

RESCUE PROJECT: Transportation Testbed

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ABSTRACT

The purpose of this paper is to describe the objectives and scope of the Transportation Testbed. Currently, the RESCUE Project employs three testbeds to test and evaluate Information Technology (IT) solutions for more effective crisis response. These testbeds are *CAMAS* (Citizen Awareness System for Crisis Mitigation), *GLQ* (Gas Lamp Quarter), and the *Transportation Testbed*. The goal of the Transportation Testbed is to provide a platform for testing and evaluating information technology and social science research with the context of regional crisis response. Ultimately, the Transportation Testbed will allow researchers to evaluate the system performance benefits of their research, and/or to determine the performance objectives (or criteria) for their research in order to achieve the targeted set of benefits.

General Terms

Algorithms, Management, Measurement, Documentation, Performance, Design, Economics, Reliability, Experimentation, Security, Human Factors, Standardization, Verification.

Keywords

Transportation networks, testbed, information technology solutions, crisis response.

1. INTRODUCTION

To provide a platform for testing and evaluating the efficacy of information technology and social science research within the context of regional crisis response, the RESCUE project is utilizing a multi-dimensional testbed that simulates the performance of large transportation networks during catastrophic events. The reasons for selecting transportation networks are three-fold: 1) transportation networks are geographically very large, and therefore, are susceptible to a broad range of hazards or events, 2) because they are interconnected systems, effective performance is often based on the proper performance of its components, i.e., a damaged component such as a bridge can disrupt the entire system, and 3) information technology can play a key role in improving the performance of transportation networks during disasters by identifying problem areas and implementing more efficient solutions to overcome these problems.

In setting up this testbed, certain criteria were established to ensure that it could effectively be used as a platform for testing

and evaluating the value of information technologies. These criteria included:

1. The testbed must allow a real-world evaluation of the efficacy of information technologies for crisis response,
2. The testbed should include two major components: an information technology and social science (IT-SS) component, and a simulation component,
3. The testbed must be easily accessible to all users, i.e., an internet-based platform,
4. The testbed must be set up to allow users to define the scope of their test or evaluation, and
5. The testbed must provide quantitative results or feedback quickly.

The two components defined in (2) have specific objectives. The purpose of the IT-SS component is to develop methodologies and solutions that allow for more rapid evaluation of damage or impacts in large disasters, for better communication and dissemination of data and information between critical response organizations and the public, and for better decision-making capabilities. An important overall goal of these technologies is to mitigate the potential for secondary impacts or events, i.e., cascading failures or incidents.

The purpose of the simulation component is to serve as a surrogate for real-world conditions in a disaster. This component must be able to simulate results with and without the use of improved information technologies in order to quantify their value.

Information technology and social science research being performed in the RESCUE project includes:

- Dynamic data collection
- Rendering multimodal data
- Reliable knowledge from unreliable informants
- Event extraction from multimodal data streams
- Adaptive filtering of event streams
- Damage and impact assessment
- Optimizing organizational structure in dynamic and evolving virtual organizations (DEVO)
- Open distributed computing support for DEVOs
- Trust management in DEVOs
- Structured approach to disseminating information
- Emergent social behavior within the context of a disaster
- System for customized information delivery

The simulation model will be used to approximate the following conditions:

- Damaged transportation elements, e.g., bridges
- Disrupted highway links,
- Release and spread of gaseous hazardous materials,
- Travel times (and delays) between destinations with and without technology solutions, and
- Evacuation times with and without technology solutions.

The following sections describe the basic framework for the transportation testbed, the simulation scheme for evaluating the value of information technologies during crises, integration of the transportation testbed with communication networks (cellular), and key milestones over the next several years.

2. FRAMEWORK

The basic framework for the model that is used in the Transportation Testbed is described in a complementary paper in this Research Accomplishments Volume (*A Centralized Web-based Loss Estimation and Transportation Modeling Platform for Disaster Response* by H. C. Chung, et al., 2005a). The Chung (2005) paper introduces the computational platform that is used to “operationalize” the Transportation Testbed. The platform is called INLET for Internet-based Loss Estimation Tool.

INLET has been designed as a web-based solution to test the efficacy of information technologies within the context of crisis response. The platform offers a centralized, web-based modeling environment, where the level of effectiveness (as measured by reduction in expected losses, evacuation times and other impacts) can be determined for each technology tested. Centralized and wireless dissemination of loss results can improve response efforts by ensuring 1) that the same information reaches all parties, thus minimizing the potential for conflicting response, and 2) that critical information be readily accessible.

The simulation platform consists of seven major blocks, as illustrated in Figure 1. The first block is the *Disaster Simulation* module. This module simulates the initial conditions of the disaster. In the case of earthquake, information on the location and size of the event, the expected ground motion patterns, an assessment of the number of damaged buildings and resulting economic loss, the number and locations of damaged highway bridges, and other impacts such as number of casualties are calculated. The next module is the *Network Configuration* module. This module updates the physical composition of the system by identifying and closing down those highway bridges that have been impacted by the disaster. In order to perform this assessment, damage functions and structural fragility models are employed that correlate different performance states (e.g., operating or not operating) with different levels of damage. The next module is the *Evacuation Demand* module. This module is used to quantify population exposures throughout the study region. In general, this information is needed in order to determine how many people need to be evacuated from an area. The fourth module is the *Origin-Destination* module. In this module, travel patterns are documented between different transportation analysis zones. This information is key in establishing 1) what the likely loads will be on the transportation system during a crisis, and 2) which areas will be affected by an incident. The *Driver’s Behavior* module describes, in a

quantitative sense, how driver’s will respond in different crisis situations and more importantly, to different messaging. Accurate and complete information can effectively reduce travel times when viewed in the context of evacuation (see example in Chung, 2005a) The *Dynamic Network Rerouting* module is key in characterizing traffic movement when bridge or highway closures are introduced. An optimized algorithm can also be useful in identifying efficient strategies to overcome these obstacles. Finally, the last block provides the end result of the analysis. That is, measuring the performance of the system under crisis conditions, and more importantly, the performance of the system when IT solutions are introduced. Initially, we are planning to quantify system performance using the following measures: a) total time to evacuate, b) total travel time delays, and c) total casualties resulting from exposure to gaseous toxic materials.

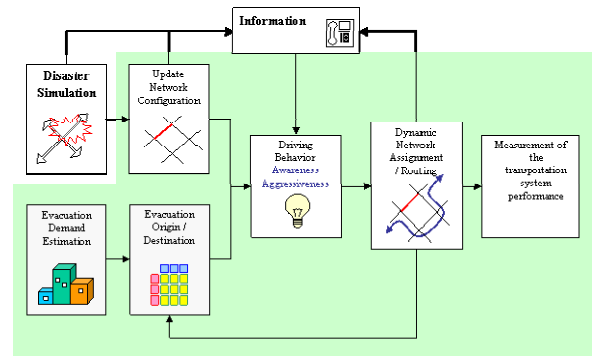


Figure 1. Transportation Simulation.

3. SIMULATION SCHEME

The simulation scheme is based on modeling the movement of people in cars both before and after information technologies are applied. For example, one of the information technology solutions that will be tested is the use of customized messaging for cell phone users based on where the users are located. Since most cell phones are geo-locatable, it is possible that custom messages could be sent to cell phone users based on their current locations. So, in the case of a serious incident (such as a hazardous materials release), drivers could be instructed to stay away from the incident or be given directions that will help them evacuate safely away from the incident. This technology solution (i.e., customized messaging) would be evaluated in the INLET platform by modifying the parameters of the *dynamic network assignment or routing* module in Figure 1, i.e., re-routing drivers based on different levels of information (see example in Chung 2005a). The measure of effectiveness might be the number of people avoiding the effects of the incident, or the time required to evacuate vehicles from the affected area.

Another example would be the use of in-situ sensors on bridges or other key transportation elements in quickly identifying the damage states of these elements after a large disaster (see Chang et al., 2005 paper in this volume.) One of the more difficult tasks that structural engineers face after a major earthquake is assessing the amount of damage caused by the disaster. This task often requires field inspections that can be time consuming and limited because of the large demand on resources. With sensors on key bridges, it is possible that the performance state of these bridges

could be determined in near real-time and relayed back to some central site for evaluation. The benefits of these rapid evaluations are 1) better information to prioritize response, 2) more reliable data on “troubled” spots that can be passed on to drivers in the area, and 3) a more informed basis for assessing the structural safety of key bridges. The value of this information technology solution could be tested by modifying the parameters of the *Update Network Configuration* module.

Other information technologies that can be evaluated include:

- Remote sensing to more rapidly quantify the scope and magnitude of the disaster, especially on a large regional scale,
- Use of loop sensors to estimate daytime populations in densely-populated areas,
- Use of cell phones to estimate daytime populations in all areas,
- Smart transportation traffic systems to more effectively implement traffic movement after a disaster.

INLET has been designed to ensure user-friendly access to the Transportation Testbed. The implementation plan calls for a user interface that allows the user to adjust key parameters within INLET to simulate the conditions that would result if the technology solution is implemented. For example, in the case of the customized messaging, the user will be able to adjust the level of information reaching a driver, the percentage of drivers receiving these customized messages, and the reliability of these messages.

By using the INLET model, researchers will be able to achieve the following: 1) evaluate the system performance benefits of their research, and/or 2) determine the performance objectives or criteria for their research in order to achieve measurable benefits.

4. INTEGRATION WITH CELLULAR NETWORKS

A future expansion of the transportation testbed could include the addition of cellular networks. Since some of the technology solutions that will be tested in the Transportation Testbed involve the use of cellular networks, the research team is considering merging the cellular network models being developed by both UCSD and UCI with the transportation simulation model.

Figure 2 shows a possible configuration for this integration. Both networks would be connected to a *crisis simulator*. The purpose of this simulator would be to lay out the initial conditions of the disaster. In the case of earthquake, this could mean the identification of damaged bridges, the detection of damaged cell towers or other cellular infrastructure, and conditions where the performance of one network may affect the performance of the other. For example, if the cellular network is damaged and not functional in some event, this will directly impact the ability of emergency personnel to provide custom messages to drivers in these affected areas. Similarly, if the transportation system is disrupted, this will hamper the ability of cellular companies to get to affected areas to make repairs.

The simulation engines for both networks can also be merged in such a way as to provide real support during actual emergencies. For example, if the state of each system can be determined quickly and reliably in an actual event (based on the use of the

information technology solutions mentioned above), the simulation engines could provide the basis for coordinating post-event repairs or response activities for both systems. That is, the simulation engines for both networks become interactive and provide “system-level” information that can be used to evaluate different response and recovery strategies.

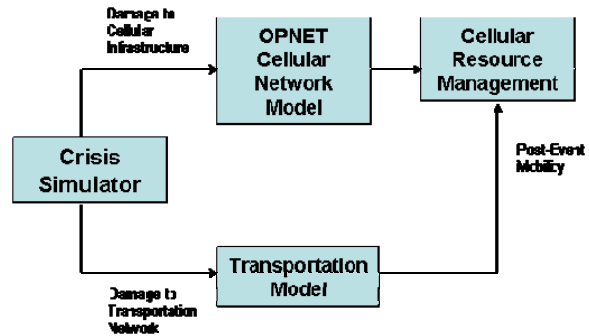


Figure 2. Multi-network Integration Scheme

5. TRANSPORTATION TESTBED MILESTONES

The following transportation testbed milestones are presented for the next several years:

- Loss estimation modules completed in 2004,
- Beta-version of INLET online at UCI in early 2005,
- Transportation module completed by Fall of 2005,
- User-interface protocols finalized by Summer 2005,
- First tests initiated in Fall 2005 or Spring 2006,
- Beta-testing of INLET at government partner’s site, Spring 2006
- INLET ready as operational testbed in Summer 2006
- Final version of INLET delivered to government partner(s) in Fall 2006.

6. COLLABORATIVE PARTNERS

The current research team is working closely with the following RESCUE team members: S. Mehrotra, University of California, Irvine (research on use of cellular networks for customized messaging), C. Butts, University of California, Irvine (research on behavior of organizations during crises); M. Shinozuka, University of California, Irvine (research on bridge fragility models and movement of injured to local hospitals); P. Chang, University of Maryland (research on damage monitoring sensors on bridges); B. Jafarian, University of California, San Diego (research on cellular system vulnerabilities and traffic mobility profiles.)

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