Report on PEER Workshop on

SEISMIC RISK ASSESSMENT AND MANAGEMENT OF TRANSPORTATION NETWORKS

March 18, 2009

By

Armen Der Kiureghian and Anne Kiremidjian

Introduction

The purpose of this workshop was to bring together a group of researchers and practitioners to discuss issues and challenges related to seismic risk assessment and management of infrastructure systems, particularly transportation networks, and to identify research topics that are most urgently needed and which will help advance applications of "systems" concepts in infrastructure earthquake engineering practice. This is a relatively new and expanding area of research and application, where many conceptual and technical gaps and challenges continue to exist. While the focus of the workshop was on transportation networks, the broader view of "infrastructure systems" was considered since (a) many of the concepts are transportable from one type of infrastructure to another, (b) interaction between infrastructure systems necessitates consideration of several systems at once, and (c) PEER may wish to develop programs for other infrastructure systems, such as water, gas and power distribution systems, or system of facilities, such as a medical center, a harbor, a university campus, etc.

The Workshop was co-chaired by A. Der Kiureghian (UC Berkeley) and A. Kiremidjian (Stanford University) and ably supported by the PEER staff. It was held in the PEER conference room, 325 Davis, and in 542 Davis Hall. Attachment A lists the participants, their affiliations and their e-mail addresses. The program of the Workshop is presented in Attachment B. As can be seen, presentations were made by a number of the participants during the morning session. In the afternoon, the participants were divided into two groups and were asked to discuss challenges and opportunities related to the following issues:

- What are useful formulations of infrastructure system performance before, during and after an earthquake? What are the relevant direct and indirect loss metrics?
- How can these metrics be incorporated in performance based engineering for transportation networks?
- What are the major sources of uncertainty in assessing infrastructure system performance?
- What are the modeling and computational challenges involved in assessing infrastructure system performance under conditions of uncertainty?

- How does the geographically distributed nature of infrastructure systems distinguish their performance relative to systems located at a single site, e.g., a nuclear power plant? What additional considerations does the geographically distributed nature mandate?
- What types of seismic hazard are relevant to geographically distributed infrastructure systems?
- Discuss the modes of interdependence between various infrastructure systems subject to earthquakes.
- Imagine a Decision Support System (DSS) to aid decision-making for seismic retrofit, for emergency response to earthquakes, or for recovery after an earthquake. Enumerate some of the desired elements of such a DSS in each case.
- How can IT (e.g., the Internet, GIS, visualization tools, cell phones, aerial photographs) assist in post-earthquake response and recovery of an infrastructure system?

Each group was assigned a Leader and a Reporter. The two groups then joined in an hour-and-half of presentation and discussion of their findings. The following pages summarize the reports from the two groups.

Group 1: Samer Madenat, Leader
Leonardo Duenes-Osorio, Reporter

Discussion Items and Recommendations:

Discussion framework: differentiate research challenges across operational phases (e.g., pre-event, emergency response, recovery). CALTRANS viewpoint for discussion is similar, since their priorities are mitigation, response, and post-event interventions.

Pre-event and recovery phase research tasks

- Improve indirect loss predictions (delays, opportunity cost, etc.) from transportation network impairment. Current methodologies for indirect loss estimation rely on steady-state traffic condition assumptions. However, these assumptions are not defensible from a transportation and traffic view point, especially during the recovery phase.
- Characterize and quantify the effect of two-way interdependencies in relation to transportation systems. Transportation systems affect most other civil infrastructures, while their operation is dependent on power and telecommunications for traffic control. Also, shifts in Origin-Destination (O-D) patterns affect the performance of transportation systems.
- Study the impact of failures in alternative modes of transportation (e.g., BART, public busses) on conventional road networks following earthquake events.
- Assess the potential of seismic-induced damage on large facilities, such as dams or chemical facilities, which can critically affect transportation system performance.
- Identify risk reduction strategies that minimize exposure, lower indirect cost, and maximize total benefit (e.g., maximum flow).

- Additional comments:
    - In relation to traffic modeling:
        - Empirical evidence does not support traffic equilibrium assumptions (deterministic or stochastic), especially in short term time frames (day, week, or even month).
        - Driver route and timing choices in traffic modeling need to be incorporated using perception-based tools and continuous updating.
        - Traffic demand forecasting methods require hierarchical analyses, including: selection of destination points, identification of modes of transportation, selection of routes, and departure time decisions (the last two items are greatly affected by earthquake events).
        - Route choice needs to be studied in segments of time: emergency time, transition time, steady-state time.
        - Agent-based models (ABM) can be used to model individual citizen driving decisions and track perception updates. This work can build upon expertise in other hazard contexts, such as hurricanes.
    - Adopt a top-down approach to identify research tasks: address technical weaknesses first.

Emergency response phase research tasks

- Address pressing needs of stakeholders, which mainly relate to assessing the state of transportation assets after an earthquake event. This requires at least two areas of research:
    - To improve existing decision support tools by refining classical hazard-damage-cost phases, and including aging effects as well as retrofit improvements in input inventories.
    - To upgrade decision support tools to be compatible with ad-hoc information generated by citizens. Need to also use indirect information from other infrastructure failures to inform state of transportation assets, and continue using recorded information from instrumented infrastructure.

- Prioritize road segments for potential evacuations after earthquake events. In particular, consider landslides, fires, flood, etc.
- Additional comments:
    - Right after earthquake events, public law enforcement personnel takes care of emergency operations traffic flow.

Group 2: Tom Shantz, Leader
Stu Werner, Reporter

Discussion Items and Recommendations:

Open Source Code

- Challenges in making it work
- Work on hazard and risk assessment nationwide
- Modules to plug in to OS program
- Interfacing of modules. Computational guru needed provide links with older and newer software modules.
- OpenSees is taking off but has implementation/use problems.
- MAEViz building in network analysis
- Challenges: Development of input data for actual highway systems to exercise code will be big effort

Data repository.

- CA focus. Generate data for CA and provide data structure (fields) to some standard that rest of US can follow.
- PEER lifeline project funds data collection?
- Tools to aid data collection?
- Data translation tool (infer missing data??) based on length, other known data, infer missing data values.
- Hypothetical realistic but not real network. Common network for testing future applications and comparing methods. Exercise different aspects of different models.
- California network cleanup was not proposed to Caltrans but they did not support it.
- Scanning of drawings. Security challenges. Sensitivity of releasing data.
- Big step to go from drawings to getting digital tabulations of boreholes, structural attributes, etc.
- CGS has 2000 Caltrans boring logs.

Reliability research test network.

- Hypothetical but realistic test network and trip demands would avoid above data collection issues. Provide a common framework for testing modules.

Disconnect between research vs what is truly needed for applications.

- Model development research should consider data needs.
- Bridge fragility modeling. Work being done to improve CA bridge fragility models.
- Expert opinion, based on column tests, etc. look at fragility relative to excess displacement.
- HAZUS good tool in its time. Now time to develop improvements.
- Retrofit of Dunbarton Bridge is moving forward.
- Bridge Liquefaction Screening Tool. Caltrans project: Keith Knudson carrying out project to identify which bridge sites are most likely to liquefy and which bridges are most sensitive to liquefaction.
- Info most important to traffic engineers: downtime is metric of most interest to Caltrans. Don't need SRA of highway system to estimate downtime. SRA tool would provide info on how downtimes impact traffic flows.

Damage state vs reduced traffic capacity

- Good repair models needed for this.

Appendix A

List of Workshop Attendees

PEER Workshop: Seismic Risk Assessment and Management of Transportation Networks **Wednesday, March 18, 2009**		
Baker, Jack	Stanford University	bakerjw@stanford.edu
Bensi, Michelle	UC Berkeley	mbensi@berkeley.edu
Bozorgnia, Yousef	PEER	Yousef@berkeley.edu
Der Kiureghian, Armen	UC Berkeley	adk@ce.berkeley.edu
Dueñas-Osorio, Leonardo	Rice University	leonardo.duenas-osorio@rice.edu
Fong, Denny	Caltrans	denny_fong@dot.ca.gov
Jayaram, Nirmal	Stanford University	nirmalj@stanford.edu
Kiremidjian, Anne	Stanford University	ask@stanford.edu
Lepech, Michael	Stanford University	mlepech@stanford.edu
Madanat, Samer	UC Berkeley	madanat@ce.berkeley.edu
Mahin, Stephen	UC Berkeley / PEER	mahin@berkeley.edu
Medury, Aditya	UC Berkeley	amedury@berkeley.edu
Shantz, Tom	Caltrans	tom_shantz@dot.ca.gov
Shinozuka, Masanobu	UC Irvine	shino@uci.edu
Song, Junho	Univ. of Illinois at U-C	junho@uiuc.edu
Werner, Stuart	Seismic Systems & Engineering	sdwerner@ix.netcom.com
Work, Dan	UC Berkeley	dbwork@berkeley.edu
Zhou, Xuesong	University of Utah	zhou@eng.utah.edu

Appendix B

Workshop Program

Time	**Speaker**	**Topic**
9:00-9:10	Steve Mahin	Remarks on PEER's objectives from the Workshop
9:10-9:30	Anne Kiremidjian Armen Der Kiureghian	Remarks on organization of the Workshop
9:30-9:45	Samer Madanat	Incorporation of seismic considerations in bridge management systems
9:45-10	Masanobu Shinozuka	Analysis of Seismic Performance of Port Facilities
10-10:15	Stuart Werner	Future Directions for Seismic Risk Evaluation and Management of Transportation Networks
10:15-10:30	Anne Kiremidjian	Transportation network risk assessment - what are the outstanding issues?
10:30-11	Coffee Break	
11-11:15	Leonardo Duenas-Osorio	Cascading failures across interdependent infrastructure systems
11:15-11:30	Junho Song	Rapid stochastic assessment of post-hazard connectivity and flow capacity of lifeline networks
11:30-11:45	Jack Baker	Characterizing seismic hazard to distributed systems using efficient simulation techniques
11:45-12:00	Michelle Bensi	Bayesian networks as a tool for seismic infrastructure risk assessment and management
12:00-12:15	Michael Lepech	Managing Infrastructure Network Performance for Increased Sustainability using Dynamic Life Cycle Assessment Models
12:15-12:30	Dan Work	Mobile Millennium: using smart phones as traffic sensors
12:30-1:30	Lunch	
1:30-1:45	Armen Der Kiureghian Anne Kiremidjian	Charge to participants
1:45-3:00	Breakup sessions A and B	
3:00-3:30	Coffee break	
3:30-5:00	Plenary session: Discuss opportunities and challenges	