17th World Conference on Earthquake Engineering, 17WCEE
Sendai, Japan - September 13th to 18th 2020

FINANCIAL PROCUREMENT FOR EARTHQUAKE DISASTER RECOVERY AND THE EFFECTS OF FINANCIAL SUPPORT MEASURES

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Abstract

Recently, many earthquakes have occurred owing to inland active faults, including the 2016 Kumamoto earthquake, the 2018 Osaka earthquake, and the 2018 Hokkaido Eastern Iburi earthquake. Earthquakes caused by inland active faults are of a scale smaller than the trench-type earthquakes. However, when major local earthquakes occur near cities, the livelihoods of the local residents are threatened. National and local governments typically aim for a rapid recovery and reconstruction from earthquake disasters. The governments implement disaster management plans and promote the estimation of the victims' economic housing damage and the development of various rehabilitation support systems. For a quick recovery from earthquake disasters, national and local governments are required to estimate the required funds for housing reconstruction after the disaster, based on various reconstruction support systems such as earthquake insurance and life reconstruction support. Particularly, these systems are often formulated on the assumption of a general urban structure (i.e., detached houses). There is a concern that the earthquake damage estimation in metropolitan areas cannot be sufficiently achieved as it does not conform to the urban structure of the metropolitan area and the damage aspect.

In this study, we focused on the type of systems that the central or local governments can build for earthquake victims to enable quick rebuilding. We estimated the necessary reconstruction funds and the benefits of the support system, including self-funding in the earthquake aftermath. We also calculated the shortage of reconstruction funds by comparing the necessary reconstruction funds with the benefits of the support system and the amount available for self-funding. We subsequently captured the trend of damage and estimated the effects of future support measures by clarifying the earthquake intensity, damage level, dwelling reconstruction, and deficient reconstruction funds for each type of structure. In addition, the self-funding assumes multiple cases due to its expected variability among households. From the earthquake simulation, we quantitatively showed that many victims are unable to raise the funds needed for reconstruction. We also showed that the tendency of the shortage differs depending on the building attributes, such as the construction method, structure, age, and degree of damage; and particularly, the damaged households in apartment houses require much funds for reconstruction. Furthermore, we clarified that despite the effects in various support systems, sufficient effects cannot be obtained depending on the building attributes and degree of damage. We also updated the measures such as seismic reinforcement and various support systems and repeated the analysis. Based on the analysis results, we were able to quantitatively understand the effects of various countermeasures and suggest effective countermeasures for the future.

Keywords: Inland Earthquake; Apartments; Economic Damage; Housing restoration; Financial Support Measure

1. Introduction

Many earthquakes have occurred due to inland active faults in recent years, such as the Kumamoto earthquake in April 2016, the Osaka earthquake in June 2018, and the Hokkaido Eastern Iburi earthquake in September 2018. Earthquakes due to inland active faults occurring near cities are associated with the risk of strong local earthquake tremors causing great damage to local infrastructure. National and local governments ascertain material and financial damage by proactively estimating earthquake damage and engaging in planning on disaster management. However, these damage estimates are limited to a quantitative ascertainment of building damages and economic losses, and the housing restoration funds required in the affected areas have not yet been adequately ascertained. Looking at the past earthquake damages, there have been cases where completely destroyed buildings were repaired and half-destroyed buildings were rebuilt. In these examples, there is no direct relationship between the cost of damage and restoration funds. Specifically, even if an amount equal to the one arising from structural damage is expended in restoration funds, there is no guarantee that the appraisal value of properties will match the former appraisal values. Partially repairing a building often clearly shows its disaster history, thereby decreasing its appraisal value beyond its original value. In such cases, more restoration funds are required to restore such buildings to the original real estate value before an earthquake can occur.

Apartments are more often than not owned as private homes. Several apartments are also owned as real estate assets for resale and are susceptible to gaps between the losses due to structural damage and the funds required to restore the property. Restoration of housing is the first step to livelihood recovery after an earthquake, and there is a debate about whether recovery of personal assets such as real estate should be included. However, the procedure for rebuilding apartments affected by disasters is specified in the Act on Building Unit Ownership and the Act on Disaster-Affected Apartments and with the procedure is conducted only after receiving consent from the building owner. Accordingly, the choice of how to rebuild is beyond individual decision-making. If there are insufficient restoration funds for the selected rebuilding method, the rebuilding negotiations would require a considerable amount of time, thereby hindering speedy recovery and reconstruction. As the Examination Committee on Ideal Ways for Housing Reconstruction Support for Victims states [1], “As single units, homes are personal assets but when large numbers of homes are destroyed over a wide area as in the Great Hanshin-Awaji Earthquake Disaster, housing is closely connected with the restoration of the local community.” Therefore, it can be concluded that when planning the recovery and reconstruction after a disaster, it is crucial to ascertain the possibilities of financial resources for the restoration funds in order to facilitate housing reconstruction in the affected areas based on various restoration support systems including the financial assets of households, earthquake insurance, and livelihood recovery support.

Prior research on the cost of rebuilding houses in disaster-affected areas includes Okada [2], who states that the financial support made available under the disaster victims livelihood recovery support system is inadequate to cover the costs of building restoration. The study constructed a hypothesis of damage from a Sapporo earthquake and demonstrated that provisionally covering the shortfall in funding for housing reconstruction by the local government would require reserve funds far exceeding the local government capacity. Furthermore, Inui [3] summarized the housing damage and reconstruction support in Ibaraki prefecture after the great east Japan earthquake. He showed that the proportion of households that received support for housing restoration rose from under 20% to 41.2%, and that the payments made under the present system were largely insufficient for home restoration. These studies have shown that funds in the form of various financial support measures are inadequate for the necessary restoration funds. However, the studies focused on Sapporo and a part of Ibaraki prefecture, none of which has many affected households. As many households will be affected in an inland earthquake in the densely populated Tokyo metropolitan area, which is expected to happen in the future, , it is expected that the necessary restoration funds and financial support measures will also differ. Predominantly in urban environments such as Tokyo with several apartments, it is feared that various financial support measures that were established based on previous disaster experiences will be ineffective. However, few studies have performed impact analyses of restoration funds and various financial support measures that focus on the difference between apartments and detached houses. Unsurprisingly, related studies on future inland earthquakes are rare.

This present study focuses on the Tokyo metropolitan area as a sample evaluation area and an earthquake in the Tachikawa fault zone as a sample earthquake. We aim to calculate the necessary restoration funds at the time of a disaster and reveal the trends in necessary restoration funds for each of the partially destroyed–completely destroyed damage types that occur in the apartment and detached housing types. Furthermore, for each housing type, we will estimate the various financial support measures for the affected households and conduct an impact analysis of each of the measures. Issues associated with various financial support measures and the measures to be considered for effective and smooth restoration and rebuilding, based on the highlighted analyses, are discussed in the subsequent section.

2. Restoration fund analysis – evaluation techniques

The analysis of restoration funds was performed based on the damage estimation techniques of the Cabinet Office and various local governments. The process for estimating material damage is divided into the following parts: exposure model evaluation, earthquake hazard evaluation and vulnerability evaluation. Concerning the techniques used by the Cabinet Office and various local governments, the one used by the Cabinet Office is the de-facto standard, and local governments aim to improve estimation accuracy through various alterations based on local characteristics. Owing to the evaluation error in each process, the estimations of the extent of damage involves a level of uncertainty. However, the authors verified the estimation techniques of the Cabinet Office in relation to the material damage caused by the Kumamoto earthquake [4], and the results confirmed that the predicted values of the model are consistent with the actual damage values. Although the area and earthquake differ between the urban inland earthquake studied in this paper and the Kumamoto earthquake, we believe it to be sufficiently accurate to further investigate the response measures. Moreover, to estimate the restoration funds, this study performed the following additional evaluations: evaluation of vulnerability to financial damage, building asset evaluation, and evaluation of financial support measures. The following subsections are a description of the various evaluation techniques.

2.1. Exposure model evaluation

The exposure model indicates the population, households, and buildings that are vulnerable to the earthquake hazards. This study considers the Tokyo metropolitan area for evaluation. Using population census mesh data based on reference [4], we created data regarding the number of households for each housing type in each 500-mesh unit. Subsequently, based on the number of households by housing type and year of construction for each prefecture or municipality in the housing and land statistics, we distributed the data, thereby generating household data by housing type and by age for each 500-mesh unit.

The total number of households in the Tokyo metropolitan area are presented in Table 1. When divided by the housing type, non-wooden apartments form the majority, whereas wooden buildings form the majority for detached homes. The overall number of households in apartments is 4,348,774, ca. 69% of the total.

Table 1 Households in Tokyo

(Unit: Household)	Non-Wooden	Wooden	Total
Apartments	3,591,007	757,767	4,348,774
Detached houses	66,285	1,848,691	1,914,976
Total	3,657,293	2,606,457	6,263,750

2.2. Earthquake hazards evaluation

The hypothetical scenario is based on the Tachikawa fault zone studied by the Tokyo inland earthquake working group at the Cabinet Office. The seismic center model used the fault dimensions outlined in the forecasting maps [5], and the earthquake force distribution used the earthquake forecasting method described in Morikawa, Fujiwara [6]. For the shallow subsurface AVS30 data and deep surface data required for earthquake predictions, the publicly available data from the Japan seismic hazard information station (J-SHIS) at the national research institute for earth science and disaster resilience were used [7].

The seismic intensity distribution for earthquakes in the Tachikawa fault zone, including the fault shape, are depicted in Fig. 1. The seismic intensity distribution shows that the seismic intensity is ca. 7 in the cities of Tachikawa and Kunitachi, which are near the fault, and ca. 5 for the Tokyo metropolitan zone, although it is at a distance from the fault.

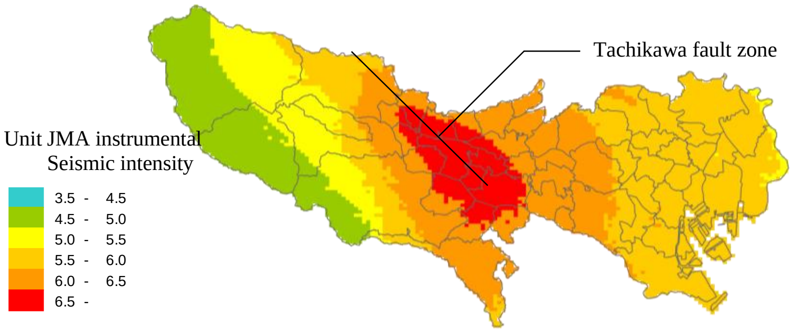

Fig. 1 Seismic intensity distribution of Tachikawa fault zone earthquake

2.3. Evaluation of vulnerability for housing restoration

Damage functions are used to indicate the vulnerability of buildings subject to an earthquake. The damage functions in this study were used to estimate the necessary housing restoration funds. They were constructed using an event tree that focuses on the housing restoration process. (Refer to reference [8] for details on constructing damage functions.) In the event tree, to estimate the contributions to the disaster victims livelihood recovery support system and earthquake insurance, the damage states are divided into the following four states: “completely destroyed,” “largely destroyed,” “under half-destroyed,” and “partially destroyed.” And, the branching probabilities of the event tree for rebuilding and repair were set using the damage resulting from the Kumamoto earthquake [9].

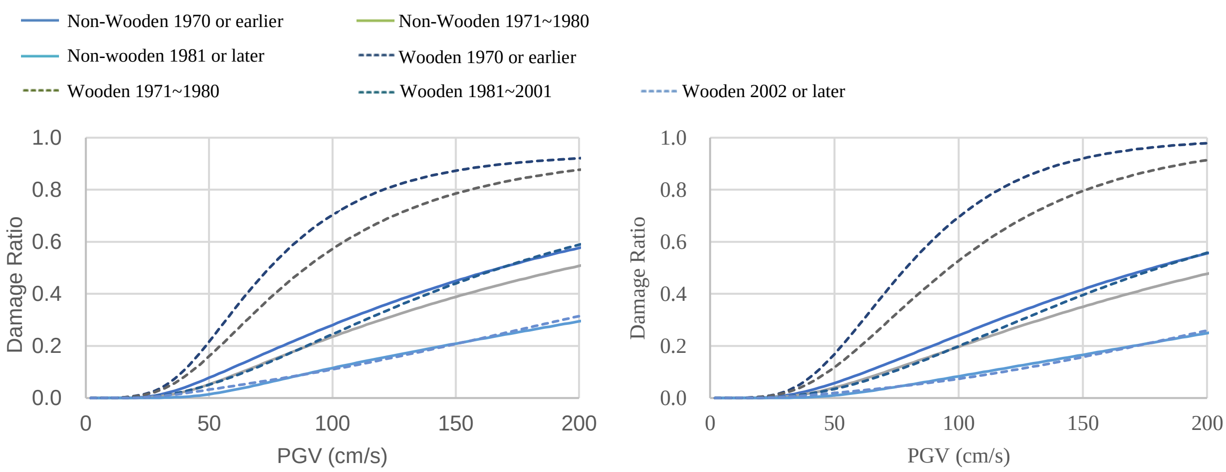

Fig. 2 Damage function of Necessary restoration fund

The damage functions obtained this way are shown in Fig. 2. The damage functions consist of the following types: two types of housing, that is, apartments and detached homes; two construction types, that is, wooden and non-wooden; and 3 periods of construction, that is, 1970 or earlier, 1971-1980, and 1981 or later. However, wooden structures only use 2 periods, which are 1981-2000 and 2000 or later. As seen from Fig. 9, damage ratios for apartments are slightly higher than those for the detached home damage functions in areas of low earthquake intensity, whereas in areas of high earthquake intensity, the damage ratios are lower than the detached home damage functions. This can be attributed to the diversity of rehabilitation methods being considered, e.g., opting to rebuild when a building is partially or half-destroyed, or opting to repair when a building has been completely destroyed.

2.4. Building asset evaluation for housing reconstruction

Building assets are calculated based on the National Tax Agency's "reasonable calculation method of loss amount" [10]; the construction costs per square footage for each building [10] are multiplied with the total area meant for exclusive usage per household [11]. However, in the case of an apartment, the shared areas are included with the areas meant for exclusive usage. Since no data on the total area of shared space per household are publicly available, it is calculated based on the asset ratio of the exclusive use area to the shared area. Generally, in fire insurance in apartment management societies, the appraised value of shared areas is ca. 40%–60% of the building's overall appraised value. The present study uses the so-called uwanuri criterium (e.g., "where the boundary is formed by the inside walls of the property") to determine the boundary between exclusive-use and shared areas, and the asset value was estimated to be 40% exclusive-use area and 60% shared area. The total shared area per household is thus calculated by multiplying the exclusive-use area by the asset ratio for exclusive-use and shared areas. Table 2 presents the building asset value for each household.

The total amount contained in the assets in the Tokyo metropolitan area are presented in Table 3. When divided by the housing type, non-wooden apartments form the majority, whereas wooden buildings form the majority for detached homes. The amounts in apartments is 113,583,264 million Yen, ca. 76% of the total amount of the assets. Based on this, we can conclude that the housing structures in Tokyo are mainly apartments.

Table 2 Building assets per household

Category	Construction area	Construction cost	Building assets
Apartments / Non-wooden	51+77m^2	¥220K/m^2	¥28,050K
Apartments / Wooden	39+59m^2	¥174K/m^2	¥16,965K
Detached houses / Non-wooden	126m^2	¥220K/m^2	¥27,720K
Detached houses / Wooden	107m^2	¥174K/m^2	¥18,618K

Table 3 Building assets in Tokyo

(Unit: ¥1M)	Non-Wooden	Wooden	計
Apartments	100,727,746	12,855,517	113,583,264
Detached houses	1,837,420	34,418,929	36,256,349
Total	102,565,167	47,274,446	149,839,613

2.5. Evaluating financial support measures for housing reconstruction

This study used the following two financial support measures in the event of a disaster: the livelihood recovery support system and the earthquake insurance system.

The housing reconstruction support system provides livelihood support to those with substantial livelihood damages caused by a natural disaster. The system utilizes funds contributed by national and local governments in the form of mutual aids. The funds considered in this paper are presented in Table 4.

Earthquake insurance is a type of damage insurance that compensates for any loss arising from damage associated with earthquakes, volcanic eruptions, or tsunamis. The government and private insurance companies are together involved in these insurances. Earthquake insurance can be claimed together with fire insurance, and premiums are set to a range of 30%–50% of fire insurance. A part of the system was updated in 2014, and currently, the payout ratio displayed is prescribed. For this study, the earthquake payments were set as detailed in Table 5. Subsequently, the ratio of the affected households that have claimed the insurance was established. This ratio indicates the ratio of households out of the total number of households that have claimed earthquake insurance. The ratio of earthquake insurance claimed for detached homes and exclusive-use areas of apartments was set at 36.7% [12]. No data are disclosed regarding the rates of earthquake insurance for shared areas of apartments, and this was thus set using the supplementary ratios indicated in [13]. The supplementary ratio refers to the ratio of households that had claimed supplementary earthquake insurance to their fire insurance for that year. This supplementary ratio was 71.9% for exclusive-use areas and 38.1% for shared areas in 2015. By multiplying these with the ratio of earthquake insurance claimed for exclusive-use areas, the ratio of earthquake insurance claimed for shared areas was set at 18.2%.

Table 4 Settings disaster victims' life reconstruction funds

Reconstruction	Base support	Additional support	Total
Completely destroyed Rebuilding	¥1,000K	¥2,000K	¥3,000K
Completely destroyed Rehabilitation	¥1,000K	¥1,000K	¥2,000K
Largely destroyed Rebuilding	¥1,000K	¥2,000K	¥3,000K
Largely destroyed Rehabilitation	¥500K	¥1,000K	¥1,500K
Half destroyed Rebuilding	¥1,000K	¥2,000K	¥3,000K

Table 5 Settings earthquake insurance

Damage State	Insurance amount	Payment rate	Total
Completely destroyed	50% of building assets	100%	50%
Largely destroyed		60%	30%
Half destroyed		30%	15%
Partial destroyed		5%	2.5%

3. Evaluation results of restoration fund analysis

3.1. Analysis of necessary restoration funds

This section summaries the estimated restoration funds based on the estimated damage and analysis results.

The distribution of the necessary restoration funds is shown in Fig. 3. The distribution of restoration funds shows a similar trend to the distribution of affected households. However, in comparison to the distribution of affected households, the areas requiring high levels of restoration funds are also more widespread in 23 wards in central and eastern Tokyo. This means that several cases requiring restoration funds will be present in areas subject to earthquake intensity that range from slightly over 5 to slightly under 6.

The breakdown of necessary restoration funds by damage states is detailed in Table 6. Necessary restoration funds due to a Tachikawa fault zone earthquake will be 15,999,405 million Yen, corresponding to ca. 11% of the amount of building assets in the Tokyo metropolitan area. Of the total amount of 15,999,405 million Yen, ca. 63% is restoration funds for apartment households, and 37% is restoration funds for detached-home households. In the breakdown by housing type for restoration funds, the ratio of apartment households is higher, which is similar to the breakdown of affected households. The breakdown of restoration funds by housing type shows that, regarding the breakdown of necessary restoration funds by damage state, partially and half-destroyed households account for 26%–28% while completely destroyed households account for 37%. Apartments are often non-wooden constructions that are highly earthquake resistant, thus a larger proportion of the total is found to be subject to minor damages. On the contrary, considering the breakdown of necessary restoration funds by damage state for detached-home households, 62% of them are completely destroyed. Therefore, it can be concluded that the distribution of damage states by necessary restoration funds varies greatly between apartment and detached-home households. However, this also shows that countermeasures for completely destroyed homes are vital for detached-home households, whereas apartment countermeasures for partially, half-destroyed, and completely destroyed households are also required.

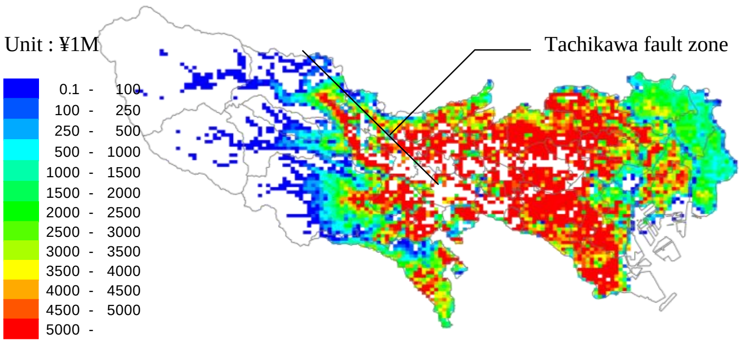

Fig. 3 Necessary restoration fund distribution

Table 6 Necessary restoration fund

(Unit: ¥1M)	Partial destroyed	Half destroyed	Largely destroyed	Completely destroyed	Total
Apartments	2,817,773	2,574,914	895,875	3,738,960	10,027,521
Detached houses	583,411	1,119,688	540,770	3,728,015	5,971,884
Total	3,401,184	3,694,602	1,436,645	7,466,974	15,999,405

3.2. Analysis of financial support measures for housing restoration

This section outlines the estimations and analysis results for financial support measures based on damage estimates.

The support funds for the livelihood recovery of disaster victims by damage state is presented in Table 7. The total amount of support funds for the livelihood recovery of disaster victims is 1,412,609 million Yen, which accounts for ca. 9% of the necessary restoration funds. The support funds in terms of funding required for housing restoration is limited, and it is clear that this system alone is incapable of covering the restoration funds. Considering it by housing type, the support fund amounts to 742,577 million Yen for the apartment households, which corresponds to ca. 5% of the necessary restoration funds and to 670,032 million Yen for detached-home households, which corresponds to ca. 10% of the necessary restoration funds. As shared areas are also added to the building assets of apartments, the amount of building assets for apartments is higher than that for detached homes. In contrast, the support for livelihood recovery of disaster victims is fixed regardless of the housing type. Therefore, the support funds are less effective for apartments when compared to the case of detached homes. Furthermore, considering the breakdown by damage type, the damage type receiving the most funds is the completely destroyed household type. No support funds are available for partially destroyed households as they are not covered by the system. Support funds are only available for half-destroyed households if the households agree to destroy the house completely and rebuild. This study only considers the rebuilds in its event tree for apartment households. Thus, support funds are available for apartment households, and not for detached-home households. In the breakdown by damage type for apartments, completely destroyed households account for 63%. Largely destroyed households and half-destroyed households are also supported with fixed funds. The breakdown for detached homes by damage type shows that completely destroyed households account for 89% with lower ratios for largely destroyed and half-destroyed households.

Furthermore, earthquake insurance payouts are listed by damage type in Table 8. The total amount of earthquake insurance payouts is 2,135,580 million Yen, corresponding to 13% of the necessary restoration funds. Compared to the support for the livelihood recovery of disaster victims, earthquake insurance payouts are more effective in relation to necessary funds for housing restoration. However, it is clear that this system alone also does not cover the necessary restoration funds. Considering housing type, it amounts to 1,039,739 million Yen or ca. 10% of the necessary restoration funds for apartment households and 1,095,84 million Yen or ca. 18% for detached-home households. Despite the fact that the shared areas in apartments are of a high asset value, the ratio covered by earthquake insurance policies is lower than that for exclusive-use areas. No adequate use is made of the earthquake insurance system for apartments, and earthquake insurance payouts are less effective than they are for detached homes.

The breakdown by damage type shows that the highest amounts of earthquake insurance payouts are made for completely destroyed households, which account for 56% of the total. This is followed by payouts for half-destroyed households, partially destroyed households, and largely destroyed households. The payment ratio for partially destroyed households is 5%, which is lower than payouts for the other damage types. However, due to the very high number of households falling in the partially destroyed category, they constitute ca. 15% of earthquake insurance payouts.

Table 7 Support money from victims' life reconstruction funds

(Unit: Household)	Partial destroyed	Half destroyed	Largely destroyed	Completely destroyed	Total
Apartments	0	165,095	111,596	465,887	742,577
Detached houses	0	0	72,025	598,007	670,032
Total	0	165,095	183,621	1,063,893	1,412,609

Table 8 Support money from earthquake insurance

(Unit: ¥1M)	Partial destroyed	Half destroyed	Largely destroyed	Completely destroyed	Total
Apartments	215,328	208,161	100,443	515,807	1,039,739
Detached houses	107,056	205,463	99,231	684,091	1,095,841
Total	322,384	413,624	199,674	1,199,898	2,135,580

3.3. Effect of financial support measures in relation to necessary restoration funds

The ratios of support for the livelihood recovery of disaster victims, earthquake insurance payouts, and self-financing are shown in Fig. 4. It is seen that the ratio of self-financing decreases by with the increase in the use of financial support measures. The ratio of self-financing for apartment households is in the range 74%–92%, and for detached-home households, it is 66%–82%. The ratio of self-financing decreases as the scale of housing damage increases to enormous levels for both apartment and detached-home households. It is clear that more support is provided for households where restoration is difficult due to the enormity of the damage. Moreover, the ratio of self-financing is higher for apartment households than it is for detached-home households. As mentioned previously, this is because apartment households have higher building assets than detached-home households, and insurance coverage is low for shared areas, which have a high building asset value. Thus, the effect of financial support measures is low. This results in financial support measures being not as effective for apartment households as they are for detached-home households, and it is clear that housing restoration is difficult to achieve.

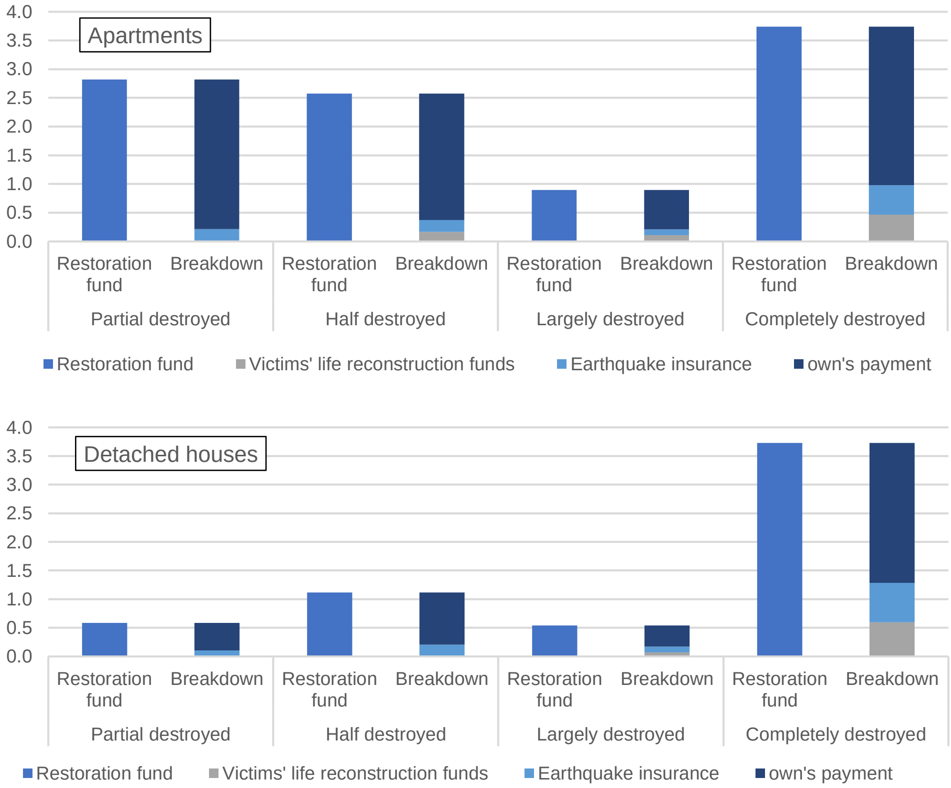

Fig. 4 Breakdown of restoration funds and financial support

4. Conclusion

In this study, we estimated the housing restoration funds required for the Tokyo metropolitan area, precisely the Tachikawa fault zone, which is a Tokyo inland earthquake zone. We showed the efficacy and trends for necessary restoration funds and each financial support measure by apartment housing, detached-home housing, and damage type (partially to completely destroyed). We focused on specific conditions; however, based on the results obtained from each analysis, we list the following issues with each financial support measure aimed at swift housing restoration and also mention the following points to be considered when adopting measures in the future:

- We clarified that the total amount of funds required for the livelihood recovery of disaster victims in relation to an earthquake in the Tachikawa fault zone is 1,412,609 million Yen, which amounts to ca. 9% of the necessary restoration funds. As Okada [2] and Inui [3] identified, this amount is insufficient for covering building restoration costs. However, due to the disasters that have occurred recently, the amount required for supporting livelihood recovery of disaster victims has decreased to 205,000 million Yen [14]. In the event of an earthquake in the Tachikawa fault zone, the fund required to support the livelihood recovery of disaster victims will deplete. Half of the payment is borne by the national government that paid 4/5th of the total amount for the great Eastern Japan earthquake. It is unclear as to if the national government would likewise bear costs for a regional disaster, such as in the case of a Tokyo inland earthquake. Furthermore, even if the government bears the cost, a contribution of 282,522 million Yen will be required, which means the fund amount for the support of the livelihood recovery of disaster victims is insufficient. Additionally, increasing the fund amount is quite challenging. The question of how the livelihood recovery of disaster victims can be dealt with in the event of a local disaster with enormous damages, such as a Tokyo inland earthquake, needs to be further investigated.

- The total sum of earthquake insurance payouts for an earthquake in the Tachikawa fault zone is 2,592,302 million Yen, which accounts for 13% of the necessary restoration funds. However, the effect of support for earthquake insurance is higher than that for the support fund required for the livelihood recovery of disaster victims, and earthquake insurance plays a significant role as a financial support measure for restoration funds. For a more effective use of this system, it is important to increase the earthquake insurance uptake. Since the Hyogo-ken Nanbu earthquake in 1995, earthquake insurance uptake has increased gradually for detached homes and exclusive-use areas in apartments. However, it has not increased significantly for shared areas in apartments. Although the value of building asset of shared areas in apartments amount to 60%, these assets are left exposed to risks without any protective measure in place. The main obstacle to taking out earthquake insurance policies is the high insurance premiums. To lower these premiums, it is necessary to promote measures to make buildings more earthquake-resistant, thereby reducing the massive costs incurred when damage occurs in the aftermath of a disaster.

A considerable amount of time is required to make decisions for rebuilding disaster-affected apartments as specified in the Act on Building Unit Ownership and the Act on Disaster-Affected Apartments; however, reaching a consensus is difficult when the funds are insufficient. Particularly in urban areas, the proportion of apartments is high, and any delay in housing reconstruction greatly affects the post-earthquake reconstruction of the entire earthquake-affected area. Based on the findings, we plan to investigate a disaster-prevention society system that combines prevention measures such as earthquake-proofing with those of financial support including systems such as support funds for the livelihood recovery of disaster victims and earthquake insurance.

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