Regional Evaluation of the Risk Price of Apartments Reflecting Seismic Indoor Risk in Japan

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Abstract

In Japan, when an earthquake occurs, several residents are exposed to a high injury risk owing to falling furniture. The Japanese government recommend securing furniture as the only manner to reduce this risk. Currently, residents can secure a maximum of 50% of their furniture if the wall materials, types of furniture, and setting place are not adequate. The number of furniture pieces is approximated based on the number of family members. Evidently, selecting a large room is an effective measure to reduce indoor risk. The size of the apartment should be moderately narrow at 44 m² compared with an owner-occupied house of 125 m² based on the average Housing and Land Survey (2013, Japan). This indicates that apartments exhibit a high injury risk compared with owner-occupied houses. The number of furniture pieces in a house is equal to the number of family members, assuming that each family member has a piece of furniture in their respective rooms. However, the number of furniture pieces should be minimized to minimize the injury risk in an apartment, and thus, live peacefully. First, we must ensure that apartments entail very narrow rooms and high injury risk compared with owner-occupied houses. We calculate the injury risk probability in two cases on a national average. In the first case, the injury ratio is determined assuming that all the furniture falls, called potential injury risk. In the second case, the injury ratio then reflects the actual seismic intensity based on the intensity of the earthquakes observed over the last 50 years which was 2%. Indoor risk probability was calculated by Nachi and Okada (2012) [1)]. Thus, all prefectures have the injury risk observed in an apartment. Here, the probability of risk depends on the intensity of the earthquake and is much lower than the potential risk. Second, we focus on the potential injury risk of the apartment for each price zone in the 47 prefectures. Presently, several residents neglect the indoor risk and there are no guidelines associated with this risk to follow when looking for an apartment. A real-estate agent LIFFUL HOME'S has detailed information of 5,273,628 apartments. We consider these data and conduct a macro analysis of each prefecture unit. We calculate the injury ratio for apartments with 50,000 and 10,000 JPY rent per month. Thus, the injury ratio has regional differences in the 47 prefectures. Tokyo (the capital city, 63% ratio) and Kyoto (a famous city, 66% ratio) have maximum injury risk; Okinawa (the southernmost country prefecture, 31% ratio), the lowest. As the rent increase, the injury ratio diminishes and differential regional risk narrows. For example, living in Tokyo (36%) or Kyoto (34 %) for 100,000 JPY rent per month has the same injury ratio as living in Okinawa for 50,000 JPY rent per month. The same-sized rooms have regional differences because of the differences in rent. This regional evaluation of the risk price demonstrated the actual risk to the residents. We should propose manners to select the best house simultaneously considering region and rent.

Keywords: Earthquake, Human Injury, Indoor Risk, Rental Housing

1. Introduction

In Japan, many people have been injured by falling furniture during earthquakes. Fixing furniture to the wall is an effective measure to reduce injuries, but not all furniture can be fixed, owing to the rules of rental housing and restrictions on the housing structure. Currently, residents can secure a maximum of 50% of their furniture, if the wall material, types of furniture, and setting place are inadequate. Additionally, the size of apartments is moderately narrow, at 44 m², compared to an owner-occupied house, at 125 m², based on the average taken from the 'Housing and Land Survey (2013, Japan)' [1]. Therefore, selecting larger rooms is an effective measure to reduce indoor risk. Disaster mitigation measures in Japan do not have appropriate measures for this risk gap between apartments and houses. Generally, real estate companies introduce apartments to their clients with consideration of profit only. Clients do not factor indoor risk into their search for an apartment, but rather focus on the age of the building, the cost, and convenience. Room conditions do not affect the seismic injury risk (and safety for the earthquake). Therefore, it is important to have customers consider risk information when choosing a home.

In this study, we firstly show residents that apartments have a higher risk than owner-occupied houses with regard to seismic indoor risks. Secondly, to determine a tangible value for the risk of apartments, we compared the ratio of the indoor injury risk of apartments with the rental price per month. We also investigated what conditions need to be met when searching for a safer apartment. Nachi and Okada (2012) [2] proposed an analysis of indoor injury risk, following a probability model, to promote seismic indoor safety. We calculated an indoor injury ratio following this model, using 'LIFULL HOME'S Data Set (2015)' [3], which includes a large dataset on apartments in Japan, providing us with realistic information on rental properties.

2. Evaluation method and LIFULL HOME'S Data Set

2.1 Evaluation method

Indoor injury ratio has been calculated by Nachi and Okada (2012) [8]. While explaining the formula simply, we show concretely examples of variables.

The effective floor area (Se [m^2]) on which the habitants stay was calculated by subtracting the sum of the furniture area (Sf) from the size of the rooms (S). In Eq. 2.1, S is the occupied area of an apartment or a house, Sf is the sum of the furniture bottom area (number of furniture × Wide × Depth sum), and m is 7, which is the number of furniture types in this study (see chapter 2.2).

$$Se = S - \sum_{i=1}^{m} Sf_i \qquad ,m = 7. \tag{2.1}$$

The ratio of the sum of the fallen over furniture area (Str) to the effective area (Se) is Rtr, which indicates the area occupied by furniture per 1 m² in each falling pattern. Str is calculated as the sum of 'the number of furniture by each furniture type' × Depth × High. In this study, t is at most 7 (m), which is the number of falling furniture.

$$Rtr = \frac{\sum_{i=1}^{t} Str_i}{Se} \qquad ,0 \leq t \leq 7. \tag{2.2}$$

The injury ratio of one resident (n=1, k=1) is equal to Rtr. When n people are in the same property room and k out of n people are injured, the injury ratio for each person is almost independent, so Nachi and Okada used the Bernoulli trial to determine whether a person is injured or not. However, since the number of household members (n) in this study is derived from their average value, which involves decimal places, a gamma function was used to express the difference in the number of household members between prefectures as the difference in the injury ratio. The injury ratio (*p*) is the probability that *k* out of *n* people will get inside the *Rtr*, that is, the probability of injury. Eq. 2.3 was used for calculating the injury ratio (*p*) using a binomial distribution. Eq. 2.4 represents the conversion from Eq. 2.3 to the gamma function. *X* represents the number of injured people.

$$p[X = k] = {}_nC_k Rtr^k (1 - Rtr)^{(n-k)} \qquad , k = 0,1,2, \dots, n. \tag{2.3}$$

$$p[X = k] = \frac{\Gamma(n+1)}{\Gamma(k+1)\Gamma(n-k+1)} Rtr^k (1 - Rtr)^{(n-k)} \qquad , k = 0,1,2, \dots, n. \tag{2.4}$$

"P" represents how much probability of injury an apartment or house has for all injury patterns ($k = 0,1,2, \dots, n$). In this study, since *n* of all prefectures average is in the range of $2 < n < 3$, the injury ratio of an apartment or a house can be expressed as follows:

$$P = p[X = 1] + p[X = 2] \tag{2.5}$$

We assumed that the degree of injury is not considered in these equations and that the furniture falls over but does not fall out.

We first varied the seismic intensity, and Rtr was determined individually for each seismic intensity. Secondly, we fixed the seismic intensity and assumed that the building will not collapse in any of the cases, considering that all furniture falls over indoors without overlapping, and Rtr was uniquely determined (*Rtr* = 1).When considering the seismic intensity, the ratio of the indoor risk is affected by the change in Rtr through the introduction of the rate of furniture that has fallen over due to shaking (see section 3.1). The potential injury ratio that Rtr determines at maximum is the worst pattern of indoor injury when all furniture has fallen over (see section 3.2). For example, an apartment of the LIFULL HOME'S Dataset has an injury ratio of about 45%, which indicates that people in this room have a 45% possibility of injury when an earthquake occurs that causes all furniture to fall over. This value is 'the potential injury ratio'.

2.2 Variables

We calculated the indoor injury ratio with the furniture sizes shown in Table 2.1. These variables represent the size and types of furniture in all prefectures. The number of furniture possessions and household members are shown in Table 2.2, and these values are based on the average of Japanese prefectures. The other values are based on references [1,3,4,5].

We termed the injury ratio, which reflects the actual seismic intensity, as 'The seismic intensity-based injury ratio'. This seismic intensity is JMA for a 2% Probability of Exceedance in 50 Years at Prefectural office locations [6, 7]. The distribution is shown in Figure 2.1 and Figure 2.2

Table 2.1 – Types and Size of Furniture

	Width *W* (cm)	Depth *D* (cm)	Height *H* (cm)
Microwave	50	46	35
Refrigerator	59.25	62.625	151.875
Washing machine	66.2	56.2	92.7
Chest	105.6	45.1	141.5
Cupboard	103.8	42.2	160.3
Dresser	73.8	38	125.8
TV	48.3	13	36.3

Table 2.2 - Quote source of variables

	Owner-occupied house and rental housing	LIFULL HOME'S Dataset
Size of rooms *S* **(m²)**	Housing and Land Survey Table 9. (2013, Japan) [1] (average on prefectures)	H27 LIFULL HOME'S Dataset (average) [3]
Number of household members ***n***	Housing and Land Survey Table 9. (2013, Japan) [1] (prefecture average)	Housing and Land Survey Table 9. (2013, Japan) [1] (prefecture average)
Number of Furniture	The National Consumption - State Survey Table 25 (2015, Japan) [5]	The National Consumption - State Survey Table 25 (2015, Japan) [5]
Furniture dimensions (width, height, depth [cm])	Architectural design document collection – goods [4] (average of 1960, 1978 and 2003)	Architectural design document collection – goods [4] (average of 1960, 1978 and 2003)

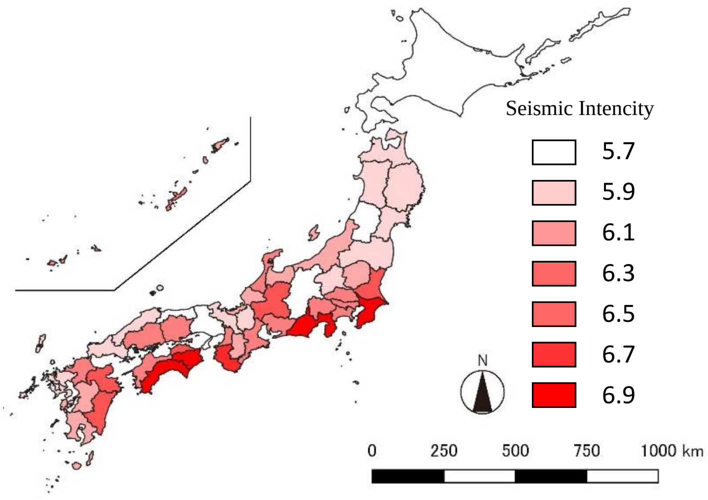


Figure 2.1 - JMA for a 2% probability of exceedance in 50 years at prefectural office locations.

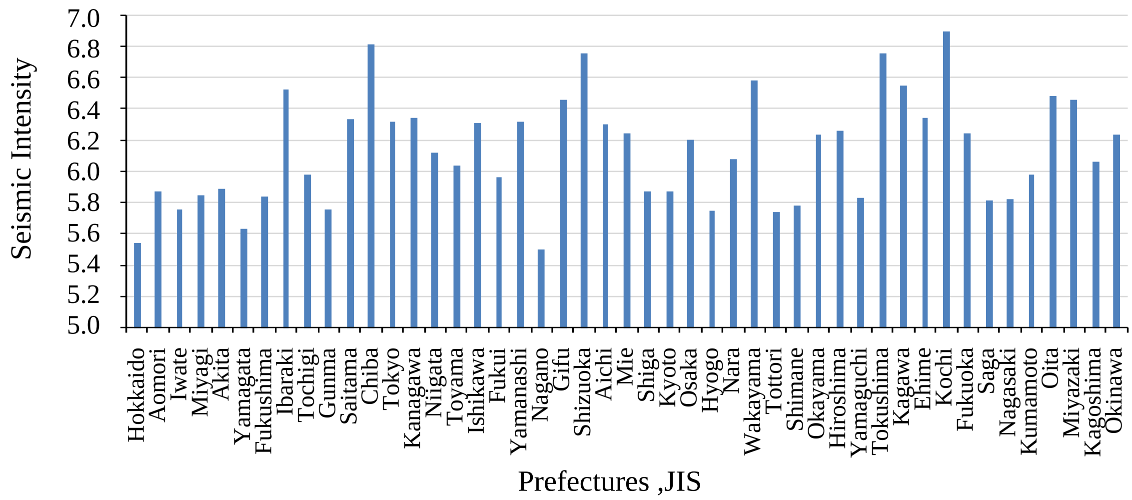


Figure 2.2 - The distribution of seismic intensity values

2.3 LIFULL HOME'S Data Set

We used the 'LIFULL HOME'S Data Set [4]' (hereinafter referred to as the HOME'S Dataset), which includes 5.34 million properties (28.5% of the total apartments and rental houses in Japan) and possesses actual data of rented and vacant properties currently on the market. Using this dataset, we have made clear the risk involved for apartments. Rental property information was included in 71 items. From the dataset, we primarily used the ID, size of the room, and price.

We excluded properties that were listed with a rent price over 10 million JPY per month and commercial properties. The average rental cost was 65,840 JPY, the maximum rent was 9250 thousand JPY, and the minimum was 1000 JPY. The total number of properties was 5,291,614. The number of data and average rent are presented in Figure 2.3 and Figure 2.4.

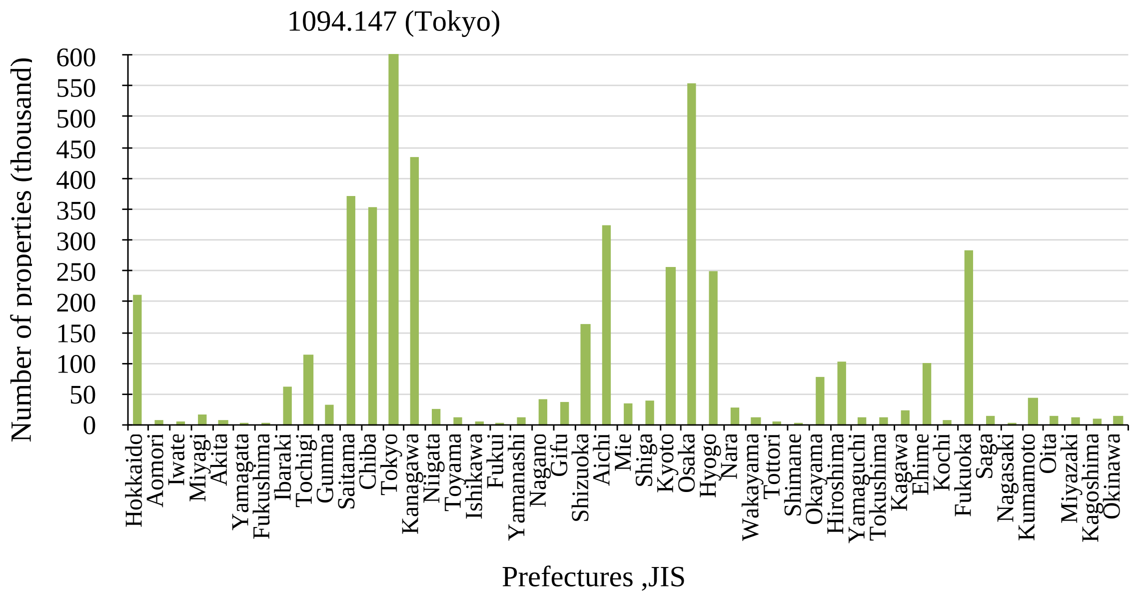


Figure 2.3 - Number of properties by prefecture from HOME'S Dataset

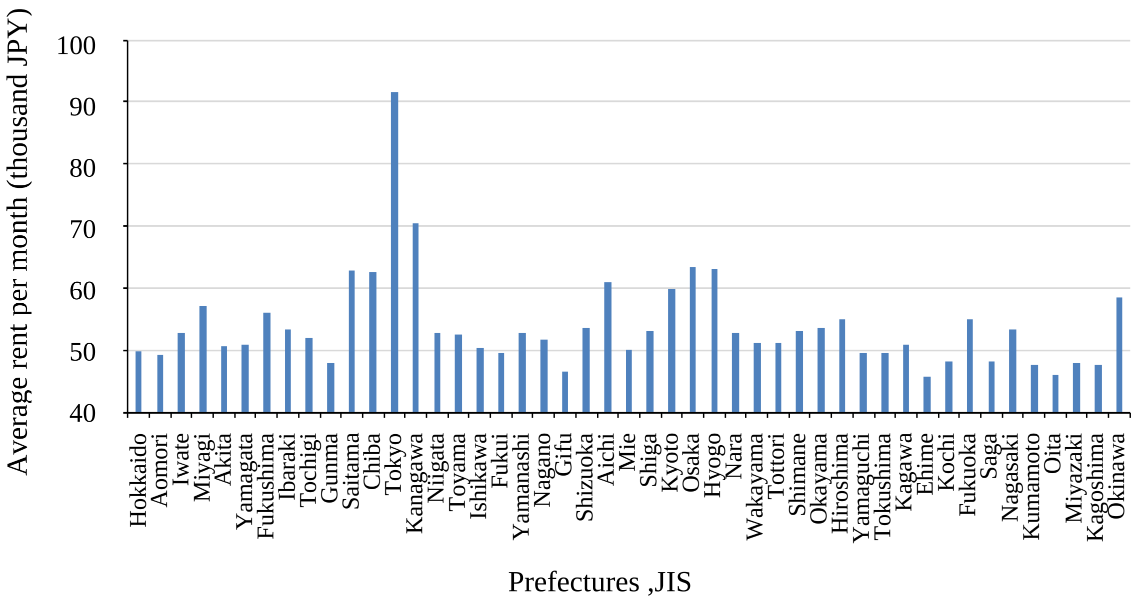


Figure 2.4 - Rent by prefecture from HOME'S Dataset

3. The risk of apartments

Using the average room size of ~~owneroccupied~~owner-occupied houses and apartments, we calculated the injury ratio, separated by prefecture. We examined whether apartments with smaller room area actually have a higher injury ratio. In section 3.1, the seismic intensity-based injury ratio is expressed on the Japan maps by prefecture. The section shows the levels of the injury ratio in an earthquake that may actually occur. Section 3.2 presents an estimation of the potential injury ratio, in the case where all furniture has been turned over. We compared owner-occupied houses and already-lived-in apartments (Housing and Land Survey [1]) and unoccupied apartments (~~Home~~HOME'~~s~~S ~~d~~Dataset [3]).

3.1 The injury ratio based on seismic intensity —1st case

Considering the seismic intensity, shown in Figure 2.1, and using Equation 2.6, the injury ratio obtained by changing Rtr is shown in Figure 3.1 and Figure 3.2. Compared to Figure 2.2, the injury ratio is higher whenthe predicted earthquake is stronger. This is because the fall area of furniture becomes larger with an increase in earthquake intensity. The injury ratio is high around the *Nankai* trough. There are many prefectures where the risk of injury for rental houses is higher than that of owner-occupied houses, and the risk of injury for LIFULL HOME'S is high among apartments. Owner-occupied houses have a few regional characteristics of injury rates. In all prefectures, regional differences are seen in the difference in the injury ratio between owner-occupied houses and apartments.

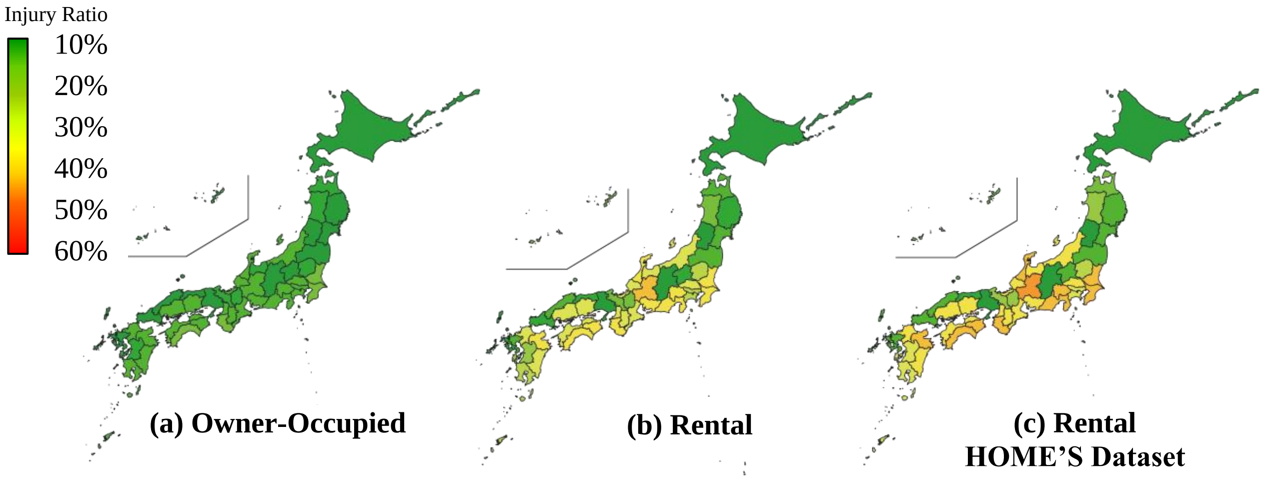


Figure 3.1 - Seismic intensity-based indoor injury ratio

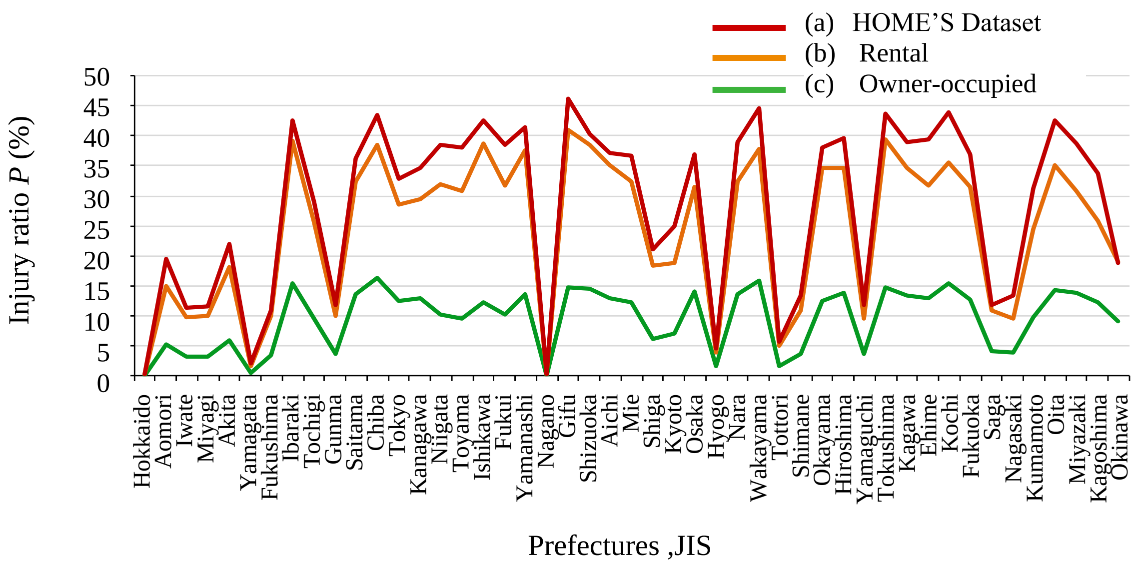


Figure 3.2 - Seismic intensity-based indoor injury ratio

3.2 The potential injury ratio—2nd case

The results for the owner-occupied house and rental apartment injury ratio are shown in Figure 3.3. The injury ratio for owner-occupied houses (Figure 3.3 (a)) is lower than that for rental houses (Figure 3.3 (b), (c)) in every prefecture. This may be due to the fact that the average room area of apartments is smaller than that of owner-occupied houses, provided that there are no differences in other variables between prefectures and that the furniture size is constant in every calculation case. The difference in room area primarily leads to such a difference in indoor risk. The regional gap of the injury ratio tended to be higher in the Japan Sea. This distribution is different to that of the seismic intensity-based injury ratio (Figure 3.1). We must separately consider the standards for the building structure, regarding earthquakes, and the standards for preventing the risk of indoor injury. From Figure 3.4, every owner-occupied house has a ratio under 20%; however, most apartments have a ratio of 30% or more. Additionally, the result shows that apartments have a regional gap of the injury ratio, however, owner-occupied houses have almost the same room size and injury ratio in every prefecture. Looking at the injury ratio based on the HOME'S Dataset (Figure3.4 (a)), it is higher than that in Figure 3.4(b). This indicates that unoccupied properties, such as HOME'S Dataset properties, have higher injury rates than apartments where people currently live.

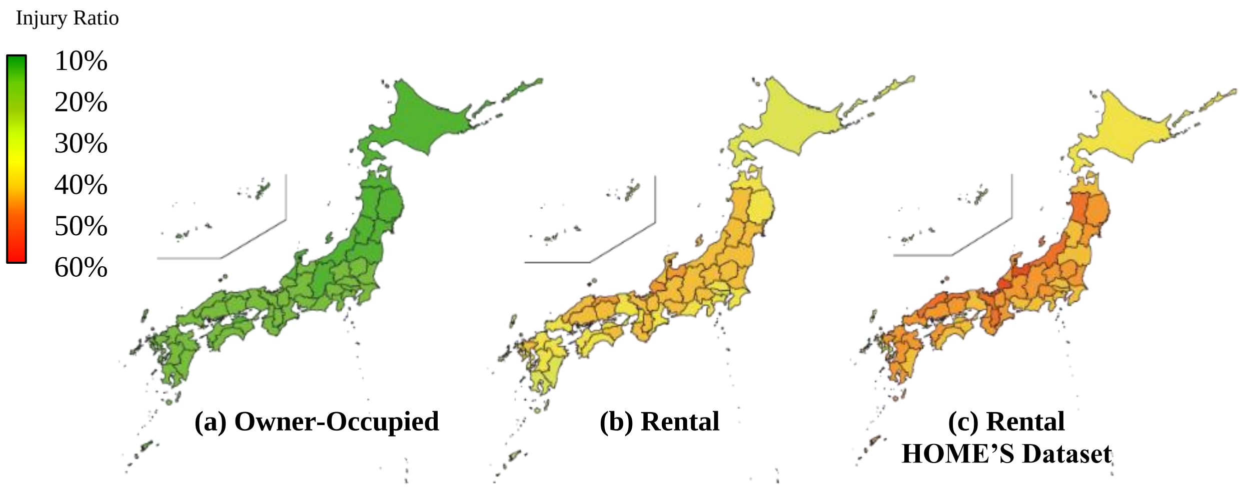


Figure 3.3 - Potential ratio of indoor injury (maps)

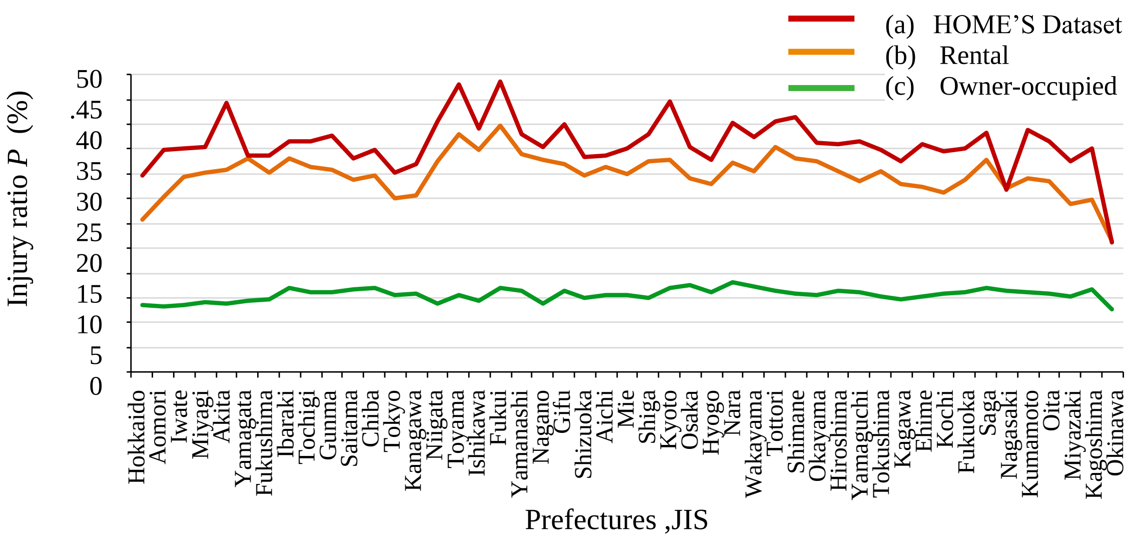


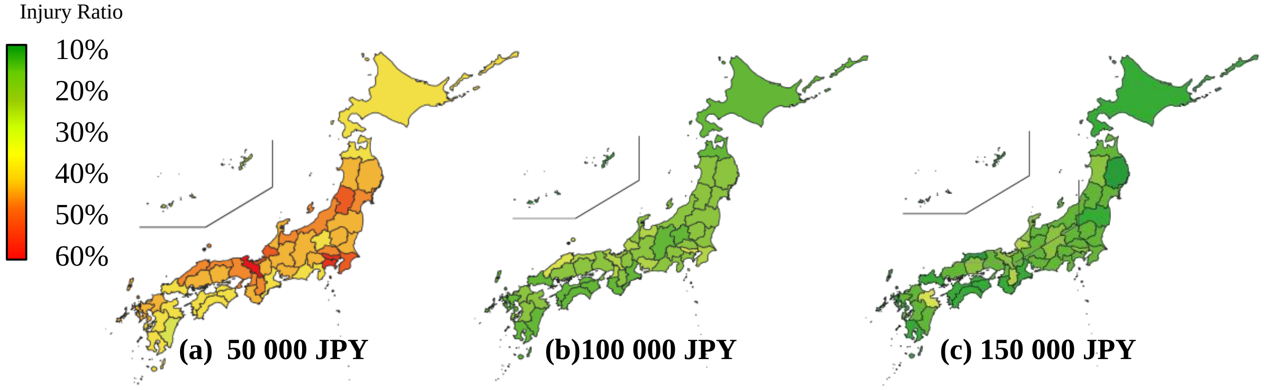
Figure 3.4 - Potential ratio of indoor injury (values)

4. The indoor injury ratio of each price range

From the LIFULL HOME'S dataset, we set price ranges of 50 000 JPY, 100 000 JPY, and 150 000 JPY (Figure 2.4 shows the average rent). Properties within 5000 JPY, before and after each price range, were took and the room area was averaged. The Japanese average rental price was 65,840 JPY. Using the average room area, the indoor injury ratio for each price range was calculated. The average disparity and price disparity of the injury ratio were measured by comparing the injury ratio at a particular rent level in a particular prefecture, using average values.

4.1 Japanese average

The average apartment, at more 100 000 JPY rent (Figure 4.1(b), (c)) shows a result indicating that is as safe as an owner-occupied house (Figure 3.3(a)), and regional differences are not clearly seen. From the Figure 4.1, it is characteristic that the decrease rate of injury probability is different, even with the same price difference of 50 000 JPY. The number of prefectures with an injury ratio exceeding 50% with 50 000 JPY is 17, and with 100 000 JPY or more, this value is 0. The price standard for the injury ratio is likely to be about 100 000 JPY. As described above, after setting the rent of the rental property and investigating the relationship between the injury probability and the rent, it was found that there were prefectural disparities. Even if the rent is raised, there is a limit in reducing the injury probability. The Nagano Prefecture had no properties with a price of 150 000 JPY and is, therefore, blank. Figure 4.3 shows the highest injury ratio (Tokyo, Kyoto), lowest injury ratio (Okinawa), and Hokkaido injury ratio from Figure 4.2, dependent on the rent per month. From this figure, the injury probability, when paying 100 000 JPY in Tokyo, is almost similar to the injury probability when paying 50 000 JPY in Hokkaido. It can be observed that the rent paid to live safely varies from prefecture to prefecture. From Figures 4.2 and 4.3, it was predicted that the difference in the ratio of injury converged as the rent increased; if the price increased, the previous regional disparity would decrease, and the room area would be similar. However, the effect of reducing the probability of injury, owing to the rise in rent, is small. It appears that there is a limit to reducing the rate of injury by only increasing the rent.



(a) 50 000 JPY (b)100 000 JPY (c) 150 000 JPY

Figure 4.1 - Potential indoor injury ratio for each rental cost

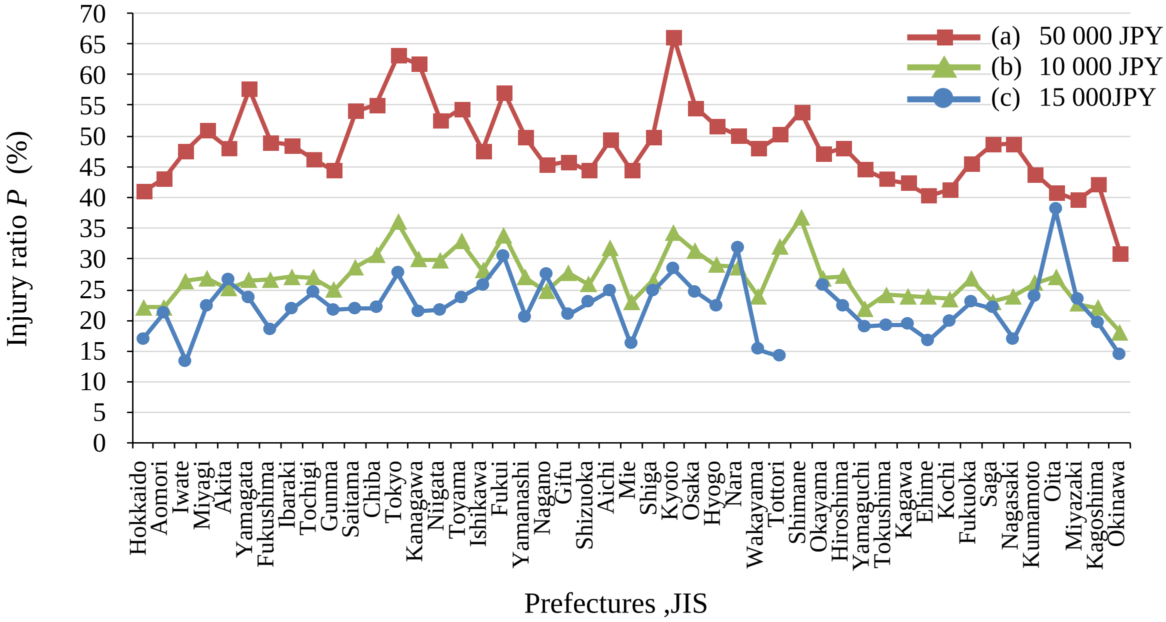


Figure 4.2 - Potential indoor injury ratio by rent section

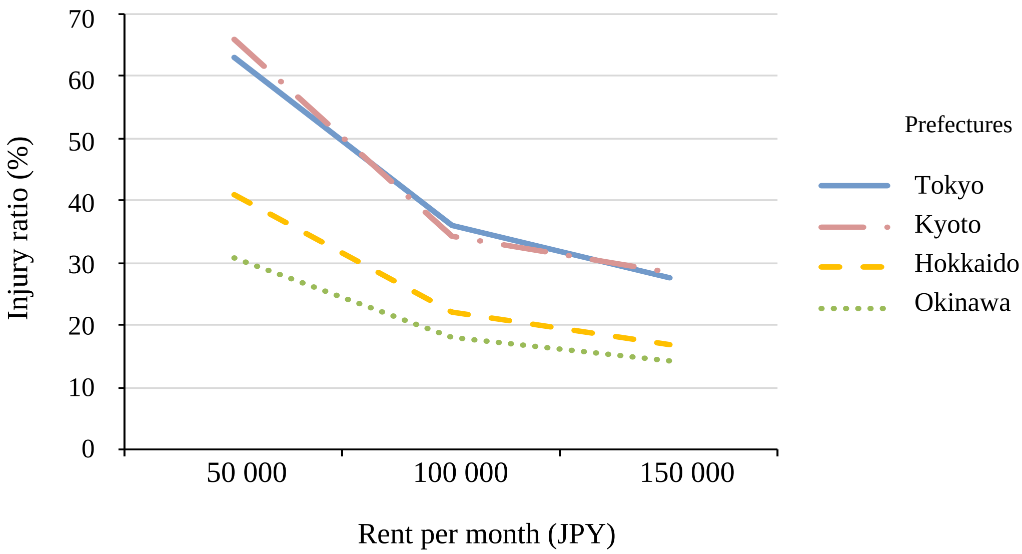


Figure 4.3 - Potential indoor injury ratio by rent section (Tokyo, Kyoto, Hokkaido, Okinawa)

4.2 In Hokkaido or Tokyo, choosing a safer room

Using the previous results, the Tokyo and Hokkaido injury ratio for apartments are shown in a histogram, with the number of cases as the frequency, in increments of 5% of the injury ratio (Figures 4.4 and 4.5). The figures show the injury ratio selection range for each price range in Hokkaido and Tokyo. Based on the previous results, the potential injury ratio for owner-occupied houses was less than 20%; we can, therefore, consider 20% injury ratio as a benchmark. In Hokkaido, a property must be carefully chosen around 50 000 JPY because there are many properties with an approximately 40% injury ratio and there are no apartments with 20 % or less injury ratio. At 100 000 JPY and 150 000 JPY, most of the properties are as safe as the average owner-occupied house, however, there are also high ratio properties in the distribution. In Tokyo, if a 50 000 JPY property is chosen, the ratio of injury will be over 50%, regardless which property type is chosen. When a rent of 100 000 JPY is chosen, the property type can be selected because the distribution is wide. Even for a rent value of 150 000 JPY in Tokyo, the situation is not promising.

When comparing Tokyo and Hokkaido, there was a regional disparity — when choosing a rental house, it was not possible to select a safe property at the same price. It was also found that there was only a limited number of properties in the same prefecture that could be selected to rent. Usually, when people look for apartments, the area and price will be fixed. It is necessary to fill the regional disparity seen in Section 4 by criteria other than a high rent.

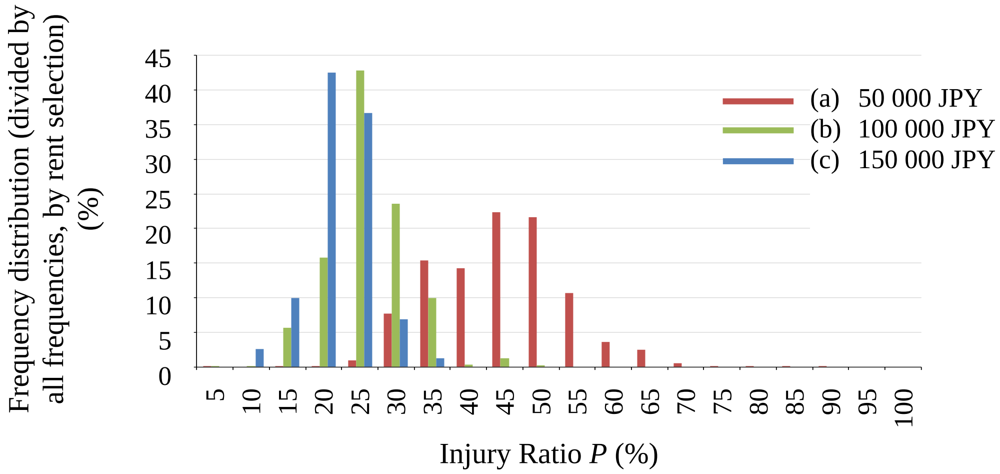


Figure 4.4 - Potential indoor injury ratio by rent section (Hokkaido)

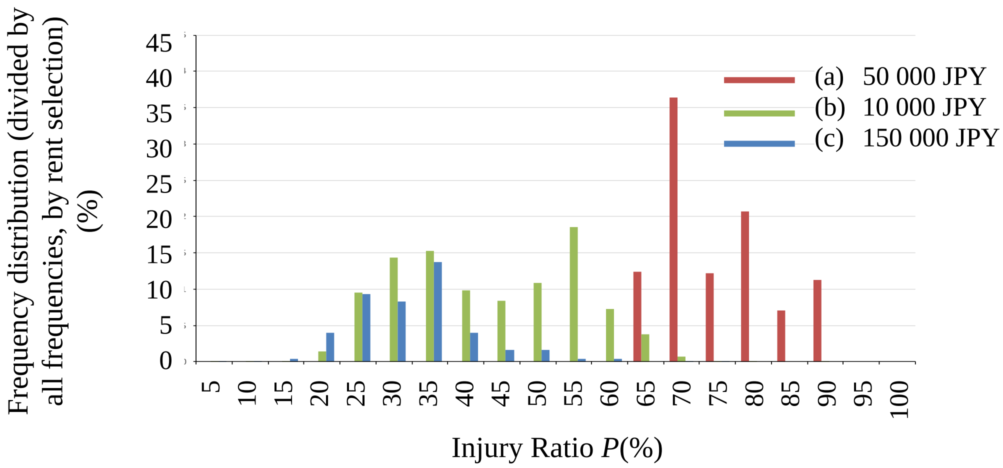


Figure 4.5 - Potential indoor injury ratio by rent section (Tokyo)

5. Summary

This study clarified the high danger of rental properties and regional disparities in Japan. However, there is currently no method to choose a safer property at the same price. We plan to investigate the details of how to search for safe residences during an earthquake and how we can choose a safer house in the same rent range and prefecture. We aim to develop systems to allow residents to choose their rooms with safety.

6. Acknowledgements

The property data of LIFULL HOME'S used in this study was the "LIFULL HOME'S Data Set" provided by LIFULL Inc. for research purposes in cooperation with the National Institute of Informatics. Thank you.

7. References

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