California Seismic Safety Commission

Global Earthquake Model Foundation (GEM)

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"Back to Normal": Earthquake Recovery Modelling

Possible Applications to Policy Making

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1. Introduction

The rapid and efficient recovery of a community following a damaging earthquake constitutes the main concern of the affected residents. Uninformed and hasty decisions and actions during the immediate response and recovery stage, may lead to long recovery times and/or leave the community exposed to the same risk as before the event. Lessons learned from previous earthquakes and the identification of the factors that impede the recovery process, provide stakeholders and decision-makers with valuable information on how to be better prepared and more resilient against earthquakes. Existing studies on recovery have demonstrated that the time of a community to recover is not only affected by the extend of the physical damage, but is strongly related to the pre-existing socio-economic conditions of the affected regions. To this end, the work within the project "Back to Normal": Earthquake Recovery Modelling, intends to facilitate stakeholders to take decisions based on the actual needs of their community. The tool provides (predicts) an immediate overview of the recovery progress over time, taking into account both the physical damage and the differential socio-economic conditions within communities. To exemplify, stakeholders can identify vulnerable areas that take longer to recover and prioritize their actions accordingly. In addition, the tool may be used not only following an event, but could be valuable beforehand for the development of efficient pre-disaster recovery plans.

2. Recovery Modeling Tool

For the integration of physical risk modeling, socioeconomic parameters, and recovery prediction capabilities, the work utilizes the OpenQuake Integrated Risk Modelling Toolkit (IRMT). The IRMT leverages the open-source QGIS platform http://www.qgis.org/en/site/. A GIS based platform was chosen explicitly to utilize a geographic information systems ability to store, manage, manipulate, analyze and present data for decision-making to facilitate recovery processes. As part of the tool's design, elements of Multi Criteria Decision Analysis (MCDA) were adopted into the workflow. MCDA is a decision-making method for dealing with complex, multidimensional, problems such as disaster recovery. It involves a problem structuring phase and the synthesising/evaluation of different criteria. MCDA can be used as a tool in a multitude of decision-making processes such as to help structure the problem at hand, to learn from the underlying data being analyzed, to identify pros and cons, and to accommodate various types of information (quantitative / qualitative).

For earthquake recovery management, analysts such as urban planners and disaster risk managers can use MCDA to offer decision-makers the opportunity to evaluate different criteria (in this case pre-existing social conditions modeled using indicators) against recovery outcomes based on the existing building stock within a community and a level of ground shaking. The MCDA framework provides methods to structure and analyze problems by means of indicators (social, political, economic, risk, hazard, etc.) and to elicitate the relative importance of the indicators within an interactive and dynamic environment. Particularly, in the context of recovery the software will allow stakeholders display the indicators that are used in the recovery model using various output and visualizations formats. To facilitate the weighting assignment process, the tool will allow the stakeholders to change and manipulate the existing weights and interactively investigate the changes upon the total ranking outcome of socioeconomic conditions and recovery outcomes.

The workflow for the development of a recovery assessment consists of an "ideal sequence" of steps, from the selection of variables to the presentation and dissemination of recovery curves. The intent is for the software to guide the user through this process via a workflow that facilitates: 1)

the selection of sub-indicators (variables); 2) the normalization of indicators; 3) assessment of the relationships between data; 4) weighting and aggregation; 5) physical risk calculation and risk integration; 6) the generation of potential recovery outcomes; and 7) presentation of the results. Due to their importance for decision-making, a brief description of the tool's variable selection and weighting components are outlined below.

3. Data Selection:

The selection of variables often comprises the first step of the tool's workflow. The case study conducted for Napa utilizes indicators of resilience to represent characteristics within social systems that affect the ability of populations to prepare for, respond to, and recover from earthquake events. An essential step for developing plans to facilitate recovery from an earthquake event is the ability to objectively measure resilience. Measurement is vital not only to evaluate and benchmark the baseline conditions of what makes communities resilient, but also to help communities to understand the factors that lead to adverse impacts and the diminished capacity to recover an event. Just as successful companies have identified areas of opportunity for betterment and benchmarked their performance against industry peers, governments are finding it useful to compare the performance of communities in terms of their resilience. The latter is partially to attract public interest in disaster loss reduction, to set priorities, to measure progress, and to aid in decision-making processes. Composite indicators (often referred to as indices) are often employed as useful tools to accomplish this objective because they convey information that may be utilized as performance measures. Generally speaking, an indicator is a quantitative or qualitative measure derived from observed facts that simplify and communicate the reality of a complex situation. A composite indicator is the mathematical combination of individual indicators that represent different dimensions of a concept that cannot be fully captured by any individual indicator alone.

Although indicators are increasingly recognized as useful tools for policy-making and public communication because they convey information that may be utilized as performance measures, they are subject to a number of criticisms that are highly applicable to modeling and understanding

recovery processes. Indicators, for instance, may send misleading messages if they are poorly constructed or misinterpreted. In addition, indicators may invite overly simplistic conclusions regarding areas of opportunity to enhance the resilience of communities. Indicators may also lead to inappropriate conclusions if dimensions of resilience that are difficult to measure are ignored. Such dimensions include the amount of social networking within and between communities, cultural attributes, and government effectiveness.

To capture local processes for decision-making and the production of relevant indicators and targets for producing actionable information different types of indicators that are representative of the local knowledge, conditions, and context are amenable to input into the recovery tool. These types of indicators cannot be computed from publically available databases (such as those from national censuses) and require the design of targeted surveys with a specific audience in mind. It is within this context that GEM and its partners developed a Resilience Performance Scorecard that is a multilevel and multi-scale self-evaluation tool that empowers stakeholders to quantitatively assess earthquake resilience parameters based primarily on qualitative information. Here, an interactive voting system is used in a workshop setting to identify priorities where activities may be pertinent for earthquake risk reduction or where existing initiatives may be improved to increase earthquake resilience in different sectors of society. Six dimensions of earthquake resilience are encompassed to address key areas that mainstream risk reduction into planning and decision-making processes: social capacity, awareness and advocacy, legal and institutional, planning and regulation, critical infrastructure and services, and emergency preparedness and response. These outcomes may be input into the IRMT and compared to recovery predictions to better understand low-hanging fruit for resilience enhancement.

4. Weighting:

Central to the construction of composite indicators is the need to meaningfully combine different data dimensions in a manner in which consideration is given to variable weighting. Most composite indicators rely on equal weighting largely for simplicity. However, equal weighting implies that

all variables within an index are of equal importance. The latter may not actually be the case, however. The IRMT and recovery modelling platform provides methods for weighting based on participatory approaches. These include the incorporation of weights based on the use of the Analytic Hierarchy Process (AHP) and the input of weights based on a graphical view of the hierarchical structure of the data that adheres to MCDA principals (see Figure 1). This AHP process promotes the role of participants in the decision process, facilitates compromise and group decisions, and provides an adequate platform for stakeholders to communicate their personal preferences regarding the input and weighting of data that will affect the recovery modelling outcomes.

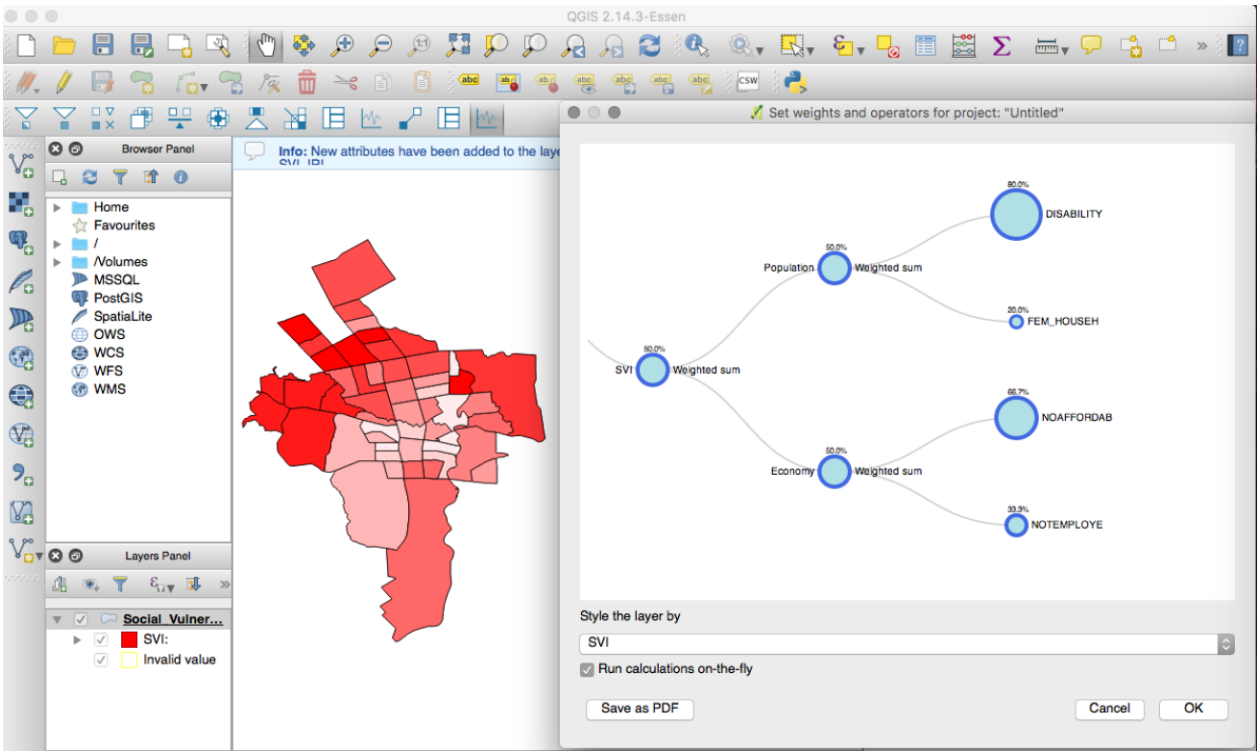

Figure 1: Example of weighting of social vulnerability indicators using hierarchical structure

5. Applications of the tools to Policy Making

National Hazard Maps

The Italian National Institute for Geophysics and Volcanology (INGV) is currently using the OpenQuake engine to produce the official national hazard map which will then be used to inform national seismic legislation including construction regulations. The same engine has been used and is being used in a number of other cities, countries and international regions for analyses at various scales.

Earthquake Scenarios and Emergency Planning

In the context of this project, we produced a scenario damage model which simulates the effects of the Napa earthquake, but it is also possible to modify this model to produce alternative scenarios to simulate earthquakes of different magnitude and/or locations and to produce estimates of damage, loss and recovery times. The results of such analyses can be used inform emergency planning activities. One possible example might be to identify the need for temporary shelter based on the estimated recovery time as predicted by the proposed model.

Benefit-Cost Calculations

The OpenQuake engine can also be used to explore the compare the performance of buildings with and without retrofitting, or with different insurance policy typologies. Similarly the tools can be used to explore how changes in building constructing might influence recovery times.

Benchmarking to produce best practices for recovery facilitation

The recovery tool was designed to utilize predictions of damage based on a community's current building stock and pre-existing social conditions to produce a predicted recovery outcome. These

can be used as benchmarks prior to an event or decision making for which policy is affected. These benchmarks can be reviewed over time to gauge changes in potential recovery outcomes to better understand policy effectiveness.

6. Possible Future Extensions

The aforementioned tool and methodologies could provide valuable information to stakeholders for more effective actions towards an efficient and rapid recovery. Thus, additional research and long-term recovery studies become imperative in order to improve the tool and the reliability of its results. Some possible future activities include:

- Continue to monitor the actual recovery in Napa, California and compare the recovery progress with the predictions produced within this project. In this way we can test the reliability of the future predictions of the model and further refine the approach and tools.
- Monitor recovery from other events which includes other perils to better understand if drivers of long-term recovery from other events (i.e. high frequency events such as floods) can be used as an effect proxy for earthquake recovery.
- Use existing results of analysis to drive further studies and damage/recovery data collection initiatives to further refine approach and explore drivers of recovery.
- Collect more recovery/damage data, but also attempt to gather other types of data by involving, for example, insurance companies and compare recovery of insured vs uninsured buildings.
- Produce application specific tools - initiate projects to build on the existing tools for specific target uses (e.g. fire department, insurance department, urban planning, site location…) which provide alternative user interfaces and bring in relevant data from other sources, so as to facilitate the use of the project results for specific activities
- Collect building inventory data and socio-economic indicators for other cities/areas so as to be able to run scenarios and provide recovery estimates for other geographic locations outside of Napa.
- Compare data for Napa recovery with that of other cities, attempt to produce a unified methodology which is applicable in different areas of the world (obviously using different parameters for different places/situations)

- Specific analysis for critical infrastructure, hospitals, schools or other buildings of particular interest or importance.
- Specific analysis for business interruption costs e.g. internet access loss, California has many organizations which will suffer enormous losses from lack of connectivity.
- To consider to what extent changes in scale might lead to contradicting results. At minimum, research should be conducted to better understand the association between damage, resilience, and recovery potential at different scales.