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Comparative Analysis of Existing Tools for Assessment of Post-Earthquake Short-Term Lodging Needs

Annibale Vecere[a,*], Ricardo Monteiro[a], Walter J. Ammann[b]

[a] *Institute for Advanced Study (IUSS) of Pavia, Piazza della Vittoria, 15, Pavia, Italy*
[b] *Global Risk Forum, GRF Davos, Promenade 35 CH-7270 Davos Platz, Switzerland*

Abstract

The assessment of shelter needs aimed at displaced population in the aftermath of major earthquake events is one the main challenges that emergency responders currently have to face. The study presented here is focused on a critical review of currently available methodologies and software packages that were developed specifically to estimate the number of displaced people and those who will most likely seek public sheltering and will need temporary housing. The main features and shortcomings of such tools are shown.

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Keywords: Seismic risk, Short-term shelter needs, 2011 Christchurch earthquake, Temporary housing software tools;

1. Introduction

Findings from various earthquake events in the past suggest that the decision to leave home and seek public shelter is influenced by the impact to the physical infrastructure: built environment, networks of water, electricity, gas, etc. (Zelaschi et al., 2015) as well as the socio-economic and demographic characteristics. Wright et al. (2010) divided factors that contribute to evacuation decision making in two groups – one related to the impact to the physical infrastructure and the levels of damage caused by earthquake shaking and the other related to socio-economic, demographic and individual characteristics, which are less tangible, but equally important. Following a thorough

* Corresponding author. Tel.: +393406560862.
E-mail address: annibale.vecere@umeschool.it

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literature review on currently available risk assessment tools (GFDRR, 2014), six software tools dealing with shelter needs estimation were identified: SYNER-G (2009-2012), HAZUS (2006), ERGO-EQ (2014), the MCEER model (Chang et al., 2008), INASAFE (2014) and RiskScape (2014). In this paper, a summary description of each software tool is presented with a view to introduce its main features. A final comparison is carried out to highlight major potentialities and shortcomings.

2. Temporary housing predicting tools

2.1. SYNER-G

The European FP7 project SYNER-G (2009-2012) presented an advanced methodology for post disaster shelter needs assessment revealing strong links between socio-economic factors influencing the decision to seek for alternative accommodation and structural damage or, generally, structural habitability (building usability, utility loss and weather conditions). In the SYNER-G tool, the shelter needs index (SNI) is a combination of a displaced persons index (DPI) (based on age, type of housing, household tenure, perceived security) and a shelter seeking index (SSI) (based on income, ethnicity, education, car ownership). Shelter accessibility is also included in the shelter needs index (Fig. 1).

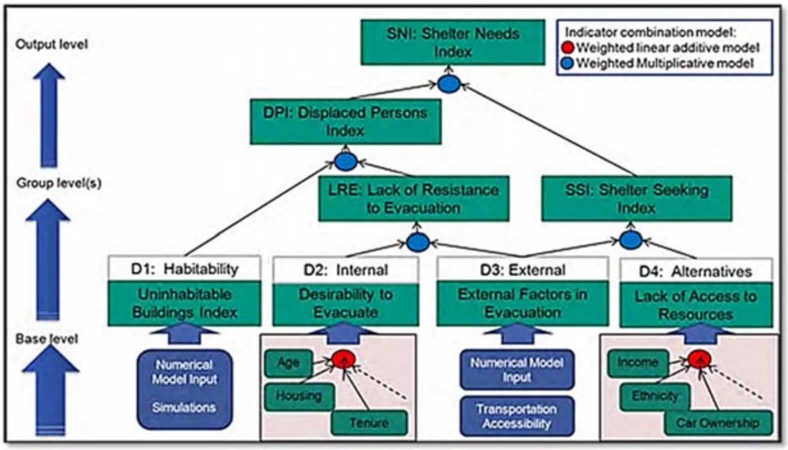

Fig. 1. SYNER-G Shelter Needs Index: hierarchical multi-criteria framework (JRC 2013).

The SYNER-G model is an open source code that provides input for a Multi Criteria Decision Analysis framework in which all of the above mentioned factors are weighted and combined. The main disadvantage of the SYNER-G framework is the limited adaptability, as it requires a significant amount of time to adapt the code to specific characteristics.

2.2. HAZUS-MH

HAZUS-MH (2006) is a geographic information system-based software platform for natural hazard loss and risk assessment developed by the FEMA in the US. It represents certainly one of the most widely used earthquake loss estimation software tools that are also capable of calculating short term shelter needs. This is accomplished by calculating, first, the number of displaced households due to loss of habitability (i.e. related to structural damage, estimated using e.g. pushover analysis – Pinho et al., 2013; Monteiro et al., 2014) and then weighting this value with other socio-economic variables such as income, ethnicity, age and ownership. Whilst considering both physical and social vulnerability models, the main limitation of HAZUS-MH relates to the number of displaced people, which is based on structural damage and socio-economic variables calibrated on a US social fabric. Furthermore, it is census based and shelter accessibility is ignored – differently from SYNER-G shelter model (Chang et al., 2008).

2.3. ERGO-EQ

ERGO-EQ (2014) is a seismic risk platform developed at the Mid-America Earthquake Center at used to estimate important data for planning and responding to earthquake disasters. It applies a Consequence-based Risk Management (CRM) methodology to evaluate and visualize expected physical, economic and social impacts of seismic hazards on geographic regions. ERGO-EQ implements a modified, improved version of the HAZUS-MH shelter algorithm, as it utilizes different damage state probabilities for estimating the number of displaced households. Furthermore, ERGO-EQ takes into account the actual number of dwellings per residential structure and calculates household dislocation for each single family structure (rather than by tract) and then aggregates the results at census block level. In addition, ERGO-EQ presents two additional displaced household algorithms: the Logistic Regression Approach, based on direct economic damage and ethnic factors (e.g. percentage of Black and Hispanic people), and the OLS through the Origin Approach, including also the number of vacant housing units and number of structures with one detached dwelling unit. Finally, the software provides an estimate of both the public shelter needs, by applying HAZUS logic, and of shelter supply requirements.

2.4. MCEER Shelter Model

The MCEER shelter model consists of a linear set of decisions, depicted in Figure 2, based on the model of Chang et al. (2008). The MCEER shelter model can be seen as an improvement of the HAZUS-MH methodology and consists of a sequence of four questions, ranging from building habitability to perceived desirability to leave home (function of tenure, age, housing conditions, weather) and shelter (public or not) accessibility parameters (distance, car ownership). This conceptual model depicts the decision making process about shelter use at household level and, for this reason, was taken as a reference in other models, such as SYNER-G. The MCEER shelter model is a theoretical model that can be implemented in a spreadsheet. As such, it represents a flexible tool for risk managers however it needs to be integrated with another risk assessment software providing the required building damage input.

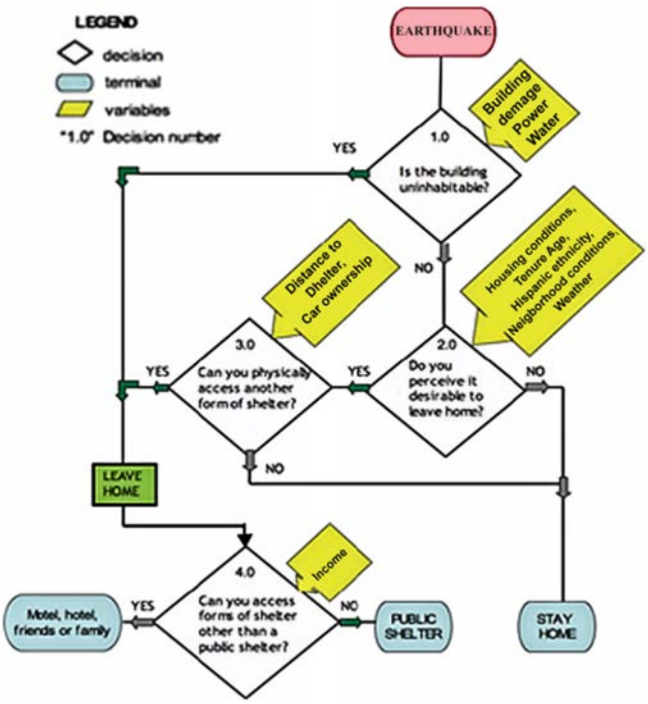

Fig. 2. MCEER shelter model – conceptual framework, Chang et al., [1].

2.5. InaSAFE

InaSAFE (2014) was developed within a project of the Australia-Indonesia Facility for Disaster Reduction (AIFDR) and GFDRR and is a plugin that takes exposure (population, buildings) and hazard data (MMI) from any model. It then couples it with simple vulnerability functions to calculate output in terms of disaster impact through a GUI in a QGIS plugin form. The software includes a tool to measure shelter needs (amount of rice, drinking water, family kits and toilets) based on the number of displaced people estimated from the exceedance of an imposed limit for a specific level of damage. In this sense, the software is not able to produce an estimate on the number of people in need of public shelter taking into account also socio-economic factors.

2.6. RISKSCAPE

RiskScape (2014) is an initiative of the New Zealand Government's Foundation for Research, Science and Technology, which in 2004 decided to fund the development of an impact and loss modelling tool. The software implements a series of fragility functions providing several measures of loss with respect to a pre-defined input hazard and in correspondence to each analysed asset. Among such loss measures, the one of interest for shelter needs calculation is represented by the human displacement measurement. This is a state based fragility measurement and represents the extent to which humans and human activities are displaced by exposure of the asset to the hazard. All the mentioned calculations are made for each spatial unit (meshblock) chosen by the user. In conclusion, RiskScape provides only a measure of human displacement (including time needed before reoccupation), relying on a state based fragility measurement.

3. Results and Discussions

A comparison of the features and potential of the different software tools is presented in Tables 1 and 2. From the observation of Table 1 is it immediate to notice that all the analysed methodologies include building structural damage (building usability) as a basis for population dislocation estimates. In particular, for InaSAFE and RiskScape, this is the only parameter used for that calculation which is based on the exceedance of an imposed threshold for a specified level of damage and a state based fragility measurement, respectively. On the other hand, the other methodologies, which represent four out of six, can also provide an additional output: shelter needs estimation. For this aim, they combine physical damage with a basic set of social vulnerability indicators (age, income, ethnicity and household tenure) to come up with a minimally accurate estimate for dislocated people.

Table 1. Parameters included in population dislocation and/or shelter needs calculation.

Parameters included in population dislocation and/or shelter needs calculation	SYNER-G	HAZUS-MH	ERGO-EQ	MCEER	INASAFE	RISKSCAPE
Building Structural Damage (Building Usability)	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓		
Income	✓	✓	✓	✓		
Ethnicity	✓	✓	✓	✓		
Household Tenure	✓	✓	✓	✓		
Utility Loss	✓	✓	✓	✓		
Weather Conditions	✓		✓	✓		
Housing Type	✓			✓		
Car Ownership	✓			✓		
Distance to Shelter	✓			✓		
Perceived Security	✓					
Enforced Evacuation Area	✓					
Education	✓					
Direct economic Damage			✓			
Neighbourhood condition				✓		
Fire, inundation and other hazardous materials		✓				

Then there are five extra variables which are used in SYNER-G and MCEER shelter model (distance to shelter, car ownership, housing type, weather conditions and utility loss) and some variables which are exclusive of specific methodologies (see Table 1). In terms of output produced, Table 2 provides a summary of the main findings.

4. Conclusions

In comparative terms, among the six currently available software tools analysed, SYNER-G represents the methodology that includes the largest and widest range of parameters in population dislocation and shelter needs calculation, even if its output is in terms of relative ranking expressed by the displaced population index (DPI) and shelter needs index (SNI). The MCEER shelter model results are a function of many of the factors used in SYNER-G and they are produced at dwelling units. However, it needs to be translated by the user in an operative tool, typically using a calculus spreadsheet. HAZUS-MH and ERGO-EQ are presented in the form of closed software packages and utilize the HAZUS logic for shelter needs calculation. ERGO-EQ has different algorithms for computing displaced people, in addition to the modified HAZUS approach, which also take into account utility loss, weather conditions and direct economic damage, and it works at dwelling unit level. InaSAFE and RiskScape methodologies provide only human displacement as a result of building damage alone. According to the authors' opinion any software tool intending to be general-purpose needs to foresee easily adaptable models tailored to the specific context and optional variables that will be able to fine tune the social components of the estimate. Further research is still needed to identify and quantitatively calibrate other relevant social and cultural location-specific parameters, which will be able to capture actual decisional processes that lead to seek public shelters in the aftermath of an earthquake. This could be accomplished by including this type of variables already in the estimation of displaced people, as it was observed in SYNER-G, MCEER or ERGO-EQ. In the calibration phase of these local variables it could also be useful to reduce the uncertainty of the building damage analysis outputs by using actual building damage observation (for example, by inferring it from building tagging system).

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