THE SEISMIC PREVENTION AS A CONTINUOUS PROJECT OF URBAN DEVELOPMENT, SAN JUAN CITY, ARGENTINE

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SUMMARY

San Juan City is located in the zone of highest seismic risk of Argentine country. It was destroyed by an earthquake in 1944 (IX Intensity Mercalli Modified). It was rebuilt between the 50 and 60 decades.

This work is based on the environmental view of urban development interrelating the main conditionals of the natural subsystem with elements of the constructed subsystem.

The seism, as conditional of the natural support, apart from causing the loss of lives and goods, it may alter the development of the urban functions, if it is not part of measures and proposals of urban development. In turn, the constructed environment may have a positive or negative influence on the conditionals of the natural environment.

Within this frame, the investigation is methodologically developed on the basis of three parts with particular significance.

The first one consists in the elaboration of seismic risk maps that graphically make up the spatial location of probable effects for seisms, IX, VIII and VII intensity Mercalli Modified Scale.

In the second part, the vulnerability coefficient with respect to the parameters and indicators of the urban normative in force are analysed in detail, proposing the necessary corrections in order to reach what we call acceptable levels of vulnerability.

The last part relates to the proposals of urban intervention strategies which take shape on the basis of the two previous stages and which represent a valuable contribution considering that seismic prevention must constitute a continuous project for a harmonious urban development

INTRODUCTION

This work has been performed for San Juan City, situated in a mid-west arid region, in Argentine, in the oriental border of the Andes Mountains. It constitutes the area of highest seismic activity in the country, as it is shown with the several destructive earthquakes that have affected it in the last 100 years. For example, the earthquake on January 15th, in 1944, caused 10. 000 deaths (10 % of the population at that time), it produced almost the whole destruction of the city and affected the integral structure of the province.

At that moment, the experience was useful to have the rebuilt city of our present time, which has a population of about 360.000 people, a housing patrimony of approximately 90.000 dwellings, from which 63% have been built under seismic resistant rules, as well as 100% of the institutional buildings. However, there is still a 37% non seismic-resistant dwelling which represent a relatively high percentage considering the seismic risk in this area.

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In cities with a high seismic risk like San Juan, **Prevention** must constitute a **Continuous Process** within an **Urban Project**, before the unresolved problem of **Prediction**, which allows to take action just in the field of **Prevention**, seeing this as a tool of mitigation. From the urban point of view, it means the consideration of the seism as an inevitable conditional of the natural environment, in the different planning and projection scales for a harmonious urban development.

PROJECT DEVELOPMENT

This work is methodologically ordered into three parts identified with the following **objectives:**

1- To make maps of probable effects of seismic risk from the urban area of San Juan considering intensity IX, VIII and VII, Mercalli Modified Scale.
2- To obtain "acceptable levels" of direct vulnerability for the different urban sectors.
3- To choose priority areas for the proposal of adequate strategies of urban intervention.

FIELD OF STUDY: urban area of Great San Juan: this area constitutes the Capital Department and the urban areas of Chimbas, Santa Lucia, Rawson and Rivadavia Departments.

UNITY OF ANALYSIS: the census Radius and Fractions of each Department from the urban area of Great San Juan was taken as a unity of analysis.

MAPS OF SEISMIC RISK

To design the maps, the following concept of reference has been used[i]:

" *Seismic Risk is the probability of occurrence and the relative grade of severity at a particular period of time, from the group of possible effects produced by an earthquake"*. It can also be interpreted as *"the probability of losses caused by the seismic action"*.

Seismic events do not have an impact in the whole extension of the urban area uniformly. For that reason, it is supposed that any type of building may suffer four states of damage[ii]:

Designation	State of Damage Description
D0	Without damage; slight damage on walls
D1	Damage in elements of partitions and others non-structural ones. Slight damage, reparable in structural elements
D2	Total loss of building, even when there is no collapse
D3	Total or partial ruin

The addition of damages D2 and D3 constitutes what is called irreparable **damages.**

To measure the **Risk** that the population of the different sectors of the urban area suffered, the group of effects which would produce a seismic event of intensity IX, VIII and VII Mercalli Modified Scale was quantitatively and qualitatively considered.
Maps for serious or irreparable damage in the constructions have been designed, for seisms of intensity IX, VIII and VII Mercalli Modified Scale, where the percentages of the affected housing with these types of damages are shown according to four ranks.

Rank 1 (Low) < 15% housing with irreparable damage.
Rank 2 (Middle) = 16% to 35% housing with irreparable damage.
Rank 3 (High) = 36% to 55% housing with irreparable damage.
Rank 4 (Very High) > 56% housing with irreparable damage.

In the maps that correspond to each intensity, the aforesaid ranks have been differentiated with distinctive colours. (Fig. 1)

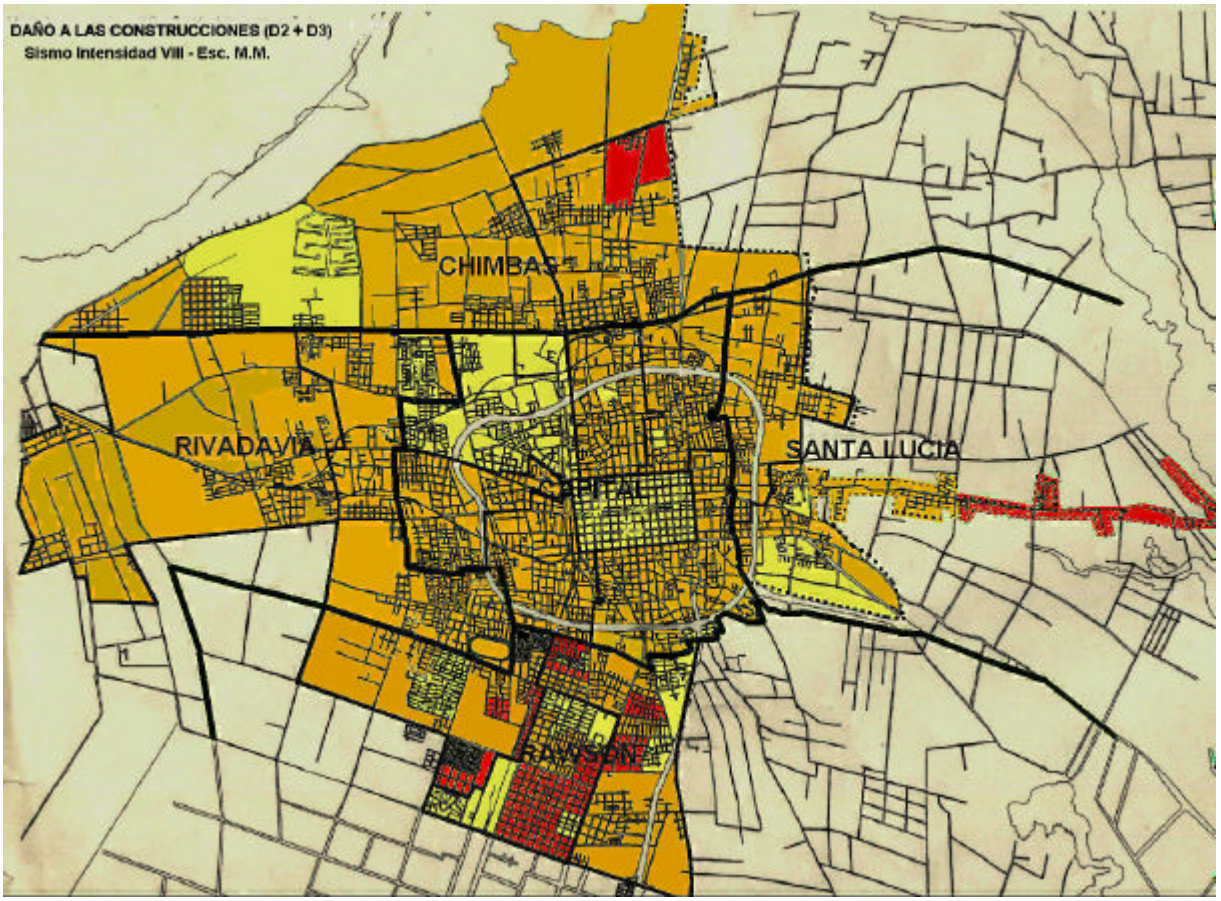

Fig. 1-Map of Seismic Risk – Intensity VIII. Mercalli Modified Scale

References: + 56% Irreparable Damage (D2 + D3) - 36% to 55% Irreparable Damage (D2+D3)

16% to 35% Irreparable Damage (D2 + D3) - - 15% Irreparable Damage (D2 + D3)

The maps of seismic risk show the serious and irreparable damage predicted in the constructions (housing), for seisms of intensity IX, VIII and VII, Mercalli Modified Scale.

- The maps of seismic risk are tools for the urban planning of seismic areas which allow to handle the city space, that is to say, the location of human settling, infrastructure, productive activities, measures for the city organisation before the seismic emergency. They constitute the graphic mould of the spatial location of probable risk effects for different seismic intensities. In spite of the fact that these risk maps have been built for San Juan City in Argentine, their methodological value allows its application in any urban centre with a high seismic potential.

DIRECT VULNERABILITY: PROPOSAL OF ACCEPTABLE LEVELS

Vulnerability is the tendency of people and goods, as well as activities that are carried out, to suffer from damage or modifications when seisms of considerable intensity take place. Within these concepts we discriminate:

Direct Vulnerability: which expresses the possible physical behaviour of the elements that are analysed. To construct its coefficient it was taken into account the population size, the constructive state of the respective superstructure and infrastructure elements.

Functional Vulnerability: which expresses the behaviour of the function of the elements which are analysed. To construct its coefficient the number of people is related with the activity they perform and with the number of hours of use from the adapted spaces where different activities take place.

Total Vulnerability: its coefficient conforms the addition of the two previous ones.

Coefficients were constructed to quantify the concepts by means of the hypothesis formulation that expresses multiple relationships among the elements to be analysed.

- It is necessary to point out that the concept of vulnerability is eminently a **concept of interrelations: Direct** vulnerability relates the population with physical elements from the internal structure of the city. On the other hand, the concept of **functional** vulnerability relates the population with its structure of **activities.**

Direct Vulnerability Matrix-Diagram

This matrix (Fig. 2) orders and systematises the analysis of each one of the urban sectors with relation to direct vulnerability, opening such analysis to each one of the component elements of the coefficient. Besides, the radius density is analysed categorising it into Low, Middle, High, Very high. It was useful to **put forward solutions** for the detected problems, **achieving levels of acceptable vulnerability.**

- Definition of Acceptable Levels of Vulnerability:

- It does not mean **to cancel** the vulnerability.
- It does not only mean **to reduce** the coefficient value.
- It is foreseen to achieve an **equilibrium** of the element conditions which conform the coefficient.
- It means a search for the equilibrium of such elements' interrelations.
- It contributes with elements for the definition of rules that constitute a previous stage to the determination of urban intervention strategies.
- The value of acceptable vulnerability **cannot be defined as a general and only value,** but it must be determined according to the characteristics of the analysed radius.
- The acceptable vulnerability must also involve:
- The compatibility with the maps of risk.
- **Acceptable Risk** for people and goods.

In this way, a classification of the proposals that represent rules for the layout of intervention strategies was obtained.

Matriz Vulnerabilidad Directa
Niveles Aceptables

DEPARTAMENTO RAWSON **FRACCION 2**

Radius	Ranks	Population	Nº Const.	% No SR	Direct Vuln.	Density
1	1					
	2					X
	3					
	4					
2	1					
	2					
	3					X
	4					
3	1					
	2					X
	3					
	4					
4	1					
	2					X
	3					
	4					
5	1					
	2					X
	3					
	4					
6	1					
	2					
	3					
	4					X

Fig. 2: Direct Vulnerability Matrix-Diagram - Department of Rawson - Fraction 2

References: Level of present vulnerability — Level of acceptable proposed vulnerability

Rank correction — Present density

The followed criteria for the proposal of adequacy of the vulnerability levels is:

- To maintain the vulnerability coefficient in low to middle levels.
- To maintain the percentage of non-seismic resistant housing in low to middle rank.
- To increase the housing number of the radius, as long as that does not raise the vulnerability level.
- To maintain the existent population number in the radius. However, this number will be a consequence of the raising, or not, of the proposed housing in the radius.
- When only the Non-S.R. housing percentage is modified, it means a replacing housing proposal in the same portion.

From the analysis of the direct vulnerability diagram, the proposal types which represent rules for the intervention strategies layout are inferred.

PRIORITY AREAS FOR THE IMPLEMENTATION OF URBAN INTERVENTION STRATEGIES

We call priority areas those urban sectors that present important grades of physical and/or functional damage in elements of its internal structure. Therefore, an intervention through the different stages is necessary, to revert such situation in short terms. The strategies should be part of a Plan with Policies and Strategic Programs to be implemented through a **Program of Environmental Urban Measure,** conceived as a **Process of Strategic Measure.**

The Seismic **Prevention** must constitute a **Continuous Process,** which considers as priority actions: the gradual eradication of sectors whose constructive quality represents serious dangers, in case of destructive seisms for the involved population and the foreseen equipped spaces to accommodate the victims. All this, within an **Urban Project**, where specific aspects are considered, such as, the extension of the urban plant and the density among others.

a) Selection of Priority Areas

For the area selection, what we determined by the seismic risk maps, taking into account the sectors with the highest percentage of irreparable damage probability has been considered. Thus, from the seismic risk map for intensity IX Mercalli Modified Scale, the sectors which present percentages of irreparable damage probability have been chosen, categorised as Very High and High.

Such sectors are located in consolidated areas of a very low constructive quality, with high percentages of non-seismic resistant housing, and in others located in border areas of the urban sector.

b) Determination and Layout of Urban Intervention Strategies

From the seismic risk maps and the vulnerability diagram arise the following proposals:

- **Construction and population densification:** searching an equilibrium with the tendency to the expansion of the urban area that poses the threat of seisms, and taking care that there must be a free space within the field as a condition of seismic security.

- **Replacement of non-seismic resistant housing:** The replacement must be foreseen, if possible in the same portion. Because there is no important quantitative and deficit but there is a qualitative one, and as a way of avoiding the population uprooting from their own environment.

- **Recovery of interstitial and free areas:** with an adequate improvement for the seismic emergency and besides for its ordinary use.

Finally, 5 strategy types were obtained from these proposals:

STRATEGIES CLASSIFICATION

Rehabilitation	**Recovery by recycling of the housing with any grade of precariousness to cover qualitative deficit.**
Renovation	Action that replaces housing whose damage grade makes its recovery impossible.
Densification	Occupation for the construction of new housing to raise levels of construction and population density.
Retention of the urban limit	Control of the limits of the urban area
Urbanisation and occupation of free areas	Action which consolidates the urban sector through the occupation of interstitial spaces.

To define the strategy to use for each of the radius, the diagram from the direct vulnerability matrix was considered, as well as the plan of free areas of more than 2.500m2 in the urban sector. On that basis, the type of proposed urban intervention strategy has been analysed, and for that, files for each one of the selected radius have been made.

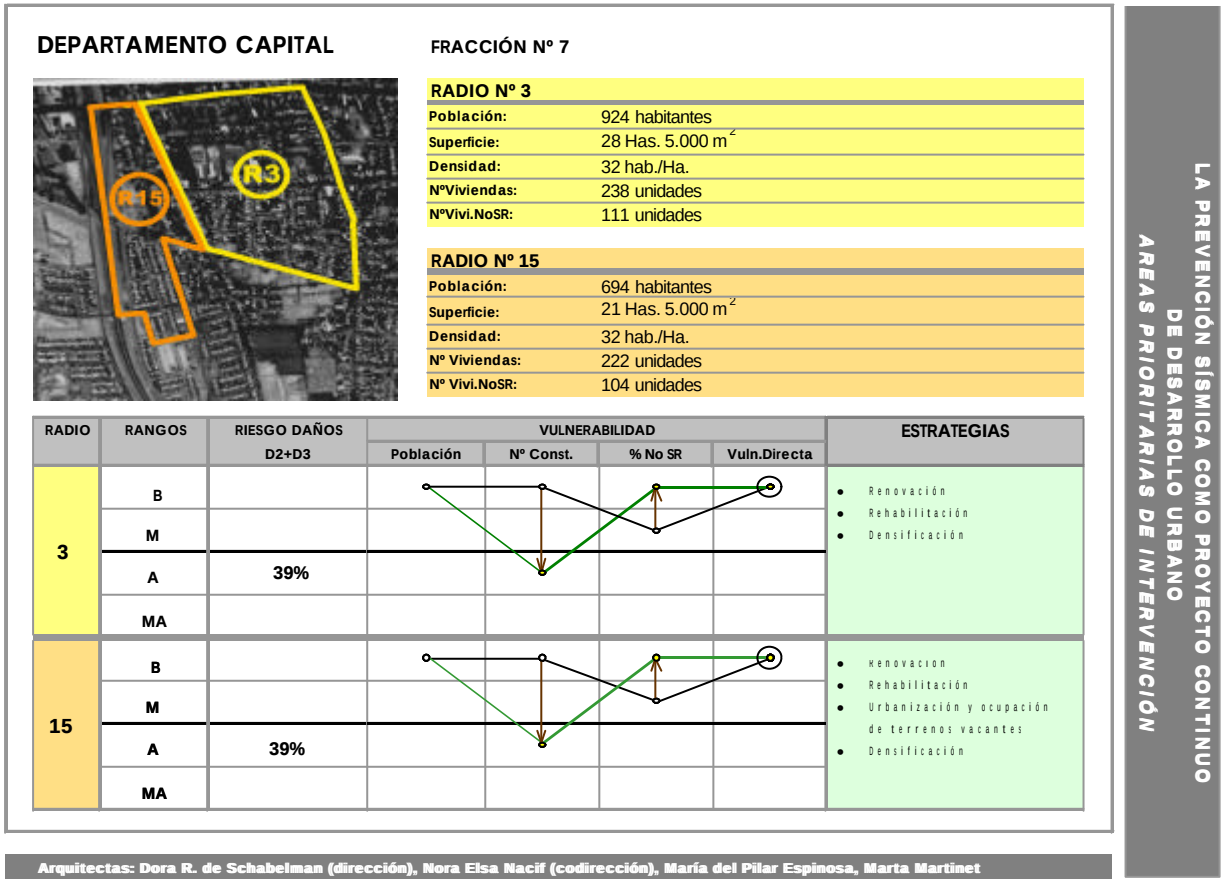

Fig.3: **File Model**

- The layout and determination of strategies is an analysis of each sector that indicates the most adequate urban intervention for the global situation in the area, in relation to the seismic problem.

- When the low constructive housing quality of the radius has been shown in the vulnerability diagram with a moving arrow indicating correction; this means that the replacing of Non-SR housing is necessary. This, in turn, involves two strategic options, " Renovation" and/or " Rehabilitation".

- From the analysis of the free areas of more than 2.500m^2, it is globally deduced that:

a) Most of the land of great dimensions is located in "border zones" in the urban sector. The strategy must tend to recover them as improved green spaces for the seismic emergency and to make a habitual use of them by the population. It functionally results in a green border of the urban sector, and it is the strategy so called " Retention of the urban limit".

b) When the free area is within the urban area, the chosen strategy has been the " Urbanisation and occupation of the free area". This does not only imply in every case a densification of the sector by means of the construction of new housing, but also includes the construction of public or semi-public spaces to foster cultural, recreation, sports activities or those ones which are considered more necessary in future particularised studies of each sector.

c) There is free land of important dimensions next to "Avenida de Circunvalacion", especially to the south. The strategies must encourage the housing construction together with the participation of the community of the area.

Finally, we can say that this work is based on a set of proposals for the seismic prevention for different sectors of San Juan City, but with an urban influence which is necessary to take advantage of and develop as a continuous project of urban development.

[1][Roitman, Dora and others. Year 1994. ***"Ciudad y Sismo. Area Urbana Gran San Juan"*** and Year 1996. ***"Probables Efectos del Riesgo Sismicos Provocados por Movimientos de Intensidad VIII y VII Esc. M.M.".*** Proyectos de Investigacion de GIUR, FAUD, UNSJ.]

[1] [This consideration was taken from the report: Grases, Jose. July 1990. ***"Notas para la estimacion de requerimientos hospitalarios en Areas Urbanas que pueden ser afectadas por sismos intensos",*** Central University of Venezuela presented in the Seminar: "Desastres Sismicos en Grandes Ciudades". Bogota-Colombia.]