Quick Risk Evaluation of Earthquake Losses on Housing

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SUMMARY:
A proposal technique for a quick risk evaluation of earthquake losses on housing is presented. Here the use of a simplify method for computing the earthquake response on masonry and concrete housing is based on the use of an equivalent single degree of freedom system for the representation of the whole structural system. Then, based on data base of full scale wall test, a damage function was developed for the evaluation of the damage cost based on the maximum earthquake response story drift on the building. Due to cost of retrofitting not only depends of the materials, since more important and costly are the finishing on the housing, the consideration of socioeconomic parameters have been introduce in the computation of the retrofitting cost. In that sense, high upper class produces a function with very expensive retrofitting cost. By the other hand, in the case of adobe masonry housing the retrofitting cost is quite low and different function has been adopted. Therefore, dependency between the socioeconomic parameter and evaluation of retrofitting cost is taken into account by the use of a series of functions. The quick risk evaluation of earthquake losses has been tested with the city of Pisco and also districts in Lima city with good results. The validation of the results is proved using the data from Pisco city that was stricken by the quake of August 15th 2007.

Keywords: Earthquake losses, Retrofitting Cost, Earthquake Response, Quick Risk Evaluation, Simple Method

1. INTRODUCTION

The development of cities depends of many factors such economic potential, population, educational level, disaster hazards, identification of risk, and others. From the point of view of an earthquake engineering engineer, the sustainable development for cities is an issue of secure buildings, secure lifelines, and education of population to behave in proper way during a disaster. Therefore the evaluation of the risk for cities and the knowledge of the decision makers prior the disaster is a key for the development of a city and also can reduce the number of causalities if the disaster manager apply a policy on this matter.

On developing countries there is a gap between the large cities and small cities, were decision makers do not take care of the risk reduction of their communities. The absence of budget or the lack of preparation of budget that contain economic items for disaster prevention are fundamental errors in the treatment of disaster prevention policies where hazard, vulnerability and risk analysis are required. Therefore in this paper a proposal technique with the use of existing information to produce a quick risk evaluation of earthquake losses on housing is presented, as a contribution for small cities where few data are available, and urgent need of the risk evaluation is needed.

2. RISK EVALUATION METHODS

Evaluation methods for seismic risk are tools to predict the amount of losses after earthquakes. The can be selected according with the purpose and who will use the results. For example in the case of insurance companies the prediction of the losses of clients portfolio is the objective. For an NGO organization, the amount losses on the population housing are the objective. In the case of a government the earthquake losses from population, housing, hospitals, schools, infrastructure, lifelines and industries are the objective. For a private investor the evaluation of risk of their infrastructure (factory, building, etc) are the objective. So, a classification of risk evaluation methods depends of the output, and it depends and the purpose of the user. Therefore, we intend to classify the methods as two big groups: Deterministic methods and Criteria Methods.

2.1. Deterministic method

The deterministic method is based on a detailed study of the structure. The study is based on the evaluation by inspection, materials samples, measurement of vibration in the structure, auscultation of the foundation, the foundation depth verification and mathematical modelling of the structure through specialized programs relevant to produce an assessment of the seismic response and find out if the building will withstand the forces and displacements induced by the earthquake. Therefore the seismic hazard analysis will provide the most likely earthquake to demands the structure, and the losses on the building can be quantified.

2.2. Criteria method

The criteria method or empirical method is based on simplifications given by experience and developed by experts in order through a questionnaire and a checklist of parameters that are used as inputs to curves, functions, or simulators seismic response, in order to give a diagnosis of his condition after the event. In many non field evaluation is required and just existing compiled information is used. Therefore it depends of probabilistic analysis of the seismic hazard and the identification of how large and where is the more probable earthquake source, to identify scenarios and predict the amount of loses during a quake.

3. ADOPTED METHOD FOR QUICK EVALUATION

3.1. Background

Lima city is the capital and the largest city of Peru. It is located in the valleys of the Chillón, Rímac and Lurín rivers, in the central part of the country, on a desert coast overlooking the Pacific Ocean. Together with the seaport of Callao, it forms a contiguous urban area known as the Lima Metropolitan Area. With a population approaching 9 million, Lima is the fifth largest city in Latin America, however is located on an earthquake prone zone. Lima had experience big earthquakes in the last century, where earthquakes of 1940, 1966 and 1974 produce strong damage on urban areas. One of the strongest earthquakes was produced in October 1966, several inhabitants of the Huacho area were killed, and over 20,000 were homeless in Huacho, the most severely damaged village. At the time of this shock a religious festival (perhaps associated with that mentioned earlier, established in commemoration of the great Lima catastrophe in October 1746) was held in Callao; several died when some churches collapsed. Landslides and huge ground cracks were noted along the Pan American Highway, and over 2,000 houses sustained severe structural damage in Lima.

On 2003 the first study for seismic risk estimation on Lima city was developed by CISMID-FIC-UNI, under the support of APESEG. Since that study, valuable information has been collected by our researchers and students, and Pisco quake data contribute for the generation of Simulator of Seismic Response and Damage Level (SRSND) for calibration of damage diagnosis on buildings. Therefore, an update of the risk analysis is needed to improve the model of lost estimation. The improvement has been developed using the data and field survey of six districts, developed in a join research project with Ministry of Housing and Construction (PGT-CISMID). Villa El Salvador, San Juan de Lurigancho, La Molina, Chorrillos, Comas and Puente Piedra districts microzoning and diagnosis have been developed. Also results from 3 districts studied under SATREPS (Chiba University-CISMID/FIC/UNI) project has been consider for the present study. The use of the results of these six districts will be used for the generation of response parameters and also loss estimation parameters due to among the districts the social class parameter will be involved and the prediction of the seismic risk analysis will produce material for the generation of functions.

3.2. Update of Microzonification Map

On October 10th 1974 and strong shock approximately 80 km. southwest of Lima rocked the southern coastal area of Peru inflicting heavy damage in the Lima area. The quake, which killed 78 and injured several thousand, was Lima's worst earthquake disaster in terms of lives lost since May 31, 1970, when a magnitude 7.9 shock killed an estimated 50,000 on Chimbote quake, the strong earthquake registered in Peru.

The update microzonification map was developed by the CISMID Geotechnical Lab staff (Aguilar & Lazares, 2011) that consider field study of the soils and recompilation on existing data of soil profiles. Zones in purple are debris areas, red colour shows bad soil, brown colour shows soft soil, yellow colour is a middle soil and green colour shows good soil. Each zone has an expected peak ground acceleration(PGA) that will be used as input data for the earthquake response of structures. Also the tsunami inundation zone, presented as a red line (Estrada & Adriano, 2011) has been include in the microzoning map.

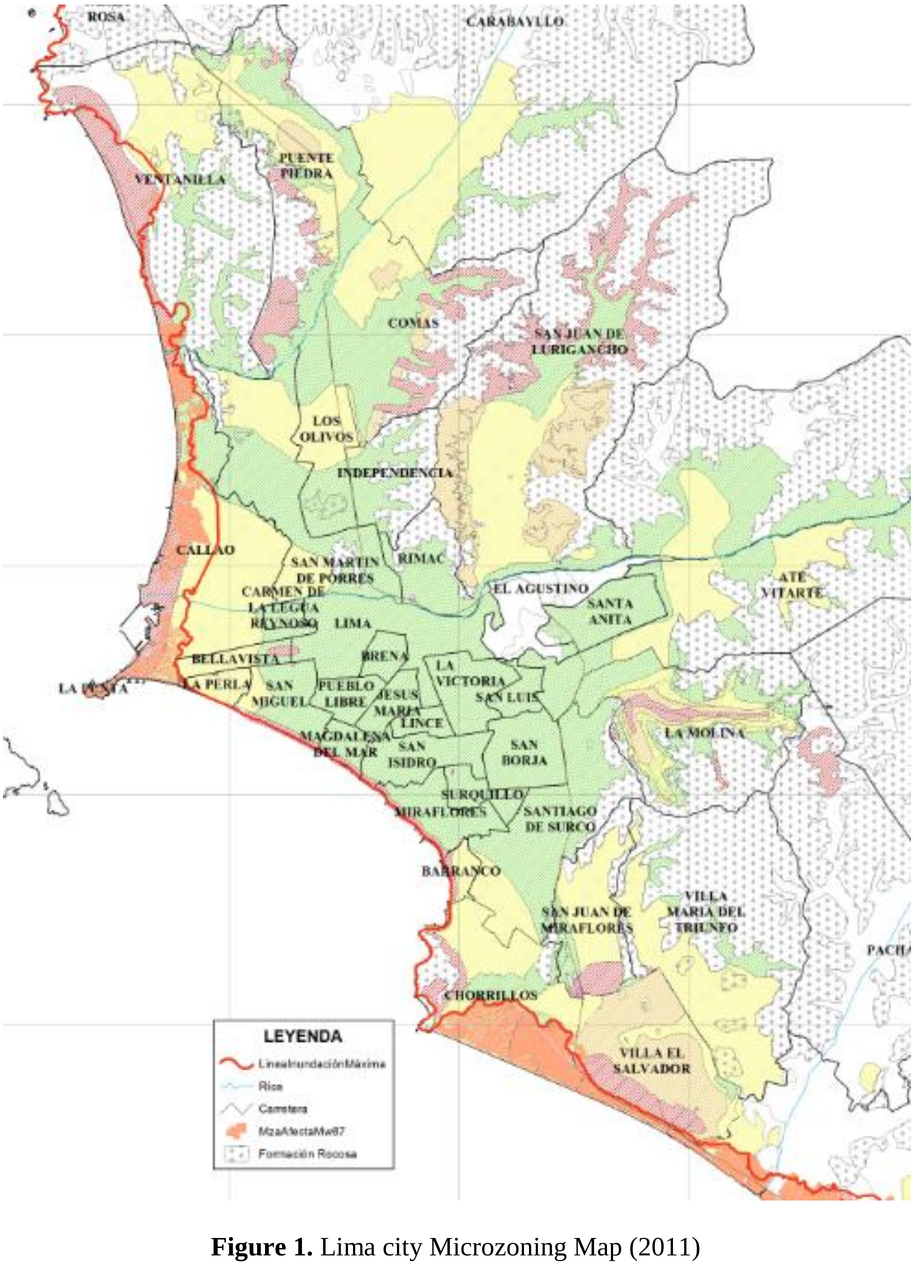

Figure 1. Lima city Microzoning Map (2011)

3.3 Building stock and vulnerability

Survey work was developed on the six update districts, were some new areas not evaluated on 2003 diagnosis has been included. In this areas a representative house for each block was study, in order to evaluate the seismic response using a simplify analysis using influence parameters, such socio economical condition, type of material, condition state, height, number of stories, etc. In Peru housing cost depends of the socio economical level. As an illustration Figure 2 and Figure 3 presents four different socio economical level housing.

Figure 2. House of Socio Economical Level B (NSE-B) and Socio Economical Level C (NSE-C)

Figure 3. House of Socio Economical Level D (NSE-D) and Socio Economical Level E (NSE-E)

3.4 Socio Economical condition and model estimation

The city of Lima (include the harbor of Callao) has a total of 43 districts, as is presented in Figure 4. Among the districts the north and south are districts where the amount slums are quite considerable. On other zones of the districts like in center south or south east the concentration of high income class is notorious. To illustrate the cost for retrofit a house in each of the study districts is presented on Table 1.

Table 1. Retrofit Cost on Housing in US$ per m2.

District	SE levels	Average Area (m2)	Retrofit Cost (US$/m2)
San Juan de Lurigancho	C, D, E	130	275
Comas	C, D, E	160	300
Puente Piedra	D, E	160	235
Villa El Salvador	D , E	130	400
Chorrillos	C, D	160	950
La Molina	A, B	250	1300

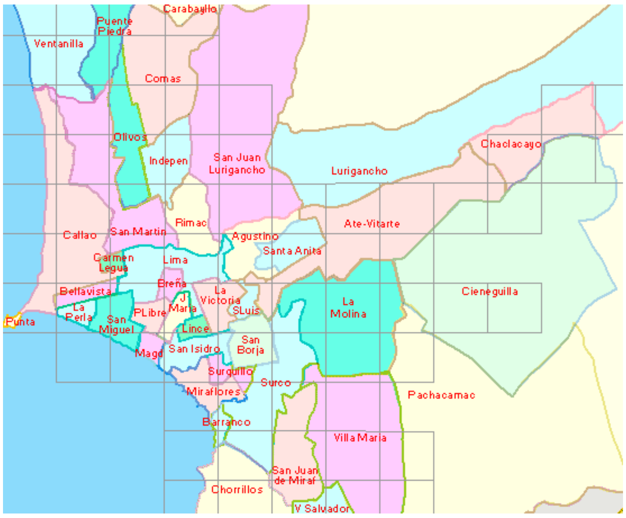

Figure 4: Districts on Lima city

Among the districts the north and south are districts where the amount slums are quite considerable. On other zones of the districts like in center south or south east the concentration of high income class is notorious.

From PGT-CISMID study districts, as an example, let´s consider one district (La Molina) belong to high upper class, another district belong to middle class (Chorrillos) and four districts area popular zones (Villa El Salvador, San Juan de Lurigancho Comas and Puente Piedra). Considering Figure 5, we can analyze the distribution of socio economical level.

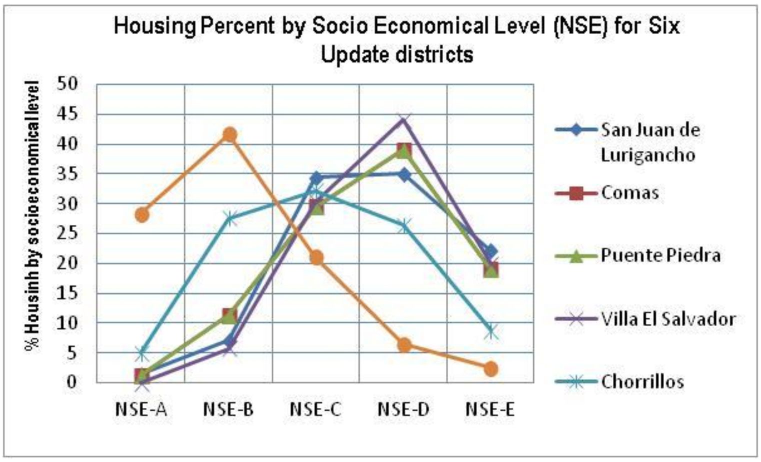

Figure 5: Housing by socio economical level

The four popular districts with low socio economical have join a group by itself and middle class district is just with a peak at socio economical level C, and high socio economical level district as La Molina have peaks as A and B levels. Therefore , type of housing (see Figure 2 and Figure 3) and cost of reposition (see Table 1) must be different for each of the socio economical level groups. Also, the consideration that in each district there are different socio economical levels as was presented in Figure 5, but each group presents a peak, we can consider an average value of the cost of reposition or retrofit cost to represents the amount of loss for a property on the district.

3.5 Risk evaluation considering damage functions involving socio economical level

For the evaluation of the risk, the retrofit cost for house unit is consider as output parameter of the presented process. We can consider the methodology propose by Miranda (1999) and implemented on

SNSRD and presented by Zavala (2007, 2010). On this method a series of βi factors together with spectral pseudo displacement are used to predict the earthquake response of a housing unit. However the process can be simplified if we consider an analysis of the response taken into account only an equivalent first mode of vibration of the structure to take advance of the spectra component of pseudo displacement.

As an example we introduce the damage function in terms of drift response (γ) on masonry buildings, where the drift is compute using the following equation:

$$\gamma = \frac{(X_i - X_{i-1})}{h} = \left(\frac{\left(\frac{ZUSC}{R} \right)}{\left(\frac{2\pi}{T} \right)^2} \right)(0.75\mu) \tag{1}$$

here X_i and X_{i-1} are the response displacement on story i and story i-1, h is the inter story high, Z is the PGA that depends of seismic microzonification, U is the building importance factor (1 to 1.5) , S is soil type factor (1 to 1.4), C is the amplification factor (function of the soil period and structure period), R is a reduction factor (3 in the case of masonry structures), T is the period of the building (here consider as function of the interstory height (h)), μ is the expected ductility on the structure.

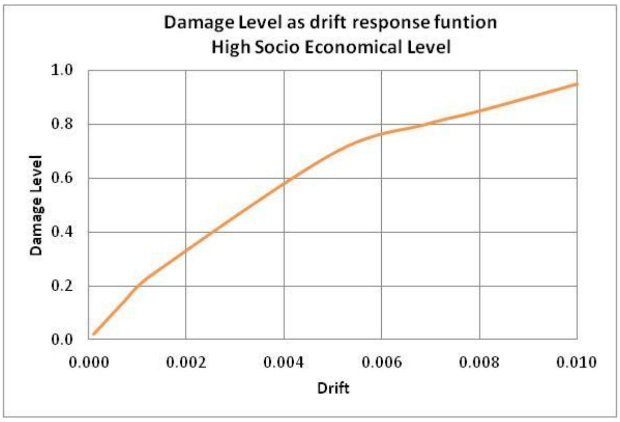

Figure 6: Damage Level on La Molina District

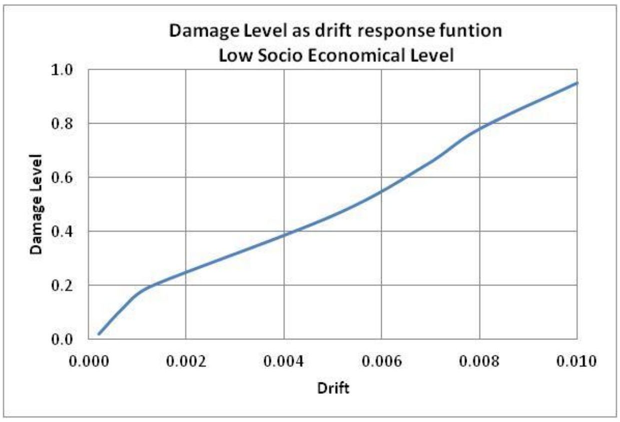

Figure 7: Damage Level on Popular Districts

Based on test results presented by Zavala (2004) and complemented with numerical simulations on non linear models, damage matrix can be computed in terms of damage functions. Therefore, involving the socio economical variable, damage level is computed with the functions calculated from a regression analysis of the six districts results, presented in Figure 6 (for high socio economical level district) and Figure 7 (for low socio economical level district).

Using the damage level expressed in percent, the damage cost retrofit functions are proposed and presented in Figure 8 where each socio economical level has a function. Under this diagnosis the update of Lima risk analysis is performed, and presented in Figure 9.

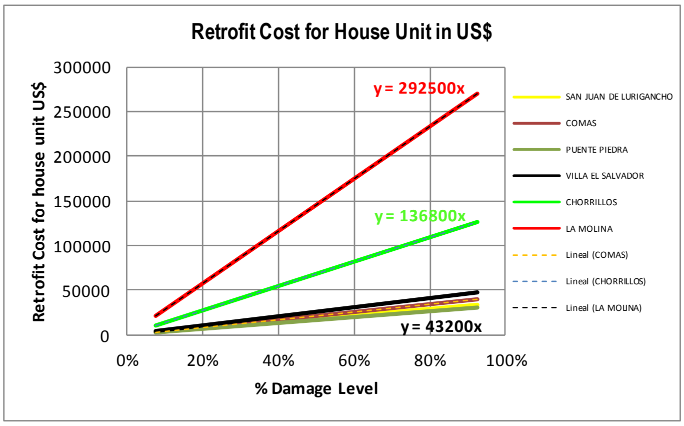

Figure 8: Retrofit cost in US$ for house unit

All this algorithm was implemented on CCRE tool a simplified version of SRSND, that implement equation (1) and functions presented on Figures 5,6,7,8. The results of the application is presented on Figure 9 for the case of Lima city, were green areas represent a retrofit cost less than 15%, yellow zones shows retrofit cost between 15% to 30% and red zones represent cost over 30% that will represent reposition of the house.

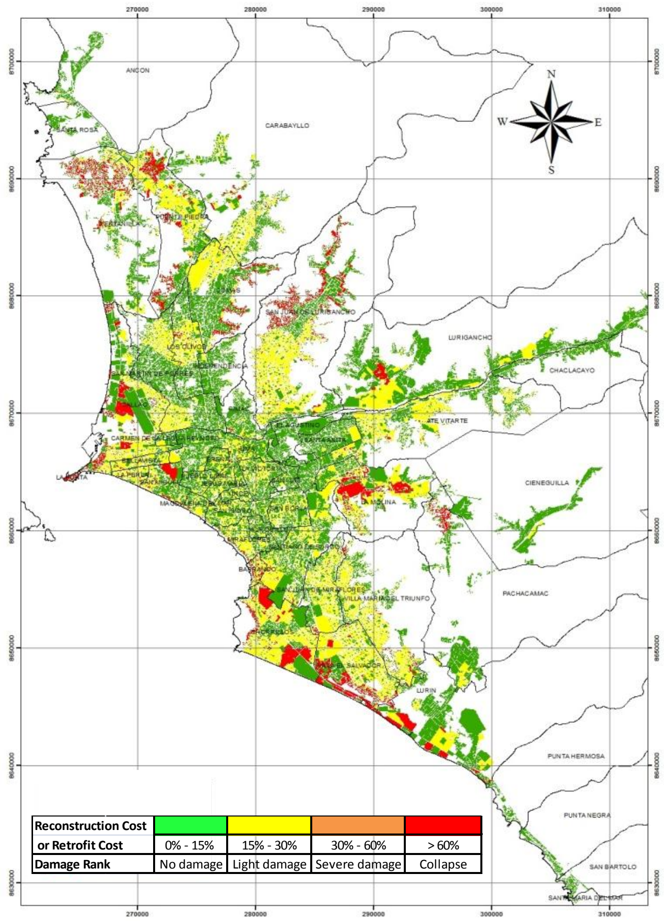

Figure 9: Seismic Risk in terms of retrofitting cost

The model was applied to Pisco city too. This city has socio economical level C, D and E, so therefore the curve presented on Figure 7 was representative for the housing on this city. Results are presented on Figure 10, where good agreement has been reach in comparison with the damage ratio after 2007 quake survey (presented in Figure 11) with 70% of hits.

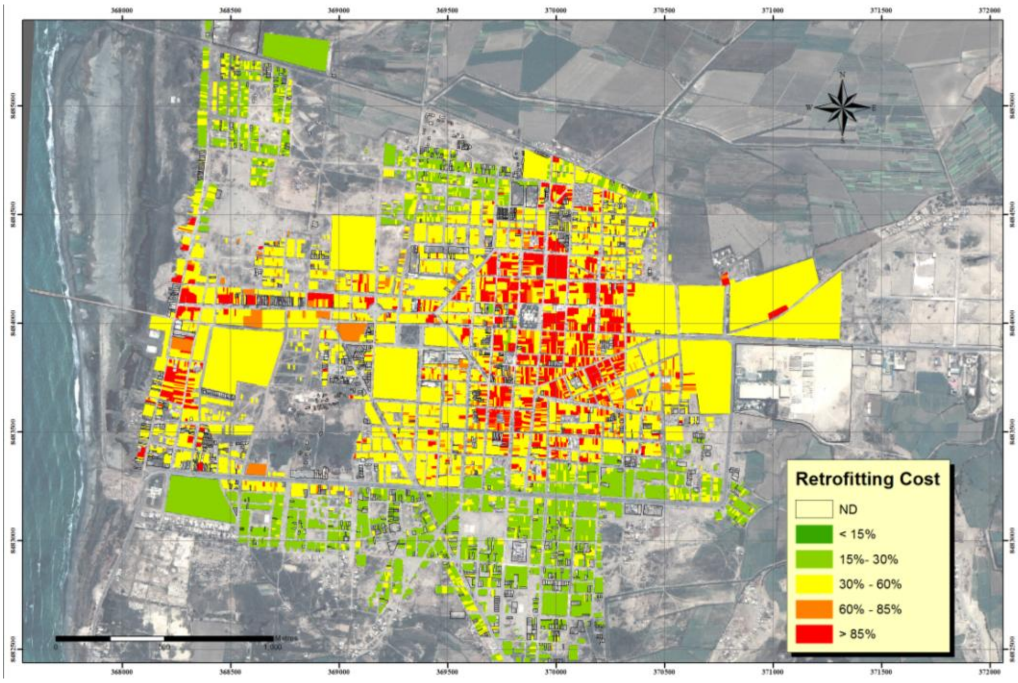

Figure 10: Seismic Risk in terms of retrofitting cost

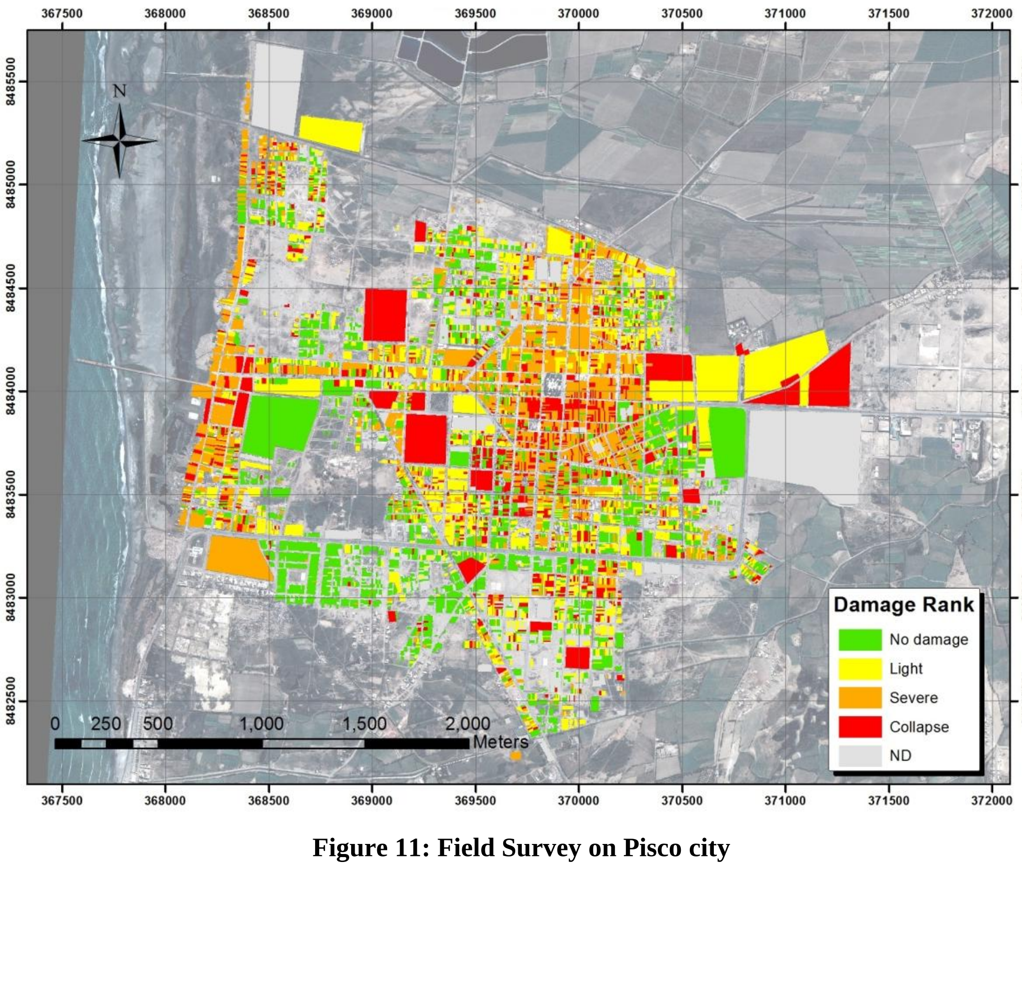

Figure 11: Field Survey on Pisco city

4. CONCLUSIONS

- Lima city is bigger city in Peru and since 1974 does not experience am strong quake. Therefore strong earthquake is expected and the worried is increasing among researchers. However we need to open the eyes of the decision makers and politicians in order they considering measures for reduces the seismic risk in the dangerous zones of the city.

- A simplified procedure has been presented in this paper for evaluate the seismic risk in terms of retrofit cost of housing unit. This process introduce the use of damage functions for each socio economical level, to improve the results of the diagnosis. This functions has been calibrated with the survey results of Pisco quake 2007 presented by Zavala (2010).

- The application of the damage functions were executed on six districts of Lima city on the PGT-CISMID project and Japan Peru SATREPS project has been consider on the development of an update risk analysis of Lima city. Improve of the results has been presented and given trust for the simulation scheme.

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