## MCEER RESEARCH TASK STATEMENT

<table>
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<tr>
<th>Thrust Area: 3</th>
<th>Budget:</th>
<th>Yr 9 Assigned Project Number: 9.3.6</th>
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**Task Title:** Modeling Individual and Regional Economic Resilience to Earthquakes in a Computable General Disequilibrium Framework: Demonstration Projects

**Investigator:** Adam Rose  
**Institution:** The Pennsylvania State University  
*indicates task leader

### Statement of Project Goals: (Conceptually describe what the work is intended to accomplish, in 100 words or less. Do not provide detailed description here.)

The overall goal is to further refine conceptual, empirical, and technology transfer aspects of a computable general equilibrium model to measure individual business, industry level, and community (regional macroeconomic) resilience to earthquakes. Conceptually, this means integrating the model into the MCEER resilience framework and incorporating dynamic features. Empirically, this means improving the accuracy of the model by implementing conceptual advances and recalibrating the model with LADWP and customer survey data. In terms of technology transfer, this refers to incorporating policy objectives of utility managers, and performing meaningful policy simulations that illustrate its usefulness to LADWP and other clients.

### Problem Description and Research Approach of Proposed Work for Year 9: (Detailed description of research to be conducted and methodology to be used.)

Computable General Equilibrium (CGE) analysis refers to a model of the entire economy based on decisions by individual producers and consumers in response to prices and markets within the limits of available capital, labor, and natural resources.

CGE is the state of the art methodology for economic impact analysis. This project will capitalize on the investigator’s recent refinements of CGE analysis, such as modeling individual business and household behavior, the collection of new empirical data, development of algorithms for their use in recalibrating key model parameters, modeling disequilibria, decomposition of direct and indirect impacts, and its application to measuring economic resilience.

The following tasks will be undertaken:

1. Continue work on integrating operational definitions of economic resilience into the overall MCEER framework.

2. Add dynamic features into the model. This would involve incorporating a link between investment (in mitigation and other capital), interest rates, and other financial variables into the core model. This will prove the model’s ability to evaluate mitigation investments, as well as investments to reduce the consequences of failure, such as adoption of less water- or electricity-intensive technologies.

3. Further develop a computable general equilibrium (CGE) model of the LA Economy by:
a. incorporating LADWP data on operating costs and sectoral sales
b. incorporating the behavioral response of lifeline customers from my own survey work and some of Kathleen Tierney's prior work and current collaboration

4. Work with Stephanie Chang on defining community level performance criteria. Also, work with Rachel Davidson on incorporating operational definitions of equity into the analysis. This would build on prior MCEER work on utility customer prioritization (in a mathematical programming framework) and perhaps some new work on multi-objective programming, as well as research data available on equity and public policy.

5. Continue to improve the visualization and information transfer aspects of my work. For example, the basic I-O table, which is a point of departure for a major component of the CGE model, is a great depiction of how utilities interact with their host economies in terms of their purchase of inputs and their provision of a lifeline product. It also helps demonstrate the general interdependence of the regional economy part of the community.

6. Perform a policy analysis experiment suggested by LADWP--business and household impacts of a “boil water” decree.

7. Perform policy simulations for the LA Demonstration Project in conjunction with:
   a. Tom O’Rourke for the water side
   b. Masanobu Shinozuka for the power side

   The simulations will first be performed for water and power separately and then for the two lifelines together to identify interaction effects.

Assessment of State-of-the-Art: (Describe other relevant work being conducted within and outside of MCEER, and how this project is different.)

No other MCEER researchers are involved in regional economic analysis in general (except for Stephanie Chang’s work on direct impacts and economic recovery) and in CGE modeling in particular. Economists and regional scientists at other earthquake centers are not working on CGE analysis (Peter Gordon of PEER continues to work on multiregional input-output analysis, and Geoff Hewings at MAE on conjoined econometric/I-O models).

Earlier attempts at adapting CGE models to natural hazards by David Brookshire at New Mexico and Dick Boisvert at Cornell have not followed through. My work has advanced on theirs and CGE modeling in general by: 1) using more sophisticated production functions, 2) incorporating a sophisticated approach to modeling household behavioral response (Year 8), 3) testing the sensitivity of key parameters, 4) refining the definition of and measuring individual business and community resilience, 5) incorporating real world data for parameter estimation (Year 8), 6) extending ways to model disequilibria (Year 8), and 7) working directly with stakeholders such as utility managers and customers.

Progress to date: (If applicable, a short description of achievements in previous years. Clearly distinguish progress achieved in the past year, i.e., accomplishments from April 1, 2004, to March 31, 2005.)

Major accomplishments this past year:
1. Expanded, clarified, and illustrated the definition of economic resiliency, and began its incorporation into the MCEER framework.

2. Refined and validated the LA County CGE Model.

3. Co-organized a Workshop with LADWP Staff on Utility Performance Objectives for utility and emergency management officials, managers and MCEER researchers on stakeholder needs and policy objectives.

4. Contributed to broader professional initiatives (primarily multi-hazard): a) Track A Team Leader on NIBS/ATC report to Congress on the Benefits of FEMA Hazard Mitigation Grants, b) member of an NRC Panel on Economic Benefits of Advanced National Seismic Monitoring System, and c) member of an EERI Sub-committee on Protocols for Economic Data Collection and Management. d) consultant to DHS Create Center on modeling economic impacts of terrorism, e) consultant to DHS (through ABS) on developing a capability to analyze the economic impact of terrorist attacks on 50,000 targets.

Major accomplishments in previous years:

1. Advanced the state of the art of I-O and LP models of indirect loss estimation for earthquakes and other hazards.

2. Identified and measured capabilities of nonstructural post-event recovery measures to reduce business interruption losses from earthquakes (e.g., restructuring of suppliers and customers, rationing of scarce lifeline services, interruptible service contracts).


4. Advanced the state of the art of CGE modeling for hazard loss estimation by developing an algorithm to incorporate real world data into the estimation of input parameters for lifeline services, criteria for validating CGE models applied to loss estimation, and modeling individual business and community resilience.

5. Demonstrated model capabilities in the Portland Water System Case Study, funded by a related NSF grant.


7. Supervised several graduate students whose research focused on natural hazards, and provided post-doc experience to others.

Role of Proposed Task in Support of Strategic Plan: (Describe how the effort will make a unique, useable contribution to the MCEER strategic plan.)

This task will uniquely contribute to the MCEER objective of analyzing individual business, household and regional economic aspects of community resiliency to earthquakes. It proposes further conceptual and empirical advances in a state of the art regional economic model, which explicitly incorporates resilience at the individual consumer and producer levels and assesses the impacts of their decisions, together with underlying engineering system features, on the community as a whole. It focuses on the economic impacts, but can be integrated with other dimensions. It is the only community-wide model at
an advanced stage at MCEER. The model is operational and can play a key role in the LA Demonstration Project in estimating direct and indirect business interruption losses from both water and electricity service disruptions, and simulating the regional economic impacts of mitigation and recovery policies (including policy criteria of utility managers). It has been successfully applied to related hazards: electricity blackouts due to deregulation and terrorist attacks. It is capable of being applied to damage to a broad set of structures (not just utilities) from all hazards.

**Task Integration:** (Describe how the work performed interfaces with other tasks and researchers funded by MCEER.)

My proposed research builds on the work of other MCEER researchers and will be part of an integrated, interdisciplinary system to measure community resilience to earthquakes. It will yield bottom line economic loss and resilience estimates for the LA economy (LADWP Demonstration Project) as a whole, and is generalizable to other regions. Also, the model is capable of being used for all hazards, including, with minor modifications, terrorist threats. the proposal relates to the on-going research of the following:

- T. O’Rourke — LA lifeline networks
- M. Shinozuka — network vulnerability/reliability
- D. von Winterfeldt — decisions processes
- K. Tierney — individual business and community resilience
- S. Chang — direct losses, recovery management & performance criteria
- R. Davidson — restoration of lifeline services

**Possible Technical Challenges:**

Major challenges include:
- reconciling spatial engineering data with spatial economic data through GIS
- incorporating dynamic elements
- matching theoretical properties of the model to real world needs
- adapting data on decision-making to calibrate the model
- streamlining the model so that it can be incorporated into a computerized integrated assessment framework with other MCEER researchers
- incorporating decision-makers’ objectives
- visualizing the model and its results

**Anticipated Outcomes and deliverables:** (Also indicate those of particular benefit to IAB members and other end users.)

1. Integrate economic resilience
2. Incorporate dynamic features
3. Further develop LA CGE model
4. Specify performance criteria
5. Improve visualization
6. Policy example
7. LA Demonstration Project

**Potential end-users beyond academic community:** (IAB members and others.)

1. Businessmen, Public Officials
2. Businessmen
3. Businessmen, Utility Managers
4. Utility Managers, Public Officials
5. All Stakeholders
6. LADWP, Emergency Managers
7. All Stakeholders
Educational outcomes and deliverables, and intended audience:

Continue to integrate REU and grad students into my research
Work with one of my students, Hubert Huang (M.S. in Energy and Environmental Economics, and currently working on an M.S. in Education) on an MCEER-related project.
Visualization of models and results for dissemination to students and stakeholders
Further refinement of courses on Human Dimensions of Natural Hazards and Ecological Economics and Sustainable Development
Further development of an undergraduate Natural Hazards Minor

Project Schedule and Expected Milestones for the Project: (Milestones and estimated time of achievement; e.g., Fall, Spring, Summer.)

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<thead>
<tr>
<th>Outcome</th>
<th>Date</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>January 2006</td>
<td>Integrate economic resilience</td>
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<tr>
<td>2</td>
<td>March 2006</td>
<td>Incorporate dynamic features</td>
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<tr>
<td>3</td>
<td>March 2006</td>
<td>Further develop LA CGE model</td>
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<tr>
<td>4</td>
<td>March 2006</td>
<td>Specify performance criteria</td>
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<tr>
<td>5</td>
<td>June 2006</td>
<td>Improve visualization</td>
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<tr>
<td>6</td>
<td>December 2005</td>
<td>Policy Example</td>
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<tr>
<td>7</td>
<td>September 2006</td>
<td>LA Demonstration Project</td>
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Team Members: (If known, provide names of team members associated with project including project leader, other faculty and their departments, undergraduate students, graduate students, postdoctoral students, industrial participants.)

- Tom O’Rourke (Team Leader)
- Masanobu Shinozuka (Co-leader)
- Kathleen Tierney
- Stephanie Chang
- Rachel Davidson
- Dan Wei and Tim Frazier (Penn State graduate students)
- Kristina Herz (Penn State undergraduate honors student)
- Gauri Guha (post-doc)
- Craig Davis and Glenn Singley (LADWP staff)
- David Lee (East Bay MUD)
- Detlof von Winterfeldt (CREATE)

Possible Direction of Work in Subsequent Years:

1. Circulation of questionnaire to incorporate more behavioral considerations of responses by producers, consumers, and policy-makers in conjunction with MCEER decision scientists.

2. Exploration of tangible policy advances to enhance regional community resilience, such as the establishment of an information clearinghouse to match customers without suppliers and suppliers without customers, sharing of information on best practices, and utilization by decision-makers.

3. Application to multi-hazard analysis.
**Multi-Hazard Statement:**

*a) (Conceptually describe in 200 words or less how some of the work you are conducting as part of your MCEER Year 9 research task can be exported/applied to other natural or man-made hazards including multi-hazard research.)*

My MCEER research has a relative advantage in applicability to a broad range of hazards. It focuses on the economic behavior of businesses, households, and markets, as well as their interaction in the regional economy. Rather than starting with earthquakes and branching out, the computable (dis)equilibrium model is highly general, and the challenge is to telescope in.

The model readily captures behavior that transcends a single hazard. For example, to reduce the consequences of failure, businesses can in the short run conserve water, add water inventories, substitute bottled or well water for water services, and in the long run adopt less water-intensive technologies. Conceptually, the response is similar in the electricity case, except here the service cannot be stored. Moreover, a business or household suffering a lifeline disruption has basically similar impacts and responses whether caused by an earthquake, tornado, flood or even terrorist attack (though subtle differences must be incorporated with respect to such things as aftershocks and continued terrorist threats). At the regional level, the major difference is that a terrorist attack is targeted, while hazard impacts are more random.

Thus, in my work, the strategy is not so much one of making conceptual advances, but of making sure key empirical parameters relevant to the case in point are accurate as possible, being able to model disequilibria (which I have refined in past work), and in designing meaningful scenarios to illustrate the capabilities of the model (this includes performing some analyses of major disasters and policy responses).

A regional CGE model also serves as an organizing framework for a broad set of MCEER research translated to the community (regional macroeconomy) level. This includes lifeline fragility, individual decision-maker and market resilience, and policy objectives. The model is especially adept at identifying the interaction of these various factors.

*b) If you are seeking supplemental multi-hazard funding, describe the multi-hazard milestones that you plan to complete as part of your Year 9 research.*

For year 9, I propose to perform an in-depth evaluation of how the CGE model can be applied to a broad set of hazards, including floods, hurricanes, tornados, and tsunamis, as well as terrorist threats. This will focus on identifying:

1. conceptual modifications (by January 2006)
2. empirical refinements (by March 2006)
3. data needs (by July 2006)
4. data collection (by September 2006)

It will also involve working with other MCEER researchers to design a case study application in Los Angeles or on the East Coast relating to one or more non-earthquake threats to a major utility lifeline for a Multi-Hazard Demonstration Project in Year 10.