PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

ANALYSIS OF THE HUMAN BEHAVIOR IN MID- AND HIGH-RISE RESIDENTIAL BUILDINGS DURING THE 2010, FEBRUARY 27 EARTHQUAKE

MARÍA DE LOS ÁNGELES JORDÁN JOANNON

Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering.

Advisor:
JUAN CARLOS DE LA LLERA MARTIN
EDMUNDO KRONMÜLLER RIOSECO

Santiago de Chile, November, 2023

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Deo Omnis Gloria

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ABSTRACT

This research examines the immediate response and evacuation decision-making of people staying at mid- to high-rise residential buildings in Santiago during the February 27, 2010 Maule earthquake. In an effort to gather reliable empirical data on their behavior during the earthquake, a survey was designed and administered to 335 randomly selected building residents living in Santiago. The survey collected information on reaction times to the earthquake, actions taken during the event, whether they evacuated the apartment or building and their social behavior. Bivariate analyses, chi-square tests, and a logistic regression were conducted to assess the statistical significance of independent variables that influenced these behaviors. These independent variables included demographic characteristics, physical and social context, previous experiences, earthquake education, observed damage, and risk perception. Additionally, a simplified seismic analysis of selected buildings was performed as a proxy of buildings performance during the earthquake in terms of floor displacements and accelerations. These performance measures were included as dependent variables in the study. The findings suggest that the presence of individuals requiring assistance was the best predictor for helping others, while being alone increased the likelihood of seeking shelter. These results are well aligned with existing empirical studies, indicating that people's behavior during earthquakes is rational, adaptive, and fulfills social roles.

Although no significant correlation was identified between the building-specific earthquake demand parameters and people's behavior during the earthquake, a fast and simple methodology is proposed for future studies that aim to explore this relationship.

Keywords: evacuation, human behavior, earthquake performance, inhabitant survey, risk perception, contingency tables, regression.

RESUMEN

El presente trabajo examina el comportamiento inmediato y la toma de decisiones de evacuación de personas que se encontraban en edificios residenciales de altura media y alta en Santiago durante el terremoto del Maule el 27 de febrero del año 2010. Con el objetivo de recolectar datos empíricos confiables sobre su comportamiento durante el terremoto, se diseñó una encuesta que se administró a 335 residentes de edificios de la ciudad de Santiago seleccionados al azar. La encuesta recopiló información sobre el tiempo de reacción al terremoto, las acciones tomadas durante el evento, si evacuaron el departamento o el edificio y su comportamiento social. Se realizaron análisis bivariados, pruebas de chi-cuadrado y regresión logística para evaluar la significancia estadística de las variables independientes que influyeron en estos comportamientos. Las variables independientes incluyeron características demográficas, contexto físico y social, experiencias previas, educación sobre terremotos, daños observados y percepción de riesgo. Además, se realizó un análisis sísmico simplificado de edificios seleccionados para estimar su comportamiento durante el terremoto en términos de desplazamiento y aceleración del piso. Estas medidas de rendimiento se incluyeron como variables dependientes en el estudio. Los resultados indican que la presencia de personas que necesitaban ayuda fue el mejor predictor para ayudar a otros, mientras que estar solo aumentó la probabilidad de buscar refugio. Estos resultados concuerdan con estudios empíricos existentes, lo que sugiere que el comportamiento de las personas durante los terremotos es racional, adaptativo y cumple con roles sociales.

Si bien no se encontró una correlación significativa entre los parámetros de demanda de terremotos específicos del edificio y el comportamiento de las personas durante el terremoto, se propone una metodología rápida y simple para futuros estudios que busquen explorar esta relación.

Palabras Claves: evacuación, comportamiento humano, comportamiento sísmico, encuesta a habitantes, percepción de riesgo, tablas de contingencia, regresión.

1. INTRODUCTION

Injuries during earthquakes are strongly associated with the movements and the actions people engage in (Ohta and Ohashi, 1985; Wagner et al., 1994; Johnston et al., 2014; Lambie et al., 2015). Consequently, understanding their behavior during earthquakes has become crucial for predicting human casualties and enabling civil institutions to arrange post-disaster support actions, design preventive measures, and improve earthquake preparedness. This is especially important in areas susceptible to consequential hazards, such as tsunamis, where prompt evacuation is critical.

Efforts have been made to develop models capable of predicting people's evacuation behavior during earthquakes (Liu et al., 2012; Poulos, 2014) and estimating the number of injuries and casualties caused by the shaking (Coburn et al., 1992). However, because it is a complex subject that involves recalling sensitive and traumatic events, and requires a multidisciplinary approach, there is little information available in the literature and most existing studies fail to address the psychological dimension of the phenomenon. Moreover, many of these studies are based on small non-random samples, making generalization precarious (Goltz et al., 1992, p. 45).

First studies regarding human behavior during earthquakes were conducted by Japanese researchers (Archea and Kobayashi, 1984; Ohashi and Ohta, 1984; Archea and Kobayashi, 1986). They used questionnaires to collect information about people behavior during a series of earthquakes finding that responses were strongly correlated with seismic intensity, the surrounding circumstances of family members, and the potential of fire hazards. At higher intensities, more people reported behaving unconsciously, experiencing greater fear and surprise, while in the presence of children, women tended to protect them. One significant discovery was the small number of people who docked under furniture, with the most prevalent and immediate response being associated with reducing the risk of fire (Ohta and Ohashi, 1985; Wagner et al., 1994; Archea and Kobayashi, 1986).

In the United States, Arnold et al., (1982) studied the reaction of individuals inside a small office building during the Imperial County, California earthquake of 1979. They found that the majority of people took protective actions, primarily seeking shelter under desks, and followed familiar paths to evacuate the building, even when those paths were not the nearest or safest exits. Goltz et al., (1992) and Bourque et al., (1993) conducted similar studies following the Whittier Narrows and Loma Prieta earthquakes. They discovered that the typical response of those at home was to avoid hazards, seek refuge under doorways or furniture and move toward other people. In a follow-up work (Goltz and Bourque, 2017) they compared people's behavior during the Whittier Narrows and Loma Prieta earthquakes with the January 17, 1994 Northridge earthquake. Using bivariate and multivariate statistical analyses, they concluded that behavior was diverse, rational, depended on the social context, adaptive and consistent with pre-disaster social roles.

Most recently Goltz et al., (2020) used DYFI (USGS "Did you feel it?") databased to analyze reported behaviors of individuals during 12 earthquakes that occurred between 2005 and 2018 in eight different countries. They found that people's behavior was strongly linked with fear and shaking intensity, and could be conditioned by educational and cultural factors.

While empirical research tends to support the idea that people's behavior during earthquakes is rational and adaptive, there are studies where the most prevalent behavior was flight, such as running outside, freeze in place, and evacuating during the ground motion (Alexander, 1990; Prati et al., 2013; Lindell et al., 2016). These studies also highlighted the importance of conducting this type of research in different countries for a better understanding of the cultural factors involved.

One important research gap is the absence of studies that evaluate behavior inside residential buildings. Existing studies primarily focus on ground-level dwellings (Archea and Kobayashi, 1984), and those that include buildings often do not differentiate between them, account for behavior based on floor level, or account for evacuation as an option (Ohta and Ohashi, 1985; Prati et al., 2013; Lindell et al., 2016; Goltz and Bourque, 2017; Lambie et al., 2017; Shapira et al., 2018). Only a few building evacuation models have been developed. Liu et al., (2012) where the first to combine nonlinear dynamic analysis of a low-rise commercial building with agent-based modeling (ABM) to represent people’s behavior and their interaction with the environment during evacuation. A similar study was conducted by Poulos (2014), who integrated human behavior with earthquake-induced environmental changes to model pedestrian evacuation from an office building and a PK-12 school. However, both are attempts with little empirical information about the real human behavior during actual earthquakes, which is needed to properly calibrate the models, including the actions people engage in, whether they try to leave the structure or seek shelter, their reaction time, social behavior, evacuation speed, and how fear and risk perception influences evacuation.

This information is also relevant for improving post-earthquake tsunami evacuations, where existing studies often do not consider the earthquake’s effects on the population or the environment (Mas et al., 2012; Wang et al., 2015). Therefore, the main goal of this study is to contribute with additional data and information concerning human responses and evacuation behaviors during a large earthquake, such as the Maule earthquake of 2010 in Chile.

1.1. Motivation

On Saturday, February 27, 2010 at 03:34 am local time (06:34:14 UTC), a powerful Mw 8.8 earthquake ruptured more than 500 km along the central coast of Chile. The movement and subsequent tsunami affected 3/4 of the Chilean population, causing 562 deaths and approximately US $30 billion in economic losses (Grossi et al., 2011). Despite its epicenter was located near the coast of Concepción, 350 kilometers southwest of Santiago, the perceived shaking at the capital was very strong with an estimated modified Mercalli Intensity of VI-VII (Unites States Geological Survey [USGS], 2010). Indeed, rupture models shows that the event was not a single event but the concatenation of two or even three mayor slip patches. However, due to strict seismic design standards required in Chile, only a small fraction of buildings in Santiago suffered major structural damage. Nevertheless, many buildings experienced substantial non-structural damage, significantly affecting the physical environment during shaking.

Although Chile is a country that has experienced several major earthquakes in the past, no study regarding the behavior of building residents during earthquakes has been conducted. This research gap is surprising given Chile’s high seismic risk, and the relevant potential of subduction earthquakes to cause catastrophic tsunamis (Thomas et al., 2007). Understanding how people behave during earthquakes, the factors influencing their decision-making, and whether they evacuate buildings is crucial for developing effective evacuation plans, improving building codes, and enhancing earthquake public awareness and education in vulnerable areas. Therefore, this study’s primary objective is to investigate the people’s behavior during earthquakes in Chile, contribute to the global understanding of the relationship between earthquake response and behavior, and gather essential information for modeling purposes.

Consequently, a survey was designed and administered to collect data on people’s behavior during the 2010 Maule earthquake. Participants were also asked about their earthquake preparedness, prior experiences, and the circumstances surrounding them before and during the shaking. This research outlines the survey design process, its implementation, presents the obtained data, and conducts bivariate and multivariate analyses to identify how participants' personal, physical, and social characteristics influenced their behavior during the earthquake. Additionally, a simplified seismic analysis 99 of the survey buildings was performed using an existing methodology (Miranda, 1999; Miranda and Taghavi, 2005) to estimate building floor displacements and accelerations during the earthquake, incorporating building seismic response among the independent variables potentially affecting behavior.

2. METHODOLOGY

A questionnaire was designed and the Direction of Social Studies at *Pontificia Universidad Católica de Chile* (DESUC) participated in designing and conducting a joint field study to define the critical aspects of the sample, validate the questionnaire through focus groups assessments, and ultimately administer the survey during the months of January and February in 2017. Given the sensitive psychological nature of the study, participation was restricted to adults aged 18 years or older and all participants were required to sign informed consent letters. Participation was voluntary, and respondent's anonymity was guaranteed.

Since this was a first study of such a kind conducted in Chile, and there is little information available on human behavior inside buildings during earthquakes, a limited sample was thoughtfully selected to account for individuals residing in residential buildings with 10 or more stories who had experienced the earthquake. This approach was chosen to ensure the replicability of the research. The questionnaire was divided into seven distinct parts (detailed in APPENDIX A). The initial section focused on collecting information concerning the physical and social contexts at the time of the earthquake. Part 2 centered on participant's reactions during the shaking. Parts 3 and 4 questioned movement perception and observed damage. Part 5, inquired about where respondents were and their subsequent reactions to the March 11, 2010 Pichilemu earthquake, so that the information obtained from the main earthquake could be compared with another important shaking (Mw 6.9) occurred under different circumstances. The Pichilemu earthquake, generally regarded as an aftershock of the Maule earthquake, occurred at 11:39 local time, found most people outside their homes, primarily at work and away from family members. Part 6 inquired about preparedness and previous earthquake-related experiences. Finally, Part 7 consisted of a set of questions about respondent's personal information.

Standardized statistics tools were used to examine the obtained data, assure the quality of the results, analyze the relationships between the variables, and test the main assumptions and patterns expected. An Exploratory Data Analysis (EDA) was employed to identify possible outliers and anomalies in the information, search for missing values, replace them if necessary and generate positive and negative correlations among target variables. After the original "raw data" was reviewed and standardized, a Bivariate Analysis was conducted using the Statistical Package for the Social Sciences software (IBM SPSS Statistics 29.0) to investigate the basic relationships between the personal characteristics of respondents and their behavior. Since most of the study variables are categorical, Contingency Tables were employed and tested using Pearson's chi-square test to determine the statistical significance of the findings. Ultimately, a Multivariate Analysis was performed using Binary Logistic Regressions to understand how the independent variables influenced resident's behavior and establish the presence of causal relationships.

Cross-tabulation, or contingency tables, are a methodology of organizing data and analyzing the relationship between categorical variables (Masashi, 2016). They display the frequency distribution of each variable, indicating how many observations fall into each category allowing to understand how the variables are related and identify patterns and trends in the data. Using the observed data, expected values are calculated, and a Pearson's chi-square test for independence is applied to test the null hypothesis H_0: "there is no relationship between the two variables", against the alternative hypothesis H_a: "there is a relationship between them". The null hypothesis is rejected when $\chi^2 > \chi^2_{critical}$ and the p-value ρ is less than a previously defined level of statistical significance α, typically set at $\alpha = 5\%$. Therefore, if $\rho \leq 0.05$, the null hypothesis is rejected and there is statistical evidence to support the research hypothesis that there is an association between variables.

Regression analysis is a statistical method employed to explore and quantify the relationships among two or more variables. It allows modeling and predicting the value of the dependent variable based on the independent variable by using the observed data. The basic linear regression model between a dependent variable y and a set of n independent variables x_i is given by equation (1), where β_0 is the intercept, ε is the error, and β_i denotes the unknown regression coefficients of the explanatory variable x_i, $i = 1, \dots, n$.

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n + \varepsilon \qquad (2.1)$$

Linear regression is a suitable statistical technique when the dependent variable is continuous and the relationship between independent and dependent variables is assumed to be linear. However, in cases involving categorical data, particularly for the case of dichotomous variables, as in this study where participants either engaged or did not engage in certain behavior, Binary Logistic Regression (BLR) is needed. Binary Logistic Regression uses the same concept as regression analysis, but since the dependent variable is not linear, and can only take two values, typically 0 or 1, the function is transformed using the logit of the probability of the event (log-odds) to solve a linear problem.

Having $\pi(X)$ defined by Equation (2.2)

$$\pi(X) = \frac{e^{\beta_0 + \beta_1 x_1 + \dots + \beta_n x_n}}{1 + e^{\beta_0 + \beta_1 x_1 + \dots + \beta_n x_n}} \qquad (2.2)$$

wich represents an S-shaped or sigmoid curve that takes values between 0 and 1, like the probability of an event, with X containing the vector of the regressor variables x_i.

Then, logit transformation is applied to Equation (2.3)

$$\log\left(\frac{\pi(X)}{1 - \pi(X)}\right) = \log\left(e^{\beta_0 + \beta_1 x_1 + \dots + \beta_n x_n}\right) = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n \qquad (2.3)$$

where the ratio $\pi(X)/(1 - \pi(X))$ represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure (Szumilas, M., 2010).

Multiple Linear Regression analysis employ Least Squares Method to identify the model that offers the best fit to the data by minimizing the sum of the squares of the regression residuals. However, in Binary Logistic Regression, the Maximum Likelihood Method is used to obtain the parameters that maximize the likelihood of obtaining results closely resembling the observed data.

2.1. Dependent Variable

To characterize their behavior, respondents were asked to choose from a provided list all the actions they took during the earthquake. This list, presented in Table 2.1, was compiled based on findings from previous studies in the literature. For a better understanding of the respondent's reactions, each selected action was categorized into one of five groups based on the nature of the response: (1) fight, (2) flight, (3) seek shelter, (4) wait, and (5) not recommended/dangerous actions. The "fight" category refers to behaviors in which residents actively reacted to the threat, such as opening doors/windows, helping others, and turning off fire/gas. The "flight" category included behaviors where residents attempted to move away from the threat, such as leaving the room, the apartment, or the building. These categories are based on Walter Cannon's research on the fight-flight-freeze response to stress-inducing situations (Cannon, 1993), where he observed that when individuals perceive a threat, they have both an emotional and a physical reaction. The sense of fear triggers the release of stress hormones in the brain, resulting in an increased heart rate and preparing the body to fight for survival, run to safety by fleeing, or even freeze in an attempt to go unnoticed.

Table 2.1: Reaction to the Earthquake: dependent variable

Fight	Open doors/windows
	Help others
	Turn off fire/gas
Flight	Leave the room
	Leave the apartment
	Leave the building
Seek for Shelter	Seek shelter under a door frame
	Seek shelter under furniture
Freeze	Stay still
Not recommended/ dangerous actions	Get dressed/change clothes
	Hold furniture

Other important factors to consider when modeling people behavior in disasters are reaction time and evacuation behavior. Participants were asked to provide information on the time it took for them to initiate their first action and, if they choose to evacuate, where they were trying to go, who did they go with, and evacuation speed. These variables were also analyzed to understand what influenced them.

In most disasters and emergency scenarios, exists a temporal gap between the onset of the event and people initial response of individuals to the threat. This phenomenon has been well-documented in studies on fire evacuation (Canter et al., 1980; Proulx and Reid, 2006) and was also observed during the World Trade Center disaster (Kuligowski and Mileti, 2009; Sherman et al., 2011). However, in most cases, earthquakes differ from other disasters because the time available for perceiving cues and gathering information about the threat last seconds rather than minutes. When individuals become aware of the movement, the earthquake is already occurring, resulting in very short reaction times This is significant because many existing models for earthquake behavior and tsunami evacuations identify the starting point as the moment when the earthquake ceases, even though evidence suggests that people may engage in various actions during the shaking (Arnold et al., 1982; Archea and Kobayashi, 1984; Ohta and Ohashi, 1985).

Whether people evacuate or not during the movement is also a critical aspect in modeling. Understanding how they interact and move within the building, how fast they do it and what is their social behavior; if they evacuate alone or in the company of others; has been reported to affect the number of injuries and human casualties. Moreover, it determines the locations of individuals at the end of the earthquake, which is significant for initiating a possible post-earthquake tsunami evacuation.

2.2. Independent Variables

From existing literature, the independent variables that influence people's reactions to earthquakes, were established. Several demographic characteristics, including gender, age, nationality, education, and marital status, as well as factors related to preparedness and past experiences, are well-reported to impact behavior, in different sociological studies on earthquake and other disasters. The circumstances surrounding individuals are also important: their location, familiarity with the place, who they were with and whether they were with individuals in need of assistance. Also, their perception of the earthquake in terms of the observed damage and perceived intensity, along with their sense of safety, preparedness and reported fear were considered. All these factors are categorized by subject in Table 2.2.

Risk perception, as outlined in Table 2.2, refers to how much danger people experienced and their level of concern regarding the threat they faced. It plays a significant role in the decision-making process during crisis situations, where higher levels of risk perception are associated with shorter pre-evacuation delay times, and greater knowledge, and emergency preparedness (Kuligowski and Mileti, 2009; Sherman et al., 2011)

Table 2.2: Independent Variables

Personal Characteristics	Gender	Previous Earthquakes	Number of Previous Earthquakes
	Age		Same Apartment
	Nationality		Other Building
	Marital Status		Property Damage
	Academic Qualification		Injuries
Physical Context	Building Location	Modified Mercalli Intensity	Observed Damage
	Familiarity with the Apartment		Earthquake Intensity
	Apartment Floor		Difficulty Standing
	Floor Level		Injured
Social Context	Alone		Noise
	Family and Relatives	Risk Perception	Prepared
	Friends and Neighbors		Safe
	Others Required of Assistance		Fear
Preparation	Drills Before 2005		
	Drills After 2005		
	Building Security Zones		
	Official Recommendations		
	Emergency Plan		

3. SURVEY RESULTS AND DATA ANALYSIS

Out of the 335 respondents, 330 (99%) were Chilean, 172 (51%) women, 163 (49%) men, and their average age at the time of the earthquake was 40 years old. Regarding marital status, 125 (37%) reported being single,120 (36%) were married in 2010, and 142 (42%) had a university degree.

In terms of past earthquake experiences, only 3 stated that they had not experienced an earthquake or strong ground shaking before. Among those who had, 58% reported experiencing 3 or more previous earthquakes. During these smaller quakes, most of them (74%) were not in the same apartment as they were during the 2010 Maule earthquake. Only 111 (33%) were inside another building with 5 or more floors, 279 (83%) reported suffering minor or no property damage, and 329 (98%) reported sustaining minor or no injuries.

Regarding earthquake preparation and education, 189 (57%) respondents mentioned that they had participated in drills before 2005, while only 115 (35%) had done so after 2005. About a third of them knew the security zones of their building (33%) and were aware of SENAPRED (ONEMI in 2010[1]) or other official entities recommendations on how to behave during earthquakes. Only 68 (21%) had a family emergency plan in place.

[1] SENAPRED, which stands for *Servicio Nacional de Prevención y Respuesta ante Desastres*, is the technical agency of the Chilean government established by Law 21.364. It was originally known as the *Oficina Nacional de Emergencia del Ministerio del Interior y Seguridad Pública* – ONEMI, through Decree Law No. 369 of 1974. SENAPRED's primary responsibility is to plan and coordinate both public and private resources dedicated to the prevention and response to natural or human-induced emergencies and disasters. It provides ministries, delegations, regional governments, municipalities, and national, regional, provincial, and municipal Civil Protection agencies with models and permanent management plans for the prevention and handling of emergencies, disasters, and catastrophes (Servicio Nacional de Prevención y Respuesta ante Desastres [SENAPRED], 2022).

Most participants were interviewed at the same building they were in during the earthquake (75%), and were very familiar (44%) with the apartment they experience the earthquake in. About the respondent's social context, 246 (73%) were with family and relatives, only 61 (18%) were alone, and 111 (33%) were with people in need of assistance, such as children under 14 or individuals with reduced mobility. This was expected given that the earthquake occurred at night during summer holidays.

Respondents described the movement (67%) and the perceived noise (48%) as very strong, reported the duration as more than 3 minutes (43%) and had strong difficulties in standing (45%). Only 4 (1.19%) individuals reported falling down due to the shaking. Shown in Figure 3.1 is a summary of these results.

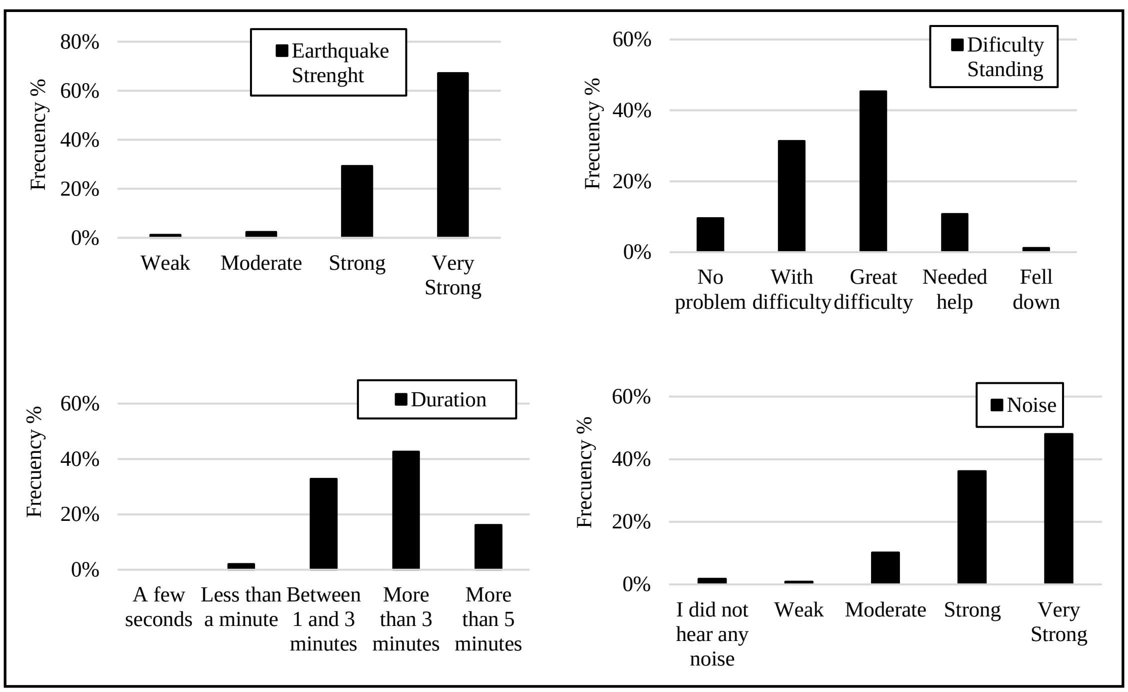

Figure 3.1: Movement and Noise Perception During the Earthquake

The survey included questions about movement perception and observed damage to estimate the Modified Mercalli Intensity (MMI) experienced by each respondent. This methodology has been widely used over the years to evaluate damage distribution and need for emergency response after earthquakes (Murakami and Katta, 2001). For each alternative, a corresponding intensity was given so MMI was estimated based on additive scores associated with the answers. Questions unanswered or “don’t know”/ “couldn’t said” add no scores. The calculated average intensity based on the answers was a MMI VI in line with published results by the USGS which estimated an intensity between VI and VII for Santiago (USGS, 2010). Additionally, when sorting the results according to each story level, those on the upper floors of the buildings reported higher intensities. Shown in Figure 3.2 are these results.

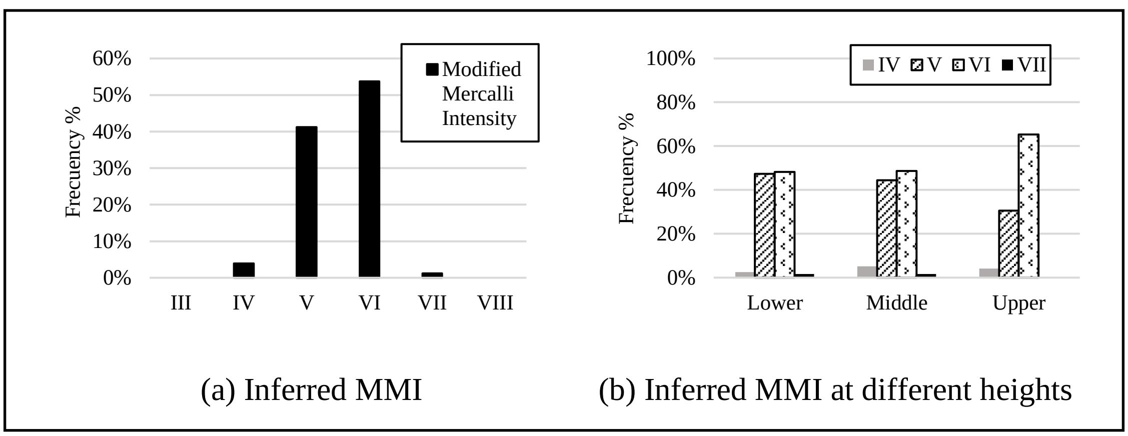

Figure 3.2: Inferred Modified Mercalli Intensity and Perception at different heights

In terms of perceived risk, participants were asked to rate their fear level on a scale of 1 to 10, with most people (24%) reporting the maximum level of fear (10 on the scale). The average fear level was 7.4, indicating a significant degree of fear. Respondents also indicated that they were either not prepared (44%) or only slightly prepared (37%), with 36% feeling very little safety and 33% feeling moderate safety during the earthquake. Shown in Figure 3.3 is a summary of these findings.

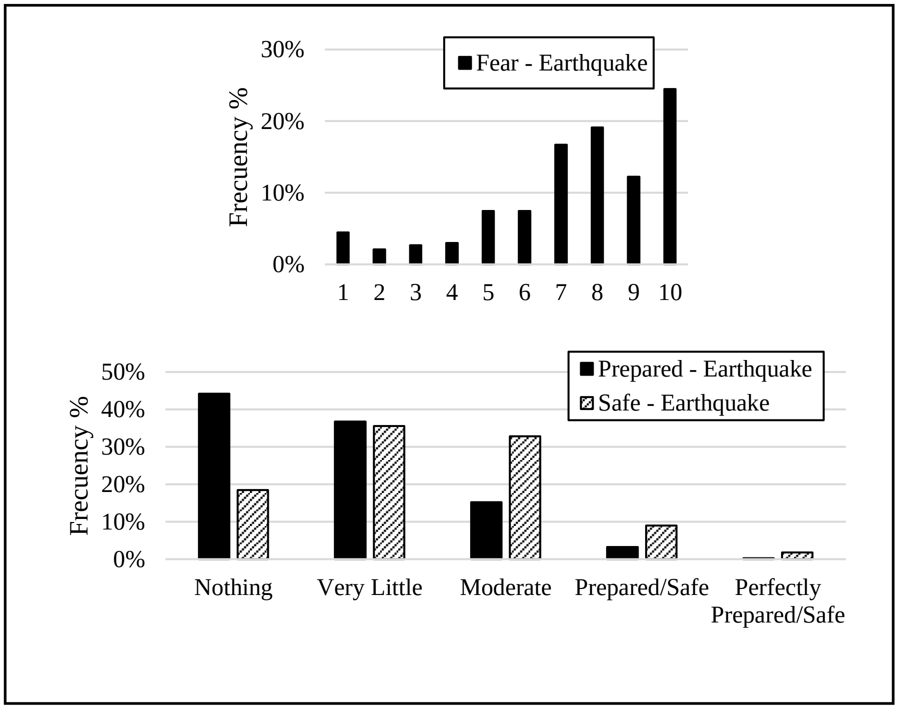

Figure 3.3: Fear and Risk Perception during the Earthquake

To facilitate statistical analysis, the 10 levels of fear were re-grouped into 5 categories: none, very little, moderate, high, and very high. Crosstabulation revealed that several variables were robust predictors of higher levels of fear, including greater perceived shaking intensity, reported difficulties in standing during the earthquake, longer movement duration and noise, and higher MMI. On the contrary, being male and being alone were associated with lower levels of fear (Table 3.1)

Table 3.1: Declared Levels of Fear during the Earthquake

	Nothing		Very Little		Moderate		High		Very High		N
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Gender											
Male	14	8,6%	9	5.5%	31	19%	78	47.9%	31	19%	163
Female	8	4,7%	10	5.8%	19	11.1%	42	24.6%	92	**53.8%**	171
Alone											
No	16	5.9%	16	5.9%	33	12.1%	102	**37.4%**	106	**38.8%**	273
Yes	6	9.8%	3	4.9%	17	27.9%	18	29.5%	17	27.9%	61
Shaking Intensity											
Very Little	0	0%	1	25%	0	0%	2	50%	1	25%	4
Moderate	1	12.5%	0	0%	2	25%	4	50%	1	12.5%	8
High	6	6.1%	5	5.1%	20	20.4%	45	45.9%	22	22.4%	98
Very High	15	6.7%	13	5.8%	28	12.5%	69	30.8%	99	**44.2%**	224
Difficulty Standing											
Nothing	6	18.8%	3	9.4%	6	18.8%	12	37.5%	5	15.6%	32
Very Little	6	5.7%	6	5.7%	23	21.9%	33	31.4%	37	35.2%	105
Moderate	6	4%	7	4.6%	17	11.3%	59	39.1%	62	41.1%	151
High	2	5.6%	1	2.8%	2	5.6%	15	**41.7%**	16	**44.4%**	36
Very High	0	0%	1	25%	0	0%	1	25%	2	50%	4

Table 3.1: Declared levels of Fear during the Earthquake (*continued*)

	Nothing		Very Little		Moderate		High		Very High		N
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Perceived Duration											
Less than a minute	3	42.9%	0	0%	2	28.6%	1	14.3%	1	14.3%	7
1 to 3 minutes	9	8.2%	9	8.2%	28	25.5%	40	36.4%	24	21.8%	110
More than 3 mins.	6	4.2%	7	4.9%	14	9.8%	53	37.1%	63	44.1%	143
More than 5 mins.	1	1.9%	2	3.8%	3	5.7%	19	35.8%	28	52.8%	53
Noise											
Nothing	1	16.7%	2	33.3%	2	33.3%	0	0%	1	16.7%	6
Weak	1	33.3%	1	33.3%	0	0%	0	0%	1	33.3%	3
Moderate	6	17.6%	2	5.9%	6	17.6%	14	41.2%	6	17.6%	34
Strong	7	5.8%	6	5%	20	16.7%	51	**42.5%**	36	**30%**	120
Very Strong	5	3.1%	8	5%	17	10.6%	53	**32.9%**	78	**48.4%**	161
Prepared											
Nothing	8	5.4%	9	6.1%	21	14.3%	39	26.5%	70	**47.6%**	147
Very Little	2	1.6%	4	3.3%	16	13%	56	45.5%	45	**36.6%**	123
Moderate	8	15.7%	4	7.8%	11	21.6%	22	43.1%	6	11.8%	51
Prepared	4	36.4%	2	18.2%	1	9.1%	2	18.2%	2	18.2%	11
Perfectly prepared	0	0%	0	0%	0	0%	1	100%	0	0%	1

Table 3.1: Declared levels of Fear during the Earthquake (continued)

	Nothing		Very Little		Moderate		High		Very High		N
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Safe											
Nothing	0	0%	0	0%	3	4.9%	16	26.2%	42	**68.9%**	61
Very Little	3	2.5%	4	3.4%	11	9.2%	42	35.3%	59	**49.6%**	119
Moderate	11	10%	11	10%	25	22.7%	46	41.8%	17	15.5%	110
Safe	5	16.7%	3	10%	6	20%	12	40%	4	13.3%	30
Perfectly safe	2	33.3%	0	0%	1	16.7%	3	50%	0	0%	6
MMI											
IV	2	15.4%	1	7.7%	4	30.8%	6	46.2%	0	0%	13
V	11	8%	9	6.5%	27	19.6%	55	39.9%	36	26.1%	138
VI	8	4.5%	9	5%	19	10.6%	59	33%	84	**46.9%**	179
VII	1	25%	0	0%	0	0%	0	0%	3	75%	4

Most participants answered their first reaction was to open doors/windows, remain still, and help others. Specifically, 40 (12%) sought shelter under a doorway, while only 2 (0.6%) sought shelter under furniture. Additionally, 35 respondents (10%) mentioned they got dressed or changed clothes, while 16 (5%) reported holding onto furniture. An equal number left the apartment, and 1 (0.3%) left the building. These actions were categorized into one of five defined categories based on their intended goals: fight, flight, freeze, seek shelter, and not recommended/dangerous actions. Table 3.2 lists the first reactions to the earthquake. In the following question, participants were asked to select from the same list all the actions they carried out during the earthquake. The most selected options included leaving the room (57%), opening doors/windows (47%), helping others (45%), and seeking shelter under a doorway (37%).

Table 3.2: First Reaction to the Earthquake

		n	%
Fight	Open doors/windows	56	**17%**
	Help others	55	**16%**
	Turn off gas/fire	6	1.8%
Not recommended/ dangerous actions	Get dressed/changes clothes	35	10%
	Hold furniture	16	4.8%
Flight	Leave the room	49	**15%**
	Leave the apartment	16	4.8%
	Leave the building	1	0.3%
Seek for shelter	Seek shelter under doorway	40	12%
	Seek shelter under furniture	2	0.6%
Freeze	Stay still	49	**15%**
		325*	**97%**

*10 (2.9%) excluded values because “don’t know/don’t answer”

When participants were asked about the time it took them to initiate their first action after the onset of the earthquake, the majority of respondents (46%) indicated that it took them a few seconds, while 27% reported reacting in less than a second. Only 7 (2%) did not react until the earthquake was over. Those who reported having participated in drills before 2005, knew behavioral recommendations of official entities and had an emergency plan exhibited shorter reaction times (Table 3.3). Suggesting that prior preparedness and knowledge can influence how quickly people respond during an earthquake.

Table 3.3: Time to First Reaction

	Less than a second		A few seconds		Several seconds		N
	n	%	*n*	%	*n*	%	
Drills before 2005							
No	21	15.1%	74	53.2%	44	31.7%	139
Yes	70	38.5%	77	42.3%	35	19.2%	182
Official Recommendations							
No	56	26.8%	90	43.1%	63	30.1%	209
Yes	31	29.2%	59	55.7%	16	15.1%	106
Emergency Plan							
No	61	24.5%	119	47.8%	69	27.7%	249
Yes	26	39.4%	30	45.5%	10	15.2%	66

Significant statistical relationships were observed in relation to evacuation behavior. Specifically, being with someone in need of assistance and having knowledge about official recommendations on how to behave were found to have a negative impact on evacuation, causing individuals to be less likely to leave their apartments. On the other hand, the level of noise and fear experienced during the earthquake were found to positively influence evacuation, increasing the likelihood of participants evacuating their apartments (Table 3.4). Furthermore, single individuals evacuated faster, while a high familiarity with the apartment and having successfully evacuated were associated with lower speeds.

Table 3.4: Evacuation During the Earthquake

	Stayed inside the apartment		Left the apartment/building		N
	n	%	*n*	%	
Reduced mobility					
No	142	59.4%	97	40.6%	239
Yes	23	82.1%	5	17.9%	28
Official Recommendations					
No	120	55%	98	45%	218
Yes	70	66.7%	35	33.3%	105
Noise Perception					
No noise	5	83.3%	1	16.7%	6
Weak	2	66.7%	1	33.3%	3
Moderate	10	29.4%	24	70.6%	34
Strong	77	65.3%	41	34.7%	118
Very Strong	97	60.2%	64	39.8%	161
Fear					
Nothing	7	31.8%	15	68.2%	22
Very Little	13	68.4%	6	31.6%	19
Moderate	32	65.3%	17	34.7%	49
High	81	68.1%	38	31.9%	119
Very High	62	50.8%	60	49.2%	122

Social interactions become very relevant during disasters, since they can influence other's actions, and cause serious injuries if individualistic behaviors prevail. In the survey, social behavior was assessed by asking respondents about their actions during the earthquake, the option "Helped Others" was included and, when asked about whether they attempted to leave their apartment, they were also asked to specify with whom they did so. 57 (16%) answered that their first action was to “Helped Others” being one of the most selected options. Additionally, 163 (45%) selected this option when asked about all the actions they engaged in during the earthquake.

Among those who reported leaving their apartments, 50% of those who chose the "Other" option as their motivation for evacuation mentioned that they did so to assist or check on neighbors and other family members.

As presented on Table 3.5 those that helped others were predominantly males, married, and were in the company of family and relatives, in the presence of others in need of assistance, knew the security zones of the building, and had an emergency plan. Also being alone was found to decreases the likelihood of helping others. Additionally, those that reported higher levels of fear (strong and very strong) had a greater probability of engaging in helping behavior.

Studies on social behavior during evacuations have shown that people tend to evacuate in groups with others they know (Hostikka et al., 2007; Jones and Hewitt, 1986; Parikh et al., 2013). Therefore, participants were asked if they evacuated alone or with others and, if they started alone, whether they later joined others during the evacuation. Most respondents reported evacuating with others (68%), while 22 (14%) started alone and later joined others, and only 23 (17%) evacuated alone. Those who evacuated alone were mostly females (57%), single (65%) or were alone (78%) at the time of the earthquake.

Table 3.5: Social Behavior and Help to Others

	Helped		Did not Help		N
	n	%	*n*	%	
Gender					
Female	65	37.8%	107	62.2%	172
Male	87	**53.4%**	76	46.6%	163
Marital status					
Single	51	40.8%	74	59.2%	125
Domestic Partnership	8	38.1%	13	61.9%	21
Married	72	**60%**	48	40%	120
Separated	16	36.4%	28	63.6%	44
Widower	3	14.3%	18	**85.7%**	21
Alone					
Yes	4	6.6%	57	**93.4%**	61
No	148	54%	126	46%	274
Family and Relatives					
Yes	140	**56.9%**	106	43.1%	246
No	8	34.8%	15	65.2%	23
Others in need of Assistance					
Yes	62	**66.7%**	31	33.3%	93
No	86	48.9%	90	51.1%	176
Security Zones					
Yes	66	**60%**	44	40%	110
No	85	38.3%	137	61.7%	222
Emergency Plan					
Yes	39	**57.4%**	29	42.6%	68
No	109	42.2%	149	57.8%	258
Previous Earthquakes Property Damage					
Yes	59	**59%**	41	41%	100
No / Very Little	69	38.5%	110	61.5%	179
Previous Earthquakes Injured					
Yes	38	**59.4%**	26	40.6%	64
No / Very Little	111	41.9%	154	58.1%	265

Table 3.5: Social Behavior and Help to Others (*continued*)

	Helped		Did not Help		N
	n	%	*n*	%	
Fear					
Very Little	4	18.2%	18	**81.8%**	22
Weak	5	26.3%	14	**73.7%**	19
Moderate	16	32%	34	68%	50
Strong	63	**52.5%**	57	47.5%	120
Very Strong	63	**51.2%**	60	48.8%	123
Prepared					
No	60	40.5%	88	59.5%	148
Very Little	69	56.1%	54	43.9%	123
Moderate	18	35.3%	33	64.7%	51
Prepared	5	45.5%	6	54.5%	11
Perfectly prepared	0	0%	1	100%	1
Safe					
Nothing	35	**56.5%**	27	43.5%	62
Very Little	64	**53.8%**	55	46.2%	119
Moderate	38	34.5%	72	65.5%	110
Safe	8	26.7%	22	73.3%	30
Perfectly safe	3	50%	3	50%	6
MMI					
IV	9	**69.2%**	4	30.8%	13
V	53	38.4%	85	61.6%	138
VI	90	50%	90	50%	180
VII	0	0%	4	100%	4

3.1. Aftershock Response

The Pichilemu earthquake had a magnitude of Mw 6.9 (USGS, 2010) and is well remembered for being the most powerful event following the 27F earthquake. It occurred on March 11 at 11:39 am local time during the presidential inauguration ceremony and is commonly referred as the “presidential inauguration ceremony aftershock”. Therefore, even though it proved to be a separate seismic event, it will be referred to as “aftershock” from now on to clearly distinguish it from the main earthquake.

When the shaking began, most of the participants reported being inside a building (40%), or inside a public space (19%). Almost all the participants felt the movement (80%), the 73 (20%) who did not where mostly inside a car or using public transportation, and most participants reported being highly familiar (67%) with the place they were.

In comparison to the main shock, the level of fear during the aftershock was lower, most people reported a level of 6 (19%) on a scale from 1 to 10, with an average fear level of 5.5. Although, people reported being more prepared than they were for the earthquake, the differences were small. A similar pattern was observed in terms of how safe they felt. The most common initial reactions were to stay still (46%), seek shelter under a doorway (9%), and open doors/windows (9%).

When participants were asked to select all the actions they engage in during the aftershock, the most reported actions were remaining still (53%), opening doors/windows (27%), leaving the room (23%) and helping others (20%). On average, each respondent performed 1.94 actions.

Among the participants that were inside and felt the shaking, only a small number (26%) attempted to evacuate the structure, and very few of them were successful (4%). During the movement, those who attempted to evacuate did it with others (44%), while only 19 (27%) did it alone, suggesting that people tend to evacuate in groups. Additionally, 57 (20%) reported helping others, a proportionally smaller number than during the 27F earthquake implying that intensity, physical and social context are factors that also impact social behavior during earthquakes. However, compared to the main earthquake, people behaved more passively, engaging in total in a lower number of actions during the shacking indicating that context and intensity can significantly influence behavior.

Table 3.6: First Reaction to the Aftershock

		n	%
Fight	Open doors/windows	24	9%
	Help others	19	7%
	Turn off fire/gas	4	2%
Flight	Leave the room	14	5%
	Leave the apartment	18	7%
	Leave the building	16	6%
Seek for shelter	Seek shelter under doorway	24	9%
	Seek shelter under furniture	1	0.4%
Freeze	Stay still	122	46%
Not recommended/ dangerous actions	Get dressed/change clothes	2	0.8%
	Hold furniture	7	3%
Other	Keep driving	3	1%
	Stop the car	6	2%
		260[1]	**100%**

[1]4 (1.52%) answer “don’t know/don’t answer”

4. INTENSITY MEASURES IN SURVEYED BUILDINGS

Earthquake engineering has evolved from a primary focus on prevention of collapse strategies to adopting a performance-based approach. The current emphasis is on developing new, more reliable codes that enable the assessment of structural performance under various scenarios (Günay and Mosalam, 2013). This approach explicitly incorporates the impact of human casualties and monetary losses for a given seismic performance of the building. To obtain realistic results, it is crucial to understand how people behave and interact with the structure during the earthquake. Therefore, to integrate seismic performance into the behavioral analysis conducted through the previously presented survey, this study utilized an approximate model for each structure (Miranda, 1999; Miranda and Taghavi 2005) and ground motions data from the SIBER-RISK database (Castro, 2020) to estimate floor displacement and acceleration demands of the buildings. The seismic records were scaled and selected using Conditional Spectrum (Lin et al., 2013) as a target for the selection process, which was constructed using data recorded during the 2010 Maule earthquake to estimate the spectral acceleration at the conditioning period.

Miranda's (1999) methodology estimated the dynamic properties of a multistory building using an equivalent continuous simplified model that represents the building as a combination of two cantilever beams: a shear beam and a flexural beam connected to each other by an infinite number of axially rigid elements that ensure both beams experience the same lateral deformation (Figure 4.1). Therefore, when subjected to horizontal acceleration at the base, the system's response is given by Equation (4.1).

$$\rho(x)\frac{\delta^2 u(x,t)}{\delta t^2}+c(x)\frac{\delta u(x,t)}{\delta t}+\frac{1}{H^4}\frac{\delta^2}{\delta x^2}\left(EI(x)\frac{\delta^2 u(x,t)}{\delta x^2}\right)-\frac{1}{H^2}\frac{\delta^2}{\delta x^2}\left(GA(x)\frac{\delta u(x,t)}{\delta x}\right)=-\rho(x)\frac{\delta^2 u_g(t)}{\delta t^2} \tag{4.1}$$

where $\rho(x)$ is the mass per unit length; $c(x)$ the damping coefficient per unit length; H the total heigh of the cantilever beam (height above ground of the building); $EI(x)$ the flexural rigidity of the flexural beam; $GA(x)$, the shear rigidity of the shear beam; $u(x,t)$ the lateral displacement at nondimensional height x ($x = 0$ at the base of the building and $x = 1$ at the roof); and $u_g(t)$ the ground displacement at time t. Therefore, assuming a uniform variation of stiffness, mass and damping coefficient along the height of the building when subjected to a horizontal acceleration at the base, the response of the system is given by:

$$\frac{\rho}{EI_0}\frac{\delta^2 u(x,t)}{\delta t^2}+\frac{c}{EI_0}\frac{\delta u(x,t)}{\delta t}+\frac{1}{H^4}\frac{\delta^4 u(x,t)}{\delta x^4}-\frac{\alpha_0^2}{H^4}\frac{\delta^2 u(x,t)}{\delta x^2}=-\frac{\rho}{EI_0}\frac{\delta^2 u_g(t)}{\delta t^2} \tag{4.2}$$

where EI_0 and GA_0 are the flexural and shear rigidity at the base of the structure, respectively and α_0 is a dimensionless parameter that define the model stiffness level by controlling the participation between the flexural and shear deformations given by Eq. 4.3:

$$\alpha_0 = H\left(\frac{GA_0}{EI_0}\right)^{1/2} \tag{4.3}$$

Considering a linear elastic behavior, the displacement and acceleration in each story can be determined as the superposition of the response of m modes of vibration (Equations (4.4) and (4.5)).

$$u(x,t) = \sum_{i=1}^{m} u_i(x,t) = \sum_{i=1}^{m} \Gamma_i \phi_i(x) D_i(t) \tag{4.4}$$

$$\ddot{u}^t(x,t) \cong \ddot{u}_g(t) + \sum_{i=1}^{m} \Gamma_i \phi_i(x) \ddot{D}_i(t) \tag{4.5}$$

with $D_i(t)$ and $\ddot{D}_i(t)$, the deformation response and the relative acceleration of the *i*th mode of a single degree of freedom system; Γ_i is the participation factor of the *i*th mode of vibration; and $\phi_i(x)$ is the amplitude of the *i*th mode shape of vibration at nondimensional height x; and $\ddot{u}_g(t)$ is the ground motion acceleration.

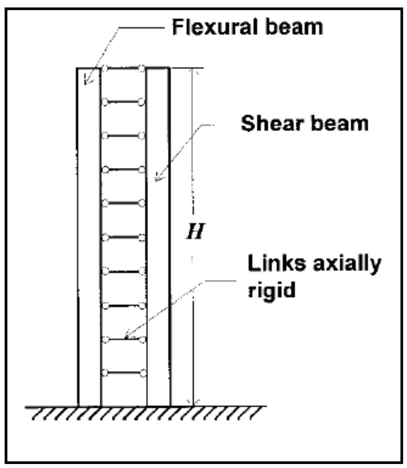

Figure 4.1: Simplified Model of Multistory Building
Source: Miranda, 1999

4.1. Calibration of Building Demand Parameters and Ground Motion Records

Chile is a country with important levels of seismicity (Ruiz and Madariaga, 2018), which has been incorporated in the Chilean design codes with strict requirements for the seismic design of buildings (INN, 1996; INN, 2008; MINVU, 2011). As a result, typical residential buildings in the country consist of a shear wall system structure with five or more stories, characterized by a high density of reinforced concrete shear walls per unit area to withstand seismic forces (Wood et al., 1987; Güendelman et al., 2010). Various approximate rules have been developed to estimate the fundamental period of vibration (T_n) for such buildings. One widely used expression is $T_n \approx N/20$ (Midorikawa, 1990), while the effect of stiffness reduction due to concrete cracking may be estimated by amplifying the previous expression by a factor of $\sqrt{2}$, as summarized in Table 4.1. For this study, the survey was restricted to reinforced concrete shear wall residential buildings with ten or more stories in Santiago, Chile. Therefore, the previously mentioned expressions were used to estimate the fundamental period of vibration for each building. Another critical parameter that requires calibration for the dynamic analysis was the stiffness ratio, α_0, in Miranda's model. For this purpose, a detailed finite element model of a typical Chilean residential building developed in ETABS (Gallardo et al., 2021) was used to calibrate the α_0 parameter resulting in $\alpha_0 = 3.766$. This calibration was performed by minimizing the mismatch in story displacement of the first mode, between the detailed and simplified models. Once Miranda's model was calibrated to represent the buildings under study, a thorough process was carried out to select the seismic records used for response history analyses. The process is summarized next.

A Deterministic Seismic Hazard Analysis (DSHA) was carried out to estimate hazard scenarios consistent with the 2010 Maule earthquake, by using the SeismicHazard software (Candia et al., 2019). The DSHA considers the spectral accelerations in the fundamental periods of vibration of the buildings as Intensity Measures (IMs), and the locations of the 99 buildings, and the 6 seismic stations in Santiago from RENADIC that recorded the earthquake are used for computing seismic scenarios. The DSHA analysis considers the earthquake recurrence model from Poulos et al., (2019) the magnitude scaling model from Strasser et al., (2010) two Ground Motion Models (GMMs), namely Zhao et al., (2006) and Montalva-Bastías (Montalva, 2017), the spatial correlation model from Goda (Goda and Atkinson, 2010), and the interperiod correlation model from Candia et al., (2020). In principle, this DSHA analysis should consider the locations of all the buildings and seismic stations, as well as the spectral accelerations at their fundamental period of vibration. However, since the goal of this study is to develop a simple yet accurate methodology to estimate what happened during the earthquake, in terms of the expected value and variance of the peak floor displacements and accelerations of the buildings, some simplifications were considered in order to avoid introducing artificial variability.

First, the DSHA analysis was simplified by reducing the number of sites under consideration. One of the most important parameters in the Ground Motion Models (GMMs) used in DSHA is a source-to-site distance metric. Given that the epicenter of the Maule earthquake was located 330 km southwest of Santiago (Ruiz and Madariaga, 2018), and all the studied buildings are located inside the city, the variability introduced by the location of the buildings may be neglected, since this distance metric would change just by a few kilometers, which is considerably lower than the error in this distance estimation and its effect on IMs. Therefore, the centroid of the locations of all buildings is considered representative for all of them, reducing the number of sites from 105 (99 buildings + 6 seismic stations) to 7 (1 building centroid + 6 seismic stations) for each vibration period.

Second, shear wave velocity V_{S30} is another important parameter in GMMs, used as a proxy to consider local amplification due to soil type, and a V_{S30} value must be assigned to each site considered in the DSHA, i.e., the 6 seismic stations and the centroid of all buildings. For the former, the actual V_{S30} values informed by RENADIC are used, while for the latter, one or more shear wave velocity values must be considered to accurately represent the buildings under study, which would imply duplicating the site for each considered V_{S30}. However, all buildings have essentially the same soil type and no important variability was observed in V_{S30}values, except for some outliers, as shown in

Figure 4.2. Therefore, a single average value of $V_{S30} = 535$ m/s was considered representative for all buildings and assigned to the centroid of their geographical locations.

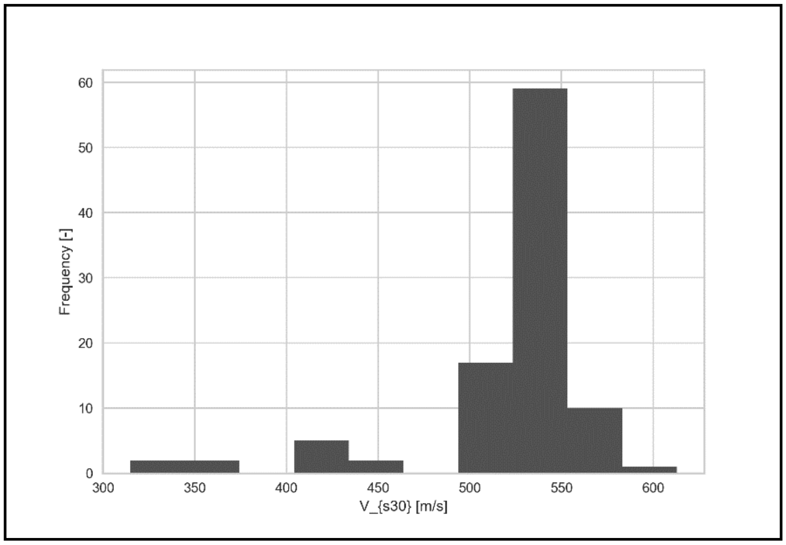

Figure 4.2: Histogram of shear wave velocity values for all studied buildings

Third, another important parameter when defining a Conditional Spectrum is the conditioning period. Since this study considers buildings with different number of stories, there is an important variability in the fundamental periods of vibration, which are estimated as stated earlier. Naturally, it is not desirable to have one set of ground motions for each building, because it would be difficult to compare results. Thus, the buildings are classified using k-means clustering, based on their vibration periods. Therefore, two clusters of buildings were obtained, with representative periods of $T_{01} = 0.8$ sec. and $T_{02} = 1.6$ sec. The DSHA considered the spectral acceleration at those two vibration periods as intensity measures.

With the simplifications mentioned earlier, a DSHA was carried out, considering 10,000 simulations, and a multivariate lognormal distribution was fitted to the generated set of IM realizations, which adequately captures spatial and interperiod correlations. This surrogate model may be used for easily obtaining new realizations of seismic scenarios in the sites under study. Note that the multivariate lognormal distribution generates a vector with 14 components, there are 7 sites (6 seismic stations and 1 building centroid) and two vibration periods for each one of them. Then, data obtained from the seismic stations was used to constrain the multivariate lognormal distribution. The spectral accelerations at vibration periods T_{01} and T_{02} computed from the 2010 Maule earthquake records of the seismic stations in Santiago were used to obtain a conditional multivariate lognormal distribution for the centroid of all buildings in the two vibration periods considered. This effectively reduces the dimension of the generated vectors from 14 to 2, because components used for conditioning correspond to the 6 seismic station sites and the 2 vibration periods for each one of them. The exponential of the mean value of log (IM) of the conditional distribution was used as an estimation of the seismic intensity experienced by the buildings during the earthquake in the two vibration periods of interest. Finally, the estimated spectral accelerations were used to build a Conditional Spectrum (CS) at the centroid of the buildings for each vibration period, and a set of ground motion records from the SIBER-RISK database (Castro, 2020) was selected for each target CS, as explained (Baker and Lee, 2017), with scaling factors limited between 0.25 and 4.00.

Hence, two different selections of ground motion records were carried out. Both of them considered the same location (centroid of all buildings) and soil type (V_{S30}), but the conditioning period was different for each group, as may be appreciated in Figure 4.3. Each building was analyzed with all the records assigned to its group, and peak responses were recorded for interstory drifts and story total accelerations.

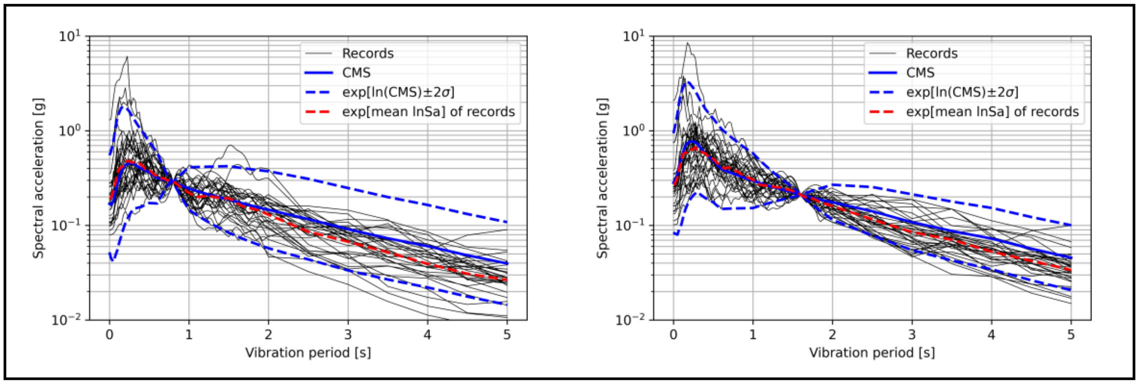

Figure 4.3: Response spectra of the selected seismic records for a vibration period of 0.8 s (left) and 1.6 s (right), and conditional spectrum in each case.

Lastly, employing Miranda's approximate methodology, building lateral displacements and accelerations were calculated. Each building was represented by its number of stories N, and a constant interstory heigh equal to 2.7 meters was assumed. Thus, the height above the ground level was estimated as $H = 2.7 \times N$, and its period by $T_n = N/20$. Table 4.1 presents the different buildings analyzed which are reduced to a sample of 18 given their number of stories. Figure 4.4 illustrates a typical lateral displacement and acceleration for $N = 15$.

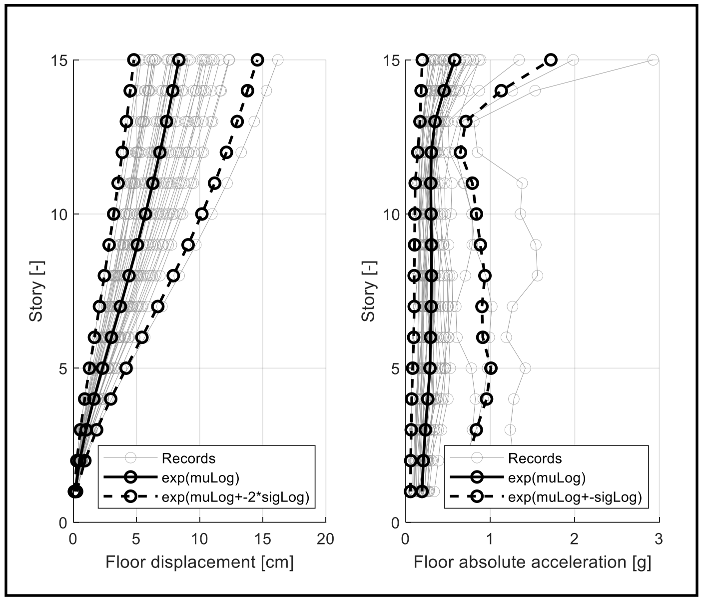

Figure 4.4: Building lateral displacement and acceleration for $N = 15$

Table 4.1: Building Demand Parameters

No. Stories N	Roof Height[1] $2.7 \times N$ [m]	Approx. Period[2] $N/20$ [s]	"Cracked" Period $\sqrt{2} \times N/20$ [s]	Max. IDR
10	27	0.500	0.707	0.00257
11	29.7	0.550	0.778	0.00277
12	32.4	0.600	0.849	0.00279
13	35.1	0.650	0.919	0.00273
14	37.8	0.700	0.990	0.00266
15	40.5	0.750	1.061	0.00262
16	43.2	0.800	1.131	0.00273
17	45.9	0.850	1.202	0.00372
18	48.6	0.900	1.273	0.00384
19	51.3	0.950	1.344	0.00403
20	54	1.000	1.414	0.00405
21	56.7	1.050	1.485	0.00409
22	59.4	1.100	1.556	0.00404
23	62.1	1.150	1.626	0.00397
24	64.8	1.200	1.697	0.00397
25	67.5	1.250	1.768	0.00400
26	70.2	1.300	1.838	0.00384
29	78.3	1.450	2.051	0.00371

[1]Assuming an interstory height constant and equal to 2.7 meters
[2]Using Wood et al., (1987)

4.2. Correlation Between Earthquake Demands Parameters (EDP), and Behavior

By incorporating the displacement and acceleration demand in each of the buildings, it becomes possible to examine their association with various factors related to earthquake experience of the interviewed people. These are scalar data sets that do not follow a normal distribution. Therefore, the Kruskal-Wallis test (Kruskal and Wallis, 1952) was used to assess the statistical significance using the SPSS software. In summary, the analysis revealed only one significant relationship: apartment floor displacement was associated with people turning off gas/fire as secondary actions ($\rho = 0.013$). The box plot of Figure 4.5 provide a graphical representation of this result.

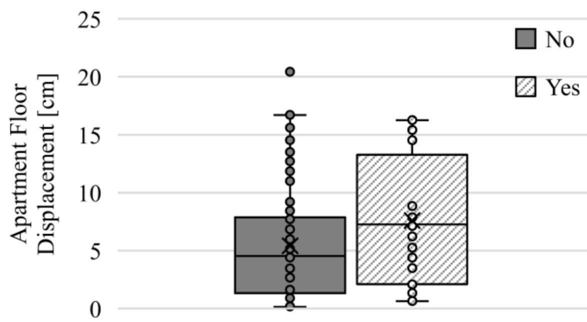

Figure 4.5: Boxplot for Turn of Gas/Fire during the Earthquake

5. DISCUSSION

Despite the respondents being Chileans with previous earthquake experience, they reported low levels of preparedness and lack of knowledge about official recommendations. They did not know the safety zones of the building, and did not have an emergency plan, though, most of those who had participated in drills had done it before 2005.

Higher levels of fear were associated not only with the physical context (higher MMI, shaking intensity, difficulty standing, perceived duration and noise), but with participant demographic characteristics such as being female, the social context (not being alone), and risk perception (feeling unprepared and unsafe during the earthquake).

Response time was directly related to the level of preparation, including previous drill participation, knowledge of official recommendations, and having a household or family emergency plan, highlighting the importance of earthquake education.

Evacuation behavior was negatively influenced by social factors (being with someone in need of assistance) and the level of preparation (knowledge of official recommendations). On the contrary, higher levels of reported noise and fear, increased the probability of evacuation.

Helping behavior increases according to participants demographic characteristics (being male and married), their social context (being with others, family and relatives and someone in need of assistance), past experiences (injuries and property damage), higher levels of fear, and preparation (knowledge of security zones and having an emergency plan). The probability of helping others also increased as participants reported less damage to the surroundings (lower MMI) and felt less secure, most likely because they perceived it as more necessary and, at the same time, more feasible to provide the assistance.

Regarding the relationship between building earthquake demand parameters and behavior, only floor displacement was found to be more significant, specifically in relation to turning off gas or fire. The other EDPs had very similar values, which may explain the lack of significant differences in behavior. To effectively analyze their influence, it would be beneficial to extend the study by including other earthquakes, or incorporating buildings located in different cities to capture varying levels of shaking intensity.

5.1. Behavior During the Earthquake

During the earthquake, people exhibited a highly active response, with an average of 2.9 actions engaged per respondent. Opening doors or windows was the most selected first action (17%), and it was also reported by a significant majority as one of the actions taken later, along with leaving the room, helping others, seeking shelter under a doorway, and getting dressed or changing clothes. Even those who initially sought shelter or froze engaged in other activities while the shaking lasted. Additionally, helping others was one of the most selected options both initially and later, confirming that behavior during earthquakes is predominantly rational and adaptive, with individuals acting in accordance with social norms and expectations.

Table 5.1 provides an overview of all the actions taken by respondents during the earthquake, highlighting the relationship between their initial and subsequent actions. Each column represents the first response to the shaking, while the rows display all the other following actions. Therefore, the values on the diagonal represent the percentages of respondents who took that first action, while the percentage in the other cells represents the number of people who took the row action after performing the corresponding first action.

During the aftershock the response was less active, the average number of actions per respondent was 1.94 and almost half of the respondents reported their first action as remaining still. Additionally, a smaller group of people reported helping others during the shaking, showing, that behavior during earthquakes is influenced by both the social and the physical context.

Table 5.1: Actions During the Earthquake

First Reaction/ Other Actions		Fight			Not Recommended Dangerous		Flight			Seek shelter		Freeze
		Open doors windows	Turn off gas/fire	Help others	Get dress/ Change clothes	Hold furniture	Leave room	Leave apartment	Leave building	Under furniture	Under doorway	Stay still
Fight	Open doors windows	**17%**	**100%**	44%	**51%**	19%	**47%**	31%	-	-	33%	18%
	Turn off gas/fire	13%	1.8%	24%	23%	6%	8%	-	-	-	8%	2%
	Help others	45%	**67%**	16%	40%	**44%**	45%	31%	-	-	23%	18%
Not Recommended Dangerous	Get dress/ Change clothes	25%	33%	27%	10%	31%	16%	25%	-	-	15%	12%
	Hold furniture	16%	17%	11%	6%	4.8%	8%	6%	-	-	3%	6%
Flight	Leave room	**61%**	**50%**	71%	40%	31%	**15%**	**50%**	**100%**	-	**48%**	24%
	Leave apartment	23%	-	16%	20%	-	16%	4.8%	**100%**	-	8%	10%
	Leave building	5.4%	-	1.8%	2.9%	-	6.1%	19%	0.3%	-	-	4.1%
Seek shelter	Under furniture	-	-	5.5%	-	-	4.1%	-	-	0.6%	-	-
	Under doorway	30%	**33%**	**45%**	20%	6%	**47%**	19%	-	**50%**	12%	6%
Freeze	Stay still	25%	17%	5%	6%	**38%**	12%	-	-	**50%**	20%	**15%**

5.2. Predictive factors of behavior

One important purpose of this study is to investigate people's behavior during earthquakes and the factors that impact the different responses. As explained in section 2, five behaviors were characterized according to the nature of the action carried out by the participants: (1) fight, (2) flight, (3) seek shelter, (4) wait, and (5) not recommended/dangerous actions. Therefore, five separate Binary Logistic Regression analyses were executed to assess the relationships between respondents' distinct characteristics and their reaction to the earthquake.

Even though the bivariate analysis provides a first general idea of the variables that influence behavior, different studies suggest that relying only on this criterion is not recommended (Heinze and Dunkler, 2017; Sun, Shook and Kay, 1996). Recommending expert judgment, existing studies, and statistical techniques like backward elimination. Backward elimination is a method of fitting regression models which starts with all possible predictors (independent variables) in the model and remove one by one the least statistically significant (largest p-value) until all remaining variables have significant p-value or until a predetermined stopping criterion is reached.

A concept used to assure balance and reliability to a statistical model is the event per variable ratio (EPV). EPV refers to the ratio between sample size (number of events or positive outcomes in binary logistic regression) to the number of predictors and however there are different guidelines, a number between 10 to 20 is commonly accepted.

The Bayesian Information Criteria (BIC) was used as a model selection tool to select the more consistency model (Schwarz, 1978).

$$\mathrm{BIC} = -2\ln L + \ln(n)\,k \tag{5.1}$$

Where L is the likelihood of the model, k the number of independent variables and n the sample size or number of events in binary logistic regression. The model with the minimum value of BIC is selected.

Finally, as information is being sought to calibrate computational models, one crucial factor to evaluate in regression models is their predicted accuracy, which is the ratio between the number of correct predictions made by the model and the total number of predictions. This allows to determine the model's performance and evaluate its predictive capabilities.

Binary Logistic Regression for Fight Behavior

The variables that were found to have a significant association with fight behavior during the earthquake were not being alone, being in the presence of family and relatives, not being with friends and neighbors, being with someone who require assistance, their level of fear experienced and how safe they felt. Considering only these variables to initiate the Logistic Regression analysis provides the following Model 1.1 (Table 5.2)

Table 5.2: BLR Fight Behavior Model 1.1

Variable	β	Standard Error	Sig.	OR	95% CI	
Family and Relatives	1.199	0.653	0.066	3.318	0.922	11.937
Required Assistance	**0.933**	0.274	**<0.001**	2.541	1.486	4.348
Fear	0.286	0.127	**0.024**	1.332	1.039	1.707
Constant	-3.067	0.840	**<0.001**	0.047		

-2LL = 325.408
Hosmer-Lemeshow: χ^2 = 1.361 / p-value = 0.987
Accuracy = 65.1%

With the EPV,

$$EPV_{fight}^{1.1} = \frac{117}{3} = 39 \quad (5.2)$$

and,

$$BIC_{fight}^{1.1} = 325.408 + 3 * \ln(117) = 339.695 \quad (5.3)$$

Also, the initial global model considering all the 25 independent variables is presented in Table 5.3

Table 5.3: Initial Model for Backward Elimination – Fight Behavior

Variable	β	Standard Error	Sig.	OR	95% CI	
Gender (Male)	0.746	0.448	.096	2.108	0.876	5.074
Age	0.103	0.190	0.590	1.108	0.763	1.609
Marital Status (Single)			0.643			
Domestic Partnership	-1.402	1.148	0.222	0.246	0.026	2.337
Married	0.331	0.533	0.535	1.392	0.489	3.959
Separated	0.061	0.646	0.925	1.063	0.300	3.767
Widower	-0.007	1.186	0.995	0.993	0.097	10.142
Apartment Floor	-0.051	0.100	0.611	0.950	0.781	1.156
Apt. Floor Level	-0.43	0.601	0.943	0.958	0.295	3.110
Familiarity	0.027	0.238	0.908	1.028	0.645	1.638
Family and Relatives	1.478	1.253	0.238	4.383	0.376	51.036
Friends and Neighbors	-0.090	0.888	0.919	0.914	0.160	5.204
Required Assistance	1.480	0.434	<0.001	4.392	1.877	10.278
Drills Before 2005	0.044	0.469	0.925	1.045	0.417	2.618
Drills After 2005	-0.208	0.494	0.674	.813	0.309	2.138
Building Security Zones	0.855	0.582	0.142	2.352	0.751	7.362
Official Recommendations	-1.197	0.628	0.057	0.302	0.088	1.034
Emergency Plan	0.056	0.537	0.916	1.058	0.370	3.028
Previous Earthquakes	-0.516	0.480	0.283	.597	0.233	1.531

Table 5.4: Initial Model for Backward Elimination – Fight Behavior *(Continued)*

Variable	β	Standard Error	Sig.	OR	95% CI	
Previous Earthquake Property Damage	0.197	0.537	0.714	1.217	0.425	3.485
Previous Earthquake Injuries	-0.884	0.720	0.220	0.413	0.101	1.694
Shaking Intensity	0.375	0.456	0.411	1.455	0.596	3.553
Difficult Standing	-0.221	0.266	0.407	.802	0.476	1.351
Duration	0.160	0.299	0.592	1.174	0.653	2.109
Noise	0.511	0.347	0.141	1.667	0.844	3.292
Fear	0.310	0.243	0.201	1.364	0.847	2.196
Prepared	0.714	0.336	0.033	2.042	1.058	3.943
Safe	-0.332	0.270	0.219	0.717	0.422	1.218
MMI	0.172	0.430	0.688	1.188	0.512	2.757
Constant	-8.563	0.100	0.611	0.950	0.781	1.156

-2LL = 173.036

Hosmer-Lemeshow: χ^2 = 6.533 / p-value = 0.588

Accuracy = 61.0%

Using backward elimination, Model 1.2 is obtained (Table 5.5).

Table 5.5: BLR Fight Behavior Model 1.2

Variable	β	Standard Error	Sig.	OR	95% CI	
Required Assistance	**1.277**	0.357	**<0.001**	3.587	1.780	7.226
Building Security Zones	0.975	0.480	**0.042**	2.651	1.035	6.791
Official Recommendations	-0.937	0.488	0.055	0.392	0.151	1.019
Noise	0.477	0.236	**0.043**	1.612	1.015	2.561
Constant	-3.078	1.088	0.005	0.046		

Initial -2LL = 173.036 / Final -2LL = 192.505
Hosmer-Lemeshow: χ^2 = 8.797 / p-value = 0.268
Accuracy = 71.7%

From the data collected, for fight behavior the event per variable is obtain (Eq. 5.4) suggesting the model is reliable and stable in terms of the number of predictors.

$$EPV_{fight}^{1.2} = \frac{117}{4} = 29.25 \qquad (5.4)$$

And,

$$BIC_{fight}^{1.2} = 192.505 + 4 * \ln(117) = 211.554 \qquad (5.5)$$

Considering $BIC_{fight}^{1.2} < BIC_{fight}^{1.1}$ is possible to affirm that Model 1.2 is better. Therefore, being in the presence of someone who may require assistance, know the building security zones, and the perceived noise are significant as predictors of fight behavior during earthquakes. The strongest relation is being in the presence of someone who required assistance (predictor that also appears as significant in the first model) and, even when the variable is not statistically significant ($\mathrm{p-value} = 0.055$), knowing official recommendations would reduce the probability of engaging in fight behavior according to the obtained model. Finally, the percentage of accuracy in classification of the model is 71.7%.

Binary Logistic Regression for Flight Behavior

Knowing the recommendations from any official entity on how to behave during an earthquake. the security zones of the building and having an emergency plan along with being with friends, neighbors, family and relatives proved to be sufficiently robust as possible predictors for flight behavior. Table 5.6 displays the model obtained by performing backward elimination, using the variables mentioned as starting point in the BLR.

Table 5.6: BLR Flight Behavior Model 2.1

Variable	β	Standard Error	Sig.	OR	95% CI	
Friends and Neighbors	1.283	0.418	**0.002**	3.606	1.590	8.179
Official Recommendations	**1.076**	0.340	**0.002**	2.933	1.506	5.710
Constant	-1.972	0.251	<0.001	0.139		

Initial -2LL = 237.985 / Final -2LL = 239.650
Hosmer-Lemeshow: χ^2 = 0.536 / p-value = 0.464
Accuracy = 81.2%

With, the EPV

$$EPV_{flight}^{2.1} = \frac{66}{2} = 33 \tag{5.6}$$

and BIC

$$BIC_{flight}^{2.1} = 239.650 + 2 * \ln(66) = 248.029 \quad (5.7)$$

Beginning with the same 25 independent variables and applying backward elimination, the resulting model is presented in Table 5.7.

Table 5.7: BLR Flight Behavior Model 2.2

Variable	β	Standard Error	Sig.	OR	95% CI	
Gender	-0.813	0.489	0.097	0.443	0.170	1.157
Marital Status (Single)			0.728			
Domestic Partnership	-19.793	14,726.207	0.999	0.000	0.000	.
Married	-0.502	0.495	0.310	0.605	0.229	1.596
Separated	-19.973	8,031.384	0.998	0.000	0.000	.
Widower	0.799	1.050	0.447	2.222	0.284	17.404
Familiarity	-0.401	0.232	0.084	0.670	0.425	1.056
Official Recommendations	**1.227**	0.491	**0.013**	3.411	1.302	8.936
Duration	0.496	0.308	0.108	1.642	0.897	3.005
Constant	-1.503	1.551	0.333	0.223		

Initial -2LL = 102.219 / Final -2LL = 118.332
Hosmer-Lemeshow: χ^2 = 3.753 / p-value = 0.879
Accuracy = 84.3%

The ratio events per variable

$$EPV_{flight}^{2.2} = \frac{66}{5} = 13.2 \quad (5.8)$$

and BIC

$$BIC_{flight}^{2.2} = 118.332 + 5 * \ln(66) = 139.28 \quad (5.9)$$

Even though the BIC value of the second model is lower than that of the first model, we can also observe that in the first model, both predictors are statistically significant, while in the second model, only one out of five is. Although the lack of significance of a variable does not exclude the possibility of it having an important effect on the model when combined with others, in this case, due to the small sample size (66), a larger amount of data would be needed to accurately estimate its behavior.

Additionally, both the bivariate analysis and the two models suggest that participants who reported being aware of official recommendations on how to respond during earthquakes were most likely to engage in flight behavior as their first reaction. Theoretically, this finding is counterintuitive, as flight behavior is not a recommended response in Chile, highlighting the necessity to expand the study to gather more data for achieving reliable predictions.

Binary Logistic Regression for Seek for Shelter

From the crosstabulation analysis seeking shelter during the earthquake was found to be associated with participant's marital status, whether they were alone, and their experience with injuries in previous earthquakes.

Table 5.8: BLR Seek for Shelter Model 3.1

Variable	β	Standard Error	Sig.	OR	95% CI	
Alone	1.148	0.376	**0.002**	3.152	1.508	6.586
Constant	-2.316	0.219	<0.001	0.099		

Initial -2LL = 212.970 / Final -2LL = 219.370
Hosmer-Lemeshow: χ^2 = 0.000 / p-value = -

$$EPV_{shelter}^{3.1} = \frac{42}{1} = 42 \quad (5.10)$$

$$BIC_{shelter}^{3.1} = 219.370 + 1 * \ln(42) = 223.108 \quad (5.11)$$

As seen in Table 5.8, the Chi-square statistic of the fitted model has a value of zero, which means that the model fits the observed data perfectly. However, considering that the number of positive events for seek for shelter is small, it rather suggests that there is an issue with the model that requires cautious review.

Following the same procedure as in previous cases, the resulting model by initially entering all the independent variables to the regression is presented in Table 5.9.

Table 5.9: BLR Seek for Shelter Model 3.2

Variable	β	Standard Error	Sig.	OR	95% CI	
Apt. Floor Level	-0.810	0.429	0.059	0.445	0.192	1.031
Previous Earthquake Property Damage	1.467	0.639	**0.022**	4.337	1.241	15.164
Duration	-1.001	0.450	**0.026**	0.368	0.152	0.888
Noise	-0.816	0.362	**0.024**	0.442	0.218	0.898
Prepared	-1.182	0.480	**0.014**	0.307	0.120	0.785
Constant	7.476	2.756	0.007	1,764.329		

Initial -2LL = 58.375 / Final -2LL = 79.834
Hosmer-Lemeshow: χ^2 = 21.036 / p-value = 0.007
Accuracy = 92.5%

The ratio events per variable

$$EPV_{shelter}^{3.2} = \frac{42}{5} = 8.4 \quad (5.12)$$

and BIC

$$BIC_{shelter}^{3.2} = 79.834 + 5 * \ln(42) = 98.522 \quad (5.13)$$

Significant variables when seeking for shelter include experienced property damage during previous earthquakes, a shorter duration of the shaking, a lower noise perception and feeling less prepared. However, the sample size problem persists, with $EPV_{shelter}^{3.2} = 8.4 < 10$ confirming the need to increase sample size to achieve accurate predictions.

Binary Logistic Regression for Freeze Behavior

For freeze behavior, the explicatory variables used to start the Logistic Regression for the first model were being with someone in need of assistance, the Modified Mercalli Intensity (MMI), the level of fear and safety. Results are presented in Table 5.10.

Table 5.10: BLR Freeze Behavior Model 4.1

Variable	β	Standard Error	Sig.	OR	95% CI	
Required Assistance	-1.083	0.481	**0.024**	0.339	0.132	0.869
Fear	-0.380	0.165	**0.022**	0.684	0.495	0.946
Safe	0.390	0.221	0.078	1.477	0.958	2.277
Constant	-1.110	1.029	0.281	0.329		

Initial -2LL = 185.524 / Final -2LL = 185.587
Hosmer-Lemeshow: χ^2 = 7.801 / p-value = 0.453
Accuracy = 86.8%

$$EPV_{freeze}^{4.1} = \frac{49}{3} = 16.34 \quad (5.14)$$

$$BIC_{freeze}^{4.1} = 185.587 + 3 * \ln(49) = 197.262 \quad (5.15)$$

And the final model starting with all the predictors is in Table 5.11

Table 5.11: BLR Freeze Behavior Model 4.2

Variable	β	Standard Error	Sig.	OR	95% CI	
Familiarity	1.158	0.415	**0.005**	3.185	1.411	7.188
Family and Relatives	-2.158	0.875	**0.014**	0.116	0.021	0.642
Required Assistance	-1.593	0.659	**0.016**	0.203	0.056	0.739
Building Security Zones	-1.695	0.732	**0.021**	0.184	0.044	0.770
Official Recommendations	1.708	0.642	**0.008**	5.516	1.567	19.420
Fear	-0.544	0.202	**0.007**	0.580	0.391	0.862
Constant	-2.497	1.683	0.138	0.082		

Initial -2LL = 81.238 / Final -2LL = 103.210
Hosmer-Lemeshow: χ^2 = 6.899 / p-value = 0.548
Accuracy = 88.7%

$$EPV_{freeze}^{4.2} = \frac{49}{6} = 8.17 \tag{5.16}$$

$$BIC_{freeze}^{4.2} = 103.210 + 6 * \ln(49) = 126{,}561 \tag{5.17}$$

Once again, due to the limited number of samples available, models obtained are not entirely capable of predicting behavior. However, it is important to note that in both models, being in the presence of individuals in need of assistance emerges as a significant predictor of the absence of freezing behavior, and similar results are observed in relation to the level of fear reported. Therefore, even though it may not be possible to establish a predictive model, these models reveal relationships between variables that enhance our understanding of engaging in freeze behavior during earthquakes.

Binary Logistic Regression for Not Recommended/Dangerous Behavior

No statistically significant relation was found from the bivariate analysis for people taking not recommended or dangerous actions during the earthquake. Table 5.12 presents the final model of the regression when considering all the predictors as starting point.

Table 5.12: BLR Not Recommended/Dangerous Actions

Variable	β	Standard Error	Sig.	OR	95% CI	
Age	-0.284	0.164	0.084	0.753	0.546	1.039
Apartment Floor	0.089	0.044	**0.045**	1.093	1.002	1.192
Family and Relatives	1.844	1.098	0.093	6.319	0.734	54.387
Required Assistance	**-1.043**	0.479	**0.030**	0.352	0.138	0.902
Building Security Zones	**-1.414**	0.590	**0.016**	0.243	0.077	0.772
Constant	-2.324	1.221	0.057	0.098		

Initial -2LL = 119.846 / Final -2LL = 138.090
Hosmer-Lemeshow: χ^2 = 6.994 / p-value = 0.537
Accuracy = 81.1%

$$EPV_{NR/D}^{5} = \frac{51}{5} = 10.2 \qquad (5.18)$$

$$BIC_{NR/D}^{5} = 138.090 + 5 * \ln(51) = 157.749 \qquad (5.19)$$

The apartment floor, the absence of individuals in need of assistance, and lack of knowledge about building safety zones appear to be statistically significant variables in predicting the occurrence of not recommended behavior. Therefore, despite the small sample size $n = 51$, the model obtained appears to effectively explain meaningful relationships between respondents' variables and their behavior during the earthquake.

A comprehensive and detailed analysis of the variables that influence various reactions to the earthquake is presented. Furthermore, preliminary descriptive statistical models are constructed, offering a methodology that, with a larger dataset, has the potential to predict earthquake behavior based on individual demographic characteristics, physical and social context, prior experiences, earthquake education, observed damage, and risk perception

5.3. Further knowledge gaps

Although several studies have analyzed people's behavior during earthquakes, very few of them use statistical methods for data collection allowing their replicability. Consequently, it is essential to continue conducting this type of research to obtain reliable empirical data for calibrating future behavior models.

Moreover, an important gap in existing studies is the absence on cultural diversity, most of them have been carried out in Japan, Italy, and the United States. Therefore, replicating similar studies in other countries or among different ethnic groups can contribute to a more comprehensive understanding of cultural factors that may influence human behavior during earthquakes.

Additionally, it became essential to expand the range of shaking intensities considered, incorporating more geographic locations for the same seismic event or by analyzing data from multiple earthquakes to improve the sensitivity and level of significance of the results.

Furthermore, studying earthquake behavior in areas with post-event tsunami risk becomes crucial to understand how people's evacuation tendencies might change during the shaking.

6. CONCLUSIONS

First, it is important to highlight that this is the first study of this kind to be conducted in Chile. Therefore, it represents an initial contribution to expanding the existing literature aimed at better understanding the cultural factors involved in people's behavior during earthquakes.

Another significant aspect that emerges from this study is that despite Chile being a highly seismic country and participants reported been familiar with ground shaking and earthquakes, they also reported been unprepared, not knowing the security zones of the building, lacking an emergency plan, and not having participated in earthquakes drills after 2005. This reinforces the necessity to elaborate a continuous education plan for earthquake response.

Moreover, one important conclusion that emerges from the statistical analysis is that behavior during earthquakes is mostly determined by the people’s social context and risk perception. Past experiences and observed damage also contribute, but in a limited way.

Finally, three of the most performed actions are directly associated with fight behavior, meaning that even when people reported been scared and poorly prepared, they did not panic. On the contrary, most people displayed an active attitude during shaking, thus confirming the hypothesis that people engage in various actions during the strong motion within the structure and interacting with others. All these are essential aspects to consider when modeling human behavior, specially in places with higher likelihood of having to evacuate due to the potential of a tsunami generated by the earthquake.

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APPENDIX

A. QUESTIONNAIRE (ENGLISH VERSION)

QUESTIONNAIRE
DEVELOPMENT AND IMPLEMENTATION OF A HUMAN-INFRASTRUCTURE INTERACTION MODEL UNDER SEISMIC LOAD

INTRODUCTION

(Informed Consent Letter): Thank you for participating in this study. First of all, I will read you the Informed Consent Letter that specifies the details of the study and your rights regarding the privacy of the information you will give us.

READ THE INFORMED CONSENT LETTER AND SIGN TWO COPIES: ONE FOR THE PARTICIPANT AND THE OTHER FOR THE INTERVIEWER.

PART 1: PHYSICAL AND SOCIAL CONTEXT

To start I will ask you some questions about the place you were and the people that where with you at the time of the earthquake.

Q1.1 Where you inside this apartment at the time of the February 27th 2010, earthquake?

1	Yes
2	No, I was inside another apartment → Go to question Q1.3
3	No, I was inside a house or another place at ground level → **END SURVEY**
8	Don’t know
9	Don’t answer

Q1.2 Since what year do you live in this apartment?

I lived in this apartment since year:

Q1.3 How familiar where you with the apartment you were in?

1	Nothing, it was my first time in the apartment
2	Very little, it was not my first time, but I do not usually frequent it
3	Moderate, I usually frequent it
4	High
5	Very high, I knew the place for some years
8	Don’t know
9	Don’t answer

Q1.4 On which floor was the apartment you were in during the 2010 earthquake?

Apartment floor:

Q1.5 How many floors have the building you were in during the 2010 earthquake?

Building height:

Q1.6 In which location of Santiago was the building you were in during the 2010 earthquake?

Location (*Comuna*):

Q1.7 What was the exact address of the building you were in during the 2010 earthquake? This data is important to understand how the earthquake was perceived in different parts of the city.

Street:

Number:

Tower:

Apartment number:

Q1.8 How many people where with you inside the apartment at the time of the earthquake?

0 I was alone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14 or more**
→ Go to question Q2.1														

Q1.9 Among those people were:
Select more than one if necessary

1	Your spouse or partner
2	Your father
3	Your mother
4	All your children
5	Some of your children
6	All or some of your grandchildren
7	Friends
8	Neighbors
9	Other people you know
10	Other:
88	Don’t know
99	Don’t answer

Q1.10 Among the people who were with you, did any of them have any type of disability or some mobility impairment?
Select more than one if necessary

1	No
2	Yes, someone with a temporary difficult in movement (physical problem, illness, etc.)
3	Yes, someone who need a cane or a walker
4	Yes, someone who need a wheelchair
8	Don't know
9	Don't answer

Q1.11 Among the people who were with you, were there minors?
Select more than one if necessary

1	No, everyone was older than 18 years
2	Yes, there were children under 18 years old
3	Yes, there were children under 14 years old
4	Yes, there were children under 5 years old
8	Don't know
9	Don't answer

PART 2: EARTHQUAKE REACTION

About your behavior during the February 27th 2010, earthquake.

Q2.1 What was the first thing you tried to do when you notice the movement? It does not matter if you did it or not.

1	Open doors and/or windows
2	Turn off gas/fire from dangerous equipment
3	Help others
4	Get dressed/change clothes
5	Hold furniture or other objects from falling
6	Leave the room
7	Leave the apartment
8	Leave the building
9	Seek shelter under a table or other furniture
10	Seek shelter under a doorway
11	Remain still where I was
88	Don't know
99	Don't answer

Q2.2 Which of the following options best describes what motivated your behavior?
Select more than one if necessary

1	It was the first thing that came to my mind, an instinctive reaction
2	Stayed away from dangerous objects (such as windows, furniture, ornaments, etc.)

3	Help or support people who were around
4	Hold ornaments, objects and/or furniture from falling
5	I followed the behavior of other people who were around
6	I followed the procedures recommended by official institutions (ONEMI, ACHS, Mutual, etc.)
7	I did what I learned during drills at school/work
8	Don't know
9	Don't answer

Q2.3 How long do you estimate it took you to react?

1	Less than a second, I reacted when I first notice the movement
2	A few seconds, it took me a while to react
3	Several seconds, I had a hard time deciding what to do
4	I reacted only when the shaking stops
8	Don't know
9	Don't answer

Q2.4 From the following actions, which one/ones you did DURING the earthquake?

	Yes	**No**	**Don't know**	**Don't answer**
Opened doors and/or windows	1	2	8	9
Turned off gas/fire from dangerous equipment	1	2	8	9
Helped others	1	2	8	9
Get dressed/changed clothes	1	2	8	9
Held furniture or other objects from falling	1	2	8	9
Left the room	1	2	8	9
Left the apartment	1	2	8	9
Left the building	1	2	8	9
Sought shelter under a table or other furniture	1	2	8	9
Sought shelter under a doorway	1	2	8	9
Stayed still where I was	1	2	8	9
I did not take any action	1	2	8	9

Q2.5 Did you left or try to leave the apartment at any time?

1	No, I stayed inside the apartment → Go to question Q3.1
2	Yes, when I first notice the shaking
3	Yes, during the movement
4	Yes, after the shaking stops
8	Don't know
9	Don't answer

Q2.6 Where you were trying to go?

1	I wanted to leave the apartment
2	I wanted to leave the apartment floor
3	I wanted to leave the building
8	Don't know
9	Don't answer

Q2.7 Did you succeed?

1	Yes
2	No
8	Don't know
9	Don't answer

Q2.8 Which of the following options best describes what motivated you to leave the apartment/building?

1	It was the first thing that came to my mind, an instinctive reaction
2	Past experiences in other earthquakes/strong tremors
3	I followed the behavior of other people who were around
4	Stayed away from dangerous objects (such as windows, furniture, ornaments, etc.)
5	Other:
8	Don't know
9	Don't answer

Q2.9 If you left the apartment/building, which of the following options best describes your SPEED?

1	Very slow
2	Slow
3	Moderate
4	Fast
5	Very fast
8	Don't know
9	Don't answer

Q2.10 If you left the apartment/building, did you do it alone or with others?

1	I did it alone
2	I started alone and then other people followed me
3	I started alone and then I followed others
4	I did it with others
5	I started with others and then more people followed us
6	I started with others and then we followed others
8	Don't know
9	Don't answer

Q2.11 Where were you when the shaking stops?

1	Inside the apartment
2	Outside the apartment, at the same floor
3	Going down to the building lobby
4	At the building lobby
5	Outside the building
8	Don't know
9	Don't answer

PART 3: MOVEMENT PERCEPTION

The following questions are about what you were doing at the time of the earthquake and your movement perception

Q3.1 What were you doing when you notice the movement?

1	Sleeping
2	Lying down awake
3	Seated
4	Walking
5	I could not tell
6	Other:
8	Don't know
9	Don't answer

Q3.2 How would you describe the shaking?

1	I did not feel the movement
2	Weak
3	Moderate
4	Strong
5	Very Strong
8	Don't know
9	Don't answer

Q3.3 During the earthquake, did you find it difficult to stayed on foot or move because of the movement?

1	No, I have no problem to stayed on foot
2	Yes, a little
3	Yes, quite a lot
4	Yes, I was unable to stand or move without help
5	Yes, I fell down because of the movement
8	Don't know
9	Don't answer

Q3.4 What was your perceived duration of the movement?

1	A few seconds
2	Less than a minute
3	Between 1 and 3 minutes
4	More than 3 minutes
5	More than 5 minutes
6	Could not say
9	Don't answer

Q3.5 How would you describe the noise?

1	I did not hear any noise
2	Weak
3	Moderate
4	Strong
5	Very Strong
8	Don't know
9	Don't answer

Q3.6 On a scale from 1 to 10, how much fear did you feel during the movement? Where 1 is I did not feel afraid and 10 I felt very scared.

1	2	3	4	5	6	7	8	9	10	88	99
										DK	**DA**

Q3.7 How prepared were you to face an earthquake of the magnitude of the 27F?

1	Nothing, I was not prepared for a movement like that
2	Very Little
3	Moderate
4	Prepared
5	Perfectly prepared
8	Don't know
9	Don't answer

Q3.7 How safe did you feel during the shaking?

1	Nothing, I felt unsafe
2	Very little
3	Moderate
4	Safe
5	Perfectly safe, I never doubted of my safeness
8	Don't know
9	Don't answer

PART 4: OBSERVED DAMAGE

In this section, I will ask you some questions about the damage caused by the earthquake in your environment.

Q4.1 With respect to the following objects that were inside the department, which option best describes what happened to them during the earthquake?

	Did not moved	Rattled Slightly	Rattled Loudly	Some fell off or broke	Don’t know	Don’t Answer
Hanging Objects	1	2	3	4	8	9
China and Glasses	1	2	3	4	8	9
Small Objects and Ornaments	1	2	3	4	8	9
Doors	1	2	3	4	8	9
Windows	1	2	3	4	8	9
Large Furniture	1	2	3	4	8	9

Q4.2 Respect to CARS, which option best describes what happened to them during the earthquake?

1	Did not moved
2	Swung from side to side
3	Swung and the alarms went on
4	I only heard the alarms
8	Don’t know
9	Don’t answer

Q4.3 Respect to the APARTMENT WALLS, which option best describes what happened to them during the earthquake?

1	No damage
2	Some surface cracks in the coating (plaster)
3	Some pieces of coating fell down (plaster)
4	Some pieces of the walls fell down (concrete)
5	Were partially or totally broken
8	Don’t know
9	Don’t answer

Q4.4 Respect to the APARTMENT CEILING, which option best describes what happened to them during the earthquake?

1	No damage
2	Partly cracked
3	Some pieces of the coating fell down (plaster)
4	Some pieces of the ceiling fell down (concrete)
5	Some pieces of the false/suspended ceiling fell down
8	Don't know
9	Don't answer

Q4.5 Respect to BUILDING WALLS, which option best describes what happened to them during the earthquake?

1	No damage
2	Some surface cracks in the coating (plaster)
3	Some pieces of coating fell down (plaster)
4	Some pieces of the walls fell down (concrete)
5	Were partially or totally broken
8	Don't know
9	Don't answer

Q4.6 Respect to BUILDING CEILING, which option best describes what happened to them during the earthquake?

1	No damage
2	Partly cracked
3	Some pieces of the coating fell down (plaster)
4	Some pieces of the ceiling fell down (concrete)
5	Some pieces of the false/suspended ceiling fell down
8	Don't know
9	Don't answer

Q4.7 Which option best describes the BUILDING DAMAGE?

1	No damage
2	Minor Damage
3	Moderate Damage
4	Severe Damage
5	Serious Damage
8	Don't know
9	Don't answer

Q4.8 When the movement began, where you with the lights on?

1	Yes

2	No
3	I could not say
8	Don’t know
9	Don’t answer

Q4.9 Did you suffer a power outage?

1	No
2	Yes, when the movement starts
3	Yes, during the movement
4	Yes, after the movement
5	Yes, but I could not tell when
8	Don’t know
9	Don’t answer

Q4.10 Because of the earthquake, where you or someone you know injured?

1	No
2	Yes, minor injuries
3	Yes, mayor injuries
4	Yes, fatal injuries
8	Don’t know
9	Don’t answer

PART 5: AFTERSHOCK CONTEXT AND REACTION

In this section, the questions are about your behavior during the aftershock of March 11th, 2010.

Q5.1 Where were you at the time of the aftershock?

1	Inside a house
2	Inside a building
3	On the street
4	In an open public space (square, park, etc.)
5	Inside a public space (supermarket, mall, restaurant, etc.)
6	Inside a private vehicle
7	Inside a public transport
8	Don’t know
9	Don’t answer

Q5.2 Did you feel the aftershock?

1	Yes
2	No → Go to question Q6.1
8	Don’t know
9	Don’t answer

Q5.3 How familiar where you with the place you were in?

1	Nothing, it was my first time there
2	Very little, it was not my first time, but I do not usually frequent it
3	Moderate, I usually frequent it
4	High
5	Very high, I knew the place for some years
8	Don’t know
9	Don’t answer

Q5.4 What was the first thing you tried to do when you notice the movement? It does not matter if you did it or not.

1	Open doors and/or windows
2	Turn off gas/fire from dangerous equipment
3	Help others
4	Get dressed/change clothes
5	Hold furniture or other objects from falling
6	Leave the room
7	Leave the apartment
8	Leave the building
9	Seek shelter under a table or other furniture
10	Seek shelter under a doorway
11	Remain still where I was
12	Keep driving
13	Stop the car
88	Don’t know
99	Don’t answer

Q5.5 Which of the following options best describes what motivated your behavior?
Select more than one if necessary

1	It was the first thing that came to my mind, an instinctive reaction
2	Stayed away from dangerous objects (such as windows, furniture, ornaments, etc.)
3	Helped or support people who were around
4	Hold ornaments, objects and/or furniture from falling
5	I followed the behavior of other people who were around
6	I followed the procedures recommended by official institutions (ONEMI, ACHS, Mutual, etc.)
7	I did what I learned during drills at school or work
8	Don’t know
9	Don’t answer

Q5.6 Of the following actions, which one/ones you did DURING the aftershock?

	Yes	No	Don't know	Don't answer
Opened doors and/or windows	1	2	8	9
Turned off gas/fire from dangerous equipment	1	2	8	9
Helped others	1	2	8	9
Get dressed/changed clothes	1	2	8	9
Held furniture or other objects from falling	1	2	8	9
Left the room	1	2	8	9
Left the apartment	1	2	8	9
Left the building	1	2	8	9
Sought shelter under a table or other furniture	1	2	8	9
Sought shelter under a doorway	1	2	8	9
Stayed still where I was	1	2	8	9
Kept driving	1	2	8	9
Stopped the car	1	2	8	9
I did not take any action	1	2	8	9

Q5.7 Did you left or tried to leave the building/structure at any time?

1	No → Go to question Q5.11
2	Yes, when I first notice the movement
3	Yes, during the movement
4	Yes, after the movement ended
8	Don't know
9	Don't answer

Q5.8 Which of the following options best describes what motivated you to leave the building/structure?

1	It was the first thing that came to my mind, an instinctive reaction
2	Past experiences in other earthquakes/strong tremors
3	I followed the behavior of other people who were around
4	Stayed away from dangerous objects (such as windows, furniture, ornaments, etc.)
5	Other:
8	Don't know
9	Don't answer

Q5.9 If you left the building/structure, did you do it alone or with others?

1	I did it alone
2	I started alone and then other people followed me
3	I started alone and then I followed others
4	I did it with others
5	I started with others and then more people followed us
6	I started with others and then we followed others
8	Don't know

9	Don't answer

Q5.10 Did you succeed?

1	No
2	Yes
8	Don't know
9	Don't answer

Q5.11 On a scale from 1 to 10, how much fear did you feel during the aftershock? Where 1 is I did not feel afraid and 10 I felt very scared.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**88**	**99**
										DK	**DA**

Q5.12 How prepared you think you were to face a movement like the aftershock of March 11th?

1	Nothing
2	Very Little
3	Moderate
4	Prepared
5	Perfectly Prepared
8	Don't know
9	Don't answer

Q5.13 How safe did you feel during the aftershock?

1	Nothing
2	Very Little
3	Moderate
4	Safe
5	Perfectly Safe
8	Don't know
9	Don't answer

PART 6: PREPAREDNESS AND PAST EXPERIENCES

Q6.1 About your previous preparation to face a potential earthquake. Which of the following actions did you take BEFORE the earthquake occurred?

	Yes	No	Don't know	Don't answer
I had participated on earthquake drills at school, work and/or other building before 2005	1	2	8	9
I had participated on earthquake drills at school, work and/or other building after 2005	1	2	8	9
I knew the security zones of the building I were in	1	2	8	9
I knew ONEMI's or other official entity recommendations on how to behave during earthquakes	1	2	8	9
I had developed a household/family emergency plan	1	2	8	9

Q6.2 How many times, before 2010, have you experienced a tremor that you consider as a very strong movement and/or an earthquake?

1	Never
2	1
3	2
4	3
5	More than 3 times
8	Don't know
9	Don't answer

Q6.3 Regardless of what happened in 2010, were you in any of those earthquake or strong motions inside the same apartment?

1	Yes
2	No
8	Don't know
9	Don't answer

Q6.4 Continuing with the previous question. Regardless of what happened in 2010, were you in any of those earthquake or strong motions inside another building of 5 or more floors?

1	Yes
2	No
8	Don't know
9	Don't answer

Q 6.5 In any of those earthquake or strong motions, did you or someone you know suffered property damage?

1	No
2	Yes, minor damages (falling ornaments and moving pictures)

3	Yes, major damages (broken glasses, locked doors, cracks in walls and ceilings)
4	Yes, significant damages (such as partial or total collapse of walls and ceilings)
5	Yes, the building collapsed partially or totally
8	Don’t know
9	Don’t answer

Q 6.6 Because of any of those earthquake or strong motions, were you or someone you know injured?

1	No
2	Yes, minor injuries
3	Yes, major injuries
4	Yes, fatal injuries
8	Don’t know
9	Don’t answer

PART 7: PERSONAL INFORMATION

Q7.1 What is your nationality?

1	Chilean → Go to question Q7.3
2	Other:
9	Don´t answer

Q7.2 If you are not Chilean, since what year do you live in Chile?

I live in Chile since the year:

Q7.3 What was your marital status at the moment of the earthquake on 2010?

1	Single
2	Domestic Partnership
3	Married
4	Separated
5	Widower
8	Don’t know
9	Don’t answer

Q7.4 What was your work status at the moment of the earthquake on 2010?

1	Unemployed	**8**	Qualified workman
2	Housekeeper	**9**	Technician
3	Student	**10**	Professional, Middle Manager

4	Domestic Worker	**11**	Senior Manager
5	Part-time worker	**12**	Retiree
6	Street Vendor	**88**	Don’t know
7	Microentrepreneur	**99**	Don’t answer

Q7.5 What was your higher educational level at the moment of the earthquake on 2010?

1	No studies	**6**	Technical Degree Incomplete
2	Elementary School Incomplete	**7**	Technical Degree Complete
3	Elementary School Complete	**8**	University Incomplete
4	Secondary School Incomplete	**9**	University Complete or more
5	Secondary School Complete	**10**	Postgraduate Degree Complete or Incomplete
		88	Don’t know
		99	Don’t answer

Q7.6 What is your higher educational level now?

1	No studies	**6**	Technical Degree Incomplete
2	Elementary School Incomplete	**7**	Technical Degree Complete
3	Elementary School Complete	**8**	University Incomplete
4	Secondary School Incomplete	**9**	University Complete or more
5	Secondary School Complete	**10**	Postgraduate Degree Complete or Incomplete
		88	Don’t know
		99	Don’t answer

B. SURVEY RESULTS

Table B.1: Participants Demographics Characteristics

	n	%
Gender		
Male	163	49%
Female	172	51%
Age		
20 or less[1]	15	4%
21 to 30	74	22%
31 to 40	91	27%
41 to 50	68	20%
51 to 60	52	16%
61 and more	35	10%
Nationality		
Chilean	330	99%
Other	5	1%
Marital Status		
Single	125	37%
Domestic Partnership	21	6%
Married	120	36%
Separated	44	13%
Widower	21	6%
Highest Academic Qualification3		
Technical degree incomplete or less	79	24%
Technical degree complete or University incomplete	98	29%
University complete	142	42%
Postgraduate degree	16	5%

[1]10 participants were 18 or younger in 2010
[2]4 (1.19%) "don't answer"/ "don't know"
[3]1 (0.30%) "don't answer"/ "don't know"

Table B.2: Number of Surveyed Buildings by Location

Location (*Comuna*)	**Number of surveys**[1]	**Number of buildings**[2]
La Florida	9	4
La Reina	1	1
Las Condes	47	21
Macul	7	4
Ñuñoa	49	18
Providencia	40	26
Quinta Normal	3	3
Recoleta	4	3
San Bernardo	1	1
San Miguel	4	4
San Ramon	1	1
Santiago	166	55
Vitacura	1	1
TOTAL	**333**	**142**

[1]2 (0.60%) “don’t answer”/ “don’t know”
[2]44 (13%) do not have enough information to confirm the exact address of the building

Table B.3: Physical Context

	n	%
Same Apartment[1]		
Yes	250	75%
No	84	25%
Familiarity with the apartment[2]		
Nothing (first-time visit)	3	1%
Very little	31	9%
Moderate (I usually go there)	40	12%
High	100	30%
Very high (I've known the place for years)	148	44%
Apartment floor level[3]		
Lower	116	35%
Middle	117	35%
Upper	98	29%

[1] 1 (0.30%) "don't answer"/ "don't know"
[2] 13 (3.88%) "don't answer"/ "don't know"
[3] 4 (1.19%) "don't answer"/ "don't know"

Table B.4: Social Context

	n	%
Who were you with?		
Alone	61	18%
Family and Relatives	246	73%
Friends and Neighbors	42	13%
Someone with mobility impairment	28	8%
Children under 14	45	13%
Children under 5	38	11%

Table B.5: Preparedness and Education

	n	**%**
I had participated in earthquake drills at school, work and/or other buildings before 2005	189	56%
I had participated in earthquake drills at school, work and/or other buildings after 2005	115	34%
I knew the security zones of the building I was in	110	33%
I knew ONEMI's or other official entity recommendations on how to behave during earthquakes	108	32%
I had developed a household/family emergency plan	68	20%

Table B.6: Past Experiences

	n	%
Previous earthquakes[1]		
Never	3	1%
1	39	12%
2	99	30%
3	111	33%
More than 3	78	23%
Previous earthquakes in the same apartment[2]		
Yes	83	25%
No	249	74%
Previous earthquakes in other building with 5 or more stories[3]		
Yes	111	33%
No	217	65%
On one of those previous earthquakes, did you or someone you know suffer property damage? [4]		
No	179	53%
Yes, minor damages	100	30%
Yes, significant damages	53	16%
On one of those previous earthquakes, were you or someone you know injured? [5]		
No	265	79%
Yes, minor injuries	64	19%
Yes, major injuries	3	1%

[1]5 (1.49%) "don't answer"/ "don't know"

[2,5]3 (0.90%) "don't answer"/ "don't know"

[3,4]7 (2.09%) "don't answer"/ "don't know"

Table B.7: Observed Damage: Apartment Contents

	Did not move	**Rattled Slightly**	**Rattled Loudly**	**Some fell off or broke**
Hanging Objects	1	51	155	122
	0.3%	15%	46%	36%
China and Dishes	10	34	106	179
	3%	10%	32%	53%
Small Objects	5	56	135	130
	1%	17%	40%	39%
Doors	18	87	194	15
	5%	26%	58%	4%
Windows	16	99	188	11
	5%	30%	56%	3%
Large Furniture	41	118	142	11
	12%	35%	42%	3%

Table B.8: Observed Damage: Cars and Structure Components

	n	%
Cars[1]		
Did not move	2	1%
Swung from side to side	5	1%
Swung and the alarms went off	21	6%
I only heard the alarms	154	46%
Apartment walls		
No damage	131	39%
Some surface cracks in the coating (plaster)	172	51%
Some pieces of the coating fell down (plaster)	18	5%
Some pieces of the walls fell down (concrete)	1	0,3%
Were partially or totally broken	1	0,3%
Apartment ceiling		
No damage	174	52%
Partly cracked	126	38%
Some pieces of the coating fell down (plaster)	2	1%
Some pieces of the ceiling fell down (concrete)	11	3%
Some pieces of the false/suspended ceiling fell down	1	0,3%
Building walls		
No damage	123	37%
Some surface cracks in the coating (plaster)	171	51%
Some pieces of the coating fell down (plaster)	15	4%
Some pieces of the walls fell down (concrete)	3	1%
Were partially or totally broken	2	1%
Building ceiling		
No damage	166	50%
Some surface cracks in the coating (plaster)	118	35%
Some pieces of the coating fell down (plaster)	7	2%
Some pieces of the ceiling fell down (concrete)	11	3%
Some pieces of the false/suspended ceiling fell down	2	1%

Building Damage		
No damage	100	30%
Minor Damage	187	56%
Moderate Damage	32	10%
Severe Damage	1	0.3%
Serious Damage	0	0%
Where you or someone you know injured?		
No	318	95%
Yes, minor injuries	17	5%

[1]153 (45.67%) “don’t answer”/ “don’t know”
[2]12 (3.58%) “don’t answer”/ “don’t know”
[3,4]21 (6.27%) “don’t answer”/ “don’t know”
[5]31 (9.25%) “don’t answer”/ “don’t know”
[6]15 (4.48%) “don’t answer”/ “don’t know”

Table B.9: Movement Perception

	n	%
What were you doing when you noticed the movement?[1]		
Sleeping	252	75%
Lying down awake	44	13%
Seated	24	7%
Walking	1	0.3%
Other	2	1%
How would you describe the shaking?		
I did not feel the movement	0	0%
Weak	4	1%
Moderate	8	2%
Strong	98	29%
Very Strong	225	67%
During the movement, did you:[3]		
Have no problem to staying on foot	32	10%
Stay on foot with difficulty	105	31%
Stay on foot with a lot of difficulty	152	45%
Needed help to stand or move	36	11%
Fell because of the movement	4	1,19%
What was your perceived duration of the movement?		
A few seconds	0	0%
Less than a minute	7	2%
Between 1 and 3 minutes	110	33%
More than 3 minutes	143	43%
More than 5 minutes	54	16%
Could not say	21	6%
How would you describe the noise?[4]		
I did not hear any noise	6	2%
Weak	3	1%
Moderate	34	10%

Strong	121	36%
Very Strong	161	48%

[1]2 (0.55%) "don't answer"/ "don't know"
[2] 1 (0.27%) "don't answer"/ "don't know"
[3] 6 (1.65%) "don't answer"/ "don't know"
[4]10 (2.75%) "don't answer"/ "don't know"

Table B.10: Risk Perception

	n	%
Fear[1]		
1	15	4%
2	7	2%
3	9	3%
4	10	3%
5	25	7%
6	25	7%
7	56	17%
8	64	19%
9	41	12%
10	82	24%
How prepared were you to face an earthquake of the magnitude of 27F?2		
Nothing, I was not prepared for a movement like that	148	44%
Very little	123	37%
Moderate	51	15%
Prepared	11	3%
Perfectly prepared	1	0%
How safe did you feel during the shaking?[3]		
Nothing, I felt unsafe	62	19%
Very little	119	36%
Moderate	110	33%
Safe	30	9%
Perfectly safe, I never doubted my safety	6	2%

[1] 1 (0.27%) “don’t answer”/ “don’t know”

[2] 2 (0.55%) “don’t answer”/ “don’t know”

[3] 9 (2.47%) “don’t answer”/ “don’t know”

Table B.11: Earthquake Reaction

	n	%
First Reaction[1]		
Opened doors/windows	56	17%
Turn off gas/fire	6	2%
Help others	55	16%
Get dressed/changed clothes	35	10%
Hold furniture	16	5%
Leave the room	49	15%
Leave the apartment	16	5%
Leave the building	1	0.3%
Seek shelter under furniture	2	0.6%
Seek shelter under doorframe	40	12%
Stay still	49	15%
First Reaction Motivation		
It was instinctive	263	79%
Stayed away from dangerous objects	36	11%
Help others	47	14%
Hold furniture or other objects	9	3%
Follow other’s behavior	8	2%
Follow recommendations from official institutions	5	1%
Did was I was taught in school/work drills	8	2%
Time to First Reaction[2]		
Less than a second	92	27%
A few seconds	153	46%
Several seconds	79	24%
I only reacted when the shaking stopped	7	2%
Actions During Earthquake		
Opened doors/windows	159	47%
Turn off gas/fire	45	13%
Help others	152	45%

Get dressed/changed clothes	99	30%
Hold furniture	45	13%
Leave the room	192	57%
Leave the apartment	64	19%
Leave the building	15	4%
Seek shelter under furniture	8	2%
Seek shelter under doorframe	124	37%
Stay still	93	28%
Did you leave or try to leave the apartment?[3]		
No	196	59%
Yes, when I first notice the shaking	33	9%
Yes, during the movement	29	9%
Yes, after the shaking stopped	74	24%
Where were you trying to go?[4]		
Leave the apartment	32	24%
Leave the apartment floor	29	21%
Leave the building	71	52%
Did you succeed?[5]		
Yes	107	79%
No	26	19%
What motivated you to leave the apartment/building?[6]		
It was instinctive	82	60%
Past experiences	14	10%
Other’s behavior	11	8%
Stayed away from dangerous objects	14	10%
Other	14	10%
Speed during evacuation[7]		
Very slow	24	18%
Slow	51	38%
Moderate	40	29%
Fast	15	11%
Very fast	3	2%

Who did you leave with?[8]		
I did it alone	23	17%
I started alone, then others followed me	16	12%
I started alone, then I followed others	6	4%
I started with others	73	54%
Where were you when the shaking stopped?		
Inside the apartment	47	35%
Outside the apartment, on the same floor	24	18%
Going down to the building lobby	20	15%
At the building lobby	21	15%
Outside the building	23	17%

[1]10 (2.99%) “don’t answer”/ “don’t know”
[2]4 (1.10%) “don’t answer”/ “don’t know”
[3]3 (0.82%) “don’t answer”/ “don’t know”
[4]4 (2.60%) “don’t answer”/ “don’t know”
[5,7]3(1.94%%) “don’t answer”/ “don’t know”
[6,9]1 (0.65%%) “don’t answer”/ “don’t know”
[8]2 (1.29%%) “don’t answer”/ “don’t know”

Table B.12: Aftershock Physical Context

	n	%
Where were you at the time of the aftershock?		
Inside a house	39	12%
Inside a building	127	38%
On the street	32	10%
In an open public space	19	6%
Inside a public space	61	18%
Inside a private vehicle	34	10%
Inside public transport	19	6%
Did you feel it?		
Yes	264	79%
No	70	20%
Familiarity with the place		
Nothing, first-time visit	12	5%
Very little	32	12%
Moderate (I usually go there)	45	17%
High	82	31%
Very high (I’ve known the place for years)	92	35%

Table B.13: Aftershock Reaction

	n	%
First Reaction		
Open doors/windows	24	9%
Turn off gas/fire	4	2%
Help others	19	7%
Get dressed/changed clothes	2	0.8%
Hold furniture	7	3%
Leave the room	14	5%
Leave the apartment	18	7%
Leave the building	16	6%
Seek shelter under furniture	1	0.4%
Seek shelter under doorway	24	9%
Stay still	122	46%
Keep driving	3	1%
Stop the car	6	2%
Actions During Aftershock		
Open doors/windows	71	27%
Turn off gas/fire	20	8%
Help others	49	19%
Get dressed/changed clothes	6	2%
Hold furniture	24	9%
Leave the room	62	23%
Leave the apartment	45	17%
Leave the building	24	9%
Seek shelter under furniture	2	1%
Seek shelter under doorway	45	17%
Stay still	142	54%
Keep driving	8	3%
Stop the car	6	2%
Nothing	4	2%

Did you left or tried to leave the building?		
No	200	76%
Yes, when I first notice the shaking	26	10%
Yes, during the movement	14	5%
Yes, after the shaking stops	22	8%
Did you succeed?		
Yes	3	5%
No	51	82%
What motivated your behavior?		
It was instinctive	27	44%
Past experiences	12	19%
Other’s behavior	13	21%
Stayed away from dangerous objects	2	3%
Other reason	7	11%
Who did you evacuate with?		
I did it alone	19	31%
I started alone, then others followed me	7	11%
I started alone, then I followed others	4	6%
I started with others	26	42%

Table B.14: Aftershock Risk Perception

	n	%
Fear		
1	27	10%
2	11	4%
3	18	7%
4	25	9%
5	31	12%
6	53	20%
7	44	17%
8	20	8%
9	10	4%
10	24	9%
How prepared were you for an earthquake of the magnitude of the Aftershock?		
Nothing, I was not prepared	48	18%
Very little	136	52%
Moderate	64	24%
Prepared	11	4%
Perfectly prepared	5	2%
How safe did you feel during the shaking?		
Nothing	27	10%
Very little	81	31%
Moderate	118	45%
Safe	26	10%
Perfectly safe	11	4%