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DECISION-MAKING BASED ON HOLISTIC SEISMIC RISK ASSESSMENT, INCLUDING SOCIOECONOMIC, RESILIENCE AND GOVERNANCE RISK DRIVERS

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ABSTRACT

Using the probabilistic and holistic approach of the CAPRA platform to assess seismic risk at the urban level, the decision-making process to reduce different dimensions of vulnerability and increase local resilience from an integral and inter-institutional perspective is described. The risk assessment methodology has been developed and applied to define real multisectoral actions, such as prioritizing the structural reinforcement of essential buildings, insuring public and private assets using cross-subsidies to cover the low-income households, making the intervention of relevant lifelines components, reviewing land-use planning, implementing automated and online shakemaps and post-earthquake damage evaluation systems, and making the generation of emergency response scenarios. This paper describes the holistic approach used for seismic risk assessment considering the direct physical effects and their impact using indicators of social fragility and lack of resilience as factors of amplification or aggravation and as socio-economic risk drivers in the different territorial units at urban level. The process of evaluation and decision-making is illustrated in the city of Manizales, Colombia; in which the effectiveness of risk management based on a comprehensive risk assessment has been demonstrated and where the assessment methodology not only reveals risk but also guides, with its approach, the actions to be taken.

Keywords: Risk drivers; probabilistic risk assessment; holistic risk evaluation; risk management, Manizales.

1. INTRODUCTION

Nowadays, disaster risk, defined as the potential losses, should be evaluated from a probabilistic approach. The reasons for this are based on the following aspects among others: i) It is necessary to consider the random nature of events and their effects; ii) The intensities of the events have a frequency of occurrence; iii) It is preferable to express potential losses in occurrence rates or return periods; iv) The best risk metrics are associated with the probability of exceeding loss levels; v) There are uncertainties that must be quantified and propagated throughout the analysis; vi) Most critical losses have not occurred yet; therefore statistics of historic events are not appropriate.

From a holistic perspective, risk involves both the physical vulnerability and the social and economic vulnerability factors that configure the susceptibility conditions of urban areas. Physical vulnerability is related to lack of structural strength of the assets exposed to hazards, based on the potential intensities of the hazardous events in a period of time. The susceptibility of the social context depends on the socioeconomic fragilities and on issues related to lack of resilience of the population in the study area. Therefore, to reduce risk it is

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necessary to implement corrective and prospective actions against both hard and soft vulnerability factors. Consequently, disaster risk management requires an interinstitutional and multisectoral structure to implement, through public policies and actions, the changes needed to reduce vulnerability and disaster risk.

Hence a holistic approach of risk assessment should be based on the integration of probabilistic and comprehensive visions. This article is focused on the holistic evaluation of the seismic risk of the city of Manizales, Colombia, based on the probabilistic evaluation of the physical seismic risk, and how the results of a comprehensive risk assessment have been used for several specific vulnerability and risk reduction actions and for updating the city planning instruments.

2. THE HOLISTIC EVALUATION OF THE DISASTER RISK

Since 1990s the authors have been working on the holistic approach for disaster risk assessment and have developed and applied evaluation methodologies and metrics for this objective (Cardona 2001, 2004a, 2004b, 2011; Carreño 2006; Carreño et al. 2007b). The evaluation methodology has been improved and adapted according to the case studies and the availability of information related to hard (physical risk) and soft vulnerability factors (Barbat et al. 2010, 2011; Carreño et al. 2012, 2014a, 2014b; Birkman et al. 2013; Cárdenas et al. 2015; Jaramillo et al. 2016).

Carreño et al. (2007a, 2012) developed two alternative versions of the evaluation model—one based on indicators and the other based on expert opinions—in which risk assessment is performed by affecting the physical risk with socioeconomic factors or risk drivers, in order to reflect how socioeconomic fragilities and lack of resilience aggravate or amplify the direct effects of disasters.

This holistic evaluation method has been implemented as a post-processing tool of the Comprehensive Approach to Probabilistic Risk Assessment (CAPRA) platform (Cardona et al. 2012; Salgado-Galvez et al. 2016). This approach contributes to the effectiveness of risk management, inviting to action through the identification of development weaknesses and shortcomings at the urban center (Carreño et al. 2007a). Socioeconomic fragility and lack of resilience are described by a set of indicators that aggravate the physical risk. Thus, the total risk depends on the direct effects 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, $(1 + F)$ is an impact factor, where F is the aggravating coefficient. This coefficient depends on the socioeconomic fragility, SF, and on the lack of resilience of the exposed context, LR. This approach is well-known as the Moncho's equation.

The physical risk, R_F, is evaluated using the following equation:

$$R_F = \sum_{i=1}^{p} F_{RFi} * w_{RFi} \tag{2}$$

where p is the total number of indicators related to the physical risk, F_{RFi} are the component factors and w_{RFi} are their weights. The physical risk factors, F_{RFi}, are calculated using the net values of physical risk indicators; they can be the result of a deterministic or a probabilistic risk assessment, such as the number of casualties, the value of destroyed area, the pure risk premium (that is, the relative average annual loss), and so on (Lantada et al. 2010). The weights are defined on the basis of local expert opinions processed by means of the Analytic Hierarchy Process (AHP) that is used to derive ratio scales from both discrete and continuous paired comparisons (Saaty 1980; Carreño et al. 2007a).

The indicators used in this evaluation have different characteristics and units, and transformation functions should be used to standardize the gross values of each indicator, transforming them into commensurable risk factors, taking a value between 0.0 and 1.0. The transformation functions used in the methodology in order to calculate the hard and soft risk factors are membership functions for high levels of risk defined for each indicator in the terminology of fuzzy sets and logic (Carreño et al. 2007a). The value 0.0 represents the non-membership and 1.0 corresponds to total membership. The limit values, X_{min} and X_{max}, are defined taking into account expert opinions and information about previous disasters (Carreño et al. 2012). Figure 1 gives a model for these functions.

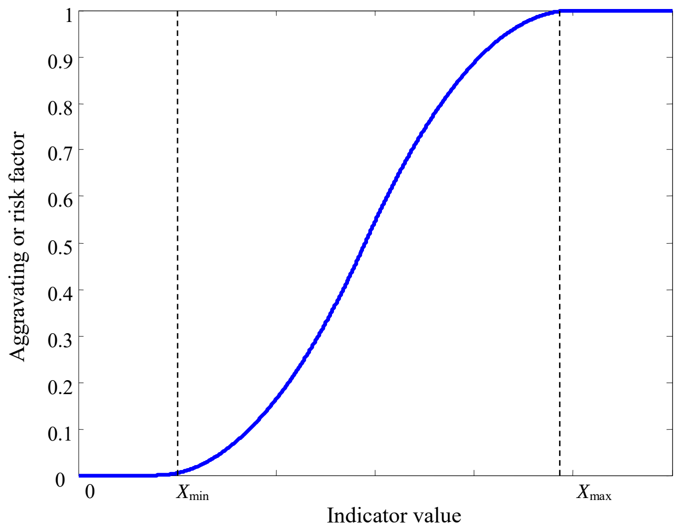

Figure 1. Model for the transformation functions applied to calculate the hard and soft risk factors.

Similar functions are used in the case of the indicators for social fragility and lack of resilience to develop the transformation functions. Sigmoid functions are used in most cases, and the type S or Z is used depending on the type of indicator. In the case of the indicators of lack of resilience, the function has an inverse (Z) shape, that is, higher values of the indicator result in lower values of aggravation. The aggravating coefficient is calculated in a way that is similar to computing the weighted sum of the aggravating factors.

$$F = \sum_{i=1}^{m} F_{SFi} * w_{SFi} + \sum_{j=1}^{n} F_{LRj} * w_{LRj} \quad (3)$$

where F_{SFi} are factors related to the socioeconomic fragility, and F_{LRj} are factors related to the lack of resilience of the exposed context. The weights w_{SFi} and w_{LRj} represent the relative importance of each factor and are calculated by means of the AHP based on local expert opinions.

The indicators are selected, depending on the case study, as the most significant for each category. For example, in the case of social fragility, it is possible to use the slum-squatter neighborhoods area, the mortality rate, the delinquency rate, and the population density. In the case of lack of resilience, the number of hospital beds, the health human resources, the public space area, the rescue and firemen manpower, the development level, and the emergency planning can be used. These indicators can be replaced by others according to the information available for each case study. There is not a minimum indicators number established to apply the methodology; instead, it is expected that the indicators involve information related to the social fragility and lack of resilience of the community. Jaramillo et al. (2016) provide an idea about indicators that can be used following the indicators applied by urban observatories of the United Nations and other social researchers.

The robustness of this methodology has been studied by assessing the uncertainty of values and the sensitivity to change of values, weights, and transformation functions. The methodology is not excessively sensitive to slight variations of the input data and to small changes in the modeling parameters, such as weights and transformation functions. If the range of variation of data and parameters is reasonable, the results of the numerical simulations will be stable and reliable. More details about the robustness analysis are given by Marulanda et al. (2009).
Detailed information about this evaluation method can be found in Carreño (2006), Carreño et al. (2007b), and Barbat et al. (2011). For management purposes, the risk assessment should improve the

decision-making process in order to contribute to the effectiveness of risk management, calling for action and for identifying the weaknesses of the exposed elements and their evolution over time (Carreño et al. 2007a). In the case that the basic information required by this methodology does not exist or is not available, the holistic evaluation of the disaster risk can be performed by using expert opinions and applying an alternative methodology based on the fuzzy sets theory (Carreño et al. 2012, 2014a).

3. THE CASE OF MANIZALES, COLOMBIA

3.1 The city

Manizales, with a population of almost 400,000 inhabitants, is located on the Colombian Central Mountain Range (part of the Andean Mountains, Cordillera de Los Andes) in the northern part of the Coffee-Growers Axis (Eje Cafetero). Due to this location, the city has an abrupt topography with steep slopes that has required public infrastructure for land stabilization in several areas of the city. Manizales has been affected by various hazards in the past: landslides induced by rain, generated in most cases by the formation of settlements in areas with very steep slopes, as a product of the dispersed and uncontrolled growth of the city; floods, mainly on the banks of the Chinchiná river and Manizales, Olivares, and El Guamo creeks; ash fall events due to volcanic threat; and earthquakes. During the twentieth century the city was affected by six major earthquakes. This experience allows a better understanding of disaster risks for the decision makers and citizens in general. The city has been developing and consolidating its practices and public policies on integrated risk management for several years, especially since the 1970s.

Manizales has invested heavily in the science and technology of disaster risk reduction in the last two decades. In the framework of the Manizales' Integrated Disaster Risk Management Program, GIRD-M, (http://www.gestiondelriesgomanizales.com), developed by the National University of Colombia at Manizales with the financial support of the environment regional authority, CORPOCALDAS, and the city administration, sixteen projects of risk knowledge and information systems, instrumentation and warning systems, and incorporation of risk in planning and awareness have been implemented, during last years. This implementation has been based on the follow-up over time of the holistic risk assessment results and the discussion, analysis and institutional decision making at city level.

3.2 The physical risk index

A probabilistic approach was used for the analysis of seismic and landslide hazards (triggered by earthquakes or heavy rainfall) to obtain stochastic event sets suitable for the probabilistic loss estimation and risk results in terms of different metrics after aggregating in a rigorous way the losses associated to the different hazards. Seismic microzoning has been used (Cardona and Yamin 1997). Detailed and high-resolution exposure databases were used for the building stock and infrastructure of Manizales, together with a set of vulnerability functions for each of the considered perils (Yamin et al. 2014).

The physical risk index, R_F in Equation 1, is based on the results of this fully probabilistic multihazard risk assessment made for the city using the CAPRA platform (Bernal 2014; Bernal et al. 2017; Salgado-Gálvez et al. 2017). Risk was assessed on a building-by-building basis, and by aggregating the metrics for the whole districts. Further details on the physical risk assessment can be found in Bernal et al. (2017) and Salgado-Gálvez et al. (2017). For this evaluation, the selected indicators correspond to the pure risk premium (average annual loss/exposed reposition value) for six sectors: residential (RF1), commercial (RF2), industrial (RF3), health (RF4), institutional (RF5), and education (RF6). These values were standardized by using a transformation function that defines a value of 10‰ as the maximum pure risk premium for a risk factor of 1.0. Table 1 shows the obtained factors, the calculated weights for each factor, and the physical risk index for each district and for the city as a whole. The weights assigned to the risk factors are the same for all districts in the city.

Table 1 Physical risk factors and physical risk index calculated for the districts of Manizales, Colombia

District	F_{RF1}	F_{RF2}	F_{RF3}	F_{RF4}	F_{RF5}	F_{RF6}	R_F
C1- Atardeceres	0.30	0.42	0.10	0.49	0.03	0.05	**0.25**
C2- San José	1.00	0.62	0.93	0.56	0.90	0.78	**0.80**
C3- Cumanday	1.00	1.00	1.00	1.00	0.51	0.68	**0.88**
C4- Estación	0.98	0.62	0.72	0.85	0.29	0.91	**0.75**
C5- Ciudadela del Norte	1.00	1.00	0.30	0.25	1.00	0.10	**0.61**
C6- Ecoturístico Cerro de Oro	0.97	0.28	0.37	0.18	0.28	0.89	**0.50**
C7- Tesorito	0.74	0.14	0.06	0.09	0.11	0.09	**0.23**
C8- Palogrande	0.92	0.78	0.87	0.25	0.70	0.62	**0.68**
C9- Universitaria	0.65	0.14	0.15	0.03	0.17	0.33	**0.25**
C10- La Fuente	0.94	0.92	0.86	1.00	0.17	0.66	**0.78**
C11- La Macarena	0.94	1.00	0.66	0.94	0.25	1.00	**0.81**
Manizales	0.93	0.87	0.36	0.70	0.49	0.59	0.67
Weight	0.20	0.15	0.15	0.20	0.15	0.15	1.00

3.3 The aggravating coefficient

Indicators related to social fragility and lack of resilience were identified to define the aggravating coefficient (F) and, therefore, the impact factor $(1 + F)$ of the potential physical damage and loss. They reflect the social absences, weaknesses, and susceptibilities from a development point of view that should be addressed by the processes of economic and social development planning to reduce vulnerability and risk from a comprehensive perspective. Table 2 shows the indicators related to social fragility (SF) and lack of resilience (LR) selected for the holistic evaluation, in accordance with the available information and the X_{min} and X_{max} parameters used in the transformation functions for each case. The indicators used to calculate the aggravating coefficient correspond to the official information provided by different agencies at the local and national levels such as: the Secretariat of Planning (Secretaría de Planeación), the Secretariat of Public Health and Legal Medicine (Secretaría de Salud Pública y Medicina Legal), the Risk Management Unit (Unidad de Gestión del Riesgo), the National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadística, DANE), the System of Identification of Potential Beneficiaries for Social Programs (Sistema de Identificación de Potenciales Beneficiarios de Programas Sociales – SISBEN), and the National Planning Department (Departamento Nacional de Planeación) (Suárez 2015).

Table 2 Indicators for aggravating conditions (risk drivers of social fragility and lack of resilience) in the districts of Manizales, Colombia

	Indicator	Unit	X_{min}	X_{max}
X_{SF1}	Slum neighborhoods	% of the district area	5	30
X_{SF2}	Murder rate	Number of murders per 100,000 inhabitants	0	10
X_{SF3}	Persons without education	% of population	0	30
X_{SF4}	Overcrowding†	% of the district area	3	30
X_{SF5}	Population density	People per square kilometer	4,000	25,000
X_{LR1}	Hospital beds	Number of beds per 1000 inhabitants	0	30
X_{LR2}	Health human resources	Health professionals per 1000 inhabitants	0	15
X_{LR3}	Public space	% of the district area	1	15
X_{LR4}	Rescue human resources	Professionals per 10,000 inhabitants	0	7
X_{LR5}	Medium/high socioeconomic stratum	% of the district area	10	40
X_{LR6}	Community participation	Community Action Boards per 100,000 inhab.	10	50

† Overcrowding is defined by SISBEN (2011) as tenement houses and dwellings with more than three people per bedroom.

Table 3 shows the results for the aggravating factors for each district of Manizales, taking into consideration the 11 indicators listed in Table 2. They have been obtained by using transformation functions type S (for social fragility) and Z (for lack of resilience) to standardize each indicator. The total aggravating coefficient (F) is obtained after scaling all the factors in commensurable units by using Equation 3. Table 3 also shows the average values of the factors for the city, normalized with the density of population. The average values for the city recognize the murder rate, the lack of hospital beds, the lack of health human resources, and the lack of public space as the main aggravating conditions. But to guide decision making it is necessary to review the situation for each district.

Table 3 Aggravating factors and aggravating coefficient calculated for the districts of Manizales, Colombia.

District	F_{SF1}	F_{SF2}	F_{SF3}	F_{SF4}	F_{SF5}	F_{LR1}	F_{LR2}	F_{LR3}	F_{LR4}	F_{LR5}	F_{LR6}	F
C1- Atardeceres	0.02	1.00	0.40	0.59	0.12	0.76	0.90	0.01	0.00	0.00	0.24	**0.37**
C2- San José	0.13	1.00	0.69	1.00	1.00	1.00	0.99	1.00	0.00	1.00	0.20	**0.74**
C3- Cumanday	0.00	1.00	0.27	0.19	1.00	0.98	0.99	0.92	0.06	0.73	0.94	**0.64**
C4- Estación	0.00	0.38	0.19	1.00	0.60	0.77	0.99	0.97	0.93	0.00	0.01	**0.53**
C5- Ciudadela del Norte	0.07	1.00	0.51	0.57	0.30	1.00	1.00	0.92	0.93	1.00	0.25	**0.69**
C6- Ecot. Cerro de Oro	0.00	0.99	0.26	0.26	0.05	1.00	1.00	0.00	0.00	0.10	0.90	**0.41**
C7- Tesorito	0.04	1.00	0.37	0.13	0.00	0.99	0.99	0.54	0.00	0.71	0.34	**0.47**
C8- Palogrande	0.00	0.30	0.27	0.00	0.01	0.99	0.99	0.98	0.00	0.00	1.00	**0.40**
C9- Universitaria	0.00	1.00	0.41	0.69	0.78	1.00	1.00	0.74	0.13	1.00	0.32	**0.65**
C10- La Fuente	0.45	1.00	0.46	0.60	0.99	1.00	1.00	0.77	0.32	0.82	0.01	**0.68**
C11- La Macarena	0.76	1.00	0.55	0.80	0.51	1.00	1.00	1.00	0.13	1.00	0.14	**0.72**
Manizales	0.16	0.92	0.43	0.52	0.70	0.96	0.99	0.81	0.24	0.70	0.34	**0.63**
Weights	0.09	0.09	0.1	0.09	0.09	0.09	0.1	0.08	0.09	0.1	0.08	1.00

3.4 The total seismic risk

The composite total risk index (R_T) is calculated based on the component indicators. It has been used as the Urban Disaster Risk Index ($UDRi$) for each district of the city, like it has been evaluated for other cities worldwide (Marulanda et al. 2009, 2013; Khazai et al. 2015). Figures 2, 3, and 4 show the results for the eleven districts, taking into consideration the physical risk, the aggravating coefficient, and the total risk, respectively. The figures show how the physical risk map values (Figure 2) are amplified by the aggravating coefficient (Figure 3), and result in the total risk or the $UDRi$ (Figure 4). All ranges of physical risk, the aggravating factor, and total risk were defined with officers and advisors of the Secretariat of Planning, taking into account the disparity and social characteristics used in the city to rank and compare the districts.

The aggravating coefficient (Figure 3) shows medium-high values for the districts of San José, La Macarena, Ciudadela del Norte, and La Fuente; medium values for the districts of Universitaria, Cumanday, and Estación; medium-low values for Tesorito, Ecoturístico Cerro de Oro, and Palogrande; and a low value for Atardeceres.

The total risk (Figure 4) shows high values for the district of Cumanday; medium-high values for La Macarena, San José, and La Fuente; medium values for Estación, Ciudadela del Norte, and Palogrande; medium-low values for Ecoturístico Cerro de Oro and Universitaria; and low values for Atardeceres and Tesorito. Once the results and the ranking of risk in Manizales have been obtained by district, it is possible to review each case and disaggregate it into its components, identify which factors and indicators are more relevant, and define the possible actions to reduce the underlying causes of risk. The $UDRi$ results for Manizales were analyzed for each district. Carreño (2015) and Carreño et al. (2017) provide detailed information related to the evaluation process and to the obtained results for the holistic evaluation of disaster risk, including the analysis for each district in the city. This key information has been useful to prioritize the interventions and actions of vulnerability and risk reduction by districts.

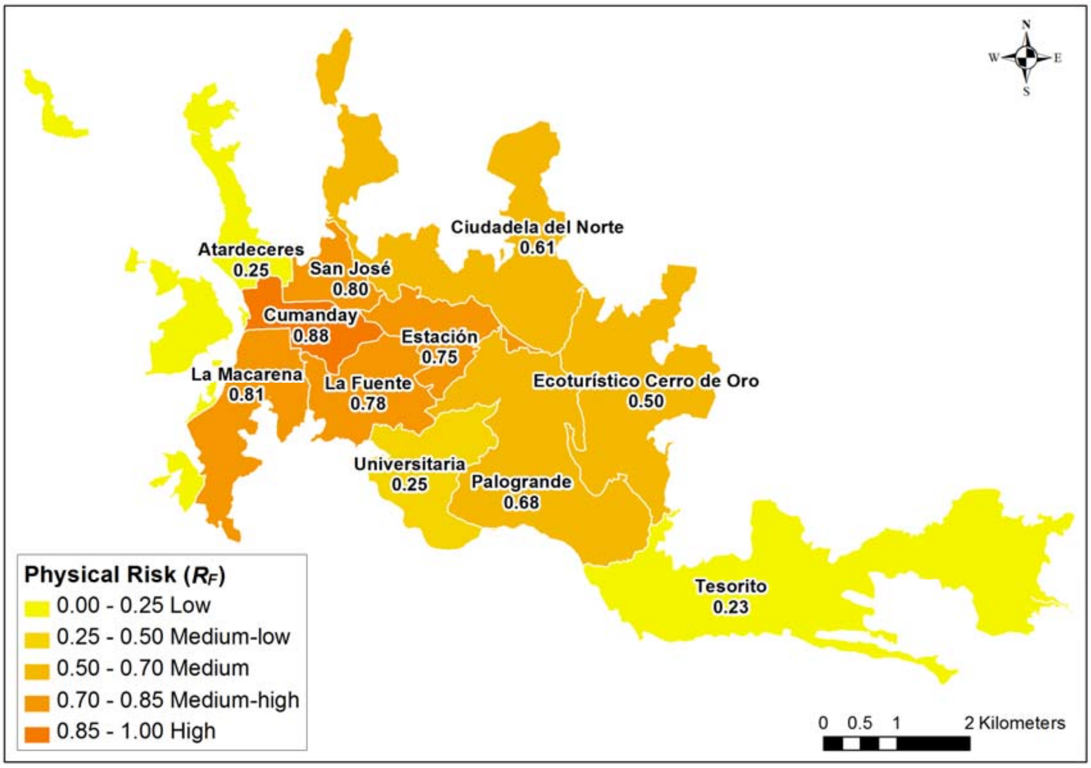

Figure 2. Physical risk index R_F, based on seismic hazards and landslides due to earthquakes and rain, for the districts of Manizales, Colombia

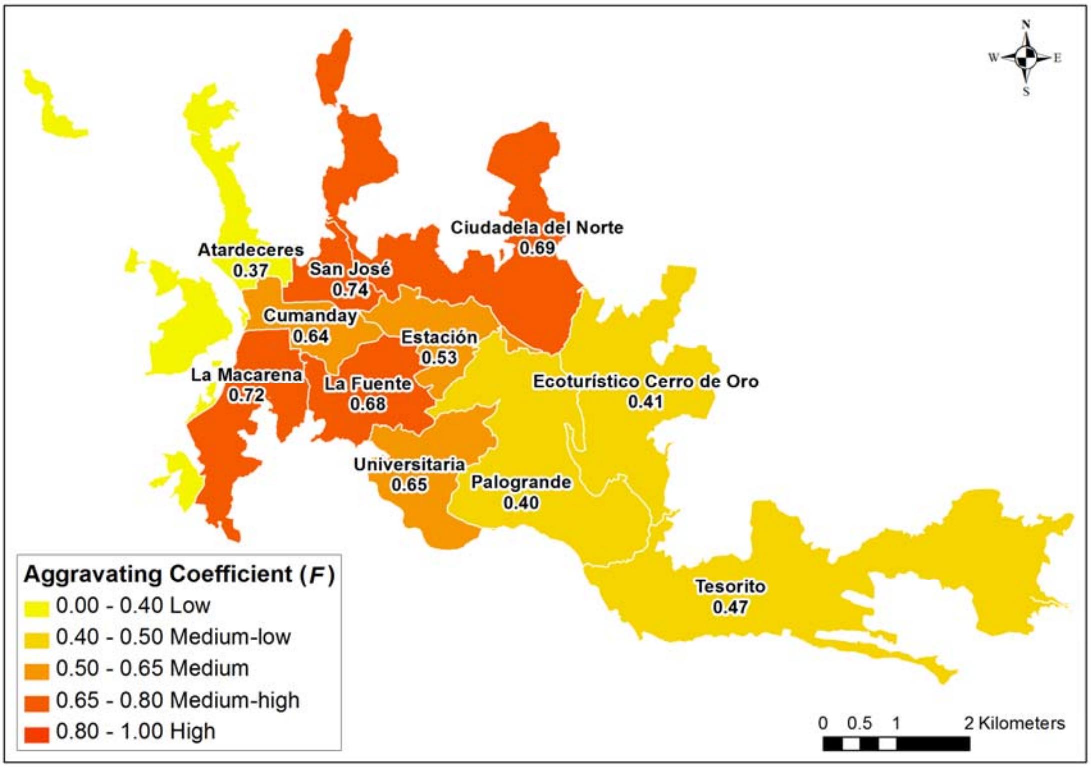

Figure 3. Aggravating coefficient F, based on socioeconomic and resilience factors for the districts of Manizales, Colombia

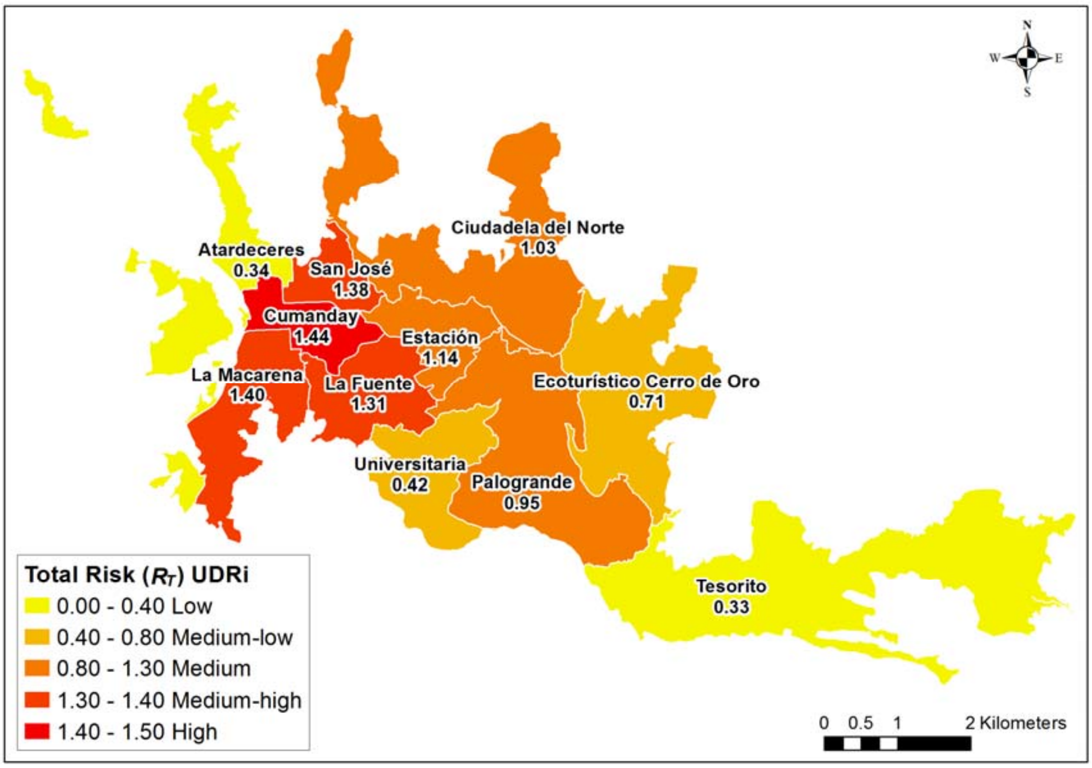

Figure 4. Total risk index R_T, or $UDRi$, for the districts of Manizales, Colombia

3.5 Disaster risk as determinant of city planning

The results of holistic risk assessment for the city of Manizales have been used to support the decision-making process on disaster risk reduction by improving the risk understanding of the stakeholders and the identification of differences and drivers of vulnerability and risk at local level. Some examples of disaster risk management initiatives and actions in the city are the following achievements:

- Seismic microzoning has served to optimize the municipality's financial protection strategies for public buildings and infrastructure and to evaluate seismic risk of all private buildings and lifelines. Microzoning involves detailed study of soil, geology, slope and modelling the forces at specific locations that are likely in earthquakes of different magnitudes.
- The city offers, with the support of the national insurance industry, housing insurance that can be paid with the property tax. This allows the full coverage of the exempted properties (by cross subsidies), which benefits the city's low-income households.
- The city promotes incorporation of risk in land-use and territorial planning, and the local building code incorporates earthquake resistance standards according to the state of knowledge.
- Key buildings such as the main hospitals, the fire-brigade stations, the administration headquarters, several schools, university campuses and the iconic Basilica Cathedral have been retrofitted using state-of-the-art earthquake resistant requirements.
- Works regarding the stability of slopes have been made in several places of the city, through the environment regional authority CORPOCALDAS (previously CRAMSA) and the Secretariat of Public Works of the city administration.
- The program 'Guardians of the Hillside' involves house-head mothers in the maintenance of drainage works that stabilize steep urban slopes, for which they receive a payment.
- A large number of housing relocation projects have been implemented for people living in areas where the risk could not be otherwise reducing, such as very steep slopes. The freed-up areas have been restored and protected, in part through community-based action.
- A Municipal Emergency Plan provides the city's response in case of crisis and defines the operational procedures and the coordination mechanisms that facilitate inter-institutional action.

- The city has an automatic evaluation of seismic damage and a specialized procedure of post-earthquake building damage evaluation. It has specific manuals, evaluation forms and a computer-based expert system (app for smartphones) for the evaluation of the buildings' safety.
- A dense online network of accelerometers and rainfall measuring stations are used to monitor hazards and warn the population and authorities in case of emergency and a volcano observatory continuously watches the area's volcanoes and the regional seismic activity.
- Teaching about disaster risk has been incorporated into formal education and there has been continuous work with the media to disseminate the message and public information.

This multidisciplinary and intersectoral effort has contributed to improve the quality of life, vulnerability reduction and protection of the economic and social development of the city. At present, all activities of risk management are programs or sub-programs and activities of the city's plan of Disaster Risk Management. The DRM plan at local level is the legal instrument, according to Law 1523 of 2012, through which the objectives, goals, strategies, actions, and actors are defined to implement the national policy of risk management of Colombia, during a period of 12 years (i.e. 2016–2028, including three local administrations). Figure 5 presents the main programs and subprograms for the city of Manizales, within the framework of the risk knowledge, risk reduction, and disaster management processes.

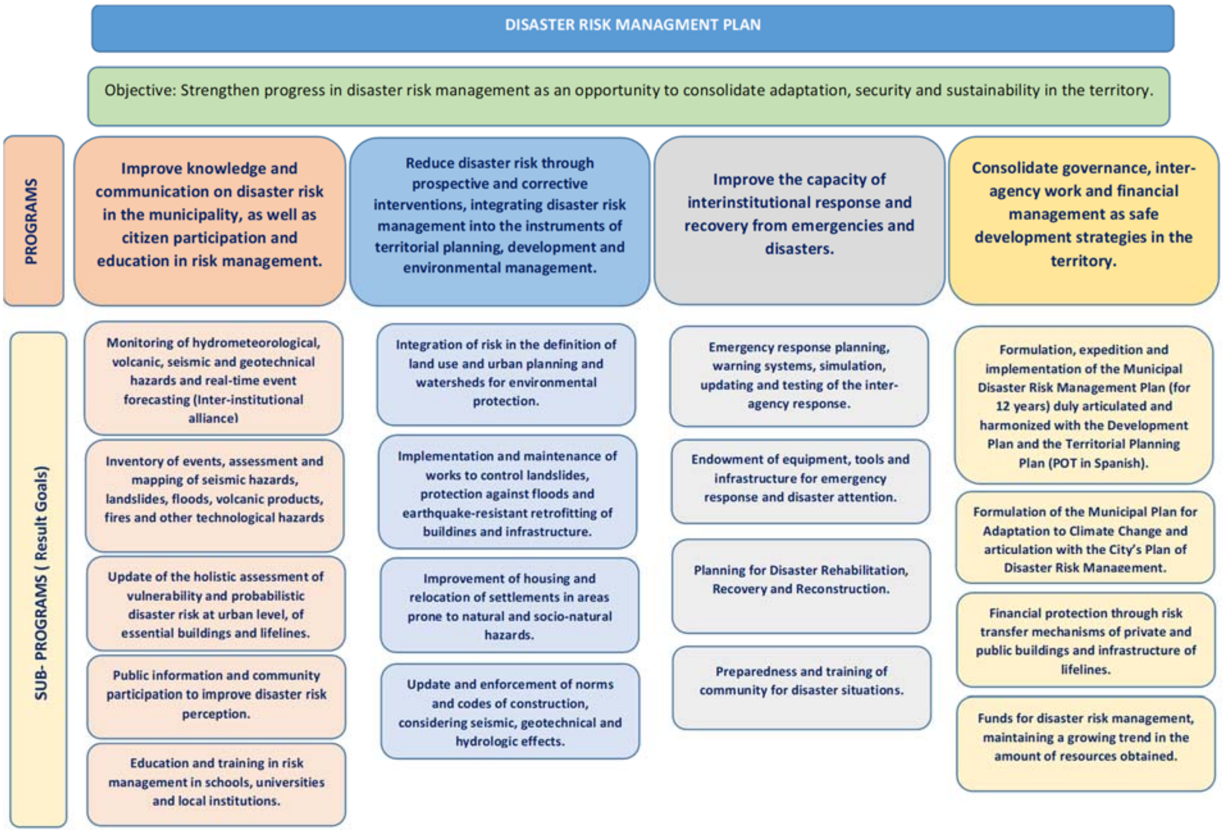

Figure. 5 Programs and sub-programs of the city's Disaster Risk Management Plan of Manizales, Colombia.

The DRM plan was adopted by decree (Alcaldía de Manizales 2016a) to define the medium- and long-term actions, derived from the general diagnosis of the city and its districts through the physical and holistic assessment of the disaster risk, above described, and the evaluation of the disaster risk management performance in the city by using the Risk Management Index (RMI) (Carreño et al. 2004, 2007a), both in retrospective and prospective ways. It also defines the goals, the general procedures, and mechanisms for achieving, the budget, and the schedule of all activities. The strategic and programmatic components of the plan have been the result of a participatory process, in which it was possible to systematize contributions from the different public and private stakeholders and actors, who attended different workshops and interagency meetings. In addition, the holistic risk assessment has been included in the plan as a recursive process and continuous risk research, facilitating the dynamic and adaptive management by risk problem framing and reframing. This specific plan, defined by law, was incorporated into the socioeconomic development plan of the current administration (2016–2019) as a component of environment, climate change, and disaster risk management and will guide the action to reach the development objectives and goals and the instruments of linkage and harmonization with other plans at the city level, such as the territorial or land-use planning (POT, Plan de Ordenamiento Territorial, in Spanish) and the emergency response plan of the city (Alcaldía de Manizales 2016b).

Regarding land-use planning deserves to underline the urban macro-project in the San José district, in which the aggravating factor has been the highest (F= 0.74). This macro-project of urban renovation includes as objectives: i) to promote and execute integral urban management operations and provision of urban land for priority interest housing (4,000 units) and social interest housing (1,500 units); ii) to generate urban land for the housing relocation of at high-risk for the district, through processes of integral improvement of neighborhoods; iii) to promote the re-densification of the territory, through the efficient use of urban land, and the control of urban expansion. The Figure 6 illustrates the localization and the current interventions in process of the San José's macro-project.

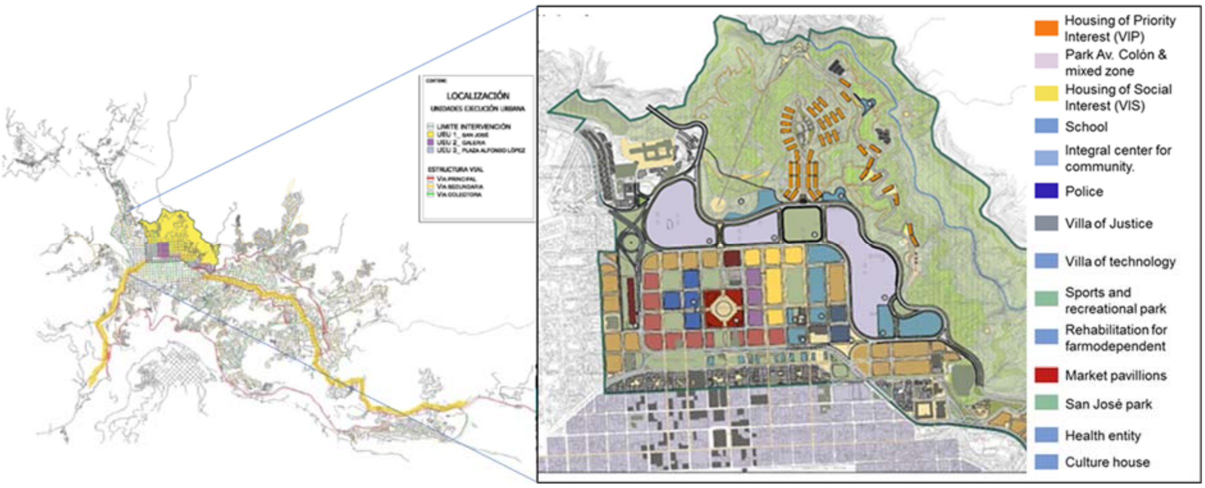

Figure 6. Proposal of interventions of the San José's macro-project of urban renovation and risk reduction

4. CONCLUSIONS

Risk understanding is an unavoidable process and early step for risk management. The formulation of a policy and process for risk reduction and of adaptation should be based on knowledge of the components and the disaggregation of the underlying causes and drivers of vulnerability and risk, taking into account both their harder and softer characteristics. Holistic risk assessment has been developed to deal with these characteristics, considering the physical risk, or potential direct effects, and its amplification, or potential indirect effects. This type of integrated and scientific approach facilitates decision making and the flexible adjustment in practice of actions to be implemented by different stakeholders and actors as a disaster risk management plan and in the framework of other relevant city planning instruments. The Disaster Risk Management Plan of Manizales, Colombia, has been formulated based on the participation of the different private and public actors and with the input from the holistic disaster risk assessment of the city. Strategic and programmatic components have been defined, framing and reframing the risk problem, and identifying the main actions to be implemented in each district of the city and making the follow-up of risk reduction in a dynamic way, using the holistic risk assessment approach to give account of the improvements and achievements on vulnerability and risk reduction. Manizales provides a good example of how a combination of technical and scientific work, political-administrative will and the community's acceptance can lead to successful initiatives. Manizales has invested heavily in the science and technology of disaster risk reduction. The administration has encouraged the diffusion of knowledge about the causes and the factors that contribute to risk and has supported the participation of citizens in the planning processes. In addition, Manizales has promoted respect for environment and the municipality's challenging geographic, topographic, seismic and climatic conditions.

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