Recibido: 06-12-2020
Aceptado: 25-04-2021

RESILIENT URBAN DESIGN IN THE FOOTHILLS OF SANTIAGO?

CONTRAST OF COMMUNAL SCENARIOS WITH SEISMIC RISK DUE TO THE SAN RAMÓN FAULT[1]

¿DISEÑO URBANO RESILIENTE EN EL PIEDEMONTE DE SANTIAGO? CONTRASTE DE ESCENARIOS COMUNALES CON RIESGO SÍSMICO FRENTE A LA FALLA SAN RAMÓN

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1 This article has the support of the project, Fondecyt Regular N°1190734 "¿Planificación urbana en riesgo? Prácticas socio espaciales de comunidades en el piedemonte de Santiago, Chile y su incidencia en la Falla de San Ramón (FSR) como nuevo escenario de riesgo sísmico y sostenibilidad", financed by the National Research and Development Agency (ANID), Chile.

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DOI: https://doi.org/10.22320/07183607.2021.24.43.09

Santiago ha experimentado en sus últimas décadas un aumento considerable de áreas urbanizadas en el piedemonte de su borde oriente, donde además se localiza la Falla San Ramón (FSR), de modo que se ha vuelto un nuevo escenario de riesgo geológico. Usando incuestionables atractivos sobre el medio natural, la vista panorámica a la ciudad y un ambiente saludable, se han promocionado proyectos de vivienda de alto costo que conviven con este riesgo sísmico, pero que parecen desestimarlo desde los instrumentos de planificación de nivel comunal y metropolitano. El presente artículo tiene por objetivo explorar las condiciones de diseño urbano que presenta el piedemonte de Santiago para enfrentar la presencia de la Falla San Ramón (FSR), mediante un análisis de contraste de dos sectores específicos localizados dentro de la franja de potencial ruptura superficial (buffer) de la FSR -distrito urbano Hospital de Carabineros en Las Condes y distrito urbano El Peral en Puente Alto- y su forma de articularse con el medio natural y con el medio construido, incluyendo la presencia de infraestructura crítica. Metodológicamente, se aplica un enfoque mixto a través de una matriz de análisis de elementos de diseño urbano que incluye tres ámbitos de acción -construido, natural y normativo- para identificar situaciones críticas de los sectores estudiados, donde se ve elevada o disminuida la respuesta resiliente. Se concluye que contrastar experiencias de diseño urbano en condiciones extremas respecto al riesgo sísmico es ilustrativo, tanto para permear las capas operativas de gestión de riesgo, como normativas comunales y metropolitanas, como para asumir el piedemonte de manera resiliente, reconociendo la Falla San Ramón como un nuevo criterio basal de diseño urbano.

Palabras clave: diseño urbano, resiliencia, riesgo sísmico, Falla San Ramón.

In recent decades, Santiago has seen a substantial increase in urbanized areas along its eastern foothills, where the San Ramón Fault (FSR) is also located. This has become a new geological risk scenario. Using the unquestionable appeal of the natural setting, the panoramic view of the city, and a healthy environment, luxury housing projects have been promoted that coexist with this seismic risk, something that seems to have been disregarded by communal and metropolitan planning instruments. The purpose of this article is to explore the urban design conditions on Santiago's foothills to face the San Ramon Fault, through a contrast analysis of two specific sectors located within the potential buffer of the San Ramón Fault - the urban districts of Hospital de Carabineros in Las Condes and El Peral in Puente Alto - and the way these articulate with the natural and built environments, including critical infrastructure. Methodologically speaking, a mixed approach is applied through an analysis matrix of urban design elements that includes three areas of action - built, natural and regulatory - to identify critical situations in the areas studied, where the resilient response is either high or low. It is concluded that contrasting urban design experiences under extreme conditions regarding seismic risk is illustrative, both for permeating the operational layers of risk management such as communal and metropolitan regulations, and to consider the foothills in a resilient way, recognizing the San Ramón Fault as a new base criterion of urban design.

Keywords: urban design, resilience, seismic risk, San Ramon Fault

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PÁG. 96 - 107
ISSN 0717 - 3997 / 0718 - 3607

I. INTRODUCTION

According to a 2014 ranking prepared by the United Nations University (UNU, 2014), Chile is among the top 10 countries for natural threats, and because of this, "its consequences appear in dimensions and on scales that impact the entire society and affect the country's development" (National Development Innovation Council [CNID], 2016, p.1). The great impact Chile endured as a result of the tsunami caused by 8.8 Mw earthquake in 2010, is an example of this (Vargas et al., 2011), and demands revising how to plan and live in our cities, with their relationship with the coastline, central valley, and mountain ranges, being among the most important areas in this sense.

In particular, Santiago in recent decades has seen a considerable increase of urbanized areas in the foothills along its eastern border, where the San Ramón Fault is located. Nowadays, quality scientific knowledge has been gathered about the San Ramón Fault that allows warning about its geological danger and risk (Easton, Inzulza, Pérez, Ejsmentewicz & Jiménez, 2018). However, luxury housing projects have been promoted, which appeal to the unquestionable attraction of the natural environment, the panoramic view of the city, and a healthy landscape, and coexist alongside this seismic risk. This though seems to have been overlooked in the planning instruments at a communal and metropolitan level.

The purpose of this article is exploring the urban design conditions that Santiago's foothills have, to counter the risk of the San Ramón Fault (SRF), by comparing two specific sectors located within the potential buffer zone of the SRF, - the Hospital de Carabineros urban district in Las Condes and the El Peral urban district in Puente Alto -, and their way of articulating with the natural and built environment, including the presence of critical infrastructure.

The article is divided into 5 parts. First, a theoretical framework is presented with the key concepts of resilient urban design and its connection to the built and natural environment. Then the proposed methodology, comprising an analysis matrix of urban design elements that includes three areas of action -built, natural and regulatory- is explained, which are then applied in the third section, along with the identification of critical situations. The results identify two at risk sectors of the communes of Las Condes and Puente Alto, which are compared to understand how the resilience response increases or decreases on facing this type of seismic risk. Finally, conclusions are provided about the importance of acknowledging the San Ramón Fault in urban regulations, and its incorporation as a new base criterion for urban design.

II. THEORETICAL FRAMEWORK

Resilient urban design in inhabited areas of the 21st century

A resilient city is one that is "capable of resisting and quickly recovering from human, social, and environmental risks, minimizing the impact and vulnerability of its citizens" (UN-HABITAT, 2018). Urbanism and resilience have become ever closer to each other as the years have gone by. Urbanism, on one hand, seeks its pragmatic side through urban design and, prior to this, in civic design, while resilience has been transformed in the performance of urban reconstruction and transformation strategies of recent decades, not just to face post-disaster events anymore, but also as a means of permanent action that is transferred to their communities.

This form of resilient action can be found in most international and domestic agreements on strategic urban development and sustainability. The 2016 New Urban Agenda points to the premise of strengthening resilience in cities to reduce the risk and impact of disasters as a priority action (United Nations, 2017), also defining six key concepts to promote in urban development: namely a compact, inclusive, participative, resilient, safe and sustainable city. These concepts are also linked with what was expressed in the new 2030 Agenda for Sustainable Development from 2017 in a broad sense and, in particular, with what was outlined in its ninth goal that seeks "to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation" (United Nations, 2018, p. 43).

Chile's National Urban Development Policy of 2014 establishes twelve basic notions to achieve sustainable cities and quality of life, where resilience plays a central role. Among those outlined to reach environmental balance, it states "considering natural systems as an essential backbone in the planning and design of interventions in the region" (Ministry of Housing and Urbanism [MINVU], 2014, p. 47). Likewise, the recently launched National Policy for Disaster Risk Reduction, outlined in five priority lines, contributes with a differentiated view about the country, with the third, "Planning and investing in disaster risk reduction for the sake of resilience", standing out (National Emergency Office [ONEMI], 2020, p. 37).

In this way, it is possible to predict that urban development and resilience to foster a sustainable quality of life, are clearly merged in the official agendas, with a systemic view of the regions at risk that, at the same time, show a high vulnerability today.

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Units of analysis	Concepts / conditioning factors	Elements / components
Built Aspect	Civility / Urbanity	Community. Collective and public spaces.
	Character / Beauty	Landscape. Building..
Natural Aspect	Sustainability / Harmony	Geology. Geomorphology. Risks. Fluvial networks. Forest systems.
Interface Aspect	Fluency / Legibility	Urban signs. Public spaces. Mobility networks.
Regulatory Aspect	Diversity	Density. Regulatory. Manuals.
	Profitability	Investment plan. Execution. Feasibility.
	Adaptability / Flexibility	Impact assessment. Projection.

Table 1. Units of analysis, concepts, and components of the inhabited region. Source: Preparation by authors based on EP&HC (2007).

The natural, built and regulatory scenario, as a sphere of action

Urban design can build a suitable response strategy for city and town reconstruction, if its core concepts and development stages are considered when building neighborhoods, including the civic attitude of their residents and their cultural practices or assets (Moser, Sou & Stein, 2011). In this line, the "Urban Design Compendium" of the United Kingdom allows obtaining a summary of key actions that should be incorporated in all urban recovery proposals, like promoting spaces for people; integrating the natural and built landscape; providing the urban shape and its mixed uses; managing the investment and production; and designing to provoke changes (English Partnerships & Housing Corporation [EP&HC]. 2007). In a broader overview of these actions, Table 1 connects the analysis units with the classic civic and urban design concepts and elements, to take on a resilient attitude in the inhabited landscape and, from there, to address the foothill region, focus of this research.

Concepts like civility and beauty are key to understanding the built environment of inhabited areas, with respect to communities and the relationship with their collective spaces and ways of living expressed in residential morphology and typology. The effects and the projection that new housing typologies or intercommunal scale facilities generate within a residential unit must be measured (Allan & Bryant, 2011). Meanwhile, the natural environment brings together as a key conditioning factor, the sustainability and harmony of the landscape, including the types of risks, as well as the fluvial and forest systems that ultimately, constitute design elements of the landscape. The "intermediate" or interface space is located within these environments, linking the natural environment with the built one, like Santiago's foothills. These have been transformed into a challenging area given the presence of a potential buffer of the San Ramón Fault, associated to large inhabited sectors and critical urban infrastructure.

As can be seen, an adequate articulation between natural and built environment, by means of fluency between these aspects, will guarantee the best performance of systems that are sought to be reconfigured, regenerated or rebuilt and, as a result, a suitable understanding of the area.

Finally, the regulatory aspect defines the diversity and profitability of a master plan or another type of regulatory planning tool, which can to be adapted in time. It is in this way, that it is crucial to incorporate the components of the inhabited area that arise from urban design in every urban development plan proposed that seeks to recover or renew cities and inhabited areas in a sustainable way. So, a "resilient urban design" is required as an articulator or interface aspect between built and natural environments that includes the relationships of people and their places; their mobility and the urban form; nature; and of course, the development of suitable public spaces from the point of view of their use, maintenance and the balance with their immediate surroundings (Moughtin, 1999).

III. CASE STUDY

The San Ramón fault as a seismic risk in the Santiago foothills

The San Ramón Fault is located along the foothills of the Los Andes Mountain Range in Santiago, the capital of Chile and its Metropolitan Region (Metropolitan Ministerial Secretariat of Housing and Urbanism [SEREMI-MINVU], 2012b). The fault has been surveyed on the surface, specifically between 33°19' and 33°37' latitude south (Figure 1). Geologically speaking, the San

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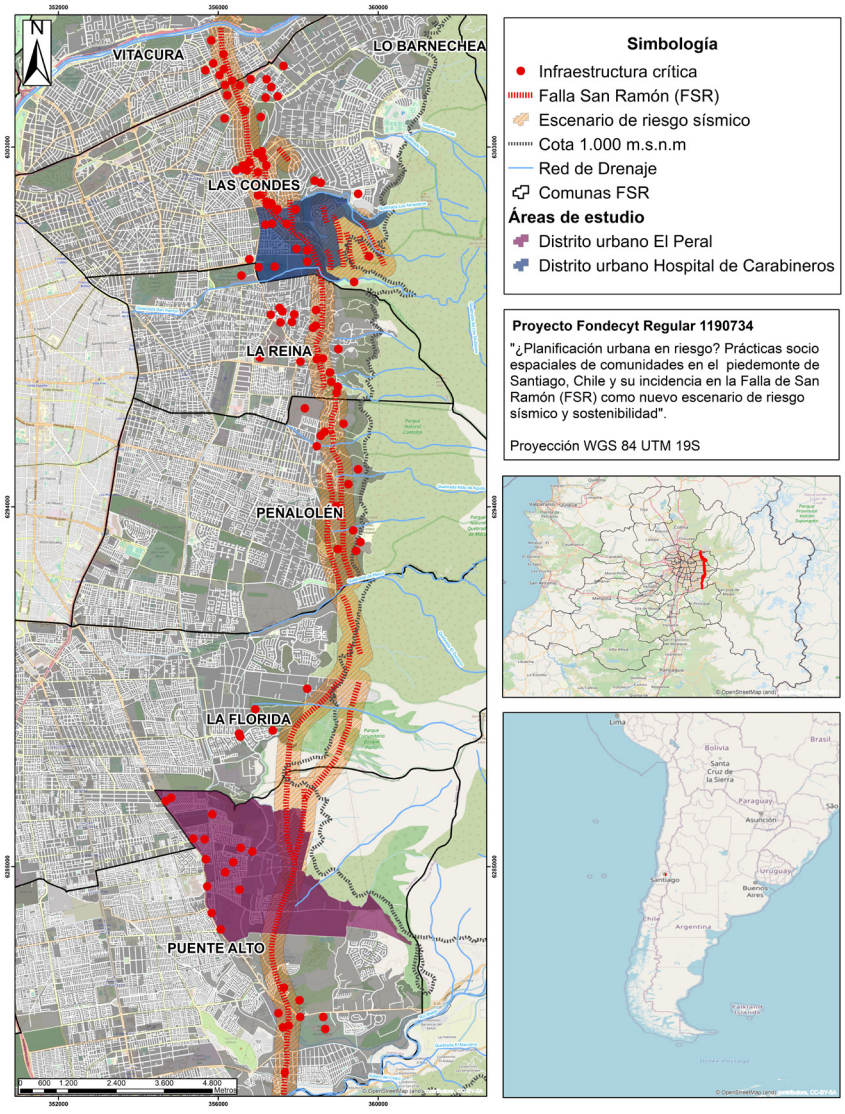

Figure 1. San Ramón Fault and the urban districts under study. Source: Preparation by the Authors based on SEREMI-MINVU (2012a, p. 121), INE (2017) and Curihuinca (2020).

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Ramón Fault is a structure with reverse behavior, that mounts the rocks of the mountain face on the sediment of the central depression and that presents the possibility of generating an earthquake with a surface rupture.

The probability that the San Ramón Fault has of generating a major physical disaster in the Santiago foothills is conditioned by its surface rupture as a risk area, where its so-called 300-meter wide buffer is identified. This buffer, outlined as the seismic risk scenario in Figure 1, was determined based on the structural and morphological observations established in the "San Ramón Fault PRMS Modification and Risk Study. ID N° 640-27-LP10", and specifically graphed in the "Report Stage 2, Analysis of prospection and test results" (SEREMI MINVU, 2012). There it is indicated that, "considering the transversal length of the fault scarps shown in Armijo et al. (2010) and Rauld (2011), and given that the scarps show different degrees of erosion, that have made its morphology fall back, in this study a potential range of influence was considered associated to surface ruptures of the SRF of 300 m; 100 m towards the face of the fault (west); and 200 m facing behind it (east), for the purpose of evaluating the associated hazard" (p. 28).

Regarding its periodicity, Easton et al. (2018) clarify that "geological evidence has shown that the SRF is capable of

Communes	0 to14 años	15 to 64 años	65 and over	Total	%
Vitacura	2.191	6.971	1.488	10.650	7,0
Las Condes	10.967	41.859	8.132	60.958	40,0
La Reina	2.506	7.928	1.042	11.476	7,5
Peñalolén	4.559	13.373	965	18.897	12,4
La Florida	2.794	6.833	416	10.043	6,6
Puente Alto	11.640	27.136	1.508	40.284	26,4
Total	34.657	104.100	13.551	152.308	100,0
%	22,8	68,3	8,9	100,0	

Table 2. Population affected by the San Ramón Fault by age group in the census areas. Source: Preparation by the Authors based on INE – National Statistics Institute (2017) and Curihuinca (2020).

Analysis units	Concepts / Conditioning factors	Elements / Components	Resilience Indicators
Built Aspect	Civility Urbanity	Community	Total district population. Population density. Predominant socio-economic level.
Natural Aspect	Sustainability	Landscape risks	Maximum distance to the SRF potential buffer. Minimum distance of critical infrastructure to the SRF. Fluvial and forest systems.
Regulatory Aspect	Diversity	Density Investment Plan Execution Feasibility	Housing type Zoning or land use.
	Profitability		Overcrowding. Average assessed and commercial value.
	Adaptability	Impact assessment	Critical infrastructure.

Table 3. Resilient urban design analysis matrix for the San Ramón Fault (SRF) buffer. Source: Preparation by the Authors based on INE (2017); CNDU (2020); Curihuinca (2020).

accumulating tectonic stresses and producing, by itself, major earthquakes, with two large magnitude events (circa 7.2-7.5 Mw) having taken place in the last 17,000 years, the last around 8,000 years ago" (p. 4). Considering the recurrence of the SRF, the possibility of a new activation with surface rupture potential is estimated at around 3% within the next 100 years, an estimation made without statistical basis, but based on paleo-seismological and geological observations that evidence the active nature of this fault (Vargas et al., 2014; Easton et al., 2018).

Now, at a level of the direct area of affectation, and considering the figures of the 2017 Census based on the outlined census areas, there are six communes along the San Ramón Fault, namely Vitacura, Las Condes, La Reina, Peñalolén, La Florida, and Puente Alto, with an affected population of 152,308 people (Table 2), which represents 2.1% of the total population of the Metropolitan Region of Santiago (7,112,808 people), and 9.2% of the total population of the six aforementioned communes (1,649,630 people).

At a communal level, a dissimilar panorama is seen, where two communes have the highest number of people (101,242), representing 66.4% of the total population affected by the San Ramón Fault buffer. Las Condes, with 60,958 inhabitants, and Puente Alto, with 40,284, figures that represent 40.0% and 26.4%, respectively. In age terms, both communes, Las Condes and Puente Alto, show a similar population percentage of under 14s. However, they differ regarding the older age groups of between 15 and 64, and 65 and over, where Las Condes almost doubles the 15-64 group, with 41,858 inhabitants, compared to Puente Alto with 27,136.

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Analysis unit	Concepts/ conditioning factors	Elements/ Components	Resilient urban design		
			Resilience indicators	Hospital de Carabineros Urban District	El Peral Urban District
Built Aspect	Civility Urbanity	Community	Total district population	19,085 inhabitants	31,212 inhabitants
			Population density	4,438 Inhab/km^2	2,856 Inhab/km^2
			Predominant socioeconomic level[6]	D	C2
Natural Aspect	Sustainability	Risks	Maximum distance to SRF buffer	1.1 km	2.8 km
			Minimum distance of the critical infrastructure to the SRF buffer	30 meters	1.05 km

Table 4. Analysis matrix of Hospital de Carabineros (Las Condes) and El Peral (Puente Alto) urban districts. Source: Preparation by Authors based on INE (2017), Internal Revenue Service [SII, in Spanish] (2020), GOPLACEIT (2020) and Growth Form Knowledge [GfK] (2019).

IV. METHODOLOGY

This research considers a mixed approach with quantitative and qualitative methods gathered using an analysis matrix of the urban design elements that includes three areas of action -built, natural and regulatory- that allow identifying critical situations with inhabited sectors, where the resilience response increases or decreases on facing the seismic risk that the San Ramón Fault represents. This analysis matrix, presented as Table 3, also combines the concepts/ conditioning factors and the elements/components of the inhabited area of Table 1, as units of analysis, and adds urban quality of life and resilience indicators which have been chosen and reinterpreted from three main sources: 2017 Census (INE, 2017), Chile's National Urban Development Council (CNDU, 2020), and the collection of data taken from the Fondecyt Regular N° 1190734 project.

For the application of these resilience indicators, two specific sectors where there is a larger population affected by the buffer were chosen. These are represented by the communes of Las Condes and Puente Alto, and within them, by the urban districts, Hospital de Carabineros and El Peral, respectively, as shown above in Figure 1. In this sense, the research supposes as a base condition, the vulnerability of said urban districts on being located on an area of high risk of the San Ramón Fault being activated. In this way, these districts are analyzed from their socio-spatial compositions, using georeferenced planimetry with data from the 2017 Census (INE, 2017).

V. RESULTS & DISCUSSIONS

Comparison of two communal scenarios with seismic risk

Table 4 presents an analysis matrix that allows comparing two of the most demanded communal settings, selected as case studies.

Regarding the total population affected, the Hospital de Carabineros urban district has fewer inhabitants, 19,085, than the El Peral urban district with 31,212. However the former, located in Las Condes, is a sector with a high population density, 4,438 inhabitants per km^2, classified as socioeconomic group D. Meanwhile, the El Peral urban district in Puente Alto, is formed as a less dense area, but one which in recent years has seen an important real estate growth, dominated by the morphology of gated communities for the medium-high socioeconomic level (C2). On comparing this information with Table 2, regarding age groups[7], both sectors have a similar population percentage of the under 14s -18.4% for Hospital de Carabineros district, and 21.2% for

6 C2 and D are 2 of the 7 socioeconomic groups classified by the Chilean National Automotive Association (ANAC, in Spanish) and the Market Researchers Association (AIM, in Spanish), based on national public statistics. Available at https://www.anda.cl/wp-content/uploads/2019/05/GfK_GSE_190502_FINAL.pdf.

7 It is important to state that the available data of the age groups from the 2017 Census has a partial coverage for both districts, with 0.9% and 3.1% of the age groups undetermined, for the Hospital de Carabineros and El Peral urban districts, respectively.

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Analysis Unit	Concepts / Conditioning Factors	Elements / Components	Resilient urban design		
			Resilience indicators	Hospital de Carabineros urban district	El Peral urban district
Regulatory Aspect	Diversity	Density Investment Plan Execution Feasibility	Type of housing	2,735 Houses 2,753 Apts. 134 Other	9,155 Houses 536 Apts. 44 Other
			Zoning or land use	Housing Commercial	Residential Facilities
	Profitability		Overcrowding	1.9	2.2
			Average assessed value	17,573 UF	1,700 UF
			Average commercial value	13,906 UF	4,796 UF
	Adaptability / Flexibility	Impact Assessment	Critical infrastructure	16 points Health Sports Worship Infrastructure Education	15 points Commercial Education Health

Table 5. Analysis matrix of the Hospital de Carabineros (Las Condes) and El Peral (Puente Alto) urban districts. Source: Preparation by Authors based on INE (2017), SII (2020) and GOPLACEIT (2020).

El Peral-, the data differs for the over 65s, where the Hospital de Carabineros district doubles that of El Peral, with 12.4% or 2,338 inhabitants, compared to 6.5% or 1,963 inhabitants. The situation shown, without a doubt affects the mobility conditions of the sectors involved, on facing an eventual evacuation generated by the activation of the San Ramón Fault.

At a risk level, it is north urban district of Hospital de Carabineros that lives, to a certain extent, with a higher seismic risk, on actually lying on top of the San Ramón Fault's buffer (1.1 km). Within this sector, there is an important road network with streets like Paul Harris and Vital Apoquindo that connect a large part of the "sloped" commune (see Figure 2, images of the urban surroundings). For the case of the southern urban district of El Peral, the highest risk from the buffer is located at a greater distance of 2.8 km from the most urbanized area, with the presence of Camilo Henríquez Ave. which intersects with Gabriela Oriente, El Peñón and El Peral, as crossroads for a possible evacuation (see Figure 3, images of the urban surroundings).

As for communal facilities, both urban districts have important intercommunal infrastructure, like the Carabineros Hospital (DIPRECA) in Las Condes, and the emblematic El Peral Psychiatric Hospital in Puente Alto. For the former, the Hospital is located 30 meters from the SRF buffer, while the El Peral Hospital is a little over a kilometer from it. This situation of great contrast and disparity is one of the essential elements that determine the resilience capacity of each urban district, with a lower articulation for the northern sector of Las Condes.

Resilient urban design from a regulatory point of view

Typologically speaking, the Hospital de Carabineros northern urban district comprises a similar number of homes and apartments, 2,735 and 2,753, respectively (Figure 2), while in the El Peral southern urban district houses outnumber apartments, 9,155 to 536 (Figure 3). The latter has an influence on the way this type of structure responds when facing a possible earthquake generated by the San Ramón Fault, being able to worsen the situation for the El Peral urban district, on considering both the higher number of dwellings -three times more than the Hospital de Carabineros urban district-, and the overcrowding factor that the southern urban district has compared to the northern sector one, 2.2 to 1.9. Both cases allow a mixed use, mainly represented by that of the houses or residential use, the commercial use -for the northern district- and that of facilities -southern district-.

In both districts under study, risk areas are identified from the Communal Zoning Plans (PRC, in Spanish) of Las Condes -modified by Decree 173/2010-, and Puente Alto -modified by Exempt Decree 423/2003-. However, most of these risks are associated to the type of landslide in the foothills' gorges. In particular, the local PRC ordinance of Las Condes does not outline in its zoning, areas restricted by natural risk, while

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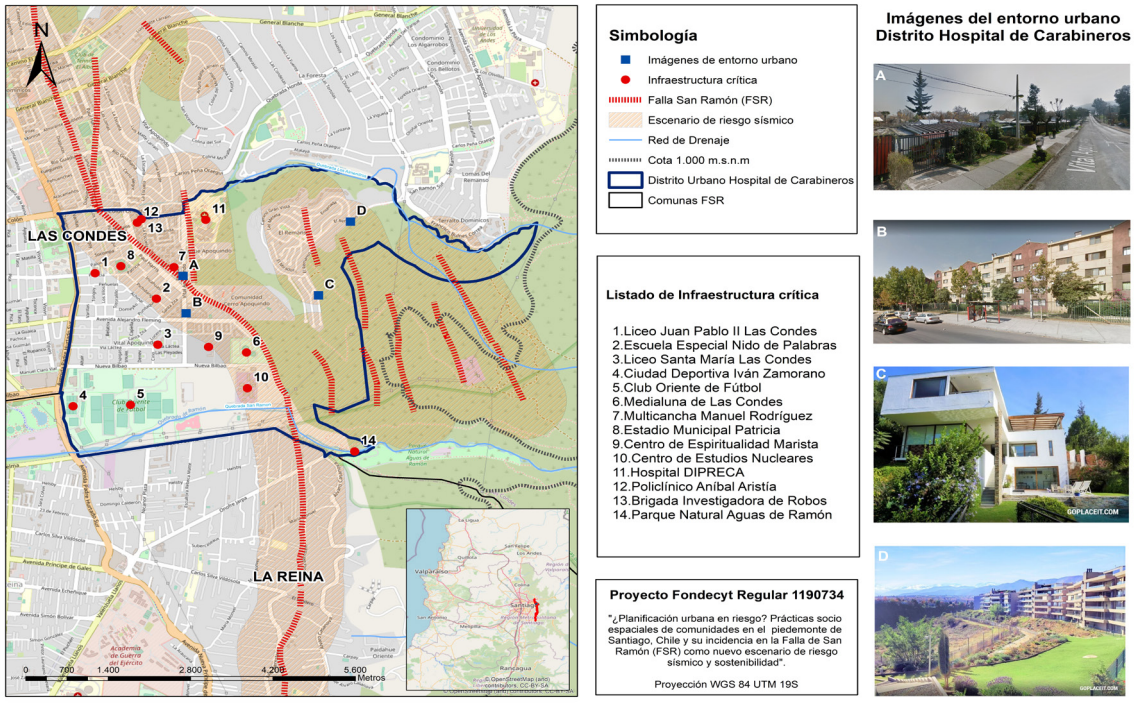

Figure 2. Hospital de Carabineros urban district, Las Condes.Source: Preparation by the Authors based on INE (2017), SII (2020), GOPLACEIT (2020), Google Maps, 2020 and Portalinmobiliario.com

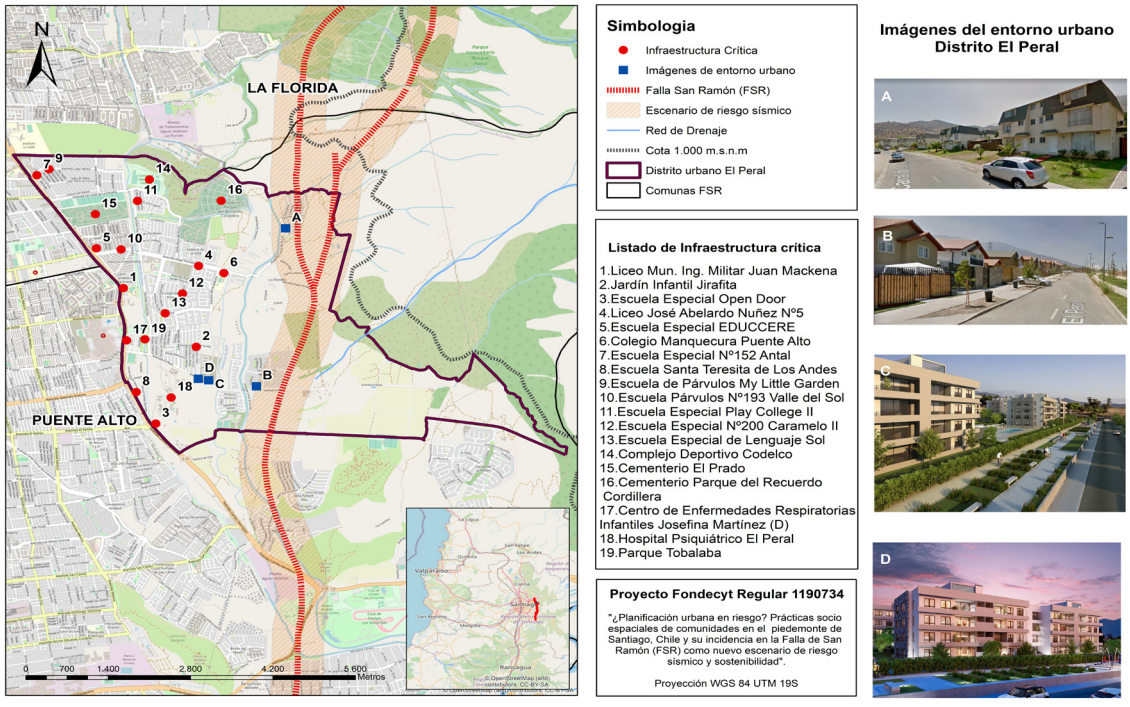

Figure 3. El Peral urban district, Puente Alto. Source: Preparation by the Authors based on INE (2017), SII (2020), GOPLACEIT (2020), Google Maps, 2020 and Portalinmobiliario.com

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REVISTA URBANO Nº 43 / MAYO 2021 - OCTUBRE 2021
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Critical Infrastructure	Hospital de Carabineros urban district, Las Condes		El Peral urban district, Puente Alto	
	Nº	Name	Nº	Name
Security	1	Theft Investigation Brigade	--	None
Healthcare	2	Anibal Aristia Polyclinic DIPRECA Hospital	2	Josefina Martínez Chile Respiratory Diseases Center (D) El Peral Psychiatric Hospital
Sports	5	Manual Rodríguez Sports Facility Iván Zamorano Sports Complex Club Oriente Football Club Las Condes Rodeo Grounds Patricia Municipal Stadium	1	Codelco Sports Complex
Worship	1	Marist Spirituality Center	--	None
Infrastructure	1	Nuclear Studies Center	2	El Prado Cemetery Parque del Recuerdo Cordillera Cemetery
Education	3	Juan Pablo II Las Condes Secondary School Nido de Palabras Special School Santa Maria Las Condes Secondary School	13	Manquecura Puente Alto School Antal Special School, N°152 My Little Garden Nursery Play College II Special School EDUCCERE Special School Valle del Sol Nursery, N°193 José Abelardo Nuñez N°5 Secondary School Ing. Militar Juan Mackenna Secondary School Caramelo II Special School N°200 Sol Special Language School Jirafita Nursery Santa Teresita de Los Andes Primary School Open Door Special School
Public Space	1	Aguas de Ramón Natural Park	1	Tobalaba Park

Table 6. Critical infrastructure in the Hospital de Carabineros and El Peral urban districts. Source: Preparation by authors based on photo-interpretation and onsite revision: Infrastructure of Geospatial Data of Chile [IDE] (2020), Ministry of Education [MINEDUC] (2020), DEIS (2020), CERET (2020) and GEORESEARCH (2020).

the local PRC ordinance of Puente Alto includes Article 40 with the Natural Origin Risk Zone from Flooding of Gorges and Artificial Watercourses, in accordance with Articles 8.2.1 and 8.2.1.1, and Zone "R2" of the Santiago Metropolitan Zoning Plan (PRMS, in Spanish). Despite this, a type of specific prohibition associated to seismic risk, and less still, associated to the San Ramón Fault, is not included in any of the analyzed sectors.

Now, in terms of land value, the Hospital de Carabineros urban district is comfortably higher in its average assessed (17,573 UF) and commercial value (13,906 UF) than the land of the El Peral urban district, whose average values are 1,700 UF (assessed) and 4,796 UF (commercial). This unequal land value situation is offset somewhat when the types of dwellings that are currently seen offered in the El Peral urban district (Figure 3C and 3D) are revised. According to the data found on the website www.goplaceit.com and on https://www.inmobiliariafg.cl/, it is possible to see "gated community" type complexes, like for example, Condominio Las Camelias, with different single-family housing models, whose sale prices fluctuate between 5,000 and 8,000 Units of Foment (UF). This situation is interesting to analyze, considering that within the Hospital de Carabineros northern urban district, an apartment type dwelling can be found that costs from 2,307 UF, and a detached house of 27,800 UF (Figure 2C)**8**

With regard to critical infrastructure, Table 6 presents the detail of the facilities for security, healthcare, sport, worship, infrastructure, education, and public space, for both sectors. It is seen there that the Hospital de Carabineros urban district has more of these in the San Ramón Fault buffer. Among this critical infrastructure, the presence of the Nuclear Studies Center is particularly concerning, given its energy

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nature, whose equipment increases the risk further still on facing a possible activation of the SRF with surface rupture. Meanwhile, the southern urban district has the El Prado Cemetery and the Parque del Recuerdo Cordillera Cemetery as part of its infrastructure which, although they constitute a contribution of spaces for rest, at the same time, they imply a considerable floating population of relatives or worshippers who are visiting their loved ones. All in all, the highest risk of the southern district lies in the 13 educational establishments of different levels: preschools (3), primary schools (7), secondary schools (3), whose student population with ages between 4 and 18, would require greater contention or supervision, if there were an evacuation due to the activation of the San Ramón Fault.

It can be confirmed that the sporting and public space facilities that both sectors under analysis have, are favorable options on facing a possible seismic event. In that line, the Hospital de Carabineros urban district has 5 sports centers -Manuel Rodríguez Sports Facilities, Iván Zamorano Sports Complex, Club Oriente Football Club, the Las Condes Rodeo Grounds, and the Patricia Municipal Stadium-, unlike the southern urban district, that only houses the Codelco Sports Complex. However, there is also the Aguas de Ramón Natural Park in Las Condes, which has over 3,500 hectares, including a nature reserve that it shares with the commune of La Reina and that, without a doubt, would contribute to the natural containment of the foothills on facing a seismic-geological activation.

VI. CONCLUSIONS

The San Ramón Fault is a new geological element that is sounding the social and urban sustainability alarms on facing a possible activation in the foothills. Starting from an analysis that articulates the built, natural, and regulatory aspects, an uneven region can be seen regarding urbanity, sustainability and adaptability, illustrated in the two urban districts that are exposed to the seismic risk of the San Ramón Fault, as contrasting scenarios.

On one hand, the Hospital de Carabineros urban district in Las Condes, is seen as a northern sector with high cost housing, natural facilities (parks) and sports facilities that must however, coexist with critical infrastructure represented by a nuclear center and an electricity substation. On the other hand, the southern sector, with the El Peral urban district in Puente Alto, offers a greater distance from the buffer for its housing areas, but has fewer urban facilities that act as a buffer on facing an activation of the San Ramón Fault, and what is even more complex, is the higher number of schools at risk, meaning a younger population that needs greater contention during an evacuation.

It is concluded that these urban design experiences under extreme conditions vis-a-vis seismic risk, are illustrative both to progress in the socio-spatial survey of the foothills and to permeate through risk management operational levels, like articulated and resilient metropolitan and communal regulations, acknowledging the San Ramón Fault as a new base criterion of urban design. Hence, new analysis of this nature and of other urban scenarios at risk is required, that nourishes and completes an intercommunal panorama of the Santiago foothills.

Specifically, three future areas of action are defined to move forward towards the articulation of the built, natural and regulatory aspects that incorporate "resilient urban design", as the analysis matrix built in this work. The first dimension is at a civic-urban level and refers to the drive for knowledge of local threats and local scale risks, and is in line with what has been suggested by the Ministry of Housing and Urbanism on the reduction of disaster risk and reconstruction. A community that cohabits with their natural risks, like the San Ramón Fault, can increase their resilience capacity, as long as they know both the geological nature -the associated hazard level-, and the socio-spatial nature of where they live. This condition implies a concrete action of investing in community relations, so that these are empowered and can systemically act in an area, with information and tried and tested evacuation protocols.

The second aspect looks at increasing the sustainability and awareness of the natural environment. The Santiago foothills represent, in one way or another, a cultural heritage of all the citizens and, as such, a relationship should be reconsidered, promoting activities and actions that foster the recreational use of this area through parks and trails that at the same time encourage walking around it and valuing its ecological-landscape value. In this vein, a type of facility could be included that reinforces these priorities and nurtures the relationship with the inhabited area through sports centers, cultural and educational activities on risk management.

Finally, a third dimension and probably the longest lasting one, is the generation of urban regulations that are in tune with the risk conditions, that do not only rely on the intercommunal level, like the already proposed modification of the Santiago Metropolitan Zoning Plan (SEREMI-MINVU, 2012a) does, and one that has a greater accent on what is

8 In particular, the following sites were checked to obtain information on property prices in the commune of Las Condes: https://www.goplaceit.com/cl/propiedad/venta/departamento/las-condes/7339105-venta-de-departamento-excelente-oportunidad-en-las-condes-2-dormitorios-48-m2; https://www.goplaceit.com/cl/propiedad/venta/casa/las-condes/5294419-venta-de-casa-los-dominicos

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outlined in the Law and the General Urbanism and Construction Ordinance, but one that also allows implementing specific investment and execution plans for risk management of Santiago's foothills. In the latter, the role that urban design plays is key, as on increasing its application in manuals, section plans or master plans where the buffer of 300 meters from the San Ramón Fault is made visible, it would be possible to guide the uses and types of buildings that are feasible to include within this restriction area.

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