Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Scoping Study for Unified Lifeline Risk/Reliability Models*—**601**		
Start/End Dates	10/1/00 – 6/31/01	Budget/ Funding Source	$64,996 / PG&E
Project Leader (boldface) and Other Team Members	**S.D. Werner (SSEC),** D.K. Ostrom, and C.E. Taylor (NHMI)		

1. Project goals and objectives

The objective of this project was to develop a program plan for a future PEER research program that will initially develop and demonstrate a modular, technically sound, and practical unified risk/reliability platform to: (a) evaluate seismic risks to as-built lifeline systems with no seismic improvements; (b) evaluate seismic risks to modified lifeline systems with physical and/or operational seismic improvements now included; and (c) provide results from the evaluations that can guide decision makers as they assess and then select seismic improvement strategies that limit risks to their system to acceptable levels. This initial research program will focus on the need for unification and commonalities of modeling methods for electric power and highway transportation systems. During future PEER research, this can be extended to other lifelines as well.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

The research defined by this program plan will lead to a unified seismic risk/reliability platform that will: (a) be initially developed as separate but parallel packages for electric power and highway transportation systems (using procedures/models from current practice and research) during the first two years of this program; (b) be further developed into a more sophisticated platform (with improved procedures and models from new research) during the remaining years of this program; (c) focus on system performance rather than merely component performance; (d) be developed not as a decision-making tool, but instead as a decision-guidance toll that provides useful results for lifeline-system decision makers (Figure 1 illustrates the role of this platform in one possible seismic risk reduction decision-making process.); (e) accommodate a wide range of decision-making approaches and contexts; and (f) be applied in a demonstration application to an actual electric-power and highway-transportation system in California.

3. Brief description of the accomplishments of the project

The unified risk/reliability modeling platform that will be developed under the research program defined by this program plan will contain the six main steps shown in Figure 2 and summarized below:

- ***Step 1. Initialization.*** Step 1 enables the user to define the type of seismic risk evaluation to be made, depending on his/her decision-making needs.

- ***Step 2. Inventory of Facilities.*** Under Step 2, an input database is prepared to define configurations, linkages, physical and operational characteristics, and soil conditions for the lifeline system and its components.

- ***Step 3. Evaluation of Seismic Hazards.*** Under Step 3, existing earthquake source models are used to define individual or multiple scenario earthquake events to be used in the system risk analysis. Then, existing seismic hazard models are adapted into a system model that can accommodate multiple random events, in order to estimate site-specific hazards from earthquake ground shaking, liquefaction, landslide, and surface fault rupture.

- ***Step 4. Evaluation of Component Performance.*** Step 4 enables the user to evaluate the seismic performance of each component in the system due to each of the hazards identified in Step 3 for each earthquake event. In this, the component's damage state, repair costs, and post-earthquake functionality (downtime) are estimated.
- ***Step 5. Evaluation of System Performance.*** Under Step 5, each component's functionality at various post-earthquake times is input into a model of the lifeline-system that evaluates its ability to function satisfactorily after an earthquake. As a minimum, this should include: (a) simple performance algorithms or expert opinion of system operators to assess post-earthquake performance of an electric power system; (b) traffic flow models to estimate post-earthquake traffic flows in a roadway system; and (c) return-to-service models.

- ***Step 6. Summary of Results.*** Step 6 enables the user to summarize and display the results from the previous steps, in order to communicate important technical results to decision makers.

4. Describe any instances where you are aware that your results have been used in industry

Prior versions of the platform that will be further developed under this research program have had the following industry uses: (a) a similar platform was used in 1999-2004 to evaluate costs and risks for various combinations of seismic upgrades for the Port of Oakland's entire system of berths; (b) the REDARS platform for evaluating seismic risks to roadway systems is now being used by the California Department of Transportation (Caltrans) to enable them to assess the utility of this platform in their future seismic risk reduction programs; and (c) the SERA platform was used in 1990 and 1998 to assess seismic risks to the Southern California Edison's electric power system, and was also used in 1993 to estimate seismic risks to the East Bay Municipal Utility District's water system.

5. Methodology employed

The following methodology was used to develop the program plan that was the end result of this project:

- ***Strawman Program Plan.*** The project investigators used their experience and knowledge of current practice and existing research to develop an initial strawman version of the program plan.
- ***Open-Ended Interviews and Mini-Workshops.*** The project investigators conducted open-ended interviews and mini-workshops with staff from electric power utilities (Southern California Edison, Los Angeles CA; Pacific Gas & Electric Company, San Francisco CA; San Diego Gas & Electric Company, San Diego CA; and Los Angeles Dept. of Water & Power, Los Angeles CA) and Caltrans offices statewide (District 7 Office, Los Angeles CA; District 4 Office, Oakland CA; and maintenance, engineering, and operations staff from Caltrans' Sacramento CA offices). These interviews/mini-workshops solicited feedback regarding: (a) anticipated value of a unified risk/reliability program to their seismic-risk-reduction activities; (b) future uses of such a program; (c) how the program should be developed to optimize its usefulness; and (d) engineering/planning elements of the program for which improvement through future research is most needed. The project investigators also held meetings/mini-workshops with members of the academic and consulting engineering communities, to obtain their feedback regarding relevant research/engineering practices that could be factored in the program planning.

- ***Review of Current Practice and Research.*** The project investigators conducted an independent review of current related practice and research, as well as experience from past earthquakes, in order to identify relevant research issues that should be addressed under the program plan for this unified risk/reliability platform.

- ***Updated Program Plan Development.*** The project investigators used the results of the above tasks to update the original strawman program plan. This updated plan was then reviewed by members of the PEER Lifelines Program's Joint Management Committee. Recommendations from this review were used to further modify the updated program plan, and develop the final version of the plan.

6. Other related work conducted within and/or outside PEER

Development of REDARS software for seismic risk analysis of roadway systems is being sponsored by the Federal Highway Administration, through the Multidisciplinary Center for Earthquake Engineering Research. PEER has just completed a one-year effort entitled "Database of Seismic Parameters for Equipment in Substations" that provides a systematic way (needed data and format) to gather substation/system physical data for an electrical utility system -- which is a necessary early step in conducting a detailed seismic risk analysis for such a system.

7. Recommendations for the future work: what do you think should be done next?

The research from this program plan should be carried out under the PEER Lifelines Program. Consistent parameters/metrics for determining the seismic performance of a lifeline system and for characterizing the seismic performance of the components that comprise the system should be developed.

8. <u>Author(s), Title, and Date</u> for the final report for this project

Two companion reports coauthored by S.D. Werner, D.K.Ostrom, and C.E. Taylor and published in October 2002 were developed under this project: (a) *Program Plan: Planning of Unified Lifeline Risk/Reliability Platform for Seismic Risk Decision Making;* and (b) *Process for Development of Program Plan: Planning of Unified Lifeline Risk/Reliability Platform for Seismic Risk Decision Making*.

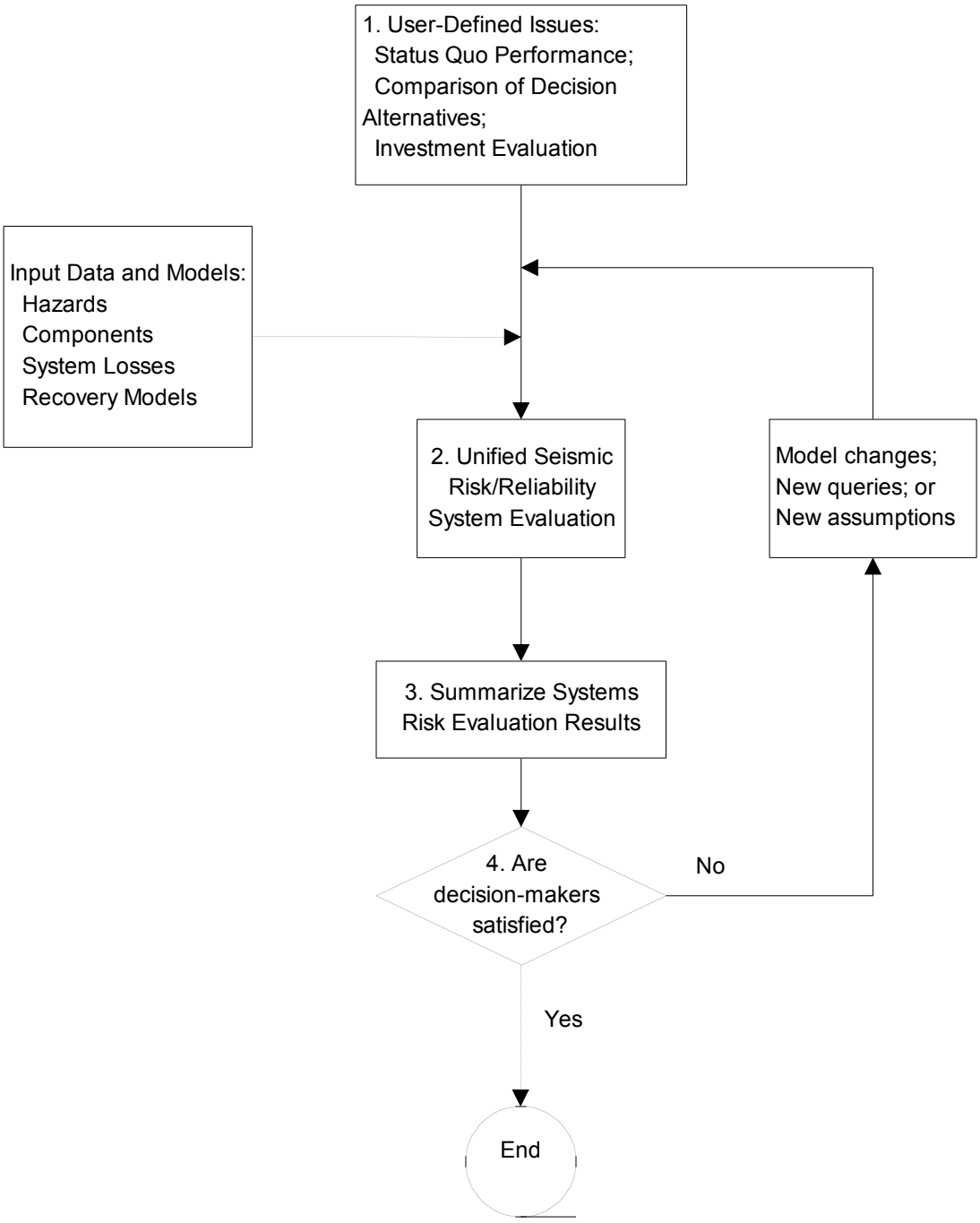

Figure 1. Role of Unified Seismic Risk/Reliability Evaluation in Seismic Risk Decision-Making for Lifelines.

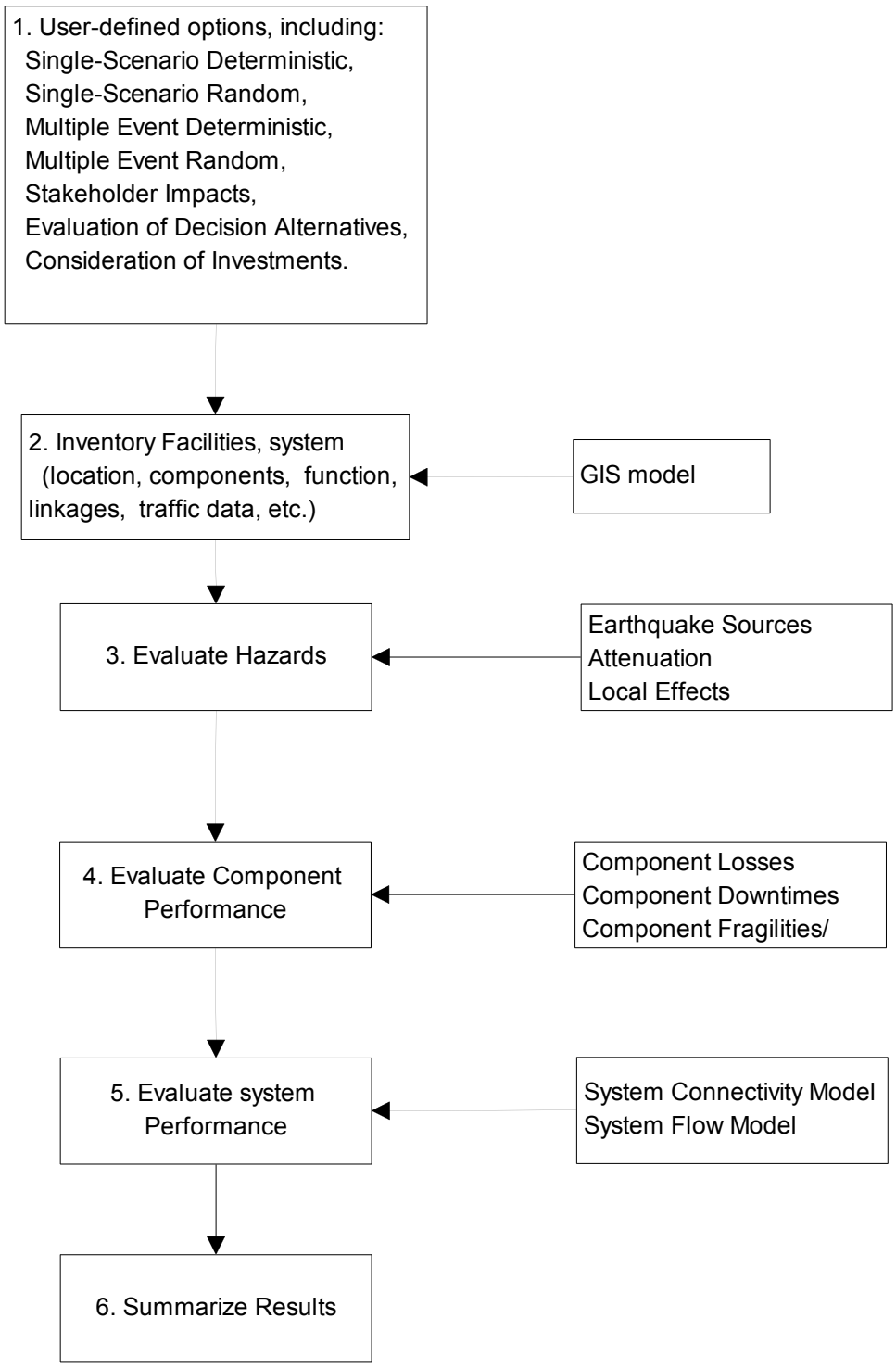

Figure 2. Basic Common Steps in a Seismic Risk/Reliability Evaluation for Lifeline Networks.