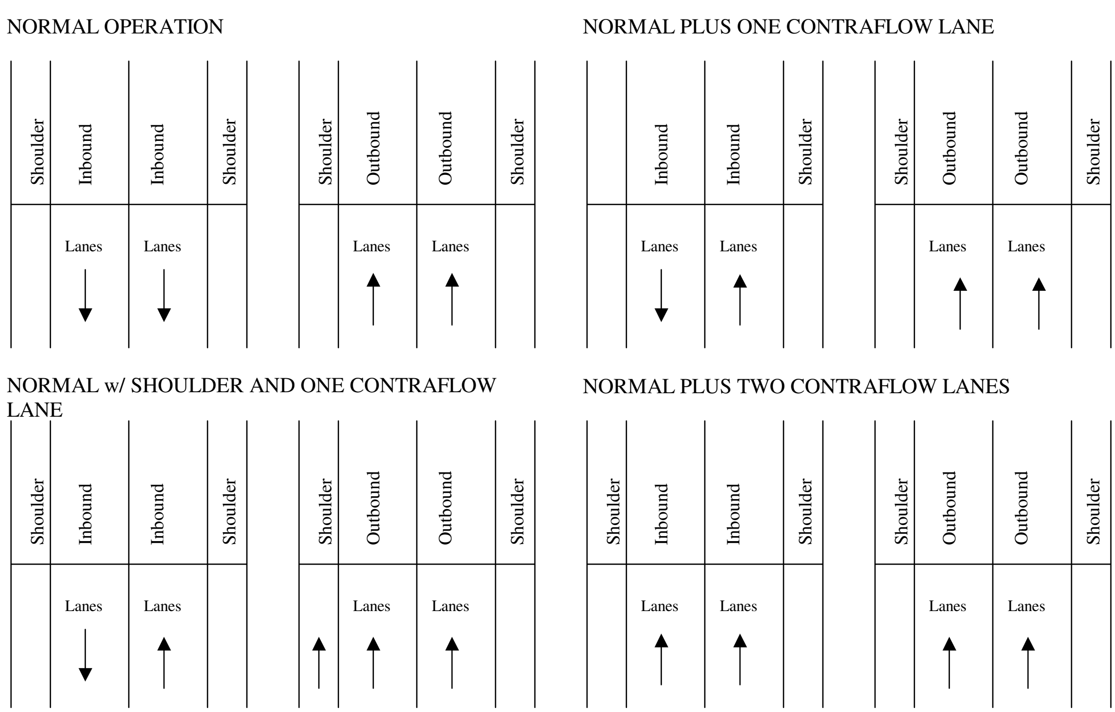


**Figure 6.** Different types of contraflow applied during an evacuation (Wolshon, 2005b).

### 4.3 OUTREACH

Informing the public about the resources available through outreach campaigns may improve the overall efficiency of an evacuation. Individuals need to be informed in advance about all issues of mass evacuation, including what to do and where to go (e.g. safe destination areas). One of the main shortcomings of the City of Houston during hurricane Rita was the inadequate communication to the public regarding the evacuation plans (Lahmar et al., 2006).

Another important consideration is to ensure that evacuation routes and contra-flow information are properly communicated to reduce possibility of collisions. Evacuations by their nature create panic and stress. Providing the evacuees with the appropriate information about which lanes to use through advance signage or Intelligent Transportation System (ITS) technologies (such as travellers information systems) may reduce unnecessary congestions or accidents (Wolshon, 2005b).

Special considerations must also be given to the carless and mobility-restricted population, which includes various people that are physically and mentally disabled, elderly, poor, and unable to speak or read English (or French). These people may not receive the information about the evacuation since they may not have access to the Internet/Cable or other services, which further marginalize this segment of population (VTPI, 2010). Appropriate outreach tools are needed to ensure that these people are well informed during evacuation situations (Schwartz and Litman, 2008). Sometimes it requires working closely with social service agencies, community organizations, medical and mental health professionals, and special service providers to explore the needs of mobility-restricted population (Reene et al., 2008). Preparing inventories of people who need special assistance is vital for providing adequate transportation support for them. If possible social service agency should create community leaders, who may travel to these vulnerable populations to provide information and assistance (Renne et al., 2008). Success in mass evacuation largely depends on timely dissemination of information.

## 5. CONCLUSIONS AND FUTURE RESEARCH

Major failures during recent hurricanes in the United States raised attention to the role of transportation planner in emergency evacuations. Although, emergency plans exist at the local level, detailed operational transportation plans are rarely a priority for most municipalities, including Halifax Regional Municipality. Moreover, the role that transit could play, particularly in evacuating those without access to private vehicles and those who need assistance, has only recently been acknowledged (TRB, 2008). This study is a first step towards studying the need for comprehensive transportation planning for evacuation in the coastal municipalities like Halifax Regional Municipality. It reviews existing policies and plans, analyze site contexts, and formulates a list of transportation strategies vital for mass evacuations. This preliminary investigation suggests that evacuation of the entire Halifax peninsula may require approximately twelve hours during work hours of the weekday. The municipality requires special attention to its network design to accommodate traffic flow off the peninsula, multi-modal alternatives to evacuate the carless population, and outreach to disseminate information during extreme events.

Further research is required to adequately explore travel demand during emergencies, and how to meet travel needs with the existing network and transit fleet. The next steps of this research include developing a comprehensive behavioural travel demand forecasting model, which reflects individuals' decision-making processes (for example, whether to move, when to move, what mode to take, which routes to take, where to go, etc.) within the modeling framework. Another important next step is to promote good quality data collection initiatives within the municipality to facilitate development of useful decision-support tools. Transportation planners should play a larger role in the preparation of emergency plans, in order to ensure safe and effective evacuations.

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