International Journal of Disaster Risk Reduction 17 (2016) 185–198

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Evaluation of social context integrated into the study of seismic risk for urban areas

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ARTICLE INFO

Article history:
Received 14 January 2016
Received in revised form
6 May 2016
Accepted 9 May 2016
Available online 10 May 2016

Keywords:
Urban seismic risk
Social vulnerability
Social fragility
Lack of resilience
Social indicators
Holistic assessment of seismic risk

ABSTRACT

Usually the seismic risk evaluation involves only the estimation of the expected physical damage, casualties or economic losses. This article corresponds to a holistic approach for seismic risk assessment which involves the evaluation of the social fragility and the lack of resilience. The complementary evaluation of social context aspects such as the distribution of the population, the absence of economic and social development, deficiencies in institutional management, and lack of capacity for response and recovery; is useful in order to have seismic risk evaluation suitable to support a decision making processes for risk reduction.

The proposed methodology allows a standardized assessment of the social fragility and lack of resilience, by means of an aggravating coefficient of which summarizes the characteristics of the social context using fuzzy sets and Analytic Hierarchy Process (AHP). The selection of 20 social indicators is based on the indicators used by urban observatories of United Nations and other social researchers. These indicators are classified according to social item they describe, in six categories. Applying the determination level analysis, thirteen prevailing social indicators are selected. The proposed methodology has been applied in the cities of Merida (Venezuela) and Barcelona (Spain).

1. Introduction

Several methodologies to evaluate risk due to natural hazards have been developed around the world. Usually, these methodologies provide an estimation of the potential physical damage in an urban area exposed to a specific natural hazard. In general, the physical damage is evaluated as damage both on buildings and lifelines, and different types of victims (people killed, injured, homeless and jobless).

Among the methodologies focused on seismic risk, some can be mentioned: the methodologies developed in EEUU, the ATC-13 [1], RADIUS [2] and HAZUS [3]; in Europe RISK-UE [4], LESSLOSS [5], SYNER-G [6], UPStrat-MAFA [7], the international initiative GEM [8] and the platform for probabilistic evaluation of risk CAPRA [9,10].

The study of the seismic vulnerability of urban areas has been focused on the physical dimension without mention of the social dimension. However, this approach is changing; the relevant authorities are recognizing the importance of social aspects, such as, rapid population growth, access to good quality education and health, application and development of construction standards and level of governance, among others [11]. Globally there are different criteria and definitions to quantify the social context [12–18].

The seismic risk in urban areas is usually assessed in terms of physical losses that can occur. However, the risk can be evaluated from a comprehensive (or holistic) approach taking into account aspects of the social context like: economic and social development absence, deficiencies of institutional management, and lack of capacity for response and recover from a dangerous event.

The first international United Nations (UN) conference to fully recognize the challenge of urbanization was held in 1976 in Vancouver, Canada (Habitat I). This conference resulted in the creation of the precursors of UN-Habitat: the United Nations Commission on Human Settlements – an intergovernmental body – and the United Nations Centre for Human Settlements (commonly referred to as "Habitat"), which served as the executive secretariat of the

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http://dx.doi.org/10.1016/j.ijdrr.2016.05.002

Commission.

Twenty years later, 1996, the second United Nations Conference on Human Settlements (Habitat II) was held in Istanbul, Turkey. The aim was to address two main twin goals, namely (1) to ensure adequate shelter for all and (2) to guarantee sound development of human settlements in an urbanizing world. This conference was organized to assess two decades of progress since Habitat I and to set fresh goals for the new millennium. As result, the Habitat agenda was proclaimed containing over 100 commitments and 600 recommendations. Other global conferences were held between the conferences Habitat I and II, on which Habitat II reaffirmed its results.

The Millennium Declaration was adopted by the 189 members of the United Nations, on September 8th of 2000. It was based on global conferences held during the 1990s. The countries committed to the right to development, peace and security, gender equality, poverty eradication and sustainable human development. The Millennium Development Goals (MDGs) by 2015 consisting in 8 goals to be achieved, with 18 targets and a set of 48 technical indicators to measure their progress were established following the adoption of the Millennium Declaration. In 2007, the monitoring framework was updated to 21 targets and 60 indicators [19].

On the other hand, the Disaster Risk Management Index (DRMi or RMI) is widely used to evaluate the risk management performance of a country or a city. The DRMi brings together a group of indicators related to the risk management performance of the country. These reflect the organizational, development, capacity and institutional action taken to reduce vulnerability and losses, to prepare for crisis, and to efficiently recover [20–22]. This index is evaluated by using the qualitative measurement based on pre-established desirable referents (benchmarking) towards which risk management should be directed, according to its level of advance. For RMI formulation, four components or public policies are considered: Risk identification (RI), Risk reduction (RR), Disaster management (DM) and Governance and financial protection (FP). According to Carreño et al. [21,22] the evaluation of each public policy takes into account 6 subindicators that characterize the performance of management in the country. Assessment of each subindicator is made using five performance levels: low, incipient, significant, outstanding and optimal, that corresponds to a range from 1 to 5, where 1 is the lowest level and 5 the highest.

As result of several World Conferences promoted by United Nations and others urban observatories, social indicators have been established to reflect different social aspects for any urban area around the world. These indicators are figures that allow describing complex and intangible aspects of the society.

Cardona [17] developed a conceptual framework and a model for risk analysis of a city from a holistic perspective, describing seismic risk by means of indices. He considered both “hard” and “soft” risk variables of the urban centre, taking into account exposure, socio-economic characteristics of the different areas or neighborhoods of the city and their disaster coping capacity or degree of resilience. One of the objectives of this model is to guide the decision-making in risk management, helping to identify the critical zones of the city and their vulnerability from the perspective of different professional disciplines. This method base the evaluation in a relative normalization of the involved indicators.

Carreño [23] developed an alternative method for Urban Risk Evaluation, starting from Cardona's model [17], in which urban risk is evaluated using composite indicators or indices. Expected building damage and losses in the infrastructure, obtained from loss scenarios, are basic information for the evaluation of a physical risk index in each unit of analysis [24]. Often, when historical information is available, the seismic hazard can be identified and thus the most potential critical situation for the urban centre. It conserves the approach based on indicators, but it improves the procedure of normalization and calculates the final risk indices in an absolute (non-relative) manner. This feature facilitates the comparison of risk among urban centers. The exposure and the seismic hazard were eliminated in the evaluation method because they are included into the calculation of the physical risk variables. The Carreño's approach [24,25] preserves the use of indicators and fuzzy sets or membership functions, proposed originally by Cardona [17], but in a different way. Afterwards, the robustness of the methodology was evaluated [26]. The methodology has been also applied to other cities as Metro-Manila, The Philippines, and Istanbul, Turkey [27,28].

The holistic evaluation of risk using indices is achieved aggravating the physical risk by means of the contextual conditions, such as the socio-economic fragility and the lack of resilience. Input data about these conditions at urban level are necessary to apply the method. The socio-economic fragility and the lack of resilience are described by a set of indicators (related to indirect or intangible effects) that aggravate the physical risk (potential direct effects). Thus, the total risk depends on the direct effect, or physical risk, and the indirect effects expressed as a factor of the direct effects. Therefore, the total risk is expressed as follows:

$$R_T = R_F\left(1 + F\right) \tag{1}$$

where R_T is the total risk index, R_F is the physical risk index and F is the aggravating coefficient. This coefficient, F, depends on the weighted sum of a set of aggravating factors related to the socio-economic fragility, F_{FSi}, and the lack of resilience of the exposed context, F_{FRj}, respectively. The descriptors used in this evaluation have different nature and units, the transformation functions standardize the gross values of the descriptors, transforming them into commensurable factors with values between 0 and 1.

An alternative method base on the fuzzy sets theory was proposed to be used in cases where information on physical risk, social fragility or lack and resilience are not available, but local expert opinion can be obtained [29,30].

This paper proposes a methodology to calculate the aggravating coefficient by using standard indicators, easy to collect, measuring social aspects which can make the situation worse in the case that a seismic event occurs. This paper defines a minimum and maximum number of indicators which can represent the social aspects that should be taken into account for a seismic risk evaluation.

2. Social context evaluation

This section proposes an indicator selection process in order to define the social indicators to be involved into the aggravating coefficient (F) for the holistic evaluation for the seismic risk. This selection is based on the indicators adopted and recognized at global level.

Based on several social indicators recognized at global level and the comprehensive or holistic approach for the seismic risk assessment, the following sub-sections show the selection process of social indicators that contribute to the aggravating coefficient, F, the determination of an optimum number of indicators (n), the calculation to establish the factors associated to each social indicator ($F_{social\ indicator\ i}$) and their participation weights (w_i) involved in Eq. (2).

$$F = \sum_{i}^{n} w_i * F_{social\ indicator\ i} \tag{2}$$