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Paper:

Time-Series Analysis of Workload for Support in Rebuilding Disaster Victims' Lives – Comparison of the 2016 Kumamoto Earthquake with the 2007 Niigataken Chuetsu-oki Earthquake –

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Japan has experienced many disasters. However, the question of when and how much work is generated in support of rebuilding disaster victims' lives remains unsolved. Considering this situation, this study solves the question through a time-series analysis of daily workload in support of rebuilding the lives of victims of the 2016 Kumamoto Earthquake. In addition, a correlation analysis is conducted through comparison with the case of the 2007 Chuetsu-oki Earthquake that a prior study focused on, and another correlation analysis is conducted between municipalities affected by the Kumamoto Earthquake. These analyses do not indicate the presence of a high correlation in tasks for which the requirements for payment vary depending on the disaster but do indicate the presence of a high correlation between disasters in tasks for which the requirements for payment are uniform, thereby indicating the presence of a possible generalization. In addition, the correlation analysis results of comparisons between municipalities affected by the Kumamoto Earthquake indicate a high correlation between local public entities that have suffered great human and property damage. These results indicate that when a certain condition is met, it is highly likely that daily workload can be estimated.

Keywords: Kumamoto Earthquake, disaster victim support, workload, time-series analysis

1. Introduction

In recent years, Japan has experienced a variety of disasters nationwide such as earthquakes, landslides, and downpours. The seriousness of the impact of these disasters has been increasing. Recently, the 2011 Great East Japan Earthquake resulted in 19,533 dead and 2,585 missing as well as 121,768 completely collapsed, 280,160 half-collapsed, and 744,396 partially collapsed houses [1]. This was an earthquake and tsunami disaster. In addition, a downpour disaster was caused by the East Asian rainy season front and Typhoon #3 in July 2017 in the northern Kyushu area. This disaster resulted in 36 dead and 7 missing, and 102 completely collapsed, 35 half-collapsed, and 85 partially collapsed houses [2].

Once a disaster occurs, disaster victims take actions to protect their lives in the emergency period, and if there is great property damage, they are then ensured temporary residential spaces in evacuation shelters, houses of relatives or acquaintances, and the like in the first-aid period. After that, in the restoration and reconstruction period, lives of disaster victims are rebuilt by their houses being repaired or by new houses being built or purchased and their household economies brought back to normal in accordance with their current living conditions.

After the 1995 Great Hanshin Earthquake, which brought about 6,400 deaths and about 105,000 completely collapsed houses, the necessity of examining rebuilding the lives of disaster victims who suffered property damage or mental damage even though they did not lose their lives was recognized [3]. In light of this, a scheme to support rebuilding disaster victims' lives was set up in 1999. After that, this scheme was applied to a variety of disasters; problems in operating the scheme were reviewed; the scheme was expanded in 2004 [4]; and the Natural Disaster Victims Relief Law was revised in 2007 [5]. The scope of support for the strategy for rebuilding disaster victims' lives went beyond that defined by this law. In the 2004 Niigata Chuetsu Earthquake, the Niigata Prefecture set up a reconstruction fund project, which promoted support in accordance with a variety of damage situations [6]. In other words, the scope of support for rebuilding disaster victims' lives varies depending on the disaster.

On the other hand, an affected local public entity has to carry out support for rebuilding disaster victims' lives after a certain period of time has elapsed by taking a variety of measures against the disaster that start immediately after the disaster occurred. For schemes that were defined in advance such as the Natural Disaster Victims Relief Law, their plans mention creation of the system. However, since support for rebuilding lives varies depending on the disaster, as mentioned earlier, not all the schemes are provided with a created plan.

Considering this situation, this study is intended to make clear the workload of affected local public entities that support rebuilding disaster victims' lives, thereby contributing to planning the creation of project operation related to support for rebuilding disaster victims' lives. In light of support measures that vary depending on the disaster, this study makes clear the daily workload in the case of the Kumamoto Earthquake that occurred in April 2016, compares it with the case of the Chuetsu-oki Earthquake that occurred in July 2007, verifies the level of correlation, and mentions possible generalization.

2. Prior Studies on the 2007 Chuetsu-oki Earthquake

2.1. Overview of the 2007 Chuetsu-oki Earthquake

An earthquake of magnitude 6.8 occurred at 10:23, July 16, 2007, with the epicenter offshore of the Chuetsu area of the Niigata Prefecture. This earthquake, named the "Niigataken Chuetsu-oki Earthquake," generated a shake of a maximum intensity of 6 upper on the Japanese seismic scale in Kashiwazaki City, Nagaoka City, and Kariwa Village, and a maximum intensity of 6 lower in Joetsu City, Ojiya City, and Izumozaki Town.

The toll of human damage to the Niigata Prefecture was 15 dead, 330 seriously injured, and 2,016 slightly injured, and the toll of property damage was 1,331 completely collapsed, 5,710 half-collapsed, and 37,633 partially collapsed houses [7]. Kashiwazaki City, the place with the largest concentration of damages, carried out a property damage certification survey after the disaster occurred and started issuing victims' certificates from August 17 of the same year [8]. After that, 39 housing complexes and 1,007 temporary houses were built [9], and thus the support for rebuilding disaster victims' lives was put into practice.

2.2. System Utilization in the 2007 Chuetsu-oki Earthquake

After this disaster, Matsuoka et al. and Yoshitomi et al. developed and implemented an effective, efficient system of support for issuing victims' certificate using GIS and quickly issued victims' certificates [10, 11]. This system proposes and implements GeoWrap, a technology to integrate information from different databases on the basis of spatial phase relationship, in order to efficiently issue victims' certificates, which are the bases of support for rebuilding disaster victims' lives. More specifically, issuing victims' certificates requires integration of three types of information, "human," "houses," and "damage," where "human" is data managed with the Basic Resident Register; "houses" is data managed with the Fixed Asset Tax Resister; and "damage" is data obtained by investigating each house after the disaster occurs. There is no common key existing for each type of information. So the positions of "human," "houses," and "damage" were plotted on the space, and spatial closeness was treated as information familiarity, so that disaster victims, damaged houses, and level of damage were identified, and thus victims' certificates were issued quickly.

Based on data of disaster victims obtained by issuing victims' certificates, using the disaster victim registry, Inoguchi et al. managed in an integrated manner to achieve progress in support of rebuilding disaster victims' lives. They thereby recorded the support-offering situation of each disaster victim and subtracted disaster victims who had received support from all disaster victims who worked as masters, and hence they successfully identified disaster victims who had not received support. In the Reconstruction Support Office of Kashiwazaki City, the staff used the system to identify disaster victims who were left behind, checked those disaster victims' current living conditions and consultation records, and ensured that support be provided to each disaster victim. This case study contributed to the realization of "support for rebuilding the lives of disaster victims with no one left behind," which was declared by Kashiwazaki City [12].

These case study outcomes were inherited and implemented also in the case of the Kumamoto Earthquake, the target of this study. For this reason, we assume a certain level of validity when comparing between disaster support for rebuilding the lives of disaster victims utilizing the system.

2.3. Workload Analysis of Support for Rebuilding Disaster Victims' Lives in the Case of the 2007 Chuetsu-oki Earthquake

In their study, Inoguchi et al. made clear the number of daily tasks with respect to 14 types of tasks in Kashiwazaki City, one of the areas affected by the 2007 Chuetsu-oki Earthquake [13]. This study targeted the types of tasks and the total number of tasks generated as presented in **Table 1**.

In this case study, on the basis of the record of handling support tasks for rebuilding disaster victims' lives for a period of about two-and-a-half years starting from July 16, 2007, the day when the disaster occurred, they aggregated data on dates such as application date, reception date, and handling date, and made clear the number of tasks generated daily. This was the detailed analysis studying daily workload on the basis of data recorded by the staff when they were in service. However, this case study focused merely on Kashiwazaki City from among the areas affected by the 2007 Chuetsu-oki Earthquake and did not mention its generality. A comparison with the case of the Kumamoto Earthquake in our study allows applicability to another case to be examined with the number of generated tasks regarded as workload.

Table 1. Target of workload analysis of support for rebuilding disaster victims' lives with the case of Kashiwazaki City.

	Name of work	Number of items
1	first-aid risk judge	32,090
2	building damage certification survey (external appearance survey)	58,828
3	building damage certification survey: re-survey (internal appearance survey)	7,942
4	building damage certification survey database set up	59,158
5	issuance of victim's certificate	60,901
6	consultation service of rebuilding lives	19,332
7	review of certificate of disaster victims	628
8	supply of prefectural scheme support money	5,729
9	supply of national scheme support money	3,512
10	supply of relief donation	34,637
11	application of first-aid house repair scheme	3,498
12	support of moving into or out of first-aid temporary houses	994
13	support of rebuilding temporary houses for occupiers	6,558
14	support of reconstruction publichousing occupancies	177

3. Introduction of System of Support for Rebuilding Disaster Victims' Lives During the Kumamoto Earthquake

3.1. Support for Implementation of System of Support for Rebuilding Disaster Victims' Lives

On April 14, 2016, a magnitude 6.5 earthquake occurred with the epicenter in Kumamoto area, and a maximum intensity of 7 in Mashiki Town, Kumamoto Prefecture. At around 01:25, April 16, two days later, a magnitude 7.3 earthquake occurred with the epicenter in the same area, and a maximum intensity of 7 in Mashiki Town and Nishihara Village. Those earthquakes are collectively referred to as the 2016 Kumamoto Earthquakes, and the earthquake on April 16 is considered to be the main quake.

The toll of human loss to Kumamoto Prefecture from this disaster was 236 dead, 1,156 seriously injured, and 1,553 slightly injured, and the toll of property damage was 8,662 completely collapsed, 34,239 half-collapsed, and 152,111 partially collapsed houses [14]. In reaction to this earthquake, the study team of the authors assumed that huge damage would occur over a wide area and many disaster victims would need to have their lives rebuilt for a long period of time; implemented the "system of support for rebuilding lives of disaster victims" in each affected city, town, and village of the Kumamoto Prefecture; and decided to support those cities and towns.

For the purpose of implementing this support activity, the study team of the authors set up the "Joint Body of Support for Rebuilding of Lives of Victims of the 2016 Kumamoto Earthquake," which was made up of industry, government, academia, and the private sector, and started to collect information and grasp the situation at the Kumamoto Prefecture Government from April 16, when the earthquake occurred, as an advance troop. After that, in cooperation with the Kumamoto Prefecture, we held a workshop for implementing the property damage certification survey; issuing victims' certificates; and subsequent support for rebuilding the lives of the affected cities, towns, and villages, and offered a cloud service for the system of support for rebuilding disaster victims' lives to the affected cities, towns, and villages. This activity was agreed, and the system was used by 16 municipalities. In addition, in a process in which the support for rebuilding lives is ongoing, the usefulness and necessity of the system was understood by one city, which used its service. As a result, 17 municipalities used the system of support for rebuilding disaster victims' lives [15].

The service of the system for rebuilding disaster victims' lives offered to the Kumamoto Earthquake does not just mean support for rebuilding lives in the affected cities, towns, and villages. Promoting work using the system caused increased staff recognition of the importance of recording work progress in digital data. As a result, information on the work operation was managed in digital data. In addition, through the activities of the Joint Body of Support for Rebuilding of Lives, rapport (trust) was formed with the staff of the affected municipalities, which enabled the base of this study, that is, collection of work data of support for rebuilding disaster victims' lives.

3.2. Collection of Work-Record Data

After one year had passed since the Kumamoto Earthquake, the affected municipalities shifted from the emergency first-aid phase immediately after the disaster to the restoration and reconstruction period. In reaction to this, from June 26 to 28, 2017, we visited cities, towns, and villages in the Kumamoto Prefecture affected by the Kumamoto Earthquake and asked them to collect recorded data of support work for rebuilding disaster victims' lives.

For the purpose of collection, we asked them to provide data in a range of not becoming a burden to the affected municipalities. The target tasks were the 14 tasks analyzed in the prior study, which focused on Kashiwazaki City in the 2007 Chuetsu-oki Earthquake. The 14 tasks in Kashiwazaki City focused on in the prior study included those not directly related to support tasks for rebuilding disaster victims' lives. In other words, the 14 tasks included the first-aid safety check and the property damage certification survey, which is a basis of the work of support for rebuilding disaster victims' lives. However, this study targets tasks from issuance of victims' certificates because it targets long-term support for rebuilding disaster victims' lives.

First, the issuance of victims' certificates was carried out by each affected city, town, and village using the system of support for rebuilding disaster victims' lives. So

Table 2. List of work data collected from municipalities.

Name of work		Number of items ∗1	Kumamoto City	Kikuchi City	Uki City	Kikuyo Town	Mashiki Town	Mifune Town	Kosa Town	Minamiaso Village
issuance of victim's certificate∗2		202,797	○	○	○	○	○	○	○	○
relief donation	house damage (city, town, and village)	57,611	○	○	○	○		○		△ ∗3
	house damage (prefecture)		○	○	○	○		○		△ ∗3
	human damage (city, town, and village)	819	○							△ ∗3
	human damage (prefecture)		○		○					△ ∗3
supportgrant for rebuilding of lives of disaster victims		25,041	○	○	○	○		○		○
condolence money		290	○							
demolition support on public expense		5,419	○		○					
first-aid house repair		21,672	○	○	○	○	○	○	○	○
temporary houses	prefabricated temporary houses∗4	884	○		○					
	privately rented and leased housing	11,332	○		○					
relief money		54,473	○	○		○		○		
impairment relief money		1	○							
general consultation service		219,490	∗5							
relief fund loan		555	○							
others	reconstruction coupon partially collapsed	1,292			○					

∗1:The number of items is an aggregate value up to the end of May 2017.
∗2: Other than above, issu ance of victim's certificates in cludes Aso City, Uto City, Koshi City, Tamana City, Ozu Town, Kashima Town, Gyoku Town, Misato Town, and Minamioguni Town.
∗3: △ (triangle) is a monthly aggregated value only, so it was exclu ded from th is an alysis.
∗4: We referred to the occupier name list. So we used it as a reference value because it does not cover all th eapplicants.
∗5: Although it is data of a single localpublic entity, we targeted it because it was characteristic in terms of correlation analysis between disasters. However, the name of the localpublic entity is not disclosed due to the condition of data provision.

data were recorded in the system, and, under an agreement with the city, town, and village, those data were referred to. In addition, there were two cases of individual support tasks for rebuilding lives in each city, town, and village: a case with data managed using the system and a case with data individually managed using Excel. We asked them to give us the data in Excel format. This study does not need personal information found in issuing victims' certificates and the individual support tasks, so the Excel files to be provided were exclusive of that information.

Regarding the individual support tasks, eight local public entities out of the cities, towns, and villages affected by the Kumamoto Earthquake replied that they were able to provide data of specific tasks presented in **Table 2** from among the data they owned. From mid- to late July 2017, we were provided with sequential data from the affected cities, towns, and villages, and obtained the amount of data presented in "Number of Items" in **Table 2**.

These data include data related to daily work operations and data related to dates that are useful for analysis of "daily workload" in our study such as "reception date," "application-processing date," and "offering date." From among those items, we picked up "reception date" as an analysis target for the following reason. The "reception date" can be regarded as the day when a disaster victim requested support from the local public entity, so it is possible for the affected local public entity to count it as workload generated. For this reason, on the basis of collected data, we handled the number of generated applications for each reception date as a daily workload.

Table 3. Population and number of households of comparison target municipalities [16, 17].

Prefectures	Municipalities	Population	Number of households	Reference source
Niigata	Kashiwazaki City	93,518	33,841	Kashiwazaki City published: end of June 2007
Kumamoto	Kumam to City	740,822	315,456	2015 National Census
	Tamana City	66,782	24,474	
	Kikuchi City	48,167	16,949	
	Uto City	37,026	13,285	
	Uki City	59,756	21,432	
	Aso City	27,018	10,078	
	Koshi City	58,370	20,560	
	Misato Town	10,333	3,611	
	Gyokuto Town	5,265	1,825	
	Ozu Town	33,452	12,705	
	Kikuyo Town	40,984	15,950	
	Minamioguni Town	4,048	1,642	
	Minamiaso Village	11,503	4,676	
	Mifune Town	17,237	6,317	
	Kashima Town	9,054	3,170	
	Mashiki Town	33,611	11,477	
	Kosa Town	10,717	3,710	

4. Time-Series Analysis of Workload of Support for Rebuilding Disaster Victims' Lives

4.1. Time-Series Analysis of Workload

With respect to the work-record data collected from each affected city, town, and village as mentioned earlier, we aggregated the number of generated applications for each reception date and aggregated it with the number of days elapsed since the disaster occurred. Some tasks include applications that were once received but later withdrawn by the disaster victim's will and withdrawn due to failure to meet the application requirements. In any case, however, we handled the withdrawn item as a workload for the local public entity because the tasks of "starting application processing" and "examining application requirements" are generated for the affected local public entity.

Next, the number of days elapsed will be defined. In the Kumamoto Earthquake, two earthquakes of intensity 7 were monitored on April 14 and 16, 2016. However, it is not confirmed that support work for rebuilding lives was carried out between April 14 and 16. So we calculated the number of days elapsed, with the main quake on April 16 as the reference. On the other hand, data on support work for rebuilding lives affected by the Chuetsu-oki Earthquake focused on in the prior study were organized on the basis of the number of days elapsed, with July 16, 2007, as the reference date, and the data were compared with those in the case of the Kumamoto Earthquake.

The data collected from the local public entities affected by the Kumamoto Earthquake had reception dates that were not uniform. Due to this, we analyzed the period of about 13 months up to the end of May 2017, when the data collected from the municipalities were all ready. As a result, the number of data items presented in **Table 2** was analyzed. In addition, since data were supposed to be provided from local public entities on condition that consideration was taken to prevent local public entities from being identified, this study did not target such tasks whose data were collected from only one local public entity. As a result, this study analyzes those tasks shaded in light blue in **Table 2** as the targets.

Next, to compare workload between different disasters and local public entities, how to handle the workload is discussed because the weight of a single item of workload is different.

If the Kumamoto Earthquake is compared with the Chuetsu-oki Earthquake, the scale of human and material damage is different. In addition, the period of analysis target was greatly different: it was about two-and-a-half years for the Chuetsu-oki Earthquake, but it was about one year for the Kumamoto Earthquake. If Kashiwazaki City is compared with the cities, towns, and villages affected by the Kumamoto Earthquake in terms of population, as presented in **Table 3**, the latter varies in scale from Kumamoto City, which is a city designated by government ordinance, to towns and villages with small populations.

In addition, regarding evaluation of quotas of local public entity staff, the Ministry of Internal Affairs and Communications categorizes all cities, wards, towns, and villages on the basis of their population and industrial structure (composition ratio of working population by industry) and calculates the average number of staff per 10,000 persons for each category. [18] In other words, population is considered to be one of the factors that define the number of staff of the local public entity. This indicates that currently the local public entity staff are allocated not depending on the damage scale at the time of disaster but depending on the population at ordinary times, and suggests that the current system should be reviewed and new organizations should be discussed in accordance with the number of tasks to be handled at the time of disaster.

Based on those conditions, we assume that the rate calculated by dividing the number of generated daily work items by the number of applications received by the local public entity can be handled as a workload that can be compared between local public entities and between disasters. In addition, since data sets have different periods of time, this study sets analysis target on the 410 days from the reference date, in other words, the day when the disaster occurred, to the end of May 2017, and designates the total number of work items generated in the entire period of time as the parameter. In other words, this study defines the workload as a value calculated by dividing the number of generated daily work items by the total number of work items of the 410 days, and analyzes daily behaviors (Eq. (1)).

On the basis of the condition mentioned above, we analyzed through time series the number of generated daily work items (proportion) of each of the nine tasks, including support for consultation work around rebuilding lives for comparison between disasters (**Fig. 1**). In **Fig. 1**, the blue bar chart represents the number of generated daily work items (proportion) in the Kumamoto Earthquake, and the red line chart represents the number of generated daily work items (proportion) at Kashiwazaki City in the Chuetsu-oki Earthquake. Although for comparison, both should have been bar charts, we represent the result of the Chuetsu-oki Earthquake in line chart form for better visibility.

$$R_{(i)} = \frac{f_{(i)}}{\left(\sum_{j=1}^{410} f(j)\right)} * 100 \quad \ldots\ldots\ldots\ldots (1)$$

i: the number of days elapsed since the reference date (days)

$R(i)$: the generated daily workload proportion of the i-th day (%)

$f(i)$: the number of generated daily work items of the i-th day (items)

4.2. Discussion on Time-Series Analysis of Workload Result

This section overviews **Fig. 1** of the previous section and discusses the generation of support workload for rebuilding disaster victims' lives in the Kumamoto Earthquake. At first, due to tasks such as issuance of victims' certificates, consultation support service for rebuilding lives, supply of support grant for rebuilding disaster victims' lives, and supply of relief donation, the workload reached a peak within the first three months and then declined in the fifth to sixth months. On the other hand, in first-aid house repair, the workload reached a peak in around the fourth month. In other words, compared to the other tasks, the task of first-aid house repair transitioned late.

In addition, from around the third month, there were days with low value on a regular basis, and from around the fifth month, there were days with 0 value. These are Saturdays and Sundays on weekends, and it was confirmed that from around the third month, some local public entities started to take days off on weekends, and from around the fifth month, almost all local public entities took days off on weekends. This indicates that a peak had been achieved for each task, and thus the local public entity staff thought that the busiest days had gone. In light of this situation, by analyzing the workload when one year had passed, we can confirm transition to peak time, when peaks occurred, and transition of generation of workload after peak. For this reason, there is certain validity as to the period of time targeted in this study.

Next, the Kumamoto Earthquake graph indicates that multiple tasks had an increased workload between the eleventh month and the first year. This indicates that there were last-minute applications rushed by the upcoming application deadline. Newsletters issued by the municipalities affected by the Kumamoto Earthquake announced that the application deadline for issuing victims' certificates was going to be at the end of March 2017. In addition, there was a one-year application deadline also for the first-aid house repair, so it is inferred that workload increased immediately before one year had passed. In other words, despite a variety of support schemes for rebuilding disaster victims' lives and an environment favorable to provision to disaster victims, some disaster victims made applications immediately before the deadline, although most applications were made in the first three months after the application was open. This is inferred as indicating that each disaster victim was not necessarily working on the support for rebuilding lives in a planned manner, was spending a period of time when they were not able to sufficiently set the direction for rebuilding their lives, and applied immediately before the deadline out of necessity.

Next, individual tasks will be discussed. At first, the tasks of issuing victims' certificates will be discussed. The other day, there was a report that issuance of victims' certificates related to the Kumamoto Earthquake was delayed. However, it was not actually late compared with the 2007 Chuetsu-oki Earthquake and past disasters. Actually, some local public entities started issuing certificates within one month of the disaster's occurrence. In addition, after that, the peak of workload was generated within one to two months, and its proportion was also similar to the case of the Chuetsu-oki Earthquake. A similar situation happened also after half-a-year had passed when the workload transitioned at a low rate.

On the other hand, in the supply work of support grants for rebuilding disaster victims' lives, the workload peaked earlier than that of the Chuetsu-oki Earthquake, even though the work began at almost the same time as that of the Chuetsu-oki Earthquake. In addition, the situation of the third month and later months is similar to that of the Chuetsu-oki Earthquake.

The situation of the relief donation supply work for the Kumamoto Earthquake is greatly different from that in the case of the Chuetsu-oki Earthquake. At the time of the Chuetsu-oki Earthquake, the relief donation was initially

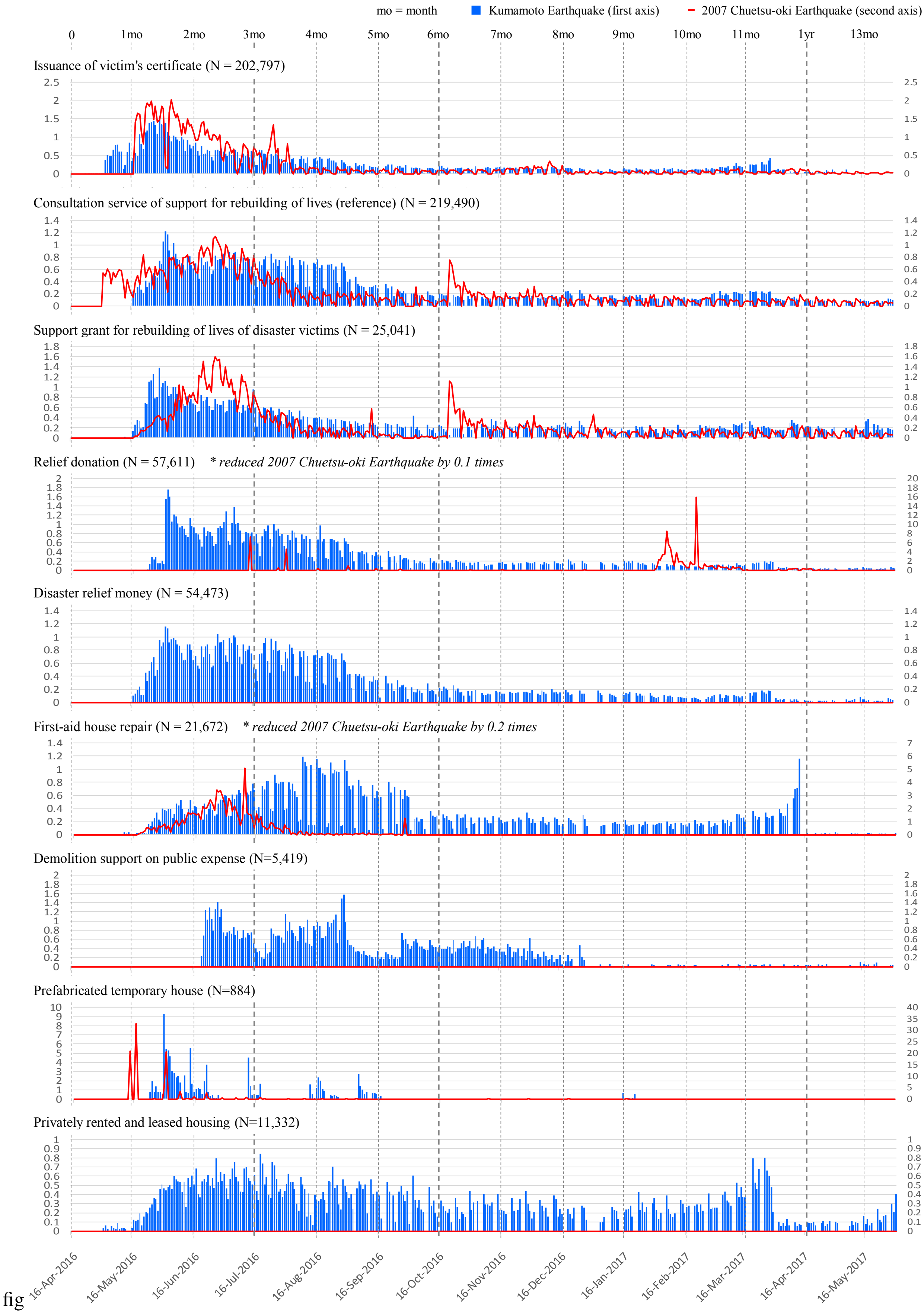

Fig. 1. Daily workload of support task for rebuilding disaster victims' lives.

supposed to be supplied to the half-collapsed houses and worse. However, after that, the relief donation requirements for payment targeted the partially collapsed houses, and there was a large peak on and after the tenth month. In the case of the Kumamoto Earthquake, workload peaked in one or two months, and, after that, a large load amount was maintained up to around the fifth month. Requirements for payment of relief donation are not determined in advance. A relief donation distribution committee was set up for each disaster, and, in light of the situation of disaster victims, the requirements for payment and the supply amount of money were determined with respect to the amount of money sent as relief donations from all over the country. For this reason, the situation varies depending on disaster, and there is a difference between disasters. In addition, for relief donations directly sent to municipalities, the requirements for payment and the supply amount of money are determined for each municipality, so a difference between municipalities is inferred. These details will be discussed in the next chapter.

The supply work of disaster relief money and the work for reception of occupancy of privately rented and leased housing cannot be compared because data collection was not possible in the case study of the Chuetsu-oki Earthquake. The transition of the workload presented in **Fig. 1** indicates no clear peak of workload in the relief money supply work during the entire Kumamoto Earthquake, and a certain amount of workload was generated around between one-and-a-half months and four-and-a-half months. After that, the workload decreased, and, similar to other tasks, the workload was low for up to one year. On the other hand, in the leased housing occupancy reception task, workload peaked in two to three months, and, although it gradually decreased after that, there was another great peak around eleven-and-a-half months, which was the fiscal year end.

After an occupancy application was received, prefabricated temporary houses were selected and provided to occupiers in accordance with the number of houses. The application reception date was limited, and workload was concentrated in that period of time. For this reason, workload was generated in a way different from other tasks in which applications were constantly received.

In this section, we observed and discussed generation of daily workload from a higher point of view. In order to verify the validity, in the next chapter, we analyze a correlation between the Chuetsu-oki Earthquake and the Kumamoto Earthquake disasters, analyze a correlation between local public entities in the case of the Kumamoto Earthquake, and hence conduct a quantitative evaluation of our discussion in this section.

5. Correlation Analyses of Workload Between Disasters and Local Public Entities

5.1. Method of Correlation Analysis Between Disasters and Local Public Entities

To conduct a quantitative evaluation of our discussion in the previous chapter, this study verifies the level of correlation of daily generated workload between the disasters and local public entities. Our discussion in the previous chapter confirmed that workload decreased on weekends after a certain period of time had elapsed. In particular, the level of correlation between the disasters is verified by taking into consideration that the number of days until the first weekend after the earthquake is not necessarily the same for the Chuetsu-oki Earthquake as for the Kumamoto Earthquake. The Chuetsu-oki Earthquake occurred on Monday, July 16, 2007, and the Kumamoto Earthquake occurred on Saturday, April 16, 2016, which is a reference date. For this reason, a difference is generated on the day when workload is decreased for each weekend.

In light of this situation, when validating the level of correlation, we aggregated the workload on a weekly basis and created a data set. The analysis target period is 410 days. So, targeting 58 weeks, we calculated the workload on a weekly basis and analyzed correlations between the disasters and local public entities.

In addition, for the Chuetsu-oki Earthquake used in our correlation analysis between the disasters, we aggregated 58 weeks-worth of data after disaster occurred from among the data picked up in the prior study of Kashiwazaki City. For the Kumamoto Earthquake, we aggregated data collected from each local public entity for each task and created a data set on a weekly basis. For this reason, we assumed that although local public entities included in the analysis varied depending on work, there would not be a great difference if the pictures between the disasters were compared.

On the other hand, for the correlation analysis between local public entities, we calculated the weekly aggregation value on the basis of the local public entity for each task and created a data set. Since the situation of damage occurrence varies depending on the local public entity, it is assumed that there may be differences in the level of peak workload and the reduction transition situation. This case study treats workload as a proportion, and an influence will be minimized.

5.2. Correlation Analysis Between the Chuetsu-oki Earthquake and the Kumamoto Earthquake

We carried out a correlation analysis for each task, using a data set in which workload was aggregated on a weekly basis based on the data set of weekly workload in Kashiwazaki City for the Chuetsu-oki Earthquake created in the previous section and the data collected from each municipality for the Kumamoto Earthquake (**Table 4**). In addition, as this study focuses on the case of the Kumamoto Earthquake, we analyze data collected from municipalities affected by the Kumamoto Earthquake. For this reason, the tasks that appeared only in the case of the Chuetsu-oki Earthquake were excluded from the correlation analysis target.

As presented in **Table 4**, we got very high correlations in the following three: “4. Issuance of victims’ certificates,” “5. Consultation service of support for rebuilding

Table 4. Correlation coefficient between disasters for each task.

Work ID	Name of work	Correlation coefficient
5	Issuance of victim's certificate	0.909**
6	Consultation service of support for rebuilding of lives (*1)	0.758**
8	Supportgrant for rebuild ng of lives of disaster victims	0.728**
9		
10	Reliefdonation (house damage)	-0.106
11	First-aid house repair	0.432**
12	Temporary house application recep tion	0.313

*1:data of single local publicentity only, so it was used as a reference value

*correlation coefficient is significant at a level of 5%

**correlation coefficient is significant at a level of 1%

of lives," and "6./7. Support grant for rebuilding lives of disaster victims supply." In addition, in "10. First-aid house repair," we got a correlation coefficient of 0.423, which is high for a relationship between two different social activity phenomena. These tasks are defined in advance in terms of procedure, application, and reception requirements, and do not greatly vary depending on disaster. However, considering that "workload" is generated by the disaster victims themselves making a decision as to "when to apply" and "when to consult," it is deemed that activities of the disaster victims themselves towards rebuilding their lives looked alike.

By comparing two disasters with different disaster scale and regional characteristics, we got a relatively high correlation result. This result indicates a possibility of guaranteeing the generality of model function of daily workload occurrence on the basis of analyzing the result of the case.

On the other hand, there is a low correlation coefficient for "relief donation" and "temporary house" with no significance presented. This means a low relationship between the disasters. As for relief donation, as mentioned above, a relief donation distribution committee is set up for the amount of money collected at each disaster, and requirements for payment, the amount of money, and the like are talked about and determined in the committee. The amount of money that can be distributed varies depending on the disaster, and, moreover, the period of time of distribution and the amount of distribution both also vary. For this reason, it is appropriate that there is no relationship between the disasters. Actually, it is hard to believe that those are uniform in any disaster because the number of temporary houses to be built also varies depending on damage scale; the occupancy application reception date varies depending on local public entity and disaster; and, according to the flow, application is received at the same time in a limited period of time, and examination results are notified. For this reason, the low correlation coefficient indicates that this hypothesis is valid.

The above discussion makes clear that in consideration of the entire disaster, there is a certain relationship found in support measures in which reception requirements are clear in advance, regardless of the disaster scale and disaster victim situation. In addition, it is inferred that although affected by activities for rebuilding disaster victims' lives, there are many common items also in rebuilding activities of disaster victims because there is a certain relationship between the disasters.

5.3. Correlation Analysis Between Municipalities Affected by the Kumamoto Earthquake

Next, we carried out a correlation analysis, intended to make clear the relationship between municipalities affected by the Kumamoto Earthquake. Similarly to the correlation analysis between the disasters, we created a 58-week data set for each local public entity and calculated the correlation coefficient for each (**Table 5**). **Table 5** presents relationships between local public entities for all the tasks other than the two tasks of "prefabricated temporary house" and "privately rented and leased housing," for which a small number of local public entities provided data.

Among support tasks for rebuilding disaster victims' lives, data on "first-aid house repair" were provided by all the eight municipalities targeted in this study, but data for other tasks were provided only by some local public entities. The local public entities that did not provide all data are indicated with "–"; in addition, both the vertical axis and the horizontal axis are provided with local public entities, presented in a cross table. For this reason, the correlation coefficient is 1 between the identical local public entities.

The overall situation presented in **Table 5** indicates that the correlation coefficient tends to be relatively high in any task between Kumamoto City, Mashiki Town, Mifune Town, and Uki City. On the other hand, although it is high in some of the other local public entities, the correlation coefficient is low overall. **Table 6** presents the damage situation of each local public entity released by Kumamoto Prefecture. Matching **Table 5** with **Table 6** indicates that the correlation coefficient is high between local public entities with great human and property damage. On the other hand, the correlation coefficient is not high between local public entities having small damages, and it is thus inferred that it is difficult to predict generation of workload when the damage is small. However, although this analysis only compared workload correlations and situations in which human and property damage is generated, and the relationship in the result may have generated spurious correlations, this study does not mention it. The possibility of spurious correlation, including the scale of local public entities and regional characteristics, is a future challenge.

In the previous section, we compared the disaster with the case of Kashiwazaki City, where the greatest damage was caused by the Chuetsu-oki Earthquake. For this reason, there was a high correlation compared with the case of the Kumamoto Earthquake. On the other hand, a close look at the municipalities affected by the Kumamoto Earthquake indicates that while a correlation tends to be

Table 5. Correlation analysis results between municipalities affected by the Kumamoto Earthquake.

Issuance of victims' certificates

	Kumamoto	Mashiki	Kikuchi	Kosa	Kikuyo	Mifune	Minamiaso	Uki
Kumamoto	1	0.550**	0.746**	0.606**	0.546**	0.826**	0.723**	0.691**
Mashiki	0.550**	1	0.750**	0.867**	0.405**	0.562**	0.868**	0.945**
Kikuchi	0.746**	0.750**	1	0.855**	0.749**	0.574**	0.777**	0.722**
Kosa	0.606**	0.867**	0.855**	1	0.707**	0.555**	0.861**	0.797**
Kikuyo	0.546**	0.405**	0.749**	0.707**	1	0.248	0.423**	0.336**
Mifune	0.826**	0.562**	0.574**	0.555**	0.248	1	0.821**	0.761**
Minamaso	0.723**	0.868**	0.777**	0.861**	0.423**	0.821**	1	0.907**
Uki	0.691**	0.945**	0.722**	0.797**	0.336**	0.761**	0.907**	1

Supportgrant for rebuilding of lives of disaster victims (basic + additional support m oney)

	Kumamoto	Mashiki	Kikuchi	Kosa	Kikuyo	Mifune	Minamiaso	Uki
Kumamoto	1	-	0.286*	-	0.019	0.710**	0.312*	0.622**
Mashiki	-	-	-	-	-	-	-	-
Kikuchi	0.286*	-	1	-	0.547**	0.343**	0.009	0.319*
Kosa	-	-	-	-	-	-	-	-
Kikuyo	0.019	-	0.547**	-	1	0.350**	0.063	0.218
Mifune	0.710**	-	0.343**	-	0.350**	1	0.279*	0.797**
Minamiaso	0.312*	-	0.009	-	0.063	0.279*	1	0.310*
Uki	0.622**	-	0.319*	-	0.218	0.797**	0.310*	1

Relief donation (house dam age)

	Kumamoto	Mashiki	Kikuchi	Kosa	Kikuyo	Mifune	Minamiaso	Uki
Kumamoto	1	-	0.300*	-	0.358**	0.771**	0.509**	0.631**
Mashiki	-	-	-	-	-	-	-	-
Kikuchi	0.300*	-	1	-	0.243	0.092	0.097	0.353**
Kosa	-	-	-	-	-	-	-	-
Kikuyo	0.358**	-	0.243	-	1	0.153	0.148	0.461**
Mifune	0.771**	-	0.092	-	0.153	1	0.352**	0.626**
Minamiaso	0.509**	-	0.097	-	0.148	0.352**	1	0.248
Uki	0.631**	-	0.353**	-	0.461**	0.626**	0.248	1

Disaster relief money

	Kumamoto	Mashiki	Kikuchi	Kosa	Kikuyo	Mifune	Minamiaso	Uki
Kumamoto	1	-	0.352**	-	0.359**	0.825**	-	-
Mashiki	-	-	-	-	-	-	-	-
Kikuchi	0.352**	-	1	-	0.285*	0.049	-	-
Kosa	-	-	-	-	-	-	-	-
Kikuyo	0.359**	-	0.285*	-	1	0.165	-	-
Mifune	0.825**	-	0.049	-	0.165	1	-	-
Minamiaso	-	-	-	-	-	-	-	-
Uki	-	-	-	-	-	-	-	-

First-aid house repair

	Kumamoto	Mashiki	Kikuchi	Kosa	Kikuyo	Mifune	Minamiaso	Uki
Kumamoto	1	0.744**	0.522**	0.615**	0.373**	0.677**	0.287*	0.695**
Mashiki	0.744**	1	0.639**	0.788**	0.382**	0.914**	0.566**	0.438**
Kikuchi	0.522**	0.639**	1	0.637**	0.507**	0.544**	0.566**	0.569**
Kosa	0.615**	0.788**	0.637**	1	0.585**	0.637**	0.551**	0.593**
Kikuyo	0.373**	0.382**	0.507**	0.585**	1	0.350**	0.322*	0.584**
Mifune	0.677**	0.914**	0.544**	0.637**	0.350**	1	0.596**	0.300*
Minamiaso	0.287*	0.566**	0.566**	0.551**	0.322*	0.596**	1	0.259*
Uki	0.695**	0.438**	0.569**	0.593**	0.584**	0.300*	0.259*	1

* correlation coefficient is significant at a level of 5%
** correlation coefficient is significant at a level of 1%

Table 6. Damage to municipalities by the Kumamoto Earthquake [19].

Damage type		Unit	Kumamoto	Uki	Kikuchi	Kikuyo	Minamiaso	Mifune	Mashiki	Kosa
Human damage	Deaths	persons	73	9	4	6	29	10	40	3
	Seriously injured	persons	750	48	20	14	29	11	134	16
	Slightly injured	persons	943	95	56	15	120	10	31	2
House damage	Completely collapsed	houses	2,455	539	57	18	692	444	3,026	105
		house hold	5,752	539	67	15	692	444	3,538	113
	Half collapsed	houses	15,194	2,372	681	671	914	2,356	3,233	986
		house hold	47,528	2,372	723	656	914	2,356	3,873	1,067
	Partically collapsed	houses	103,985	5,567	2,874	5,119	1,190	2,072	4,325	914
		house hold	80,626	5,567	2,793	4,953	1,190	2,072	4,979	927

relatively high when human and property damage is large, a correlation coefficient tends to be low when human and property damage is small.

The situation of relief donation in the identical disaster indicates a high correlation coefficient in Kumamoto City, Uki City, and Mifune Town. This phenomenon also occurred in "relief money," for which comparison between the disasters was not possible. This suggests that an estimation model of workload can be discussed on the basis of a certain level of human and property damage for each disaster case.

6. Conclusions

This study has made clear the daily workload of support for rebuilding disaster victims' lives during the 2016 Kumamoto Earthquake, and made clear the similarity of the situation of workload generation between disasters through comparison with the case of the 2007 Chuetsu-oki Earthquake in the prior studies. In addition, this study has made clear the similarity of situation of workload generation between municipalities affected by the Kumamoto Earthquake for each task.

These analyses have made clear that there actually is a relationship between the disasters even though the action of "application" by disaster victims is expected to occur at random in the process of rebuilding disaster victims' lives. Such a relationship is limited to tasks for which requirements for payment can be determined before disasters occur. For those whose situation of reception varies depending on disaster such as relief donation and relief money, a relationship was low in the workload generation situation.

On the other hand, the correlation analysis between municipalities affected by the Kumamoto Earthquake indicates that while the correlation coefficient tended to be relatively high between local public entities with great human and property damage, the correlation coefficient tended to be low between local public entities with small human and property damage. This phenomenon has made clear that it is possible to generalize and apply a model to estimate daily workload of local public entities with great human and property damage based on the outcome of this case study, but it is not effective for local public entities with small human and property damage. However, we will have another validation for this result whether or not a spurious correlation has been generated.

In the near future, the Nankai megathrust earthquakes and earthquakes directly beneath the Tokyo Metropolitan Area are expected to occur, for which the entire human and property damage will be enormous. On the other hand, it is expected that many disaster victims will need to rebuild their lives, and the workload of affected local public entities supporting the rebuilding will also be enormous. On the basis of findings obtained by this study, our future study is intended to build an estimate equation of workload. Once built, this estimate equation can classify the expected level of human and property damage of affected local public entities, estimate the daily workload of local public entities that are expected to suffer great human and property damage, and enable discussion on the countermeasures in advance. As a result, this facilitates support for rebuilding the lives of disaster victims after the disaster occurs. For this reason, we will collect data of other past disaster cases and future disaster cases, and carry out continuous analyses. Then, we intend to create an estimate equation of daily generated workload for a variety of support tasks for rebuilding disaster victims' lives.

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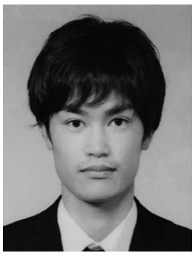

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