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SEISMIC RISK EVALUATION INCLUDING THE SOCIAL CONTEXT FOR THE CITY OF MÉRIDA, VENEZUELA

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ABSTRACT

This article presents a holistic and comprehensive approach for seismic risk assessment which involves the evaluation of the social fragility and the lack of resilience of the study area. That means, involves the characteristics of the social context that can exacerbated the situation when a hazardous event occurs.
The proposed methodology allows a standardized assessment of the social fragility and lack of resilience, by means of an aggravation coefficient of which summarizes the characteristics of the social context using fuzzy sets and analytic hierarchy process. 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 in six categories according to social item they describe: i) Dwelling, ii) Social development and poverty eradication, iii) Urban Planning, iv) Governance, v) Lack of resilience and vi) Demography. Applying the determination level analysis, thirteen prevailing social indicators are selected.
The proposed methodology was applied to the city of Mérida (Venezuela). The average value of seismic physical risk was low and high for intensities VIII and IX respectively. However, parishes present results with important differences among them. The average value of the aggravation coefficient is medium. The average total seismic risk is moderate and very high for intensity VIII and IX respectively. According to the obtained results, the social context substantially aggravates the seismic physical risk in 5 of the 11 city parishes. Seven of them have a very high level of total seismic risk.

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

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). However, this approach is changing; 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.
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 (2001) developed a conceptual framework and a model for risk analysis of a city from a holistic perspective, describing seismic risk by means of indices. Carreño (2006) developed an alternative method for Urban Risk Evaluation, starting from Cardona's model, in which urban risk is evaluated using composite indicators or indices. Expected building damage and losses in the infrastructure,

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obtained from loss scenarios, are basic information for the evaluation of a physical risk index in each unit of analysis (Carreño et al. 2007a). The Carreño's approach (Carreño et al. 2007a) preserves the use of indicators and fuzzy sets or membership functions, proposed originally by Cardona (2001), but in a different way. Afterwards, the robustness of the methodology was evaluated by Marulanda et al. (2009). 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. 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:

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

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_{SFi}, and the lack of resilience of the exposed context, F_{LRj}, 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 (Carreño et al. 2012, 2014).
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. This index reflects the organizational, development, capacity and institutional action taken to reduce vulnerability and losses, to prepare for crisis, and to efficiently recover (Carreño et al 2007b). For $DRMi$ 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. (2007b) the evaluation of each public policy takes into account 6 sub-indicators that characterize the performance of management in the country. Assessment of each sub-indicator is made using five performance levels: low, incipient, significant, outstanding and optimal.
This paper proposes a methodology to calculate the aggravating coefficient by using standard indicators, which can make the situation worse in the case that a seismic event occurs. This paper defines a minimum and maximum number of indicators, easy to collect, measuring 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 equation 2.

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

2.1 Selection process for social indicators

The evaluation of the social context is a very complex task for almost all knowledge areas since the society is a very flexible system with a high degree of uncertainty. The authors have selected twenty indicators among those used at global level to describe the social context for an urban area. These indicators correspond to indicators used by: Habitat Agenda (1996), Istanbul+5 (2001), the Millennium Development Goals (MGDs, 2008) and the Carreño's methodologies (Carreño et al. 2007a, b). The selected indicators are classified into 6 categories: *i)* Dwelling (C1), *ii)* Social development and poverty eradication (C2), *iii)* Urban Planning (C3), *iv)* Governance (C4), *v)* Lack of resilience (C5) and *vi)* Demography (C6). Two or more indicators describe each social aspect (see Table 1).

Table 1. Categories and social indicators with their level of determination (D).

Category	Social indicator		Level determination (D)
	Code	Name	
C1: Dwelling	Dw1	Sufficient living area	+0.105
	Dw2	State of dwelling	+0.000
C2: Social development and poverty eradication	SD1	Mortality rate	-0.737
	SD2	Infant mortality rate	-0.526
	SD3	Crime rate	-0.105
	SD4	Urban violence reduction policies	-0.053
	SD5	Poor households	+0.158
	SD6	Literacy rate	+0.105
	SD7	Combined enrollment rate	-0.105
C3: Urban Planning	UP1	Growth of informal settlements	+0.684
	UP2	Level of urban planning	+0.316
	UP3	Homes built in risk prone areas	+0.105
C4: Governance	G1	Disaster risk management index, *DRMi* (Carreño et al., 2007b)	+0.105
	G2	Corruption perception index	-0.211
C5: Lack of resilience	LR1	Hospital beds	+0.053
	LR2	Human resources in health	+0.000
	LR3	Relief personnel	+0.000
	LR4	Public Space	-0.105
C6: Demography	D1	Population Density	+0.158
	D2	Urban population growth	+0.053

The number of indicators related to the social context is reduced from 20 to 13 by using a selection process based on the determination level for each indicator. This reduction avoids redundancy of the indicators and it allows weight or relative importance allocation.
The determination level or subordination of each indicator is obtained based on the dichotomous question "Does the indicator x affect the y indicator?". In order to process the answers, an $n * n$ square matrix is ensemble, where n is the total number of variables. This matrix can be non-symmetric. The components of the matrix are 1 for affirmative responses and 0 for negative ones. By using this graph matrix, the influence rate (PI) and the dependency rate (PD) are evaluated. PI shows the number of variables that are influenced by the variable x; PD shows the number of variables that affect the variable x. In order to prioritize the variables, the level of dependence or independence is calculated by using Equation 3. It has a value between -1 (completely dependent) to +1 (fully independent).

$$D = \frac{PI - PD}{n - 1} \tag{3}$$

The indicators are ranked by using the values for the determination level D. The indicators with a negative value for the determination level ($D < 0$) are discarded due to the dependency on the other indicators. Table 1 shows the 20 social indicators selected and their determination level. Based on these results, 13 indicators are selected to be considered as the best indicators to describe the social context of any urban area.

2.2 Transformation functions for the selected social indicators

The social indicators selected describe different aspects of the urban area and they have different nature and units. Transformation functions are defined in order to standardize the gross values of the indicators into values between 0 and 1. Minimum and maximum values for each function are defined taking into account information about different urban centers around the world registered on international databases, urban observers and expert opinions.

Table 2 shows some examples of the minimum and maximum values adopted to define the transformation functions for the 13 social indicators as well as the rise trend for each case (see Figure 1). More information about the selected values can be find in Jaramillo et al. (2016) and Jaramillo (2014).

Table 2. Lower and upper limits of the social indicators along with the trend of their transformation functions to contributing factor of aggravating coefficient

Social Indicator	Code	Limit min.-max.	Unit of measurement	Trend of the transformation function
Sufficient living area	Dw1	0-300‰	Overcrowded dwellings per thousand dwellings	Uptrend (Ut)
Literacy rate	SD6	35-95%	Percentage (%)	Downtrend (Dt)
Growth of informal settlements	UP1	0-20	Ratio between self-construction dwellings without structural design and dwellings with structural design	Ut
Disaster risk management index ($\boldsymbol{DRMi}$)	G1	10-80	Performance level (Carreño et al. 2007b)	Dt

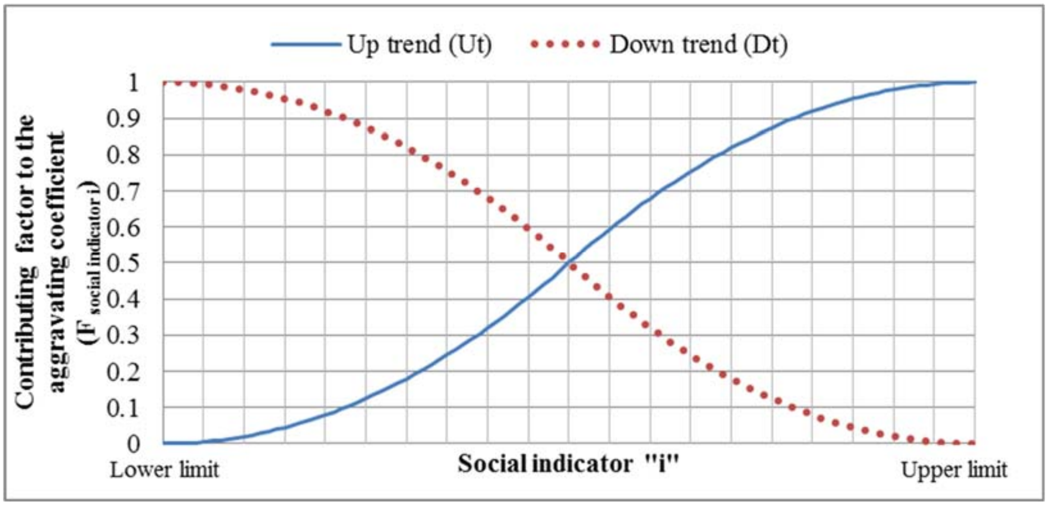


Figure 1. Transformation function for the value of the social indicator “i” to contributing factor to the aggravating coefficient

The transformation functions may have an up or down trend (see Figure 1). The functions with an uptrend have zero value for indicator values between 0 and the minimum value stablished; and they have a one value for indicator values greater than the maximum value. Functions with a down trend have the opposite behavior, they have value one for indicator values between 0 and the minimum value stablished, and they have a value zero for indicator values greater than the maximum value.

2.3 Evaluation of the aggravating coefficient

The aggravating coefficient is calculated as the weighted sum of the n contributing factors, this article deals with two cases: 13 selected indicators and 6 indicators (one for each category). The participation weights are defined by using the Analytical Hierarchical Process (AHP) (Saaty 1980; Carreño et al. 2007b).

2.3.1 General case

The aggravating coefficient (F) is calculated by using the 13 social indicators selected with the determination level. The contributing weights are defined applying the AHP (Table 3).

Table 3. Weights participation (W_i) of the contributing factors to the aggravating coefficient for simplified case ($n = 13$) and case by category ($n = 6$)

Category	W_i (*n*=*6*)	Social indicator	W_i (*n*=*13*)
C1	0.168	Dw1	0.110
		Dw2	0.090
C2	0.123	SD5	0.051
		SD6	0.062
C3	0.224	UP1	0.054
		UP2	0.074
		UP3	0.067
C4	0.220	G1	0.092
C5	0.088	LR1	0.087
		LR2	0.115
		LR3	0.079
C6	0.177	D1	0.063
		D2	0.056

2.3.2 Simplified case: One indicator by category

In this case the aggravating coefficient is calculated based on 6 indicators, one for each proposed category ($n = 6$). This simplification allows to facilitate the evaluation in two ways: *i)* by reducing the information search, the evaluation depends on the quality of the information, this selection focuses the research in the most relevant indicators. *ii)* The participation weights for each category are obtained by applying the AHP (see Table 3).

3 HOLISTIC EVALUATION OF THE SEISMIC RISK

As it was mentioned in section 1, from a holistic approach, the total risk depends on the direct effect, or physical risk (R_F), and the social context conditions (F), such as the socio-economic fragility and the lack of resilience indirect effects, which can worsen the situation when a hazard event strikes an urban centre (Carreño et al. 2007a; b). This article standardizes the values of the Total Risk Index (R_T) of Equation 4 into a range between zero and one.

$$R_T = R_F * (1 + F) \leq 1.0 \tag{4}$$

Where R_F corresponds to weighted sum:

$$R_F = \sum_{i=1}^{m} W_{RFi} * F_{RFi} \tag{5}$$

Where W_{RFi} are weights for each risk factor, F_{RFi}.
In order to make the analysis of the obtained results easier, this paper proposes to have pre-established levels and range of values for each component in the evaluation, these levels are defined in Table 4.
The proposed methodology allows adjusting the participation weights for the contributing factors to F when the number of available social indicators in the urban area is greater than 6 and fewer than 13.

Table 4. Ranges for each level of seismic physical risk, R_F, Total seismic risk, R_T, and the aggravating coefficient, F

Level	Range for R_F and R_T	Range for F
Very low	(0.00 a 0.02]	[0.00 a 0.10]
Low	(0.02 a 0.18]	(0.10 a 0.30]
Moderate	(0.18 a 0.50]	(0.30 a 0.60]
High	(0.50 a 0.82]	(0.60 a 0.80]
Very High	(0.82 a 1.00]	(0.80 a 1.00]

4 HOLISTIC SEISMIC RISK EVALUATION IN MERIDA, VENEZUELA

The city of Merida, Venezuela, is located in the Nord-Est Venezuela, in the central part of Venezuela Andes. It has a total population of less than 250 thousand inhabitants, and it is the capital of both the Merida's State, and the Libertador municipality. It is made up of 12 of the 15 parishes (in Spanish "Parroquias") of Libertador municipality. Merida is located within an area of high seismic activity (zone 4 and 5) according to the seismic classification of structural normative in Venezuela (COVENIN 2001). Below the city runs the major tectonic fault in the western Venezuela, the Boconó fault, which forms part of the South American Plate (Funvisis 2000).
This research considers the seismic hazard in terms of macroseismic intensity, according to the European Scale EMS-98 (Grünthal 1998), considering two scenarios defined by seismic intensities VIII and IX. In addition, the possible effects induced by liquefaction and landslides were evaluated through HAZUS-99 methodology by Castillo (2005). These local effects are indicated with an increment in intensity of 0.5 degrees in some areas of the city of Merida.
To present the numerical and cartographic results of seismic risk assessment in Merida the political-territorial division of parishes is used, because it helps to determine the effect of social context.

4.1 Physical risk

To evaluate the physical risk index of each of the parishes of the city of Merida, damage of elements exposed to seismic hazard are estimated, such as: collapsed buildings area, damage to lifelines and human victims (dead, injured and people who become homeless).

4.1.1 Damage estimation in exposed elements

Based on the classification of buildings (BTM, Building Typology Matrix) of Risk-UE Project (Milutinovic and Trendafiloski 2003), Castillo (2005) identifies the following seven predominant building typologies in the city of Merida, and their respective more plausible vulnerability indexes (between zero and one), indicated between brackets:

- Reinforced concrete frame buildings, with or without seismic design: RC3.1 (0.402), RC3.2 (0.522), RC5 (0.384), NENG_RC (0.685).
- Adobe or earth houses, with timber or similar roofs and slabs, M2 (0.840).
- Classic steel structures, with horizontal and vertical elements, S1 (0.363).
- Type of buildings called "Rancho", extremely precarious houses built by their habitants with very low quality materials and without any design code, R (0.900).

As in previous studies (Castillo 2005; Laffaille 1996; Castillo et al. 2011), the metropolitan area of Merida is divided into sectors, considering the homogeneity (similarity among buildings), physical barriers (especially the two rivers close to the city) and accessibility (bridges and roads). Each sector is divided into several subsectors, such that most of the buildings in each subsector belong to the same class of physical vulnerability. This implies that there is no information about the specific location of each type of buildings. However, sectors and subsectors provide useful information on the distribution of the different structural typologies within them.

In this research, the database of buildings used by Castillo (2005) (16,147 buildings) is completed, incorporating all existing buildings in a sector (Los Curos) of the parish Osuna Rodriguez, which had not been considered in the previous studies (Castillo 2005; Laffaille 1996). These new buildings are characterized with the classification matrix of buildings of the Risk-UE Project, adopted for the city of Merida in Castillo (2005). Therefore, the total number of buildings considered in Merida is 17,664 and the percentage distribution of typologies in the city is: 40.27% for NENG-RC, 33.03% for RC3.1, 15.20% for M2 and 9.86%, for RC3.2, while each of the R, S1 and RC5 typologies exhibit a percentage less than 1%.

Using the Vulnerability Index Method of the Risk-UE Project (Milutinovic and Trendafiloski 2003; Lantada 2007) the damage probability matrices are established for each representative typology of the city for macroseismic intensities VIII and IX-X, and considering five damage states plus a no-damage state according to the macroseismic scale EMS-98. Then, using the damage probability matrices, the potential destroyed area for each parish to seismic intensities VIII and IX are estimated (Jaramillo 2014). The potential damage in the system of potable water and the damage to the road system is evaluated based on the study of Astorga (2011). The physical risk for the drinking water system is estimated in terms of tears per kilometer in the different parishes for two seismic intensities VIII and IX (Jaramillo 2014). The average damage in the transportation system is established as a weighted average of damage, depending on the length road affected by each of the levels of ground motion (peak ground displacement, PGD) for a given seismic intensity. For this purpose, different systems of urban roads are categorized, based on HAZUS-99 (FEMA 1999).

The number of victims is calculated by using the model of Risk-UE Project (Coburn and Spence 1992; Vacareanu et al. 2004; Lantada et al. 2010).

4.1.2 Index of physic risk

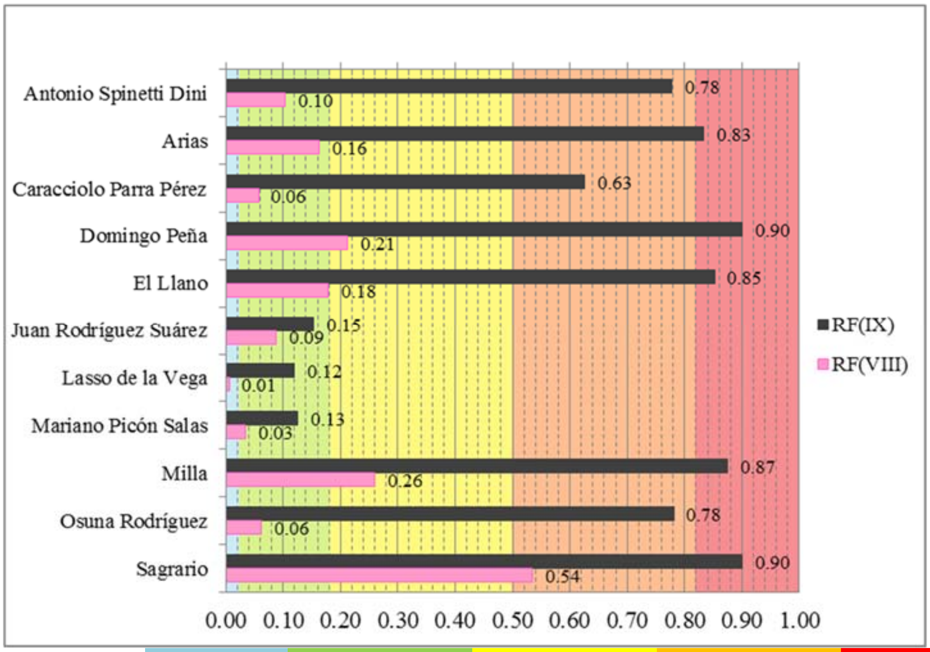
Once the physical risk of exposed elements in the parishes of Merida are estimated, they become contributing factors to physical seismic risk, applying the corresponding transformation functions. Subsequently, according to equation 5, for $m = 6$ categories and their respective weights W_{RFi}, values of seismic physical risk index are obtained for each of the parishes of the city in two seismic scenarios (intensity VIII and IX) (Figure 2).

The values estimated for the physical damage (intensity IX) by parish for Merida correspond to: percentage of destroyed area (X_{RF1}), dead people per thousand inhabitants (‰) (X_{RF2}), injured people (‰) (X_{RF3}), homeless (‰) (X_{RF4}), potential damage in the system of potable water (tears per kilometer) (X_{RF5}), and damage for the road system (percentage affected of the road system) (X_{RF6}). Table 5 shows the obtained values for the physical risk factors based on the damage estimations and the Physical risk index, R_F.

Table 5. Calculated factors of physical risk and Physical risk index (intensity IX)

Parish	F_{RF1}	F_{RF2}	F_{RF3}	F_{RF4}	F_{RF5}	F_{RF6}	R_F
Antonio Spinetti Dini	0.88	1.00	0.59	0.99	1.00	0.00	0.78
Arias	1.00	0.99	0.76	0.89	1.00	0.00	0.83
Caracciolo Parra Pérez	0.32	1.00	0.64	1.00	1.00	0.00	0.63
Domingo Peña	1.00	1.00	1.00	1.00	1.00	0.00	0.90
El Llano	0.84	1.00	0.99	1.00	1.00	0.00	0.85
Juan Rodríguez Suárez	0.01	0.07	0.01	0.26	1.00	0.00	0.15
Lasso de la Vega	0.04	0.01	0.003	0.03	1.00	0.00	0.12
Mariano Picón Salas	0.02	0.03	0.01	0.10	1.00	0.00	0.12
Milla	0.91	1.00	1.00	1.00	1.00	0.00	0.87
Osuna Rodríguez	0.97	1.00	0.47	1.00	1.00	0.00	0.78
Sagrario	1.00	1.00	1.00	1.00	1.00	0.00	0.90

Additionally, physical risk levels can be described by linguistic or numerical limits, which are delimited by vertical color stripes (both are described in table located at bottom of Figure 2).



Physical risk level	Very low	Low	Moderate	High	Very high
Range	$R_{Fi} \le 0.02$	$0.02 < R_{Fi} \le 0.18$	$0.18 < R_{Fi} \le 0.50$	$0.50 < R_{Fi} \le 0.82$	$0.82 < R_{Fi} \le 1.00$

Figure 2. Seismic physical risk for intensities VIII, R_F (VIII), and IX, R_F (IX), for the parishes of the city of Merida, Venezuela. Bars in pink and grey color represent the physical seismic risk values for intensity VIII, R_F(VIII), and IX, R_F(IX) respectively.

4.2 Social Context

In order to calculate 11 of the 13 prevailing social indicators proposed in the methodology described in this article, for the city of Merida, information from different urban observers was used. Such urban observers were: Statistics Institute of Venezuela (INE 2001); interviews with local experts in risk management (to establish the risk management index for 2010) and information from various local researchers (Rebotier 2006; INGEOMIN 2010; Ramírez and Saito 2011). Information from Firefighters Group of Merida (internal census), and CORPOANDES was also used (SIGRA 2008).
The methodology was adapted to the city of Merida establishing 11 ($n = 11$) contributors to aggravation. Share weights are set using the AHP. Once the different prevailing social indicators of Merida are established, they become contributor factors of the aggravation generated by the social context, applying the corresponding transformation functions (section 2.2). Then, the numerical value of the aggravating coefficient (F) for each parish is obtained for the following two cases:
Case 1: adaptation of the general case of the proposed methodology, considering eleven factors contributing to the aggravation ($n = 11$). Table 6 presents the calculated contributing factors based on the values of the prevailing social indicators with their participation weights, for the parishes.
Case 2: considering a factor for each of the six categories proposed ($n = 6$), with the weights given in the proposed methodology (Table 3). In this case, the aggravating coefficient corresponds to the combination of the six factors F(Dw1), F(SD5), F(UP2), F(G1), F(LR1) and F(D1) (Table 1). In both cases, the numerical values of the aggravating coefficient for each of the parishes studied in the city of Merida, correspond to the average level of aggravation (range from 0.30 to 0.60) (Figure 3).
In Case 1 ($n = 11$), the parish of Sagrario has the highest aggravating coefficient and Domingo Peña parish has the lowest. In Case 2 ($n = 6$) the highest and lowest aggravating coefficient correspond to Antonio Spinetti Dini and Juan Rodriguez Suarez parishes, respectively.

Table 6. Contributing factors, with their participation weights (W_i), calculated for the parishes of Merida

Parish	F(V1)	F(V2)	F(DS5)	F(DS6)	F(UP2)	F(UP3)	F(G1)	F(LR1)	F(LR3)	F(D1)	F(D2)
Antonio Spinetti Dini	0.10	0.10	0.19	0.00	0.65	0.21	0.75	0.99	1.00	0.55	0.02
Arias	0.20	0.15	0.30	0.00	0.65	0.84	0.75	1.00	1.00	0.07	0.03
Caracciolo Parra Pérez	0.03	0.02	0.06	0.00	0.65	1.00	0.75	1.00	0.31	0.04	0.65
Domingo Peña	0.07	0.00	0.09	0.00	0.65	0.39	0.75	0.00	0.95	0.55	0.00
El Llano	0.01	0.00	0.02	0.00	0.65	1.00	0.75	0.30	0.95	0.22	0.00
Juan Rodríguez Suárez	0.02	0.002	0.02	0.00	0.35	0.89	0.75	1.00	0.96	0.02	0.00
Lasso de la Vega	0.12	0.03	0.14	0.00	0.65	1.00	0.75	1.00	0.31	0.02	0.13
Mariano Picón Salas	0.01	0.05	0.05	0.00	0.50	0.76	0.75	0.96	0.31	0.71	0.00
Milla	0.10	0.09	0.21	0.00	0.65	0.93	0.75	1.00	1.00	0.29	0.00
Osuna Rodríguez	0.16	0.003	0.13	0.00	0.78	1.00	0.75	0.62	0.31	0.07	0.03
Sagrario	0.03	0.00	0.02	0.00	0.78	1.00	0.75	1.00	0.95	0.55	0.00
W_i	*0.122*	*0.106*	*0.054*	*0.065*	*0.110*	*0.109*	*0.135*	*0.084*	*0.074*	*0.093*	*0.048*

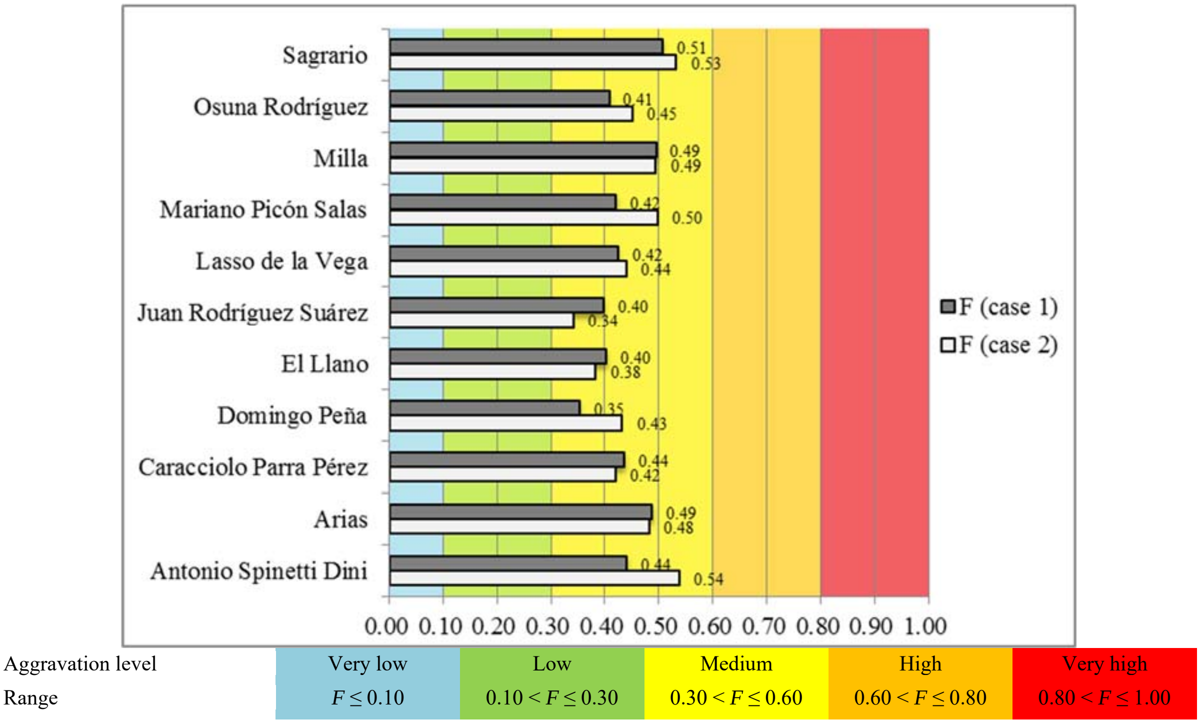


Figure 3. Aggravating coefficient (*F*) by parish of the city of Merida, Venezuela: for the adaptation of the general case (case 1) for proposed methodology with 11 indicators, and for the simplified case (case 2)

4.1.5 Total seismic risk

The total seismic risk obtained with Equation 4, in each of the parishes of the city, for VIII and IX seismic intensity scenarios is shown in Figures 4 and 5 respectively. The values of total seismic risk are greater than physical seismic risk values, due to the average level of aggravation, which is generated by the social context of each of the parishes of the city.
The total seismic risk level is a level greater than the physical seismic risk level for the scenario of intensity VIII (Moderate level regarding to Low level.) in El Llano and Arias parishes (see arrows in Figure 4). Other parishes have a total seismic risk level similar to the level of physical seismic risk. For intensity IX parishes which increase one risk level relative to seismic physical seismic risk, from Moderate to High level, are: Antonio Spinetti Dini, Caracciolo Parra Perez, Osuna Rodríguez, and from Low to Moderate level: Juan Rodriguez Suarez and Mariano Picon Salas parishes; while the Very High level of risk remains unaltered in the parish Sagrario (see arrows in Figure 5).
The level of total seismic risk for the scenario of intensity IX is much greater than for the scenario of

intensity VIII. The total seismic risk increases at least two levels in almost all parishes except Mariano Picon, Lasso de la Vega and Juan Rodriguez Suárez, because the predominant building types in these parishes are less vulnerable to seismic hazard. It should be noted that parishes Antonio Spinetti Dini, Caracciolo Parra and Rodriguez Osuna increase their level of total seismic risk from Low to Very High. The parishes of Arias, Domingo Peña, El Llano and Milla move from Moderate to Very High level. Parishes less affected by the aggravation coefficient (up only one level) are: Juan Rodriguez Suarez and Mariano Picon Salas.

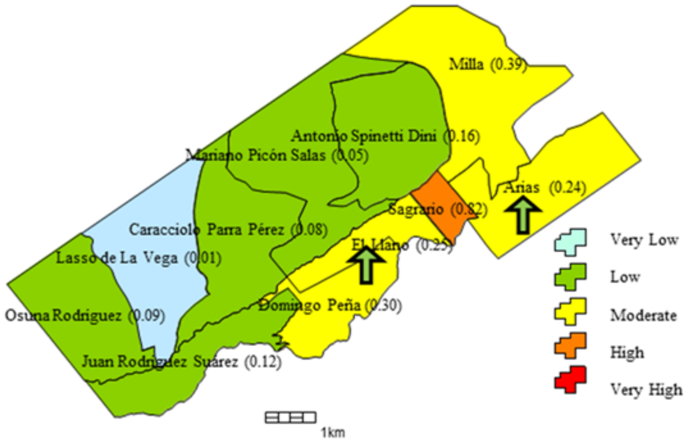


Figure 4. Total seismic risk (R_T) to intensity VIII by parish of the city of Merida, Venezuela

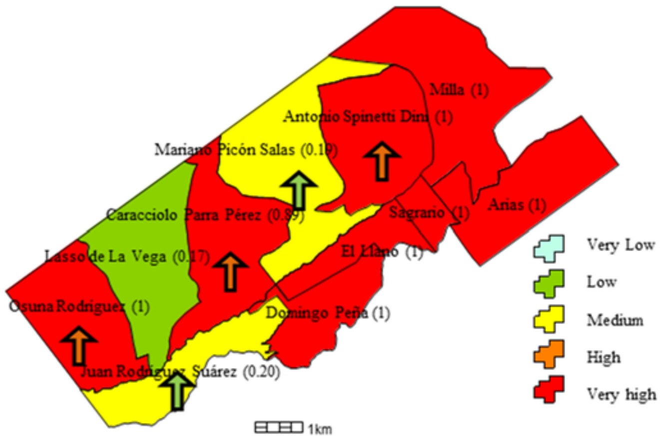


Figure 5. Total seismic risk (R_T) to intensity IX by parish of the city of Merida, Venezuela

5 CONCLUSIONS

The social context can aggravate the physical seismic risk; therefore, it is desirable to establish a methodology to evaluate it. Once this estimation is done, it is possible to implement actions to improve the social context, in order not to aggravate the situation that could be generated by an earthquake that interacts with the vulnerability of any urban area.

It is expected that necessary social indicators will be easier to obtain because they have been selected from the indicators used by urban observatories of United Nations and other social researchers; such as indicators of the Habitat Agenda (1996), Istanbul+5 (2001), Millennium Development Goals (MDGs, 2008) and Carreño et al. (2007a). A total of 20 indicators were defined to describe the social context in urban areas. These indicators were classified according to social item they describe, in the following six categories: Dwelling (C1), Social development and Poverty eradication (C2), Urban planning (C3), Governance (C4), Lack of resilience (C5) and Demography (C6).

Applying the determination level analysis thirteen prevailing social indicators are selected: Sufficient

living area (Dw1); State of dwelling (Dw2); Poor households (SD5); Literacy Rate (SD6); Growth of informal settlements (UP1); Level urban planning (UP2); Dwellings built in location subject to risk (UP3); Disaster risk management index (G1); Hospital beds (LR1); Human resources in health (LR2); Relief personnel (LR3); Population density (D1); Urban population growth (D2).
In the event that not all information is available for the 13 indicators, the methodology may be simplified by using one social indicator per category. These indicators should be selected based on the determination level analysis as follows: Sufficient living area for C1 category, Poor households (C2), Growth of informal settlements (C3), Disaster risk management index (C4), Hospital beds (C5) and Population density (C6).
In summary, the resolution level for the application of this methodology depends on the available information in the urban area. Therefore, the aggravation coefficient F can be established by: a) General case with the 13 prevailing social indicators ($n = 13$) or b) Simplified case by only six predominant indicators ($n = 6$), one for each category and higher level of determination. Obviously, according to available information of the case of study the number of indicators could be between 6 and 13.
The proposed standard methodology for estimating the coefficient of aggravation (F) in urban areas has been applied to the city of Merida in Venezuela. The methodology was adapted to the available information for the city and applied by using both 11 and 6 indicators. Therefore, the proposed methodology to measure the social context is easy to adapt to study of different urban areas.
The results for Merida had on average a higher contribution to the aggravating factor (F) from hospital beds, disaster risk management index and level of urban planning. The physical seismic risk in Merida was low and high for the scenarios of intensity of VIII and IX, respectively. The level of aggravation coefficient is a moderate level. Finally, the average value of total seismic risk (R_T) is moderate and very high in the city of Merida for scenarios of intensities VIII and IX, respectively.

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