Design and Implementation of a Collective Insurance Program based on Cross Subsidies for Recovery of Low Income Homeowners

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SUMMARY:
Understanding disaster risk due to hazard events creates powerful incentives to develop planning options and tools to reduce and finance potential damages. This paper describes how probabilistic metrics such as the loss exceedance curve, the expected annual loss and the probable maximum loss, calculated with catastrophe risk models, are used for the designing of a risk transfer instrument to cover the private housing in Manizales, Colombia. This voluntary collective instrument promotes the insurance culture and provides financial protection not only to the estate-tax payers but also covers the low-income homeowners through a cross-subsidy strategy. This program is promoted by the city administration and the insurance industry, using the mechanism of the property-tax payment. This collective insurance helps the government to access key resources for low-income householder recovery and improve disaster risk management at local level.

Keywords: Seismic risk, insurance instruments, catastrophe risk model, probable maximum loss, expected annual loss, risk premium

1. INTRODUCTION

Social, environmental and economic sustainability depend not only from the identification of risk conditions but from the planning measures to reduce disaster risk and from the implementation of development actions, looking for an equilibrium between the economic, social and environmental issues to reduce possible future economic and social losses. This process is a long term set of actions because building a culture of prevention is not an easy task. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disaster that did not happen as was pointed out by Kofi Annan, UN General Secretary, in 1999. In addition, individuals faced with the possibility of a catastrophic loss tend to ignore the event until after it occurs. Usually, prior to a catastrophe, individuals underestimate the chances of such a disaster occurring (Marulanda *et al.* 2008).

One of the key strategic activities of disaster risk management is the assessment of the risk to extreme events, which requires the use of reliable methodologies that allow an adequate calculation of probabilistic losses of exposed elements. The use of models for catastrophic risk assessment and the results they provide make feasible to determine the potential deficit existing in case of the occurrence of an extreme event. Catastrophe risk models –based on metrics such as the Probabilistic Maximum Loss and the Average Annual Loss– are used to estimate, building by building, the probabilistic losses of different portfolios of exposed elements. Usually, these kinds of evaluations where performed by the private financial markets; nevertheless, at present, it is understood that estimations and quantification of potential losses in a given exposure time are of interest not only for the private insurers, reinsurers and investors but also for the governments since the budget for both the emergency response and the recovery and reconstruction could mean a fiscal exposure and a non explicit contingent liability for governments at city and country levels (Pollner 2001; Andersen 2002). Besides, estimation of contingency losses provides information and permits to set out strategies *ex ante* for reducing or financing them (Marulanda *et al.* 2008; Cardona *et al.* 2010a; Cardona *et al.* 2010b; Marulanda *et al.* 2010). Assessment of potential losses allows considering budget allocation for structural retrofitting in order to reduce damages and also implementing an effective financial protection strategy meant to provide loss coverage of public infrastructure and private buildings to protect government resources and safeguard socioeconomic development. In summary, to achieve a greater awareness, security culture and economic prosperity, the financial protection must be a permanent and long term policy (Freeman *et al.* 2003). Nevertheless, it is important to remember that insurance, or in general, risk financing strategies, are not a mitigation measure strictly speaking, because they do not reduce damage and its objective is covering losses once the damage is materialized (Cardona *et al.* 2008d). However, "world experience shows that disaster insurance has two big advantages: stimulate prevention oriented by insurers and guarantee financing and efficiency in post disaster reconstruction activities" (Vargas 2002).

The persistence of negative impacts has become a fiscal and social issue for the city government of Manizales. This is the reason why the designing and establishment of a collective voluntary insurance policy to protect the city's assets, both from public and private sector has been of interest of the local government. The city administration uses its information systems to process and facilitate the collection of disaster insurance payment of each property of the city, accordingly on its official valuation. The scheme is voluntary and makes use of the property-tax system, for which billings are sent out every two months or every year with a discount (for advance payment). The billings include an invoice which allows the estate-tax payer to pay the property tax only, or to make an extra payment including the insurance premium (Marulanda 2009).

The social benefit of this collective insurance consists of the fact that once a defined percentage or threshold of the insurable value of the properties in the municipal area is reached –i.e. those that pay the property-tax pay the insurance premium– the insurance protection is extended to the properties of the poorest people whose property value is exempt to pay the property tax. The possibility to cover the poorest socio-economic layers and, overall, the promotion of a culture of insurance in Manizales was considered from special interest for the city administration, which should restrict its activities to the collection of premiums with the tax gathering. The insurance company is indeed the organization which has the direct contractual relationship with the insured, and therefore it solves problems and processes the claims derived from the policy.

The scheme or mechanism of disaster risk transfer of private buildings of Manizales has been the result of the development of a series of evaluations, using a sophisticated catastrophic risk model, of the portfolio of private buildings that was comprised with aims of evaluating risk premiums and probable losses. Taking into account that Manizales has a detailed seismic microzonation (ITEC 2004), a vulnerability and risk analysis was developed based on the cadastral information for obtaining the probable maximum losses (loss exceedance curve) and pure risk premiums (average annual loss) of each building of the city. Using these risk metrics was feasible to design the "collective risk transfer instrument" to cover damage and losses of poor homeowners by cross-subsidies and to promote the insurance culture (Cardona *et al.* 2004; Cardona *et al.* 2005a; Cardona *et al.* 2005b; Marulanda 2009).

2. PROBABILISTIC RISK EVALUATION MODEL

Applying of probabilistic risk evaluation models allow evaluating risk due to natural phenomena, and more specifically the evaluation of loss exceedance curves of extreme events in a specific area, that is, the losses that a city or a country would have when events occur. Therefore, the results from the models are useful for establishing the government liabilities due to future disasters. When understanding probable losses due to earthquakes, incentives to develop planning options and tools to reduce and to cope with risk, exist. From the financial protection perspective, designing of a collective insurance is possible when considering reposition costs of the affected assets.

The seismic risk model takes into account the probability of occurrence of earthquakes in the whole generating sources of the surrounding region. It also considers the attenuation of the seismic waves of earthquakes which magnitudes and epicentres are transformed in local intensities in firm soils. In addition, it uses relations between intensity of the seismic action and damage in buildings, also known as vulnerability functions that depend, directly, on the characteristics of the exposed elements at risk. Since large uncertainties related to the severity and frequency characteristics of the events are inherent in the models, the earthquake risk models use probabilistic formulations that incorporate these uncertainties into the risk assessment. The probabilistic risk model (PRM) quantifies potential losses arising from earthquake events (Woo 1999;2011; Grossi *et al.* 2005; Cardona *et al.* 2008a; b; c; d).

2.1. Seismic hazard assessment

The hazard module defines the frequency and severity of a peril at a specific location. This is completed by analyzing the historical event frequencies and reviewing scientific studies performed on the severity and frequencies in the region of interest. Once the hazard parameters are established, stochastic event sets are generated which define the frequency and severity of thousands of stochastic events. This module can analyze the intensity at a location once an event in the stochastic set has occurred, by modeling the attenuation of the event from its location to the site under consideration, and evaluates the propensity of local site conditions to either amplify or reduce the impact. The SisMan V1.1.0 system (ITEC 2004) was used for estimating the seismic hazard in Manizales. For the seismic microzonation, through site specific studies, three kinds of soils were identified: ashes, fills and firm soil or rock. These three areas were divided in polygons or subzones and site effects assigned (calculated from different drills made in the urban perimeter of the city).

2.2. City exposure

Shaping of the database of private buildings of Manizales was obtained based on the information supplied by the public administration through the Municipal Office of Disaster Prevention and Attention (OMPAD in Spanish).

In Manizales were obtained 85.816 valid properties (for the purpose of the project), where 15.741 belong to the non-property-tax payers and 70.345 belong to the property-tax payers. Three portfolios were constructed for estimation of the seismic risk: 1) non-exempt property tax payers (property value greater than Col$ 8'950.000), 2) exempt of property tax (property value equal or lower than Col$ 8'950.000) and 3) both portfolios abovementioned, for a global valuation of risk. Table 1 presents the number of registers and the insured value corresponding to each portfolio of analysis (Marulanda 2009).

Table 1. General data of the portfolios of private buildings. Figures in Col$ (US$ 1: Col$ 2.000)

Portfolio	Description	Number of registers	Percentage of registers	Insured value (million Col$)	Percentage of insured value
1	Non-exempt of property tax	15.342	18	78.590	3
2	Exempt of property tax	70.474	82	3.046.606	97
3	Total private buildings	85.816	100	3.125.196	100

Cadastral information was complemented with information taken from other municipality databases. Subsequently an optimization algorithm was developed for information assignment, which was based on information obtained from field visits and punctual and zones inspections, maps of parameters of reference and default information. The main objective of the algorithm is to identify the structural system from available information of other sources.

2.3. Vulnerability of buildings

The vulnerability module quantifies the damage caused to each asset class by the intensity of a given event at a site. The development of asset classification is based on a combination of construction material, construction type (say, wall & roof combination), building usage, number of stories and age. Estimation of damage is measured in terms of the mean damage ratio (MDR). The MDR is defined as the ratio of the expected repair cost to the replacement cost of the structure. A vulnerability curve is defined relating the MDR to the earthquake intensity which can be expressed in terms of maximum acceleration, spectral acceleration, velocity or displacement at each location.

Specific vulnerability curves can be defined for building contents and for business interruption (BI) costs. A total of 20 construction classes are included in the system as detailed in Figures 1 and 2. The system also allows for the use of customized vulnerability curves for other structural or construction classes (Cardona et al 2008a/b/c/d).

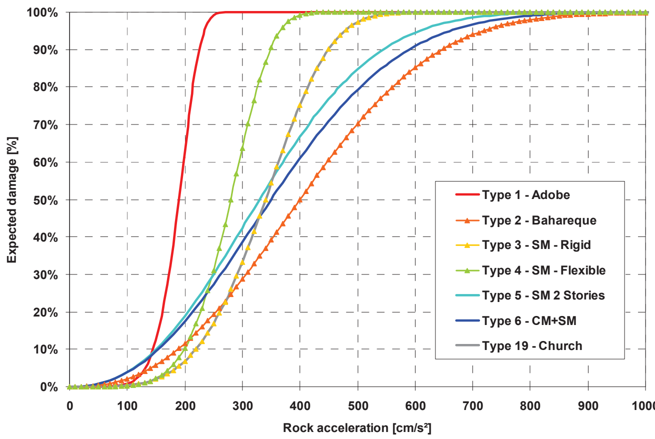

Figure 1. Vulnerability curves based on peak ground acceleration

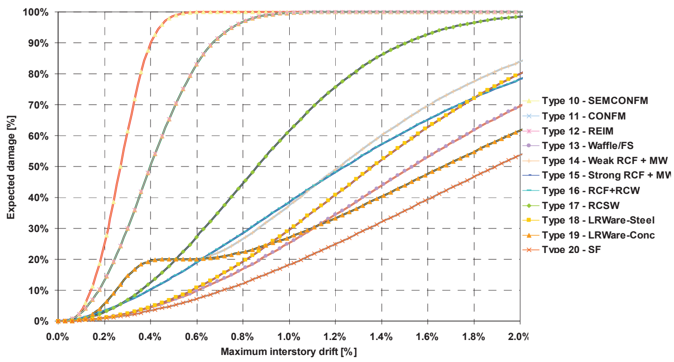

Figure 2. Vulnerability curves based on maximum inter-story drift

2.4. Damage and loss evaluation

It is well known that risk is usually measured by means of the exceedance rate of loss, $\nu(p)$ which is the expected number of earthquakes, per unit time, that will produce losses equal or larger than p. It is computed by using the total probability theorem

$$\nu(p) = \sum_{i=1}^{Events} \Pr(P > p | Event\ i) F_A(Event\ i) \quad (2.1)$$

where $\Pr(P>p|Event\ i)$ is the probability of exceedance of the loss p given the occurrence of the event i, and $F_A(Event\ i)$ is the annual occurrence frequency of event i. Vulnerability functions are used to compute $\Pr(P>p|Event\ i)$.

Normally, a seismic event would be specified in terms of, at least, its magnitude and the location of its hypocenter. Hence, in order to compute $\Pr(P>p|Event\ i)$ some considerations have to be made. First, it is assumed that, given the occurrence of the event i, with known magnitude and hypocentral location, the intensity at the site of the structure is a lognormal random variable with median and logarithmic standard deviation that, in general, depend on magnitude and source-site distance. Under this assumption, the required probability Pr ($P>p|Event\ i$) is computed by chaining two conditional distributions:

$$\Pr(P > p \mid Event) = \int_0^\infty \Pr(P > p \mid Sa)\, p_{SA}(Sa \mid M, R)\, dSa \tag{2.2}$$

where $p_{SA}(Sa|M,R)$ is the probability density function of the intensity Sa given that a magnitude M earthquake occurs at a source-site distance R. As mentioned before, it is often assumed for $Sa|M,R$ a lognornal distribution, with median and logarithmic standard deviation that depend on M and R, which are computed using the ground-motion prediction model selected by the analyst. The first term of the integrand is, obviously, computed using the vulnerability relation that describes the behaviour of the structure under analysis. The above equations give a clear indication of how uncertainties in vulnerability are propagated throughout the risk analysis.

Thus, in order to calculate losses using this risk module, the damage ratio calculated in the vulnerability module is transformed into economic loss by multiplying it by the value at risk. This operation is done for each asset class, and at each location. Losses are then aggregated as stated by Ordaz *et al.* (1998) and Ordaz (2000). The loss module estimates the net losses. They can be useful for insurance information taking into account for example deductible, sum insured, etc. Risk metrics produced by the model provide risk managers and decision makers with essential information required to manage future risks. The main metrics for risk assessment are the following:

Loss Exceedance Curve, LEC, represents the annual frequency with which a loss of any specified monetary amount will be exceeded. This is the most important catastrophe risk metric for risk managers, since it estimates the amount of funds required to meet risk management objectives. The LEC can be calculated for the largest event in one year or for all (cumulative) events in one year. For risk management purposes, the latter estimate is preferred, since it includes the possibility of one or more severe events resulting from earthquakes. Once calculated the Loss Exceedance Curve, it is possible to obtain other appropriate metrics for the financial analysis of the losses such as the Average Annual Loss or Pure Risk Premium for each building and for sets of buildings, like, for instance, the AEBs. The Probable Maximum Loss is obtained for the whole portfolio, that is, the entire city (Ordaz *et al.* 2003; Cardona *et al.* 2008a).

Average Annual Loss, AAL, is the expected loss per year. Computationally, AAL is the sum of the product of the expected losses in a specific event and the annual occurrence probability of that event, for all stochastic events considered in the loss model. The expected annual loss considers the losses of each building for all the events that can occur; supposing that the process of occurrence of hazard events is stationary and that damaged structures have their resistance immediately restored after an event. The average annual loss can be calculated as follows (Ordaz *et al.* 1998; 1999):

$$AAL = \sum_{i=1}^{Events} E(P|Event\ \mathrm{i})\, F_A(Event\ \mathrm{i}) \tag{2.3}$$

where AAL is the Average Annual Loss, $E(P/Event\ i)$ is the expected loss value for the event i and F_A $(Event\ i)$ is annual occurrence frequency of the event i. The annual occurrence frequency of events depends on the results of hazard assessments. The loss expected value, given the occurrence of a particular event, depends on the vulnerability of the exposed element.

Probable Maximum Loss, PML, represents the loss amount for a given annual exceedance frequency, or its inverse, the return period. The PML curve is generally specified as the PML in economic value or in percentage with regard to the return period. The PML of an exposed base is an appraiser of the size of maximum losses that could be reasonably expected in a set of elements exposed during the occurrence of a hazard event. It is typically used as a fundamental data to determine the size of reserves insurance companies should maintain to avoid excessive losses that might surpass their adjustment capacity. It is defined in this model as the average loss that could occur for a given return period.

For estimation of losses of the group of buildings included in the database it was used the RN-Col System Version 2.1. This system allows calculating values of pure risk premium for each building and for the group or portfolio of buildings and evaluating the probable maximum loss for the database as well as expected value of loss for each building. This model also allows estimating losses taking into account the influence of deductibles, liability limits and coinsurance.

Model's objective is to calculate the level of risk of a group of buildings taking into account main parameters of evaluation of the Pure Risk Premium or Technical Premium for each register and for the whole group, and the Probable Maximum Loss (PML) of the group.

3. IMPLEMENTATION OF THE RISK TRANSFER INITIATIVE

Extreme disasters are characterized by the occurrence of low frequency/high severity phenomena, moreover, by difficulty of predicting the moment and place of its occurrence. Overall costs of prevention increase disproportionately with the severity of the consequences and losses generated by these events can cause solvency problems and economic insecurity. Thus, combined structures of different adequate financial instruments and options that cover various risk layers must be designed, analyzed and established according to benefits and costs that allow the government to face consequences of an extreme event without compromising the financial and fiscal stability and minimizing social losses (Pollner 2001; Marulanda *et al.* 2008; Cardona 2009; Cummins *et al.* 2009).

The purpose of risk transfer by layers is to have a change in the premium or premiums values per layer. Usually, analysis by layers must be done when insurance company, for example, has not the capacity to cover the entire expected loss defined for a given return period. In that case, the company must pay from the attachment point (or lower retention layer, if it has been defined) up to an established limit. This means that premium that must be paid to the insurance company is reduced, but a part of the loss remains uncovered over the limit, which in turn can be other layer that have to be negotiated with other insurance or reinsurance company or, as is usual in significant losses, capital markets through a catastrophe bond or other kind of transfer or financial instrument (Banks 2004; Marulanda *et al.* 2008; Cardona 2009).

As was previously set, various actors are involved: individuals with intermediate-high economic capacity, individuals with low or very low economic capacity and the government as the entity co-responsible of losses of less favorable social layers. According to this, risk transfer and retention alternatives of private buildings must consider interaction between different actors. Different alternatives that are proposed are oriented to capacities, conditions and will of the government, searching attractive incentives for the majority of homeowners.

A layer structure was made due to it is desirable to explore the way to reach the greatest insurance coverage of private buildings including the properties of the poorest socio-economic layers. Thus, with the purpose of defining the best strategy for financial protection of the private buildings of the city, taking into account different analyses, alternatives and recommendations in financial protection, a set of options was selected and considered as the most appropriate and feasible with the city mayor and officials from the financial secretariat, the legal secretariat and the OMPAD of Manizales.

As it has been mentioned, analyses of private buildings of the city include a total of 85.816 properties. They were subdivided in three portfolios. The risk analyses were made with: Percentage of retention of 100%, maximum limit of 100%, deductible of 0%, 1.5%, and 3% of the insured value or limit (cadastral value) and coinsurance of 0%.

The best scenario makes reference to the modeling with a deductible 3% of the insured value. Table 2 presents a summary of the results for the different portfolios and figure 3 shows a structure of risk transfer, retention and financing for the private buildings of Manizales based on the probable losses estimated (Marulanda 2009).

Table 2. Results of the seismic risk analysis for private buildings with 3% of deductible (US$ 1: Col$ 2.000)

DEDUCTIBLE 3%										
ASPECT		**PRIVATE BUILDINGS**								
		EXEMPT			**NON-EXEMPT**			**TOTAL**		
Number of buildings		15.342			70.474			85.816		
Estimated insurable value (Mill Col$)		98.237			3.893.812			3.893.812		
Insured value, cadastral value (Mill Col$)		78.590			3.115.050			3.115.050		
Average Pure Premium		**Mill Col$**	**‰ insurable**	**‰ cadastral**	**Mill Col$**	**‰ insurable**	**‰ cadastral**	**Mill Col$**	**‰ insurable**	**‰ cadastral**
		56	0,59	0,741	5.747	1,561	1,963	5.803	1,537	1,932
PML	**Return periods**	**Mill Col$**	**% insurable**	**% cadastral**	**Mill Col$**	**% insurable**	**% cadastral**	**Mill Col$**	**% insurable**	**% cadastral**
	100 years	1.115	1,42	1,42	94.430	3,03	3,03	93.140	2,99	2,99
	500 years	4.311	5,48	5,48	262.481	8,44	8,43	260.003	8,36	8,35
	1000 years	5.935	7,55	7,55	361.179	11,64	11,59	357.831	11,54	11,49
	1500 years	7.142	9,1	9,09	427.531	13,81	13,72	423.771	13,68	13,6
Expected Loss (%)		20.834	27,23	26,51	928.876	30,58	29,72	923.351	30,5	29,64

For covering exempt buildings it is necessary that non-exempt homeowners cover (subsidy) the total premium of exempts (Col$ 56 million). This would mean to increase in Col$56 million the total premium value of non-exempt buildings portfolio, independent of the number of persons voluntary to subscribe the insurance (Marulanda 2009).

Figure 4 shows the behaviour of the average pure premium of the non-exempt homeowners according to the level of insurance participation and considering the cross subsidy. When a participation of 10% exists, the premium without the portfolio of low-income homeowners is 2.1‰, while including them, the value is 2.3‰. When participation increases to 20%, the premium without subsidy is 2.0‰ and including it is 2.1‰. These values are positive for both, the city administration and the participants, given that although the pure premium increases when including the subsidy, as it was expected, the increased is not significant. It allows considering viable the subsidy of the poor people. In the case of the deductible of the low-income homeowners, the government would cover that layer in the case of an event occurs (Marulanda 2009).

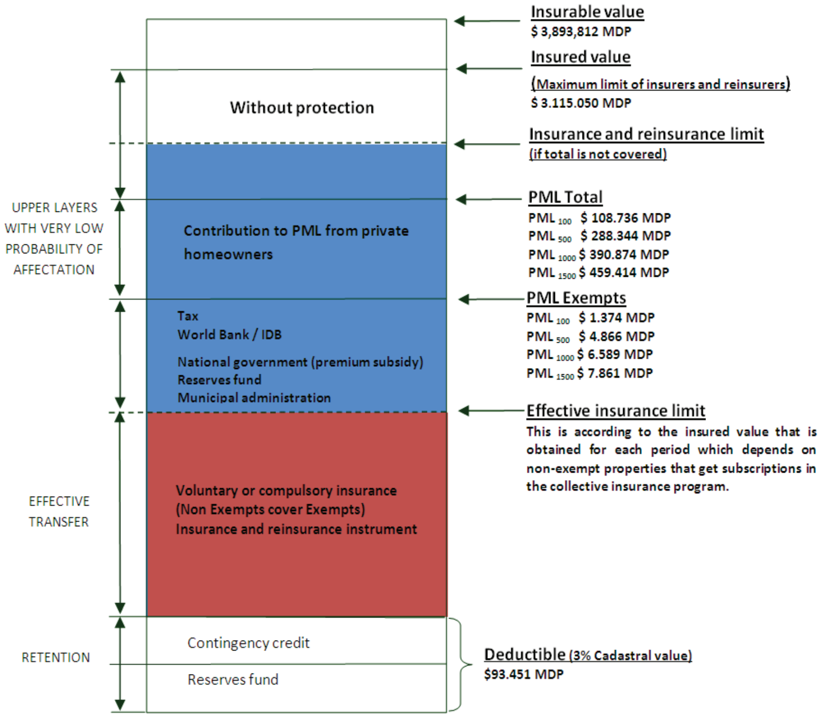

Figure 3. Retention and transfer structure with 3% deductible (US$ 1 million: Col$ 2.000 MDP)

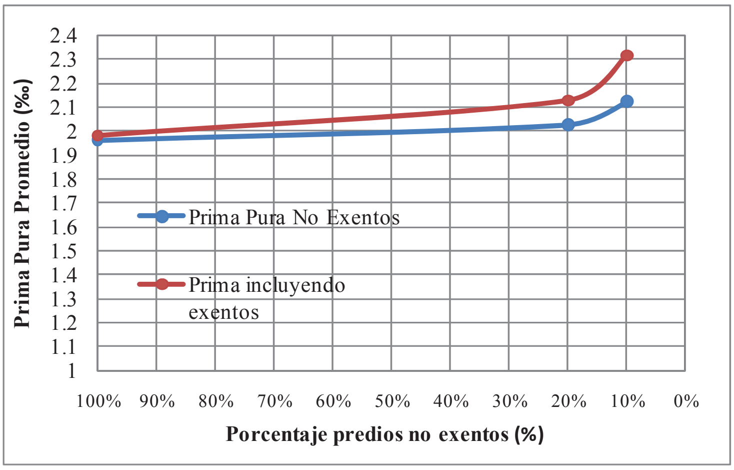

Figure 4. Average pure premium for non-exempt properties portfolio for different levels of insured value with respect to total portfolio.

4. CONCLUSIONS

In this collective insurance program, the annual premium has been estimated and agreed with the insurance company to be 2.5‰ [1] of the cadastral value of each building. Deductible is 3% of loss value in case of earthquake and a minimum of three current minimum legal month salaries. In case of other natural phenomena or events like strike, riot, civil or popular commotion, bad intentioned acts to third parties or terrorism deductible agreed to be 10% of the loss of the affected building and at least two minimum legal month salaries. The insurance company (La Previsora) issued a matrix policy, which Manizales municipality is the taker on behalf of the citizens and repose in the Mayor's office, a registry

[1] Within the technical Premium it is included the operational costs, acquisition and utility among others.

office and in a branch of the insurance company in the city for revision of the users. Given that the average participation has been of the order of 12%, an agreement between the public administration and the insurance company was settled; the total low-income homeowners in Manizales are covered.

This innovative instrument of financial protection implanted in Manizales that has been improving with carefully studies of scientific-technical and actuarial character, without any doubt constitutes a successful experience and is a good practice promoted between the local government and the private sector that could be replicated in other cities of the country like Bogota and in general in other developing countries prone to disasters if appropriate studies of risk are made for its implementation.

This initiative is mainly a social action developed by a local government that can be supported, in addition and when it is feasible, by a national government in different places of a country. The cost effectiveness is clear from sustainability, prevention, socio-economic well-being, financial protection and macroeconomic contingent liabilities points of view. It has been based on technical studies made with robust engineering risk models, but the most important elements of this initiative are the political will, governance, citizen solidarity, and risk perception of the society and the government leaders and officials. This mechanism of risk transfer is undoubtedly a successful experience and a good practice promoted by the government and the private sector, which can be replicated in other disaster-prone developing countries, if appropriate risk studies are made for the implementation.

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