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FOUNDATIONS FOR MODELING COMMUNITY RECOVERY FROM EARTHQUAKE DISASTERS

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SUMMARY

We set out the foundations for developing robust models of community recovery from earthquake disasters. These models are a core requirement of decision support tools for increasing community resilience and reducing social vulnerability. We first present a comprehensive conceptual model of recovery. The conceptual model enumerates important relationships between attributes of a community's lifeline network, households, and businesses. The conceptual model can be operationalized to create a numerical model of recovery. To demonstrate this, we present a prototype model and graphical user interface. Being intended for decision support, it is important to involve potential model users in model development. We conducted a workshop involving Puget Sound, WA area disaster management practitioners to elicit model development needs using the prototype as stimulus.

INTRODUCTION

The 10-year anniversary of the **M** = 6.7 1994 Northridge, CA earthquake reminds us that losses to a community are not limited to the immediate physical aftermath of an earthquake. Indeed, socio-economic losses accumulate over the course of what can sometimes be a long and complex recovery process. The speed and quality of recovery with respect to recovery indicators, such as population, number of household residences, and occupancy rates, varied across different neighborhoods and socio-economic groups. A recently completely study of recovery from the Northridge earthquake found that areas that were most severely affected and lagged in recovery had higher than average populations of Hispanic, renter, low income, and non-English speaking households (Loukaitou-Sideris and Kamel [1]). Such disparities, which are also characteristic of business recovery, illustrate the strong geographic character (in terms of time, space, scale, and demographics) of socio-economic vulnerability to earthquake disasters. Fortunately, decisions made prior and subsequent to an earthquake significantly affect a community's resilience, or its robustness against initial loss and rapidity of recovery.

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It is useful then to model the effects of a community's geography and policy decisions on disaster losses and recovery trends. Recovery modeling should facilitate "what if" analyses through comparison of different pre- and post-disaster scenarios. Specifically, it is valuable to be able to characterize the effects of different policy and management decisions. However, no comprehensive model of disaster recovery currently exists in the literature. Very little research has been conducted on how recovery proceeds over time, on the spatial dimensions of recovery, and on the interdependencies between economic sectors in the recovery process. Many studies touch upon facets of recovery, but none take it as their analytical focus.

Based on previous studies on recovery, reviewed in-depth elsewhere (Miles and Chang [2]), we have developed the foundations for a comprehensive conceptual model of community recovery processes at the household and business scale. Modeling at this scale offers a component to risk assessment compatible with social vulnerability theory of risk by facilitating questions about the relationships between households, businesses, lifelines, and earthquake mitigation decisions. In the first section of this paper, we enumerate and explain the conceptual model. We have developed a prototype computer model of community recovery with a graphical user interface (GUI) to demonstrate feasibility and desirability of a robust computer model leading toward a spatial decision support system. Herein, we focus primarily on the prototype GUI and visualization of outputs. Details on computer model development, including mathematical algorithms, can be found in Miles and Chang [2]. Following presentation of the prototype recovery model, we describe a participatory workshop involving disaster management practitioners conducted to elicit practical insights for guiding future earthquake recovery research and model development efforts.

A CONCEPTUAL MODEL OF RECOVERY

Disaster recovery is fundamentally a social process involving decision-making, institutional capacity, and conflicts between interest groups. Social vulnerability theory in disaster studies suggests that marginal groups may not only be especially vulnerable to suffering losses, but they are likely to have more difficulty in recovering (Hewitt [3], Blaikie et al. [4]). They may, for example, have lesser access to insurance, loans, relief aid, or government bureaucracies and decision-making, or face shortages in low-income housing (e.g., Bolin and Stanford [5], Hirayama [6]). With respect to disparity across businesses, four main factors significantly influence the survival and recovery of small businesses: entrepreneurial skill of the business owner, post-event demand for the business' products, pre-event business characteristics such as financial condition, and availability of resources for recovery (Alesch and Holly [7], Tierney et al. [8]). Further, spatial effects have been found to be important in disaster recovery. Decentralization of population and economic activity may be accelerated (Chang [9]). Also, locally-oriented businesses generally lag in recovery (Alesch and Holly [7]; Kroll et al. [10]). To date, few of the insights culled from empirical studies have been formalized within a modeling framework. Most modeling efforts have focused on the economic losses from natural disasters. Modeled impacts are primarily driven by damage to various economic sectors and inter-industry linkages at the urban or regional scale (e.g., Gordon et al. [11]; Cho et al. [12], Chang et al. [13]).

While the literature on loss modeling has been growing rapidly, modeling of recovery processes has been largely neglected. The significance of this distinction can be illustrated by the schematic diagram of recovery in Figure 1. Loss models generally focus on initial loss (i_d), with respect to some indicator of recovery, caused by a disaster relative to the pre-disaster indicator level (i_0). A community's capacity to minimize this initial loss is referred to as robustness (Chang and Shinozuka [14]; Bruneau et al. [15]). Loss models, such as HAZUS (Whitman et al. [16]), treat the recovery timepath in a summary fashion; in the extreme case, losses are assumed to be incurred over one year, after which the economy returns to normal. Yet the recovery timepath itself clearly makes a great difference in determining overall loss. Whether a community has recovered from its losses can be measured against two baselines: the pre-disaster indicator level (i_0), illustrated by the timepath of Case A, or the likely indicator trend in the absence of the disaster (Case B). Clearly it is possible that a community's recovery timepath may equilibrate below the pre-disaster indicator level (a net loss) or, conversely, exceed the expected without-disaster trend (a net gain against either baseline). It is obviously beneficial for a community to increase the speed or rapidity with which it recovers from damage incurred immediately after an earthquake (t_0), as well as subsequent indirect losses.

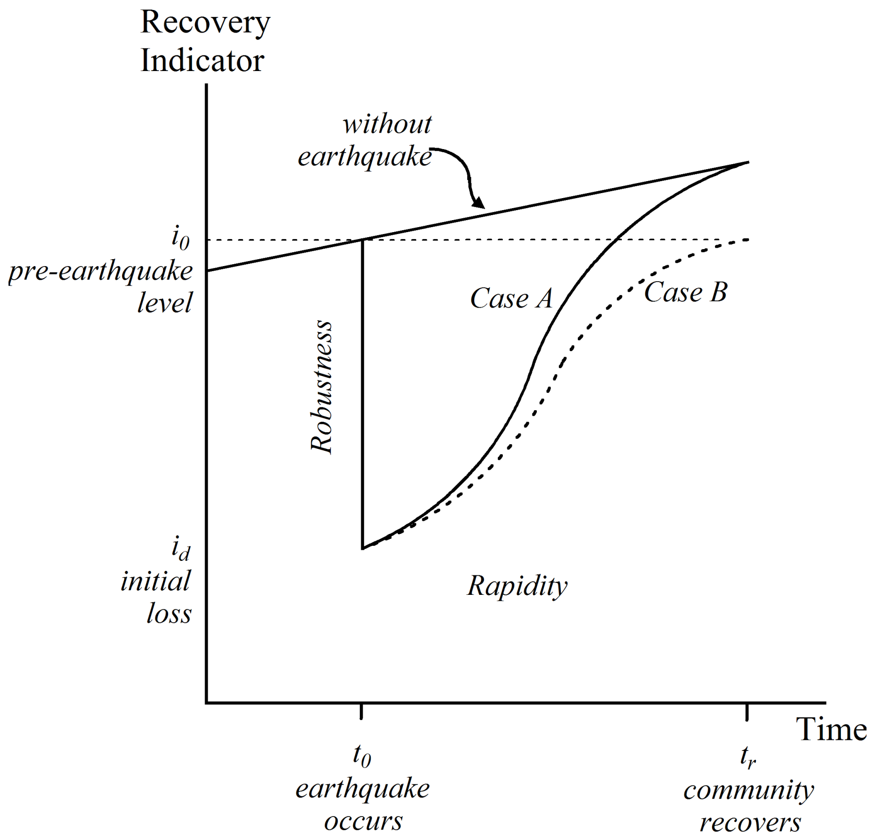

Figure 1. Schematic of Disaster Recovery

The methodology adopted for designing the recovery model is based on the object-oriented design technique introduced in Rumbaugh et al. [17]. With object-oriented design, the conceptual model of the real-world system is comprised of at least two components: the object (or static) model and the functional model. The most appealing reason for using object-oriented conceptual modeling is the paucity of numerical data that can be used in developing a model of such high detail and broad scope. There is a rich body of diverse knowledge, both in the literature and locally, on which to base a model. Object-oriented analysis provides an effective way of incorporating this array of knowledge. Another significant reason is the desire for an implementation-independent design. That is, it is important to have a robust blueprint for multiple approaches to computer modeling, while facilitating easy model modifications and development.

For initial development of the conceptual model, we constructed a narrative of community recovery based on the empirical studies described in literature (see Miles and Chang [2] for the problem narrative). From the narrative we extracted important agents, events, and interactions during an earthquake disaster. Some of these elements of recovery are presented in Figure 2, which provides a concise overview of the static and functional components of the conceptual model.

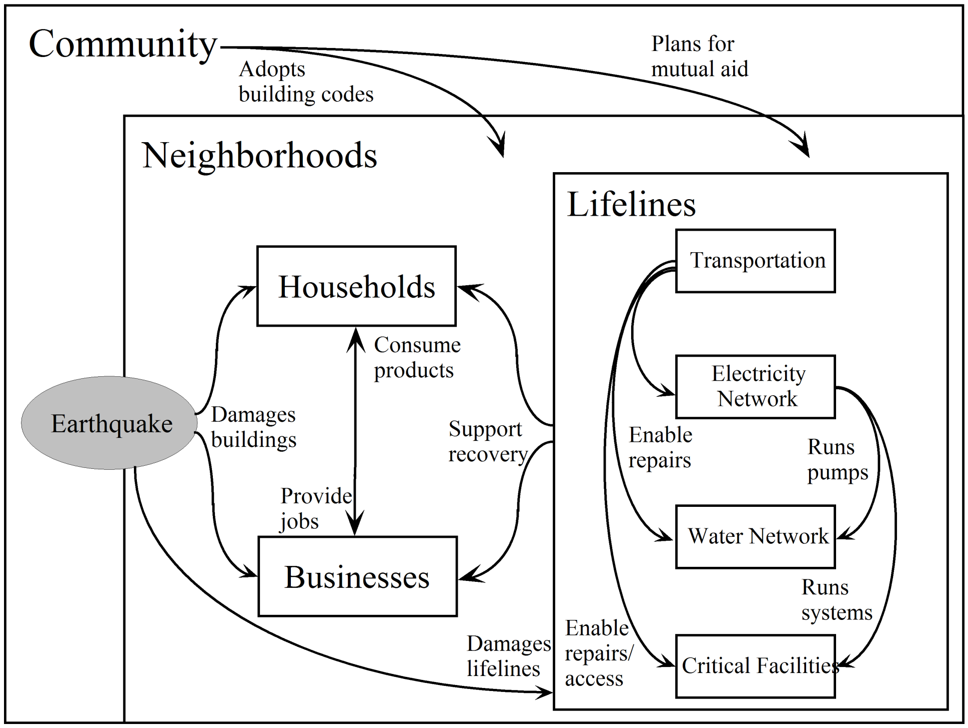

Figure 2. Overview of conceptual model of community recovery from earthquakes.

Static Model

An object model captures the static structure of a system by showing the objects or agents in the system, relationships between objects, and the attributes and behaviors that characterize each class of objects. An object can be anything that makes sense to the particular application: typically a concept, abstraction, or physical thing with well-defined boundaries. Modeled objects should promote understanding of the system (i.e., disaster recovery) and provide a sound basis for implementation.

The important object types (also referred to here as agents) of the conceptual model are the community, neighborhoods, households, businesses, and lifelines (transportation network, electric system, water network, and critical facilities). Each agent has a specific set of attributes (characteristics) and behaviors (important functions). For example, an object of type "business" has attributes of size, economic sector, year building was built, and whether any building mitigation has been done. Businesses then engage in behaviors that influence, for example, their level of indebtedness, and whether they remain in their particular neighborhood after the earthquake. These behaviors form the basis of the functions or algorithms for implementing the conceptual model. Within an implementation of the conceptual model there may be any number of businesses having the same data structure, but with different values for the respective attributes (and thus different output for the respective functions). Several agent attributes are default restoration variables. These attributes describe an agent's "normal" (without disaster) capacity for restoration with respect to some indicator. Behaviors can be associated with any agent and are either aggregated or intermediate recovery indicators.

Functional Model

The functional model specifies the meaning of the behaviors described within the object model. The functional model shows the relationship between inputs and outputs *without* regard to the specific algorithms or order of computation. This modularity is important so that it can be carried over to the computer implementation. In this way, existing equations or algorithms can be used or experimented with, without affecting the overall structure or function of the model. Whereas the object model is represented using an object diagram, a function model is typically represented using a data flow diagram. The data flows (i.e., agent attributes) are passed between the functions, represented by ellipses, of the different objects. The data flows are represented with an arrow indicating the direction of relationship (i.e., input or output). A plus sign (+) next to a data flow arrow indicates a positive relationship (i.e., increasing input value results in increasing output values), while a minus sign (-) indicates an inverse relationship.

Some of the functional dependencies within the disaster recovery conceptual model are illustrated in the flow diagrams of Figure 3 and Figure 4. (All of the static and functional diagrams of the conceptual model are given in Miles and Chang [2].) Figure 3 describes the data flow for determining the recovery of an individual business within a given neighborhood. The data flow of lifeline recovery within a particular neighborhood is encapsulated in the business functional model component by rectangles, which refer to Figure 4. (Rounded rectangles refer to aggregation of data flows described within the particular diagram.)

The functional model describes five principal types of inter-related recovery influences: (1) dynamic effects; (2) agent-attribute effects; (3) interaction effects; (4) spatial effects; and (5) policy effects. Dynamic effects refer here to changes over time. In true dynamic processes, an indicator's current level depends upon its level in a previous period. What can be called pseudo-dynamic processes – changes over time that can proceed independently of indicator levels in previous periods – also play an important role. In addition to temporal processes, a second type of recovery influence consists of agent-attribute effects. For example in Figure 3, attributes of a business – whether it is in a locally-oriented or export-oriented sector and whether it is a large or small business –may influence its recovery trajectory pertaining to the post-earthquake demand for a its product. For locally-oriented businesses, the recovery of nearby households – the customers – matters.. Similarly, transportation access influences locally-oriented business's product demand. A third type of recovery influence consists of interaction effects. For example, in Figure 4, water availability is influenced by the survival of the electric power and transportation systems. Electric power may be needed to drive pumps that enable the water system to function; transportation disruption can impede the ability of the water utility to make expedient repairs. Further, the availability of lifelines and critical facilities influence business recovery, as does the overall recovery level of households and other businesses in the economy. The fourth type of influence, spatial effects, can be seen in the examples presented so far. Households and businesses are affected by conditions in their specific neighborhoods, whether in terms of water availability, transportation conditions, or local employment opportunities. Thus, the same type of household or business may recover differently depending in which neighborhood it is located.

The final type of influence consists of policy or decision effects. These are organizational decisions made either before the event, such as emergency planning and mitigation measures, or afterwards, such as restoration prioritization and recovery policy decisions. Figure 4 illustrates the influence of decisions regarding mutual aid and neighborhood prioritization on lifeline availability. Other decisions represented in the conceptual model of recovery include the year that the community put into effect a seismic design code for its buildings (if it did); emergency planning for alternative water supplies such as water trucks; whether mitigation has been conducted for lifeline systems; the availability of a disaster plan; use of short-term housing in place of temporary shelter; and a measure of a community's political integration and capacity for consensus.

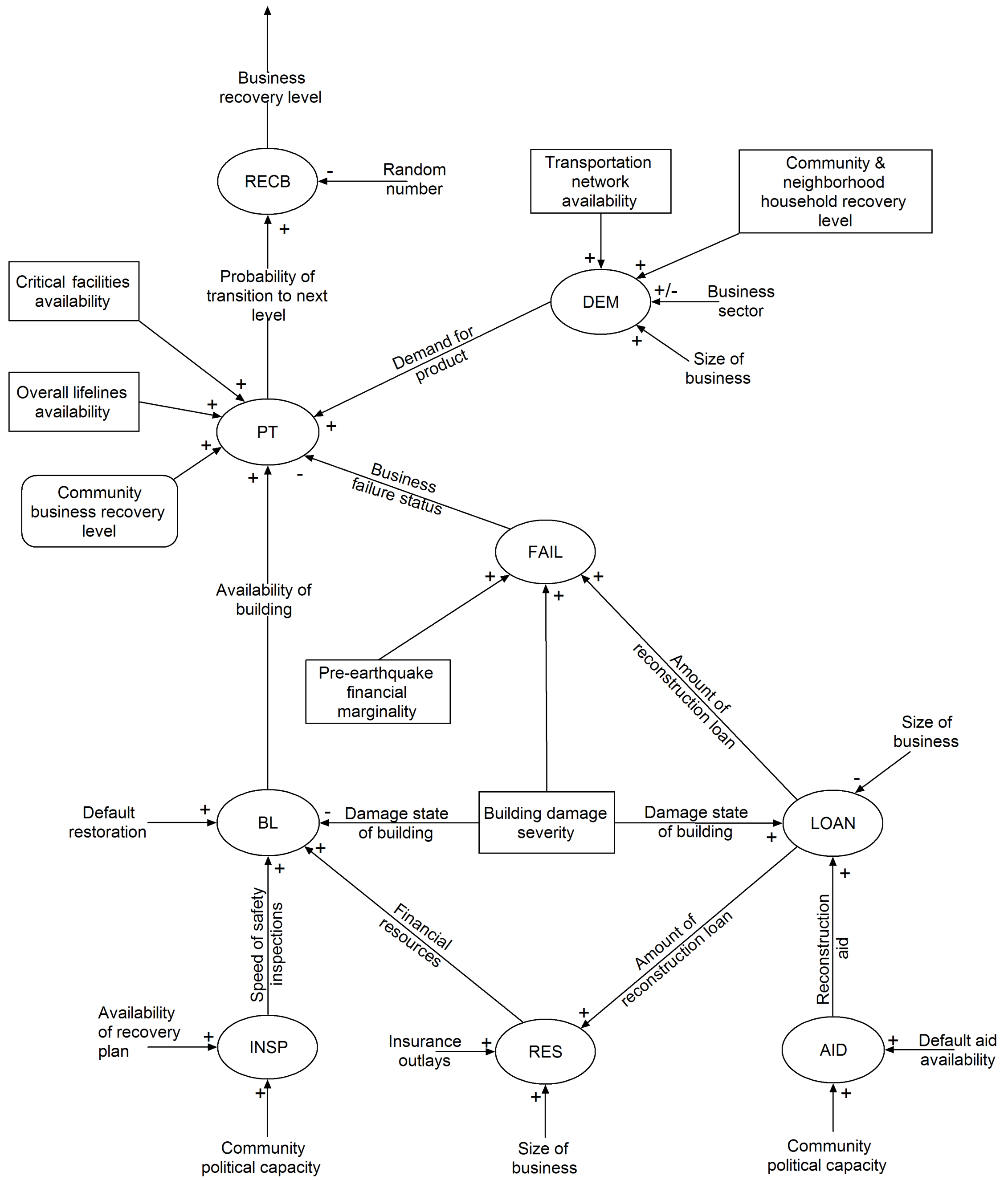

Figure 3. Flow diagram for business recovery component of the functional model. Arrows represent object attributes and the direction of their influence. Diagram elements are defined within text.

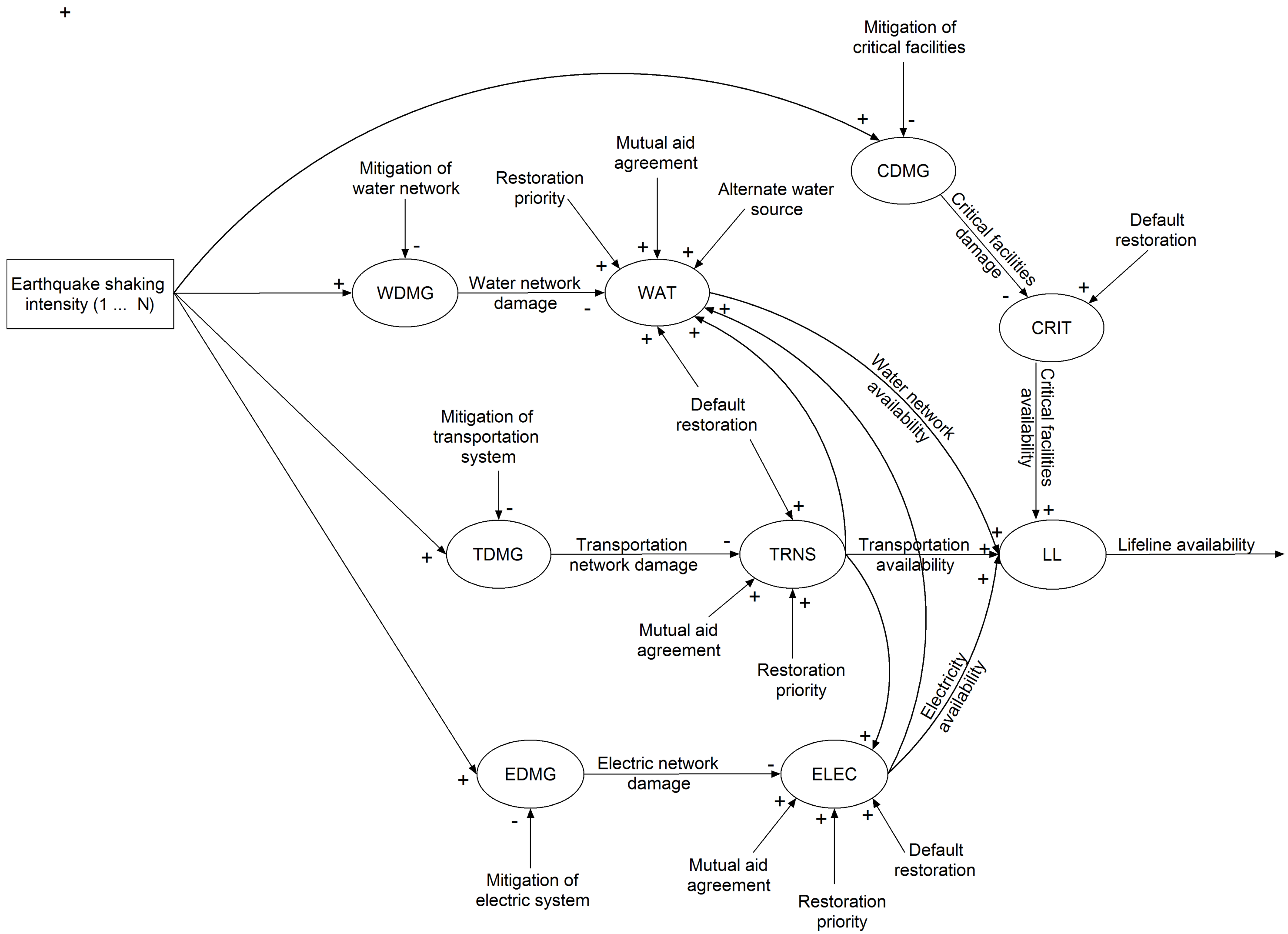

Figure 4. Flow diagram for lifeline recovery component of the functional model, referred to in Figure 3. Diagram elements are defined within text.

PROTOTYPE IMPLEMENTATION

In order to stimulate research and development on much needed decision support tools, we have implemented the conceptual model described above in the form of a prototype computer model and graphical user interface (GUI). For brevity, only a general overview of the prototype development and specifications is given here (see Miles and Chang [2]). The prototype was developed towards two objectives. The first objective was to demonstrate the feasibility of implementing the complex set of relationships that make up the conceptual model for a community populated with a large number of households and businesses. The second objective was to elicit critical issues, needs, and applications for developing future decision support tools.

The conceptual model enumerates relationships between many of the critical objects or agents within the recovery process, but does not specify the means for operationalizing these relationships. We devised a simple numerical framework to facilitate convenient implementation of the functional relationships. The framework takes the form of 32 unique equations, including 9 equations to define the behaviors of businesses and 10 for households. The total number of equations for a particular application of the model depends on the particular number of households and businesses. Operationalizing the diverse relationships of the functional model was done by specifying each model variable (attribute or characteristic) as a relative index that varies between 0 and 1, rather than in real world metrics, such as dollars. The approach taken is useful for integrating many metrics that would otherwise be difficult to mathematically combine. We then derived basic first-order algebraic equations based on the relationships specified in the functional model.

The prototype, implemented with the Simulink modeling tools of Mathwork's MATLAB software, is for a community consisting of four neighborhoods or analysis zones, each having 100 businesses and 100 households. The seismic hazard, community characteristics and demographics within the prototype implementation are based on the city of Kobe, Japan and the earthquake disaster of 1995 (see Miles and Chang [2] for details). A GUI, shown in Figure 5, was constructed to afford the posing of "what if" questions related to attributes of a community's demographics, lifeline network, building infrastructure, and socio-political preparedness. The questions are formed by indicating (via checkboxes) desired community or lifeline mitigation policies and by specifying the attributes of businesses (size, sector, and building resilience) and households (income and building resilience) as a percentage of the neighborhood population. Based on these questions, a user can run the underlying prototype recovery model to graphically observe the possible influence on the degree and speed in which the community will recover from a significant earthquake. As Figure 6 illustrates, model users can explore the recovery disparity between neighborhoods (analysis zones) for different scenarios of disaster preparedness and mitigation decisions.

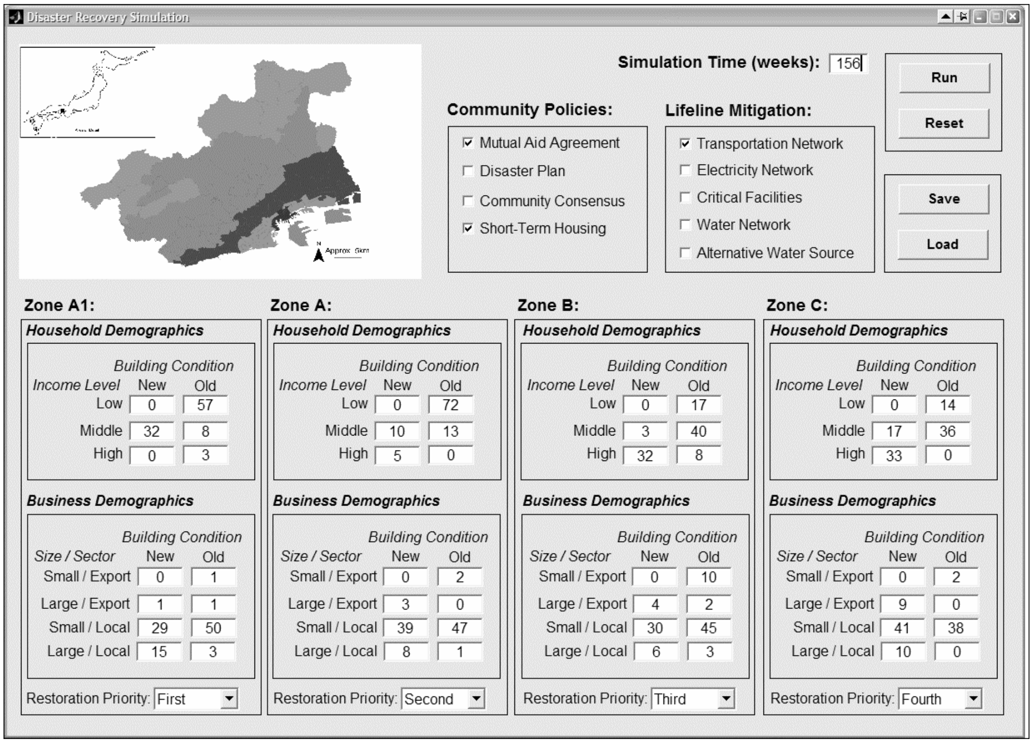

Figure 5. Graphical user interface of the recovery model prototype.

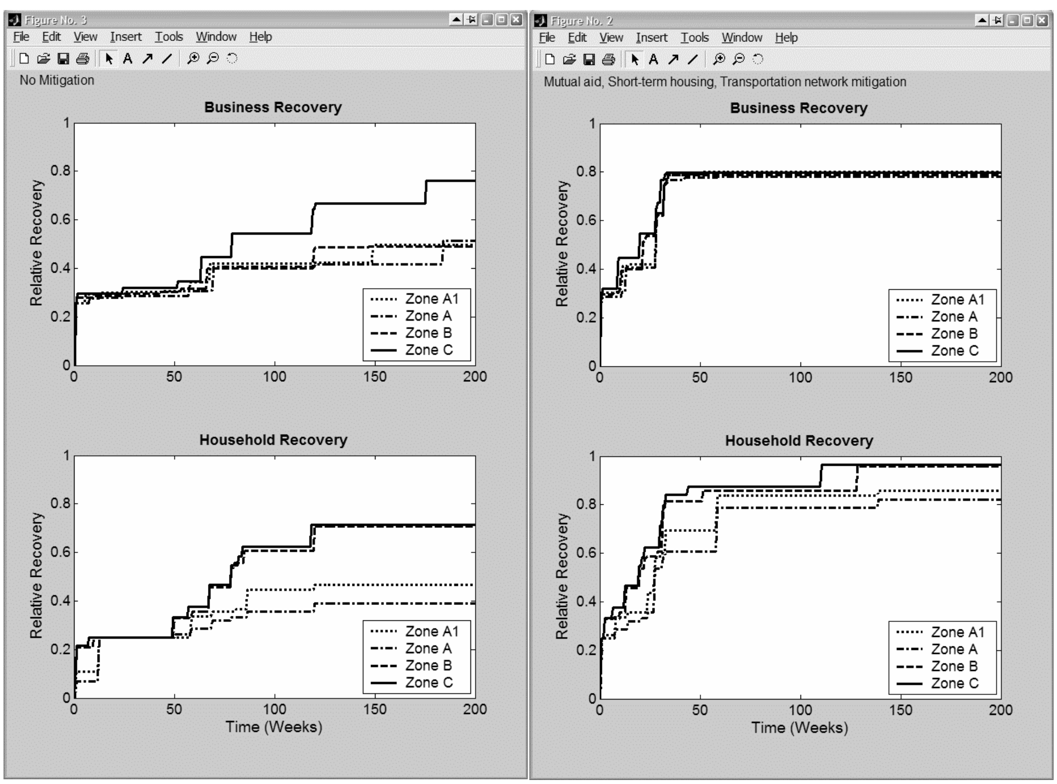

Figure 6. Graphical output generated using prototype recovery model and graphical user interface. Left-most output represents a "no mitigation" scenario, while the right-most output represents a scenario incorporating disaster preparedness and lifeline mitigation.

PARTICIPATORY MODEL ASSESSMENT

Computational models are typically evaluated analytically through sensitivity analysis and empirical comparison, with the results of analysis being used to guide further model development. The analytical evaluation conducted on the prototype to date is described in Miles and Chang [2]. Because the recovery model is intended for supporting people in making collaborative decisions, it is important to involve potential users in developing the prototype recovery model. Participatory model assessment elicits model development needs and perspectives on model appropriation that cannot be done using purely analytical techniques (Miles [18], Hornecker et al. [19], Durrenberger et al. [20], Hennen [21]). With respect to the prototype recovery model, issues requiring feedback include the following: the most suitable uses for recovery models; the best way of delivering the model (i.e., software development); what inputs the model needs to consider, and what indicators of recovery the model should predict.

Participatory Assessment Workshop

To solicit feedback on the prototype model, we invited Puget Sound, WA area disaster management practitioners to participate in a model assessment workshop. The workshop involved nine participants employed by a variety of organizations: FEMA, county disaster management, city disaster management, a local public utility, a local university, a regional non-profit for earthquake mitigation, and a local engineering/planning firm. The workshop was held in the Department of Geography's "collaboratory" at the University of Washington, which is specifically designed for computer-assisted group collaboration. Following introductions, two informal presentations (i.e., discussion was encouraged) were given: the first about concepts of community loss and recovery; the second about the development of the prototype recovery model and GUI. Participants were broken into two arbitrary groups of four or five to interact with the prototype recovery model GUI by suggesting decision scenarios for project personnel to explore. Participants were then asked to complete a questionnaire asking about their field of work, the best uses for the future model (or decision support system), what policy and decisions are most useful to model (i.e., input variables), and what indicators of recovery are most important. Each set of multiple-choice questions (on a 5-point scale) was accompanied by a solicitation for free form comments. Before wrapping up the meeting, participants engaged in a discussion on two general topics: (1) suggestions/requirements for further development of the model and software and (2) appropriate/expected roles and applications for the decision support tool.

Workshop outcomes

With respect to potential uses of the recovery model, mitigation and recovery planning were rated highest by participants. The other suggested uses – emergency manager training, general (K-12) education, emergency response, and public awareness – on average scored increasingly lower. Participants commented that the technical model outputs would need to somehow be translated, simplified, or contextualized for educational or public awareness purposes. Participants commented that the recovery model would be a useful tool within planning offices because planners are often less knowledgeable about recovery issues than, for example, emergency managers.

Workshop participants had a wide range of views regarding the means of delivering the recovery model (i.e., software application). Most interestingly, participants were unsure whether the loss estimation software HAZUS is the appropriate means of disseminating the recovery model. One participant commented that the outputs of HAZUS are not accurate enough to serve as the basis of the recovery model. Some suggested that it is important to be able to input damage data (or HAZUS output) into the recovery model. The suggestion of a non-HAZUS extension to ESRI's ArcGIS received the highest score from participants. However, participants commented during the group discussion that not all organizations have or can afford GIS. Thus, they expressed a need for scalable solutions, including non-GIS tools available over the World Wide Web.

Overall, participants thought that all decisions or community characteristics currently represented within the prototype are important. Participants expressed a need for more detailed and explicit definitions for the modeled decisions – impetus for further social science research on the influence of policies, plans and mitigation strategies. On average, participants felt that the influence of decisions related to a community's political integration (capacity for consensus) and mutual aid agreements were least important. The former is likely because of the ambiguity of the decision variable as represented in the conceptual model; the latter perception reflects the wide spatial effect of severe earthquake shaking on a region's response and restoration capacity. Comments given indicated that disaster plans should be represented at finer scales, including the neighborhood level and within individual businesses or organizations. Other characteristics suggested by participants include some indication of a community's experience with previous disasters. Lastly, it was suggested to include some measure of the strength of neighborhood organizations.

Many useful insights were provided by participants' regarding business and household characteristics. They noted the importance of modeling business and household post-earthquake movements between neighborhoods and other communities. With respect to businesses, participants felt that more detailed characterization of a business's building(s) is needed, including the physical type of building (e.g., brick or wood-frame). Further, it is important to track the number of buildings a business leases or owns, especially if these buildings are not contiguous. Participants suggested that additional business sectors be modeled, including manufacturing, retail, and government agencies. Unique perceptions regarding households included the value of characterizing whether residences are single- or multi-family homes. With respect to a household's ability to earn (and spend) an income, participants discussed characteristics such as residents' ages, number of wage-earners, family composition, and source of income(s). A final requested household characteristic is the English speaking ability of a household.

In terms of indicators or measures of recovery, several participants commented on the need to include some indicator of communication systems recovery. An additional suggested lifeline recovery indicator was capacity of solid waste and sewage service. Participants felt that critical facilities needed to be represented in more detail, modeling hospitals, fire, police, etc. separately within the recovery process. Not surprisingly, participants indicated that economic indicators are critical to include in the recovery model. Conversely, participants brought up several social indicators including measures of a community's mental health, quality of life, or degree to which social support systems are in place. They observed that these indicators are necessary to temper unsustainable strategies for economic recovery.

CONCLUSION

This paper embodies a foundational effort towards developing robust models of community recovery from earthquakes and other disasters. The comprehensive conceptual model set out here is the first of its kind since the simple framework presented by Haas, Kates, and Bowden [22]. The conceptual model provides a common and flexible basis for building complementary computer models of socio-economic recovery from disasters. Modelers can focus on developing algorithms for some subset of the relationships within the model or can use integrated modeling methodologies to create a consistent set of algorithms. In parallel, software tools can be constructed for facilitating interaction with recovery models and communication of their results. Group support tools for organizing and choosing alternatives can be identified towards creating a comprehensive decision support system, which could possibly include the array of alternative models that researchers develop.

Further, our conceptual model provides a systematic framework for empirical research into the important agents and relationships in the recovery process after an earthquake disaster. Which variables and relationships within the conceptual model are most important? Do the direction and sign of influence reflect future empirical findings? Which objects, attributes or behaviors are not yet included? What empirical data is needed to make these assessments? Like the insights gained during the participatory assessment workshop, which need to be integrated into the conceptual model, local knowledge from practitioners and citizens can be elicited to investigate and expand the conceptual model. The participatory model assessment workshop conducted as part of this work clearly demonstrates the value of this type of knowledge elicitation for future research and development efforts. Participation will also instill a sense of trust and familiarity on the part users and stakeholders with the tools that are developed and, most importantly, the decision processes in which they are appropriated. Finally, participatory inquiry will help to build an understanding about how these tools should be used within different management and planning contexts towards reducing social vulnerability and increasing community resilience.

REFERENCES

1. Loukaitou-Sideris A and Kamel N. "Residential Recovery from the Northridge Earthquake:An Evaluation of Federal Assistance Programs." Berkeley, CA: California Policy Research Center, 2004.
2. Miles S and Chang S. "Urban Disaster Recovery: A Framework and Simulation Model." Buffalo, NY: Multidisciplinary Center for Earthquake Engineering Research Technical Report 03-0005, 2003.
3. Hewitt K. "Regions of Risk: A Geographical Introduction to Disasters." Essex, England: Addison Wesley Longman Limited, 1997.
4. Blaikie PCT, Davis I and Wisner B. "At Risk: Natural Hazards, People's Vulnerability, and Disasters." New York: Routledge, 1994.
5. Bolin R and Stanford L. "Shelter, Housing and Recovery: A Comparison of U.S. Disasters." Disasters 1991; 15(1): 24-34.
6. Hirayama Y. "Collapse and Reconstruction: Housing Recovery Policy in Kobe after the Hanshin Great Earthquake." Housing Studies 2000; 15(1): 111-128.
7. Alesch D and Holly J."Small Business Failure, Survival, and Recovery: Lessons from the January 1994 Northridge Earthquake."1998.
8. Tierney KJ and Dahlhamer J. "Business Disruption, Preparedness and Recovery: Lessons from the Northridge Earthquake." NEHRP Conference and Workshop on Research on the Northridge, California Earthquake of January 17, 1994. Richmond, CA: CUREe, 1998.
9. Chang S. "Structural Change in Urban Economies: Recovery and Long-Term Impacts in the 1995 Kobe Earthquake." The Kokumin Keizai Zasshi (Journal of Economics & Business Administration) 2001; 183(1): 47-66.
10. Kroll C, Landis J, Shen Q and Stryker S. "Economic Impacts of the Loma Prieta Earthquake: A Focus on Small Businesses." Berkeley, CA: U.C. Transportation Center and the Center for Real Estate and Urban Economics working paper #91-187, University of California at Berkeley, 1991.
11. Gordon P, Richardson H and. Davis B. "Transport-Related Impacts of the Northridge Earthquake." Journal of Transportation and Statistics 1998; 1(2): 21-36.
12. Cho S, Gordon P, Moore II J, Richardson H, Shinozuka M and Chang S. "Integrating Transportation Network and Regional Economic Models to Estimate the Costs of a Large Urban Earthquake." Journal of Regional Science 2001; 41(1): 39-65.
13. Chang S, Svekla W and Shinozuka M. "Linking Infrastructure and Urban Economy: Simulation of Water Disruption Impacts in Earthquakes." Environment and Planning B 2002; 29(2): 281-301.
14. Chang S and Shinozuka M. "Measuring Improvements in the Disaster Resilience of Communities." Earthquake Spectra in review.
15. Brunea et al. "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities." Earthquake Spectra 2003; 19(4): 733-752.
16. Whitman R, Agnagnos T, Kircher C, Lagorio H, Lawson R and Schneider P. "Development of a National Earthquake Loss Estimation Methodology." Earthquake Spectra 1997; 13(4): 643-661.
17. Rumbaugh J, Blaha M, Premerlani W, Eddy F and Lorenson W. "Object-Oriented Modeling and Design." Upper Saddle River, NJ: Prentice-Hall, 1991.

18. Miles S. "Participatory Assessment of a Comprehensive Geographic Model of Earthquake-Induced Landslides." Seattle, WA: Department of Geography, University of Washington, 2004.
19. Hornecker E, Eden H and Scharff E."Role Play as Assessment Method for Tools Supporting Participatory Planning."Binder T, Gregory J and Wagner I, Editors, Proceedings of the Participatory Design Conference, 2002: 243-247.
20. Dürrenberger G, Kastenholz H and Behringer J. "Integrated assessment focus groups: bridging the gap between science and policy?" Science and Public Policy 1999; 26(5): 341-349.
21. Hennen L. "Participatory technology assessment: a response to technical modernity?" Science and Public Policy 1999; 26(5): 303-312.
22. Haas JE, Kates R and Bowden M, Editors, "Reconstruction Following Disaster." Cambridge, MA: MIT Press, 1977.