ISSN 8755-6839

SCIENCE OF TSUNAMI HAZARDS

Journal of Tsunami Society International

Volume 38 Number 1 2019

REDUCTION OF THE RISK BY TSUNAMI: EVACUATION PROCESSES IN CHILEAN CITIES DURING THE EARTHQUAKES OF 2010 AND 2015

Leonel Ramos [1*] - Hitomi Murakami [2]

[1] Professor, Arq, Department of Urbanism, University of Concepcion, Chile.
[2] Professor, Dr. Engr, Yamaguchi University, Japan.
*Corresponding author lramos@udec

ABSTRACT

Tsunamis have always affected Chilean coastal communities, causing great loss of lives and property, and pose a permanent threat to their inhabitants. The Sumatra tsunami in 2004 took hundreds of thousands human lives along the Indian Ocean; similarly, the Chile 2010 and Japan 2011 tsunamis caused great land devastation, though less lives were lost. The Chilean case is of special interest since tsunamis have struck consistently during the last decade, which demands higher social resilience and increased effectiveness in mitigation measures to reduce local and national risk. This research presents a study of the tsunami evacuation processes carried out by the inhabitants during the earthquakes of 2010 and 2015 in the Biobío region, applying a statistical methodology to understand the behavior of the population within a diverse urban and territorial context, with plain and hilly areas. A total of 251 surveys were conducted with inhabitants affected by the tsunamis, to assess the evacuation processes, considering starting time, means of transport, the use of automobiles, traffic jams, and the quality of evacuation routes and safe zones. The objective of the study is to quantify these evacuation processes in an urban context, to prospect possible improvements in the future planning and design of coastal cities.

Keywords: *Tsunami, earthquakes, behavior, evacuation route, safety zones, traffic jams, hazard zones*

1. Introduction

This research presents a study of the tsunami evacuation processes in the cities of Talcahuano and Dichato during the 2010 Maule earthquake, and for the 2015 Coquimbo earthquake; both disasters produced human losses and major material damages on the south-central and northern Chilean coasts; in addition, tsunami warnings led to the evacuation of a significant number of inhabitants from the risk zones to the highlands of the hills along the country's coast in search for shelter.

The 2010 Maule earthquake 8.8 (Mw) occurred at 3:34:08 local time (UTC-3), on Saturday February 27, and triggered a tsunami that affected large parts of the central coast of Chile. The tsunami caused extensive damage in the cities of Talcahuano (Fig. 1) and Dichato; however, the loss of life was very low due to the timely evacuation process performed by the population. The 2015 Coquimbo earthquake occurred at 19:54:31 local time (UTC -3) on Wednesday, September 16, 2015, reaching a magnitude of 8.4 Mw. The epicentre was located 37 kilometres northwest of Los Vilos and 37 kilometres southwest of Canela Baja, in the region of Coquimbo, northern Chile. It was vastly perceived along the country, and also in some areas of Argentina, Uruguay and Brazil. This is the largest event recorded since the 2010 Maule earthquake, and the third largest since May 22, 1960, surpassing the magnitude of the event that occurred off the coast of Pisagua-Iquique on April 1, 2014. The Hydrographic and Oceanographic Service of the Chilean Navy (SHOA) issued a tsunami alarm for the entire Chilean coastal border and almost one million people were orderly and timely evacuated to the security zones. The alarm spread to the shores of the Pacific Ocean abroad, including Peru, Ecuador and Hawaii.

The main objective of the study is to analyze the behavior of the population during the tsunami evacuation process in the earthquakes of 2010 and 2015, considering the time taken to evacuate the hazard zones after the earthquake, the geographical conditions, to determine the main means of transport for evacuation, the start time of the evacuation, the time and distance of the evacuation, the quality of evacuation routes and safe zones, and problems with car traffic and the roads. Furthermore, comparing both experiences will allow to define the strengths and weaknesses as experienced by people during the evacuation process, considering the differences between geographical areas, as well as behaviors that may endanger people and affect the normal evacuation procedure.

2. Research methods and overview of data sources

The main research method used for this paper was the application of 251 surveys to people that were caught in tsunami flood areas during the 27F, 2010 Maule earthquake and the 2015 Coquimbo earthquake. The surveys were applied in different areas (Fig. 1), defined by the morphological characteristics of the territory (flat areas and areas with nearby hills), and by the type of urban land use (residential, industrial, etc.). To facilitate contact with the affected communities, the municipalities of Talcahuano and Tomé collaborated in contacting local leaders to support the implementation of the surveys in each of their community centres.

The sorting and analysis of the results were performed through simple statistics using spreadsheets and crossing information between the different selected areas. The start time of evacuation, evacuation routes and safe locations were marked using Geographic Information System (GIS) maps, according to information provided by people and duly recorded in the surveys.

To enrich the analysis, specific comparisons were made with the evacuation process performed during the 2011 tsunami in Tohoku region, Japan.

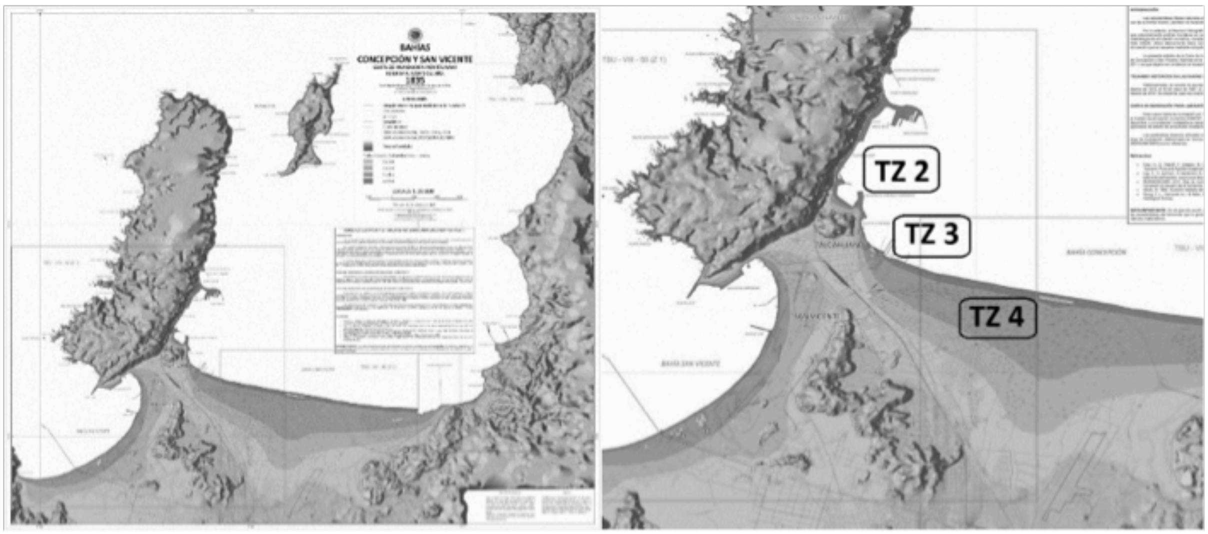

Fig. 1 Study area. Left, Tsunami flood maps of Talcahuano published by SHOA, Chile, based on the historical tsunami events. Right, detail of the area.

3. Earthquake of 2010 and cities affected by the tsunami in Chile

Table 1 shows characteristics and damage conditions in the cities of Talcahuano and Dichato, hit by the 2010 earthquake. The 2010 Maule earthquake (8.8 Mw) occurred at 3:34:08 local time (UTC-3), on Saturday February 27^{t}, and triggered a tsunami which affected large parts of the central coast of the country. The tsunami caused extensive damage in the cities of Talcahuano and Dichato; however, the loss of life was very low due to the timely evacuation process performed by the population. Damage caused by the 2010 tsunami in the cities of Talcahuano and Dichato was very high (Table 1), affecting 26.6% and 65% of the urban area, respectively, and destroying more than 8900 homes. In the case of the 2015 Coquimbo earthquake (8.4 Mw), which occurred on Wednesday, September 16 at 19:54:31 local time (UTC -3), after the activation of the tsunami alarm the population of the cities of Talcahuano and Dichato began the evacuation to the safer higher areas; finally, the waves reached the coast with a height of 1.2 meters, causing minor damage.

Table 1 Cities affected by the tsunami and damage conditions. Developed by author. Source of data: Biobío Region Coastal Border Reconstruction Plan; PRBC18, Master Plan for Dichato and Talcahuano, Government of Chile, 2011. Reconstruction Plan for 27F Earthquake and Tsunami, Government of Chile, August 2010. Statistics of the legal medical service for the 2010 Earthquake, Government of Chile, 2010.

	Talcahuano 2010 8.8 Mw	**Dichato 2010** 8.8 Mw
Population	163.626 people	3.488 people
Extension of urban area	40,3 km²	1,22 km²
Tsunami affected area	10,72 km²	0,803 km²
Houses destroyed by tsunami	7.636	1.343
Tsunami victims	**3**	**16**

4. Questionnaire on tsunami evacuation for the 2010 Maule earthquake

4.1 Geographical conditions of survey area and time to start evacuation

To elucidate tsunami evacuation behaviors in the 2010 Maule earthquake in Chile, a questionnaire survey was conducted in December 2013 for the severely affected city of Talcahuano and the Dichato district of Tomé city, with students of the University of Concepcion participating as interviewers. The survey areas are DCH (Dichato), TZ2 (Talcahuano Central), TZ3 (El Morro), and TZ4 (Salinas). Altogether 193 cases of data were collected. The survey results for: means of tsunami warning, means of transport for evacuation, evacuation routes and conditions; are examined here.

An official tsunami warning was not issued for this earthquake. According to the hearing survey from the disaster management section of Talcahuano municipal office, by the author (H. M.) in 2012, there was a notice from ONEMI that there was no risk of tsunami and that information was broadcast via a local radio station. In the hearing survey at the Dichato temporary housing village on the same occasion, local people and community leaders confirmed the same conditions. Fig. 2 shows tsunami alarm conditions. Overall, 56% of respondents reported that the tsunami alarm did not exist, while 25% said they got some alarm information from neighbors or family.

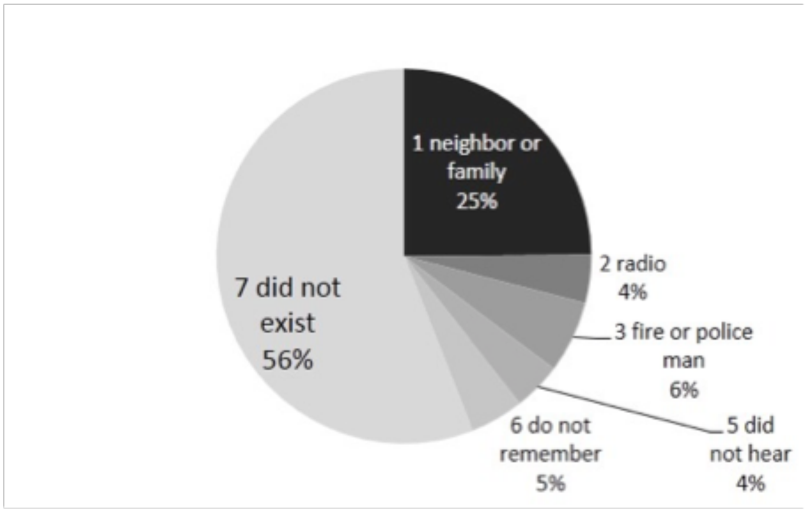

Fig. 2 Tsunami alarm in Biobío (Q3, n=193)

Fig. 3 shows the time taken to start evacuation for each survey zone. Overall, half of respondents started evacuation during the shaking or immediately after the earthquake. Still, 14% of respondents did not, or could not evacuate, and seem to have stayed on the upper floors of apartments or houses. Evacuation was faster in Dichato, and TZ3 El Morro, while it was slower and more respondents did not evacuate in TZ Talcahuano Central. Fig. 4 shows actions taken before starting to evacuate (MR: multiple response) in relation to disabilities. The percentage of those starting evacuation immediately is higher (61%) for those cases with no disability followed by those cases with little disability in walking, and then by those cases of vision or hearing disability. Family teaching of tsunami evacuation prior to the F27 event tends to make people evacuate quicker (Fig. 5), so that it seems to be a primary and basic requirement to promote a quick start for evacuation.

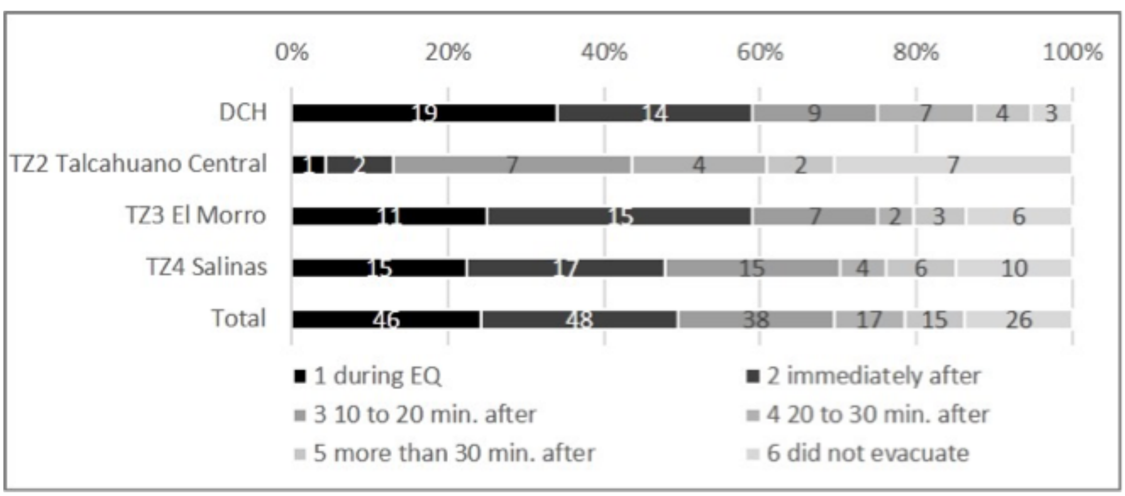

Fig. 3 Time taken to evacuate vs. survey zones (Q5, n=190)

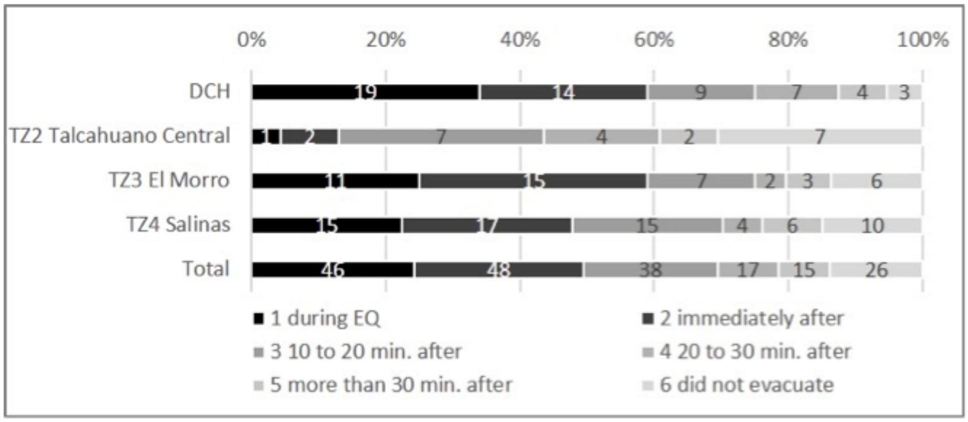

Fig. 4 Actions taken before evacuation vs. disability (MR: multiple response, n=160)

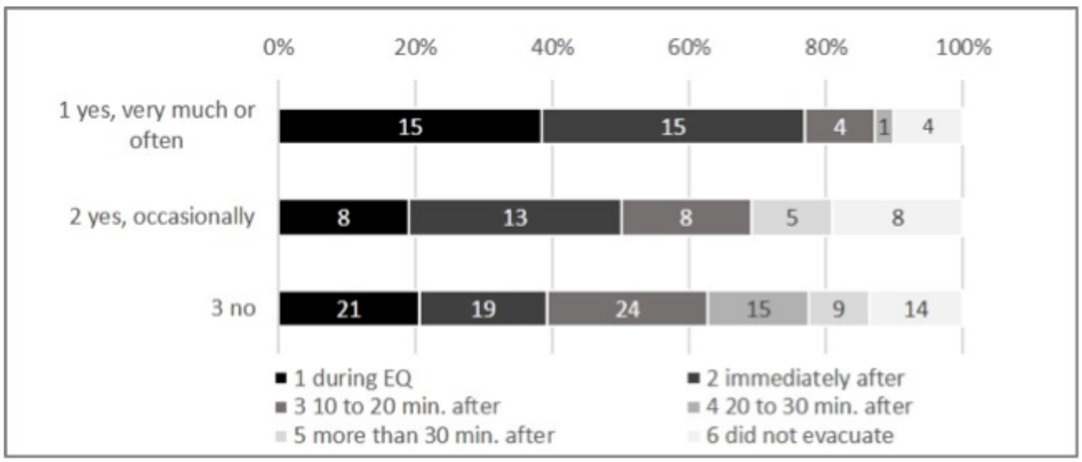

Fig. 5 Q20 Family teaching of tsunami evacuation prior to 27F event and Q5 time to start evacuation (n=183) Pvalue =0.003<0.01

4.2 Transport means for evacuation

Fig. 6 and Fig. 7 show the topography of Talcahuano and Dichato with evacuation routes marked. In Talcahuano, evacuation distances are short (mostly less than 500m) in Zones 2 and 3, and are much longer in Zone 4. Fig. 8 depicts means of transport for evacuation. The percentage of people on foot is high in TZ3 El Morro, and TZ2 Central Talcahuano, while use of cars (4 to 7, both driving a car or pickup, and getting a car ride or a pickup ride) is higher in TZ4 Salinas, followed by DCH, Dichato. In this figure, ‘other’ refers to those who could not or did not evacuate and stayed in the buildings. Such cases represent a share of more than 30% in TZ2 Central Talcahuano, where 3-4 story apartments are common. Traffic jam conditions (Fig. 9) vs survey zones indicate similar patterns of severe conditions in TZ4 Salinas and Dichato.

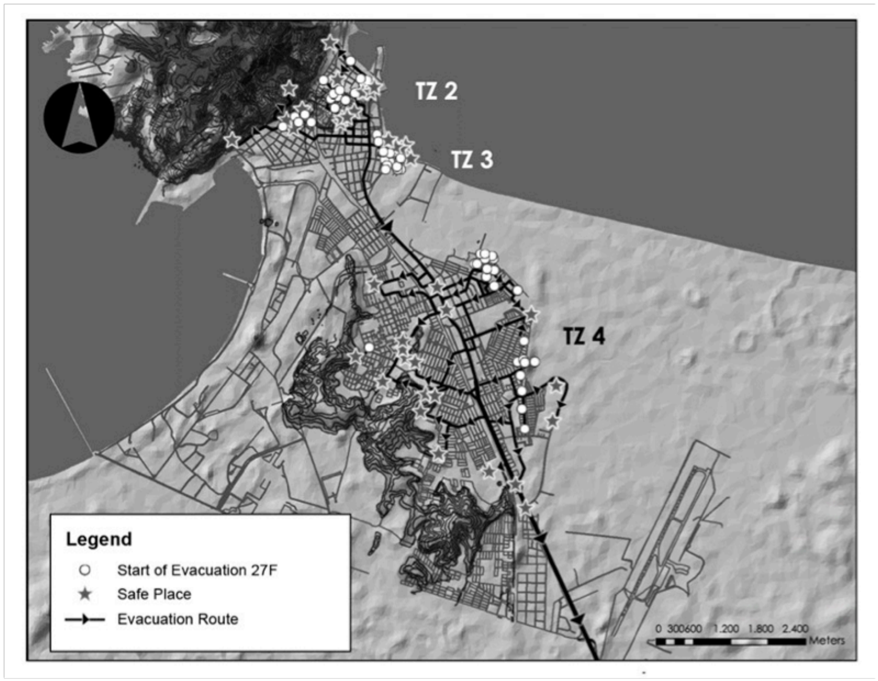

Fig. 6 Evacuation GIS map of 27F2010, in Talcahuano (Zone 2 is Central, Zone 3 is El Morro, and Zone 4 is Salinas). Circles are origins of evacuation and stars are destinations in safety zones.

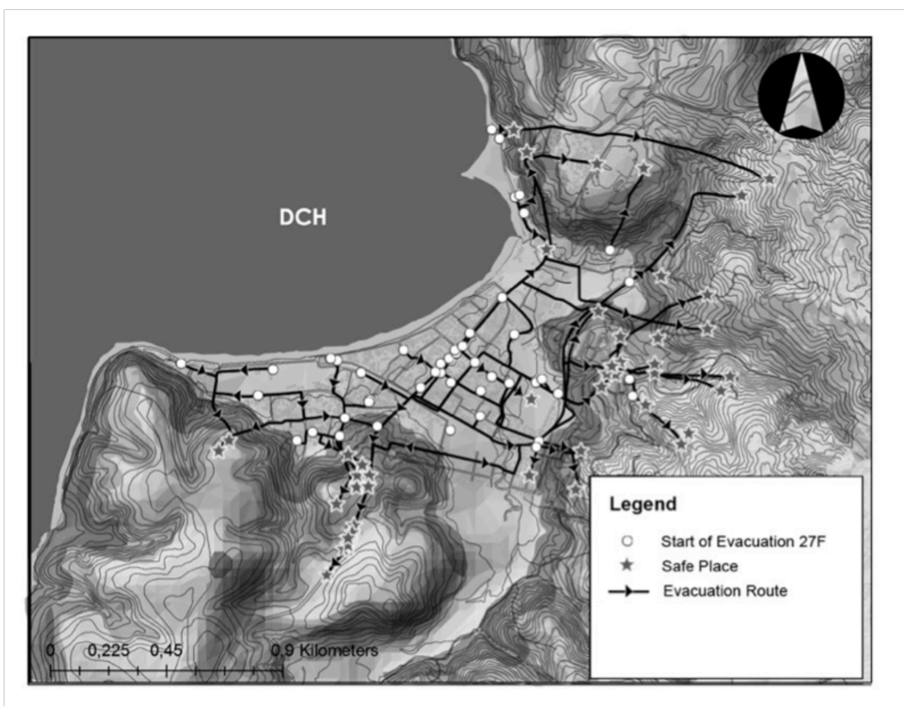

Fig. 7 EvacuationGIS map of 27F, 2010 in Dichato (DCH). Circles are origins of evacuation and stars are destinations in safety zones.

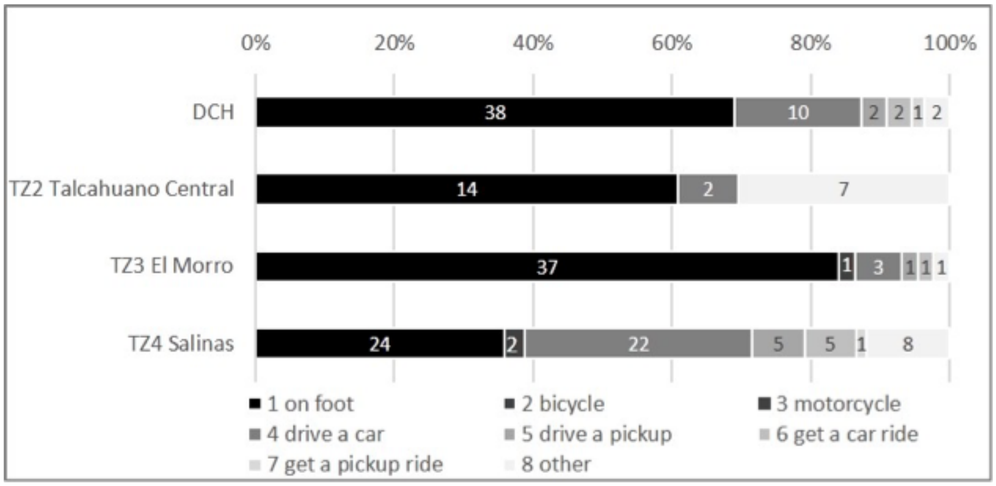

Fig. 8 Means of transport for evacuation vs. survey zones (Q6, n=189)

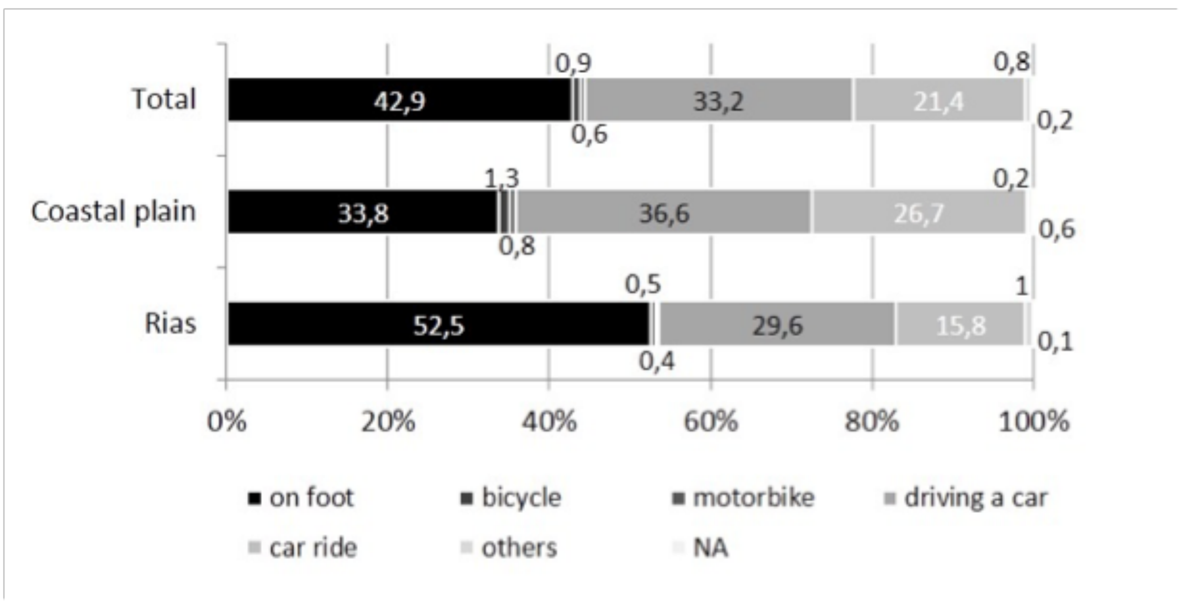

Fig. 9 Traffic jams observation vs. survey zones (Q14, n=186)

The reasons for predominant pedestrian evacuation in Talcahuno and Dichato are based on rules and morals, and people tend to consider it is safer to walk than to drive or ride a car. Fig. 10 shows mobility patterns in the 2011 Great Tohoku earthquake and tsunami. Automobile evacuation was higher in the coastal plain area than in Rias region, and automobile use in Tohoku was much higher than in Talcahuano and Dichato.

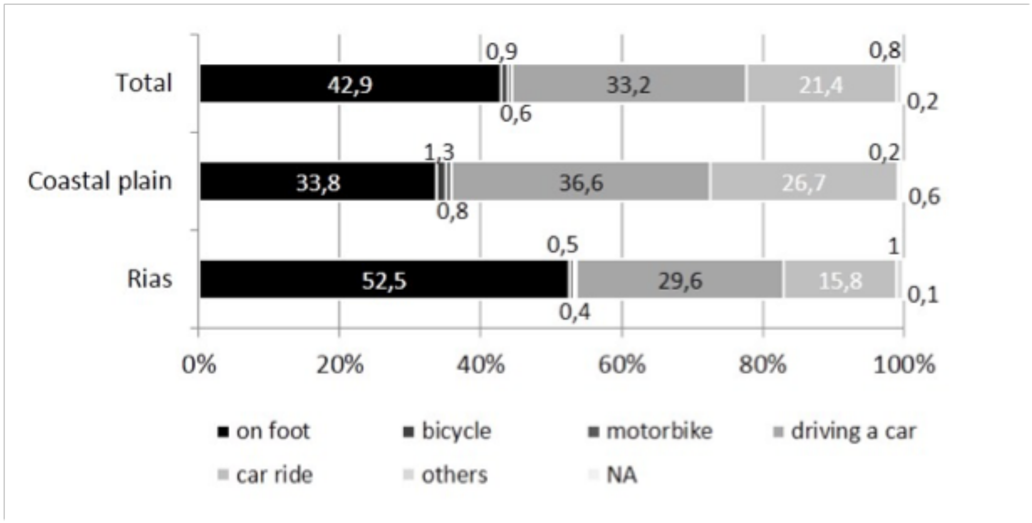

Fig. 10 Relation between means of transport for tsunami evacuation and regional topography in the 2011 Great Tohoku earthquake and tsunami (Fukko Shien survey archive, MLIT survey, n=5524 cases)

4.3 Conditions of evacuation routes, evacuation zones and universal access

Most people evacuated to safe areas just to walk in the nearby hills (Fig. 11). The evaluation of evacuation routes ranked 'bad' and 'very bad' in all areas where surveys were conducted (Fig. 12). This is mainly due to poor signage of the tsunami evacuation routes, or to routes being blocked by debris from the earthquake, or to lack of artificial lighting. Safe places are also classified as 'bad' because they do not have any basic facilities or services (bathrooms, drinking water, electricity, climate protection) to enable the sheltering of people.

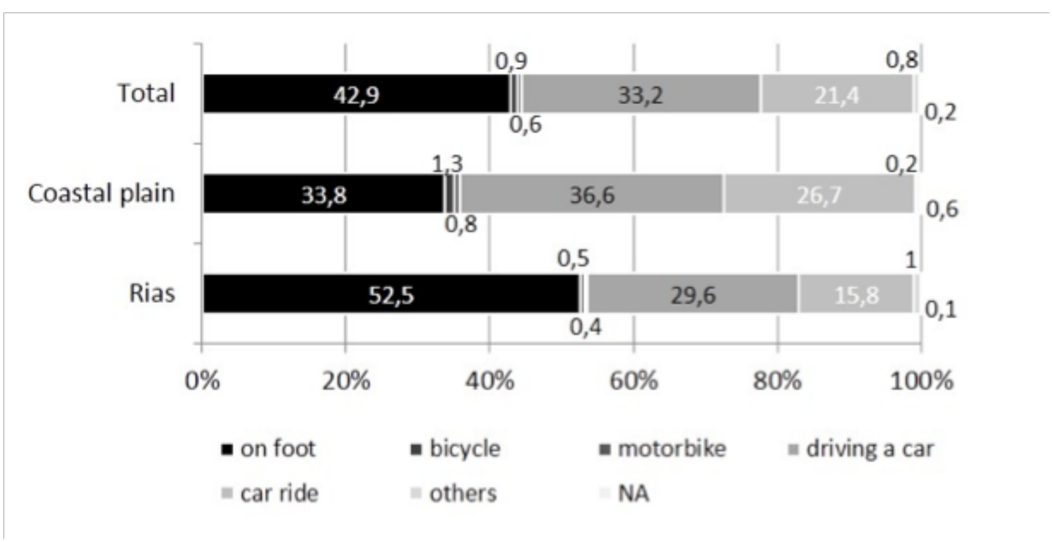

Fig. 11 Evacuation place vs. survey zones (Q10, n=187)

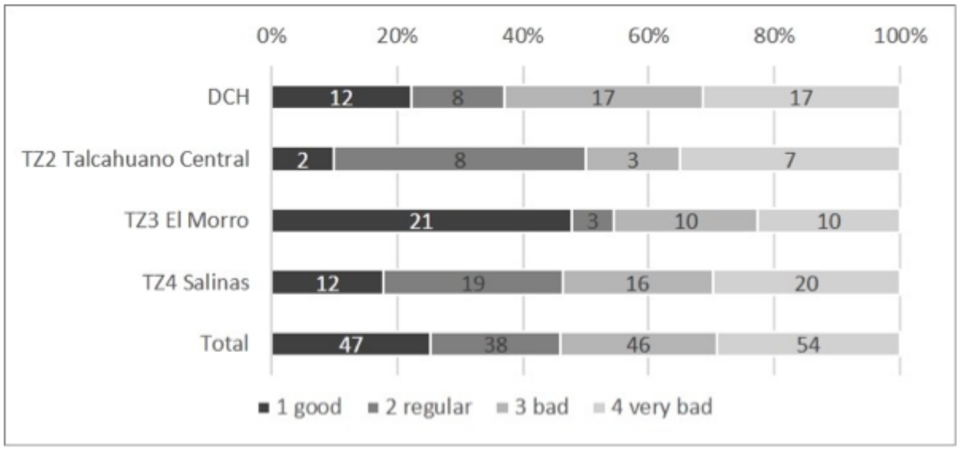

Fig. 12 Rating evacuation route vs. survey zones (Q13, n=185)

4.4 Assumption of a daytime earthquake on a weekday

The 2010 Maule earthquake occurred at night time at the weekend. As for the means for travelling, 40% do it on foot and 27% by buses or trains, while private car travellers are 11%. Supposing an earthquake should have occurred during day time of a week day, the means of transport and travelling patterns are of critical interest (Fig. 13). The daytime evacuation pattern is shown in Fig.13. Those who plan to go back home from work places are about 25%, and those who plan to go and see their family and then evacuate are about 10%. A day time earthquake and tsunami threat seems to increase two-way traffic going home, going to see family and then evacuating, though car use may not increase much in such cities, as the majority of commuters still use public transportation like buses and trains.

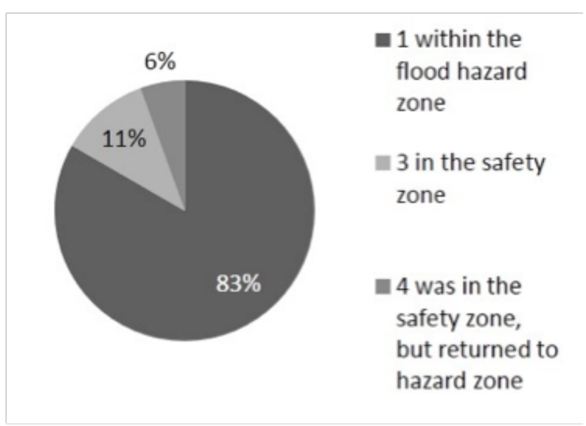

Fig. 13 Evacuation pattern assuming daytime earthquake vs. survey zones (Q24, n=191)

4.5 Summary of findings in the Biobío tsunami evacuation 2010

A questionnaire survey was conducted in Talcahuano and Dichato to investigate evacuation behavior after the 2010 Biobío Earthquake and subsequent tsunami.

1. Most of the people evacuated within 20 minutes after the earthquake, even though there was no official tsunami warning. However, about 30% of cases could not or did not evacuate in due time and stayed on the upper floors of apartment buildings or second floor of houses.
2. The majority (nearly 60%) of transportation for evacuation was on foot, while about 15% occurred by driving a car or a pickup, and getting a car or pickup ride. Use of cars for evacuation is much higher in TZ4 Salinas and in Dichato, and a correlation between the use of cars and evacuation distances is obvious. Traffic jams occurred more in Dichato and TZ4 Salinas than in TZ2 Central Talcahuano and TZ3 El Morro.
3. In case of a daytime earthquake, many think they would either go home or go to see their family before evacuating. Such behavior may increase demand for traffic and increase traffic jams and the difficulty of evacuation.
4. Family education on tsunamis and evacuation tends to increase the percentage of respondents who evacuate quickly.

5 Questionnaire on tsunami evacuation for the 2015 Coquimbo earthquake in the city of Talcahuano.

5.1 Perception of risk after the evacuation alarm and evacuation start time

In order to elucidate the behavior of inhabitants during the tsunami evacuation in Talcahuano for the 2015 Coquimbo earthquake, a survey was conducted during January 2015, with the help of students from the University of Concepción. The study areas are the same as for the 2010 tsunami study, TZ2 (Central Talcahuano), TZ3 (El Morro) and TZ4 (Salinas), aimed at comparing the behavior during the evacuation for the 2010and 2015 tsunamis in Talcahuano. A total of 58 data cases were collected. The results of the surveys for: tsunami warning, evacuation means, evacuation routes, and participation in evacuation drill are discussed here.

After the 2010 earthquake, Chile implemented a tsunami alarm system in the main coastal cities of the country, so in Talcahuano the authorities activated the sirens after the strong earthquake in 2015. Fig. 14 shows that 83% of the respondents were in the flood hazard zones, 11% in safe areas, and 6% said they had been in a safe area but returned to the hazard zone to see their relatives or protect their houses from thieves.

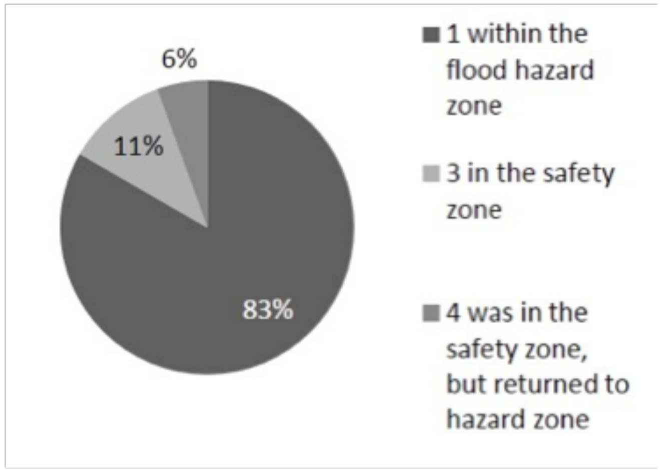

Fig. 14 Where were you when you heard siren (Q5B, n=58)

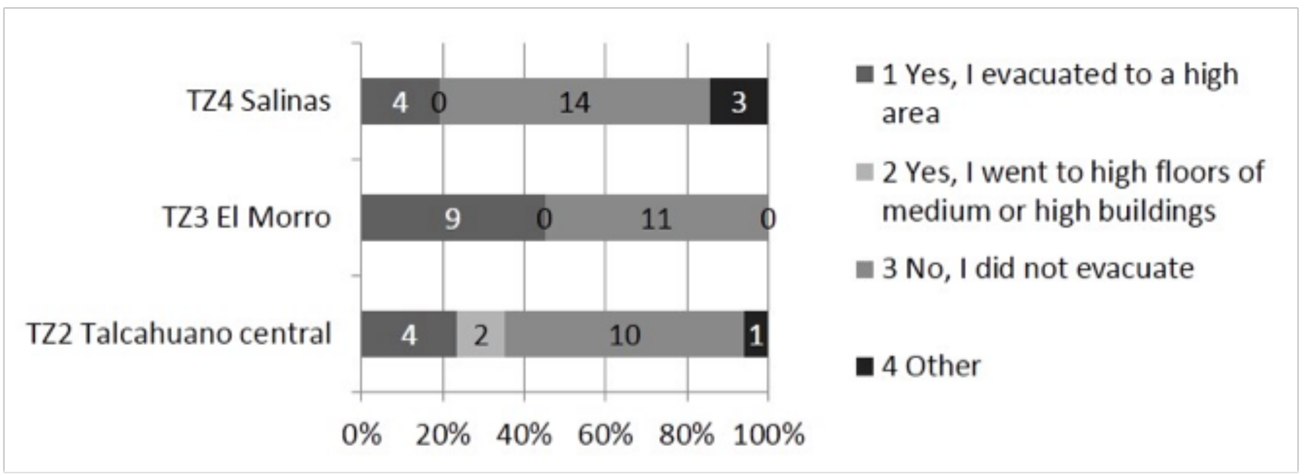

Fig. 15 Did you evacuate from tsunami (Q4, n=58)

Fig. 15 shows whether respondents evacuated to security zones or not, where 32% evacuated to high security areas and 68% said they did not evacuate, mainly because they considered that the earthquake was not strong enough compared to 27F in 2010, despite the fact that 72% reported having heard the evacuation siren (Fig. 16).

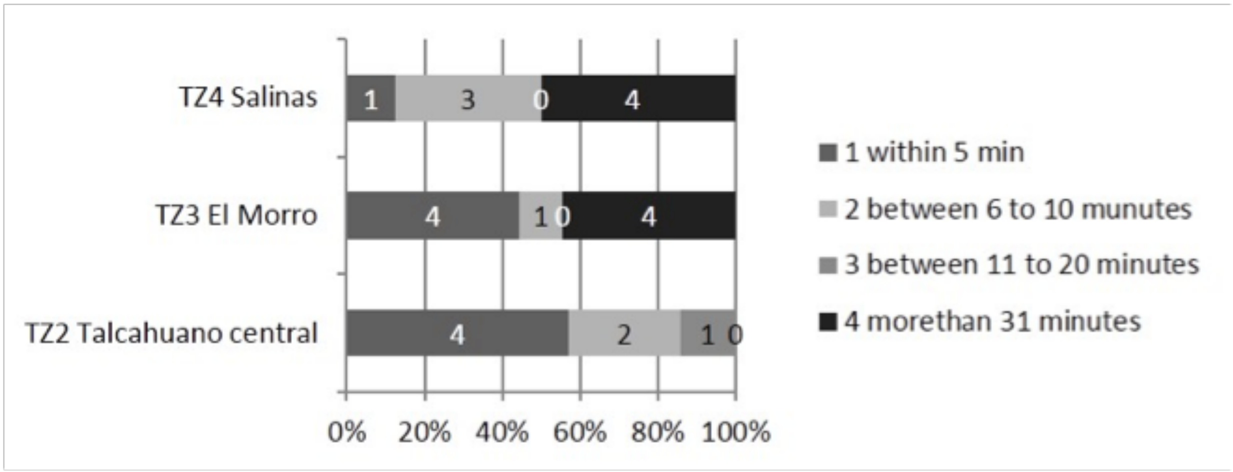

Fig 16 Did you hear tsunami alert or siren (Q5, n=58)

Of all respondents 38% evacuated 5 minutes after the earthquake, 25% between 6 and 10 minutes later and 33% after 31 minutes from the earthquake. In the TZ4 Salinas area, which is characterized by a flat area with distant hills, the slowest evacuation was recorded, where 50% evacuated to security zones between 5 and 10 minutes after the earthquake; meanwhile, in the TZ2 Central Talcahuano zone, the evacuation was the fastest, with 83% evacuated to high safety zones between 5 and 10 minutes after the earthquake (Fig. 17). Table 2 shows time taken to start evacuation in the 2011 Great Tohoku earthquake tsunami. It is clear that evacuation of Talcahuano in 2010 and 2015 is much faster.

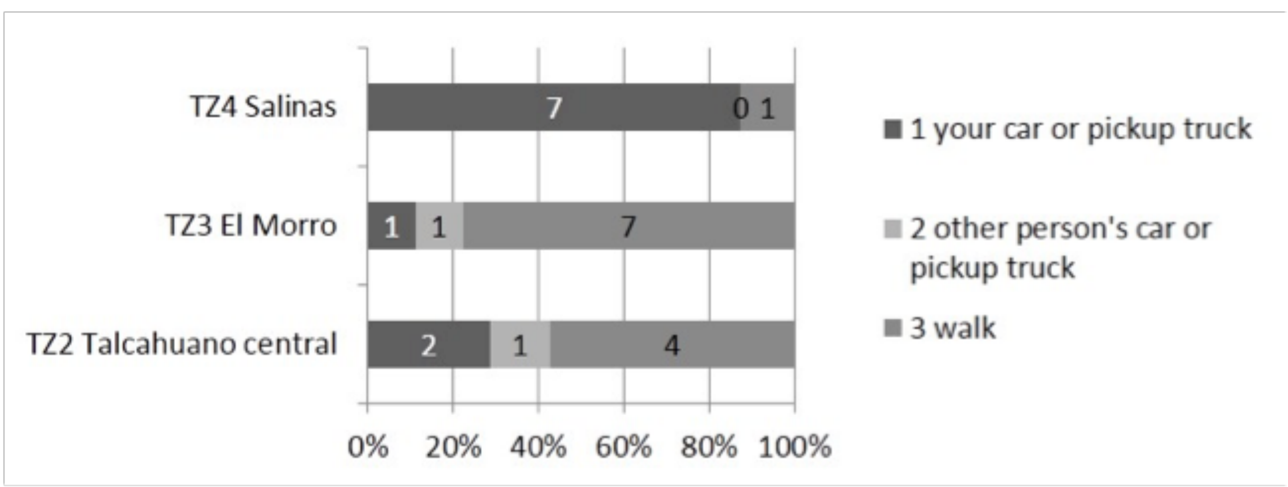

Fig. 17 When did you start to evacuate? (Q6B, n=58)

Table 2 Time taken to start evacuation in the 2011 Great Tohoku earthquake tsunami, by MLIT survey for disaster restoration (Murakami).

Tsunami risk perception after eq.	No. of cases	Average starting time after eq. (min.)	Time at which 50% of people started evacuation (min.)	Time at which 80% of people started evacuation (min.)
I thought tsunami should come, or I thought tsunami might come.	3105	18	14	29
I thought tsunami would noto come, or I didn't think about tsunami.	2411	25	24	42
Total	5524	22	14	34

5.2 Transport means for evacuation

Fig. 18 shows that in the TZ4 Salinas area, where the flattest topography is observed, 87% of people evacuated by cars or pickup trucks, mainly because the safety zones are defined in the hills, 2 kilometres away from residential areas, a distance which people avoid walking, despite the fact that during the evacuation of 2010 a high traffic jam was recorded on the escape routes in this area. In the case of the TZ2 Central Talcahuano and TZ3 El Morro areas, where the safe zones are defined in the hills that are less than 500m away, the evacuation was conducted mainly walking.

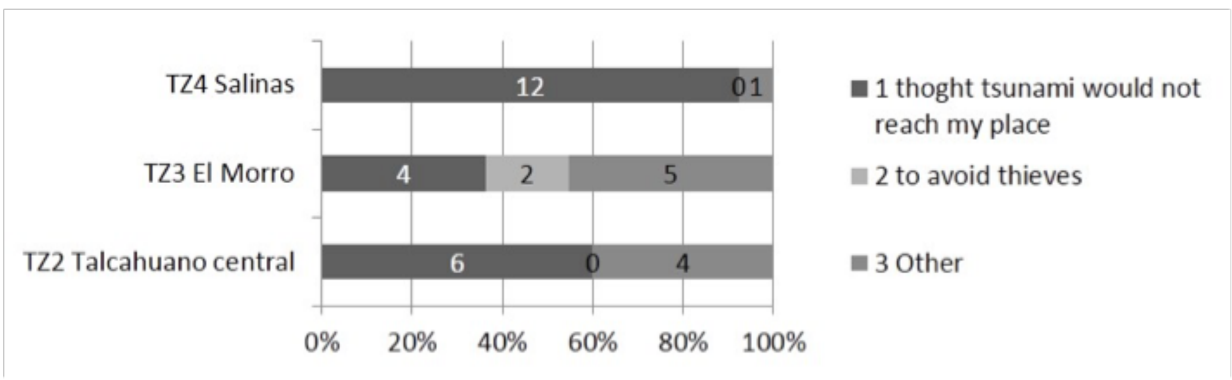

Fig. 18 Transport means to evacuate (Q6C, n=58)

Fig. 19 shows that people in the TZ4 Salinas area (where the flattest topography is observed and where safe hill areas are 2 km from point at the highest risk) did not evacuate because they thought the tsunami would not reach their houses, even though the evacuation alarm was activated. This shows the low perception of the risk by the population when comparing the smaller magnitude of the 2015 earthquake with that of 2010. Another factor that influenced the decision not to evacuate was to avoid leaving their homes alone for fear of thievery.

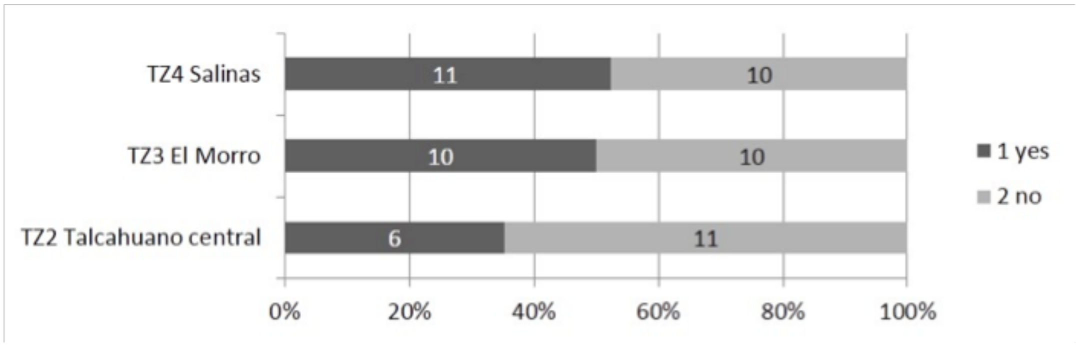

Fig. 19 Main reason you did not evacuate (Q7, n=58)

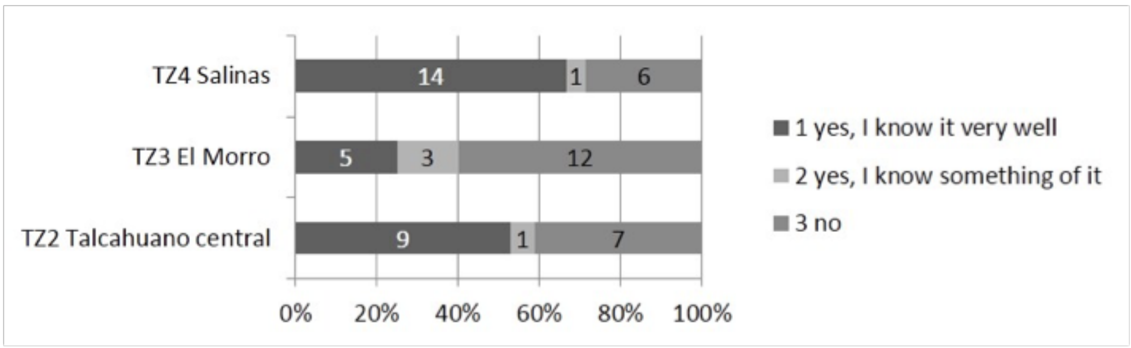

Fig. 20 Did you participate in tsunami evacuation drills? (Q10, n=58

Fig. 20 and Fig. 21 show that approximately 50% of people participated in evacuation drills and claimed to know the evacuation maps spread by the Municipality, which shows an interest in preparing for future emergencies.

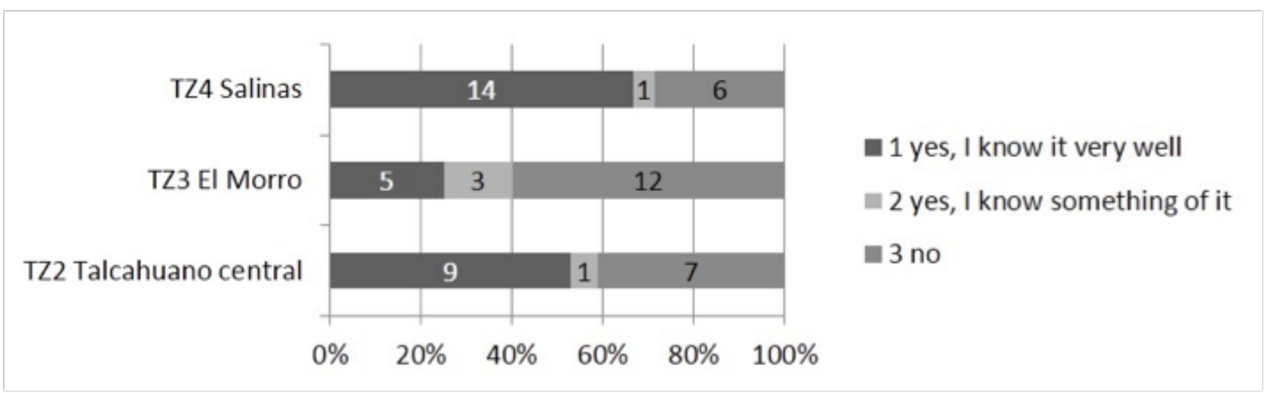

Fig. 21 Did you know the city tsunami risk map (Q22, n=58)

5.3 Summary of findings in the Talcahuano tsunami evacuation 2015

A questionnaire survey was conducted in Talcahuano to investigate evacuation behavior after the 2015 Coquimbo Earthquake and subsequent tsunami.

1. In relation to the 2015 earthquake, respondents point out that the perception of risk was lower than for the 2010 tsunami, despite the activation of the alarm for evacuation, which is reflected in the fact that only 32% of the respondents evacuated to high areas.
2. People from the TZ4 area evacuated the risk zone mainly by car, because of a greater distance to the safe areas, causing traffic jams in the evacuation routes, which triggered conflicts between the pedestrians and the car occupants. In the case of TZ2 and TZ3 areas, people evacuated mainly by walking to nearby hills, within 500 m distance.
3. After the 2010 earthquake, the Municipality of Talcahuano has constantly carried out tsunami evacuation drills where the population generally participate; this certainly helps to prepare for future events. However, the low percentage of evacuation during the 2015 tsunami alarm is mainly due to the low levels of perception of risk among the population, when compared to the great earthquake of 2010.
4. In general, families claim to know the tsunami risk maps, which helps to keep track of evacuation routes and safe areas to react in a timely manner. This contrasts with the perception of risk when people compare the lower magnitude of the 2015 earthquake with that of the 2010 disaster, not aware that a smaller magnitude earthquake can equally trigger a potentially disastrous tsunami.

6. Conclusions

The 2010 Maule earthquake and the 2015 off coast Coquimbo earthquake caused tsunami in Chile, and the questionnaire surveys were conducted in the cities of Talcahuano and Dichato, the most affected cities. This study analyzed and compared tsunami evacuation behavior and affecting factors in view of urban form and evacuation environments. The findings are as follows.

Tsunami evacuation tends to be faster in Chile than in Tohoku, however, it is important to address the fact that tsunami arrival times in Chile can be much faster than in Tohoku. An approximate 5% to 10% of people did not evacuate as they thought the tsunami would not affect their homes or they wanted to protect their homes from thieves. Besides, it is important to determine how to better support elderly and handicapped people for evacuation. Tsunami warning systems in Chile are developing fast and now people are getting more frequent warnings than before, in cases of smaller seismic activities. As for the means of transport, the majority of people evacuate on foot as they respect it as a basic rule. However, automobile evacuation tends to increase in areas where car ownership and daily use of automobiles are common, such as suburbs where evacuation places are far or in upper class communities. People evacuating on foot face various difficulties and risks due to traffic jams caused by automobiles or fast moving vehicles.

A difference is detected in the evacuation process between the areas of the city where hills are higher and closer and the flat sectors with distant hills; in the first areas, evacuation is faster and it is mainly on foot, unlike the second areas, where evacuation tends to be slower and the use of an automobile increases considerably, causing jams on the roads.

At the moment of the tsunami, evacuation routes in the cities of Talcahuano and Dichato were poorly signposted and 25% of people rated them as good, 21% as ‘regular’, and 54% as ‘bad’ and ‘very bad’; this is mainly because their design did not facilitate the displacement of people and, after the earthquake, the roads were obstructed by debris that fell off the facades of buildings; similarly, the safe zones did not provide a minimum of facilities or services, such as drinking water, protection against the weather, or health services, making it difficult for people to remain in them.

The two earthquakes occurred at night time when family members were mostly at home and together. In cases of a daytime earthquake, people may try to get back home to help the elderly or children, at home or in nursing schools and such trips by automobiles increase traffic. Studies on working people and work places, such as industries and offices, with regards to tsunami evacuation are important as they improve protocols and awareness of tsunami related hazards.

In the case of the 2015 earthquake, in Talcahuano the evacuation rate of people away from the risk zone was low (32% evacuated to high areas), despite the fact that the tsunami alarm was activated. This was due to the low perception of risk among the population, because of the lower magnitude of this earthquake (8.4 Mw) compared to that of the 2010 earthquake (8.8 Mw). This behavior may constitute a false perception of risk considering that an 8.4 Mw magnitude earthquake can produce a potentially destructive tsunami.

Acknowledgements

The study was conducted for the research project in Chile entitled “Enhancement of Technology to Develop Tsunami-Resilient Communities”, which was headed by Dr. T. Tomita of Port and Airport Research Institute, supported by JST/JICA SATREPS in collaboration with Chilean researchers and counterparts. The authors acknowledge inhabitants of Talcahuano and Dichato, who kindly answered questionnaires, JICA Chile office and the project coordinators who continuously supported our field work in Biobío. The authors express sincere gratitude to the students of the University of Concepción who participated in the survey, Ms. Alejandra Contreras, and Mr. Patricio Diaz who assisted the study by GIS mapping of evacuation routes, and Prof. Edilia Jaque who kindly provided us with GIS base map data.

References

Ayala, F and Olcina, J.,2002. Riesgos naturales. Barcelona: Ariel.

Boisier, S., 2001. Desarrollo local: ¿De qué estamos hablando ? Transformaciones globales. Instituciones y politicas de desarrollo local, pp. 48-74. Rosario: Homo Sapiens.

Fraser, S., Graham, L., Murakami,H., and Matsuo, I., 2012. Tsunami Vertical Evacuation Buildings- Lessons for international Preparedness Following the 2011 Great East Japan tsunami, Journal of Disaster Research Vol. 7 No.sp, 2012.

Gusiakov, V. K., 2005. Tsunami generation potential of different tsunamigenic regions in the Pacific. Marine Geology, 215 (1-2): 3-9.

Imamura, F. U., Bernard, E. N. and Robinson, A., 2009. Tsunami modeling: calculating inundation and hazard maps. The sea, 15: 321-332.

Kastenberg, W.E., 2015. Ethics, risk, and safety culture: reflections on Fukushima and beyond. Journal of Risk Research, 18 (3): 304-316.

Kelleher, J. A., 1972. Ruptures zones of large South American earthquakes and some predictions. Journal of Geophysical Research, 77 (11): 2087-2103.Kontar, Y. A., Santiago-Fandiño, V. and Takahashi, T. (2014). Tsunami Events and Lessons Learned. Springer Netherlands: 467 pp.

Liu, Y., Santos, A., Wang, S.M., Shi, Y., Liu, H. and Yuen, D.A., 2007. Tsunami hazards along Chinese coast from potential earthquakes in South China Sea. Physics of the earth and planetary interiors, 163(1): 233-244.

Maruyama, Y., S. Matsuzaki, F. Yamazaki, H. Miura and M. Estrada, 2010. Development of GIS dataset for damage distribution analysis after the 2010 Chile Earthquake, Journal of Japan Society of Civil Engineers, A1, Vol. 66, No.1, pp.377-385.

Murakami, H., Ramos, L., 2014. Tsunami evacuation questionnaire survey for cities of Talcahuano and Dichato in the 2010 Maule earthquake in Chile, Part 2 Survey results, Proc. 14th Japan Earthquake Engineering Symposium, paper number OS13-Fri-AM-3.

Murakami, H., Nagase, Y., Takahashi, M., Asai, K., Ikeda, M., and Sase, K., 2015. Study on Tsunami Evacuation after the 2014 Iquique Earthquake, Chile (2) Results of Questionnaire Survey for Inhabitants, Proc. Annual Research Meeting, Chugoku Chapter, Architectural Institute of Japan, No. 38.

Murakami, H. and Okumura, Y., 2014. Study on Tsunami Evacuation after the 2014 Iquique Earthquake, Chile (1) Hearing Survey for Public Offices, Communities, and Shopping Center, Proc. Annual Research Meeting, Chugoku Chapter, Architectural Institute of Japan.

Pujadas, R. y Font, J., 1998. Ordenacion y planificacion territorial. Madrid: Síntesis.

Ramos, L., and Murakami H., 2014. Tsunami evacuation questionnaire survey for cities of Talcahuano and Dichato in the 2010 Maule earthquake in Chile Part 1 Background and survey scheme, Proc. 14th Japan Earthquake Engineering Symposium, paper number OS13-Fri-AM-2.

Ramos, L., 2016. Urban Evacuation Tsunamis: Guidelines for Urban Design. Journal of Engineering and Architecture, Vol. 4, No. 2, pp. 117-132.

Saito, T., Ito, Y., Inazu, D. and Hino, R., 2011. Tsunami source of the 2011 Tohoku‐Oki earthquake, Japan: Inversion analysis based on dispersive tsunami simulations. Geophysical Research Letters, 38 (7): 1-5.

Serra, A., 2011. Turning hazards into resources? Floods, wetlands and climate change in Mediterranean coast of Spain. (Tesis doctoral), Universidad Autonoma de Barcelona, Barcelona.

Tomita, T., Kumagai, K., Mokurani, C., Cienfuegos, R., and Matsui, H., 2014. Post field survey on the April 2014 Earthquake and Tsunami in Northern Chile, Proc. 14th Japan Earthquake Engineering Symposium, paper number OS12-Fri-AM-4.

Wilches- Chaux, G., 1993. La vulnerabilidad gloval. Los desastres no son naturales, pp. 11-44: La Red.

Zilbert, L., 2010. Evolución de las políticas de la reducción de riesgo de desastres. En PNUD (Ed.), Diplomado de Especialización en Desarrollo Local y Gestión Integral del Riesgo (hoja de ruta) PNUD: escuela virtual.