TRAVEL BEHAVIOUR ANALYSIS FOR URBAN DISASTER PREVENTION COMBINING WITH GEOGRAPHICAL INFORMATION*

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1. Introduction

In terms of urban transport planning, the database of the regional trip survey (so-called PT survey) might be significantly important for the traffic demand estimation of the city area. Even though it should be an important application of the PT survey, the large scale accumulated information of trip makers in the database might be applicable to another aspect of the urban transport problem. The individual trip patterns for a whole day are captured and reported in the scale of urban area. Therefore, the distribution of individual trips might be relatively easily estimated from the database to find the effective applications.

In the study, the urban disaster prevention would be focused as a specified topic of urban transport problems. The advanced technique to reform the PT database precisely combining with GIS functions would be proposed. Since the sufferers in the earthquake would be estimated in the urban daily conditions, it might provide another application of PT survey.

2. The spatial distribution of travel behaviour

(1) The travel behaviour database

As an important topic of urban problem, the disaster prevention planning is discussed in the study. The target area is Gifu city as a middle size city with about 402,185 populations. The basic statistics as shown in Table 1 are summarized referring to the PT database. It is obvious from the statistics that the city has been suburbanized rapidly because of recent large scale motorization. The car trips have been increasing gradually. Figure 1 illustrates as well that the residential spots are widely spread even in the surrounding area of the city.

The result of regional trip survey so-called "Person trip survey" should be an essential database of urban transport planning which has recorded the trips and activities of trip makers dynamically as well as spatially for the target city. Even though all the travel patterns are recorded in the PT database, there is a limitation of the detail analysis because the spatial activities are recognized only as zone size level. It means that the activity site of the trip makers cannot be pointed out from the PT database information[1].

Table 1: Statistics of Research Area

Population	402,185	Schooling from the outside	11,772
[Centeral area]	74,531	Driving license holders	247,607
[Surrounding area]	162,653	Car owners	279,177
[Suburbun area]	165,001	Large size shops	64
Daytime population	426,865	Normal shops	7,585
Families	153,336	Commercial sales [yen]	18,918
Elderly person	73,492	Business sites	25,382
Commuters	279,224	Workers	185,614

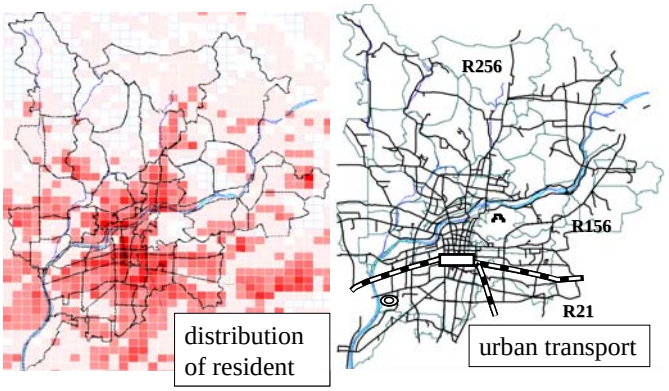

Figure 1: Outline of Target Area

Therefore, the technique of GIS can give spatial information to combine with the PT survey database.

(2) Spatial information in GIS

The spatial information accumulated in GIS is effectively applied in the research connecting to the PT database[2]. The algorithm can be developed to specify the activities of trip makers spatial for a whole day in the city. According to the proposed algorithm, the dynamic behaviour of the trip makers in the area of the city can be easily observed. The algorithm would be applied extendedly to determine the sufferers in the earthquake. The proto type of the sufferers is determined as a person who might not come back home from the present position after the earthquake. The definition corresponds to the isolated peoples after the earthquake. The number of sufferer would be an essential index of disaster prevention planning for the city[3].

(3) The estimation algorithm to point of sojourns

The algorithm of sojourns estimation is shown in Figure 2. In the study, the estimation flows are specified according to the types of stop in travel patterns of trip makers. The destinations for all trips are classified into three types such as home base, office base and the others. The essential idea of the algorithm is derived from the fact that family members come

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back to the single location of home. Another important fact is that large scale building of the city can be pointed spatially in GIS. Therefore, the stop can be determined from the facilities recorded in PT database.

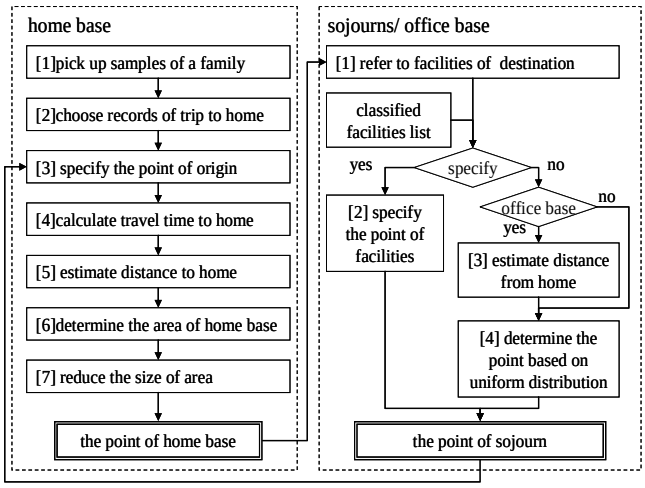

Figure 2: The Estimation Process of the Point of Sojourns

The left side of the figure indicates the outline of estimation for home base. According to the algorithm, 1) Trips of family members are investigated. 2) Trips to home for samples are engaged. 3) The point of origin is initially determined from facility information. 4) The OD travel time is recorded in PT database. 5) The spatial distance can be estimated with assuming the average speed of individual travel mode recorded in PT database as well. 6) The spatial range of home base is determined corresponding to the distance. 7) The size of estimated can be reduced with iteration of update the trip information for other family members. If the area size of home base cannot be reduced, the estimation is shifted to the office base and sojourns.

In the right side of the algorithm, the estimation of sojourns is mentioned. The essential algorithm is similar to that of office base. 1) The destination would be pointed referring to the facilities recorded in PT database. 2) If a particular facility can be specified, the spatial point of sojourn is determined precisely. 3) The distance from home base to office base should be estimated. 4) Determine the point among the same types of facilities with equivalent probability.

For example, it is assumed that the purpose of trip is shopping and the facility is reported as a department store. Since department stores generally exist with limited number, the location of department stores can be focused with rather high probability

In the algorithm, it is iterated that the information of specified location is exchanged between the right and left estimations.

3. Application to earthquake sufferer distribution

In the previous algorithm, the individual travel pattern can be estimated with small spatial range. The study tried to apply the earthquake sufferer distribution as an important index of urban disaster prevention.

(1) The definition of sufferers in earthquake

The natural disaster prevention for urban area is strongly connected to the daily activity of citizens. In particular, the earthquake problem might be serious in urban area. Many local governments estimate the impact of earthquake to establish the future disaster prevention plan. In the estimations, the sufferers are often discussed who cannot come back home in the earthquake. A person temporary staying over 20km from home can be usually defined as a sufferer regarding with the available walking distance.

For example, Tokyo metropolitan government has reported that the number of sufferers can be estimated from 3.92 to 4.48 million in case of earthquake with magnitude 5. It can be mentioned that the number of sufferers might be an essential indicator for the level of urban disaster prevention

(2) The estimation of sufferer distribution

According to the definition mentioned previously, the distribution of sufferers must strongly connect to the activities of trip makers in the city. Therefore, the specification algorithm of sufferers developed as shown in Figure 3.

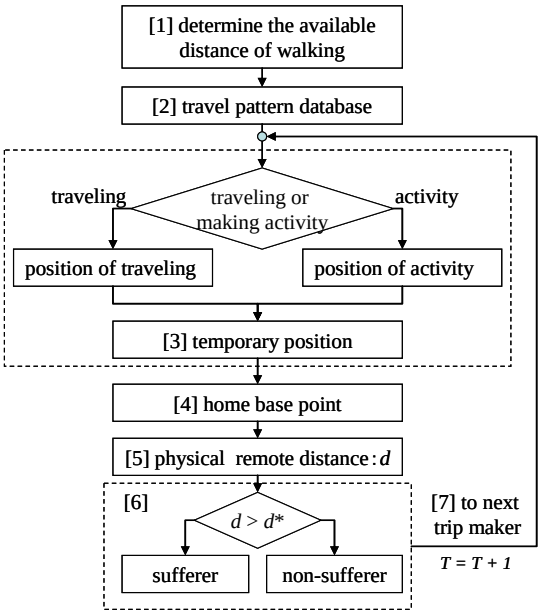

Figure 3: Estimation Process of Sufferer Distribution

The outline of the algorithm is summarized as follows: 1) The available walking distance as d^* is defined beforehand to determine the sufferers. The value of distance may change between 10 and 20 kilometer corresponding to the planning scale. 2) The data of travel patterns and stops for all trip makers are stored with specifying results from the previous analysis in Figure 2. This means that time and spatial distribution for all trip makers can be captured before the analysis of sufferers. 3) As the time T is assumed of the earthquake occurrence, a trip maker can be distinguished traveling from making activity temporally. The estimation process should be implemented separately for both cases. 4) The home base site can be specified with referring to the trip

pattern database as accumulated previously. 5) The physical traveling distance between the current position and home base as *d* is calculated assuming that the road network may not have any trouble even after the earthquake. The shortest path algorithm can be applied in the algorithm. 6) If the value of indicator for a trip maker, *d* is larger than *d** as the critical value, the trip maker is determined as a sufferer of the earthquake. 7) The estimation process can be iterated with next time period as *T=T+1*. The time interval is determined as five minutes in original algorithm.

(3) The sufferer distribution in urban area

The spatial distribution of suffers can be estimated corresponding to any clock time in city area. As the value of indicator as *d** reflects on the range of disaster prevention focused by the local government, the value of 20km is applied as the first stage of analysis.

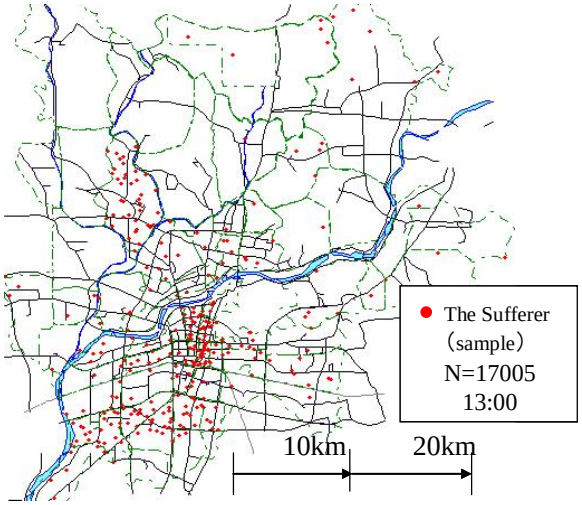

Figure 4: The Distribution of Sufferers in the City

Figure 4 illustrates the distribution of sufferers at peak time as 13:00 in Gifu City. The graphic description is provided through the spatial information processing in GIS. It is assumed in estimation that all trip makers have to come back to home by walking leading to the road network after the earthquake without any other transport mode. There are 17,005 sufferers observed in figure, which is about 5.0% of trip makers with activities in the city. It can be obvious from the distribution that many sufferers are founded in the central area because of mostly daytime working.

(4) The detail analysis of sufferer distribution

The number of sufferers changes dynamically in proportion to daily activities in the city. Therefore, the dynamic change of sufferer distribution would be discussed as well. Figure 5 depicted the sufferers with different activities known from the purpose of trips.

As an average weekday is observed in the PT survey, the sufferers reflect on the daily spatial activity pattern in the city. The peak time of sufferers is deferent in each type of activity. The duration in office and school indicating by commuters seems to lie between 9:00 and 16:00 with flat distribution. On the other hand, the peak times of shopping/leisure and working are 12:00 and 14:00 respectively.

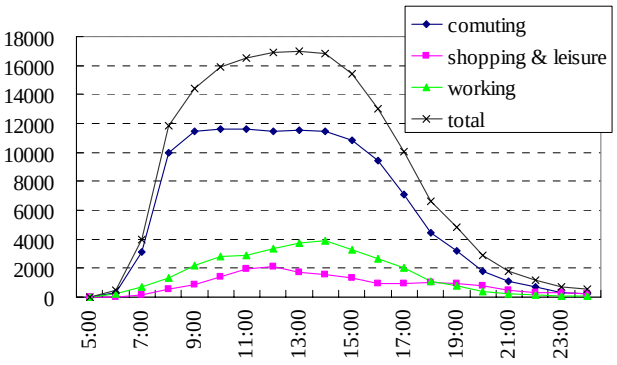

Figure 5: The Hourly Change of Sufferers

Furthermore, the proportion of sufferers with each activity can be observed at the peak time period for total number as 13:00 to 14:00. The office workers and students are involved as 68% of sufferers. The outside workers and trip makers with shopping/leisure consist of 10% and 22% of sufferers respectively.

4. Application of for sufferer distribution

(1) Home base distribution of sufferers

Application of sufferer distribution would be discussed. As shown in the previous results, it is known that many sufferers tend to come into the city centre from the outside. The proposed algorithm may provide the residential place such as home bases of sufferers because the GIS information is available as well. Therefore, all home base points for individual sufferers are specified according to the algorithm. Figure 6 indicates the direction of home bases of sufferers.

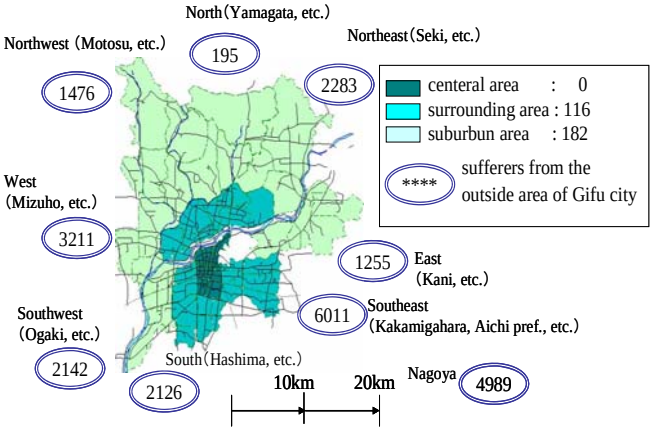

Figure 6: Sufferers from Different Areas

It is obvious that many trip makers from Nagoya as well as southeast areas (Kagamigahara, Aichi prefecture) might be involved in the earthquake confusion with high percentage. Furthermore, it is known as well that many sufferers have home bases in the west and southeast area. This tendency may be understood from the fact that many workers are commuting from the above mentioned areas.

(2) The installation of disaster prevention scale

The target city is a middle size city. The definition of available distance for walking might reflect on the scale of disaster prevention plan of the city. It is recommended that the distance should be defined with the range between 10km and 20km because the structure of the city and share of transport mode cannot be uniform among the different cities. In particular, the shortest available distance for walking is assumed to be 10km.

The number of sufferers is estimated in Figure 7 as the available distance, d^* is defined differently with one kilometer interval. The number of sufferers is counted to point out all temporary sojourns of trip makers determined as suffered position. In the original definition as 20km, 23,969 sufferers are estimated. On the other hand, 64,259 sufferers are determined in case of definition of 10km. It is reasonable that the number of sufferers tends to increase in proportion to the reduction of available distance value of d^*. Roughly speaking, about 4,000 sufferers would be incrementally taken into account if the defined distance is reduced by one kilometer. This definition seems to reflect on the future disaster prevention plan of the local city government.

The available walking distance can defined before the estimation in the analysis. It may connect to the allowable risk of earthquake to daily activity of trip makers in the city. Therefore, the change of the definition of the distance is useful to find another issue in the earthquake.

Figure 8 illustrates the sufferer distribution at the peak time (13:00) with the available distance defined as 10km. Many sufferers are founded in central area similarly to the result in the original case such as the distance equals to 20km. On the contrary, the sufferers in suburban and surrounding area can be found in the case. It is obvious that the sufferers are spread widely comparing to Figure 4.

5. Concluding Remarks

An application of PT survey database to urban disaster prevention problem has been discussed. The major findings of the study can be summarized as follows:

- The trip pattern survey result is useful to describe the position of trip makers in a city area for daily activities. A sufferer is defined as to be a trip maker who cannot come back home by walking after an earthquake. The spatial distribution can be illustrated from the integration of GIS.
- It is obvious that sufferer distribution relates with the population distribution in the city. The structural problems of the city are pointed out corresponding to the earthquake disaster.
- As the sufferers can be estimated from the travel pattern combining with using GIS, the level of urban disaster prevention of local government would be installed as an available walking distance of trip makers.

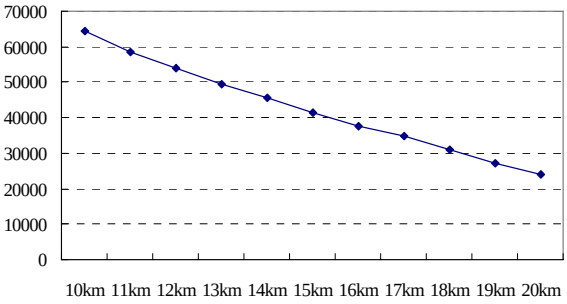

Figure 7: Physical Distance of Survival

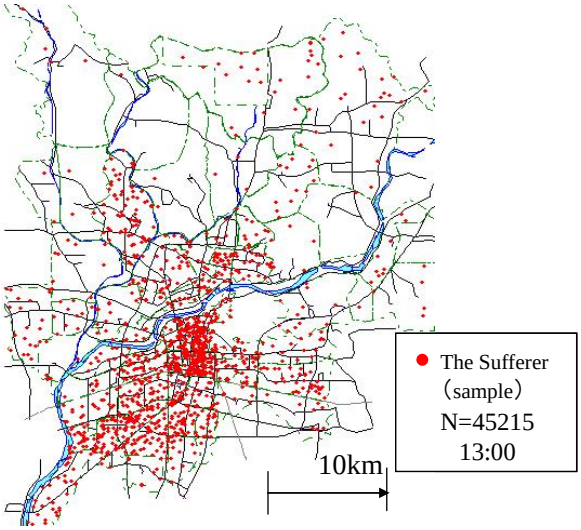

Figure 8: The Distribution of Sufferers (10 km)

In addition, it is known that PT survey database can be applicable to the practical problem rather than urban transport planning. For further study, it is recommended that: 1) The proper indicator of available walking distance can be installed from the several examples. The relation between the sufferers and urban structure would be discussed. 2) Since the change of daily travel pattern is described from the PT survey results of different time periods, the disaster prevention connecting to the urban spatial structure can be mentioned with comparison study.

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