EARTHQUAKES AND MEGACITIES INITIATIVE

HOLISTIC EVALUATION OF THE SEISMIC RISK FOR METRO MANILA

CHECK LISTS AND FORMS FOR THE REQUIRED INFORMATION

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HOLISTIC EVALUATION OF THE SEISMIC RISK

In the past, the concept of risk has been defined in a fragmentary way in many cases, according to each scientific discipline involved in its appraisal. At nowadays, the risk is defined, for management purposes, as the potential economic, social and environmental consequences of hazardous events that may occur in a specified period of time. From the perspective of this article, risk requires a multidisciplinary evaluation that takes into account not only the expected physical damage, the number and type of casualties or economic losses (direct impact), but also the conditions related to social fragility and lack of resilience conditions, which favour the second order effects (indirect impact) when a hazard event strike a urban centre. The urban seismic risk evaluation is proposed from a holistic point of view; that is, an integrated and comprehensive approach to guide decision-making. Evaluation of the potential physical damage (hard approach) as the result of the convolution of hazard and physical vulnerability of buildings and infrastructure is the first step of this method. Subsequently, a set of social context conditions that aggravate the physical effects are also considered (soft approach). In this method the holistic risk evaluation is based on urban risk indicators. According to this procedure, a physical risk index is obtained, for each unit of analysis, from existing loss scenarios, whereas the total risk index is obtained by factoring the former index by an impact factor, based on variables associated with the socio-economic conditions of each unit of analysis.

This method developed by Carreño, Cardona and Barbat[1] for urban risk evaluation is based on Cardona's model and uses a holistic approach and describing seismic risk by means of indices. Expected building damage and losses in the infrastructure, obtained from future loss scenarios are basic information for the evaluation of physical risk in each unit of analysis. Starting from these data, a physical damage index is obtained.[2] The holistic evaluation of risk by means of indices is achieved affecting the physical risk with an impact factor, obtained from contextual conditions, such as the socio-economic fragility and the lack of resilience, that aggravate initial physical loss scenario. Available data about these conditions at urban level are necessary to apply the method. This approach contributes to the effectiveness of risk management inviting to the action identifying the hard and soft weaknesses of the urban centre.

In this paper the proposed holistic evaluation of risk is performed using a set of input variables, herein denominated descriptors. They reflect the physical risk and the aggravating conditions that contribute to the total potential impact. Those descriptors, listed forward, are obtained from the loss scenarios and from socio-economic and coping capacity information of the exposed context. The socio-economic fragility and the lack of resilience are a set of factors (related to indirect or intangible effects) that aggravate the physical risk (potential direct effects). Thus, the total risk[3] depends on the physical risk and the indirect effects expressed as a factor, as follows:

[1] See paper of the Annex 1
[2] The method is developed for a multi-hazard evaluation however it is necessary to dispose of physical damage estimations for all the significant hazards. Often, when historical information is available, the major hazard can be usually identified and the most potential critical situation.
[3] Expression known as the Moncho's equation in the field of disaster risk indicators.

$$R_T = R_F(1+F) \quad (1)$$

where R_T is the total risk index, R_F is the physical risk index and F is the impact factor. 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}

$$F = \sum_{i=1}^{m} w_{FSi} \times F_{FSi} + \sum_{j=1}^{m} w_{FRj} \times F_{FRj} \quad (2)$$

where w_{FSi} and w_{FRj} are the weights or influences of each i and j factors and m and n are the total number of descriptors for social fragility and lack of resilience respectively. The aggravating factors F_{FSi} and F_{FRj} are calculated using transformation functions[4]. These functions standardise the gross values of the descriptors transforming them in commensurable factors. The weights w_{FSi} and w_{FRj} represent the relative importance of each factor and are calculated by means of the Analytic Hierarchy Process (AHP). It is used to derive ratio scales from both discrete and continuous paired comparisons. The physical risk, R_F, is evaluated in the same way, using the transformation functions.

$$R_F = \sum_{i=1}^{p} w_{RFi} \times F_{RFi} \quad (3)$$

where p is the total number of descriptors of physical risk index, F_{RFi} are the component factors and w_{RFi} are their weights respectively. The factors of physical risk, F_{RFi}, are calculated using the gross values of physical risk descriptors such as the number of deaths, injured or the destroyed area, and so on. It is estimated that the indirect effects of hazard events, sized by the factor F in equation 1, can be the same order of the direct effects. According to the Economic Commission for Latin America and the Caribbean, it is estimated that the indirect economic effects of a natural disaster depend on the type of phenomenon. The order of magnitude of the indirect economic effects for a ‘wet’ disaster (as one caused by a flood) could be of 0.50 to 0.75 of the direct effects. In the case of a ‘dry’ disaster (caused by an earthquake, for example), the indirect effects could be about the 0.75 to 1.00 of the direct effects, due to the kind of damage (destruction of livelihoods, infrastructure, housing, etc.). This means that the total risk, R_T, could be between 1.5 and 2 times R_F. In this method, the maximum value selected was the latter. For this reason, the impact factor, F, takes values between 0 and 1 in equation 2, in this case.

In summary, risk estimation requires a multidisciplinary approach that takes into account not only the expected physical damage, the number and type of casualties or economic losses, but also other social, organizational and institutional issues related to the development of communities that contribute to the creation of risk. At the urban level, for example, vulnerability seen as an internal risk factor should be related not only to the level of exposure or the physical susceptibility of the buildings and infrastructure

[4] See Annex 1 for details.

material elements potentially affected, but also to the social fragility and the lack of resilience of the exposed community. The absence of institutional and community organization, weak preparedness for emergency response, political instability and the lack of economic health in a geographical area contribute to risk increasing. Therefore, the potential negative consequences are not only related to the effects of the hazardous event as such, but also to the capacity to absorb the effects and the control of its implications in a given geographical area.

The process is initiated with the identification of imaginable variables that may “reflect” the status of the urban center. The different descriptors should be defined using available information for all cities of the metropolitan urban center. Conceptually they should reflect, in the more direct possible manner, what is being valorized and the simultaneous use of variables or indicators that closely express the same aspect should be avoided.

The variables may perhaps not have a strong comparability or commensurability. Before integrating the descriptors, these should be scaled in compatible non-dimensional units that allow commensurable relative analyses. The area of public space available for the mass attention of people and rescue personnel, for example, cannot be related directly, because square meters is used for the first variable, and a people count for the second. The technique adopted for this case is to scale with regard to a set of transformation functions. Once the scaled values are represented in graphic form this facilitates the comparison of results between different cities of the metropolitan urban center. The transformation functions are inverse when the factor is inverse to the descriptor which is valued, as is the case with the resilience indicators, which are inverse to the vulnerability of the context.

To express the result as a linear combination implies that interaction does not exist among the indicators or between the indicators and the participation factors used for the weighting. Nevertheless, almost all the indices of this type, developed so far, use an approach based on a linear combination and the search for other approaches has allowed the conclusion that the linear combination is acceptable if the uncertainties and inaccuracies inherent in the data are considered.

The hierarchical or structural analysis of the variables (indicators) is the following step. It consist of determining the impact or influence of each variable on all of the rest for the purpose of determining its “weight” or importance using matrices of relationships. This activity may be done by taking into account the opinion of experts or different social actors by using the Delphi Method (consensus and feedback process with anonymity of the participants). Multi-criteria evaluation is a decision-making technique that allows the involvement of different perspectives, for example the seismic risk estimation from a physical, economic, social, political, institutional, etc. point of view. Multidisciplinary evaluation techniques, like the one mentioned, based on indicators or indices, have recently been recommended by different specialists for the purpose of reformulating public policies regarding disaster prevention and risk reduction.

Check list 1. Physical risk descriptors, their units and identifiers

Descriptor		Units	Is this information available for all cities?		If not, this indicator could be replaced by
			Yes	No	
X_{RF1}	Damaged area	% (destroyed area / constructed area)			
X_{RF2}	Dead people	Number of deaths per 1,000 people			
X_{RF3}	Injured people	Number of people injured per 1,000 people			
X_{RF4}	Damage in water mains	Number of breaks / km^2			
X_{RF5}	Damage in gas network	Number of breaks / km^2			
X_{RF6}	Fallen lengths on HT power lines	Meters of fallen length / km^2			
X_{RF7}	Telephone exchanges affected	Vulnerability index			
X_{RF8}	Electricity substations affected	Vulnerability index			

The descriptors presented in this table have been used as proxies to depict physical risk (X_{RF1} to X_{RF8}) of each city of the metropolitan urban center.

Check list 2. Aggravation descriptors, their units

Descriptor		Units	Is this information available for all cities?		If not, this indicator could be replaced by
			Yes	No	
X_{FS1}	Slums-squatter neighbourhoods	Marginal settlements area / district area			
X_{FS2}	Mortality rate	Number of deaths per 10,000 people			
X_{FS3}	Delinquency rate	Number of crimes per 100,000 people			
X_{FS4}	Social disparity index	Index between 0 and 1			
X_{FS5}	Population density	Inhabitants / km^2 of constructed area			
X_{FR1}	Hospital beds	Number of beds per 1,000 people			
X_{FR2}	Health human resources	Human resource in health per 1,000 people			
X_{FR3}	Public space	Public space area/ total area			
X_{FR4}	Rescue and firemen manpower	Rescue personal per 10,000 people			
X_{FR5}	Development level	Qualification from 1 to 4 (1,2,3 or 4)			
X_{FR6}	Emergency planning	Qualification from 0 to 2 (0,1 or 2)			

The descriptors presented in this table have been used as proxies to depict social fragility (X_{FS1} to X_{FS5}) and resilience (X_{FR1} to X_{FR6}) of each city.

Forms 1 and 2 allow allocation of importance factors for determination of weights by means of the Analytic Hierarchy Process (AHP). Comparisons are made by pairs. Also, the preference is expressed by means of a scale from 1 to 9. Preference 1 means equality between indicators while a preference of 9 means that an indicator is 9 times more important that the other. These comparisons result in a comparison matrix to which its consistency is processed by means of a numerical process later. It is requested to select which of the indicators is perceived as more important and in which degree, pair by pair, using an X, according to the judgment of the advisor. The Table 1 shows the scale for assigning the comparative importance between pairs of indicators (Saaty and Vargas 1991) [5].

Table 1. Scale for the comparative importance

Importance judgment	Points
Extremely more important	9
	8
Very strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

[5] See paper of Annex 1.

Form 1. Qualifications for physical risk factors (AHP)

Which of the factors perceives like more important? **In which degree?**

Place an **X** in front Place an **X**

					1	2	3	4	5	6	7	8	9
	F_{RF1}. Damaged area	vs.		F_{RF2} Number of deceased									
	F_{RF1}. Damaged area	vs.		F_{RF3}. Number of injured									
	F_{RF1}. Damaged area	vs.		F_{RF4} Rupture of water mains									
	F_{RF1}. Damaged area	vs.		F_{RF5} Rupture of gas network									
	F_{RF1}. Damaged area	vs.		F_{RF6} Length of fallen power lines									
	F_{RF1}. Damaged area	vs.		F_{RF7} Affected telephone exchanges									
	F_{RF1}. Damaged area	vs.		F_{RF8} Affected electricity substations									
	F_{RF2} Number of deceased	vs.		F_{RF3}. Number of injured									
	F_{RF2} Number of deceased	vs.		F_{RF4} Rupture of water mains									
	F_{RF2} Number of deceased	vs.		F_{RF5} Rupture of gas network									
	F_{RF2} Number of deceased	vs.		F_{RF6} Length of fallen power lines									
	F_{RF2} Number of deceased	vs.		F_{RF7} Affected telephone exchanges									
	F_{RF2} Number of deceased	vs.		F_{RF8} Affected electricity substations									
	F_{RF3}. Number of injured	vs.		F_{RF4} Rupture of water mains									
	F_{RF3}. Number of injured	vs.		F_{RF5} Rupture of gas network									
	F_{RF3}. Number of injured	vs.		F_{RF6} Length of fallen power lines									
	F_{RF3}. Number of injured	vs.		F_{RF7} Affected telephone exchanges									
	F_{RF3}. Number of injured	vs.		F_{RF8} Affected electricity substations									
	F_{RF4} Rupture of water mains	vs.		F_{RF5} Rupture of gas network									
	F_{RF4} Rupture of water mains	vs.		F_{RF6} Length of fallen power lines									
	F_{RF4} Rupture of water mains	vs.		F_{RF7} Affected telephone exchanges									
	F_{RF4} Rupture of water mains	vs.		F_{RF8} Affected electricity substations									
	F_{RF5} Rupture of gas network	vs.		F_{RF6} Length of fallen power lines									
	F_{RF5} Rupture of gas network	vs.		F_{RF7} Affected telephone exchanges									
	F_{RF5} Rupture of gas network	vs.		F_{RF8} Affected electricity substations									
	F_{RF6} Length of fallen power lines	vs.		F_{RF7} Affected telephone exchanges									
	F_{RF6} Length of fallen power lines	vs.		F_{RF8} Affected electricity substations									
	F_{RF7} Affected telephone exchanges	vs.		F_{RF8} Affected electricity substations									

Form 2. Qualifications for the aggravating conditions (AHP)

Which of the factors perceives like more important? Place an **X** in front

In which degree? Place an **X**

	Factor			Factor	1	2	3	4	5	6	7	8	9
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FS2} Mortality rate									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FS3} Delinquency rate									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FS4} Social disparity index									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FS5} Population density									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FR1} Hospital beds									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FR2} Health human resources									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FR3} Public space									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FR4} Rescue and firemen manpower									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FR5} Development level									
	F_{FS1} Slums-squatter neighbourhoods	*vs.*		F_{FR6} Emergency planning									
	F_{FS2} Mortality rate	*vs.*		F_{FS3} Delinquency rate									
	F_{FS2} Mortality rate	*vs.*		F_{FS4} Social disparity index									
	F_{FS2} Mortality rate	*vs.*		F_{FS5} Population density									
	F_{FS2} Mortality rate	*vs.*		F_{FR1} Hospital beds									
	F_{FS2} Mortality rate	*vs.*		F_{FR2} Health human resources									
	F_{FS2} Mortality rate	*vs.*		F_{FR3} Public space									
	F_{FS2} Mortality rate	*vs.*		F_{FR4} Rescue and firemen manpower									
	F_{FS2} Mortality rate	*vs.*		F_{FR5} Development level									
	F_{FS2} Mortality rate	*vs.*		F_{FR6} Emergency planning									
	F_{FS3} Delinquency rate	*vs.*		F_{FS4} Social disparity index									
	F_{FS3} Delinquency rate	*vs.*		F_{FS5} Population density									
	F_{FS3} Delinquency rate	*vs.*		F_{FR1} Hospital beds									
	F_{FS3} Delinquency rate	*vs.*		F_{FR2} Health human resources									
	F_{FS3} Delinquency rate	*vs.*		F_{FR3} Public space									
	F_{FS3} Delinquency rate	*vs.*		F_{FR4} Rescue and firemen manpower									
	F_{FS3} Delinquency rate	*vs.*		F_{FR5} Development level									
	F_{FS3} Delinquency rate	*vs.*		F_{FR6} Emergency planning									
	F_{FS4} Social disparity index	*vs.*		F_{FS5} Population density									
	F_{FS4} Social disparity index	*vs.*		F_{FR1} Hospital beds									
	F_{FS4} Social disparity index	*vs.*		F_{FR2} Health human resources									
	F_{FS4} Social disparity index	*vs.*		F_{FR3} Public space									
	F_{FS4} Social disparity index	*vs.*		F_{FR4} Rescue and firemen manpower									
	F_{FS4} Social disparity index	*vs.*		F_{FR5} Development level									
	F_{FS4} Social disparity index	*vs.*		F_{FR6} Emergency planning									
	F_{FS5} Population density	*vs.*		F_{FR1} Hospital beds									
	F_{FS5} Population density	*vs.*		F_{FR2} Health human resources									
	F_{FS5} Population density	*vs.*		F_{FR3} Public space									
	F_{FS5} Population density	*vs.*		F_{FR4} Rescue and firemen manpower									
	F_{FS5} Population density	*vs.*		F_{FR5} Development level									
	F_{FS5} Population density	*vs.*		F_{FR6} Emergency planning									
	F_{FR1} Hospital beds	*vs.*		F_{FR2} Health human resources									
	F_{FR1} Hospital beds	*vs.*		F_{FR3} Public space									

	F_{FR1} Hospital beds	***vs.***		F_{FR4} Rescue and firemen manpower									
	F_{FR1} Hospital beds	***vs.***		F_{FR5} Development level									
	F_{FR1} Hospital beds	***vs.***		F_{FR6} Emergency planning									
	F_{FR2} Health human resources	***vs.***		F_{FR3} Public space									
	F_{FR2} Health human resources	***vs.***		F_{FR4} Rescue and firemen manpower									
	F_{FR2} Health human resources	***vs.***		F_{FR5} Development level									
	F_{FR2} Health human resources	***vs.***		F_{FR6} Emergency planning									
	F_{FR3} Public space	***vs.***		F_{FR4} Rescue and firemen manpower									
	F_{FR3} Public space	***vs.***		F_{FR5} Development level									
	F_{FR3} Public space	***vs.***		F_{FR6} Emergency planning									
	F_{FR4} Rescue and firemen manpower	***vs.***		F_{FR5} Development level									
	F_{FR4} Rescue and firemen manpower	***vs.***		F_{FR6} Emergency planning									
	F_{FR5} Development level	***vs.***		F_{FR6} Emergency planning									

Form 3. Collection of the physical risk descriptors

	Cities													Municipalities			
Descriptor	**Quezon**	**Kaloocan**	**Valenzuela**	**Muntinlupa**	**Las Piñas**	**Marikina**	**Manila**	**Parañaque**	**Makati**	**Mandaluyong**	**Malabon**	**Pasay**	**Pasig**	**Taguig**	**Pateros**	**San Juan**	**Navotas**
X_{RF1}																	
X_{RF2}																	
X_{RF3}																	
X_{RF4}																	
X_{RF5}																	
X_{RF6}																	
X_{RF7}																	
X_{RF8}																	

Form 4. Collection of the impact factor descriptors

	Cities													Municipalities			
Descriptor	**Quezon**	**Kaloocan**	**Valenzuela**	**Muntinlupa**	**Las Piñas**	**Marikina**	**Manila**	**Parañaque**	**Makati**	**Mandaluyong**	**Malabon**	**Pasay**	**Pasig**	**Taguig**	**Pateros**	**San Juan**	**Navotas**
X_{FS1}																	
X_{FS2}																	
X_{FS3}																	
X_{FS4}																	
X_{FS5}																	
X_{FR1}																	
X_{FR2}																	
X_{FR3}																	
X_{FR4}																	
X_{FR5}																	
X_{FR6}																	

ANNEX 1