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ORIGINAL ARTICLE

Reduction Effects on Amount and Disposal Cost of Debris by Planned Clearance of Vacant Houses —A Case Study of Enshu, Shizuoka Prefecture, Japan—

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Abstract: Although each Municipal Disaster Waste Treatment Plan has been drawing up in order for the disposal to be carried out promptly, efficiently, and appropriately in the pre-disaster phase, most municipalities haven't fully discussed how to reduce the amount of disaster waste, such as removing vacant houses. This study aims to clarify the reduction effects on the amount and disposal cost of debris by planned clearance of the detached wooden vacant houses which are out of repair before the occurrence of Nankai Trough Earthquake in Enshu of western Shizuoka prefecture, using GIS and statistical analysis. As a result, maximum 505,012 tons of debris, which are equivalent to 0.83 percent of the total amount of debris, are reduced, and the disposal cost defrayed by central government and municipalities is lowered by up to 11.9 billion Japanese yen. This finding indicates that reinforcing incentive for the owners before the disaster is one of the effective measures.

Keywords: pre-disaster management, debris, disposal cost, vacant house, Nankai Trough Earthquake

1. Introduction

In the worst-case scenario, Nankai Trough Earthquake, which has a high probability of the occurrence of large-scale earthquakes in the near future, will cause 2.4 million buildings (including houses) to collapse and generate a massive amount of debris in Japan (Central Disaster Management Council, 2012a). In fact, Ministry of the Environment (MOE) reported that as much as 320 million tons of disaster waste would be created by the event ― 16 times the amount resulting from the Great East Japan Earthquake of March 2011, which was one of the most powerful in world history (Ministry of the Environment, 2014a). According to the Guideline for Disaster Waste Management under the Japanese Waste Management and Public Cleansing Law, municipalities have responsibility for disposing of disaster waste (Ministry of the

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Environment, 2014b; Shizuoka Prefecture, 2017). Thus, each Municipal Disaster Waste Treatment Plan, based on an estimation result of debris quantity, has been drawing up in order for the disposal of disaster waste to be carried out promptly, efficiently and appropriately.

On the other hand, most municipalities haven't fully discussed how to reduce the amount of disaster waste in the pre-disaster phase coordinated with other policies, such as removing vacant houses.

Housing and Land Survey, which is the statistics of Ministry of Internal Affairs and Communications (MIC)[12], shows that the number of vacant houses in Japan has increased 4.8 times in the past 40 years, from 1.7 million in 1973 to 8.2 million in 2013 (Ministry of Internal Affairs and Communications, 2013). Moreover, 2.1 million vacant houses are out of repair, and 69 percent of them are wooden, which are liable to collapse by earthquake and tsunami. These destructible vacant houses will continue to increase with depopulation and aging in Japan. Accordingly, removing vacant houses is appreciated to conserve townscapes, improve land use, and reduce the pressure of debris in the post-disaster phase.

Indeed, the data from Ministry of Land, Infrastructure, Transport and Tourism (MLIT)[13] show that the total number of collapsed unoccupied houses exceeded 30,000 units in the 27 coastal municipalities affected by the Great East Japan Earthquake of March 2011 in Iwate and Miyagi prefectures (Ministry of Land, Infrastructure, Transport and Tourism, 2012). Planned clearance of these unoccupied houses before the disaster could have reduced the amount and disposal cost of debris significantly.

The purpose of this study is to clarify the reduction effects on the amount and disposal cost of debris by planned removing vacant houses before the occurrence of Nankai Trough Earthquake in Enshu of western Shizuoka prefecture.

2. Study site

Based on the lessons learned from the Great East Japan Earthquake of March 2011, the Central Disaster Management Council (CDMC) was determined to assume the maximum possible earthquake and tsunami to occur, taking all possibilities into account (Central Disaster Management Council, 2011). With this underlying assumption, the possible maximum seismic movements and tsunami height were simulated. An earthquake with Shindo 7, Japan Meteorological Agency seismic intensity scale of 7, and a tsunami as high as 19 meters could hit Enshu (Central Disaster Management Council, 2012b).

As shown in Figure 1, the residential areas extend over the plains adjacent to the Coast of Enshu, and 10 percent of all buildings are located in the tsunami inundated areas. In addition, Nankai Trough Earthquake will shake 70 percent of all buildings with Shindo 7 and generate a huge amount of debris. Although each Municipal Disaster Waste Treatment Plan has been making, most municipalities haven't fully discussed how to reduce the debris quantity.

Housing and Land Survey[12] shows that the number of vacant houses in Enshu has increased 1.5 times in the past 5 years, from 52,760 in 2008 to 80,650 in 2013. Moreover, 15,940 vacant houses are out of repair, and 59 percent of them are wooden. These destructible vacant houses will have a tendency to increase with depopulation and aging in the future. Therefore, planned removing vacant houses in the pre-disaster phase is effective for reducing the amount and disposal cost of debris in Enshu.

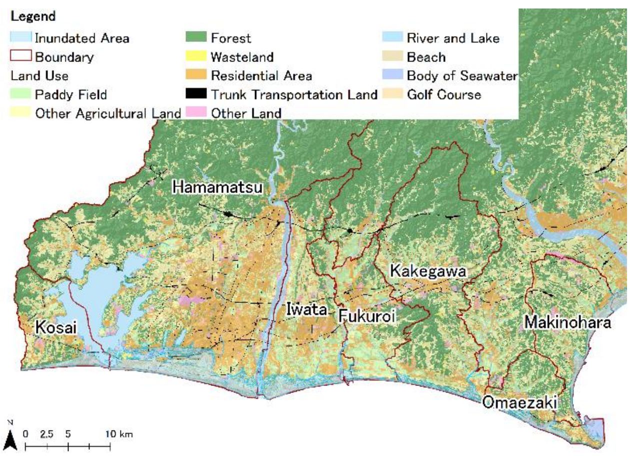

Figure 1 Land use map of Enshu (source: MLIT)

3. Methodology

In order to clarify the reduction effects by planned removing vacant houses before the occurrence of Nankai Trough Earthquake, the amount and disposal cost of debris by doing so are compared with those of by not doing so.

3.1 Estimation procedure

There have been many studies which have retrospectively quantified debris following disaster events. The studies have been conducted in an attempt to improve debris estimation techniques. As a result, estimation procedures to assess the amount of debris resulting from earthquake and tsunami have been establishing.

The majority of conducted studies have been based in Japan (Brown et al., 2011). For instance, the study identified by Hirayama et al. (2009) estimated debris weight or volume per unit building or per unit floor area. Hirayama et al. (2010) used these parameters to predictively estimate the amount of disaster waste in Tokyo by using natural hazard maps. Yamanaka et al. (2014) described some factors of tsunami disaster waste generated by the Great East Japan Earthquake of March 2011, and clarified that there was a good relationship between damage level of buildings and tsunami inundation depth. Yamanaka et al. predictively estimated the amount of disaster waste resulting from Tonankai-Nankai Earthquake by multiplying the number of inundated buildings and calculated per unit generation of tsunami disaster waste, using Geographic Information System (GIS).

Using GIS and statistical analysis, this study tries to clarify the reduction effects on the amount and disposal cost of debris by planned removing vacant houses in the pre-disaster phase. A geographic database is developed, including buildings, tsunami inundation depth, seismic intensity, and vacant houses in Enshu (see Section 3.2 and Figure 2). Based on the Japanese Architect Act, the buildings can be roughly classified into wooden buildings and non-wooden buildings according to the following standards. The standards return wooden building if the number of floors is less than or equal to 2 floors and the total floor area is less than or equal to 300 square meters, and non-wooden building otherwise.

After assuming fragility curves of buildings, per unit generation of debris, input rates of building materials, and per unit disposal cost of debris by types of building structures, the amount and disposal cost of debris are estimated by Equation (1), (2), and (3).

$$D = \sum B_i F_i (PC_i GC_i + PH_i GH_i) \qquad (1)$$

$$DM = \sum B_i F_i (PC_i GC_i M_i + PH_i GH_i M_i) \qquad (2)$$

$$TC = DC \qquad (3)$$

where:

D is the total amount of debris

DM is the total amount of building material

TC is the total disposal cost of debris

B_i is the building area

F_i is the number of floors

PC_i is the probability of building collapse

PH_i is the probability of building half-collapse

GC_i is the basic unit of debris from collapse

GH_i is the basic unit of debris from half-collapse

M_i is the input rate of building material

C is per unit disposal cost of debris

Damage rates with inundation depth are assigned to inundated buildings, and damage rates with seismic intensity are assigned to non-inundated buildings.

Housing and Land Survey[12)] show that the non-wooden dwellings in Enshu are composed of 34.4 percent steel framed buildings, 65.3 percent reinforced steel-framed concrete (RC) buildings, and 0.3 percent other structural buildings. Since the number of steel framed buildings and RC buildings accounts for more than 99 percent of the total non-wooden dwellings, each parameter of non-wooden building is set in consideration of the two types.

3.2 Using data

The main GIS and statistical data used in this study are as follows: buildings data created by ZENRIN in 2014 (GIS data), 10 meter-mesh tsunami inundation depth data created by the Committee for Modeling a Nankai Trough Megaquake set up at the Cabinet Office in 2012 (GIS data), 250 meter-mesh seismic intensity data created by Shizuoka prefecture in 2016 (GIS data), and vacant houses data created by MIC in 2013 (statistical data). Housing and Land Survey[12)] is substituted because no GIS data is available.

3.3 Target vacant houses

In MIC's Housing and Land Survey[12)], vacant houses are divided into four categories: “as second house”, “for rent”, “for sale”, “others”. In particular, vacant houses within “others” category, which are defined as vacant houses whose owners neglect without looking for tenants or buyers, are troublesome to handle. The majority of vacant houses within “others” category are hazardous wooden vacant houses, which become subject to collapse, fire, illegal disposal of rubbish, and squatters.

This analysis targets at wooden detached vacant houses which are out of repair in “others” category. Based on Housing and Land Survey[12)], the number of target vacant houses and the average total floor area per unit are set as follows: Hamamatsu City has 3,990 units (134.7 square meters per unit), Iwata City has 760 units (131.2 square meters per unit), Kakegawa City has 470 units (140.8 square meters per unit), Fukuroi City has 240 units (133.4 square meters per unit), Kosai City has 350 units (135.4 square meters per unit), Omaezaki City has 50 units (139.9 square meters per unit), and Makinohara City has 350 units (148.4 square meters per unit).

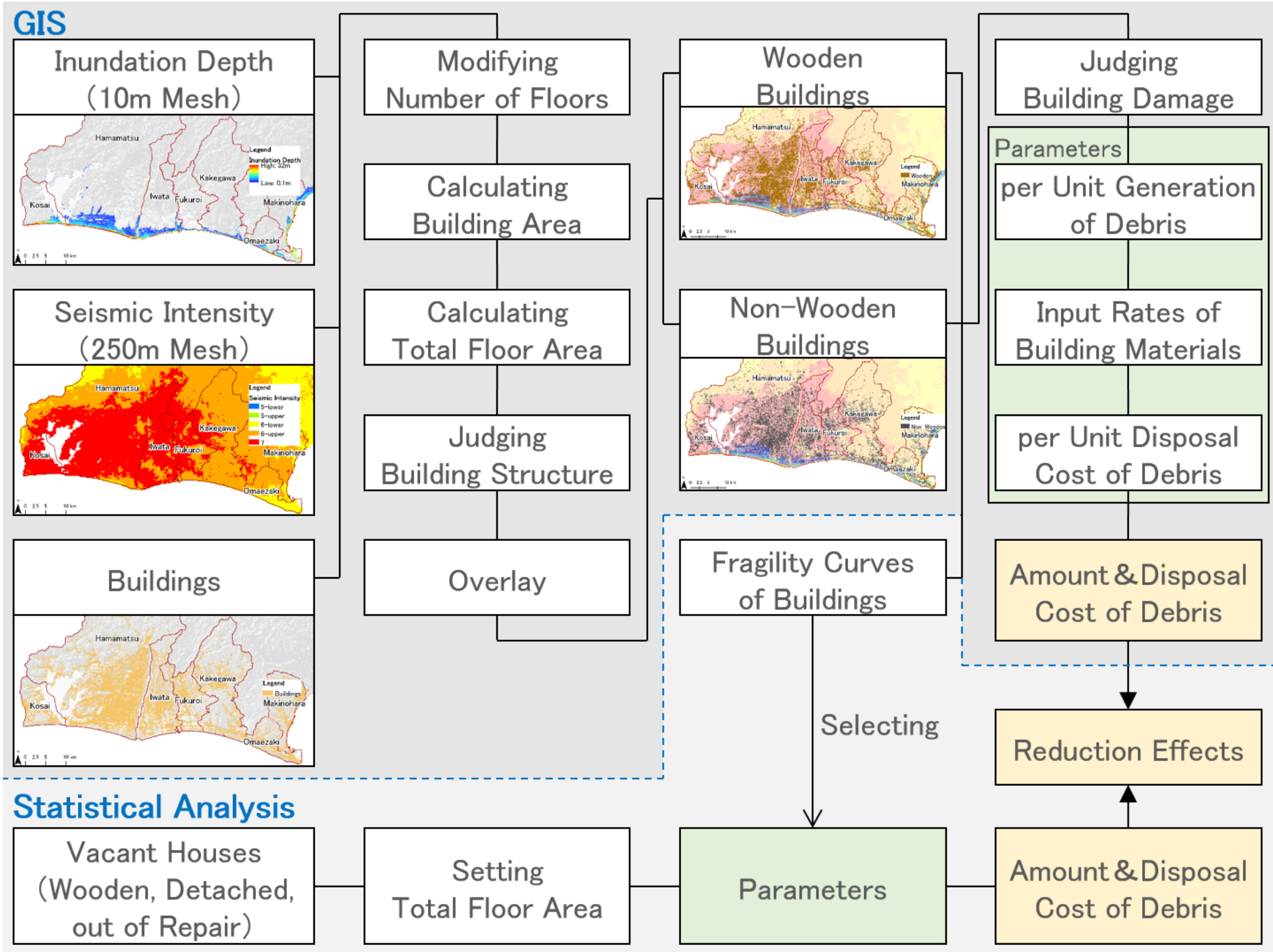

Figure 2 Estimation procedure to assess the reduction effects by planned removing vacant houses

3.4 Fragility curves of buildings

Fragility curves of buildings are expressed as the structural damage probabilities with regard to some measure of environmental excitation, such as inundation depth and seismic intensity. In general, each fragility curve of buildings is represented by a cumulative distribution function (CDF) of normal distribution or log-normal distribution, which means the probability that an uncertain quantity will be less than or equal to a given value (Koshimura et al., 2009). Although many fragility curves have been developed for buildings in relation to inundation depth and seismic intensity, most of the detailed results of data analysis are not open to the public.

In this study, the tsunami fragility curves of buildings are proposed by integrating the structural damage with the inundation depth in the 27 coastal municipalities affected by the Great East Japan Earthquake of March 2011 in Iwate and Miyagi prefectures. Each CDF of normal distribution is obtained by statistical analysis based on non-public GIS data from MLIT[13], as shown in Equation (4).

$$P_D(x) = \Phi\left[\frac{x-\mu}{\sigma}\right]$$

$$= \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{(t-\mu)^2}{2\sigma^2}\right) dt \quad (4)$$

where:

x is the maximum inundation depth

μ is the mean

σ is the standard deviation

This work can provide the damage rates of buildings with inundation depth (see Table 1).

Additionally, the seismic fragility curves, based on Japan Meteorological Agency seismic intensity scale, are proposed by statistically analyzing the data of the report on estimating structural damage issued by

Tokyo Disaster Management Council (Tokyo Disaster Management Council, 2013). This work can also provide the damage rates of buildings with seismic intensity (see Table 2).

Table 1 Damage rates with inundation depth（ID）

ID	Collapse		Half-Collapse	
（m）	Wooden	Non-Wooden	Wooden	Non-Wooden
0.1	14.2%	14.0%	63.9%	64.5%
1	26.4%	22.5%	61.0%	64.5%
2	44.6%	34.5%	49.6%	58.7%
3	63.9%	48.3%	33.7%	48.6%
4	80.2%	62.4%	19.0%	36.4%
5	91.0%	74.9%	8.7%	24.6%
6	96.7%	84.8%	3.3%	15.0%
7	99.0%	91.7%	1.0%	8.2%
8	99.8%	95.9%	0.2%	4.0%
9	100.0%	98.2%	0.0%	1.8%
≧10	100.0%	99.3%	0.0%	0.7%

Table 2 Damage rates with seismic intensity（SI）

SI	Collapse		Half-Collapse	
	Wooden	Non-Wooden	Wooden	Non-Wooden
≦5.0	0.0%	0.0%	0.1%	0.1%
5.1	0.0%	0.0%	0.2%	0.2%
5.2	0.0%	0.0%	0.5%	0.4%
5.3	0.0%	0.0%	1.0%	0.6%
5.4	0.0%	0.0%	2.1%	1.0%
5.5	0.1%	0.1%	3.8%	1.4%
5.6	0.3%	0.3%	6.4%	2.0%
5.7	0.9%	0.5%	9.9%	3.0%
5.8	1.9%	0.8%	14.2%	4.2%
5.9	3.8%	1.4%	18.7%	5.7%
6.0	6.8%	2.1%	22.6%	7.5%
6.1	11.3%	3.2%	25.4%	9.6%
6.2	17.0%	4.8%	26.5%	12.0%
6.3	23.9%	7.0%	26.1%	14.4%
6.4	31.3%	9.7%	24.4%	16.9%
6.5	38.6%	13.2%	22.3%	19.1%
6.6	45.6%	17.5%	20.2%	21.1%
6.7	51.9%	22.4%	18.6%	22.6%
6.8	57.6%	28.0%	17.5%	23.5%
6.9	62.7%	34.2%	16.7%	23.8%
≧7.0	67.5%	40.7%	16.1%	32.9%

3.5 Per unit generation of debris

In Japan, studies on per unit generation of debris have been conducting since the Great Hanshin-Awaji Earthquake of January 1995. For instance, Takatsuki et al. (1995) calculated per unit generation of demolition waste on the basis of measured data. In the latest technical material for estimating the amount of disaster waste released by MOE, per unit generation of debris is set as follows: 117 tons per unit building from collapse, 23 tons per unit building from half-collapse, 4.6 tons per household from inundation above a floor level, 0.62 tons per household from inundation below a floor level (Ministry of the Environment, 2014c).

However, this study needs basic unit of debris not per unit building but per floor area. Taking per unit generation of debris used by CDMC, the interview with an architect, and the statistical analysis result that per unit generation of debris of collapse is approximately 5 times as heavy as that of half-collapse shown in that latest technical material into consideration, basic unit of debris per floor area is set as follows (see Table 3) : 0.6 tons per square meter from collapsed wooden building, 0.12 tons per square meter from half-collapsed wooden building, 1.1 tons per square meter from collapsed non-wooden building, 0.22 tons per square meter from half-collapsed non-wooden building (Central Disaster Management Council, 2003).

3.6 Input rates of building materials

MLIT conducts the survey of inputted weight or volume of 5 main building materials for construction, which are categorized into wood, cement, aggregate and stone, ready-mix concrete, and steel, per floor area by types of building structures every two years

(Ministry of Land, Infrastructure, Transport and Tourism, 2016). As can be seen from Table 4, the input rates of building materials based on the inputted total weight are calculated after multiplying the inputted volume per floor area of the latest survey by the known weight per unit volume from literature as necessary (Japan Industrial Waste Information Center, 2016; Karahashi et al., 1983).

Table 3 Basic unit of debris per floor area

Building Structure		Basic Unit of Debris per Floor Area: CDMC[3]	Interview with Architect	This Study	
Wooden		0.60 （t/㎡）	0.40 – 0.60 （t/㎡）	Collapse	0.60 （t/㎡）
				Half-Collapse	0.12 （t/㎡）
Non-Wooden	Steel	1.00 （t/㎡）	1.00 （t/㎡）	Collapse	1.10 （t/㎡）
	RC		1.20 （t/㎡）	Half-Collapse	0.22 （t/㎡）

Table 4 Input rates of building materials based on inputted total weight

Building Material	Inputted Weight or Volume per 100 ㎡ [15]: Wooden	Steel	RC	t/㎥ [9)10)]	Input Rate: Wooden	Non-Wooden
Wood	19.2 ㎥	1.1 ㎥	3.2 ㎥	0.55	7.7 ％	0.3 ％
Cement	8.3 t	14.7 t	31.0 t	—	6.0 ％	6.7 ％
Aggregate and Stone	38.7 ㎥	65.7 ㎥	113.3 ㎥	1.80	50.4 ％	47.0 ％
Ready-Mix Concrete	20.8 ㎥	37.2 ㎥	87.8 ㎥	2.33	35.1 ％	42.5 ％
Steel	1.1 t	13.9 t	10.0 t	—	0.8 ％	3.5 ％

3.7 Per unit disposal cost of debris

Little information exists on per unit disposal cost of debris (including the cost of demolishing collapsed buildings and carrying debris). If the records of past disasters have been kept appropriately, the direct disposal cost of debris can be estimated easily by multiplying the amount of debris and per unit disposal cost of debris, as shown in Equation（3）.

MOE discloses the limited cost data on treatment of disaster waste on its website (Ministry of the Environment, 2012). This study refers to these cost data. The disaster waste resulting from the Great East Japan Earthquake of March 2011, taken a case of tsunami disaster, was treated at a cost of around 37,000 Japanese yen per ton. The disaster waste resulting from the Great Hanshin-Awaji Earthquake of January 1995, taken a case of earthquake disaster, was treated at a cost of around 22,000 Japanese yen per ton. In general, the disposal cost of tsunami disaster waste is slightly higher unlike other disaster waste. Yamamoto and Kirikawa (2015) indicated that one major factor was that tsunami debris was mixed with other waste containing salt.

Referring to those cost data, the total disposal cost of debris is estimated by Equation（5）.

$$TC = 37000D_1 + 22000D_2 \qquad (5)$$

where:

TC is the total disposal cost of debris

D_1 is the total amount of tsunami debris

D_2 is the total amount of earthquake debris

With the assumption that vacant houses are uniformly distributed, the disposal cost of debris from collapsed target vacant houses is estimated as well.

3.8 Burden of disposal cost of debris

In a normal case, 50 percent of expenses required for the disposal of disaster waste by municipalities are backed by governmental subsidies based on the Waste Management and Public Cleansing Law. Moreover, up to 40 percent of them are backed by MIC’s special local allocation tax. Consequently, each municipality is bound to bear more than 10 percent of disposal cost of debris at least.

On the other hand, considering the extensiveness and severity of the damage caused by the Great East Japan Earthquake of March 2011, the central government raised the rate of governmental subsidies for the disposal of disaster waste implemented by municipalities based on the Act for Extraordinary Expenditures and Assistance to Cope with the Great East Japan Earthquake, as an exception (Ministry of the Environment, 2011). In addition, each municipality was also supported by the Green New Deal Fund based on the Guidelines for Special Measures regarding Disaster Waste Disposal. For the residual part to be borne by municipalities as well, MOE adopt the extraordinary measure of not burdening municipalities with the full amount by allocating tax for reconstruction.

Thus, these two types of ratio of disposal cost borne by national and local governments reflect this study.

Incidentally, the disposal cost of debris from vacant houses collapsed by tsunami and earthquake was borne by the central government or municipalities although the owners of vacant houses have responsibility for managing their property at their own expense.

4. Results and Discussion

In this paper, as much as 61 million tons of debris will be created by Nankai Trough Earthquake in Enshu — 3 times the amount resulting from the Great East Japan Earthquake of March 2011 (see Table 5). As can be seen from Figure 3, the debris will be distributed unevenly, and have a tendency to concentrate in the plains adjacent to the Coast of Enshu. In particular, the event will generate an enormous amount of concrete waste, which can be recycled for a number of post-disaster applications, owing to the large proportion of whole weight occupied by cement, aggregate and stone, and ready-mix concrete (see Table 5). Additionally, 224,150 tons of wood waste will be produced by the tsunami, which have some risk of generating polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and coplanar polychlorinated biphenyls in the municipal solid waste incineration plant (Bhurter et al., 2001; Yasuhara et al., 2003).

Maximum, 505,012 tons of debris, which are equivalent to 0.83 percent of the total amount of debris, can be reduced by planned removing target vacant houses in the pre-disaster phase (see Table 5). These reduction effects depend on cities. In Makinohara City, 1.28 percent of the total amount can be reduced. However, only 0.28 percent of the total amount can be reduced in Omaezaki City. Moreover, the disposal cost of debris defrayed by the central government and municipalities can be reduced by up to 11.9 billion Japanese yen as a result of planned clearance of target vacant houses before the disaster (see Table 6). These reduction effects also depend on cities. In Makinohara City, 1.05 percent of the total disposal cost can be reduced. However, only 0.21 percent of the total disposal cost can be reduced in Omaezaki City. In short, planned clearance of target vacant houses in the pre-disaster phase has the reduction effects on the amount and disposal cost of debris to some extent in Enshu on a case-by-case basis.

Although the estimation result in this study depends on the precision of required GIS data, statistical data, four fragility curves of buildings, and three parameters, these results suggest that municipalities need to properly manage vacant houses continuously before disaster occurrence. Normally, it is highly desirable for the owners of vacant houses to properly manage their property at their own expense in the pre-disaster phase. On the other hand, the statistics of MLIT show that about 40 percent of owners in Japan leave their property undisturbed because they don't want to bear the cost of demolishing their vacant houses (Ministry of Land, Infrastructure, Transport and Tourism, 2014).

According to the results of hearing survey with Hamamatsu City Office in July 2017, local governments have a passive way of thinking concerning the participation of municipalities on vacant houses matters due to private property. However, the presence of debris from vacant houses impacts almost every aspect of recovery and reconstruction in the post-disaster phase. For instance, in the immediate response, the debris can cause blockage which prevents access to emergency transportation roads, and impede rescuers, emergency-services and lifeline support reaching survivors as the Great Hanshin-Awaji Earthquake of January 1995. Therefore, municipalities should reinforce incentive for the owners of vacant houses greatly appreciated to conserve townscapes, improve land use, and reduce the pressure of debris in the post-disaster phase by planned clearance, including subsidy programs and tax systems. In order to encourage owners to tear down vacant houses, some municipalities provide subsidies. For instance, the inhabitants in Iwata City can receive one half of demolition expense up to 500,000 Japanese yen.

It is also important to strengthen ties with other policies, such as the implemented law in 2015 which allows municipalities to order the demolition of hazardous vacant houses.

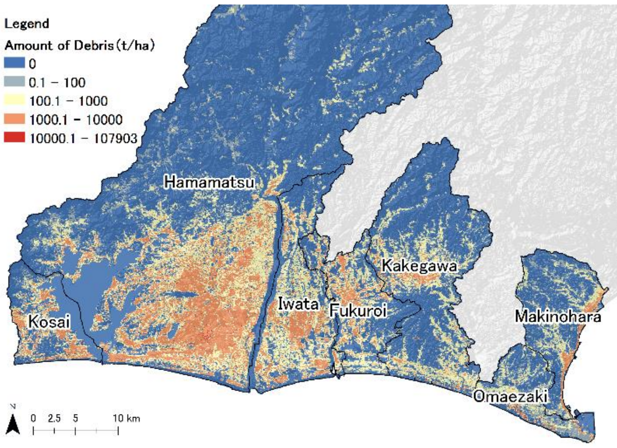

Figure 3 Debris distribution map of Enshu

Table 5 Reduction of the amount of debris by planned removing target vacant houses in Enshu (upper row: the total amount of debris, lower row: the maximum amount of debris from collapsed target vacant houses)

City	Wood (t)	Cement (t)	Aggregate and Stone (t)	Ready-Mix Concrete (t)	Steel (t)	Total (t)
Hamamatsu	1,197,438	2,290,397	17,291,368	14,092,575	852,552	35,724,330
	24,830	19,348	162,526	113,188	2,580	322,472
Iwata	287,675	512,437	3,890,756	3,145,100	184,534	8,020,502
	4,607	3,590	30,153	20,999	479	59,828
Kakegawa	162,570	295,993	2,243,352	1,818,102	107,720	4,627,737
	3,057	2,382	20,012	13,937	318	39,706
Fukuroi	149,344	259,609	1,975,148	1,591,922	92,356	4,068,379
	1,479	1,153	9,682	6,743	154	19,211
Kosai	125,962	282,960	2,111,638	1,749,775	112,228	4,382,563
	2,189	1,706	14,331	9,980	227	28,433
Omaezaki	30,642	96,479	706,231	601,512	42,131	1,476,995
	323	252	2,115	1,473	34	4,197

Makinohara	74,313	157,213	1,178,067	970,452	60,994	2,441,039
	2,400	1,870	15,707	10,939	249	31,165
Total	2,027,944	3,895,088	29,396,560	23,969,438	1,452,515	60,741,545
	38,885	30,301	254,526	177,259	4,041	505,012

Table 6 Reduction of disposal cost of debris by planned removing target vacant houses in Enshu（upper row: borne disposal cost in a normal case, lower row: borne disposal cost in a special case like the Great East Japan Earthquake of March 2011）

City	with Option（10K Yen）		without Option（10K Yen）		Cost Reduction
	Central Government	Municipality	Central Government	Municipality	（10K Yen）
Hamamatsu	77,041,554	8,560,173	76,358,871	8,484,319	758,536
	85,601,727	0	84,843,191	0	
Iwata	17,113,336	1,901,482	16,990,734	1,887,859	136,225
	19,014,818	0	18,878,593	0	
Kakegawa	9,571,915	1,063,546	9,492,614	1,054,735	88,113
	10,635,462	0	10,547,349	0	
Fukuroi	8,101,887	900,210	8,063,636	895,960	42,501
	9,002,096	0	8,959,595	0	
Kosai	9,937,237	1,104,137	9,873,041	1,097,005	71,329
	11,041,374	0	10,970,046	0	
Omaezaki	4,318,803	479,867	4,309,814	478,868	9,989
	4,798,671	0	4,788,682	0	
Makinohara	7,400,846	822,316	7,323,274	813,697	86,191
	8,223,162	0	8,136,971	0	
Total	133,485,578	14,831,731	132,411,984	14,712,443	1,192,884
	148,317,310	0	147,124,427	0	

5. Conclusions

Based on an estimation result of debris quantity, Japanese Municipal Disaster Waste Treatment Plan has been drawing up in order for the disposal of disaster waste to be carried out promptly, efficiently, and appropriately. However, most municipalities haven't fully discussed how to reduce the amount and disposal cost of debris in the pre-disaster phase.

The purpose of this study is to clarify the reduction effects by planned removing detached wooden vacant houses which are out of repair before the occurrence of Nankai Trough Earthquake in Enshu, using GIS and statistical data. In this study, the amount and disposal cost of debris are estimated based on 4 custom parameters: damage rates, per unit generation of debris, input rates of building materials, and per unit disposal cost of debris.

Consequently, maximum 505,012 tons of debris, which are equivalent to 0.83 percent of total amount, can be reduced and disposal cost defrayed by national and local governments can be lowered up to 11.9 billion Japanese yen. In addition, planned clearance of target vacant houses before the disaster has reduction effects on the amount and disposal cost of debris to some extent on a case-by-case basis. This finding indicates that reinforcing incentive for the owners in the pre-disaster phase is effective, considering regional difference.

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