Evaluating the Damage of Great Earthquakes in Aggregate Units Based on Detailed Population Distribution for Each Time Frame

Yoshiki Ogawa, Yuki Akiyama, Hiroshi Kanasugi,
Hiroaki Sengoku and Ryosuke Shibasaki

Abstract

The objectives of this study are: 1) to develop a method for estimating the population distribution of the approximately 35 million people within the Tokyo Metropolitan Area for each time frame (by hour), based on data from traffic surveys, 2) to develop a method for evaluating human damage due to fire and collapse in the event of a Nankai megathrust earthquake in the Tokyo Metropolitan Area, for each time frame, by using a combination of the data developed in the first objective and our "Micro-geo data", data we have developed to reflect information about building structures, building age, and so on. As this study enables us to assess damage for any time frame and any aggregate unit, it will be useful to consider provision for various situations when an earthquake will hit, such as during commuting hours or working hours.

Y. Ogawa (Corresponding author)
Graduate School of Frontier Science, The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo, 153-8505, Japan
Email: ogawa@csis.u-tokyo.ac.jp
Y.Akiyama • Y. Kanasugi
Earth Observation Integration & Fusion Research Institute, The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo, 153-8505, Japan
Email: aki@iis.u-tokyo.ac.jp
Y. Kanasugi
Email: yok@iis.u-tokyo.ac.jp
H. Sengoku • R. Shibasaki
Center for Spatial Information Science, The University of Tokyo, Meguro-ku, Tokyo, 153-8505, Japan
Email: xianshi@csis.u-tokyo.ac.jp
R. Shibasaki
Email: shiba@csis.u-tokyo.ac.jp

1. INTRODUCTION

In recent years, a Nankai megathrust earthquake with a scale of at least Mm9 is predicted to occur with 70% probability within the next 30 years (The Headquarters for Earthquake Research Promotion, 2014). Furthermore, a Near-field earthquake in the Tokyo Metropolitan Area is also expected to occur, and therefore, the risk of confusion due to the destruction of buildings, fire, and tsunamis at such a time is increasing everywhere in Japan. For disaster mitigation, the Japanese government is to determine a basic plan for advancing disaster prevention measures in the case of a Nankai megathrust earthquake or Near-field earthquake in the Tokyo Metropolitan area. Developing an environment for evaluating and comparing earthquake disaster risks for specific regions with high accuracy is strongly required.

However, essential data for estimating precise damage by earthquakes in Japan is not yet prepared or fully open to the public. Human damage estimation that takes time frames into consideration is necessary, yet population distributions depending on time frames have not been developed yet. Current damage assessments in Japan usually rely on static population distribution data, such as statistical nighttime population data, organized in 500m grid units obtained from national census. Considering disaster prevention policies, it is important to develop population distribution which can evaluate disaster risk in a variety of units, from macro scale such as prefectures to micro scale such as city block units.

Against this background, when performing damage assessment and forming evacuation plans for catastrophic earthquakes and tsunamis, it is essential to have data that can grasp the detailed location information of people distributed in cities for each time frame. In order to understand the congestion and flow of people for each time frame, the National Person-Trip (PT) Survey, which is a kind of traffic survey data, has been used. This survey examines the actual stationary travel patterns of people living in each survey area, and its objective is to figure out “who” travels “from where to where” “when” “for what purpose” and “by which mode of transportation”. Since the Person-Trip Survey is a questionnaire, representative of only a part of the actual population, a magnification coefficient is allotted to each dataset according to the actual population, and data is aggregated for each survey area. Although PT data can solve many of the problems described above to understand the distribution and flow of people in a city, often the survey area becomes larger in rural areas and overseas. Since the positions of origins and destinations in PT data is typically represented by the center of a survey area (zone), when mapping PT data on a map the population of that area becomes focused on that center point and the data becomes biased. To solve such problems, it is necessary to clarify the spatial definition of the position information of PT data, based on the distribution of buildings. There are no previous studies about spatial definition for each time frame based on the actual position information of buildings that consider the magnification factor in such a wide area.

However, in order to evaluate damage for each time frame for catastrophic earthquakes expected in Japan in the future, implementation of this technique is important. By realizing this method, risk assessment for any time frame and any aggregate unit will be possible and lead to the optimal decision-making for disaster management. On a municipal scale, it is important for advancing urban planning and development in times of disaster. At the residential level, disaster prevention awareness is important for decision-making, such as overall improvement as well as time frame based analysis for each evacuation plan. Rescuers such as firefighters can consider their measures and correspond in accordance with scenes for each time frame.

Although printed data for damage assessment is insufficient, digital maps currently allow us to observe the distribution of each building and a digital telephone directory can provide the distribution of offices and shops managed in Japan. These data can play an important role in the precise estimation of earthquake damage over broad areas. In addition, improvements in data processing due to the increased capacity of PCs enable the handling of massive quantities of micro data. As we obtain an environment that can estimate the damage of an earthquake with high reliability in broad areas, the development and establishment of detailed population distribution data, by building, in order to estimate damage from earthquakes is necessary and meaningful.

1.1 Previous studies

In a previous study, we developed an automated method for estimating the structural type (wood-frame or non-wood-frame) and the fire-resistance performance (fire-proof, semi-fire-proof, or fire-preventive) of buildings using the statistical data and residential maps and evaluating the risk of building fire and collapse of earthquakes (Ogawa et al., 2013).

Recently, there have been some studies related to detailed population distribution in Japan. Akiyama et al. (2013) developed detailed population distribution by using statistical nighttime population data obtained from distribution of national census to each building. Personal attributes (gender and age) have also been granted by using cross-tables from the census. In addition, Osaragi and Shimada (2009) converted PT data for weekdays to data for holidays by using data such as Lifetime Surveys (NHK) and the numbers of people getting on and off trains, and also estimated and compared casualties from building collapse for weekdays and holidays. Cabinet Office, the Government of Japan and some local governments are using PT data for the estimation of earthquake damage in recent years. However, these previous studies have two main problems. First, the studies could not evaluate risks on a residential scale because they calculated risk by municipality units or 500 meter grid square units and the spatial resolution was not high enough. Second, the studies did not consider the time axis of people distribution, and fire rates vary greatly. As this study enables us to assess damage for any time frame and any aggregate unit, it will be useful to consider provision for various situations when an earthquake may hit, such as during commuting hours or working hours. In addition, there is also an institutional problem, that the data related to the structural types and fire prevention of buildings required for damage assessment are not open to the public in most municipalities. However, the data we have developed will make it possible to evaluate the damage of earthquakes.

1.2 Objective

There are three objectives of this study. First, to develop a method for estimating the population distribution of the approximately 35 million people within the Tokyo Metropolitan Area (Tokyo, Kanagawa, Chiba, Saitama, Ibaraki) for each time frame (by hour), based on data from traffic surveys (PT data (the Ministry of Land, Infrastructure, Transport and Tourism (2008)))and by using residential maps(Zenrin Co., Ltd.). We confirm the reliability of our data by comparing it with statistical nighttime population data obtained from national census (2010) aggregated to 250m grid units. The second objective is to develop a method for evaluating human damage due to fire and collapse in the event of a Nankai megathrust earthquake in the Tokyo Metropolitan Area, for each time frame, by using a combination of the data developed in the first objective and our “Micro-geo data”, data we have developed to reflect information about building structures, building age, and so on. The third objective is to discuss the factors which cause the differences in human damage for each time frame.

2. Development

2.1 Flow of estimating the risk of an earthquake

There are three main advantages to our method. First, we can compare damage evaluation for many time frames, instead of just nighttime and daytime. Second, high-definition population data enables us to evaluate casualties in high-spatial resolution. Third, our method can evaluate the risk of physical damage and fatalities from fires and building collapse caused by earthquakes, for any aggregate unit from building unit to mesh grid unit, considering the ground characteristic and properties of each building (building structure, age, usage, etc.). Fig. 1 shows the processing flow of our method. To perform the evaluation for each building unitsunit for each time frame, we use the Person Trip data and Digital Residential Maps (Zenrin Co., LTD. (2008-2009)) to grasp the number of floors, usage, and area of each building for each survey area unit of the PT data, and distribute population accordingly. Next, to calculate fire probability, we connect the digital telephone directory with longitude and latitude called “Telepoint Data” (Zenrin Co., LTD., described in “Telepoint Data” in the following text) to clarify the type of industry, and calculate fire probability based on season, building usage, and input ground motion (JMA seismic intensity scale) published by the Tokyo Fire Department (2007). In addition, we calculate fire-spread rate from fire-spread cluster by using the fire-resistance performance and polygons of residential maps. The probability of collapse for buildings is also estimated from structural type, building age, and ground motion intensity by using fragility carves which are used in damage assessment by the Japanese government. We used the Probabilistic Seismic Hazard from the National Research Institute for Earth Science and Disaster Prevention (NRID(2013) for ground motion intensity. The Probabilistic Seismic Hazard is calculated as the probability of experiencing the exceeded level of ground motion intensity within a target period at a given site. Finally, we estimate the damage assessments of humans, such as the number of casualties, by combining detailed population distribution and each building’s fire spread and collapse probability. This amount can be aggregated to any unit (municipality, prefecture, etc.) to get the numbers of casualties for each unit.

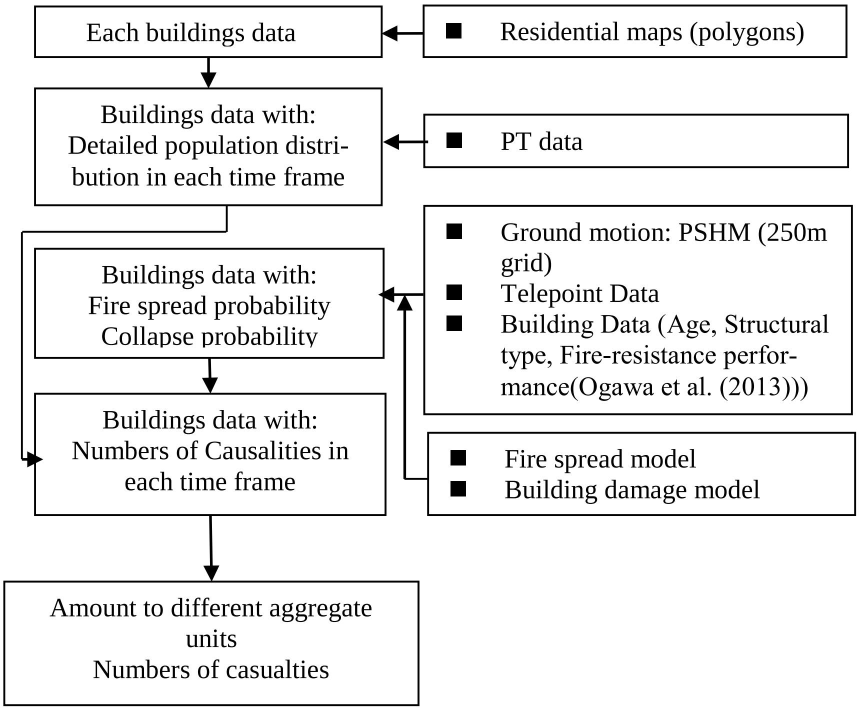


Fig. 1. Flow chart of estimating the risk of causalities in each time frame

2.2 Development of Estimation of detailed population distribution

2.2.1 Person Trip Data

In this study, the National Person Trip Survey, which is a kind of traffic survey data, is used in order to understand the congestion and flows of people in each time zone. The National Person Trip Survey is made by an investigation of stationary and actual traffic conditions of people living in each survey area. The objective of the survey is to figure out "who" and "when" transport "from where to where" on "what purpose" and "by which transportation." The number of samples conducted in 2008 in Tokyo metropolitan area was about 600 thousand. Therefore, 35 million person's trip, which are sum of the expansion coefficient of the Person Trip Survey of survey unit wards, are distributed to each space based on the building use (house, office, landmark and others), number of stories and area in this study.

2.2.2 Method for estimating detailed population distribution

Until now, PT data were geocoded by using the center of gravity for each zone based on the area name data for each survey unit, to identify the location of the origin and destination of each trip. However, in the suburbs and local city, the survey area becomes wide area and many PT data is thus distributed on behalf of a single point of broad center of gravity. It is great problem when using PT data for the purpose of estimation of casualties by fire or building collapse caused by earthquake, because the population distribution in the survey area is important. Since the same problem occurs in the PT data other than Japan, there are examples that made the space complemented by applying the kernel density estimation using the land use data obtained from the satellite data (MODIS) in Bangkok(Watanabe et al. (2012)). However, due to the enormous quantity of data, previous studies did not consider the magnification coefficient of PT data for high definition in building units.

2.2.3 Method of estimation in this study

Figure 2 shows the distribution of PT data for each survey area in the target area. The total number of data is about 600,000 but a magnification coefficient is added to represent the entire population. Figure 3 expands on a certain area and overlays the national census of 500m grid data. In the census the population is distributed over the whole area, but in the PT data there are some meshes with no data. This is because PT data are distributed as a stacked number of data at the same points. Thus all data in stages of staying at home, work, school, etc. will be distributed in the center of gravity for each zone.

In this study, the location data of PT data in 2008 are distributed to each space based on the building use (house, office, landmark and others), number of stories, location and area. Processing of distributing (redistribution) of PT data uses a residential map for collecting detailed distribution of buildings. This study only uses data of people staying in a certain area.

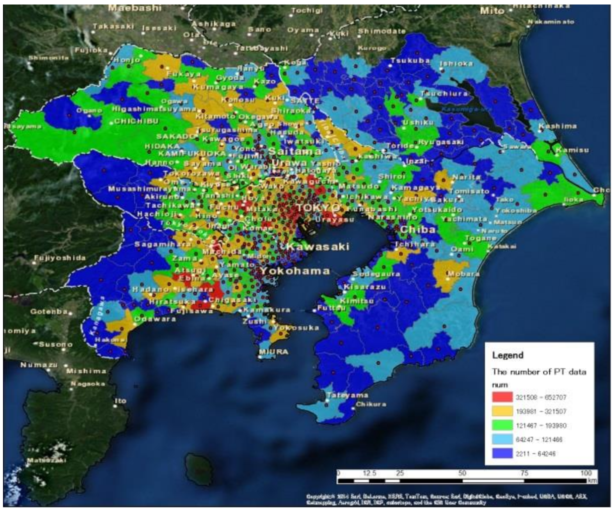


Fig. 2. The number of PT data in the Target area.

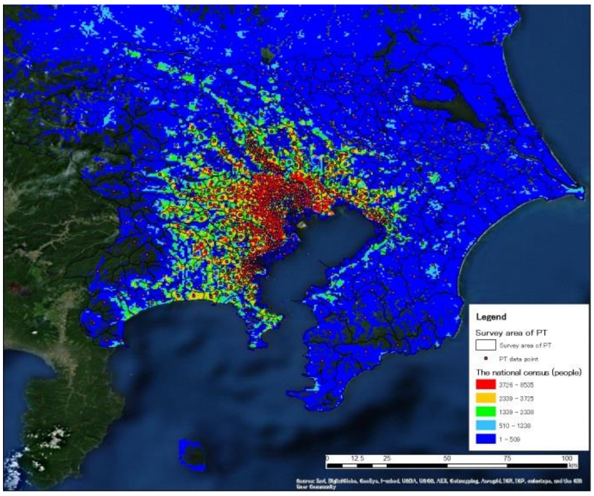


Fig. 3. PT data for target area overlays the national census of 500m mesh data.

About redistribution of PT data to each survey area units of the residential map: a house is redistributed to each building, and an apartment (building) is redistributed depending on the function of each floor and room. Each PT data uses information about previous and following behavior and about travel purpose to identify whether the person is staying at home, work, school, etc. Therefore, it is necessary to determine which buildings are distribution destinations, depending on each person's staying areas. Table 1 shows the association between objectives of travel and usages of distribution buildings. Thus, if we can grasp all the building stories and usages of each room, and identify whether they are houses oroffices or schools, we can redistribute PT data to optimal buildings. Table 2 shows attribute information for each building polygon data of digital residential maps. We use the latitude and longitude for each building to identify which survey area it belongs to.

Next, we understand the function for each building by using the attribute value called ATYPE. A building in ATYPE is a building of multiple residences, offices, or a mixture of both. During the distribution process, if a building is a condominium or apartment, people staying at home are allocated. If it is an office building, people staying at workplaces are allocated. Combined with other data of attributes from the residential map, it is possible to grasp the information of tenants of the building. We can also understand which floor or what room that person is, as well as distinguish whether it is a residential or office. Schools are buildings that include the following words in the building name or nameplate: "academy ","elementary school", "junior high school", "high school", "high school", "university", "nursery", "nursery "," kindergarten "," school ". Finally, we calculate the floor area of each building (in the case of buildings, the average floor area), and redistribute PT data accordingly.

The number of people in building *i* in the survey area is given by (see Eq. 2.2.1):

$$N_i = \sum_{j=0}^{n} kr_j \frac{Sr_i}{Sr} + \sum_{j=0}^{n} kb_j \frac{Sb_i}{Sb} + \sum_{j=0}^{n} ks_j \frac{Ss_i}{Ss} \qquad (2.2.1)$$

where Ni is the number of people in each building, krj (/ kbj / ksj) is the number of magnificent coefficient of de facto people in the house (/ office/ school), Sr （/ Sb / Ss） is the number of total floor area of the house(/ office/ school) of each survey area, Sri （/ Sbi / Ssi） is the number of area of building *i* of the house (/ office/ school).

Figure 4 shows detailed population distribution at 2 A.M., 9A.M., 12A.M. and 6 P.M. of study area of PT data aggregated to 250m grid units. Figure 5 shows example of PT data after spatial definition in Urayasu city. High definition redistribution can be seen conducted according to the distribution of actual buildings when compared with Figure 3.

Table 1. Objectives of travel and usages of distribution buildings.

Objectives of travel	Usages of distribution
01: To work place	Office
02: To school	School
03: To home	House
04: To shopping	Office
05: To restraint and recreation	Office
06: To hospital	Office
07: To pick-up	Office
08: To sightseeing	Office
09: To other private	Office
10: To Sell, delivery and Purchase	Office
11: To meeting and conference	Office
12: To work and repair	Office
13: To agriculture and fisheries	Office
14: To other business	Office

Table 2. Attribute information for each building polygon data.

Name of attribute	Description
NAME	Name of buildings
ADDRESS	Street address
ATYPE	Building usage as below - Landmark - Office - Houses - Buildings - Others
FLOOR	Total Number of stories
AREA	Building area [m^2]
ID	Building ID
LONGITUDE	Longitude [wgs1984]
LATITUDE	Latitude [wgs1984]

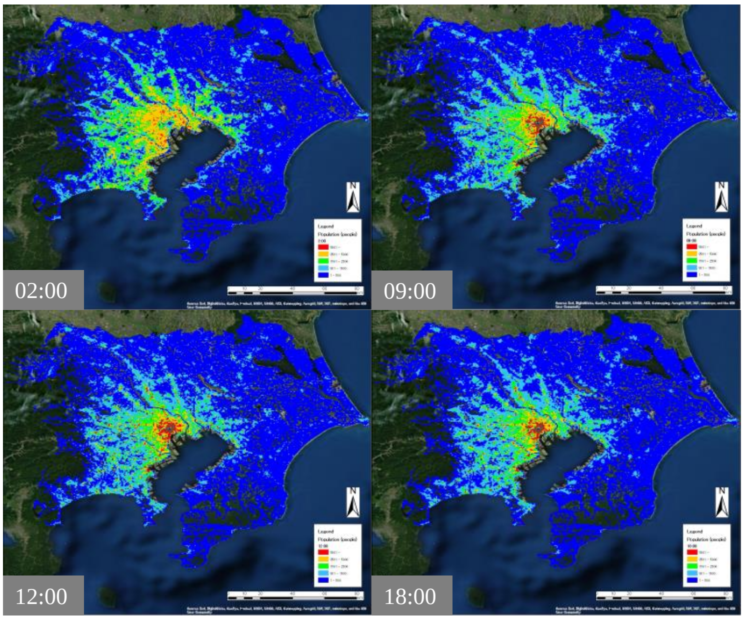


Fig. 4. Estimated detailed population distribution (aggregated to 250m grid units)

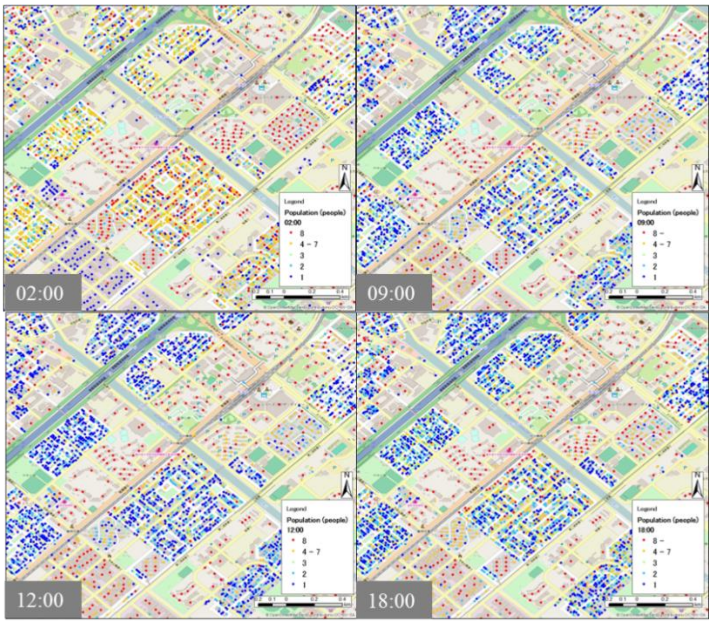


Fig. 5. Estimated detailed population distribution at Urayasu city (Chiba prefecture).

2.2.4 Reliability verification of the detailed person distribution

We aggregate our data to 250m grid units to compare the number of people in PT data with the data from the national census. Fig. 6 shows the comparison results for detailed population data at 2 A.M.. There is a strong correlation between the numbers of people from our data with the numbers of people in the national census. As a result, our estimated detailed population distribution data is reliable for evaluating performances in each local community. In addition, it is reliable when it is aggregated by gender.

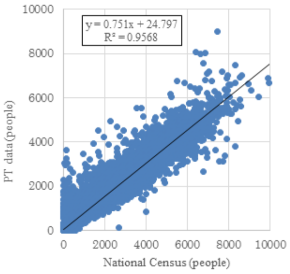
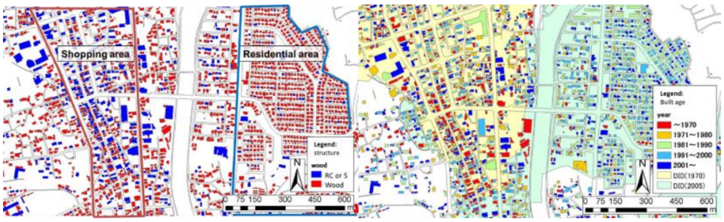


Fig. 6. Comparing the number of people in PT data with the data from the national census (aggregated to 250m grid units).

3. Damage assessment due to catastrophic earthquake disaster

3.1 Evaluation of fire risk by earthquake

First, we obtain the building information of the Probabilistic Seismic Hazard by the National Research Institute for Earth Science and Disaster Prevention (NRID). Second, we estimate the fire probability of every single building. The Probabilistic Seismic Hazard is calculated by the probability of experiencing exceeded level of ground motion intensity within a target period at a given site. For this calculation, an evaluation is conducted by using a probabilistic approach on an epicenter, occurrence probability, magnitude of all earthquakes that could occur in and around Japan, and the intensity of the ground motions caused by those earthquakes are evaluated with variance. We assumed ground motion 2% of excess probability more within 50 years. Building data of structure, age and fire performances are developed by Ogawa et al. (2013) and used for evaluating the damage (Figure7). Table 3 shows fire probability according to the input ground motion (JMA seismic intensity scale) published by the Tokyo Fire Department (2007). We connect the Telepoint Data to the building and clarify the type of industry, and give a fire probability corresponding to the type of industry of table 3. Finally, we assign fire probability from predicted ground motion and the building types.



(a) Building structure (b) Building construction period

(c) Fire-resistance performance (d) Fire-spread cluster

Fig. 7. Single building data (Micro-geo data) for evaluating damage of fire and building collapse developed by Ogawa et al. (2013).

In this study, the fire-spread probability of buildings of any different totaled-units is using method as follows (Kato et al. 2006). The clusters of fire spread are calculated by using the distance of buildings and fire performances (figure 7 (d)).

The burned down probability of each cluster of fire spread is given by (see Eq. 3.1.1)

$$P = 1 - \prod_{i=1}^{n}(1 - p_i) \tag{3.1.1}$$

where P is the burned down probability of any different totaled-units, p_i is the fire probability of building i,. The fire risk is evaluated by calculating the number of the burn down buildings and can extract high fire risk area. The calculation is performed by using an approximate expression of the following formula to shorten the calculation time is given by (see Eq. 3.1.2)

$$P = 1 - \exp(-\textstyle\sum_{i=1}^{n} p_i) \tag{3.1.2}$$

Table 3. Fire probability(%) of predicted ground motion and the building types.

Type of industry	JMA seismic intensity scale									
	5-lower		5-upper		6lower-		6-upper		7	
	DS	IW	DS	IW	DS	IW	DS	IW	DS	IW
Theater	0.0043	0.0039	0.0116	0.0125	0.0300	0.0305	0.0832	0.1005	0.1865	0.2956
Cabaret	0.0000	0.0041	0.0000	0.0100	0.0000	0.0242	0.0006	0.0860	0.0229	0.2902
Bar	0.0049	0.0058	0.0044	0.0086	0.0131	0.0231	0.0323	0.0771	0.0954	0.2292
Restaurant	0.0069	0.0073	0.0096	0.0106	0.0291	0.0306	0.0808	0,0858	0.2058	0.2168
Department store	0.0271	0.0211	0.1000	0.0774	0.2531	0.1928	0.7232	0.5694	1.8200	1.6071
Article store	0.0017	0.0014	0.0041	0.0042	0.0107	0.0105	0.0384	0.0458	0.3243	0.3866
Hotel	0.0148	0.0151	0.0644	0.0653	0.1600	0.1618	0.4566	0.4752	0.9663	1.0709
Apartment	0.0007	0.0012	0.0011	0.0027	0.0031	0.0070	0.0090	0.0249	0.0349	0.0757
Hospital	0.0045	0.0035	0.0093	0.0089	0.0247	0.0222	0.0701	0.0759	0.2191	0.4329
Clinic	0.0013	0.0014	0.0013	0.0034	0.0040	0.0082	0.106	0.0282	0.0495	0.1250
Dormitory	0.0014	0.0016	0.0028	0.0025	0.0075	0.0068	0.0228	0.0244	0.1116	0.1456
Nursery school	0.0025	0.0002	0.0033	0.0009	0.0095	0.0019	00.246	0.0094	0.0694	0.0393
Kindergarten	0.0019	0.0013	0.0019	0.0042	0.0056	0.0109	0.0137	0.0594	0.0431	0.1772
Elementary school	0.0083	0.0022	0.0136	0.0058	0.0374	0.0142	0.1002	0.0612	0.2989	0.2175
University	0.0037	0.0007	0.0062	0.0020	0.0170	0.0050	0.0458	0.0155	0.1263	0.0604
Public bath	0.0006	0.0009	0.0009	0.0027	0.0026	00064	0.0073	0.0225	0.0282	0.0874
Factory	0.0016	0.0013	0.0046	0.0046	0.0118	0.0117	0.0330	0.0564	0.0796	0.1529
Office	0.0024	0.0012	0.0069	0.0038	0.0176	0.0095	0.0496	0.0307	0.1208	0.0980
House	0.0007	0.0016	0.0007	0.0035	0.0021	0.0094	0.0058	0.0505	0.0274	0.1521

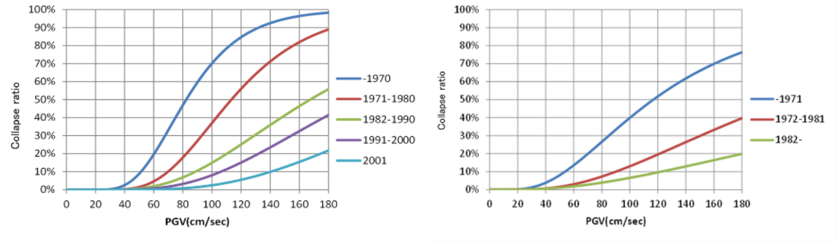
DS day time in summer, *IW* evening in winter.

3.2 Evaluation of building collapse risk by earthquake

The occurrence probability of building damage is defined by using the vulnerability functions as expression of relations between the peak ground velocity (PGV) and building damage. Ground motion is obtained from PGV from a Probabilistic Seismic Hazard. We use the vulnerability functions which is often used to assess building damage in Japan. By refer to their method, we use two kinds of structure (wood-frame and non-wood-frame) considering the construction period. For a strong motion index x, the cumulative probability P_r (x) of the occurrence of damage equal or higher than rank R is assumed to be lognormal given by (see Eq.3.2.1)

$$P_r(PGV) = \Phi((In\ PGV - \lambda)/\xi \qquad (3.2.1)$$

where Φ is the standard normal distribution, and λ and ξ are the mean and the standard deviation of $ln\ PGV$. Figure 8 shows the interim vulnerability functions for wood-frame buildings and non-wood-frame buildings.



Wood-frame buildings

Non-wood-frame buildings

Fig. 8. Interim vulnerability functions of wood-frame buildings and non-wood-frame buildings with respect to PGV

3.3 Evaluation of causalities risk by earthquake

The causalities risk evaluation supposes that the death is caused by a fire and a collapse in each building units in each time frame. The calculation unit, based on each building, applies to the number of the de facto people in a building at the outbreak time. The method of the causalities risk evaluation by a fire refes the death rate with burned out probability and the number of the residents in the building. The dead ratio by the fire uses 0.046 (dead/a fire), the number of casualties per a fire (except the arson) in the 5years whole country from 2005 to 2010. It also used in the Central Disaster Prevention Council2012. The number of casualties per each building is given by (3.3.1)

$$x_i = P_i * P_{f\,i} * R_i \qquad (3.3.1)$$

where x_i is the number of casualties of building i, P_i is the burned down probability of building i,P_{fi} is the dead ratio by the fire of building i, R_i is the number of people of building i.

The method of the causalities risk evaluation by a building collapsed is using the death rate with building damage ratio and the number of the residents in the building. The dead ratio by the collapse is 6.8% in wooden buildings and 0.8% in non-wooden buildings which is taken from the number of casualties per a collapse building at the 5 kinds of earthquake (The Tottori earthquake, The Tonankai earthquake, Nankai earthquake, Fukui earthquake, Hanshin-Awaji earthquake). The number of casualties per each building is given by (3.3.2)

$$y_i = P_{ri} * P_{ci} * R_i \tag{3.3.2}$$

where y_i is the number of casualties of a building i, P_{ri} is building damage ratio of a building i , P_{ci} is the dead ratio by collapse of building i, R_i is the number of people of a building i. Thus an estimated the number of dead ratio caused by a fire and a collapse is given by (see Eq. 3.3.3).

$$Nd_i = \sum \{x_i(1 - y_i) + (1 - x_i)y_i\} \tag{3.3.3}$$

where Nd_i is the number of dead ratio of a building i.

4. Result

Figure 9 shows the result of human casualties *Nd* evaluation caused by fire and building collapse in the event of an earthquake. Figure 10 shows the result of human casualties in single building units. The target area of the result was the Tokyo Metropolitan area and we input grand motion with a 2 percent of excess probability within 50 years for each building in the targeted area. The result shows that our method can evaluate the damage in a broad area for each time frame. The result reveals that damage situation in some area depends on the time frame. We visualized the result and clarified the differences in damage for each time zone and each region. The damage on weekdays depends on each time frame as people move around the city. Figure 11 shows total human casualties by earthquake for the each time zone in the Tokyo Metropolitan areas. Since ground motion assumed in this scenario is large, casualties vary greatly from morning commuting time which people leave their house to night time which people return and stay at their house. The damage is small at 8 A.M. because it is commute time zone and thus de facto population is small. On the other hand, in residential areas in the suburbs, the damage is increased between 6 P.M., because it is a time that residents are likely to use fire. In addition, this is the first data to input any expected seismic motion data and evaluate human fatalities in each time frame by considering de facto population.

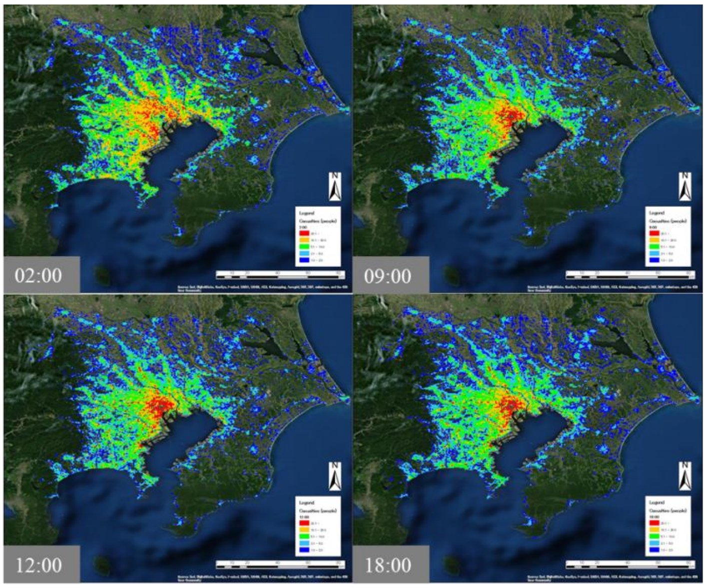


Fig. 9. Evaluation of human casualties *Nd* by earthquake in the each time frame (aggregated to 250m grid units)

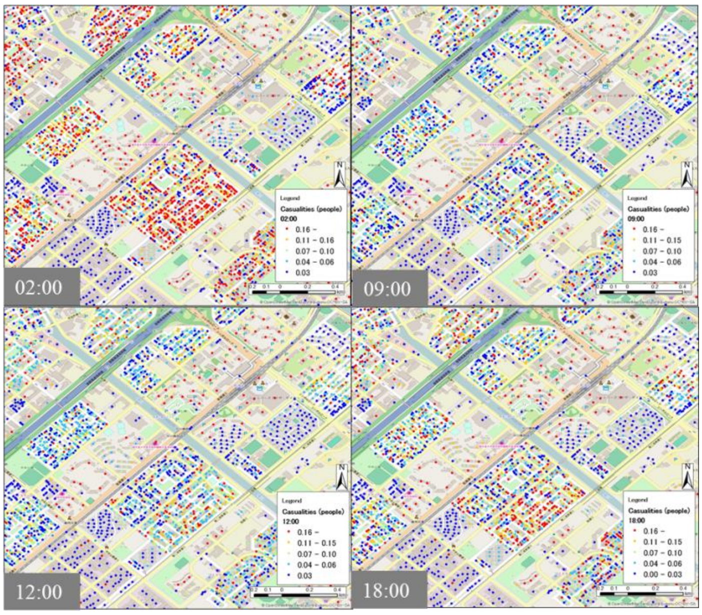


Fig. 10. Evaluation of human casualties *Nd* by earthquake in the each time frame in Urayasu city

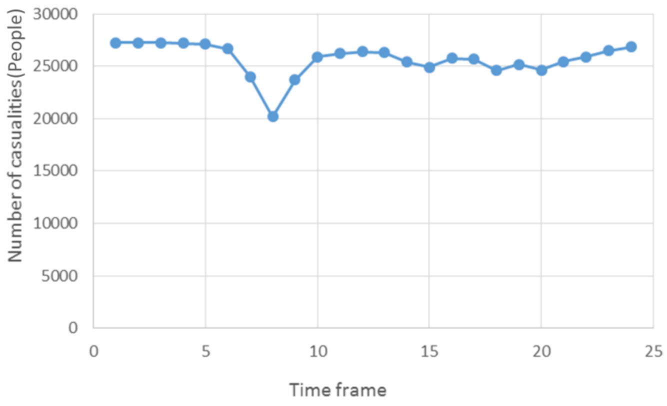


Fig. 11. Total human casualties *Nd* by earthquake in the each time frame in the Tokyo Metropolitans areas

5. Conclusion and future work

In this study, we estimated the detailed population distribution for each time frame by distributing PT data to each building data obtained from digital residential map. In addition, we evaluated the possibility of fire and building collapse taking into consideration the magnitude of earthquake by adding probabilistic grand motion intensity to each building. By combining these data and building de facto population for each time frame, we evaluated human damage caused by earthquake. Our method is unique in that it enables us to assess damage for any time frame and any aggregate units, and thus it also enables us to evaluate human damage due to fire and building collapse caused by earthquakes in broad areas by aggregating the evaluation of each building scale. In the present study, the target area of damage evaluation was the Tokyo Metropolitan area, yet we also can evaluate other areas, for calculation of evaluation were set automatically. We have two issues as future outlook; firstly, we only used night time population data obtained from national census to verify the reliability of our detailed population distribution. In present situation in Japan, there is not enough data for verification though we should verify the reliability of our results in other time frames. In the future, we are planning to verify our results by using available GPS data. Secondly, we classified buildings into only three kinds (house, school and office). In the future, we will consider more detailed building usage and business hours in order to estimate with higher accuracy.

Acknowledgements

We would like to thank ZENRIN Co., LTD for providing the digital telephone directory (Telepoint data) and residential maps used in this study.

References

Akiyama Y, Takada H, Hiroyuki T, Shibasaki R (2013) Development of Micro Population Census through Disaggregation of National Population Census. Computers in Urban Planning and Urban Management (CUPUM), conference papers110

Central Disaster Prevention Council, 2012, “About the Nankai Trough earthquake measures of building damage and human damage (in Japanese)”.

Kato T, Hong C, Yusfu Y, Yamaguchi M, Natori A (2007) A Method for The Integrated Earthquake Fire Risk Evaluation Based on The Single Building Fire Probability Applying to any Different Map-Scale (in Japanese). Journal of Institute of Social Safety Science 8:279-288

Ogawa Y, Akiyama Y, Sengoku H, Shibasaki R(2013) Development for the evaluation of Catastrophic Earthquake Damage throughout Japan Using Estimated Micro Data. Computers in Urban Planning and Urban Management (CUPUM), conference papers103

Osaragi T and Shimada R (2009) SPATIO-TEMPRAL DISTRIBUTION OF POPULATION ON WEEKDAYS AND HOLIDAYS FOR ESTIMATING HUMAN DAMAGES FROM DEVASTATING EARTHQUAKE. Japan Architectural Planning, 74.635: 145-152.
Tokyo Fire Department (2007), Report of About the local disaster prevention power and problem at the time of the earthquake (in Japanese).

Tokyo Fire Department (2006), Council for the 16th Tokyo fire prevention report (in Japanese).

Watanabe A, Nakamura T, Sekimoto Y, Usui T, Shibasaki R(2011) A Study on Automatic Kernel Bandwidth Selector for Questionaire-Based Statistics–Using JICA Person Trip Data in Various Developing Cities. The 32nd Asian Conference on Remote Sensing (ACRS)