TECHNICAL REPORT

URBAN RISK AND RISK MANAGEMENT DIAGNOSIS FOR PLANNING AND IMPROVEMENT OF EFFECTIVENESS AT LOCAL LEVEL: APPLICATION TO MANIZALES CITY

- COLOMBIA -

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SEPTEMBER, 2009

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1 CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Disasters have been become a problem that increases and worries governments and some international agencies. Actually, the reduction of disaster risk frequency, severity and its impacts are part of the challenges especially for developing countries.

The International Strategy for Disaster Reduction (ISDR), of United Nations, has pointed that the number of people at risk around the world has been augmented in a rate of 70 to 80 million per year, leaving in evidence the amplification of human vulnerability in different places. In the last years Europe has suffered the worst floods, Australia has been beaten by strong droughts and the Caribbean, Japan and the United States were affected by hurricanes (ISDR, 2004). The Munich Re assurance agency registered close to 700 natural catastrophes in 2002 and economical losses of $55 billion of dollars (ISDR, 2004).

In 2005 occurred the higher number of hurricanes (13) leaving devastating effects for Mexico, Central America, the Caribbean and the Gulf of Mexico: Louisiana, Missouri, Mississippi and Texas. The global impact is around 200 and 210 mil million de dollars, more than 4600 death people, more than six million of affected people and preliminary estimations of damages and losses in America Latin and the Caribbean over 6 mil millions of dollars (EIRD, 2006a).

The period between June 2005 and May 2006 registered 404 disasters at the national scale; which represents an average of one per day, a number higher in 25% than the average of the period 1995-2004, with a total of 115 countries affected, 93,000 death people and economical costs that achieve the 173,000 millions of dollars (ONU, 2006).

In the specific case of Colombia this is a country were occurs several disasters. The eruption of the volcano "*Nevado del Ruiz*" in 1985 caused the destruction of the municipality of *Armero* and caused serious damages in Chinchiná and other small villages. This event signified no less than 20,000 death people and notable economical losses (211.8 millions of dollars, UN, 1985).

By other hand, the Niño's phenomenal also has affected the country. It caused economical loses around 564 millions of dollars between 1997 and 1998. In 1999 an earthquake occurred in the coffee region that leaved losses estimated in 1589 millions of dollars (equivalent to 2.2% of the GDP of 1998). This event caused the death of 1230 people, 3000 injured and close to 200,000 affected (Cardona, 2004).

In addition, the rain seasons have generated floods and landslides in all the country with a total of 703,010 affected in the period 2002 – 2003 and 495,809 in 2004, according to the data of the National Direction of Disaster Prevention and Attention (DNPAD, 2005).

At the local level Manizales has been affected also by important disaster in its history. The location in an area of volcanic activity and seismic area caused notable earthquakes in 1938, 1962, 1964, 1979 and recent regional earthquakes in 1995 and 1999. The last two generated few victims in the city but the material damages (in houses, water pipes and roads) were important.

Nevertheless, the more frequent disasters in the last years in Manizales have been the landslides. The most important events were in 1993 and 2003, which caused a big number of death people, affected and evacuated population (Cardona, 2005; Chardon, 2002).

Also the city suffered two devastating fires in 1925 and 1926. Even today it is vulnerable to fire in the central zone due to the traditional habitat in "*bahareque*" construction.

Additionally, there are some zones vulnerable to floods next to the Chinchiná and Olivares rivers.

In conclusion, the disaster risk management is an important goal for local and national governments, as well as for the international agencies in the last years. A particular objective is the risk reduction and the evaluation existing risk. The Hyogo's framework 2005-2015, from the World Conference on Disaster Reduction in 2005**,** reflects this situation declaring the importance of searching the identification, valuation and monitoring of disaster risk, the improvement of early warning and the development of indicators systems for disaster risk and vulnerability evaluation in different territorial scales (UN, 2005; Birkmann, 2006).

As part of the context, Manizales has had important improvements in the risk management. It has include this concept in planning, it has promoted seismic and geotechnical studies, it has done structural reinforcements and slope stability works, it has developed strategies for a collective assurance and public edifications, among others.

All this points exposed show that the evaluation of disaster risk and disaster risk management can be significant tools for the city of Manizales, integrating a comprehensive vision of risk to establish risk reductions projects and searching the vulnerability reduction.

1.2 OBJECTIVE

The main objective of this research is to adequate and apply methodologies of evaluation of risk and risk management performance at local level, taking into account the previous work made at national level by the Institute of Environmental Studies, (IDEA in Spanish), of the National University of Colombia, in Manizales, providing new elements and continuing its application at urban level.

This methodology is related to the construction of two indexes:

- The Urban Seismic Risk Index, USRi, based on a holistic perspective for evaluating the eleven localities (*comunas*) in the city of Manizales, taking into account not only direct effects related to the physical risk but also indirect effects related to the eco-social fragility and lack of resilience or capacity to cope.

- The Disaster Risk Management Index, DRMi, to evaluate the different components or policies regarding disaster risk management in the city of Manizales, to have a benchmark of the advances and shortcomings to improve decision making at local level.

Using these indexes a set of recommendations will be made to be included in the socio-economic development plan and the territorial plan (land use) of the city. They will pointed out the social and institutional issues of risk and not only the physical risk or the potential damage. The researcher and the researchers of IDEA share this process from the beginning with the city administration officers, particularly from the office for disaster risk management (OMPAD) and the planning office of the city.

2 CHAPTER 2 FRAMEWORK

2.1 THE HOLISTIC APPROACH OF VULNERABILITY AND RISK

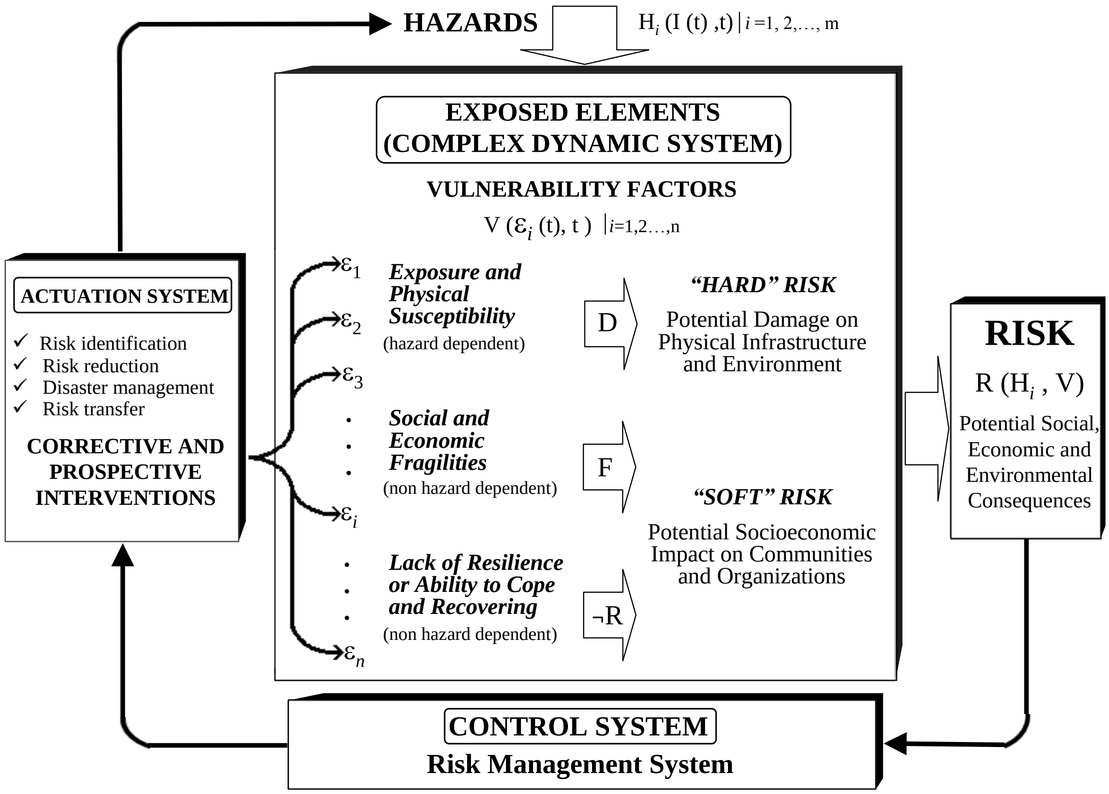
This approach is considered by Birkmann (2006) as one of the six existing schools of discussion for the conceptual and analytic frameworks of disaster risk and disaster risk management. The approximation to the holistic assessment of risk and vulnerability was proposed by Cardona at the end of the 90's (Cardona 2001) and it was applied with Hurtado and Barbat in 2000, where the vulnerability was evaluated considering tree dimensions or aspects (Cardona, et al., 2005; Carreño, et al., 2004, 2005a, 2005b, 2006):

Exposure and physical susceptibility, D, which is designated as "hard" risk, related to the potential damage on the physical infrastructure and environment (hazard dependent),

Socio-economic fragilities, F, which contribute to "soft" risk, regarding the potential impact on the social context (hazard independent), and

Lack of resilience to cope disasters and recovery,¬R, which contributes also to "soft" risk or second order impact on communities and organizations (hazard independent).

This model of holistic perspective consists in the conformation of a dynamic complex system by the exposed elements, which have characteristics or factors of vulnerability ("hard" and "soft" risk) and in the presence of a hazard generate risk conditions. The management disaster risk system has to count with a control system and an actuation system; these are represented by the institutional organization and determinate the measures and corrective and prospective interventions. The application of the public policies and actions of risk reduction to hazards and principally to each of the variables of the vulnerability factors (exposure and physical susceptibility, social and economic fragilities and lack of resilience) constitute a feedback loop.

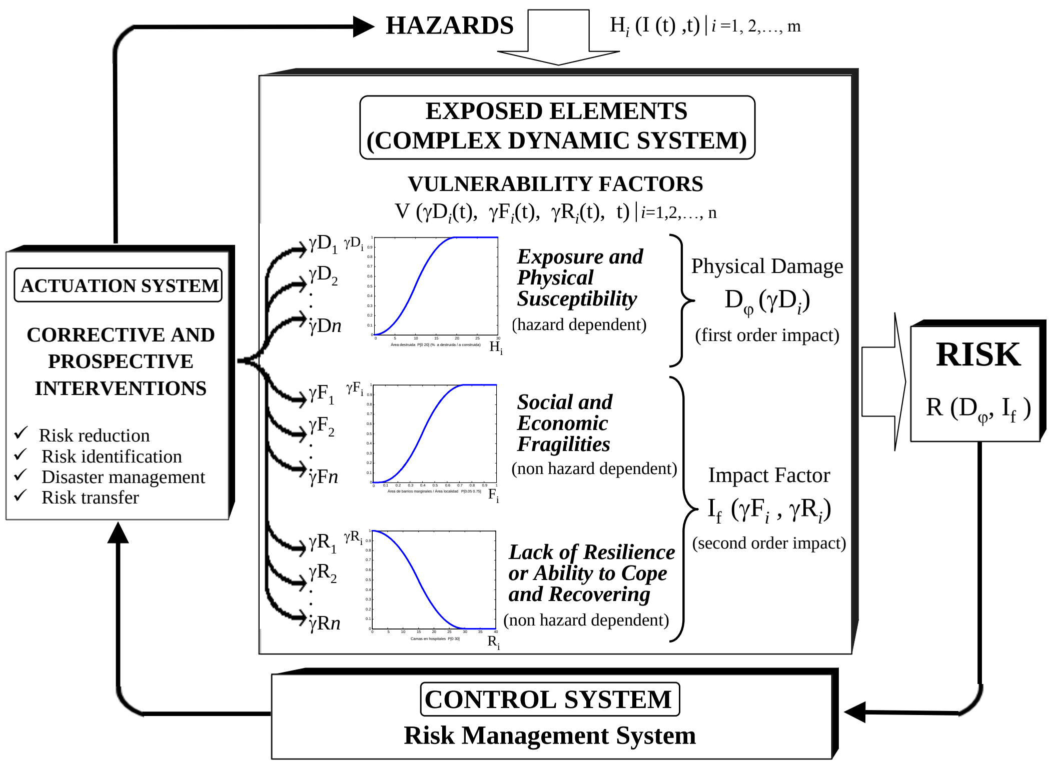


Fuente: Cardona et al. (2005).

Figure 2-1. Framework and theoretical model for the holistic approach for vulnerability and disaster risk management assessment, by Cardona and Barbat (2000)

"Vulnerability, and therefore, risk are the result of inadequate economic growth, on the one hand, and deficiencies that may be corrected by means of adequate development processes. Indicators or indices could be proposed to measure vulnerability from a comprehensive and multidisciplinary perspective" (Cardona, et al., 2005; Carreño, et al., 2004, 2005a, 2005b, 2006).

The holistic model was actualized by a new version by Carreño, Cardona and Barbat in 2004 and 2005, where it was redefined the meaning of "hard" and "soft" risk in terms of "physical damage". This concept is obtained from the exposure and physical susceptibility and an "impact factor", this last one as a product of the socio-economic fragilities and the lack of resilience of the system to cope and recovering.



Fuente: Cardona et al. (2005).

Figure 2-2 New Version of the Model (Carreño et al. 2004; 2005)

"From a holistic perspective risk, R, is a function of the potential physical damage, D_φ, and an impact factor, I_f. The former is obtained from the susceptibility of the exposed elements, γD_i, to hazards, H_i, regarding their potential intensities, I, of events in a period of time t, and the latter depends on the social fragilities, γF_i, and the issues related to lack of resilience, γR_i, of the disaster prone socio-technical system or context. Using the meta-concepts of the theory of control and complex system dynamics, to reduce risk it is necessary to intervene in corrective and prospective way the vulnerability factors and, when it is possible, the hazards directly" (Cardona, et al., 2005; Carreño, et al., 2004, 2005a, 2005b, 2006).

3 CHAPTER 3 METHODOLOGY FOR THE EVALUATION

In general, an indicator is an empiric observation that synthesizes aspects of a phenomenon, which is important for analytic and practical propose. The term indicator can allude to any observable characteristic but it is usually susceptible of a numeric expression (CEPAL, 2001). Indicators are criteria for assessment, analyze and evaluation of the behavior of variables, it is to say the characteristics, components, factors and elements reason of study (Quintero, 1997).

The assessment through the indicators has been very common especially for economic, social and industrial situations, not only for evaluate realized actions but also to define policies for public and private administration. The development of indicators has been important also in the health and hosing sectors, even for the design of the human development index. More recently, the environmental segment has recognized the necessity of assessment and measure different aspects such as environmental impacts, resources state, environmental conditions and sustainable development, as it was established in the Declaration of Rio de Janeiro, 1992.

Into this environment theme the problematic of risk also needs to define indicators, which allows the decision making in a more effective and successful way.

Taking into account the importance of indicators for the diagnosis and the general vision of a problem and its evolution, the present work pretends the assessment of risk and disaster risk management for the case of Manizales. The indicators adapted and applied are the Urban Seismic Risk Index (USRi) and the Disaster Risk Management Index (DRMi).

The methodology employed it is part of a technique oriented to the holistic approach of risk which was the fundamental framework of the Project of Indicators of Disaster Risk and Disaster Risk Management, of the Inter-American Development Bank, IADB, and the Institute of Environmental Studies, IDEA, of the National University of Colombia, in Manizales, developed between 2003 and 2005.

3.1 URBAN SEISMIC RISK INDEX, USRi

The holistic approach takes into account not only the physical risk of the exposed urban center but also variables related to economical, social and capacity of hope aspects. The methodologies based in this approach allow the orientation of the decision making in the disaster risk management by identifying especially problematic zones if a catastrophic event occurs, in this case an earthquake (Carreño, 2007; Carreño, et al., 2004, 2005a, 2005b, 2006).

The urban seismic risk index defined in this work as R_T (total risk) is obtained from descriptors or variables for physical risk and the risk of the context. Descriptors of physical risk are attained departing from scenarios according to the hazard; descriptors of the context are developed from initial information related to socio-economic and the lack of resilience of the context. This context conditions actually "aggravate" the physical risk or direct impact of the event.

The procedure proposed by Cardona (2001) for the holistic estimation and related to the urban seismic risk departs from the identification of unit of analysis k, these are the areas for the determination of the total risk index, IR_{Tk}. The index is expressed as it is show in the equation 3.1.1:

$$IR_{T_k} = IR_{H_k} \, . \, \delta IR_{H_k} + IR_{S_k} \, . \, \delta IR_{S_k} \qquad (3.1.1)$$

where IR_{Hk} is physical seismic risk (*hard*) that is based in descriptors obtained from the estimation of potential urban losses caused by future earthquakes;

IR_{Sk} is a seismic risk index of the context (*soft*) that is obtained from the scaled value of the product between descriptors of seismic hazard and vulnerability of the context;

δIR_{Hk} y δIR_{Sk} are the factors of the participation of each index for each area of analysis, k. the physical risk index is obtained by the equation 3.1.2:

$$IR_{H_k} = \sum_i XIR_i \, . \, \delta IR_i \qquad (3.1.2)$$

where XIR_i is the value of each indicator i obtained from the information of the scenarios of losses and δIR_i is the factor of participation for each indicator i, for each area of analysis k. The seismic risk index of the context can by estimated by the equation 3.1.3:

$$IR_{S_k} = \alpha \left((H_{S_k} - \beta)(V_{S_k} - \beta) + \beta \right) \qquad (3.1.3)$$

where H_{Sk} is the descriptor of the seismic hazard of the context, V_{Sk} the descriptor of the vulnerability of the context and α and β constants of visualization, which are related to the average and the standard deviation of the values.

The descriptor of seismic hazard of the context is expressed as follows:

$$H_{S_k} = \sum_i XH_i \, . \, \delta H_i \qquad (3.1.4)$$

where X_{Hi} is the value of the indicators *i* got from the urban seismic microzonation study and δH_i is the factor of participation for each indicator *i*, for each area of analysis *k*; and the descriptor of the vulnerability of the context proposed as:

$$VS_k = EV_k \,.\, \delta E_k + FV_k \,.\, \delta F_k + RV_k \,.\, \delta R_k \qquad (3.1.5)$$

where E_{Vk}, F_{Vk}, R_{Vk} are indicators of exposure, social fragility and lack of resilience and δE_k, δF_k and δR_k are their factors of participation for area of analysis *k*. The equation 3.1.5 can be re-write in the next way:

$$VS_k = \left(\sum_i XE_i \,.\, \delta E_i\right) \delta E_k + \left(\sum_i XF_i \,.\, \delta F_i\right) \delta F_k + \left(\sum_i XR_i \,.\, \delta R_i\right) \delta R_k \qquad (3.1.6)$$

The variables X_{Ei}, X_{Fi} and X_{Ri} are the values of the indicators *i* that compose the exposure, social fragility and lack of resilience and δE_i, δF_i y δR_i are participation of each indicator *i* for each area of analysis *k*, respectively.

The indexes, descriptors, factors and indicators should be defined with the data base available for all units of analysis. Conceptually they should express, as direct as possible, the desired assessment avoiding the simultaneous use of variables or indicators that can reflect similar aspects; this rule is due to the additive model where the variables are mutually exclusive (Cardona, 2001).

Although, the work of Carreño et al. (2004, 2007) change the normalization processes which uses the average and the standard deviation for each descriptor and index. In this way the results obtained are absolute and not relative, allowing the comparison between cities. Also, in this method, hazard and physical exposition have been eliminated due to they are consider into the physical risk calculation. As a result the model acquires more soundness in the theoretical and analytical way.

To obtain total risk it is applied the next equation:

$$R_T = R_F\left(1+F\right) \qquad (3.1.7)$$

In this equation, known as Moncho's equation, R_T is the total risk index, R_F is the physical risk index and *F* is the impact factor. This coefficient depends on the weighted sum of a set of aggravating factors related to the socioeconomic fragility, F_{FSi}, and the lack of resilience of the exposed context, F_{FRj}

$$F = \sum_{i=1}^{m} w_{FSi} \times F_{FSi} + \sum_{j=1}^{m} w_{FRj} \times F_{FRj} \qquad (3.1.8)$$

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 shown in the Appendix 7.1. Figure 3.1 shows an example. These functions standardise the gross values of the descriptors transforming them in commensurable factors.

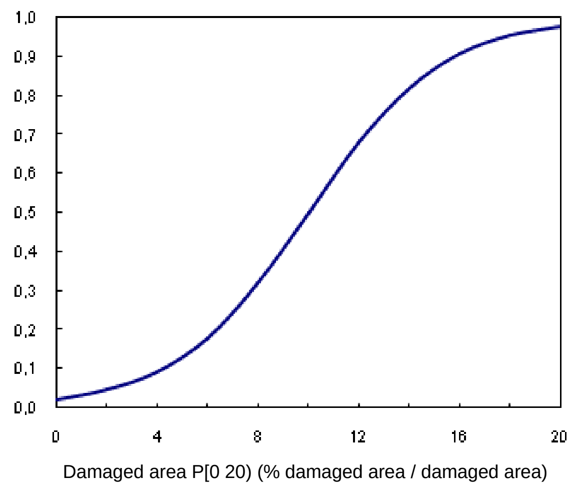


Figure 3-1 Example of transformation function for damaged area

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).

The physical risk, R_F, is evaluated in the same way, using the transformation functions.

$$R_F = \sum_{i=1}^{p} w_{RFi} \times F_{RFi} \tag{3.1.9}$$

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. The transformation functions take values between 0 and 1.

In general, the process of the data to arrive to total risk is the next:

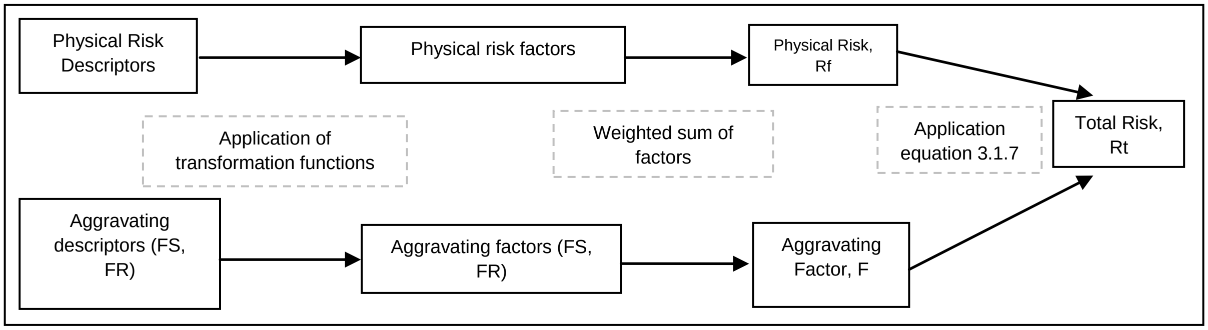


Figure 3-2 Scheme of the calculation process of the USRI

3.2 DISASTER RISK MANAGEMENT INDEX, DRMi

The objective of the Disaster Risk Management Index, DRMi, is the assessment of risk management performance. The evaluation starts from a qualitative measure based on pre-establish levels or desirable referents, those towards the risk management should be directed to, at different degrees of advance. These means that the DRMi is based on the definition of a scale with different performance levels, or in other words a “distance” regarding to certain threshold targets, or to the performance obtained by a country or a city leader considered as a referent (Carreño, 2007; Carreño et al, 2004, 2005c; Cardona et al, 2005).

For the DRMi formulation there are four aspects or components of the public policy of risk management:

a) Risk Identification, RI
b) Risk Reduction, RR
c) Disaster Management, DM
d) Governance and Financial Protection, FP

Then, the DRMi is obtained by the average of the four composed indicators, as it is presented in the equation 3.2.3 and in the figure 3.6:

$$DRMi = \left(DRMi_{RI} + DRMi_{RR} + DRMi_{DM} + DRMi_{FP}\right)/4 \qquad (3.2.1)$$

The indicators of risk management conditions for each type of public policy (RI, RR, DM, FP) are calculated in the equation 3.2.2,

$$DRMi^{t}_{c(RI,RR,DM,FP)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Bigg|_{(RI,RR,DM,FP)} \qquad (3.2.2)$$

where, w_i is the weight assigned to each indicator; I^{t}_{ic} corresponds to each indicator for the considered territorial unit c and the period t -normalized or obtained from the defuzzification of the linguistic values-, representing the risk management performance levels defined to each public policy respectively. Such linguistic values, according to Cardona's proposal (2001) and Carreño (2001), are equivalent to a fuzzy set[1] that have a membership function of the bell or sigmoidal (at the extremes) type, given parametrically by the equations 3.2.3 and 3.2.4.

$$bell(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \qquad (3.2.3)$$

where the parameter b is usually positive.

$$sigmoidal(x;a,c) = \frac{1}{1+\exp\left[-a(x-c)\right]} \qquad (3.2.4)$$

where a controls the slope at the crossing point, 0.5 of membership, $x = c$.

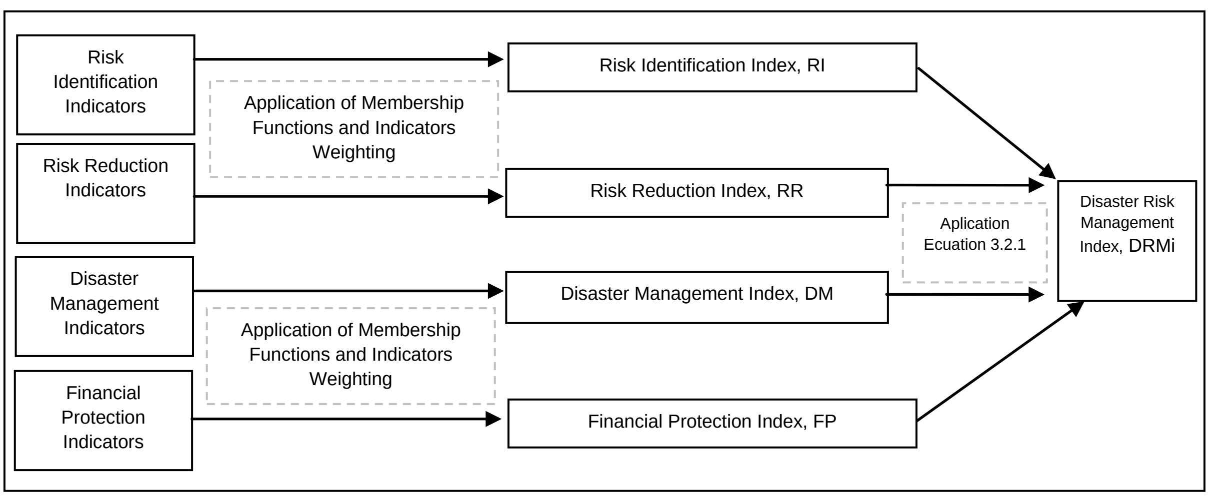


Figure 3-3 General calculation scheme for the DRMi

[1] A fuzzy set A in X is defined as $A = \{(x, \mu_A(x)) | x \in X\}$ where $\mu_A(x)$ is the membership function for the fuzzy set *A*. This function gives for each element of *X* a grade or value of membership in a range between 0 and 1, where 1 signifies maximum membership. If the value of this function was restricted only to 0 and 1, we would have a classic or non fuzzy set.

Indicators

Each index of public policy has six indicators composing it, which characterize themselves the performance of the risk management. The assessment of each indicator uses five levels of performance: low, incipient, appreciable, notable and optimal, those correspond to a range from 1 to 5, where one is the lowest and five is the highest level. The methodological approach allows the use of each level of reference simultaneously as a "performance objective", it also facilities the comparison of results or achievements, those towards the governments should guide the work of formulation, implementation and evaluation of each policy component (Carreño et al, 2004; Cardona et al, 2005). These performance levels are established consulting external experts and delegated of the institutions involved in the public policy execution related to risk management.

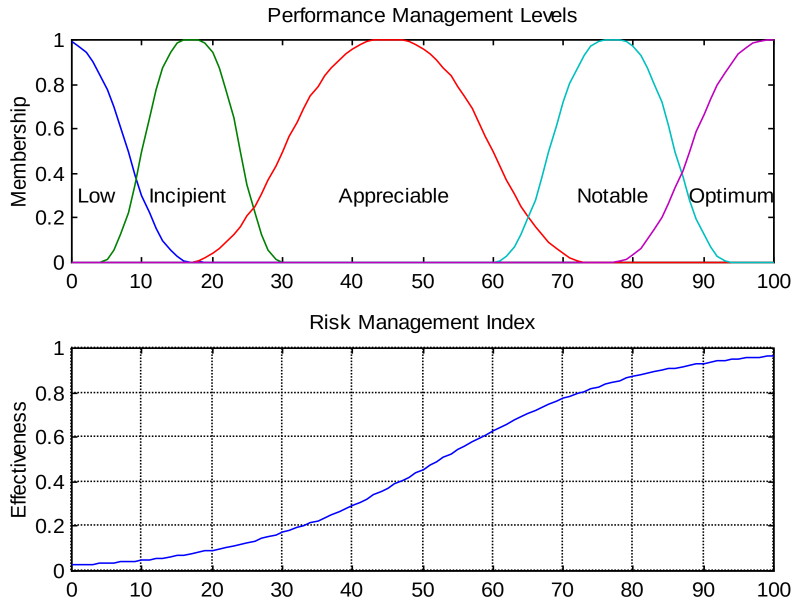
Weights

In addition, a weight is assigned to each indicator (w_1, w_2… w_6) that represents the relative importance of the aspects evaluated in each one of the four policy components. In the same way as the performance levels these weights are established consulting external experts and institution delegates. The weights sum is 1 or 100% for each public policy.

Membership Functions

The qualifications are processed with membership functions defined for fuzzy sets, each qualification represent a level of possible qualification for the indicators[2]. These functions are illustrated in the superior graphic of figure 3.7. The risk management performance is defined by the functions, and it is obtain a curve, illustrated in the lower graphic, where it is indicated the degree of risk management effectiveness according to the performance level related to the indicators.

[2] It is possible to estimate alternatively the *DRMi* as the weighted sum of the fix numeric values (1 to 5 for example), instead of the fuzzy set of the linguistic valuation. Nevertheless, this simplification eliminates the no-lineal behavior of the risk management, having results less appropriated.



Source: Carreño et al, 2004

Figure 3-4 Fuzzy Sets of Risk Management Performance Levels and Probability of Effectiveness

The lower graphic illustrates the no lineal behavior of the risk management. At the beginning there is a small progress and then, when the risk management is bigger and becomes sustainable, performance growths and effectiveness is improved. In a high degree of performance any additional small effort increases significantly the effectiveness. On the contrary, small achievements in risk management are translated in to despicable performance and less sustainability; for this reason their results have few or no effectiveness (Carreño et al, 2004; Cardona et al, 2005).

Indicators of risk identification

According to the framework, risk identification makes reference to the possibility of assess, dimension and representation of the hazard, vulnerability and risk; taking into account not only the technical and scientific point of view but also the community perception, in order to take action. Indicators for risk identification, RI, established by Carreño 2007, Carreño, et al, 2004, 2005c, and Cardona et al., 2005, are:

- RI1. Systematic Disaster and losses inventory
- RI2. Hazard monitoring and forecasting
- RI3. Hazard evaluation and mapping
- RI4. Vulnerability and risk evaluation
- RI5. Public information and community participation
- RI6. Training and education in risk management

Indicators of risk reduction

The risk reduction is a policy that takes structural and no structural measures to reduce the impacts of the hazard and/or the vulnerability presented in a community. The indicators defined to represent risk reduction, RR, in this methodology are the next:

- RR1. Risk consideration in land use and urban planning
- RR2. Hydrographic basing intervention and environmental protection
- RR3. Implementation of hazard-event control and protection techniques
- RR4. Housing improvement and human settlement relocation from prone-areas
- RR5. Updating and enforcement of safety standards and construction codes
- RR6. Reinforcement and retrofitting of public and private assets

Indicators of disaster management

The disaster management represents preparation and actuation during and after a disaster event, by the authorities, first-aid teams, institutions and the community in general. Indicators considered by this model to represent the capacity of disaster management, DM, are show as follows:

- DM1. Organization and coordination of emergency operations
- DM2. Emergency response planning and implementation of warning systems
- DM3. Endowment of equipments, tools and infrastructure
- DM4. Simulation, updating and test of inter institutional response
- DM5. Community preparedness and training
- DM6. Rehabilitation and reconstruction planning

Indicators of governance and financial protection

The governance and financial protection for the risk management, related to the public policy of risk transfer, is fundamental to the development sustainability and the economical growth of the country. This subject implies the coordination of different social actors who had diverse disciplinary approaches, values, interests and strategies. The effectiveness in this aspect is related to the interdisciplinary and integration level of institutional and social participation actions. By other hand, such governance depends of the adequate assignation and use of financial resources in management and in implementation of adequate risk transfer strategies (Carreño et al, 2004; Cardona et al, 2005). Representative indicators of financial protection, FP are the next:

- FP1. Interinstitutional, multisectoral and decentralizing organization
- FP2. Reserve funds for institutional strengthening
- FP3. Budget allocation and mobilization
- FP4. Implementation of social safety nets and funds response

- FP5. Insurance coverage and loss transfer strategies of public assets
- FP6. Housing and private sector insurance and reinsurance coverage

In conclusion, the general calculation model for the DRMi can be understood as it is show in the figure 3.8:

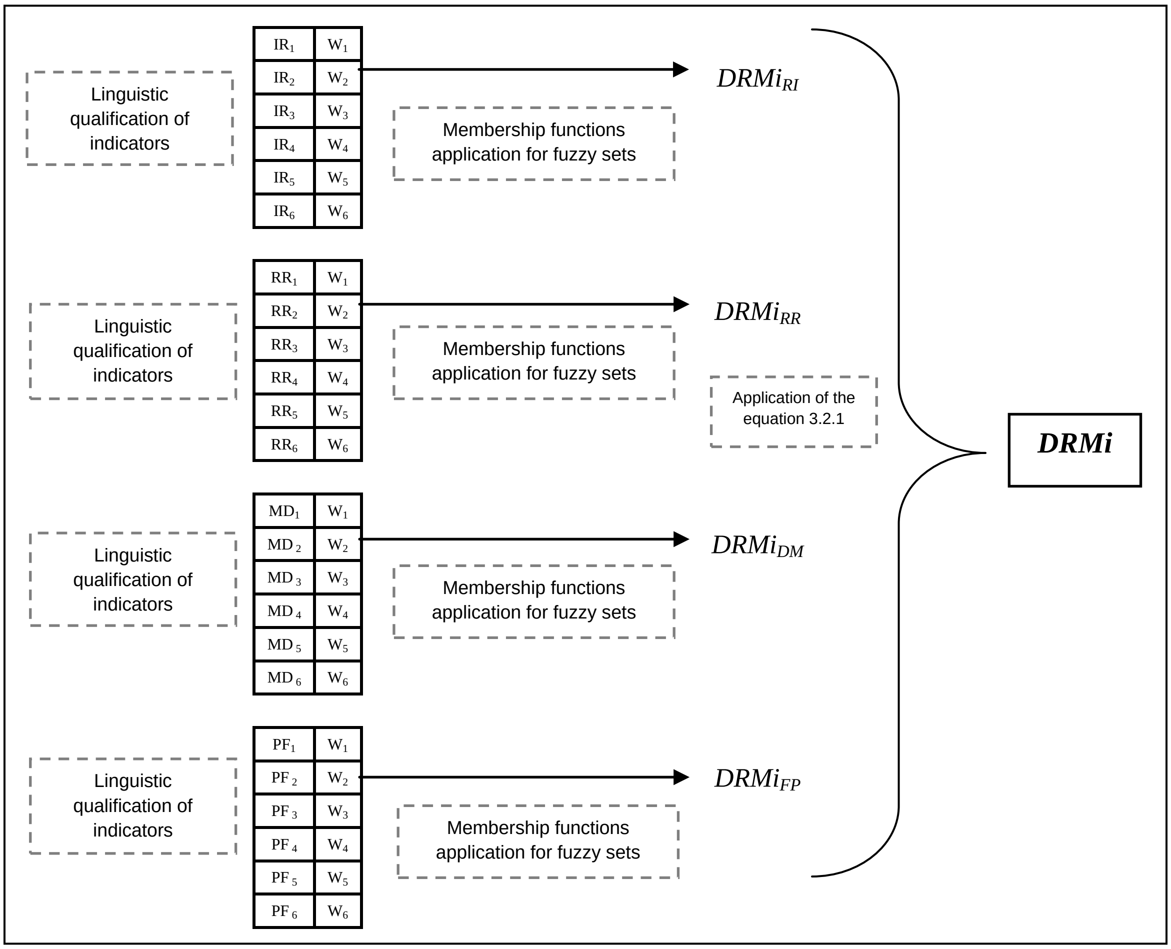


Figure 3-5 Calculation process scheme for the *DRMi*

4 CHAPTER 4 APPLICATION OF THE URBAN SEISMIC RISK INDEX, USRi

The application of the USRi methodology was made for a seismic event due to this could generate the more catastrophic scenario for Manizales. The unit of analysis for the calculation process was the territorial unit called *comuna*. Localities or *comunas* are conformed by a group of neighborhoods. The follow figure shows the division of Manizales by *comunas*.

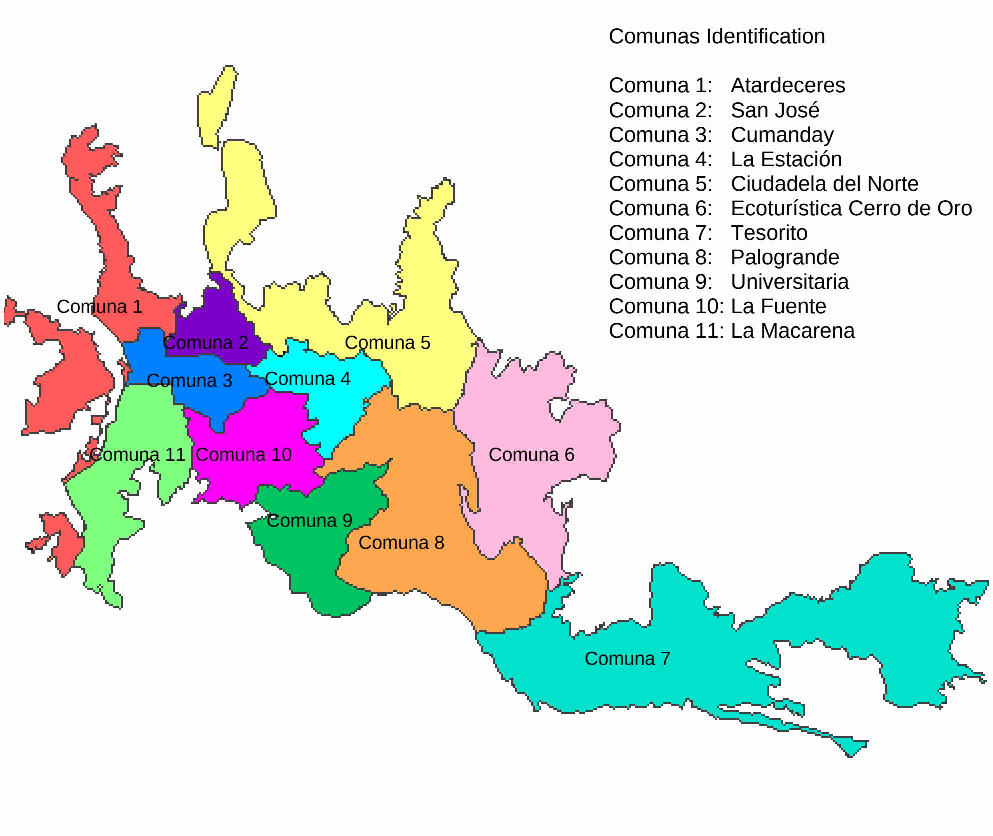
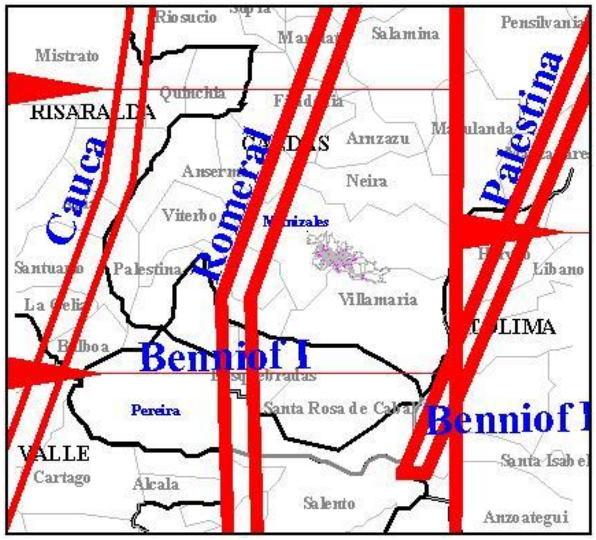


Figure 4-1 Manizales Localities

4.1 PHYSICAL RISK

The evaluation of physical risk was made developing the probable damage scenarios for different seismic sources in Manizales, the faults: Romeral, Murindo, Palestina and Benioff zones. This process was possible due to important information related to many studies of the municipality, such as the seismic microzonation (CEDERI, 2002), the Seismic Information System of Manizales – SISMan v1.1.0, the study of the Financial Protection Strategy for Public and Private buildings in Manizales (ERN, 2005), and the Geographical information System for the reference process of the public properties and risk scenarios visualization: SISMan + Risk (ERN, 2005).



Source: CEDERI- Manizales Mayor’s Office, 2002. Manizales Seismic Microzonation.

Figure 4-2 Distribution of sources strokes which can generate earthquakes in the Andean region

In the Appendix 2 there is a short abstract about the SISMan and SISMan Risk software.

Additionally, the aggregation of the properties city data base into the software allows the calculation of possible damages in houses for the seismic risk scenario defined.

The variables used into the software are:

- Property type: plot, residential use, industrial use, health related, others.
- Total built area
- Property cadastral value
- Collapse factor
- Building type:

Lotes o sin área construida	Adobe o tapia pisada
Bahareque	Mampostería simple
Mampostería confinada	Mampostería reforzada
Pórticos de concreto + mampostería	Pórticos de concreto+ divisiones ligeras
Pórticos de concreto + muros concreto	Reticular cedulado
Muros de concreto	Prefabricado de concreto
Pórticos de acero	Bodegas luces cortas
Bodegas luces medias	Bodegas luces largas
Iglesias, coliseos y estadios	Mampostería semiconfinada

According to these variables it is possible to obtain results about:

- Affected properties (buildings, houses and other type): damages higher or equal to 20%
- Destroyed properties (buildings, houses and other type): damages higher or equal to 50%
- Total affected area (buildings, houses and other type): damages higher or equal to 20%
- Total destroyed area (buildings, houses and other type): damages higher or equal to 50%

Indicators of physical risk are built using the results mentioned.

The formulation of indicators took into account different alternatives of damage scenarios according to probabilistic earthquakes generated for different faults could affect the city. However, the results corresponded to extreme events with a low probability or either to earthquakes that could caused despicable effects. For this reason it was developed a case in the middle, taking into account the effects caused by Romeral fault and other less intense in the Benioff Zone; this last one characterizes the more frequents events of subduction.

The following map presents the probable average damage scenario of the effects caused by two probabilistic earthquakes: one in Romeral fault and one in Benioff Zone.

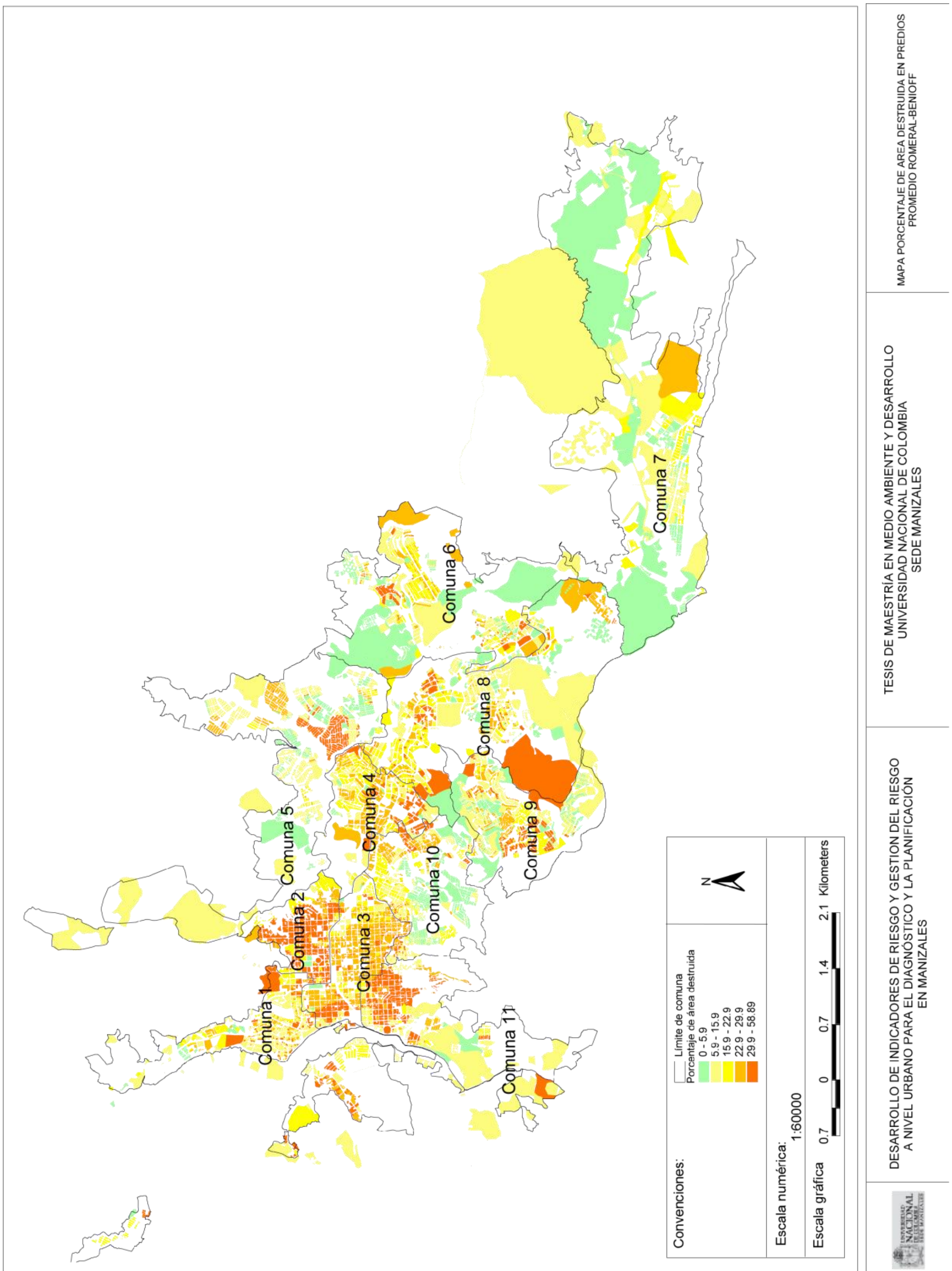


Figure 4-3 Probable damage areas, seismic scenario Romeral – Benioff

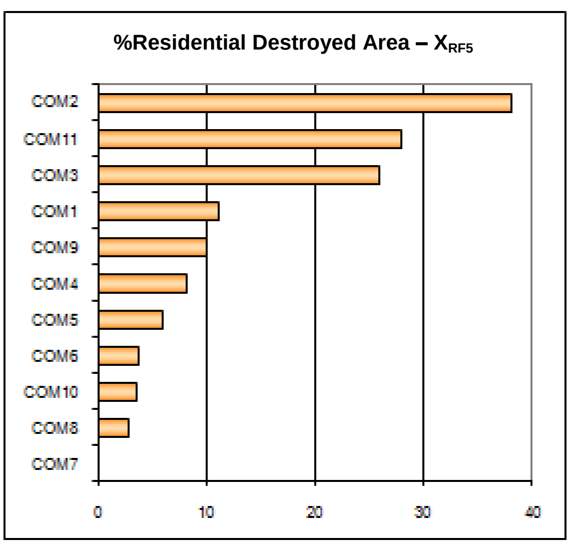
4.1.1 Physical Risk Descriptors

The next table has the values of indicators selected for the eleven localities of the city of Manizales and in the figures 4.4 and 4.5 there are their respective graphics.

Table 4-1 Values of physical risk for the localities of Manizales

LOCALITY *COMUNA*	Deaths (per 1000 peop)	Injured (per 1000 peop)	Homeless peop (per 1000 peop)	Peop jobless (per 1000 peop)	%damaged area (housing)	%damaged area (indust, health sector, other)
	XR_{F1}	XR_{F2}	XR_{F3}	XR_{F4}	XR_{F5}	XR_{F6}
Atardeceres (C.1)	5,6	12,3	130,0	107,5	11,07	12,43
San José (C.2)	8,0	14,2	388,4	256,6	38,07	35,92
Cumanday (C.3)	8,1	15,6	246,4	417,9	25,92	18,46
La Estación (C.4)	7,2	15,5	77,9	93,1	8,05	8,09
Ciudadela Norte (C.5)	0,4	1,8	45,5	0,4	5,97	0,75
Ec. Cerro de Oro (C.6)	2,9	6,1	32,0	23,6	3,74	5,00
Tesorito (C.7)	1,0	3,0	0,0	1,9	0,00	0,11
Palogrande (C.8)	18,8	22,7	20,2	176,9	2,67	7,22
Universitaria (C.9)	2,4	5,7	95,8	14,7	9,89	12,12
La Fuente (C.10)	1,5	3,7	37,3	12,3	3,56	10,63
La Macarena (C.11)	2,9	7,7	235,0	70,6	27,92	17,77

Results for damage area (for housing and for other uses: industrial, health, etc.) reveals that locality 2, San José, would have the higher percentage in comparison with the others localities. By other hand, locality 7, Tesorito, would have practically no percentage of damages.



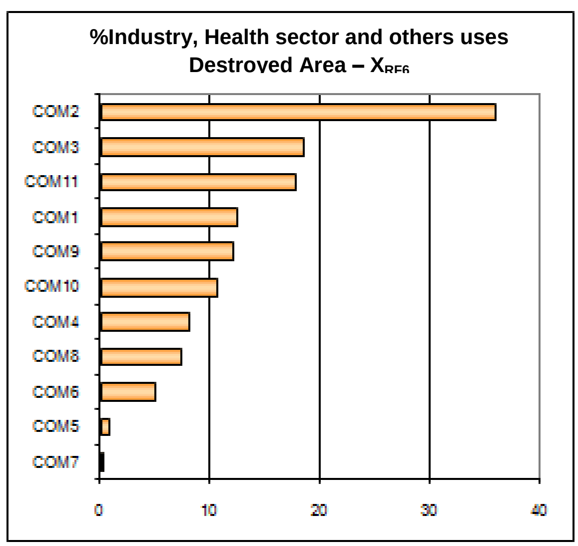


Figure 4-4Values of destroyed area descriptors for the localities of Manizales

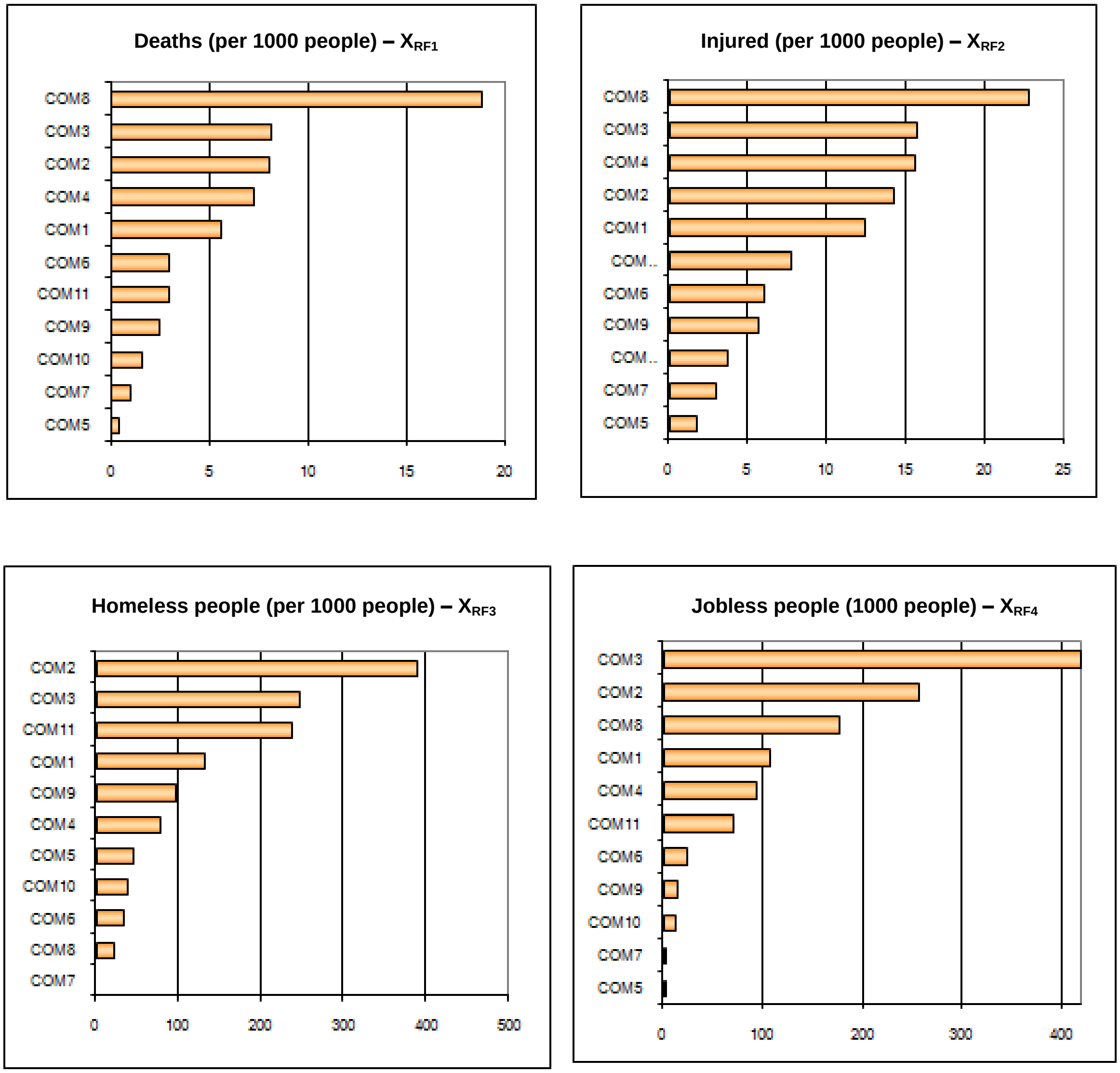


Figure 4-5 Values of the physical risk descriptors for the localities of Manizales

Regarding to the possible death and injured people for the damage scenario developed it was founded that locality 8, Palogrande, would have the bigger number. Locality 2 would be in fourth place, locality 7 in the tenth and locality 6, Ecoturistico Cerro de Oro, in the last place.

Finally, for the indicators related to people who would lost their jobs and/or their houses, we found that locality 3, Cumanday, and locality 2, would have the higher number. However, locality 7 and 6 would remain in the last places.

The next step after defining descriptors is the application of transformation functions. Te curve of transformation for each indicator is the Appendix 1. The process allows the manipulation of values between 0 and 1.

The transformation process was made applying the equation of the sigmoidal function, as it is showed in equation 4.1.1

Sigmoidal function:

$$X' = \frac{1}{1 + e^{-\beta\left(\frac{X-m}{M-m} - \mu\right)}} \qquad (4.1.1)$$

where:

X'= transformed value
X = descriptor net value
β: constant for the slope, the sign defines if it is ascending or descending
m: X minimal value
M: X maximal value
μ: *crossover*

4.1.2 Physical Risk Factors

The physical risk factors have been obtained using the equation 4.1.1 and parameters in table 4.2.

Table 4-2 Parameter for the application of sigmoidal function to physical risk descriptors

	Deaths (per 1000 peop)	Injured (per 1000 peop)	Homeless peop (per 1000 peop)	Peop jobless (per 1000 peop)	%damaged area (housing)	%damaged area (indust, health sector, other)
	F_{RF1}	F_{RF2}	F_{RF3}	F_{RF4}	F_{RF5}	F_{RF6}
Maximum value	50	75	500	300	20	20
Minimal value	0	0	0	0	0	0
Beta, β	7,80	7,72	8,08	7,90	7,57	7,57
Crossover, μ	0,50	0,50	0,50	0,50	0,50	0,50

Maximal and minimal values and the crossover for the transformation of housing damaged area, X_{RF6}, are the same as other uses (industrial, health, etc.) damaged area, X_{RF7}. The values for factors of physical risk are presented in table 4.3.

Table 4-3 Physical risk factors

LOCALITY *COMUNA*	Deaths (per 1000 peop)	Injured (per 1000 peop)	Homeless peop (per 1000 peop)	Peop jobless (per 1000 peop)	%damaged area (housing)	%damaged area (indust, health sector, other)
	F_{RF1}	F_{RF2}	F_{RF3}	F_{RF4}	F_{RF5}	F_{RF6}
Atardeceres (C.1)	0,046	0,070	0,126	0,246	0,600	0,715
San José (C.2)	0,066	0,083	0,904	0,943	1,000	1,000
Cumanday (C.3)	0,067	0,095	0,485	0,999	0,998	0,961
La Estación (C.4)	0,059	0,094	0,058	0,183	0,324	0,327
Ciudadela Norte (C.5)	0,021	0,025	0,035	0,019	0,179	0,029
Ec. Cerro de Oro (C.6)	0,031	0,038	0,029	0,035	0,086	0,131
Tesorito (C.7)	0,023	0,028	0,017	0,020	0,022	0,023
Palogrande (C.8)	0,275	0,180	0,024	0,670	0,059	0,259
Universitaria (C.9)	0,029	0,036	0,076	0,028	0,489	0,690
La Fuente (C.10)	0,025	0,030	0,031	0,026	0,080	0,559
La Macarena (C.11)	0,031	0,044	0,440	0,110	0,999	0,950

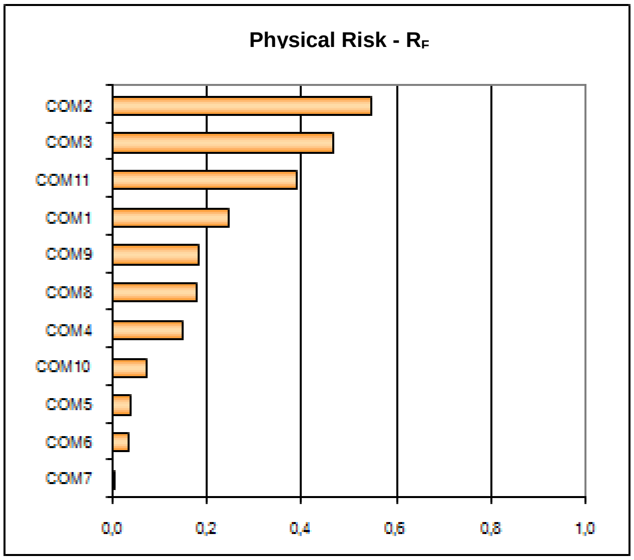
Weights of each factor were assigned according to the relative importance of each indicator. Also it was consider other applications of USRi in other cities, such as Bogota, Barcelona and Manila, where were done analysis between many interested parties.

Table 4-4 Weights for physical risk factors, Manizales

R_F	Weights
F_{RF1}	25
F_{RF2}	22
F_{RF3}	18
F_{RF4}	5
F_{RF5}	20
F_{RF6}	10
TOTAL	100

The factor of total damaged area is represented by housing destroyed damaged area, F_{RF5}, and industrial, health and other uses, F_{RF6}. The damaged area causes several consequences for the city and it is associated to other physical problems, for this reason it was assigned a weight of 30%. Indicators for number of deaths and injured people, F_{RF1} and $F_{RF2,}$ also have an important value, 47%, due to these indicators are related to the emergency attention. This weight was product of rescue-firemen organisms' opinions as well as the considerations of the public administration entities.

In addition, the indicator F_{RF3}, homeless people, is also important because it reflects the quantity of people who would need shelter or other places to be relocated in the moment of the crisis. The indicator F_{RF4}, related to jobless people, gives an idea about the impact over the local economy, and this state could make more difficult the recovering after the disaster. The final process of weights and factors are illustrated in figure 4.6.



	R_F
COM2	0,55
COM3	0,47
COM11	0,39
COM1	0,25
COM9	0,18
COM8	0,18
COM4	0,15
COM10	0,07
COM5	0,04
COM6	0,03
COM7	0,00

Ranges for the Physical Risk Index, R_F	
Very high	0.45 - 1.00
High	0.30 - 0.44
High-Medium	0.20 - 0.29
Low-Medium	0.10 - 0.19
Low	0.00 - 0.09

Figure 4-6 Physical Risk Index

The physical risk index for the city of Manizales covers different ranges, from low qualifications to high. Localities in the very high physical risk range are 2 and 3, San José and Cumanday. Then, in range high is locality 11, Macarena, and in range high-medium is locality 1, Atardeceres. In range low-medium are *comunas* 9, 8 and 4 (Universitaria, Palogrande and La Estación); and finally in the low range are four *comunas:* 10, La Fuente, 5, Ciudadela Norte, 6, Ecoturistica Cerro de Oro, and 7, Tesorito.

The map illustrated in the figure 4.7 presents the physical risk index, where it can be observed the geographical distribution, which shows the west part of the city in higher risk.

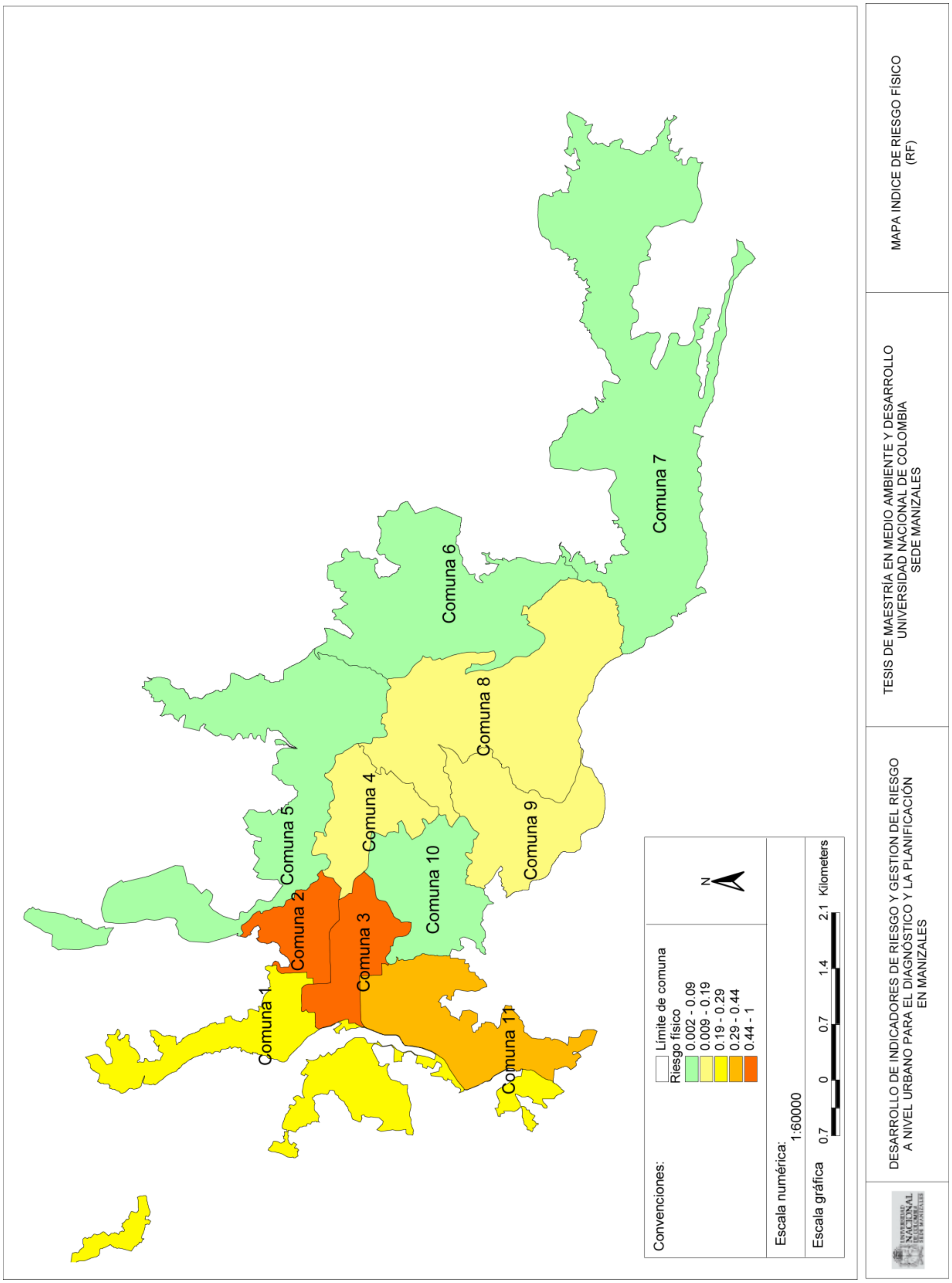


Figure 4-7 Physical Risk Index Map

4.2 AGGRAVATING COEFFICIENT

Indicators of the impact factor were built with the information of the Statics Information Center (CIE), The Municipal Office for Prevention and Attention of Disasters (OMPAD), The Planning Department, the Health Department, among others at the Mayor's Office, in 2006. The data about built areas by stratum and by localities was obtained from the SISMan + Risk data base.

4.2.1 Social Fragility Descriptors

The social fragility is composed by the following descriptors:

Marginal area: calculated using the built area of stratums 1 and 2 (m^2) and total area built by locality

Mortality rate: it was exclude mortality by heart attack, homicides and lower intentional lesions by other people, pulmonary chronic obstruction disease, diabetes, other accidents, brain vascular diseases, stomach tumors, pneumonias, libber tumors, bronchia and pulmonary tumors, other maligned tumors, cardio-pathology, among others. This selection of mortality causes was made to reflect more accurately the diseases by low healthiness conditions. The mortality rate is calculated of every 10.000 inhabitants.

Delinquency rate: this indicator compiled the information related to crimes that illustrate social degradation and quality of life's population, for each locality. The number of crimes was standardized in proportion to the population of each locality and to every 100.000 inhabitants.

The Social Disparity Index: index obtained from an indicator of housing conditions and other of educational level, by locality, applying the next equation:

$$\text{Soc. Disp. Index} = \left[\frac{\text{Hous. Cond. Ind.}^2 + \text{Educ. Lev. Ind.}^2}{2} \right]^{1/2}$$

Details about the development of this index are in Appendix 4.

Population Density: inhabitants number (CENSO 2005) / locality area (km^2).

In table 4.5 there are the values of social fragility descriptors for the eleven localities in the city of Manizales.

Table 4-5 Values of social fragility descriptors for the localities of Manizales

LOCALITY *COMUNA*	Marginal area /Total area	Mortality (per 10.000 peop)	Delinq. (per 100.000 peop)	Dispar. Index	Popul. Density (peop / Km^2)
	X_{FS1}	X_{FS2}	X_{FS3}	X_{FS4}	X_{FS5}
Atardeceres (C.1)	0,0586	3.081	1.160	0,189	8.516,72
San José (C.2)	0,4217	2.434	1.655	0,764	27.634,83
Cumanday (C.3)	0,0168	3.747	3.264	0,725	23.212,71
La Estación (C.4)	0,0005	1.789	1.041	0,053	14.279,86
Ciudadela Norte (C.5)	0,7802	2.372	562	0,710	12.670,11
Ec. Cerro de Oro (C.6)	0,0710	1.591	420	0,189	7.427,11
Tesorito (C.7)	0,0646	2.061	547	0,111	2.725,73
Palogrande (C.8)	0,0070	3.364	1.412	0,178	4.987,50
Universitaria (C.9)	0,3739	1.939	404	0,413	16.990,82
La Fuente (C.10)	0,2572	2.241	637	0,434	21.993,16
La Macarena (C.11)	0,2607	2.335	676	0,353	13.797,33

Indicators show that in localities 2, San José, and 3, Cumanday, have the higher evaluations, although for the marginal area locality 5, Ciudadela Norte, has a greater value. The mortality in locality 8 also has a big value, getting to the second place. The case of delinquency, locality 3 has the higher level in comparison with the others, and then it is locality 2. Related to the social disparity index there are localities 2, 3 and 5 in the first places, with a high difference over the other localities. Results are illustrated in figure 4.8.

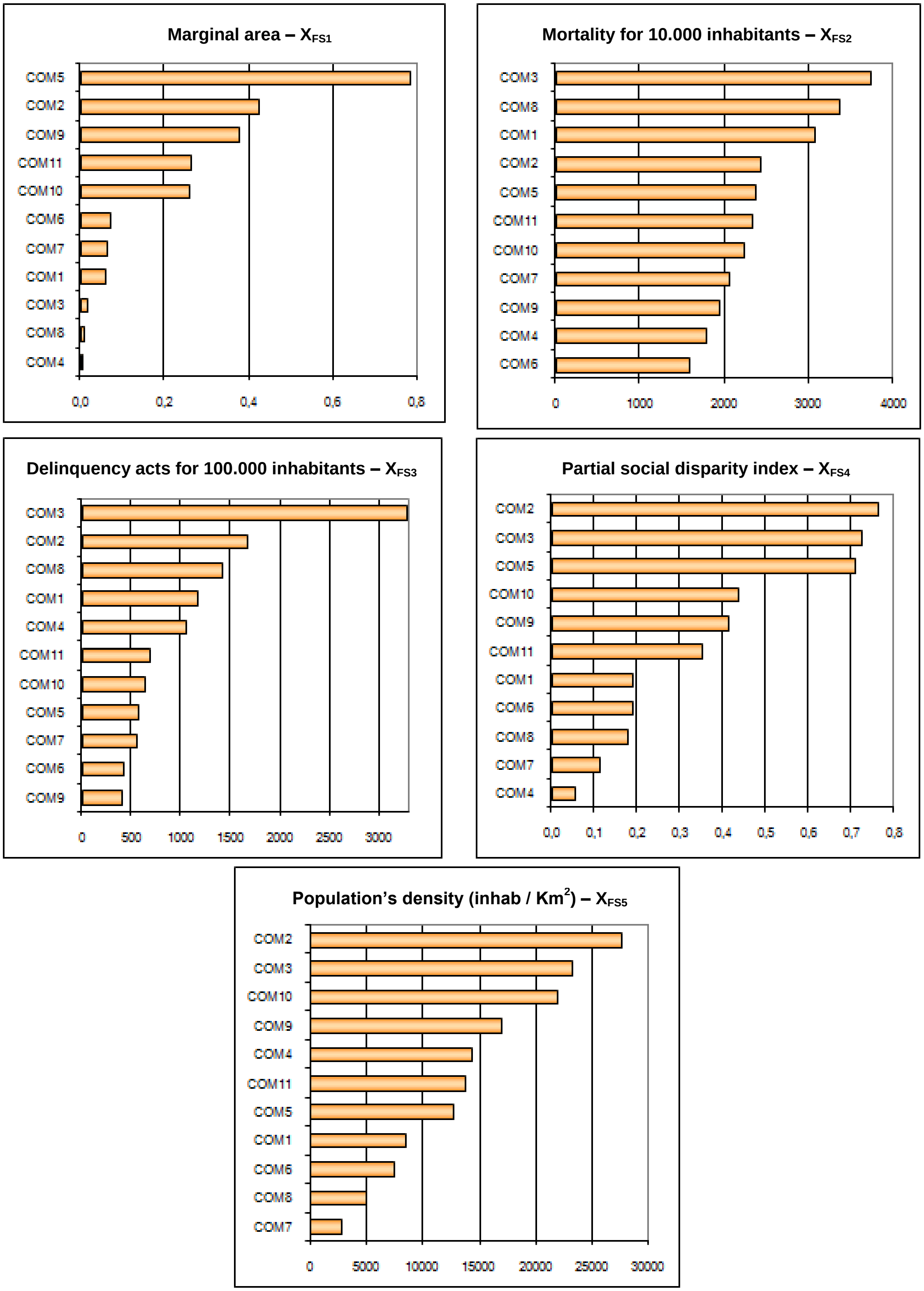


Figure 4-8 Social Fragility descriptors values

Calculation for the social fragility factors was made using equation (4.1.1) and parameters in table 4.6. The partial social disparity index, F_{FS4}, doesn't have this procedure due to its own evaluation make it a value between 0 and 1 already.

Table 4-6 Parameters for the sigmoidal function application to descriptors of social fragility

	Marginal area /Total area	Mortality (per 10.000 peop)	Delinq. (per 100.000 peop)	Dispar. Index	Popul. Density (peop / Km^2)
	F_{FS1}	F_{FS2}	F_{FS3}	F_{FS4}	F_{FS5}
Maximum value	0,75	4000	1400	1	25000
Minimal value	0,05	50	10	0	4000
Beta, β	7,57	7,57	7,49		6,87
Crossover, μ	0,50	0,50	0,50		0,50

Table 4-7 Factores de fragilidad social

LOCALITY *COMUNA*	Marginal area /Total area	Mortality (per 10.000 peop)	Delinq. (per 100.000 peop)	Dispar. Index	Popul. Density (peop / Km^2)
	F_{FS1}	F_{FS2}	F_{FS3}	F_{FS4}	F_{FS5}
Atardeceres (C.1)	0,024	0,884	0,878	0,189	0,108
San José (C.2)	0,488	0,688	0,988	0,764	0,970
Cumanday (C.3)	0,016	0,965	1,000	0,725	0,900
La Estación (C.4)	0,014	0,390	0,800	0,053	0,396
Ciudadela Norte (C.5)	0,972	0,662	0,269	0,710	0,290
Ec. Cerro de Oro (C.6)	0,027	0,304	0,154	0,189	0,081
Tesorito (C.7)	0,026	0,519	0,255	0,111	0,022
Palogrande (C.8)	0,015	0,929	0,962	0,178	0,041
Universitaria (C.9)	0,371	0,460	0,144	0,413	0,592
La Fuente (C.10)	0,154	0,604	0,348	0,434	0,863
La Macarena (C.11)	0,159	0,646	0,395	0,353	0,363

4.2.2 Lack of Resilience Descriptors

The lack of resilience is composed by next descriptors:

- *Hospital beds*: indicator built using information about beds in health institutions. The distribution for each locality was as follows: half of beds are assigned to the locality where the health center is located; other half is distributed to all localities according to the population proportion of each of them. The number of beds is taken for each 1.000 inhabitants.

- *Health Human Resources*: Represented by doctors, nurses and medicals. The assignment to each locality was used the same thinking that the last indicator. The number of people was taken for each 1.000 inhabitants.

- *Public space*: this indicator took into account considerations from the Territorial Ordering Plan (POT in Spanish), such as the permanent public space, which includes green areas, parks, central squares, etc.; the minimum public effective space, it should be $15m^2$ per inhabitant. The public space indicator was determinate as the public effective space (m^2) divided by the locality area (m^2).

- *Rescue and firemen manpower*: the Municipal Office for Prevention and Attention of Disasters (OMPAD) has assigned the groups for emergency attention to different localities: civil defense or emergency squad attends localities 1 and 7; the group of Searching and Rescue covers localities 3, 10 and 11; the Special Rescue Team is responsible of localities 2, 4, 5, 6 and 8; and the Firemen for all the city. The number of firemen was assigned to localities by the location of the stations and proportional to the population of each locality. This indicator is assessed for each 10.000 inhabitants.

- *Development level*: essays to represent of some way the economical level at the locality. It was obtained from the built area for the higher socio-economical level (5 and 6) (m^2) and the total built area in the locality. It was normalized using the maximum and minimum obtained.

- *Operability in emergency case*: this indicator was analyzed with the OMPAD director; he considered all localities in level 1 (taking into account a range between 0 and 2). We decided not to use this indicator due to it doesn't generates a difference between localities.

- *Community participation:* it was utilized the number of community groups and then it was normalized by population and for the data range.

Table 4.8 shows the values for lack of resilience indicators, for the 11 localities of the city.

Table 4-8 Lack of resilience descriptors values for Manizales

LOCALITY *COMUNA*	Hosp. beds (1.000 peop)	Health human resour.(1.000 peop)	Public space/sheltFacil.	Rescue & firemen manpower (10.000 peop.)	Devel. level	Comm. particip.
	X_{FR1}	X_{FR2}	X_{FR3}	X_{FR4}	X_{FR5}	X_{FR6}
Atardeceres (C.1)	8,5	1,02	0,020	19,4	0,0513	0,59073
San José (C.2)	1,1	0,60	0,010	3,5	0,0000	0,66072
Cumanday (C.3)	3,1	0,87	0,024	18,9	0,0007	0,33902
La Estación (C.4)	4,8	3,47	0,019	3,9	0,0695	0,56448
Ciudadela Norte (C.5)	1,4	0,52	0,010	2,2	0,0000	0,73291
Ec. Cerro de Oro (C.6)	1,1	0,32	0,003	3,2	0,0460	0,47965
Tesorito (C.7)	1,9	1,17	0,072	31,6	0,0236	0,65098
Palogrande (C.8)	4,4	0,51	0,026	9,8	0,4715	0,00000
Universitaria (C.9)	1,1	0,99	0,016	1,2	0,0000	0,92409
La Fuente (C.10)	1,1	0,45	0,018	9,2	0,0000	1,00000
La Macarena (C.11)	1,1	0,67	0,009	12,0	0,0084	0,89737

In figures 4.9 and 4.10 there are the diagrams for descriptors values.

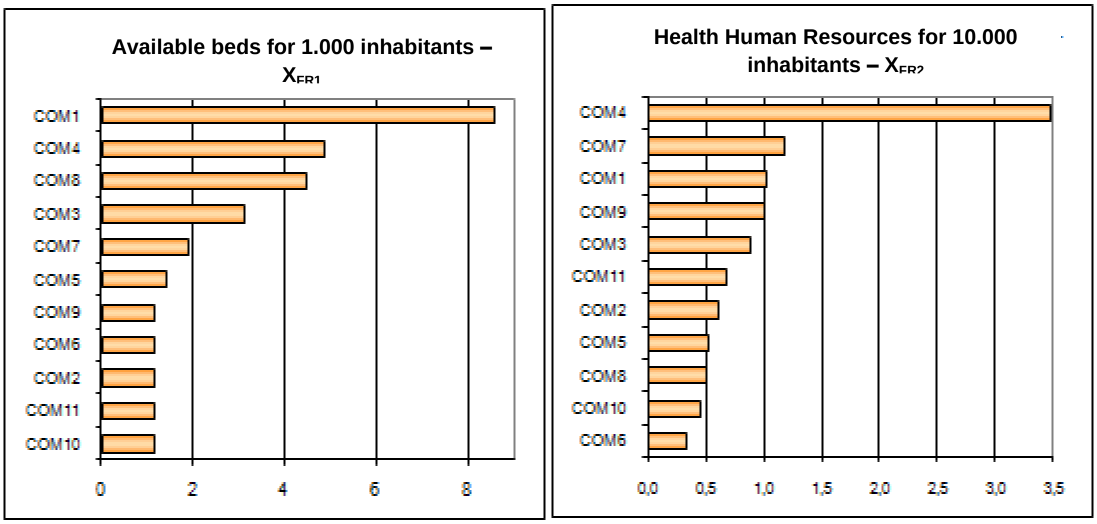


Figure 4-9 Values for descriptors related to health in lack of resilience indicators

The hospital available beds indicator has a higher value for locality 1, with a big difference among the other localities. The presence of the State Hospital "Seguro Social" Clinique in locality 1 explains this great difference due to its bigger attention capacity than the rest hospitals of the city. By other hand, the health human resources is higher for locality 4 because there are several medical centers such as "Presentación" Clinique, Infant Hospital, Manizales Clinique, which count with a important number of people to take care of the medical services.

The public space is bigger for locality 7 due to its many green areas, including 12 parks.

Rescue and firemen manpower indicator shows locality 7 with more personal available followed by locality 1 and 3. The advantage is related to the location of the civil defense or emergency squad and the firemen in this *comuna*. The lower covering of people for rescue and emergency attention is for locality 9.

For the development level, the socio-economic level 5 and 6 in general is not very representative. Only locality 8 has a development level appreciable.

Finally, the community participation is contrary to the last indicator, showing that even with a high development in locality 8 there are no community groups to create and manage community programs. This is not the case for *comunas* 10, 9 and 11 which have 18, 14 and 12 groups respectively.

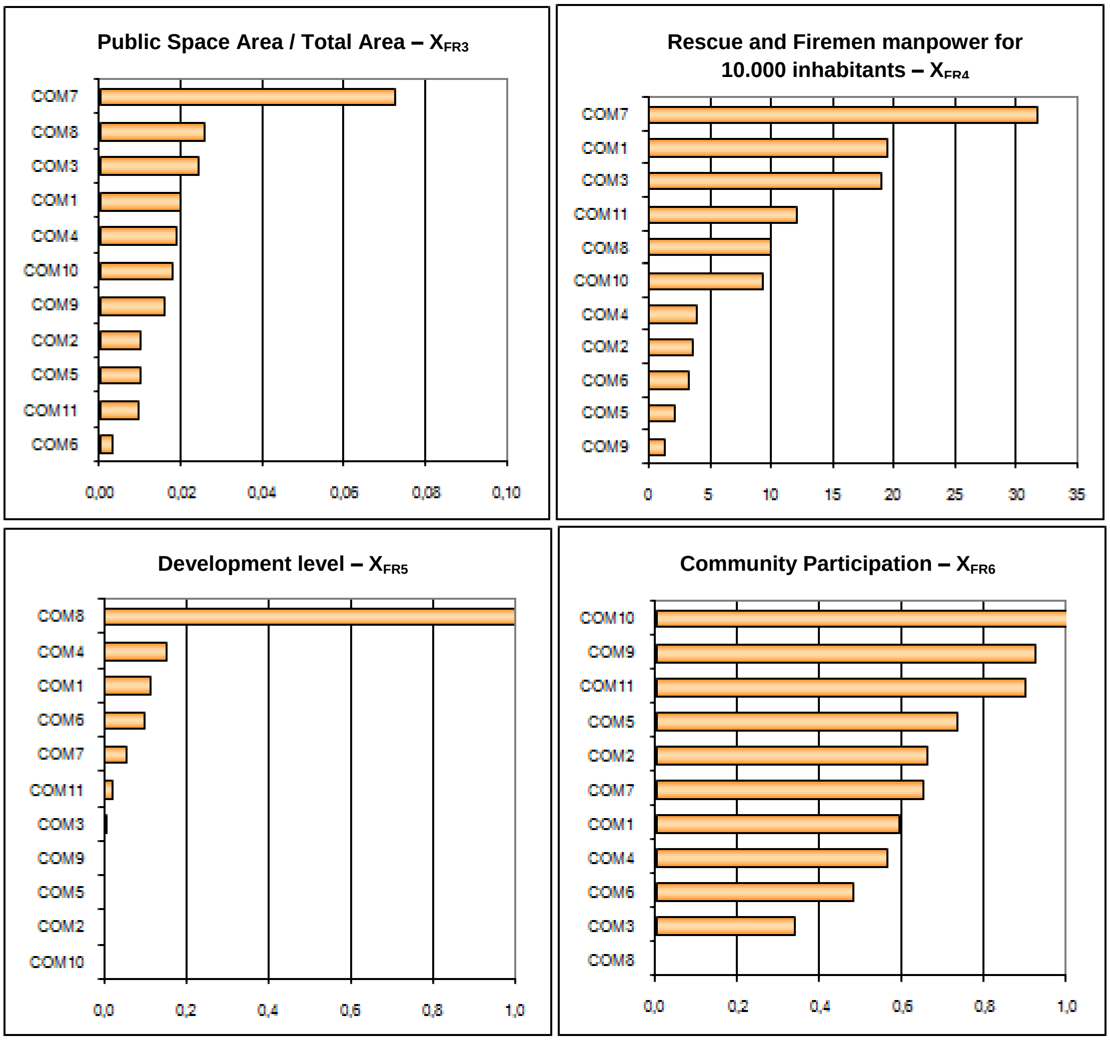


Figure 4-10 Lack of Resilience descriptor values

The application of transformation functions for lack of resilience show that it should be take into account that indicators at this moment represent positive characteristics for the city and the locality to attend or acting in case of disaster. However, the applications of these transformation functions represent needs and weakness, reason for what the curve has the decreasing shape (it means β has a negative value in equation 4.1.1).

In addition, level of development indicators, F_{FR5}, and community participation were considered with a lineal variation, so we didn't apply the same transformation functions just the lineal equation with negative slope.

Table 4-9 Parameters for application of the sigmoidal function, lack of resilience descriptors

	Hosp. beds (1.000 peop)	Health human resour.(1.000 peop)	Public space/sheltFacil.	Rescue & firemen manpower (10.000 peop.)	Devel. level	Comm. particip.
	F_{FR1}	F_{FR2}	F_{FR3}	F_{FR4}	F_{FR5}	F_{FR6}
Maximum value	30	15	0,15	7		
Minimal value	0	0	0,01	0		
Beta, β	-7,58	-7,64	-7,63	-7,65		
Crossover, μ	0,50	0,50	0,50	0,50		

The application of these values into equation 4.1.1 has as a result factors of lack of resilience, presented in table 4.10.

Table 4-10 Lack of resilience factors

LOCALITY *COMUNA*	Hosp. beds (1.000 peop)	Health human resour.(1.000 peop)	Public space/sheltFacil.	Rescue & firemen manpower (10.000 peop.)	Devel. level	Comm. particip.
	F_{FR1}	F_{FR2}	F_{FR3}	F_{FR4}	F_{FR5}	F_{FR6}
Atardeceres (C.1)	0,837	0,965	0,964	0,000	0,891	0,409
San José (C.2)	0,971	0,971	0,979	0,499	1,000	0,339
Cumanday (C.3)	0,953	0,967	0,954	0,000	0,999	0,661
La Estación (C.4)	0,929	0,886	0,966	0,380	0,852	0,436
Ciudadela Norte (C.5)	0,969	0,972	0,979	0,813	1,000	0,267
Ec. Cerro de Oro (C.6)	0,971	0,975	0,985	0,593	0,902	0,520
Tesorito (C.7)	0,965	0,962	0,603	0,000	0,950	0,349
Palogrande (C.8)	0,935	0,972	0,951	0,001	0,000	1,000
Universitaria (C.9)	0,971	0,965	0,970	0,923	1,000	0,076
La Fuente (C.10)	0,971	0,973	0,967	0,002	1,000	0,000
La Macarena (C.11)	0,971	0,970	0,979	0,000	0,982	0,103

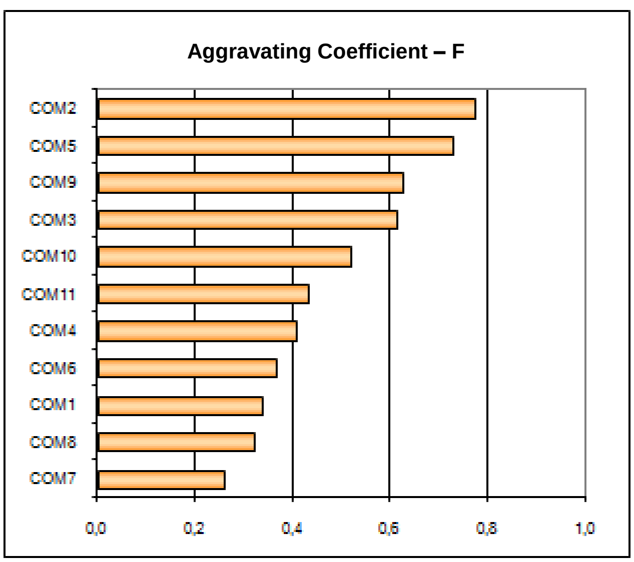
4.2.3 Aggravating coefficient weights

Weights for each factor were assigned according to the relative importance of each indicator and according also to the USRi application in other cities, such as Bogota, Barcelona and Manila.

Table 4-11 Weights for social fragility and lack of resilience factors

F	Weights
F_{FS1}	18
F_{FS2}	4
F_{FS3}	4
F_{FS4}	18
F_{FS5}	18
F_{FR1}	6
F_{FR2}	6
F_{FR3}	4
F_{FR4}	12
F_{FR5}	5
F_{FR6}	5
TOTAL	100

Social fragility weights are the same as those applied for the city of Bogotá, in Cardona et al, 2004 and Carreño, 2005; these weights were obtained using the Analytic Hierarchy Process (AHP) at that time. In the case of lack of resilience, the rescue and firemen manpower, F_{FR4}, was considered more important, and it was followed by health indicators (F_{FR1} and F_{FR2}), community participation and development level (F_{FR6} and F_{FR5}), and public space (F_{FR3}).



	F
COM2	0,77
COM5	0,73
COM9	0,63
COM3	0,61
COM10	0,52
COM11	0,43
COM4	0,41
COM6	0,36
COM1	0,34
COM8	0,32
COM7	0,26

Aggravating Coefficient ranges, F	
Very High	0.65 - 1.00
High	0.55 - 0.64
Medium-High	0.40 - 0.54
Medium-Low	0.20 - 0.39
Low	0.00 - 0.19

Figure 4-11 Aggravating Coefficient

Manizales aggravating coefficient doesn't present values in the low range for the different localities. In the opposite way, seven of the eleven localities are in range High. Localities in Very High range are 2 and 5, localities in rage High are 9 and 3; range Medium-High: 10, 11 and 4; and range Medium-Low: 6, 1, 8 and 7.

Figure 4.12 presents the aggravating coefficient map. The values show that social fragility and lack of resilience in the city is bigger in the north zone and downtown, where it is important to pay attention to the institutional programs and plans for risk reduction and especially for vulnerability reduction.

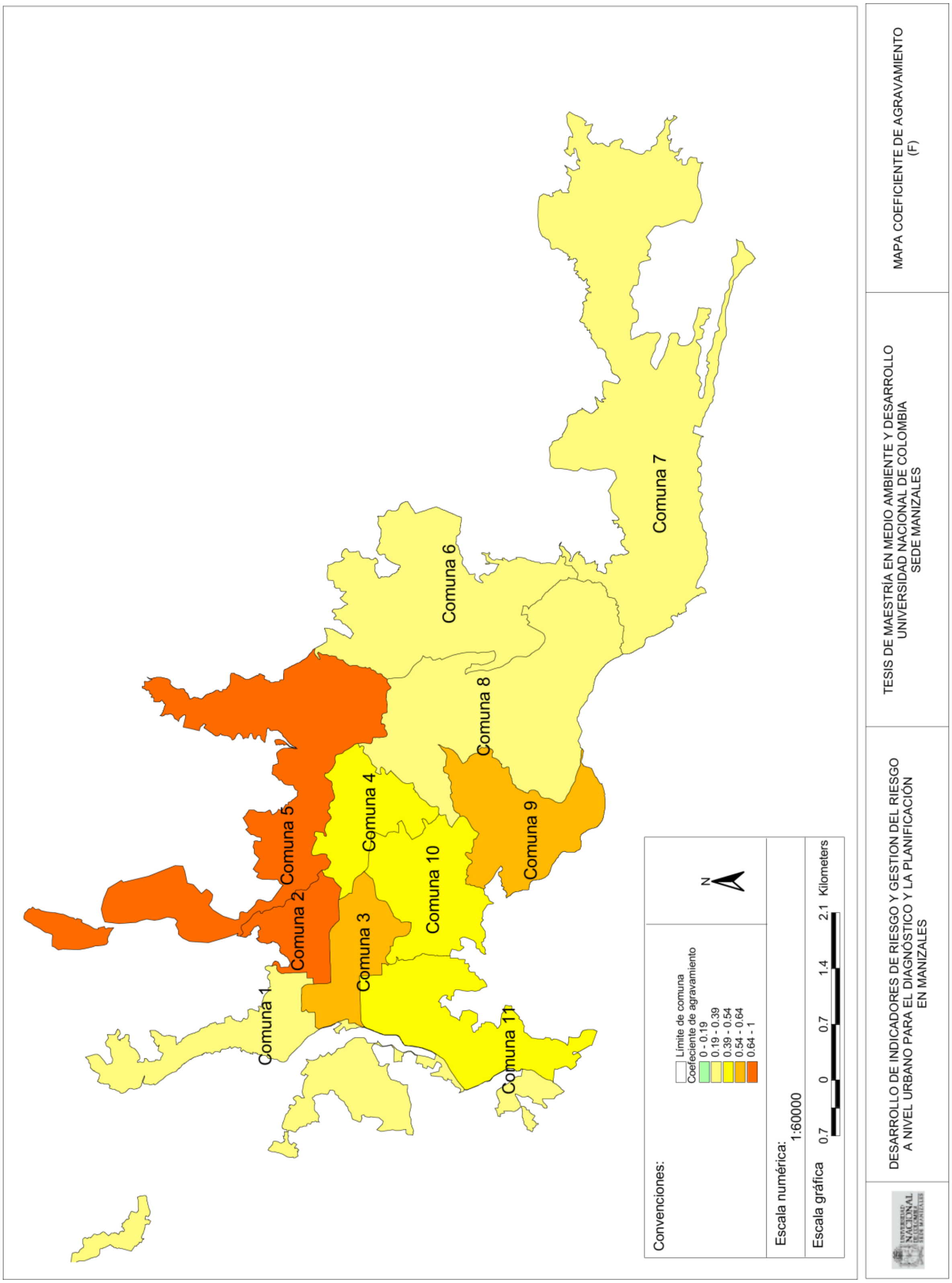


Figure 4-12 Aggravating Coefficient Map

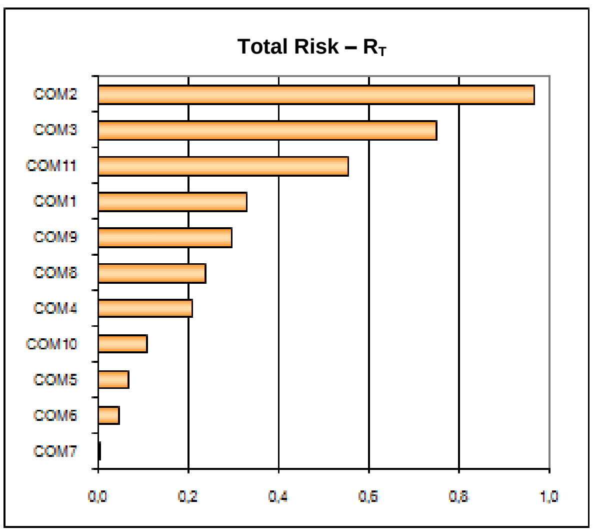
4.3 TOTAL RISK INDEX

According to the application of equations 3.1.7 and 3.1.8 are obtained outcomes for the weighted sum of factors, F and R_F, as well as the final R_T. Results are shown in table 4.12.

Table 4-12 Total Risk, Physical Risk and Aggravating Coefficient Indexes for Manizales

LOCALITY -*COMUNA*	R_F	F	R_T
Atardeceres (C.1)	0,25	0,34	0,33
San José (C.2)	0,55	0,77	0,97
Cumanday (C.3)	0,47	0,61	0,75
La Estación (C.4)	0,15	0,41	0,21
Ciudadela Norte (C.5)	0,04	0,73	0,07
Ec. Cerro de Oro (C.6)	0,03	0,36	0,04
Tesorito (C.7)	0,00	0,26	0,00
Palogrande (C.8)	0,18	0,32	0,24
Universitaria (C.9)	0,18	0,63	0,30
La Fuente (C.10)	0,07	0,52	0,11
La Macarena (C.11)	0,39	0,43	0,55

The results for total risk index, for the city of Manizales, show that localities in the higher risk level are 2, San José, and 3, Cumanday. Localities the next ranges are 11, Macarena (High), 1, Atardeceres and 9, Universitaria (Medium-High).



	R_T
COM2	0,97
COM3	0,75
COM11	0,55
COM1	0,33
COM9	0,30
COM8	0,24
COM4	0,21
COM10	0,11
COM5	0,07
COM6	0,04
COM7	0,0024

Total Risk ranges, R_T	
Very High	0.70 - 1.00
High	0.45 - 0.69
Medium-High	0.30 - 0.44
Medium-Low	0.15 - 0.29
Low	0.00 - 0.14

Figure 4-13 Total Risk Index

The Medium-Low range has the values for the localities 8, Palogrande, and 4, La Estación. At the range Low we have localities 10, La Fuente, 5, Ciudadela Norte, 6, Ecoturistica Cerro de Oro, and 7, Tesorito, with the lowest total risk index. Comparison between localities is presented in figure 4.13.

Figure 4.14 illustrates the total risk map, where it is noticed that there is a risk bigger tendency in the city toward the west-centre.

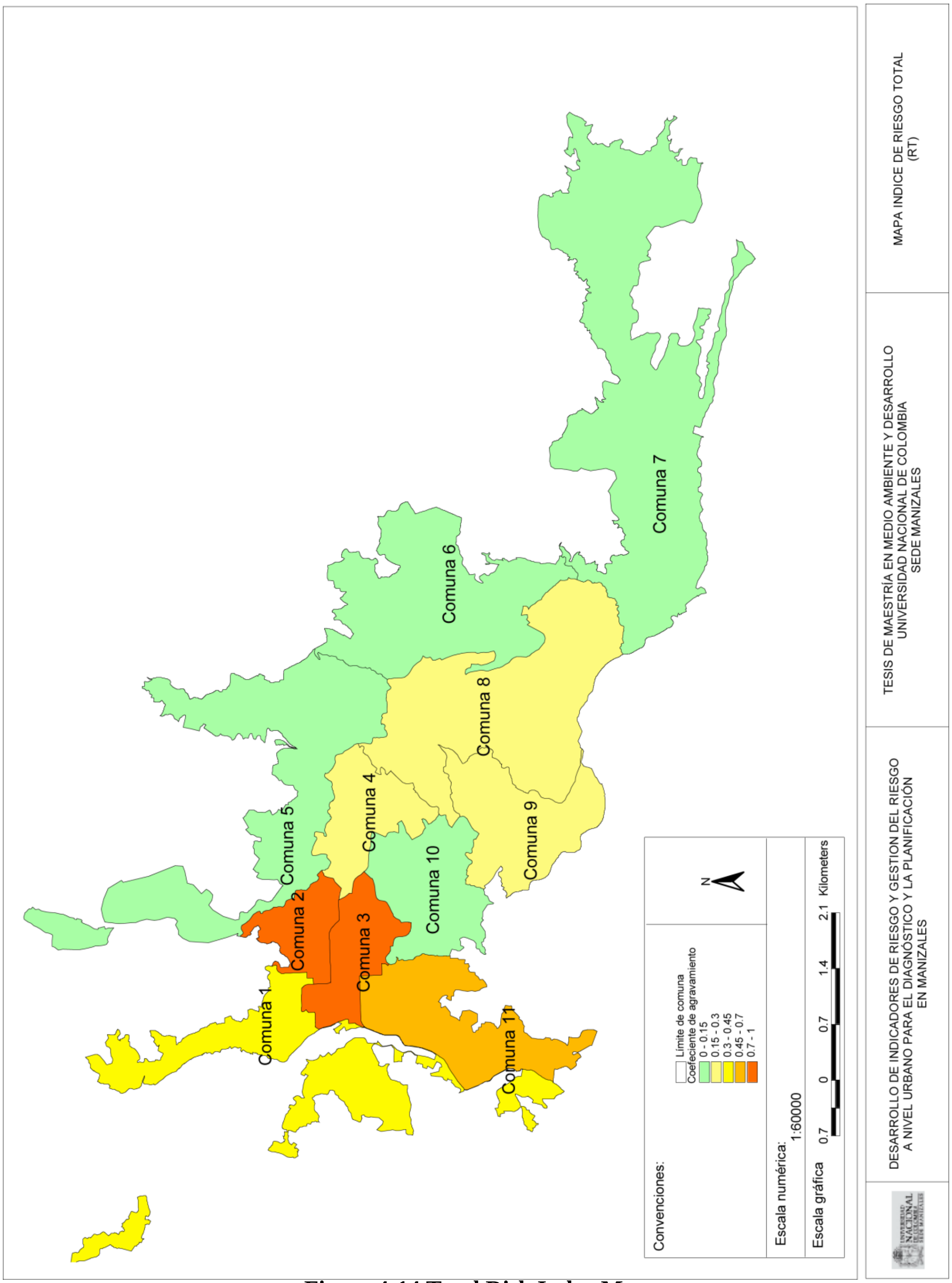


Figure 4-14 Total Risk Index Map

5 CHAPITRE 5. APPLICATION OF THE DISASTER RISK MANAGEMENT INDEX, DRMi

Initial data were obtained evaluating the performance level for each indicator for each risk management public policy for each period. To do so it should be taken into account five parameters, which are assessed as low, incipient, appreciable, notable and optimum. The relative importance is assigned simultaneously to each indicator, saving the proportions and generating a hierarchy between them. This is the Analytic Hierarchy Process (AHP) that is explained in Appendix 6.

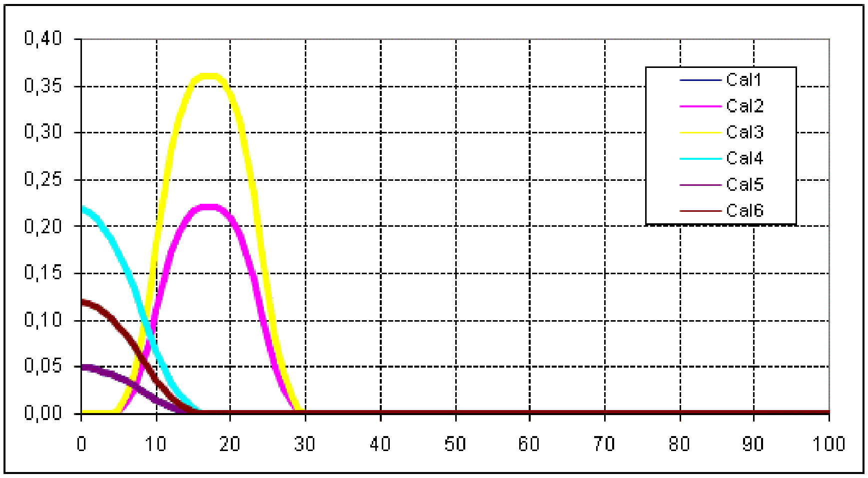
An example of the evaluation can be appreciated for the case of risk identification. Assessment of indicators is made using the formats as in table 5.1. Appendix 5 has all characteristics for evaluate each indicator and formats for the four risk management policies.

Table 5-1Indicators of Identification Risk for Manizales

Place an **X** in front of the performance level obtained in each year according to the table

Indicador	1990		1995		2000		2005	
	X	1. *Low*		1. *Low*		1. *Low*		1. *Low*
		2. *Incipient*	X	2. *Incipient*		2. *Incipient*		2. *Incipient*
RI1. Systematic disaster and loss inventory		3 *Appreciabl.*		3 *Appreciabl.*	X	3 *Appreciabl.*	X	3 *Appreciabl.*
		4. *Notable*		4. *Notable*		4. *Notable*		4. *Notable*
		5. *Optimum*		5. *Optimum*		5. *Optimum*		5. *Optimum*
		1. *Low*		1. *Low*		1. *Low*		1. *Low*
	X	2. *Incipient*	X	2. *Incipient*		2. *Incipient*		2. *Incipient*
RI2. Hazard monitoring and forecasting		3 *Appreciabl.*		3 *Appreciabl.*	X	3 *Appreciabl.*		3 *Appreciabl.*
		4. *Notable*		4. *Notable*		4. *Notable*	X	4. *Notable*
		5. *Optimum*		5. *Optimum*		5. *Optimum*		5. *Optimum*
		1. *Low*		1. *Low*		1. *Low*		1. *Low*
	X	2. *Incipient*		2. *Incipient*		2. *Incipient*		2. *Incipient*
RI3. Hazard evaluation and mapping		3 *Appreciabl.*	X	3 *Appreciabl.*		3 *Appreciabl.*		3 *Appreciabl.*
		4. *Notable*		4. *Notable*	X	4. *Notable*		4. *Notable*
		5. *Optimum*		5. *Optimum*		5. *Optimum*	X	5. *Optimum*
	X	1. *Low*		1. *Low*		1. *Low*		1. *Low*
RI4. Vulnerability and risk assessment		2. *Incipient*		2. *Incipient*		2. *Incipient*		2. *Incipient*
		3 *Appreciabl.*	X	3 *Appreciabl.*		3 *Appreciabl.*		3 *Appreciabl.*
		4. *Notable*		4. *Notable*	X	4. *Notable*	X	4. *Notable*
		5. *Optimum*		5. *Optimum*		5. *Optimum*		5. *Optimum*
	X	1. *Low*		1. *Low*		1. *Low*		1. *Low*
RI5. Public information and community participation		2. *Incipient*	X	2. *Incipient*	X	2. *Incipient*	X	2. *Incipient*
		3 *Appreciabl.*		3 *Appreciabl.*		3 *Appreciabl.*		3 *Appreciabl.*
		4. *Notable*		4. *Notable*		4. *Notable*		4. *Notable*
		5. *Optimum*		5. *Optimum*		5. *Optimum*		5. *Optimum*
	X	1. *Low*		1. *Low*		1. *Low*		1. *Low*
		2. *Incipient*		2. *Incipient*	X	2. *Incipient*	X	2. *Incipient*
RI6. Training and education in risk management		3 *Appreciabl.*	X	3 *Appreciabl.*		3 *Appreciabl.*		3 *Appreciabl.*
		4. *Notable*		4. *Notable*		4. *Notable*		4. *Notable*
		5. *Optimum*		5. *Optimum*		5. *Optimum*		5. *Optimum*

Total DRMi is assessed after the calculation of each one of the indexes as it is illustrated in the figure 5.1 using a fuzzy set sum:



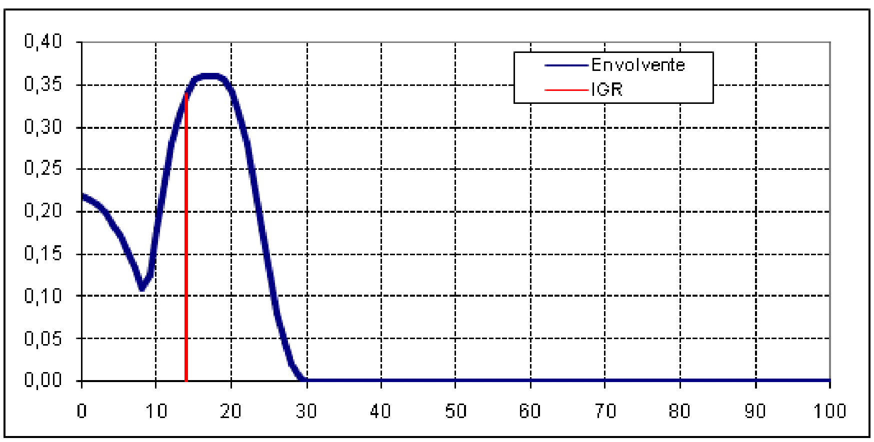


Figure 5-1 DMRi Evaluation for Risk Identification

Results for the four indexes of Risk Management are presented as follows for the city of Manizales.

5.1 RISK IDENTIFICATION

The performance levels for indicators in Manizales were evaluated as it is showed in this way:

Table 5-2 Assessment of each of risk identification indicators, RI

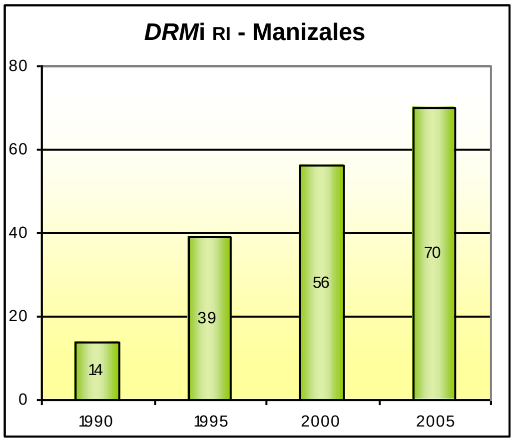
NIVEL	1990	1995	2000	2003
RI.1	5	2	3	3
RI.2	17	2	3	4
RI.3	17	3	4	5
RI.4	5	3	4	4
RI.5	5	2	2	2
RI.6	5	3	2	2

Table 5-3 Relative importance assigned to each indicator for risk identification and HAP application

	RI1	RI2	RI3	RI4	RI5	RI6
RI1	1	0,2	0,2	0,2	1	0,33
RI2	5	1	0,5	1	5	2
RI3	5	2	1	2	5	4
RI4	5	1	0,5	1	5	2
RI5	1	0,2	0,2	0,2	1	0,33
RI6	3	0,5	0,25	0,5	3	1
eigenvalue = 6.0877 CI = 0.018 CR = 0.014						

Relative importance is obtained by comparing pairs of indicators. The comparison is made defining the number of times is more important one indicator related to the other, depending of the issue treated.

Figure 5.2 illustrate the quantification for $DRMi_{IR}$ indicators and the respective weights obtained by the Analytic Hierarchy Process (AHP) for Manizales.



LEVEL	1990	1995	2000	2003	W ahp
RI.1	1	2	3	3	5
RI.2	2	2	3	4	22
RI.3	2	3	4	5	36
RI.4	1	3	4	4	22
RI.5	1	2	2	2	5
RI.6	1	3	2	2	12

Figure 5-2 Manizales, DRMi $_{RI}$

Risk identification for Manizales can be considered in increase through the time. Performance levels for the year 1990 where *low* and *incipient*; for 1995 the systematic disaster and loss inventory (RI1), the hazard monitoring and forecasting (RI2) and public information and community participation (RI5) have a level *incipient* and the Hazard evaluation and mapping (RI3), Vulnerability and risk assessment (RI4) and Training and education in risk management (RI6) present a level *appreciable*. For 2000 the RI1 and RI2 have a level *appreciable*. In 2005 the RI2 rises to notable and RI3 changes to an optimal level.

5.2 RISK REDUCTION

The risk reduction for Manizales was assessed for Manizales as follows:

Table 5-4 Qualification for risk reduction each indicator, RR

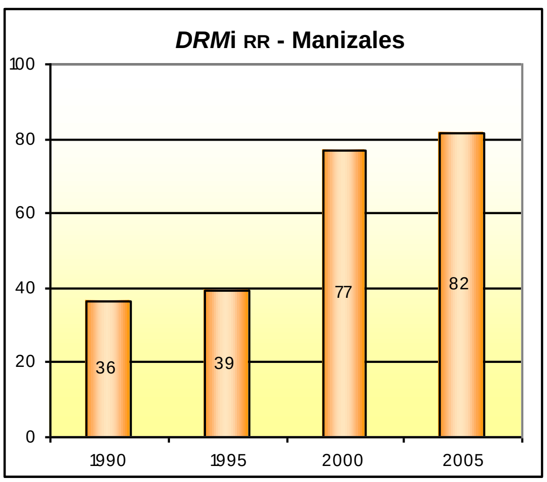
LEVEL	1990	1995	2000	2005
RR.1	2	3	4	4
RR.2	2	3	4	4
RR.3	2	3	4	5
RR.4	3	3	4	4
RR.5	3	3	4	5
RR.6	1	2	4	4

Comparisons between risk reduction indicators can be founded in table 5.5.

Table 5-5 Relative importance assigned to each indicator for risk reduction and HAP application

	RR1	RR2	RR3	RR4	RR5	RR6
RR1	1	1	0,25	0,5	3	1
RR2	1	1	0,25	0,5	3	1
RR3	4	4	1	2	5	4
RR4	2	2	0,5	1	5	2
RR5	0,33	0,33	0,2	0,2	1	0,33
RR6	1	1	0,25	0,5	3	1
eigenvalue = 6.1343 CI = 0.027 CR = 0.022						

Figure 5.3 shows the quantification for $DRMi_{RR}$ indicators and the respective weights obtained by the Analytic Hierarchy Process (AHP) for the city.



LEVEL	1990	1995	2000	2005	W ahp
RR.1	2	3	4	4	14
RR.2	2	3	4	4	9
RR.3	2	3	4	5	7
RR.4	3	3	4	4	31
RR.5	3	3	4	5	20
RR.6	1	2	4	4	19

Figure 5-3 Manizales, $DRMi_{RR}$

The risk reduction in Manizales has had a good level between 1990 and 1995. For 2000 it has a significant progress and then also for 2005. It happens due to the change of indicators from *incipient* and *appreciable* to *notable* in 2000. Implementation of hazard-event control and protection techniques (RR3) in 2005 and Updating and enforcement of safety standards and construction codes (RR5) achieve the performance level to optimum.

5.3 DISASTER MANAGEMENT

The disaster management valuation for Manizales is indicated in the table 5.6 and 5.7 illustrates important comparisons between indicators.

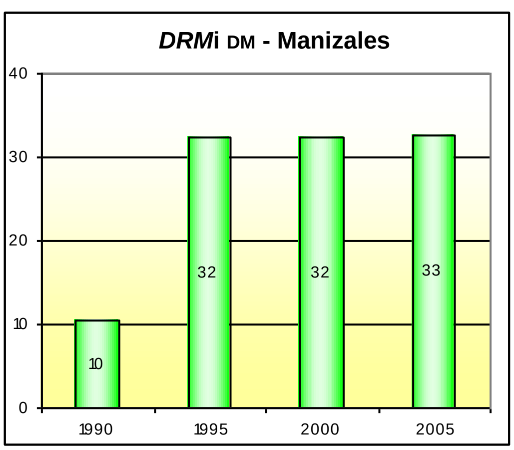
Table 5-6 Qualification for disaster management each indicator, DM

LEVEL	1990	1995	2000	2005
DM.1	1	2	3	4
DM.2	2	3	3	4
DM.3	1	2	2	2
DM.4	2	3	3	2
DM.5	1	2	3	2
DM.6	1	2	3	2

Table 5-7 Relative importance assigned to each indicator for disaster management and HAP application

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	1	2	2	5	4	5
DM2	0,5	1	1	5	2	5
DM3	0,5	1	1	5	2	5
DM4	0,2	0,2	0,2	1	0,33	1
DM5	0,25	0,5	0,5	3	1	3
DM6	0,2	0,2	0,2	1	0,33	1
eigenvalue = 6.0684 CI = 0,014 CR = 0.011						

Figure 5.4 indicates qualifications of indicators composing the $DRMi_{DM}$ and their respective weights calculated using the Analytic Hierarchy Process (AHP) for Manizales. The policy of disaster management in Manizales has improved in bigger proportion for the year 1995 and it keeps in the same for 2005. For 1990 indicators have a performance level *low* and *incipient* and for 1995 change to *appreciable* level, specifically emergency response planning and implementation of warning systems (DM2) and Simulation, updating and test of inter institutional response (DM4). For 2000, the most of indicators got an *appreciable* level, and for 2005 the organization and coordination of emergency operations (DM1) and (DM2) are *notable*, when the others indicators decrease to *incipient* levels.



LEVEL	1990	1995	2000	2005	W ahp
DM.1	1	2	3	4	11
DM.2	2	3	3	4	11
DM.3	1	2	2	2	40
DM.4	2	3	3	2	22
DM.5	1	2	3	2	5
DM.6	1	2	3	2	11

Figure 5-4 Manizales, DRMiDM

5.4 GOVERNABILITY AND FINANTIAL PROTECTION

Governability and financial protection was estimated as it is exposed in the next table:

Table 5-8 Qualification of each indicator of financial protection, FP

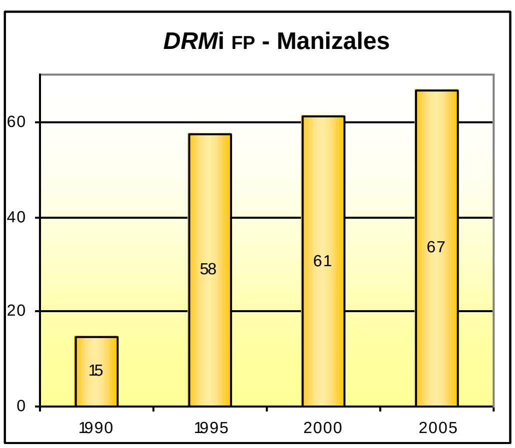
LEVEL	1990	1995	2000	2005
FP.1	1	2	3	3
FP.2	2	4	4	5
FP.3	1	2	3	4
FP.4	1	2	2	2
FP.5	2	3	4	5
FP.6	1	2	4	5

The relative importance of financial protection indicators are in the next table.

Table 5-9 Comparison of the relative importance between FP indicators, and AHP application

	FP1	FP2	FP3	FP4	FP5	FP6
FP1	1	0,33	2	5	2	5
FP2	3	1	5	6	5	6
FP3	0,5	0,2	1	3	1	3
FP4	0,2	0,167	0,33	1	0,33	1
FP5	0,5	0,2	1	3	1	3
FP6	0,2	0,167	0,167	1	0,33	1
eigenvalue = 6.0909 CI = 0.018 CR = 0.,015						

The figure 5.5 has the qualifications for indicators composing the $DRMi_{FP}$ and the respective weights obtained by the Analytic Hierarchy Process (AHP) for Manizales.



LEVEL	1990	1995	2000	2005	W ahp
FP.1	1	2	3	3	21
FP.2	2	4	4	5	46
FP.3	1	2	3	4	12
FP.4	1	2	2	2	5
FP.5	2	3	4	5	12
FP.6	1	2	4	5	4

Figure 5-5 Manizales, $DRMi_{PF}$

In the case of the financial protection, Manizales has started in a lower level in the year 1990, but it improves for 1995 and it increases until 2005. Indicators increasing are Inter-institutional, multisectoral and decentralizing organization (FP1) and reserve funds for institutional strengthening (FP2) from *notable* to *optimum*, from 1995 to 2005. This indicator was considered with a higher relative importance that contributes to improve the index. Other important indicators improving are Insurance coverage and loss transfer strategies of public assets (FP5) and Housing and private sector insurance and reinsurance coverage that achieve the *optimum* level.

5.5 DISASTER RISK MANAGEMENT INDEX

Total DRMi and their components are showed in table 5.10, for each period, the risk identification, $DRMi_{RI}$, risk reduction, $DRMi_{RR}$, disaster management, $DRMi_{DM}$ and governability and financial protection, $DRMi_{FP}$ and the city of Manizales.

Table 5-10 DRMi for Manizales

	1990	1995	2000	2005
$DRMi_{IR}$	13.9	39.2	56.2	70.0
$DRMi_{RR}$	36.5	39.2	77.0	81.8
$DRMi_{DM}$	10.5	32.3	32.3	32.7
$DRMi_{PF}$	14.6	57.6	61.3	66.8
DRMi	**18.9**	**42.1**	**56.7**	**62.8**

Figure 5.6 has the total DRMi for Manizales and the way it is conformed for the 4 indicators. As a conclusion the increasing of the DRMi has been important, especially in 1995 and then it continued until 2005. All indicators have had a similar increase in the first two periods, then it is important the performance of risk reduction, RR, followed by risk identification, RI, and the financial protection, FP. The disaster management is the component with the less advance.

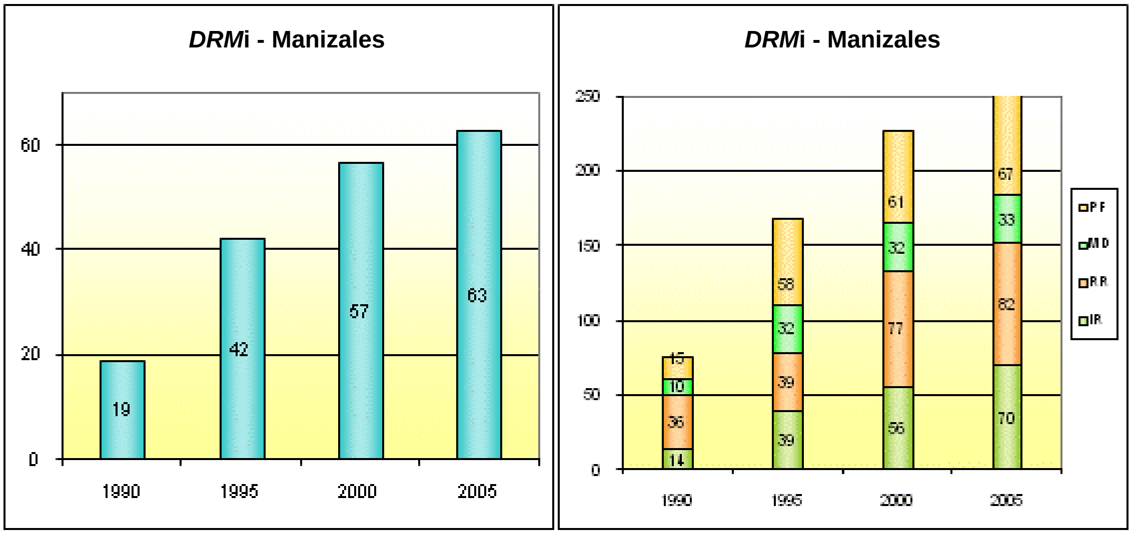


Figure 5-6 Manizales, total DRMi

Table 5.11 illustrates changes levels in the performance levels in the four indexes for disaster management between the first and last period. The analysis allows the identification of straights and weakness.

According to the table can be appreciated the DRMi has had important changes between the first and the last period. The higher progress has been in risk identification and financial protection and the least advances have been in disaster management. The indicators revision allows the identification of aspects in which it had happened improvements and which where it is necessary to make bigger efforts.

Table 5-11 Differences between the first and the last DRMi indicators for Manizales

	Values of indicators performance functions							
1990	RI.1	5	RR.1	17	DM.1	5	FP.1	5
	RI.2	17	RR.2	17	DM.2	17	FP.2	17
	RI.3	17	RR.3	17	DM.3	5	FP.3	5
	RI.4	5	RR.4	45	DM.4	17	FP.4	5
	RI.5	5	RR.5	45	DM.5	5	FP.5	17
	RI.6	5	RR.6	5	DM.6	5	FP.6	5
	$DRMi_{RI}$	13.9	$DRMi_{RR}$	36.5	$DRMi_{DM}$	10.5	$DRMi_{FP}$	14.6
	DRMi	18.87						
2005	RI.1	45	RR.1	77	DM.1	77	FP.1	45
	RI.2	77	RR.2	77	DM.2	77	FP.2	93
	RI.3	93	RR.3	93	DM.3	17	FP.3	77
	RI.4	77	RR.4	77	DM.4	17	FP.4	17
	RI.5	17	RR.5	93	DM.5	17	FP.5	93
	RI.6	17	RR.6	77	DM.6	17	FP.6	93
	$DRMi_{RI}$	70.0	$DRMi_{RR}$	81.8	$DRMi_{DM}$	32.7	$DRMi_{FP}$	66.8
	DRMi	62.80						
Change	RI.1	40	RR.1	60	DM.1	72	FP.1	40
	RI.2	60	RR.2	60	DM.2	60	FP.2	76
	RI.3	76.4	RR.3	76	DM.3	12	FP.3	72
	RI.4	72	RR.4	32	DM.4	0	FP.4	12
	RI.5	12	RR.5	48	DM.5	12	FP.5	76
	RI.6	12	RR.6	72	DM.6	12	FP.6	88
	$DRMi_{RI}$	56.1	IGR_{RR}	45.3	$DRMi_{DM}$	22.2	$DRMi_{FP}$	52.2
	DRMi	43.94						

6 CHAPITRE 6. CONCLUSIONS

Application and adaptation of Urban Seismic Risk Index, USRi, and Disaster Risk Management, DRMi, allow a higher and more comprehensive vision of disaster risk problem in the city of Manizales. The aim is not to precise exactly the problematic but to estimate its dimension and coverage. The conceptual framework from the holistic perspective is achieved using indicators and indexes which allow the desegregation and the analysis about what and how generate the results. This is the reason why it becomes a useful tool for planning and land regulation.

At first, based in the analysis of USRi results, it is possible to identify the principal weaknesses of localities, in physical risk, social fragility and lack of resilience aspects in specifically way, going into descriptors or factors, in order to establish risk reduction priorities.

According to the ranges for Total Risk, R_T, the most critical results were for localities 2, San José, and 3, Cumanday, with a total seismic risk is in Very High range, due to not only physical risk but also the aggravating coefficient.

In San José's locality indicators related to percent of destroyed area and probable homeless are extremely high. This situation shows that it should be strategies for physical vulnerability reduction, as structure reinforcement, bigger control for construction processes, as well as relocation of critical neighborhoods actually in lands zones, such as *la Avanzada* and *San Ignacio*.

At the same way, the local government should intervene into social fragility, because locality San José has the greater partial social disparity index and population density, a big marginal area; in addition it is second locality in the range of crime indicator.

By the other hand, this *comuna* has a low coverage of hospital beds, public space, firemen and rescue manpower and almost cero development level, which means that its resilience is incredibly low.

In locality Cumanday, the indicator in relation to the percentage of damaged industrial, health and other equipments area has a high component, as well as the number of deaths, injured and people without work.

The social fragility has high levels of mortality, social disparity and population density. The lack of resilience is evident by the firemen and rescue manpower, the development level and the lack of community participation.

Other important case is the one for locality 11, La Macarena, due to the results of high total risk not only for physical risk but also for aggravating coefficient. Indicators related to these results damaged area, homeless and the most of the lack of resilience in low level.

Total risk index in a Medium-High range is for locality 1, Atardeceres, where physical risk and aggravating coefficient have a Medium-High level too. Also *comuna* 9, Universitaria, is this range, for its physical risk level Medium-Low and a High level of indirect impact factor.

Locality 8, Palogrande, and locality 4, La Estación, have a value of physical risk and aggravation coefficient in a range of Medium-Low.

Finally *comuna* 10, La Fuente, 5, Ciudadela Norte, 6, Ecoturística Cerro de Oro, and 7, Tesorito, present a low total seismic risk. Nevertheless, locality 5with a low physical risk results has a Very-High aggravating coefficient, for the marginal area, partial social disparity index and the general low resilience.

The strength of this method of assessment can be proved with the sensibility analysis realized, that it is explained in the complete thesis document. This analysis allows the change of the enter variables, such as the expert assignation for the Analytic Hierarchy Process (AHP), producing new calculations that won't produce a big change of obtained results.

Besides, despite seismic risk conditions, social fragility and lack of resilience seems still in very high levels, moreover when comparing R_F, F and R_T averages with other cities (Appendix that will appear in the complete thesis document), the Disaster Risk Management Index, DRMi, shows significant advancement for the city. It should be taken into account that risk in Manizales is high also for the intensity of the hazards and that the systematic risk management has been done recently.

Since 1990 and until 2005 advances in risk identification are notable, RI, standing out evaluation and hazard mapping (RI3); between 1995 and 2000 there is a growth almost of the double in risk reduction, RR, because for this period all indicators show a performance notable value. The disaster management has improved but it keeps constant between 1995 and 2005. Financial protection, FP, increases drastically between 1990 and 1995 where one of the most important indicators and best qualified is the reserves founds for the institutional strengthening (FP2).

Therefore, for the year 2000, Manizales in comparison with Bogotá, Pereira and Armenia, has the elevated DRMi, where risk reduction and financial protection are the stronger policies of risk management.

In brief, disaster risks management should be focus on the reduction of social fragilities and the improvement of resilience in key zones in the city (such as the center and north of the city), with the implementation of projects for public investment toward the life conditions amelioration of the citizens.

Furthermore, through the financial protection policy can be attempted a wider coverage of the city with insurance, specially for localities in higher risks; this proposal can be made by encouraging the extension of the program of collective insurance which has been executed since 1999.

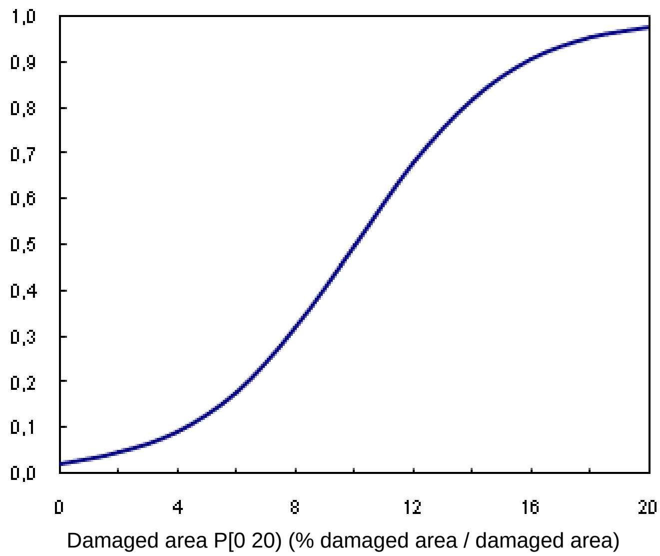
As a conclusion, the risk is a development problem and if it is possible to achieve live conditions improvement and poverty reduction it will be reduce the risk significantly to future disasters.

7 APENDIXES

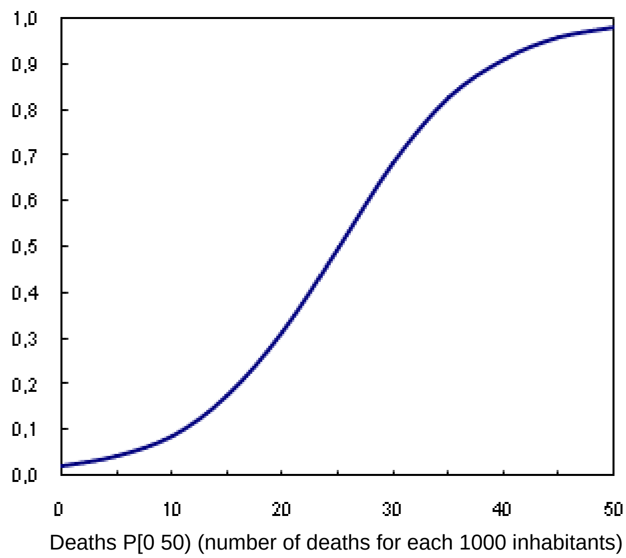
7.1 APPENDIX. TRANSFORMATION FUNCTIONS

This appendix shows the transformation functions used and its equations for the calculation of factors for physical risk and aggravating coefficient related to the Total Risk Index.

Transformation functions used to obtain physical risk factors

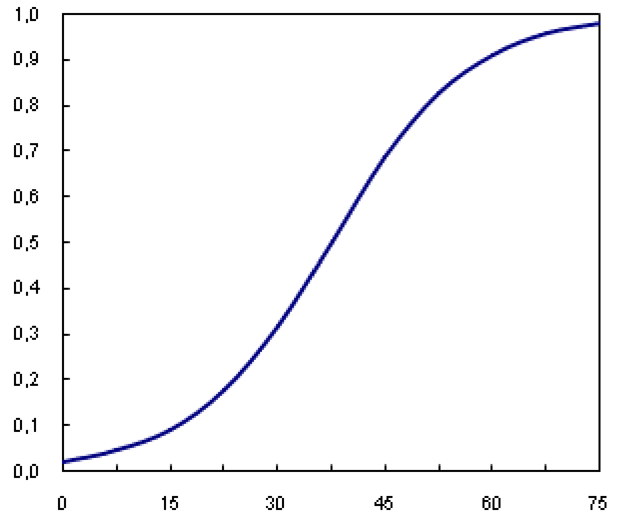


Damaged area as a percent of the total built

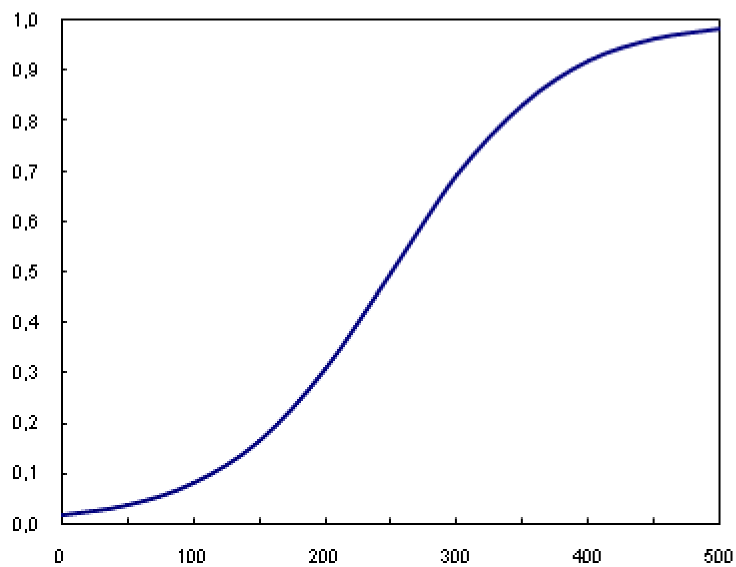


Deaths for each 1000 inhabitants

Figure 7-1 Transformation functions for damaged area and deaths

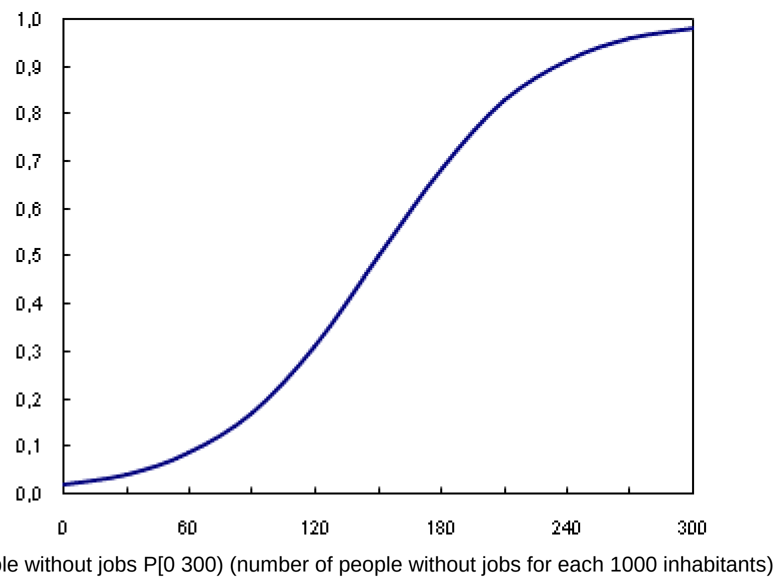


Injured for each 1000 inhabitants



Homeless for each 1000 inhabitants

Figure 7-2 Transformation functions for injured and homeless

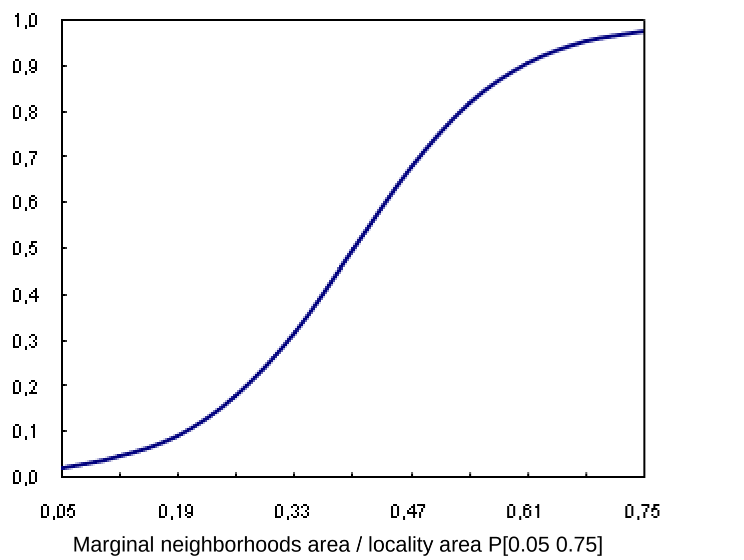


People without jobs for each 1000 inhabitants

Figure 7-3 Transformation functions for people without jobs

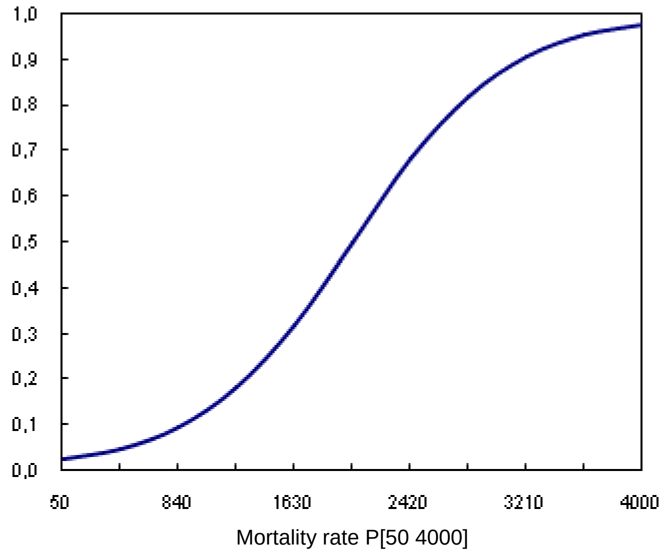
Transformation Functions used to obtained the Agravating Coefficient Factors

Transformation functions used to obtained the factors for Social Fragility

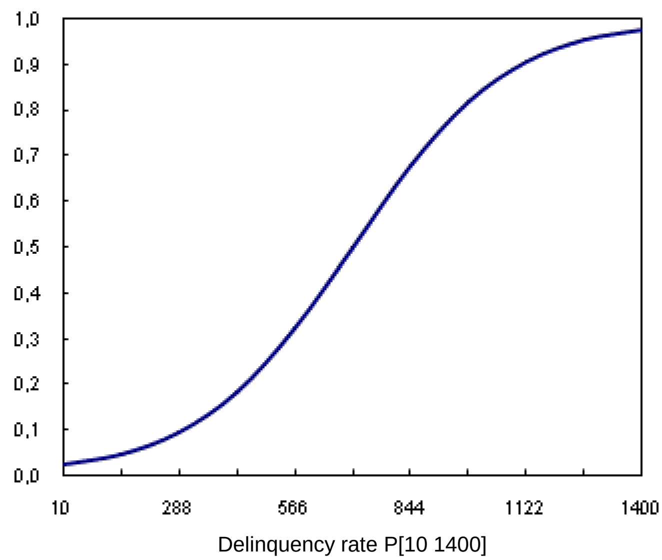


Área barrios marginales en porcentaje del área construida

Figure 7-4 Transformation Functions for marginal neighborhoods area

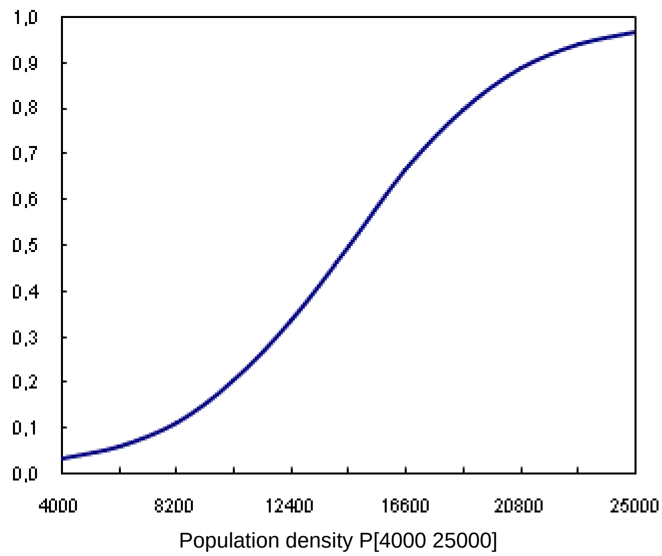


Mortality rate for each 10,000 inhabitants



Delinquency rate for each 100,000 inhabitants

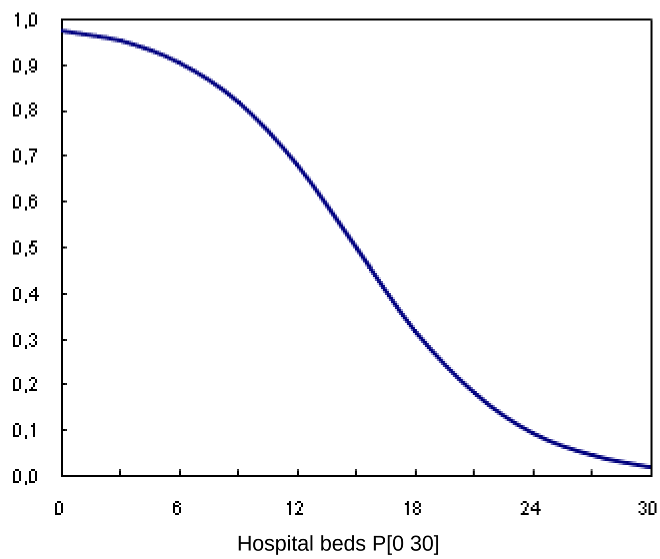
Figure 7-5 Transformation functions for mortality rate and delinquency rate



Population density in inhabitants for km²

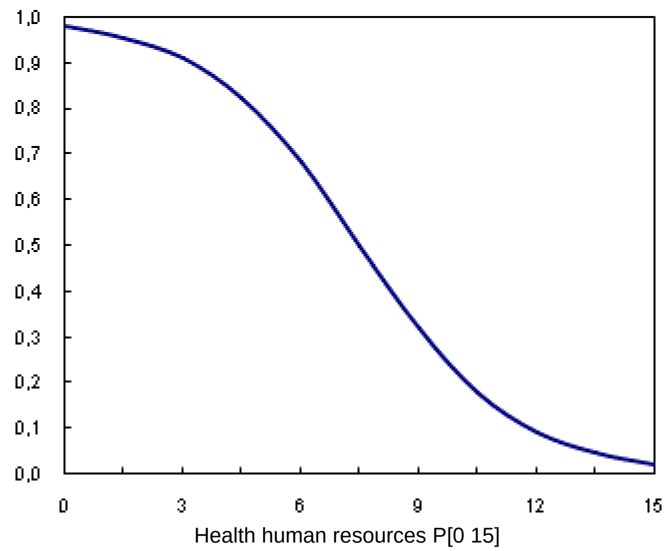
Figure 7-6 Transformation functions of population density

Transformation functions used to obtain the aggravating factors for Lack of Resilience

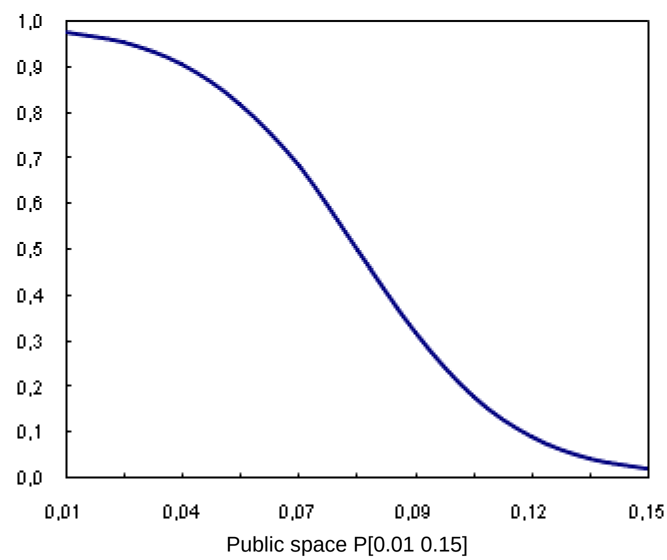


Hospital beds for each 1,000 inhabitants

Figure 7-7 Transformation functions for hospital beds

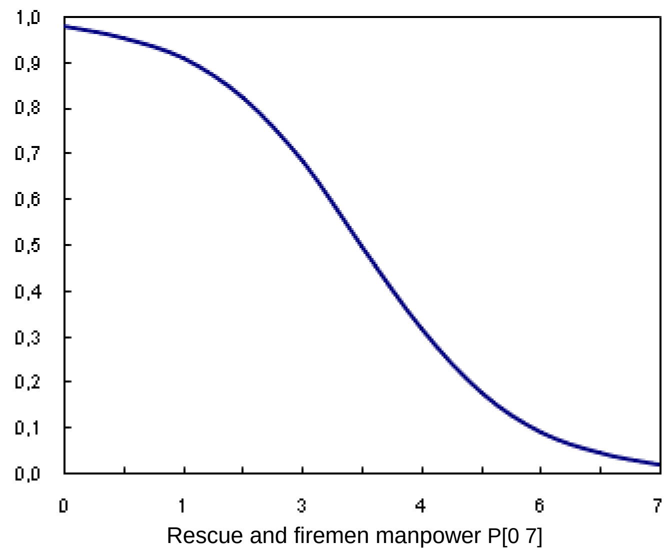


Health Human Resources for each 1,000 inhabitants

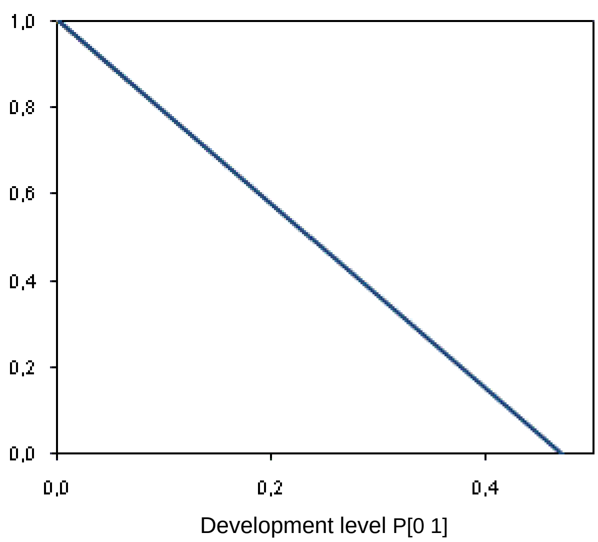


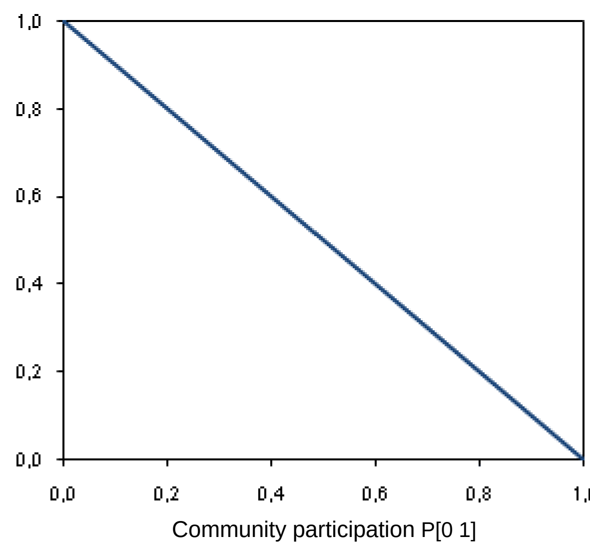
Public space available for the percentage of total area

Figure 7-8 Transformation functions for health human resources and public space



Rescue and firemen manpower for each 10,000 inhabitants





Development level between 0 and 1

Community participation between 0 and 1

Figure 7-9 Transformation functions for rescue and firemen manpower, development level and community participation

7.2 APPENDIX. RESULTS OF PHYSICAL RISK DESCRIPTORS FOR DIFFERENT RISK SCENARIOS IN MANIZALES

The appendix shows the data and results obtained for the risk scenarios considered for Manizales; for the faults of Romeral, Palestina, Murindó, Benioff and an average of all of them.

Initial Information

The followings are de data related to population and constructions in Manizales used for the evaluation of risk scenarios.

Table 7-1 Population during the day and the night for each locality

	Population at night	Population during the day
COM1	38.620	28.783
COM2	25.859	22.605
COM3	27.679	67.336
COM4	25.321	27.249
COM5	45.931	12.312
COM6	28.673	19.215
COM7	38.814	39.883
COM8	20.362	64.208
COM9	34.374	11.044
COM10	45.183	13.467
COM11	27.962	17.576
TOTAL	358.777	323.678

Table 7-2 Build area for each locality

Build Total Area [m²]

	Const_type 0	Const_type 1	Const_type 2	Const_type 3	Const_type 4	**TOTAL**
COM1	0	690.823,0	40.073,0	36.107,4	143.014,3	910.017,7
COM2	0	340.580,0	7.282,0	864,0	153.875,3	502.601,3
COM3	83.801,0	783.717,0	15.200,0	2.288,0	554.574,5	1.439.580,5
COM4	0	612.728,0	24.368,0	45.695,4	161.552,8	844.344,2
COM5	0	1.218.392,0	204,0	292,1	28.426,3	1.247.314,4
COM6	0	610.633,0	32.218,0	10.216,0	92.488,2	745.555,2
COM7	3.176,0	473.622,0	196.461,0	83,6	134.042,3	807.384,9
COM8	29.704,0	1.163.013,1	16.122,0	9.730,0	534.868,2	1.753.437,4
COM9	0	551.541,0	73,0	4.228,2	36.196,1	592.038,3
COM10	0	689.515,0	9.945,0	5.801,0	29.724,0	734.985,0
COM11	17.085,0	705.700,0	17.818,0	1.421,3	94.853,4	836.877,7
	0	9.044,0	0	1.049,6	30.336,2	40.429,8
TOTAL	133.766,0	7.849.308,1	359.764,0	117.776,6	1.993.951,6	10.454.566,3

The structural systems evaluated for Manizales were:

Table 7-3 Structural systems evaluated for Manizales

Structural Systems – Private

Structural System	Description	Struc Syst POPULATION
1	Casas de tapia	1
2	Casas de bahareque	2
3	Mampostería sin confinar sin refuerzo con entrepiso en madera	3
4	Mampostería sin confinar sin refuerzo con entrepiso en concreto	18
5	Mampostería confinada con entrepiso en madera	4
6	Mampostería confinada con entrepiso en concreto	4
7	Mampostería reforzada	5
8	Pórticos con entrepisos en una dirección y con defectos (frágiles)	6
9	Pórticos en concreto reforzado con rellenos de mampostería (dúctiles)	6
10	Sistema reticular celulado	9
11	Sistema industrializado de muros de concreto reforzado	10
12	Muros prefabricados de concreto	11
13	Muros de asbesto-cemento y similares	11
14	Bodegas con luces medianas y cubierta liviana	14
15	Pórticos de acero, estructuras metálicas	12
16	Mamposteria simple con diafragma	18

Structural Systems - Public

Sistema Estructural	Description	Struc Syst POPULATION
1	Muros de adobe o tapia pisada	1
2	Mampostería simple	3
3	Mampostería confinada	4
4	Mampostería reforzada	5
5	Pórticos de concreto	6
6	Pórticos de concreto con muros de mampostería	6
7	Pórtico y muros de concreto	8
8	Reticular celulado	9
9	Prefabricado de concreto	11
10	Muros y losas planas de concreto	10
11	Pórticos de acero	12
12	Bodega	14
13	Bodega Luces Largas	15
27	Mampostería sin diafragma rígido (madera)	3
28	Mampostería con diafragma rígido (concreto)	18

Results for risk scenarios

Results, obtained for the SISMan + Risk, taking into account the collapse factor- Bogotá-DPAE, were the next:

Table 7-4 Results for the build area for different risk scenarios

ROMERAL-N
Total Build Area [m²]

Damages 50%	Build Edifications (total)	Damaged Houses	Damaged buildings for industry, health and others
COM1	207.418	152.911	54.507
COM2	375.736,7	259.351	116.385,7
COM3	617.363	406.202	211.161
COM4	136.152	98.665	37.487
COM5	145.884	145.448	436
COM6	58.977,0	45.688	13.289,0
COM7	737	0	737
COM8	126.321	62.070	64.251
COM9	118.856	109.042	9.814
COM10	58.751	49.086	9.665
COM11	434666,4188	394.110	40556,419
	14.161	345	13.816
TOTAL	2.295.022	1.722.918	572.104

PALESTINA-N
Total Build Area [m²]

Damages 50%	Build Edifications (total)	Damaged Houses	Damaged buildings for industry, health and others
COM1	0	0	0
COM2	0,0	0	0,0
COM3	0	0	0
COM4	0	0	0
COM5	0	0	0
COM6	193,3	0	193,3
COM7	0	0	0
COM8	16.756	0	16.756
COM9	0	0	0
COM10	0	0	0
COM11	0	0	0
	0	0	0
TOTAL	16.949	0	16.949

MURINDÓ -N
Total Build Area [m²]

Damages 50%	Build Edifications (total)	Damaged Houses	Damaged buildings for industry, health and others
COM1	0	0	0
COM2	0,0	0	0,0
COM3	2.336	0	2.336
COM4	0	0	0
COM5	0	0	0
COM6	193,3	0	193,3
COM7	0	0	0
COM8	16.756	0	16.756
COM9	0	0	0
COM10	0	0	0
COM11	0	0	0
	0	0	0
TOTAL	19.285	0	19.285

BENIOFF-N
Total Build Area [m²]

Damages 50%	Build Edifications (total)	Damaged Houses	Damaged buildings for industry, health and others
COM1	0	0	0
COM2	0,0	0	0,0
COM3	0	0	0
COM4	0	0	0
COM5	0	0	0
COM6	193,3	0	193,3
COM7	0	0	0
COM8	16.756	0	16.756
COM9	0	0	0
COM10	0	0	0
COM11	0	0	0
	0	0	0
TOTAL	16.949	0	16.949

Table 7-5 Results for the damaged area for different risk scenarios

AVERAGE

	Build Edifications (total)	Damaged Houses	Damaged buildings for industry, health and others
COM1	51.854	38.228	13.627
COM2	93.934	64.838	29.096
COM3	154.925	101.551	53.374
COM4	34.038	24.666	9.372
COM5	36.471	36.362	109
COM6	14.889	11.422	3.467
COM7	184	0	184
COM8	44.147	15.518	28.630
COM9	29.714	27.261	2.453
COM10	14.688	12.272	2.416
COM11	108.667	98.528	10.139
	3.540	86	3.454
TOTAL	587.051	430.730	156.322

AVERAGE Romeral-Benioff

	Edificaciones Destruidas (total)	Viviendas Destruidas	Industria Salud y otros Destruidos
COM1	103.709	76.456	27.253
COM2	187.868	129.676	58.193
COM3	308.681	203.101	105.580
COM4	68.076	49.333	18.743
COM5	72.942	72.724	218
COM6	29.585	22.844	6.741
COM7	368	0	368
COM8	71.539	31.035	40.504
COM9	59.428	54.521	4.907
COM10	29.376	24.543	4.833
COM11	217.333	197.055	20.278
	7.081	173	6.908
TOTAL	1.155.985	861.459	294.526

Table 7-6 Results for deaths, injured and trapped, average for the day and night for different risk scenarios

AVERAGE-Romeral N-D

	Deaths	Injured	Trapped
COM1	299	669	968
COM2	386	687	1074
COM3	432	846	1278
COM4	290	628	918
COM5	46	211	257
COM6	161	341	502
COM7	41	128	169
COM8	765	953	1719
COM9	161	388	549
COM10	126	305	431
COM11	178	475	653
TOTAL	2887	5631	8518

AVERAGE-Palestina N-D

	Deaths	Injured	Trapped
COM1	6	7	12
COM2	9	11	20
COM3	6	8	14
COM4	8	11	19
COM5	0	2	2
COM6	9	12	21
COM7	6	13	19
COM8	144	146	290
COM9	9	11	20
COM10	1	2	4
COM11	1	3	4
TOTAL	201	225	426

Table 7-7 Results for deaths, injured average for the day and night for different risk scenarios

AVERAGE-Murindó N-D

	Deaths	Injured	Trapped
COM1	22	23	45
COM2	34	35	69
COM3	39	40	80
COM4	14	15	29
COM5	0	1	1
COM6	10	11	22
COM7	3	3	6
COM8	172	173	345
COM9	16	16	32
COM10	3	3	6
COM11	4	5	9
TOTAL	319	325	644

AVERAGE -Benioff N-D

	Deaths	Injured	Trapped
COM1	9	9	19
COM2	10	11	21
COM3	11	11	22
COM4	8	11	19
COM5	0	2	2
COM6	9	12	21
COM7	1	1	3
COM8	134	135	269
COM9	8	10	19
COM10	1	2	3
COM11	2	2	3
TOTAL	193	208	400

AVERAGE N-D

	Deaths	Injured	Trapped
COM1	84	177	261
COM2	110	186	296
COM3	122	226	349
COM4	80	166	246
COM5	12	54	66
COM6	47	94	141
COM7	13	36	49
COM8	304	352	656
COM9	49	106	155
COM10	33	78	111
COM11	46	121	167
TOTAL	900	1597	2497

AVERAGE -Romeral-Benioff N-D

	Deaths	Injured	Trapped
COM1	154	339	493
COM2	198	349	547
COM3	222	428	650
COM4	149	319	468
COM5	23	106	130
COM6	85	177	261
COM7	21	65	86
COM8	450	544	994
COM9	85	199	284
COM10	64	153	217
COM11	90	238	328
TOTAL	1540	2919	4459

Table 7-8 Losses summary for different risk scenarios

Type Property	Cadastral Value	Reference Value	Romeral	Palestina	Munrindó	Benioff
1-Municipality	133.448.217.844	133.448.217.844	28.992.151.250	3.148.196.475	4.702.955.170	2.917.803.516
2- Des-centralized	40.910.635.219	40.910.635.219	10.483.530.433	1.878.159.095	2.738.757.800	1.943.675.603
3-Department	33.009.092.000	33.009.092.000	7.981.047.685	1.860.963.532	2.602.986.633	1.938.615.427
4-Nation	104.387.643.000	104.387.643.000	21.157.190.427	5.618.652.754	7.292.198.001	5.255.668.485
5-Exempt	78.589.968.900	98.237.461.125	29.301.195.980	4.200.190.291	2.488.109.655	4.200.190.291
6-Exent special	40.587.145.000	50.733.931.250	14.352.359.546	1.883.785.338	1.198.802.672	1.883.785.338
7-No exempt	2.995.872.563.000	3.744.840.703.750	1.172.266.748.312	183.876.359.587	143.234.307.380	141.904.912.047
TOTAL	3.426.805.264.963	4.205.567.684.188	1.284.534.223.633	202.466.307.072	164.258.117.312	160.044.650.707
		Lost [%]	30,5%	4,8%	3,9%	3,8%

Table 7-9 Results for homeless and without jobs for different risk scenarios

ROMERAL-N

Damages 50%	Homeless	People without job
COM1	7.150	5.912
COM2	19.107	12.623
COM3	13.498	22.892
COM4	3.204	3.829
COM5	5.478	45
COM6	1.859	1.348
COM7	0	80
COM8	968	6.646
COM9	6.739	1.036
COM10	3.120	1.028
COM11	14.592	4.385
TOTAL	75.715	59.824

PALESTINA-N

Damages 50%	Homeless	People without job
COM1	0	0
COM2	0	0
COM3	0	0
COM4	0	0
COM5	0	0
COM6	0	21
COM7	0	0
COM8	0	1.823
COM9	0	0
COM10	0	0
COM11	0	0
TOTAL	0	1.844

MURINDÓ -N

Damages 50%	Homeless	People without job
COM1	0	0
COM2	0	0
COM3	0	254
COM4	0	0
COM5	0	0
COM6	0	21
COM7	0	0
COM8	0	1.823
COM9	0	0
COM10	0	0
COM11	0	0
TOTAL	0	2.098

BENIOFF-N

Damages 50%	Homeless	People without job
COM1	0	0
COM2	0	0
COM3	0	0
COM4	0	0
COM5	0	0
COM6	0	21
COM7	0	0
COM8	0	1.823
COM9	0	0
COM10	0	0
COM11	0	0
TOTAL	0	1.844

Table 7-10 Homeless and people without job

AVERAGE

Damages 50%	Homeless	People without job
COM1	1.788	1.478
COM2	4.777	3.156
COM3	3.375	5.786
COM4	801	957
COM5	1.370	11
COM6	465	353
COM7	0	20
COM8	242	3.028
COM9	1.685	259
COM10	780	257
COM11	3.648	1.096
TOTAL	18.929	16.402

AVERAGE Romeral-Benioff

Damages 50%	Homeless	People without job
COM1	3.575	2.956
COM2	9.553	6.311
COM3	6.749	11.446
COM4	1.602	1.915
COM5	2.739	22
COM6	930	685
COM7	0	40
COM8	484	4.234
COM9	3.369	518
COM10	1.560	514
COM11	7.296	2.193
TOTAL	37.858	30.834

7.3 APPENDIX. SOCIAL DISPARITY INDEX

As one of the social fragility indicators, of the Aggravating Coefficient, it was build a Partial Disparity Social Index. Initially, for the formulation of the Partial Disparity Social Index was made a review of the next indicators:

Human Development Index, HDI

This index evaluates the achievement of a country or region in three fundamental dimensions: long and healthy life (using the life expectancy); knowledge acquisition and skills that allow people to participate creatively in life (using adult literacy and gross enrollment rate primary, secondary and tertiary combined) and the achievement of a decent life level (through the per capita income adjusted for purchasing power parity) (PNUD, 1999). According to any HDI component it is possible to calculate individual indexes applying the general formula:

$$\text{Index} = \frac{(\text{Value}) \text{ x } (i \text{ effective}) - (\text{Value}) \text{ x } (i \text{ minimum})}{(\text{Valor x } i \text{ maximum valor x } i \text{ minimum})}$$

$$\text{Life expectancy: } \frac{(\text{Value assessed in years} - \text{Minimum value})}{(\text{Maximum value} - \text{Minimum value})}$$

$$\text{Adult literacy: } \frac{(\text{Measured percentage} - \text{minimum value})}{(\text{Maximum value} - \text{Minimum value})}$$

$$\text{Average of schooling years: } \frac{(\text{Measure value - Minimum value})}{(\text{Maximum value} - \text{Minimum value})}$$

$$\text{Educational attainment: } \frac{((2 \text{ x Literacy}) + \text{Average schooling years})}{3}$$

$$\text{Income: } \frac{(\text{Income PPA en dollars - Value minimum})}{(\text{Maximum Value} - \text{Minimum Value})}$$

$$\text{HDI} = \frac{(\text{life expectancy} + \text{educational attainment} + \text{adjusted income})}{3}$$

Human Poverty Index, HPI

Constitute a multi-dimensional measure of the poverty that gathers in a complex index the privation of four basic dimensions for human life: a long and healthy life (represented by the percentage of people that won't survive until the 40's, P_1), knowledge (illiteracy adults percentage, P_2), economical provisioning and social inclusion (through the simple average of three variables: percentage of people without potable water, P_{31}, percentage of people without health services, P_{32}, and percentage of children under five years with insufficient weight, P_{33}). These dimensions of privation are the same for developing countries as the industrialized ones, but indicators differ for the measure (HPI-1, for developing countries and HPI-2 for developed countries), in order to reflex a different reality between countries and limitation of data (PNUD, 2000; Mancero, 2001). The indicator aggregation is made by the expression:

$$HPI = \left[\frac{(P_1^3 + P_2^3 + P_3^3)}{3} \right]^{1/3}$$

Definition and housing indicators

The review of definition and housing indicators includes the Housing Indicators Program of the World Bank (Mayo, S: Stephens, W., 1992), Housing Indicators Program for Chile (Min. Planificación y Cooperación, Chile, 2002), Manizales Indicators for Habitat Quality (Marulanda, 2000, Arias, s.f.) and the development housing indicators for Medellin neighborhoods (Taborda H., 1991). Some of the concepts are the followings:

Overcrowding: measures the relationship between the number of people at home and the number of places habitable in one house. The overcrowding is estimated when in one home there are more than three people by habitable place.

Public service coverage: percentage of urban population with access to potable water system, sewer system, cleanliness, electricity and public telephones.

Unsatisfied Basic Needs Index

The NBI is used in Colombia as a measure of poverty. NBI's methodology defines poverty in terms of five indicators: a) inadequate housing (according to house materials), b) the lack of access to public services, such as electricity, potable water and sanitation, c) high density for home occupation (being the limit more than three people for occupied space). A home is considered poor if it presents any of the five conditions (May, 1996).

Table 7-11 NBI Dimensions and Variables

Basic needs	Dimensions	Census Variables
Housing access	a) Housing quality	Construction materials used in floors, walls and roofs
	b) Overcrowding	i) Number of people at home ii) Number of house rooms
Sanitary services access	a) Potable water availability	Source of housing water supply
	b) System types for excreta elimination	i) Sanitary service availability ii) Excreta elimination system
Education access	Assistance of children in scholar age to go to an scholar establishment	i) Home members age ii) Assistance to a scholar establishment
Economic capacity	Probability of low income at home	i) Home member age ii) Last educative level approved iii) people number at home iv) Activity condition

Source: CEPAL /PNUD (1989) In: Feres, and Mancero, (2001).

The living condition index is other measure developed in Colombia. This is a composed index by elements as: living conditions, environmental sittings, security environment (violence, etc.) education access, overcrowding, incomes, etc. (Bula, 2002).

Definition of the Partial Social Disparity Index

The index intends to represent inequity in the life quality of the eleven localities. It depends of housing occupation conditions, for the housing habitability, overcrowding and public services presence. Other condition related to the quality of life is the education access, as an indicator of opportunities for the population and possibilities to access a better educational level.

- Housing conditions indicator:

First of all it was obtained a housing conditions indicator, which is composed by three sub-indicators:

<u>Housing type</u>: classified as house, apartment, indigenous house, room and other type, which give an idea of space for the family and the income level to accede to a specific house. In order to reflect the population in the lower conditions it were elected rooms and other types.

<u>Total housing home</u>: selects the houses by locality with 1 home, 2 homes, 3 homes, etc. until 6 homes. This information is valuable as grade of family overcrowding and it was elected houses with three or more homes for indicate this situation.
<u>Total housing without public services</u>: takes into account houses without some or any public services (water supply, sewerage and electricity). Then it was made a difference

between the house total and houses with public services, to show bad habitability conditions.

The housing conditions indicator is obtained, at first, adding the number of houses type four and others, the number of houses with 3 or more homes and houses without some public service; then results are normalized.

Hous. Condit. Ind. = Housing with low habitability conditions

#Low Hous Condit. =

(#Hous. type room and others + # Hous.with 3 or more homes + # Hous. Without pub. Serv.)

$$\text{House low condit. .=} \quad \frac{(\text{\# Hous. low condit.} - \text{Minimum value})}{(\text{Maximum value} - \text{Minimum value})}$$

- Educational level indicator:

The second indicator is the educational level, which is defined as:

Educational level: for population with 3 years or more, censed in particularly homes, with scholar levels from preschool, primary, secondary, academic, technical, normal, technical, technological, professional, specialization, master's and doctoral degrees. To show lower educational opportunities and incomes was taken into account people without any education, and those with incomplete primary and secondary.

The educational level indicator low or cero is obtained, first, adding the number of people without any educational level, with primary incomplete education and secondary incomplete education; then results are normalized.

Educ. Lev. Ind. low = People without any or low educational level

Peop. Low educ. lev. = (# Peop. without educ. + # Peo. primary incompl. + # Peo. secundary incompl.)

$$\text{Peop. low educ. lev. =} \quad \frac{(\text{\# Peop. low educ. level} - \text{minium value})}{(\text{Maximum value} - \text{mínimum value})}$$

Finally, the Partial Social Disparity Index is obtained using the next equation:

$$\textbf{Part. Disp. Soc. Index} = \left[\frac{(\text{Hous. Cond. Ind.})^2 + (\text{Educ. Level Ind.})^2}{2} \right]^{1/2}$$

Data

Data was given by the Information and Statistics Center, CIE, of Manizales Mayor's Office, from the Census in 2005.

Living conditions

In the table 7.12 has the data of the variables that conformed housing conditions indicator.

Table 7-12 Data for the living conditions indicator, for Manizales

	Type room and other type	House total x home 3, 4, 5 and 6	House total without some public services	House total in low habitability conditions
Atardeceres (C1)	108	114	121	343
San José (C2)	694	71	249	1014
Cumanday (C3)	659	258	89	1006
La Estación (C4)	73	72	23	168
Ciudad. Norte (C5)	91	59	95	245
Ecot. Cerro de Oro (C6)	72	31	170	273
Tesorito (C7)	72	58	104	234
Palogrande (C8)	222	126	33	381
Universitaria (C9)	173	133	116	422
La Fuente (C10)	225	92	63	380
La Macarena (C11)	265	111	74	450

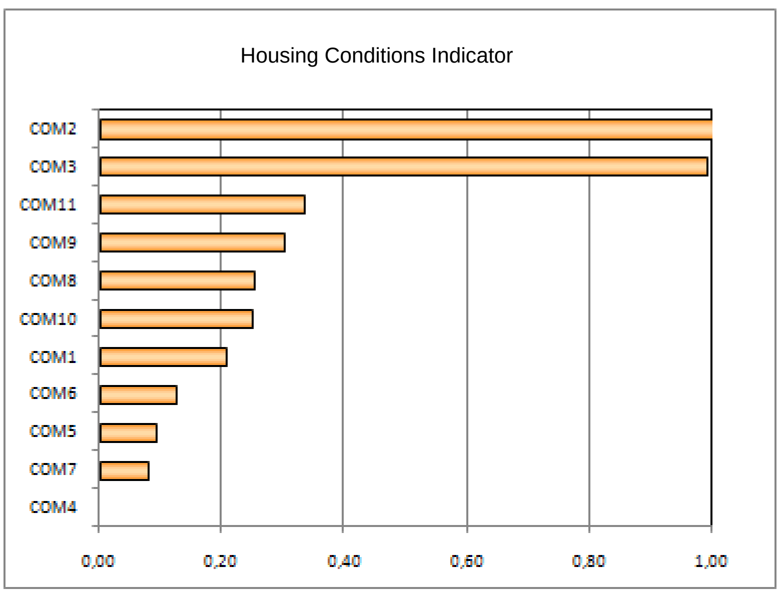


Figure 7-10 Habitability conditions indicator for Manizales

Educational level

Table 7-13 Data for the Educational Level Indicator for Manizales

	Without	Incomplete primary	Incomplete secondary	Total without education and Incomplete education
Atardeceres (C1)	675	3303	3242	7.220
San José (C2)	2195	6221	4045	12.461
Cumanday (C3)	925	4065	4291	9.281
La Estación (C4)	491	2200	2487	5.178
Ciudad. Norte (C5)	3402	11890	10181	25.473
Ecot. Cerro de Oro (C6)	1014	3949	3741	8.704
Tesorito (C7)	626	2977	2903	6.506
Palogrande (C8)	257	1430	1830	3.517
Universitaria (C9)	1835	6834	5847	14.516
La Fuente (C10)	2082	7243	6499	15.824
La Macarena (C11)	1390	5425	4841	11.656

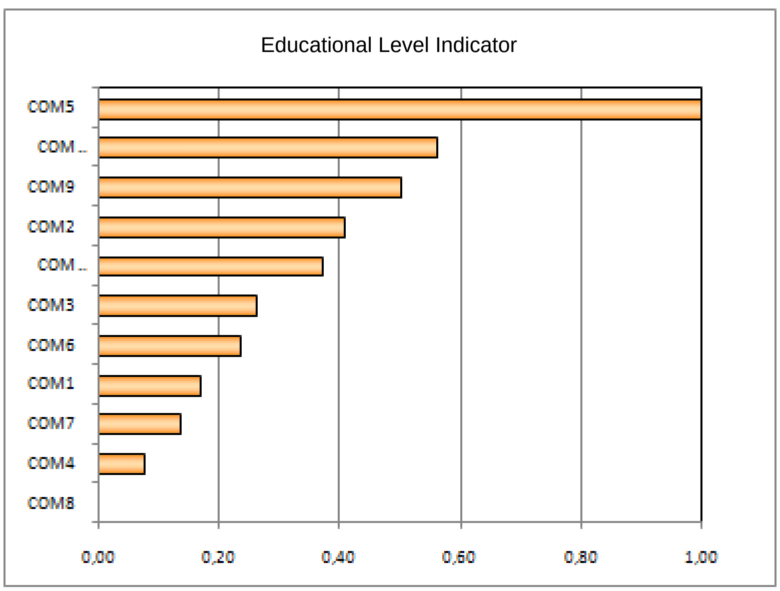


Figure 7-11 Educational level indicator for Manizales

Results

Table 7-14 Partial Social Disparity Index for Manizales

	Habitability conditions indicator	Educational level indicator	Partial Social Disparity Index
Atardeceres (C1)	0,2069	0,1687	0,18872
San José (C2)	1,0000	0,4074	0,76353
Cumanday (C3)	0,9905	0,2625	0,72460
La Estación (C4)	0,0000	0,0757	0,05349
Ciudad. Norte (C5)	0,0910	1,0000	0,71003
Ecot. Cerro de Oro (C6)	0,1241	0,2362	0,18870
Tesorito (C7)	0,0780	0,1361	0,11095
Palogrande (C8)	0,2518	0,0000	0,17803
Universitaria (C9)	0,3002	0,5010	0,41298
La Fuente (C10)	0,2506	0,5605	0,43416
La Macarena (C11)	0,3333	0,3707	0,35251

7.4 APPENDIX. THE ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) was proposed in the 1970s and is a widely used technique for multi-attribute decision making (Saaty 1987). It enables decomposition of a problem into hierarchy and assures that both qualitative and quantitative aspects of a problem are incorporated in the evaluation process, during which opinion is systematically extracted by means of pair-wise comparisons. AHP is a compensatory decision methodology because alternatives that are efficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP allows for the application of data, experience, insights, and intuition in a logical and thorough way within a hierarchy as a whole. In particular, AHP as weighting method enables decision-maker to derive weights as opposed to arbitrarily assign them.

The core of AHP is an ordinal pair-wise comparison of attributes, sub-indicators in this context, in which preference statements are addressed. For a given objective, the comparisons are made per pairs of sub-indicators by firstly posing the question "Which of the two is the more important?" and secondly "By how much?". The strength of preference is expressed on a semantic scale of 1-9, which keeps measurement within the same order of magnitude. A preference of 1 indicates equality between two sub-indicators while a preference of 9 indicates that one sub-indicator is 9 times larger or more important than the one to which it is being compared. In this way comparisons are being made between pairs of sub-indicators where perception is sensitive enough to make a distinction. These comparisons result in a comparison matrix A (see table 7.15) where $A_{ii} = 1$ and $A_{ij} = 1 / A_{ji}$.

Table 7-15 Comparison Matrix A of Three Sub-indicators (Semantic Scale)

Objective	**Indicator A**	**Indicator B**	**Indicator C**
Indicator A	1	3	1
Indicator B	1 / 3	1	1 / 5
Indicator C	1	5	1

For the example shown in table 7.15, Indicator A is three times more important than Indicator B, and consequently Indicator B has one-third the importance of Indicator A. Each judgment reflects, in reality, the perception of the ratio of the relative contributions (weights) of the two indicators to the overall objective being assessed as shown in table 7.16.

Table 7-16 Comparison Matrix A of Three Sub-indicators (Weights)

Objective	Indicator A	Indicator B	Indicator C
Indicator A	**wA/wA**	**wA/wB**	**wA/wC**
Indicator B	**wB/wA**	**wB/wB**	**wB/wC**
Indicator C	**wC/wA**	**wC/wB**	**wC/wC**

The relative weights of the sub-indicators are calculated using an eigenvector technique. One of the advantages of this method is that it is able to check the consistency of the comparison matrix through the calculation of the eigenvalues.

AHP tolerates inconsistency through the amount of redundancy. For a matrix of size $n \times n$ only n-1 comparisons are required to establish weights for n indicators. The actual number of comparisons performed in AHP is $n(n-1)/2$. This redundancy is a useful feature as it is analogous to estimating a number by calculating the average of repeated observations. This results in a set of weights that are less sensitive to errors of judgment. In addition, this redundancy allows for a measure of these judgment errors by providing a means of calculating an inconsistency ratio (Saaty 1980; Karlsson 1998). According to Saaty small inconsistency ratios (less than 0.1 is the suggested rule-of-thumb, although even 0.2 is often cited) do no drastically affect the weights.

AHP is well suited to the type of complex decision-making problems involved and to the multiple goals related to the decision-making. The main advantage of AHP is that it is based on pair-wise comparison; the human mind can easily handle two distinct problems and examine their differences. Another advantage of AHP is that unlike many other methods based on Utility Theory, its use for purposes of comparisons does not require a universal scale.

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