EMERGENCY PREPAREDNESS/RISK MANAGEMENT

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1. INTRODUCTION

1.1 Emergency Preparedness/Risk Management

Good surface transportation system operation allows accessibility and mobility of people and goods, and economic productivity at the local and national levels. Therefore, it becomes important to ensure the operation and integrity of the transportation system and enhance its ability to provide service in the event of an emergency through strategic planning and active management. An important step toward this direction is emergency preparedness.

Emergency preparedness typically involves the preparation of detailed plans that can be implemented in response to a variety of possible emergencies or disruptions to the transportation system. In the past, such emergency response plans ranged from small scale (e.g., response to an individual traffic accident) to large scale (e.g., hurricane evacuations) and a variety of scenarios in between. Disruptions to the transportation system can generate complex interactions and unforeseen effects as drivers divert to alternate routes which themselves may already be congested or incapable of handling the increased demand. Therefore, emergency preparedness planning can greatly benefit from the use of micro simulation models to evaluate the impacts of natural and man-made incidents and assess the effectiveness of various responses. In the event of a natural or man-made disaster, emergency preparedness plays a vital role in ensuring the safety, security, and efficiency of the transportation system. Emergency preparedness greatly depends on the understanding of the scope and magnitude of potential incidents and the significance of their disruptions to the mobility of people and goods in the transportation system. Preparedness involves anticipating a range of emergency scenarios and developing and testing plans to respond to them. Emergency preparedness for a state or locality is often measured in terms of its ability to respond to an emergency in a timely and effective manner. In the case of emergencies that affect the transportation system, the response time is a critical factor in minimizing adverse impacts including fatalities and loss of property.

2. METHODOLOGY

2.1 Traffic Simulation Model Selection

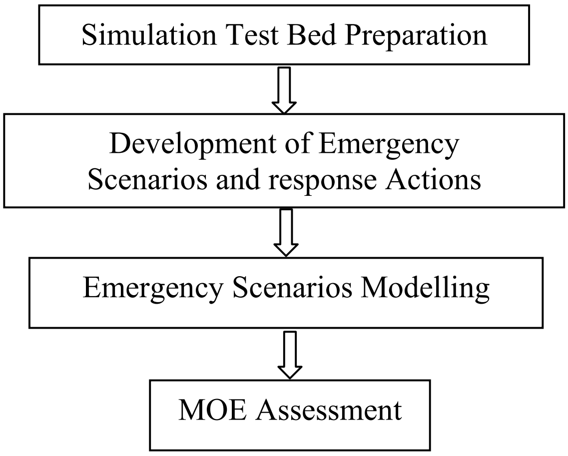

Fig. 1: Steps of Traffic Simulation Modeling Approach

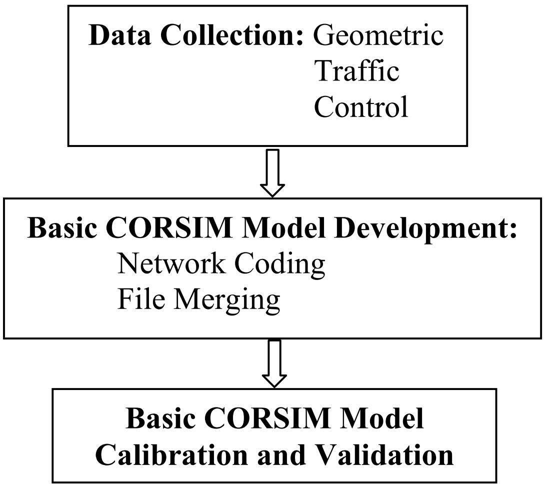

Fig. 2: Simulation Test Bed Preparation

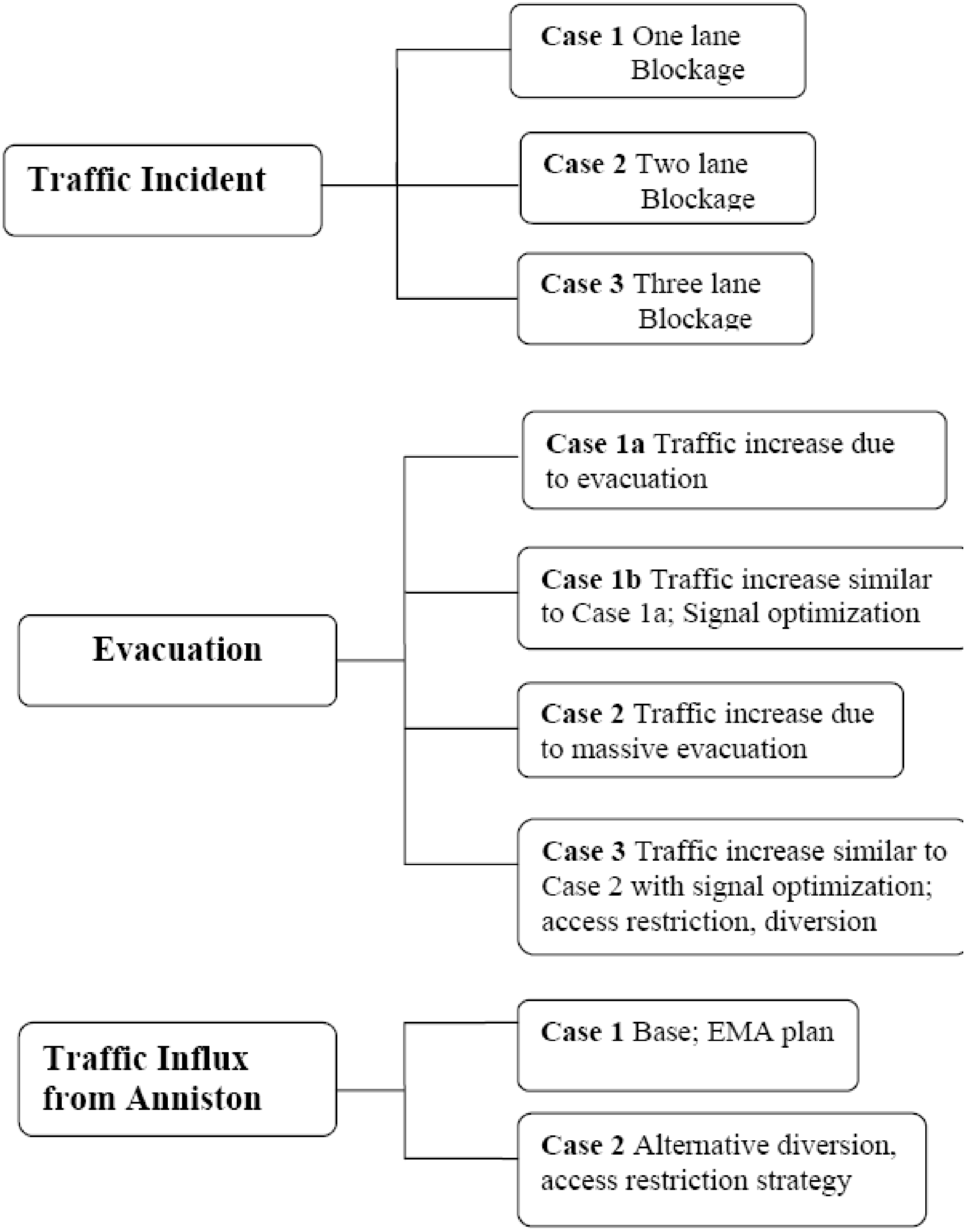

Fig. 3: Emergency Scenario Development

2.2 CORSIM Features

As mentioned earlier, CORSIM (CORridor microscopic SIMulation) is a combination of two other micro-simulators;

1) The urban micro-simulator NETSIM and
2) The freeway micro-simulator FRESIM.

This has resulted in a simulation model is capable of representing traffic flow in large urban areas containing both surface streets and freeways. CORSIM is aimed at the development and evaluation of Transportation Systems Management (TSM) strategies. To test the effect of TSM schemes on trip patterns it is necessary to analyze an area that contains a substantial portion of the routes that the trip makers follow.

a) *Ability to model complicated geometric conditions*.
b) *Ability to simulate different traffic conditions*.
c) *Ability to simulate different traffic control, management and operation conditions.*
d) *Ability to account for the interactions between different components of networks*.
e) *Ability to interface with external control logic and programs*.
f) *Ability to model time-varying traffic and control conditions*.

2.3 CORSIM Inputs and Outputs

Input to CORSIM includes geometric specifications, traffic volumes entering the network, turning movement data, topology of the road network and information about heavy vehicles and buses. For the analysis performed at the arterial level using NETSIM, information about parking activity, actuated controllers, pedestrians, and special events can be also specified. For freeway modeling using the FRESIM model, the user can input incident specification and detection information, lane adds/drops, and ramp metering.

CORSIM provides a variety of numerical output that is link specific, aggregated for multiple links, and network wide. The user may specify time intervals for generating output reports. Measures of effectiveness are provided as outputs from the CORSIM software include average vehicle speed, vehicle stops, delays, travel times, vehicle miles traveled (VMT), fuel consumption, and pollutant emissions.

2.4 Development of Emergency Scenarios and Response Actions

Following the selection of the simulation model and the definition of the test site, emphasis was devoted to the development of emergency scenarios and response actions. In order to develop detailed emergency scenarios, it is important to understand and consider the various steps of the disaster process. Comprehensive emergency management should take into account not only the response to a specific emergency but also the conditions prior to and following the crisis. With these considerations in mind and with input from the Project Steering Committee, a number of options were identified and three of them were selected for further consideration. These include:

i) Traffic incident simulation
ii) Evacuation Simulation,
iii) Evaluation of existing emergency preparedness plans.

2.4.1 Traffic incident simulation

The CORSIM simulation model allows the user to test scenarios involving alternative geometric configurations (weaving, merging, diverging), incident and work zone impacts, and various ramp metering options (Adams, 2003). It is also feasible to simulate traffic incidents, vary their locations, duration, and severity, and compare the resulting network performance against a no incident base scenario.

At the heart of this approach is the traffic simulation model that can predict changes in the behavior of individual drivers on the road network in response to a set of conditions, and provide output in the form of MOEs. Furthermore, incident simulation can also be used to test the benefits of ITS technologies to incident management. Examples of incident management strategies which are feasible for testing and evaluation by the model are summarized as in the following paragraphs.

ITS Deployment

The presence of ITS may reduce the emergency response time and mitigate the negative impacts of a traffic incident. By varying the incident duration and percentage of traffic diversion in simulation scenarios, the user can evaluate the benefit of advanced technologies deployment related to incident management. In the presence of ITS, diversion can be achieved through the dissemination of traffic information using ITS systems. These include changeable message signs (CMS), highway advisory radio (HAR), advanced traveler information systems, etc. It should be pointed out that the CORSIM model by itself does not have the ability for real-time vehicle rerouting, thus the adjustments in the inputs must be manually performed to account for traffic diversion.

Signal Timing

It is feasible to test and evaluate the effect of adjusting signal timings in response to a traffic incident using the CORSIM model. The optimal signal timing strategies can be obtained through other optimization models (e.g. SYNCHRO), and then be coded into the CORSIM scenario to evaluate the impact of signal timing optimization as a strategy for incident management.

2.4.2 Emergency Evacuation Simulation

In general, simulation of an evacuation is a complex scenario. It should be noted that the type of data normally collected in system monitoring and management falls short of the data needed to fully characterize and model an evacuation event. Such characterizations include driver behavior under possible panic conditions, the degree to which the emergency overwhelms the environment (e.g. smoke limiting visibility), unusual driver behavior (e.g. leaving the roadway to cut across a landscaped lot), etc. But a micro-scale traffic simulation model can be used under certain assumptions to estimate clearing time for an emergency evacuation, even when an accurate calibration is simply not possible (Church, 2002). In addition, the methodology of evacuation modeling using micro-scale traffic simulation model should consider the following:

Shape and Size of Evacuation Area

The size and shape of an evacuation area may vary considerably depending on the size, strength and rate of growth of the emergency source. For micro-scale evacuation simulation, the evacuation scale is limited by the computer technology and the coded network.

Traffic Demand Forecasting

The evacuation demand depends on the size of the evacuation area as well as the level and type of development contained within it. In forecasting the evacuation demand, it becomes essential to have information about the makeup of the population, including household size, age, income level etc. The demand also depends on the time of day and location of the evacuation area.

The general steps involved in travel demand forecasting for evacuation include the following:

a. *Evacuation traffic generation forecasting*. Usually, the methods to forecast the traffic demand in the evacuation area are largely simplified. For example, often vehicles trips per household are used as the trip generation rate. It is practical to forecast the evacuation demand using the trip generation and attraction information of the Traffic Analysis Zone (TAZ) in the evacuation area to forecast the evacuation traffic.

b. *Evacuation traffic distribution*. Evacuation traffic distribution refers to evacuation destination choice. For an individual, the choice of destination depends on minimizing the perceived cost, such as travel time to destination, proximity of destination to origin, and time available to reach a safe area. The system management goal is to minimize the total system travel time and maximize distribution of emergency services.

c. *Mode choice*. Mode choice refers to the distribution of traffic among the various available modes. During evacuation some shift from one mode to another is expected due to mode accessibility issues, street closures and constraints on travel options. Mode choice that realistically depicts available options and user preferences should be modeled accordingly.

d. *Evacuation route choice*. The process refers to the traffic assignment in the network under evacuation. The user optimal route choice is based on the perception of shortest distance to destination, safety of the route, evacuation information and familiarity with the route.

Strategies to Facilitate the Evacuation

The strategies to facilitate the evacuation fall into two categories, namely highway system strategies and traffic demand strategies. Combinations of such strategies should be also considered along with transit system strategies, where feasible. More specifically, highway system strategies may include:

1) Changes in traffic signals and traffic control.

2) Dissemination of evacuation-related information through closed circuit television, and other communication options**.** This strategy is reflected in the simulation procedure as the reactive time needed for people to decide to evacuate.

3) Roadway clearance. For example, CORSIM has the ability to simulate on-street parking, so a strategy to clear the on-street parking in emergency can be coded in the simulation procedures.

4) Access Restrictions. Restricting access to ensure available capacity for access evacuation from the area at risk is both an access management and a demand strategy. This could entail ramp closures in the perimeter of the incident, for example, by deploying maintenance vehicles or physical barriers to impede access to the roads from outside the danger zone.

5) Reversing Lanes/ Roadway Directions. Modeling contra-flow operations along with the required access restrictions and traffic diversions may also be used, when practical, as a strategy in support of emergency evacuation.

Typical traffic demand strategies in support of emergency evacuations include:
1) Improved communications for demand management.
2) Staggered/ timed release, and
3) HOV management.

Such strategies are expected to control traffic demand during evacuation and improve the spatial and temporal distribution of traffic. The HOV management has the potential to change the vehicle occupancy and result in the change of total evacuation traffic on route. Traffic demand strategies may be used alone or in addition to highway system strategies to assist evacuation and minimize its adverse effect to traffic operations.

2.4.3 Testing of Existing Emergency Preparedness Plans

As mentioned earlier, the cornerstone of effective emergency management during a crisis is the execution of previously developed emergency plans that guide the decision-making process and address demands for travel and special services in the most efficient way. Many local and state agencies with the assistance of FEMA and the Department of Homeland Security developed emergency response plans for hypothetical emergencies. Equally important to the preparation of emergency plans in anticipation of the crisis is their assessment through mock exercises (when practical) or simulation testing. Testing of the proposed plans' performance is expected to provide valuable information about emergency management and response and preparedness capabilities so that strengths and weaknesses can be identified and feedback can be obtained for improving the emergency plans, and consequently, optimizing the transportation network performance.

Determination of whether a proposed set of plans is the best option in case of an emergency can be reasonably estimated using traffic simulation outputs. Performance measures obtained from the simulation of traffic conditions and proposed actions detailed in one set plans can be compared to those obtained assuming an alternative set of plans. From the results of the comparison, the best possible plan can be selected for future implementation.

2.5 Integrated Modeling and Simulation for Emergency Response

There is a growing need for preparedness for emergency response both for man-made and natural disaster events. It is recognized that the area of modeling and simulation of emergency response is attracting a lot of attention and the expected rapid development may lead to enhancements in the architecture in the near future.

2.5.1 Proposed Overall Solution

The types of simulations envisioned for emergency response will be multi-facetted, real-time, and synchronized, i.e., no single simulation model or software system will be capable of representing all aspects of the emergency response problem. Furthermore, these simulations will need to be rapidly configured to respond to changing threats. The key technical elements of the proposed solution to be developed successively are:

a) *Emergency Response Framework.*
b) *Architecture for distributed simulation.*
c) *Simulation transactions.*
d) *Simulation templates and model formats.*
e) *Reference data sets.*

2.5.2 Proposed Architecture

The intent of the architecture is to provide a common backplane that allows plug and play with tools from various sources for modeling, simulation, visualization, data access and management for emergency response. The architecture for the emergency response simulation is shown in figure 1. It is divided into the following component elements:

- Simulators
- Scenario Emulator
- Data access and management
- Human interface modules
- Tools for identification, detection and learning

Simulators

i. Disaster Event Simulator.
ii. Impact Simulators.
iii. Response Agent Simulators.
iv. Information Flow Simulator.

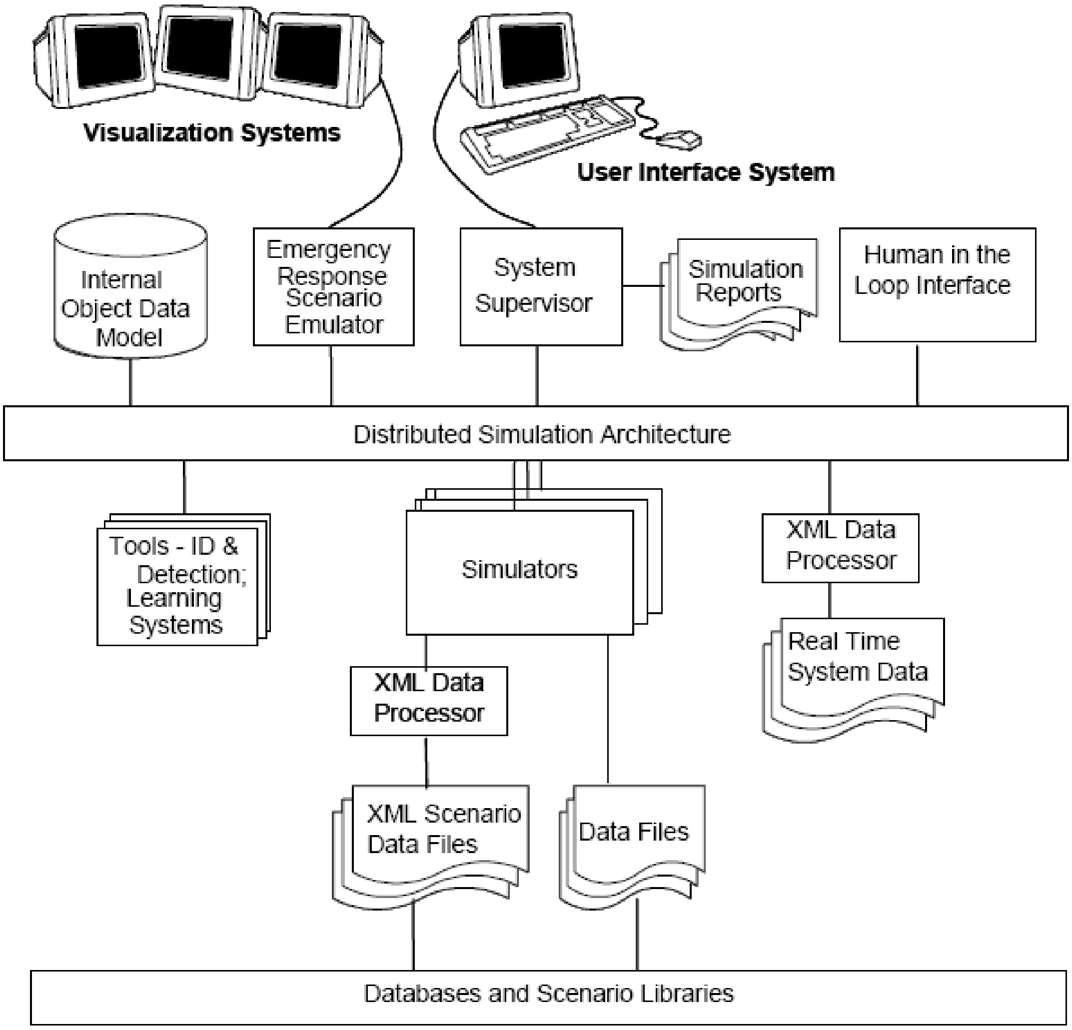

Fig. 4: Schematic of architecture for integrated modeling and simulation of emergency response.

Emergency Response Scenario Emulator

This module brings the results of all the different simulators together by emulating the status of all the objects in the scenario. The emulator also serves as the communication medium between the simulators and as the input for visualization systems. For an event involving a building explosion, one of the impact simulators will model the panic evacuation of occupants of the building and that will be emulated in the emulator. This information will be used by the traffic simulator to model a traffic jam and the scenario will be updated in the emulator. The traffic jam information will be used by the response agent simulators for planning the arrival routes of emergency response crews and for using some of the police crews for crowd control.

The integrated scenario information will be used for the animated display of the scenario using the visualization systems.

Data Access and Management

1. Databases and Libraries
2. Real time Systems Data.
3. Data Files.
4. XML Scenario Data Files
5. XML Data Processor.
6. Internal Object Data Model.

Human Interface Modules

1. Simulation Supervisor.
2. User Interface System.
3. Visualization Systems.
4. Human-in-the-loop Interface System.

2.6 GOOD PRACTICES OF RISK MANAGEMENT

2.6.1 Traffic Interruption due to a Scenario Earthquake and Resultant Landslides

This study focuses on landslide dangers of a mountainside. It is risk analysis for a scenario earthquake that causes the mountain slope above a transportation route to collapse, thereby blocking the transportation corridor. Based on the analytical results, a technique to quantitatively estimate the loss associated with a landslide has been proposed, which is applicable to establish rational countermeasures. The mechanism of earthquake occurrence and subsequent landslide is very complicated by nature. This study assumed a scenario earthquake, for which the location of epicenter was systematically varied, and consequently the distribution of horizontal ground accelerations were changed. By modeling the supposed distribution of ground accelerations, it is possible to calculate a probability of landslide occurrence. After observing the site, the hillside was divided into three separate blocks. Allowing that each block of earth can slide on its own, 10 possible landslide cases were assumed. The amount of loss suffered from an earthquake and the resultant landslide can be estimated by Eq. (1):

$$R = \sum_{i=1}^{n} P_i \times \sum_{j=1}^{m} (Q_j \times C_j) \quad \text{..........} \quad (1)$$

Where,

R: Risk (Expected loss value)

Pi: Probability of earthquake occurrence

Q_j: Probability of a damaging landslide occurrence for an assumed earthquake

Cj: Individual damage loss

Note that Cj includes not only direct reconstruction cost but also traffic, social and physical loss costs. In this particular case the social loss is much larger than the traffic loss.

2.6.2 Transit's Risk Management Practices

Transit applies the following three approaches to risk management practices: Informal Approach, General Approach and Advanced Approach. The Informal Approach consists of the application of existing procedures and controls. It is applied where a formal risk management process is not necessary. The General Approach is to be used for all Transit activities where the informal approach is not used. This approach is a qualitative approach. It is targeted at achieving the appropriate management of opportunities and threats, through the systematic application of generalized risk management processes and qualitative tools. The Advanced Approach is to be used in particular circumstances as a "one off" or discrete application within a continuous General Approach.

Using the General Approach

1. Establish the Context

Establishing the risk management context of an activity is a pivotal step in the risk management process. It defines the basic parameters within which risks must be managed and sets the scope for the rest of the risk management process. When establishing the context of risk management for an activity consideration must be given to the objectives, obligations, stakeholder expectations and risk tolerance involved.

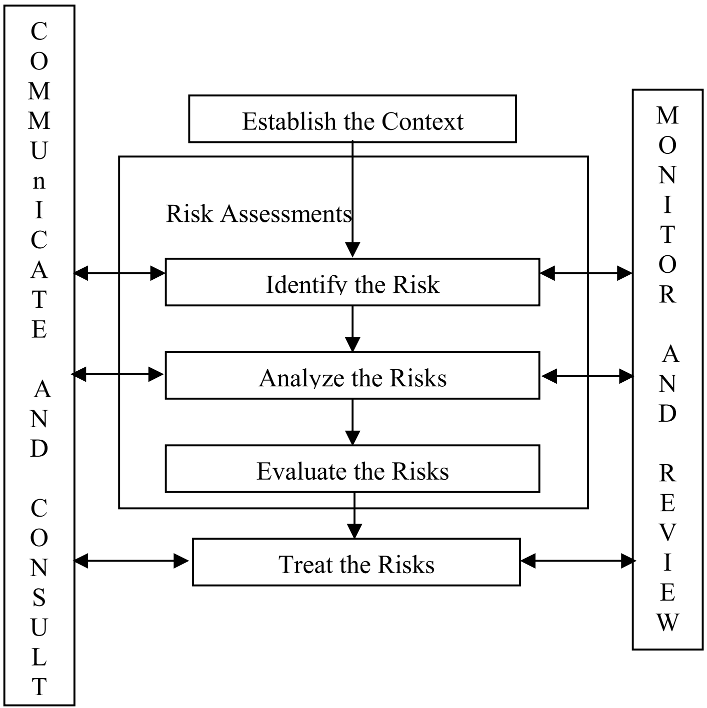

Fig. 5: Risk management Process Overview

2. Identify the Risk

All risks (threats and opportunities) must be identified. To complete the risk identification, each risk must be recorded in a risk register for that activity or business level. The recorded risk must be given a unique identifying number, given a name, clearly described in the words, and assigned either emerging, live, parked or closed status.

3. Analyze the Risks

The General Approach provides a qualitative technique for analyzing the identified risks. This technique is useful for considering diverse types of risk exposure, which would not otherwise be readily comparable. The analysis consists of Existing Controls, Consequence and Likelihood. The Existing Controls deals existing processes, devices, practices or controls that act to minimize threats or enhance opportunities, including an indication of how they might be of influence. The Consequence is a description and rating of the consequence of a risk, in terms of the loss or gain that may be experienced if the risk event occurs. The Likelihood is a description and a rating of the likelihood of the risk for the full range of risk event consequences. In particular for opportunities it is the likelihood of the stated gain being realized if the opportunity is pursed. The analyzed consequences and likelihoods of each risk are those that apply after the application of existing control measures, but before the implementation of further risk treatment actions.

4. Evaluate the Risks

For each given risk, the General Approach evaluates risk by establishing Risk Score, Risk Category and Risk Ranking. The Risk Score is the multiple of the ratings for likelihood and consequences for that specific risk. The Risk Category is a description of the risk score in words (i.e., "negligible", "low", "moderate", "high"). The Risk Ranking is established by listing of all the risks associated with the activity or business level. The existence of one "extreme" risk or 5 "very high" risks within an activity or business level indicates a significant risk, and triggers the requirement for the Advanced Approach.

5. Treat the Risks

The development of a risk treatment plan involves the selection of a treatment type and the identification of treatment actions. The decision of a treatment type is the first step in the risk treatment planning and should be made in consideration of the Risk Score. For opportunities or threats, there are four types of treatment: "Actively accept", "Passively accept", "Transfer/share" and "Avoid threats or reject opportunities."

CONCLUSIONS

Emergency preparedness is vital to ensure the safety, security, and efficiency of the transportation system in the event of natural or manmade disasters. It has been recognized that emergency preparedness can greatly benefit from the development of a range of realistic emergency scenarios and testing of plans to respond to each scenario. More specifically, after emergency scenarios are developed, the consequences of emergencies on the operation of the transportation infrastructure should be assessed. Given the magnitude of the problem and availability of resources, possible response actions can be identified and evaluated and necessary adjustments be made to the original plans, when feasible, to minimize the disruption to transportation operations resulting from the emergency.

This study shows how microscopic traffic simulation can be used to assist decision making for regional emergency preparedness. Details are offered on simulation model selection, data collection, model calibration and validation, emergency scenario development and testing. The objective of each case study was twofold. First, to offer examples of common emergencies (such as traffic accident, evacuation etc) and evaluate their impact on network performance. Second, to introduce strategies for traffic management (e.g. traffic diversion, access restriction, signal optimization to favor evacuation flow etc) and assess their potential benefit on traffic operations. The results of the first case study showed significant improvement of network performance with the traffic diversion strategy. The findings may lead to the conclusion that investment in ITS technologies that support dissemination of traffic information (such as Changeable Message Signs, Highway Advisory Radio, etc) would provide a great advantage in traffic management under emergency situations. This study shows how an evacuation could be carried out with different strategies (e.g., optimization of traffic signals, diversion strategies, and staged evacuation strategies). The third case study shows how previously prepared plans can be tested using simulation to assess their validity. Overall, the work reported in this research study demonstrates the feasibility of the simulation approach in emergency preparedness and highlights some of the challenges in the development of large scale microscopic simulation models.

This paper also presented an architecture that provides for integration of modeling and simulation tools to allow a systems approach to study and analysis of emergency response. The architecture is intended to provide a generic platform that allows plugging in legacy and new applications on a common backplane provided by distributed simulation architecture. The adequacy and validity of the architecture may be tested using a prototype. It is recognized that the area of modeling and simulation of emergency response is attracting a lot of attention and the expected rapid development may lead to enhancements in the architecture in the near future.

A future extension of this work should involve the integration of the CORSIM microscopic transportation model and a dynamic traffic assignment model in an attempt to develop a comprehensive model for emergency planning at the regional level. The addition of the traffic assignment model will allow modeling of travel behavior at a network level and will produce route choices of users under emergency conditions, providing a more comprehensive representation of the distribution of traffic in a dynamic way.

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