COMPARISON OF TRIP GENERATION RATES CONSIDERING REGIONAL CHARACTERISTICS

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ABSTRACT

One of the major issues in city planning is to integrate land use and transportation. Therefore it is important for city planners to forecast traffic demand generated from land use. In this study, authors aimed to examine the difference and variation of automobile trip generation rate by regional characteristics and land use for the purpose of integrating land use and transportation. We use Geographic Information System (GIS) to grasp regional characteristics of trip generation rate. As a consequence, the variation in trip generation rate depends upon the automobile usage ratio and the level of availability of public transportation systems. The automobile usage ratio by land use influences trip generation rate, and the level of public transportation system provide the choice of transportation modes. Therefore it is necessary to adjust trip generation rate that reflects regional characteristics. Moreover, comparing microscopic trip generation rate of cities in the United States and the local cities in Japan in terms of commercial land use, there is a large difference of trip generation rate according to types of business category.

KEY WORDS

GIS, land use and transportation, trip generation rate, automobile usage ratio

INTRODUCTION

BACK GROUND AND PURPOSE OF STUDY

It is very important in the city planning to integrate land use and transportation because trip is considered as a demand derived from land use. One of the methods to forecast traffic demand derived from land use is to estimate trip generations and attractions based on the trip generation rate per floor area for various land uses or building uses. However, the actual trip generation rate varies depending on the level of automobile usage, land use type or local conditions such as CBD or suburbs. Therefore, it is important to use the automobile trip generation rate that reflects regional characteristic to correctly forecast traffic demand.

In this study, authors aimed to examine the difference and variation of automobile trip generation rates by regional characteristics and land use types for the purpose of integrating land use and transportation. We use Geographic Information System (GIS) to grasp regional characteristics of trip generation rate.

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REVIEW OF EXISTING STUDIES

Many researchers have studied the relationships between land use and transportation system from various aspects. Farhad Atash (1996) enumerated the problem of land use policies and transportation policies, and suggested a new direction of land use and transportation policies based on mixed land use and Transit Oriented Development (TOD). According to Gakkenheimer (1993), it is not as easy as in theory to actually integrate land use and transportation systems because there are different points in the operating mechanism between land use planning and transportation system planning.

Then, there are many studies that pay attention to trip generation rate. Especially, Asano et al. (1988) researched the characteristcs of trip generation rate and classified in both microscopic and macroscopic basic trip generation rates in Tokyo. However there is no research which studied the difference between large metropolis and local cities. In this research, authors examine the characteristics not only in metropolis but also in local cities.

ABOUT THE CATEGORY OF TRIP GENERATION RATE

There are two kinds of trip generation rate. One is the macroscopic trip generation rate and the other is the microscopic trip generation rate. For instance, floor area ratio (FAR) of a zone is based on the macroscopic trip generation rate and Traffic Impact Assessment (TIA) is based on the microscopic trip generation rate. 'Trip Generation' published by the Institute of Transportation Engineers (ITE, 1997) shows various trip generation rates categorized by land use type, and many states and municipalities adopt the values shown in this manual. However the cause of variation is hardly examined, if any, and it is important to clarify it.

ANALYSIS OF MACROSCOPIC TRIP GENERATION RATES BY USING GIS

COMPARISON BETWEEN METROPOLIS AND LOCAL CITY

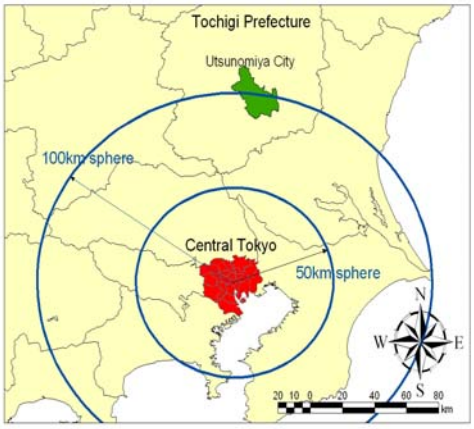


Figure 1: Study Areas

As the first step, macroscopic trip generation rates for each traffic zone are calculated by using GIS based on the person trip survey data. Then, the characteristics of macro trip generation rates are compared among cities and among districts in a city. We chose Tokyo as a metropolis and Utsunomiya City as a local city. Utsunomiya City is a regional capital city that is located 100km from Tokyo, and has the population of approximately 450 thousand. Generally speaking, Japanese local cities are highly automobile dependent, and their public transportation systems are in poor condition except bus transportation. As for Tokyo, an extensive and well-established railway system is in existence.

Analysis of Utsunomiya as a local city

First, macroscopic automobile trip generation rates by land use type in Utsunomiya are studied. Person trip survey data in greater Utsunomiya region metropolitan area was used to

calculate trip generation data, and floor area data was obtained from real estate tax data. Figure 2 shows macroscopic trip generation rates by land use in Utsunomiya city. Trip generation rates for automobile trips have lower correlation rates than trip generation rates for all transportation modes for various land use types. As for automobile trip generation rate, the R-square values of residential, business and commercial land uses are 0.957, 0.731 and 0.580, respectively. The accuracy of automobile trip generation rates varies among residential, business and commercial land use types.

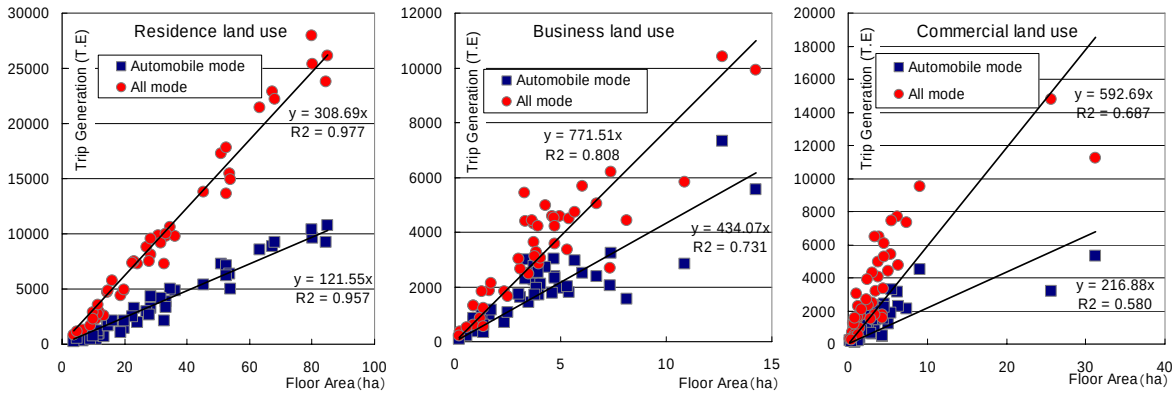
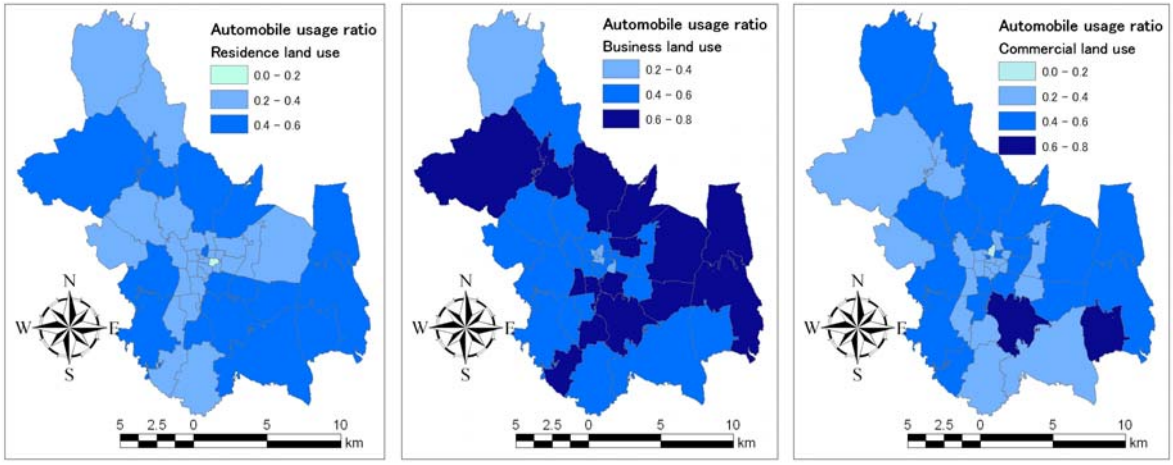


Figure 2: Trip Generation Rate by Land Use in Utsunomiya
(Left: Residential, Middle: Business, Right: Commercial)



Average	0.368	Average	0.553	Average	0.398
Standard Deviation	0.068	Standard Deviation	0.095	Standard Deviation	0.102

Figure 3: Automobile Usage Ratio by Land Use in Utsunomiya
(Left: Residential, Middle: Business, Right: Commercial)

Next, the distribution of automobile usage ratio by land use is shown in Figure 3 to figure out why the accuracy of automobile trip generation rates are different by land use. Figure 3 shows that automobile usage ratio for residential land use varies from 0.0 to 0.6, and

that for business varies form 0.2 to 0.8, and that for commercial varies form 0.0 to 0.8. As for the standard deviation, the largest variability is found in residential land use and the smallest variability in commercial land use. Thus, it can be said that the automobile modal share has a big influence on the automobile trip generation rate, and causes the accuracy of the automobile trip generation rate to be decreased.

Analysis of Tokyo as a metropolis

Secondly, macroscopic automobile trip generation rates by land use in Tokyo as a metropolis are analyzed as is shown in Figure 4. The commercial land use is omitted in Tokyo due to the data restriction.

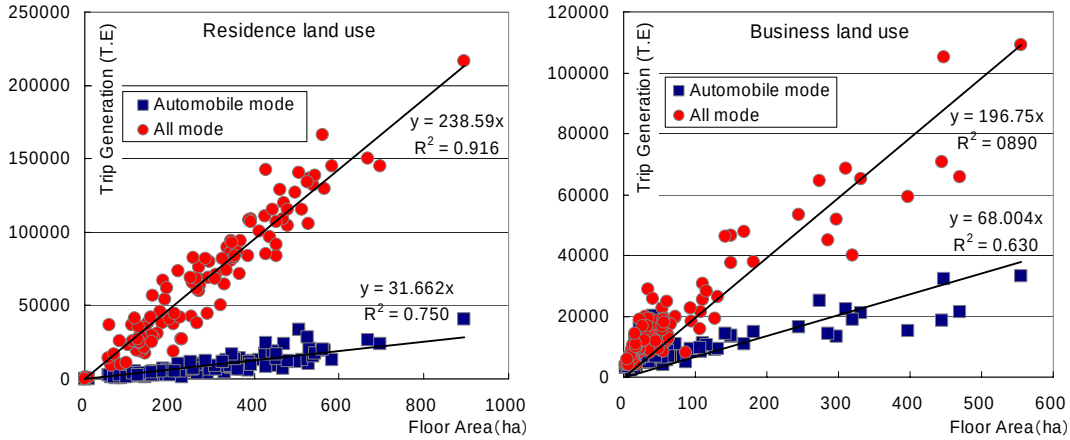
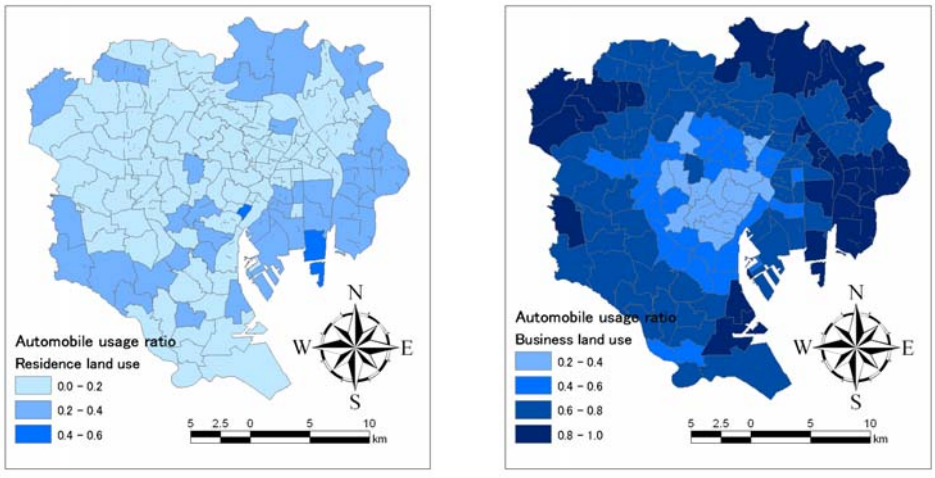


Figure 4: Trip Generation by Land Use in Tokyo (Left: Residential, Right: Business)



Average	0.181	Average	0.634
Standard Deviation	0.063	Standard Deviation	0.173

Figure 5: Automobile Usage Ratio by Land Use in Tokyo (left: Residential, Right: Business)

As you see in Figure 4, R-square values for automobile generation trip rates are lower than trip generation rates for all transportation modes in both land use types, like in Utsunomiya city. As for automobile trip generation rate, the R-square values for residential

and business are 0.750 and 0.630, respectively. When automobile usage ratio by land use is compared between a metropolis and a local city, the automobile modal share is much lower in a metropolis because of the prevalence of public transportation in large metropolitan areas.

In the foregoing section, a wide variation was found in trip generation rate in business and commercial land use, because there is large variation of automobile usage compared with residential land use. When we compare accuracy in Utsunomiya city with that in Tokyo about automobile trip generation rate, however, Tokyo shows lower values in residential and business land use. This is explained by a hypothesis that the more a city has stocks of public transportation system (railway system), the larger the variability of automobile trip generation rate becomes, because the choices of transportation mode expand.

Figure 6: Overlay of Zone and Lane

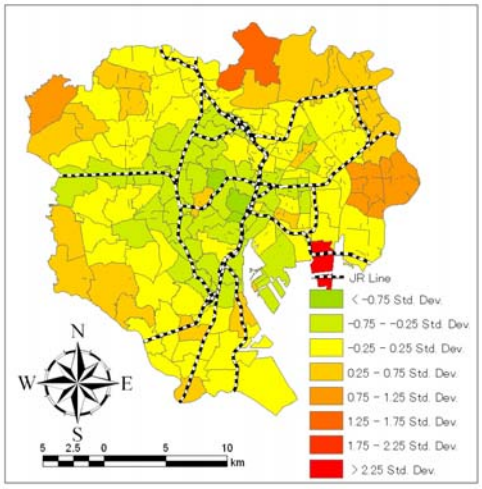


Figure 7: Automobile Trip Generation Rate

Table1. Average and Standard Deviation of Trip Generation Rates for Residential Land Use

Trip Generation Rate Residence Land Use	Zone include JR Line	Zone exclude JR Line
Average	28.00	30.62
Standard Deviation	33.75	12.03

To prove the above hypothesis, the following analysis was conducted. As the first step, traffic zones and railway links are overlaid on GIS map. Then the zones with railway links and zones without railway links are distinguished. (See Figure 6) The distribution of automobile trip generation rate is shown in Figure 7. The average and standard deviation, which is distinguished by railway links, are shown in Table 1. Here, the trip generation rate of residential land use was compared. As is shown in Figure 6, the zones including railway links have high automobile trip generation rates, and the farther the zones are from railway links, the lower the trip generation rates become. In addition, as is shown in Table 1, the average trip generation rates are higher in zones excluding railway links than zones including railway links. As for the standard deviation, the zones excluding railway links are lower than the zones including railway links. Therefore, you can find that the trip generation rates of zones including railway links show wider variation because the choices of transportation

modes such as automobile or railway expand.

Thus, it can be said that with or without public transportation remarkably influences the contribution ratio of trip generation rates, which proves the above-mentioned hypothesis be true.

BORDER LINE BETWEEN TRIP GENERATION RATE AND GIS ANALYSIS

Up to now, authors have explained that the accuracy of the automobile trip generation rate by land use in a city depends on the difference of the automobile usage ratio. In addition, it has also been explained that the level of availability of public transportation (railway) contributes to the accuracy of the trip generation rate when comparing the same land use among cities. The accuracy of automobile trip generation rates by land use between a metropolis and a local city is shown in Table 2.

From this figure, the usage of trip generation rate can be judged as follows. If the accuracy requires more than 0.7, traffic demand forecast for residential land use in a local cities and metropolis and for business land use in local city can be done by using the method based on the trip generation rate per floor area. However, for business land use in a metropolis and for commercial land use in a local city, it is necessary to forecast traffic demand that reflects regional characteristics by using GIS.

In addition, the following two findings also justify the above conclusion. (1) The accuracy of automobile trip generation rate decreases in the order of the residential land use, the business land use and commercial land use. (2) The accuracy of automobile trip generation rate in a metropolis is lower than that in a local city, due to the level of availability of public transportation. From these findings, it can be assumed that the accuracy of automobile trip generation rate for commercial land use in a metropolis becomes lower than above five cases of automobile trip generation rates, and it is difficult to forecast traffic demand by the basic unit method for the commercial land use in a metropolis.

Based on these results, it would be effective for the estimation of automobile trip generation rate to use GIS method, while considering how much accuracy is necessary.

Table 2: Accuracy of Trip Generation Rate and the Method

City Type, Land Use Type	The R-square value	Method
Local City, Residence	0.957	The method based on the trip generation rate
Metropolis, Residence	0.750	The method based on the trip generation rate
Local City, Business	0.731	The method based on the trip generation rate
Metropolis, Business	0.630	GIS analysis
Local City, Commercial	0.580	GIS analysis

ANALYSIS OF MICROSCOPIC TRIP GENERATION RATES BY USING GIS

Next, the microscopic automobile trip generation rate was analyzed for commercial land use which shows low accuracy in the analysis of macroscopic automobile trip generation rate. We compared micro trip generation rate of cities in the United States and the local cities in Japan like Utsunomiya which have similar urban characteristic where automobile usage rate is much higher than the national average. Because there are many kinds of business

categories on commercial land use, the characteristics of trip generation rates are different according to business category.

In this section, we classify commercial land use into five business categories, namely, Shopping Center, Supermarket, Home Improvement Superstore, Electronics Superstore and Funiture Store, and compared microscopic automobile trip generation rates for these categories. The result to make up trip generation rates in the United States by ITE is shown in Table 3, and that in local cities in Japan is shown in Table 4.

When you see average rate, there is a difference of variation according to business category. Especially, average rate in Supermarket is too large, which is because articles for daily use consumed every day are sold in Supermarket. Therefore trip generation per floor area is much higher than any other categories in which articles for luxury are sold. Moreover, because Supermarket has the highest standard deviation and wide variation, it is difficult to forecast traffic demand for Supermarket.

Table3. Trip Generation per 1000 Sq. Feet Gross Floor Area in America

ITE	Number of Studies	Average Rate	Range of Rates	Standard Deviation	Remarks
Shopping Center	124	4.97	1.46 - 18.32	3.11	Holiday
Supermarket	20	12.25	5.38 - 22.60	4.63	Holiday
Home Improvement Superstore	3	5.40	4.79 - 5.62	2.33	Holiday
Electronics Superstore	2	4.50	3.45 - 5.78	2.37	Weekday
Furniture Store	12	0.78	0.15 - 2.79	1.05	Holiday

Table4. Trip Generation per 1000 Sq. Feet Gross Floor Area in Japan

Local City in Japan	Number of Studies	Average Rate	Range of Rates	Standard Deviation	Remarks
Shopping Center	23	4.06	1.36 - 13.00	2.17	Holiday
Supermarket	20	7.12	2.39 - 12.17	2.98	Holiday
Home Improvement Superstore	23	4.18	1.30 - 8.70	2.03	Holiday
Electronics Superstore	9	5.23	2.22 - 9.47	2.17	Holiday
Furniture Store	5	1.97	0.53 - 3.03	1.07	Holiday

In general, similar results are obtained comparing Japan and the United States, though American Supermarket is larger than Japanese Supermaket in average rate and standard deviation. Although a certain level of variation can be controlled by classifying by business category, it is effective to incorporate regional characteristics such as using GIS if the accurate traffic demand forecasting like TIA is demanded.

CONCLUSIONS

In this study, authors aimed to examine the characteristic of macroscopic trip generation rate according to land use type and city category, and that of microscopic trip generation rate according to business category. As a conclusion, the following points are found.

- The accuracy of macroscopic trip generation rate by land use type is decreasing in order of residential, business and commercial. It is due to the disparities of automobile usage ratio among regions, and it was shown quantitatively that the larger the variation of automobile usage ratio becomes the lower the accuracy of trip generation rate.

- Comparing macroscopic trip generation rate among cities for the same land use type, the accuracy in the local cities is higher than that in the metropolis. This is because the metropolis has large amount of railway stock compared with local cities, different transportation mode can be chosen in the metropolis. On the other hand, the variation of trip generation rate is small in the local cities, because it is forced to use only automobile.
- Comparing micro trip generation rate of cities in United States and the local cities in Japan as for commercial land use, there is a large difference of trip generation rate according to business category. Particularlly, the variation is widely in Supermarket which sells articles for daily use, and it is effective to analyze trip generation rate that reflects regional characteristics.

In this study, authors paid attention to trip generation rate. The variation of trip generation rate is based on the transportation mode and land use type. It is important to reflect this result when using trip generation rate in the planning such as master plan and traffic impact assessment, and to integrate land use and transportation systems in order to form sustainable cities.

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