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Collaborative Mapping for the Assessment of Seismic Vulnerability and Urban Resilience in Valdivia (Chile) †

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Abstract: The present work is part of the resilience study of urban areas, where the study area is the urban center of Valdivia (Chile). The aim is to catalog and identify buildings and urban blocks for the subsequent evaluation of exposure and vulnerability to seismic risk. This is done through a collaborative mapping with the participation of a local team of volunteers (of the Technological University of Chile INACAP) that was previously trained on vulnerability issues and OpenStreetMap platform. The study area comprises 83 urban blocks. Each urban block is subdivided into parcels, which contain buildings with different type of construction and different uses. In the future, this research will continue with the development of urban resilience indexes at physical and social scales.

Keywords: seismic risk; collaborative mapping; resilience; urban resilience

1. Introduction

The city of Valdivia (Chile) is inside an area of high seismic risk, where the largest magnitude earthquake (9.5 Mw) registered instrumentally occurred in 1960, causing a natural disaster of great proportions. The conditions of exposure in these last 60 years have undergone changes [1], where the development of seismic and urban regulations involve greater capabilities when facing and recovering the system in the event of an emergency or disaster. However, the importance of studies related to exposure and vulnerability with up-to-date data, both physical and social, are required for an integral risk and to develop greater capacities contributing to reduce vulnerability to a natural threat such as earthquakes [2].

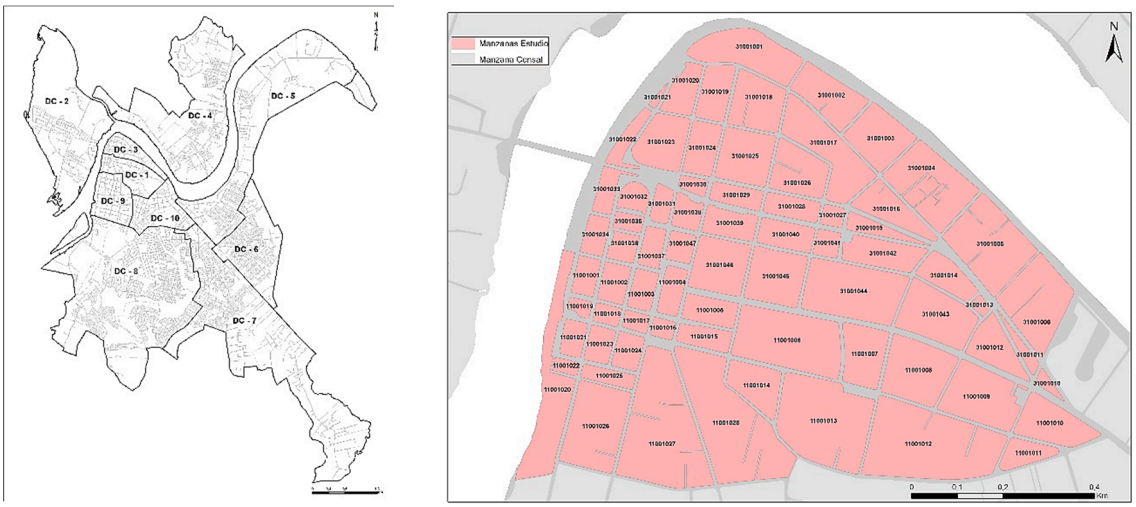
In the framework of the research on resilient urban societies, a field survey was done with the collaboration between researchers, teachers, and students of the Technical University of Madrid and INACAP Valdivia. The main objective was to recognize the city and capture physical information in the survey at two scales: census tract and urban parcel. The study area, the center of Valdivia, was selected according to its constructive heterogeneity where data related to urban modifiers [3] were taken, which will serve as a basis for the calculation of vulnerability indexes.

2. Study Area

The study area corresponds to the Census Districts (DC) 1 and 3, according to the administrative division of the National Institute of Statistics (INE). The DCs of the study area contains a total of 83 census urban blocks (MZ), of which 72 MZ were mapped. According to the configuration and coding of the INE, each parcel contains a unique identification code, which was taken as a reference for the

preparation and processing of a Database (BD). Each MZ is subdivided into parcel that were used to quantify, initially, the number of approximate buildings in each MZ with the objective of planning the field work to be carried out in Valdivia (Figure 1). The buildings finally analyzed and introduced in the BD to those observed in the field, which correspond to different uses (residential, commercial, mixed, etc.).

As for residential buildings and according to INE data (Census, 2017), the total number of dwellings within the study area is 1.257, divided between private and collective homes, and the total resident population is 2.835 inhabitants.



(**a**) (**b**)

Figure 1. (**a**) Administrative division according to the National Institute of Statistics of Chile (INE) [4]; (**b**) Urban blocks contained within the study area [4].

3. Phases

The work and development in the field data collection (Figure 2) were developed in the following stages:

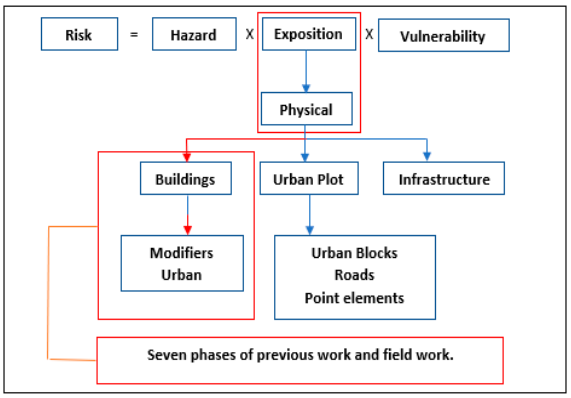


Figure 2. Phases of the study. Source: Own elaboration

1. Office work to identify constructive typologies, urban modifiers (building typology, occupancy type, number of floors, different height, soft storeys, soft column and irregular elevation) and urban plot characterization, including data analysis of the 2017 Census; 2. Collaborative mapping workshop with OpenStreetMap platform carried out at the ETSI in Topography, Geodesy, and Cartography (UPM); 3. Validation of previous analysis, with satellite images of the Open Street Map platform and virtual roads with Street View; 3. Detection of data not available at two scales: building (annexes or informal constructions and non-structural components) and urban plot (elements that determine the flow of people and vehicles). Design and planning of field work, through segmentation of the city in

a group of blocks and making cards to solve the lack of data. 4. Induction to concepts of exposure and vulnerability to a team of volunteers in the Engineering career in Risk Prevention, Quality and Environment (INACAP Valdivia); 5. Validation of data obtained in the field work through virtual roads with Street View and satellite photos; 6. Preparation of final database; 7. Preliminary results.

4. Results and Analysis

The results of the field work and the analysis of the obtained data are presented in this section.

4.1. Real Estate Park

The data collection was obtained observing the main building, without considering possible buildings or structures that could not be observed. The observed real estate park (Figure 3) corresponds to 980 buildings. The largest number of buildings identified in the study area corresponds to residential use (430 buildings), followed by commercial use (295 buildings). However, mixed-use buildings (66 buildings) where the main variable is residential, indicates a low proportion of buildings compared to the total (955 buildings) intended to contain private homes.

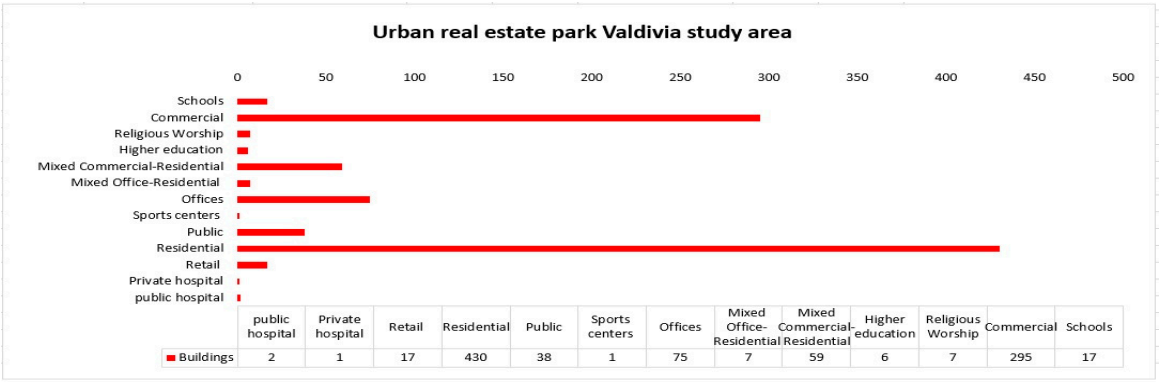


Figure 3. Uses of the real estate park within the study area. Source: Own elaboration.

4.2. Urban Modifiers

4.2.1. Building Typology, Number of Floors and Different Height

The largest number of buildings (597) correspond to isolated structures, which are contained in a single parcel (Figure 4a).

Most of these structures correspond to isolated, 1- to 2-floor (Figure 4b), single-family houses. Other types include: 1. Adjacent buildings (165), corresponding to buildings contained in two adjacent parcels that share the same building structure; 2. The buildings between partition wall (77), corresponding to buildings that may be within the same property or adjoining property, separated by dividing but not necessarily share the same building structure.

There is a greater number of buildings (675) corresponding to detached single-family homes, paired, grouped in a row or between partition walls; with maximum heights of 2 floors. Buildings (198) with heights between 3 and 5 floors are distributed among private homes (lesser extent considering the use of the building), and buildings for commerce or offices. Buildings with heights greater than 6 floors (22) are less frequent within the study area. These buildings correspond to recent constructions, in areas with a greater population density for residential use and, to a lesser extent, for commerce or offices. The height difference greater than 2 floors is not a recurring factor in the study area and in general in the urban structure of the city (Figure 4c). Of all the buildings analyzed, only 10% (86 buildings) present this characteristic.

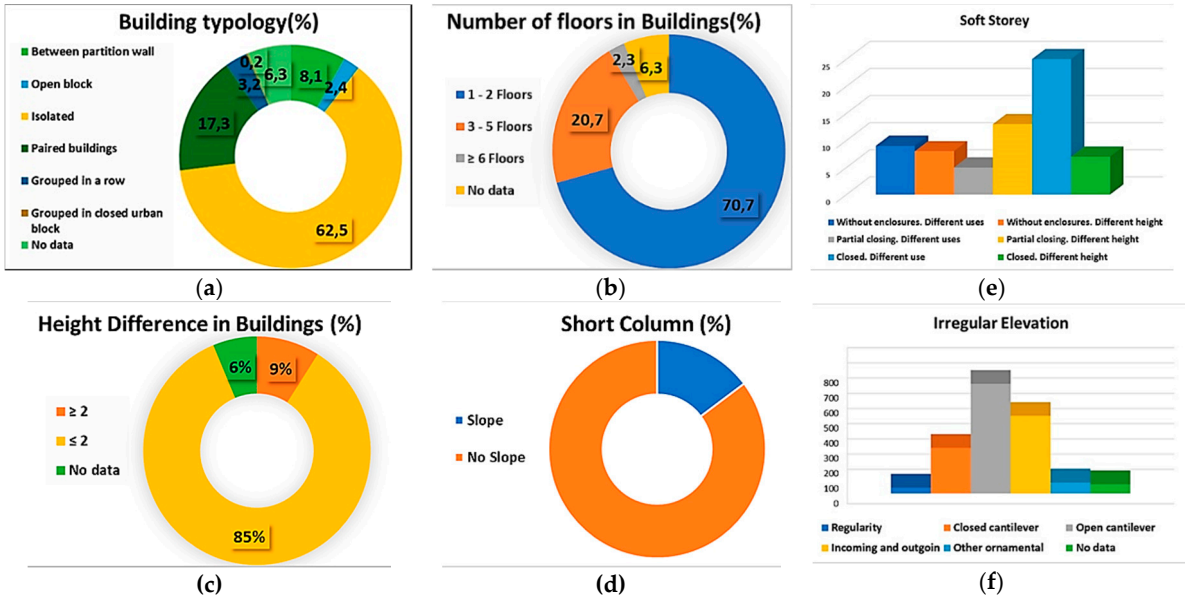


Figure 4. (**a**) Building typologies within the study area; (**b**) Building floors within the study area; (**c**) Height differences within study area; (**d**) Short column within the study area; (**e**) Soft storeys within study area; (**f**) Irregular elevation of buildings within the study area. Source: Own elaboration.

4.2.2. Short Column, Soft Storey and Irregular Elevation

Sloping buildings (141), is a common feature in stretches of roads with access to the riverbank Calle-Calle, which surrounds a large part of the downtown sector of the city ((Figure 4d). The buildings identified with the soft floor (67), mostly correspond to structures intended for different use in the plant, where most of them have plant heights different from the rest (Figure 4e).

Buildings with irregular elevation (1662) are characteristic within the study area, with less recurrent buildings (38) with regular facades (Figure 4f). Buildings with irregularity in elevation stand out as compared to those with open or closed cantilever. Open cantilevers (more characteristic in Valdivia) are structures configured on the first floor, whose extensions are horizontal or slightly inclined, supported by the exterior wall. Its use is quite widespread due to the climatic characteristics, intense rains during a great part of the year, in Valdivia. Buildings with inward features and salients are quite recurrent (510), mainly in buildings with 2 floors. Higher buildings are mostly homogeneous in elevation.

5. Conclusions and Future Lines

The results obtained represent an advance of the investigation. The heterogeneity of buildings contained in the study area is verified, which present different constructive configurations related to urban modifiers and uses. It emphasizes the low density of population in the zone, constructions mainly of 1 and 2 plants and little amount of tall buildings. The preliminary results give a general view, according to the physical exposure of the study area to earthquakes. The collected data are of great importance for the subsequent calculation of vulnerability indexes.

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References

1. Espinoza, D.; Zumelzu, S.; Burgos, R. *Transformaciones espaciales en ciudades intermedias: el caso de Valdivia Chile y su evolución post-terremoto*; Arquitectura y Urbanismo: 2016; Volume XXXVII, ISSN 1815-5898. Instituto Superior Politécnico José Antonio Echeverría, Ciudad de La Habana, Cuba.
2. Carreño, M.L.; Cardona, O.D.; Barbat, A.H. Urban Seismic Risk Evaluation: A Holistic Approach. *Nat. Hazards* **2006**, *40*, 1–38. doi:10.1007/s11069-006-0008-8.
3. Martínez-Cuevas, S.; Benito, M.B.; Cervera, J.; Morillo, M.C.; Luna, M. Urban modifiers of seismic vulnerability aimed at Urban Zoning Regulations. *Bull. Earthq. Eng* **2017**, *15*, 4719. doi:10.1007/s10518-017-0162-2.
4. Instituto Nacional de Estadisticas de Chile; Censo 2017. Available online: https://www.censo2017.cl/ (accessed on 4 January 2019).