Issue No. 33 Winter 2003

THE JOHN A. BLUME EARTHQUAKE ENGINEERING CENTER

Department of Civil & Environmental Engineering, Stanford University

Director: **Professor Gregory G. Deierlein**
Administrative Associate/Editor: **Racquel Hagen**
Telephone: (650) 723-4150, Fax (650) 725-9755 E-mail: earthquake@ce.stanford.edu Website: blume.stanford.edu

Billington Joins StrGeo Faculty

Sarah Billington became the newest faculty member in the Structural Engineering and Geomechanics program in January. She joins us from Cornell University where she was an Assistant Professor for five and a half years.

Billington's research focuses on the behavior, design and simulation of structural systems using high performance structural materials. A current focus is on highly ductile fiber-reinforced cement-based composites. Her research includes material characterization under quasi-static cyclic and sustained loading as well as testing of structural systems and seismic retrofitting methods that use new materials. Her group is also developing simulation tools and methods to analyze the use of new materials in structural systems.

Billington was a consulting engineer with Greiner Engineering in 1992 and is an active member of ASCE and ACI committees related to structural concrete and finite element analysis.

She and her husband, Peter Feenstra, come to Stanford with their baby girl, Anna Kate, born on September 28. We are very happy to have them all here.

Deierlein Wins Norman Medal

Gregory G. Deierlein and **Sherif El-Tawil** (Professor, University of Michigan) are the winners of the ASCE Norman Medal for their papers "Nonlinear Analysis of Mixed Steel-Concrete Frames. I: Element Formulation" and "Nonlinear Analysis of Mixed Steel-Concrete Frames. II: Implementation and Verification," Journal of Structural Engineering, June 2001. The Norman Medal is bestowed upon the author or authors of a paper that is judged worthy of special commendation for its merit as a contribution to engineering science. An outgrowth of a project sponsored by the National Science Foundation to investigate the seismic design and behavior of composite steel-concrete structures, these two papers describe the formulation, computer implementation, and calibration of a flexibility-based beam-column element to simulate the response of such elements to the combined effects of axial loading and biaxial bending. Deierlein received a National Science Foundation Presidential Young Investigator Award in 1990 and is a former winner of ASCE's Raymond C. Reese Research Prize and its State-of-the-Art of Civil Engineering Award. He won the Norman Medal once before, in 1994.

New StrGeo Admin

We are very pleased to welcome **Kimberly Vonner** to the Structural Engineering and Geomechanics Program as Administrative Associate. A mother of five, Kim started with us in September and has been a wonderful asset. A Stanford University employee for many years, she most recently worked with Stanford News Services.

Blume Center News

The Blume Center hosted a three week visit by **Prof. Yukihiro Harada** of Chiba University, who is involved with **Greg Deierlein** and PhD candidate **Amit Kanvinde** on a US-Japan collaborative project concerning fracture in steel structures.

Dr. Renate Fruchter gave a keynote presentation on "Metaphors for Knowledge Capture, Sharing and Re-use" at the *European Conference on Product and Process Modeling - eWork and eBusiness in A/E/C*, Slovenia, Sept. 9-11.

Anne Kiremidjian presented an overview paper on the "Potential Uses of Imagery in Earthquake Engineering" at the *CODATA* conference in Montreal, Sept. 27-29.

In Sept., **Dr. Renate Fruchter** was the guest of Mr. M Shears of *Ove Arup London* where she gave an invited lecture on the "AEC Global Teamwork" CEE 222/122 course.

PhD Candidate **Dimitris Pachakis** presented a joint paper with **Anne Kiremidjian** on "Statistical Analysis of Container Port Traffic and Operations Data", at the *International Workshop on Harbour, Maritime & Multimodal Logistics Modelling and Simulation*, Bergeggi, Italy, Oct. 3-5. The paper received the Best Paper Award at the conference.

Dr. Renate Fruchter visited *Obayashi Corp*. in Tokyo to discuss the second pilot of the joint project on knowledge management "Obayashi-PBL Hub, Oct. 7-10.

Greg Deierlein presented a paper co-authored by **Amit Kanvinde** at the *US-Japan Workshop* in Kyoto on "Micromechanical Simulation of Ductile Fracture under Monotonic and Cyclic Loading in Steel Structures", Oct. 21-22. **Allin Cornell** also attended the workshop.

Anne Kiremidjian was the US organizer of the *4th China-Japan-US Tri-lateral Symposium on Lifeline Earthquake Engineering,* Qingtao, China, Oct. 27-31, 2002. The symposium was jointly supported by the NSF, and PEER, MCEER and the MAE Centers. **Meredith Williams** from Stanford and Prof. Kiremidjian each presented papers reporting on the PEER Demonstration Project. Proceedings from the symposium are available by contacting Anne Kiremidjian.

PhD Candidate **Peter Demian** and **Dr. Renate Fruchter** presented a paper on "Corporate Memory in Action" at the *Computing in Civil Engineering - International Workshop on Information Technology in Civil Engineering* in conjunction with the annual *ASCE convention*, Nov. 2-3, in Washington D.C.

Greg Deierlein presented an invited paper co-authored by **Scott Hamilton** (PhD Candidate) and **Charles Menun**, "Probabilistic Aspects of Performance-Based Engineering Methodologies for Fires and Earthquakes" at a symposium on *Fire Risk Assessment and Management* in New Orleans, Dec. 5-6.

RESEARCH SPOTLIGHT

Estimation of Downtime Related Revenue Losses in Seaports Following Scenario Earthquakes

By Dimitris Pachakis and Anne Kiremidjian

Introduction

In the past, ports have suffered grave damages after earthquakes because their location near estuaries and river deltas and their construction on landfills has made them particularly susceptible to liquefaction and ground failure. Damage to port structures that reduces their functionality will limit the port's operational capacity which will result not only in monetary losses attributed to replacement cost of the structures, but will also result in revenue losses due to reduced throughput. Consequently, when authorities plan and design new ports or evaluate and expand existing ones, it is necessary to examine the possible repercussion of potential failures due to extreme events. The expected cost incurred by a port after an earthquake is divided into repair cost of the damaged port facilities and revenue loss due to ceased functionality of those facilities while repairs are taking place. In this article, a methodology to estimate probabilistically the expected revenue losses incurred by a multi-terminal port after a scenario earthquake is summarized. The use of the methodology is demonstrated in a simple example where the effects of a scenario earthquake on a multi-terminal port container are studied.

Methodology

In order to estimate loss after such events, two necessary interrelated components are needed: a methodology to predict the damage state of the port facilities, named vulnerability model thereafter, and a methodology to relate the damage state with the monetary loss. The vulnerability model is used to connect the characteristics of the scenario earthquake to the functional state of the port system. Deterministic Hazard Analysis can be used for determining the ground motions at the port site which takes as input the geographical, geological and seismological data and calculates the site ground motion intensity measure, for example, Peak Ground Acceleration (PGA) or Spectral acceleration (Sa), with the use of readily available attenuation functions. Given this intensity measure, the damage state probabilities can be calculated through fragility curves. At the present, fragility functions can be found, among other sources, as part of HAZUS, a hazard and loss estimation tool developed by FEMA. With regards to their operational status, the facilities are considered either fully or non-operational, depending on their damage state. Then, the damage states of the port components (buildings, cranes, wharves and utilities) and their probabilities can be calculated. The determination of the functional state of the port terminals after the earthquake is critical for assessing the revenues from post-event operation of the ports. A system approach is required, where the damage states of the port components that contribute to the cargo handling operations are combined through fault trees and event trees to produce the functional states of the terminals and their associated probabilities.

The consequences of the post-earthquake functional state of the port system to the port revenues are studied by means of a port operations simulation model. Although there are many simulation models suitable for generic purposes available in the literature, none is specifically formulated for this purpose, so a new one had to be written to accommodate the needs of this type of analysis which has are a few differences from the existing ones. Firstly, the analysis is transient after an event occurrence and during recovery, which creates the need for multiple replications instead of regenerative cycles in order to get the sample losses. Also, a different level of modeling detail in the port operations themselves is required. The simulated operation time, which can be months after an event, is much greater than in the usual simulation models and the required output is mostly revenues. Finally, detailed representation of the loading, discharge and storage operations, as presented in most models would impose large computer memory and run time requirements without real necessity and is not done in this model. An overview of the loss estimation methodology and its various components is shown in Figure 1. The port operations simulation model takes as input the current ship traffic characteristics and the terminal operation's details (cranes, berths, productivities) before and after an earthquake.

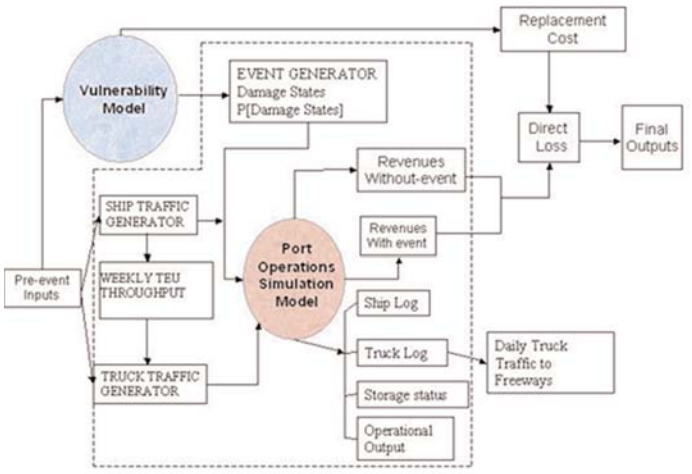

Figure 1. Components of the loss estimation methodology.

Given the damage states of the port components after a catastrophic event and the traffic input that is going through the port, the simulation model is used to calculate port revenues for a long period of time with and without the event. The difference in

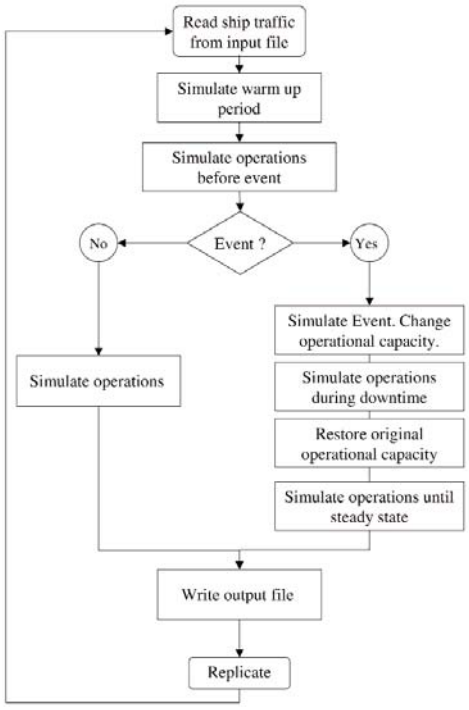

Figure 2. Simulation setup

the revenues in the two cases gives a sample of the losses due to the event. Since the transient behavior of the port system after the event is of interest, the method of multiple replications was chosen for obtaining the statistical characteristics of the revenue losses, as opposed to the method of regenerative cycles where a long run is divided in similar cycles in order to obtain a sample population. The simulation setup is also shown on Figure 2.

Application

One of the advantages of the proposed methodology is that one can built a multi-terminal port model and study the effects of different emergency operating modes. Interactions between the terminals can be observed so that a sound emergency planning strategy can emerge.

The scenario that is described here is as follows. The port has eight container terminals, one of which (here denoted as terminal 6) has to close for six months for repairs immediately after the earthquake. In this scenario, the ship traffic of 1999 is used to estimate the differences in revenues if an earthquake closed one terminal out of eight for six months. The ships that cannot be serviced get diverted either to each of the other terminals or to another port. Due to decreased capacity in the whole port, some ships would have to be diverted to other ports eventually, and the revenues would decrease. Simulation was used to determine the expected revenue loss for each of the different diverting options. Moreover, the variance of the losses was calculated. The warm up period is one year and the total run time after warm up is another two years. The event is assumed to take place on day 290 (October of the first year after warm up) and the downtime is 182 days. The terminal opens to full operational status following this time period.

The calculated losses reflect the difference in total revenues for the two-year period. One hundred replications were necessary to achieve loss convergence and small standard error. The statistics of the simulated revenue differences are shown on Table 1. Figure 3 shows the expected losses together with uncertainty bounds (plus and minus one standard deviation) for the different diversion options. It can be seen that even though the losses could be significant if all the traffic was diverted to another port (20.6M), it can be minimized (2.2M) if the ships are diverted to terminal 7 instead, which appears to be the least busy terminal. The differences in losses from diverting the ships to different terminals within the same port can also be significant (to the order of thirteen million dollars). As can be seen in Table 1, the standard deviation of the revenue losses ranges is in the order of millions but the standard error of the expected losses is relatively small, in the order of hundreds of thousands. The losses are also compared with the total revenues for the two-year period and they are found to range from one to seven percent. This means that even if one of its eight terminals closes for six months, the port has enough operational capacity, compared to its traffic, that the losses due to diverted ships will be relatively small.

Table 1. Estimated statistics of revenue differences.

Divert to:	Mean [Mill. USD]	Std error [USD]	Std Deviation [Mill USD]	% Revenue difference	C.O.V
Other port	-20.6	164,922	1.65	-0.07	0.08
Terminal 1	-8.6	197,737	1.95	-0.03	0.23
Terminal 2	-13.3	220,213	2.2	-0.05	0.17
Terminal 3	-5.7	156,087	1.56	-0.02	0.27
Terminal 4	-9.5	180,449	1.8	-0.03	0.19
Terminal 5	-6.4	169,846	1.7	-0.02	0.26
Terminal 7	-2.2	29,352	0.29	-0.01	0.13
Terminal 8	-2.6	53,452	0.53	-0.01	0.21

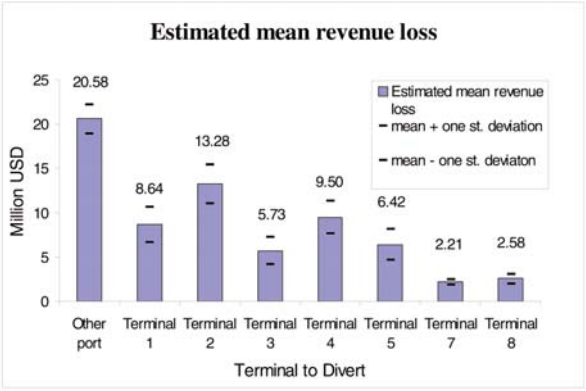

Figure 3. Estimated mean revenue differences (losses)

Summary

A comprehensive simulation model for downtime revenue loss estimation after catastrophic events in seaports was presented. Using this simulation model one can estimate the expected losses after catastrophic events and their uncertainty. The use of the methodology is demonstrated with a realistic example of an eight terminal port where an earthquake causes the closure of a terminal for six months. It is shown that simulation can assist in making emergency response decisions regarding the post event operations that can minimize the revenue losses.

The Blume Center hosted a dinner in recognition of past director **Anne Kiremidjian's** contributions to the Center on Oct. 4. The dinner followed an Affiliates Advisory Meeting to discuss future plans for the Center. Greg Deierlein presented Anne with a framed photo of herself and John Blume with a congratulatory inscription signed by Stanford President, John Hennessy.

Ph.D. Candidate **Paul Cordova** and **Greg Deierlein** participated in a full-scale composite moment frame experiment on October 7 - 18 in the National Center for Research on Earthquake Engineering (NCREE) in Taipei, Taiwan. Cordova also spent two months this past summer at the NCREE laboratory working with **Dr. Keh-Chyuan Tsai** (MS '80) and his researchers in preparation for the testing program.

Alumni News

Victor M. Nakano (MS '00) has been named the winner of the ASCE Daniel W. Mead Prize for Younger Members for his paper "Ethics and Civil Engineering: Past, Present, and Future." The Mead prize for younger members is awarded to the author or authors of a paper on professional ethics.

Keith Porter (PhD '00) and his wife, **Eve Cohen**, welcomed a baby girl, Althea Rose, on December 6. She weighed 5lbs., 6oz. and was 17" long.

Congratulations also to **Ricardo Medina** (MS '99, PhD '03) and **Gabriela Vergara-Reyes** (MS '00) on the birth of their daughter, Jennifer Alessandra, born December 28 (8lb., 5oz., 20" long).

******Alumni, Affiliates and Friends are encouraged to send any news items about yourselves to earthquake@ce.stanford.edu for inclusion in the next newsletter.******

Autumn 2002 Graduates

Ian Glaser and **Seyed-Mazier Motahari** graduated with Master's Degrees in Structural Engineering and Geomechanics and **Christopher Fleming** received a Master's Degree from the Design Construction Integration Program. **Ricardo Medina** and **Jun Peng** received their Ph.D. degrees. Ricardo is an Assistant Professor at University of Maryland, and Jun is continuing working on research with **Prof. Kincho Law** here at Stanford.

The John A. Blume Earthquake Engineering Center
Department of Civil & Environmental Engineering
Stanford University
Building 540, MC: 4020
Stanford CA 94305-4020