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Research on Methods of Assessing Traffic Accident Risk in Residential Road Block Areas Surrounded by Arterial Roads

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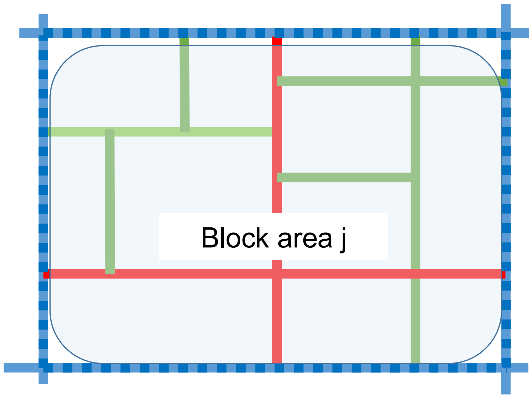
1. Introduction

Generally, when comparing numbers of traffic accidents by road type, it is well known that residential roads such as municipal roads account for a higher proportion of accidents than arterial roads. For example, a breakdown of 2018 statistics from the Chiba Prefectural Police[1)] shows that 60.3% of traffic accidents and 45.4% of fatal accidents occurred on such municipal roads[1)]. Furthermore, the fact that a high proportion of these accidents involve pedestrians is one of their known features. Given such circumstances, it goes without saying that ensuring safe passage on residential roads is important. However, in recent years, probe data showing individual vehicle behavior has been collected and accumulated from sources such as vehicle navigation systems, making it possible to collect information on the traffic conditions of residential roads. By utilizing this information to perform “bird’s eye view” macro analysis of accident situations together with conventional "worm's eye view" micro investigations and analysis, it is expected that more effective and efficient safety measures can be developed. When planning such measures, it is extremely important to grasp the relationships between factors that determine the features of an area and the likelihood of an accident occurring (hereinafter, “accident risk”). Despite much research having been performed on these relationships over the years, most of that research has analyzed the road characteristics and roadside characteristics of a given area, with no analytical research being performed by focusing on macro traffic characteristics such as the congestion statuses of peripheral arterial roads, at least as far as we are aware. Against this background, the purpose of this research is to clarify relationships between macro-traffic characteristics of residential roads and accident risks in the same area, while also examining accident risk assessment methods that comprehensively investigate these relationships.

2. Analysis methods

2-1. Data overview

The six types of data used for the analysis performed in this research are described in detail below. The traffic accident data used in this analysis is data provided by the Chiba Prefectural Police. This data can be confirmed on GIS using information for the location of accident occurrence (latitude/longitude). Furthermore, approximately 22 data items are recorded for each location, including the date and time of the occurrence and the type of accident. The period of the data spans over four years from January 1, 2015 to December 31, 2018, with the 34,751 traffic accidents that occurred within that period being subjected to analysis. The traffic accidents extracted and subjected to analysis were accidents that occurred on municipal roads within the skeletal trunk road block defined in this research as roads with a width of 3.5 m or more and less than 13.0 m. Other data used included road network data in the form of 2019 DRM data and road network data from ArcGIS Geo Suite (ESRI Japan). Also, the probe data used included such data obtained from mobile GPS employing mobile vehicle navigation services provided by Navitime® Japan. 41 items of data are recorded in these data, including average travel speed, number of unique users, and number of passes per link for each aggregation period. In this research, we used data on the number of probe passes, link length, and average travel speed per link collected over a four-year period from January 1, 2015 to December 31, 2018 in Chiba Prefecture. As road traffic census data, it is based on the general traffic volume survey data from the 2015 road traffic census, and references congestion level data and census road link position data. As peripheral environment data, it uses information such as the area of 30 km/h zones set up by the Chiba Prefectural Police[2)], positional information on schools, stations, and medical institutions obtained from digital national land information, DID area data, and positional information on large shopping malls and convenience stores obtained from Navitime and Zenrin. Furthermore, actual measurement surveys were conducted during this research to obtain observation traffic volume data for residential roads. These surveys were conducted on weekdays from April to July under clear weather and for approximately one-hour observation periods between 10 AM and 11 AM. Also, 50 locations on residential roads with differing features were used as the locations of these surveys, with results for the number of observed passing vehicles being used.



Type of road	Road width	Traffic type
Census road link	13 m or more	Two-way
Main community road	5.5-13.0m	Two-way
Neighborhood road	Less than 5.5 m	Two-way/One-way

Fig. 1 - Concept diagram of block areas

2-2. Methods of analyzing accident risk models

(1) Definition of "residential road block area"

The block area, which is the aggregate unit used in this research, is set based on skeletal arterial roads in order to be consistent with the area bordered by the arterial roads, which is the area in which safety measures have been implemented. Residential roads consist of main community roads and neighborhood roads, which are bordered by the census links (road links shown in blue in the figure) as shown in the concept diagram (Fig. 1). Also, a certain standard will be set for the size of the area. For this reason, subject block areas are extracted based on the conditions of (1) block area size: 1.0 to 10.0 [km^2] and (2) residential road density: 1.0 [km/km^2] or more. As a result, 287 areas out of a total of 507 areas were extracted for analysis.

Table 1 - List of explanatory variables

Characteristic	Variable	Average value	Min. value	Max. value
Traffic characteristics	Average degree of congestion of surrounding trunk roads	0.90	0.21	1.90
	Average travel speed (main community roads) [km/h]	32.0	0.0	54.4
	Average travel speed (neighborhood roads) [km/h]	22.9	9.6	53.0
	Variance of average travel speed (main community roads) [km^2/h^2]	173.4	0	2947
	Variance of average travel speed (neighborhood roads) [km^2/h^2]	239.4	47.4	5145
Road characteristics	Signalized intersection density (medium × medium) [location/km]	0.16	0	1.23
	Signalized intersection density (medium × small) [location/km]	0.12	0	0.71
	Signalized intersection density (small × small) [location/km]	0.002	0	0.10
	Unsignalized intersection density (medium × medium) [location/km]	0.36	0	4.88
	Unsignalized intersection density (medium × small) [location/km]	2.60	0.22	7.03
	Unsignalized intersection density (small × small) [location/km]	5.30	0.49	11.7
	Road density [km/km^2]	11.26	1.24	27.8
	Ratio of major community roads	0.23	0	0.89
	Connection density with arterial roads [location/km]	0.45	0.19	0.96
Surrounding environment characteristics	Ratio of areas in which 30 km/h zones have been set up	0.01	0	0.33
	School density [location/km]	0.06	0	0.88
	Station density [location/km]	0.01	0	0.43
	Large shopping mall density [location/km]	0.008	0	0.19
	Medical institution density [location/km]	0.26	0	2.00
	Convenience store density [location/km]	0.09	0	0.75

(2) Block area accident risk

Block area accident risk λ_j^m as specified in this research is calculated using the formula (1) shown below. Specifically, block area accident risk is expressed as the number of traffic accidents per hundred million vehicle-kilometers, or in other words, the number of accidents per unit total traffic volume (vehicles) × distance (km) in a certain block area. Note that the number of accidents used for counting here is only for accidents that occurred on residential roads, in other words, major community roads and neighborhood roads.

$$\lambda_j^m = \frac{N_j^m}{L_j} \tag{1}$$

Here, j is the block area ID (j = 1,2,3 ..., 287), while N_j^m is the total number of accidents (no. of accidents/year) of accident type m that occurred at each of the links that constitute block area j in a certain target period. Also, L_j is the total traffic volume (vehicles) × distance (km) [hundred million vehicle-kilometers] of each link that constitutes the block area j for a certain target period.

(3) Accident risk model

In this research, the relationships between each feature quantity of the block area shown in the previous section and the block area accident risk were analyzed using the Poisson regression model. Specifically, the objective variable is the number of traffic accidents in the block area, and the explanatory variables include various factors such as traffic characteristics and their offsets are formulated as the total traffic volume (vehicles) × distance (km) in a block area. For this reason, the model formula is described as shown by the formulas (2) and (3) shown below.

$$Y_j^m \sim \text{Poisson} \ (\mu_j^m) \tag{2}$$

$$\ln(\mu_j^m) = a^m + \sum \beta_{jk}^m x_k + \ln(Lj) \tag{3}$$

Here, $Y_j{}^m$ is the annual number of accidents of accident type m (m = vehicle-vehicle accident, pedestrian-vehicle accident) that occurred in block area j, $\mu_j{}^m$ is the number of accidents (accidents/year) of accident type m expected to occur in area j, x_k is a group of variables indicating the features of the block area (k = 1,2,3, ..., 20), a is a constant, β is an unknown parameter, and L_j is the total traffic volume (vehicles) × distance (km) [hundred million vehicle-kilometers] for each link of which block area j is constituted in a certain target year. Also, the features of the areas inside the block are varied and include road characteristics and roadside conditions, in addition to traffic characteristics. For this reason, these factors are also considered so that factors that impact the block area accident risk can be comprehensively analyzed. The explanatory variables used in this research are shown in Table 1. Here, factors are roughly classified into three types of characteristics including traffic characteristics, road characteristics, and surrounding environmental characteristics, with a total of 20 explanatory variables corresponding to each characteristic being taken into account.

3. Model estimation results

The results of estimations performed using the Poisson regression model are shown in Table 2. In those analysis results, the likelihood ratio ρ^2 (goodness of fit) of both models was high (0.36 and 0.40), indicating that they are good models. The impact of each type of variable is as follows. In the case of vehicle-vehicle accidents, three variables of (1) traffic characteristics were extracted as significant parameters, including average degree of congestion (census links), average travel speed on major community roads, and average travel speed on neighborhood roads. It has been shown that accident risk increases in block areas with multiple links in which the average travel speeds on major community roads and neighborhood road is decreasing. Of the variables considered as (2) road characteristics, all variables except unsignalized intersection density (medium × small) have a significant impact. For example, while road density shows a positive value, the ratio of major community roads shows a negative value, meaning the higher the ratio of main community roads, the lower the accident risk tended to be. It has been shown that the density of schools and other facilities such as large shopping malls and convenience stores has a significant positive impact on the factors of the (3) surrounding environment, causing accident risk to increase.

In the case of pedestrian-vehicle accidents, impact from average degree of congestion (census links), average travel speed on major community roads, and average travel speed on neighborhood roads were added as (1) traffic characteristics, and it has been shown that the variance of average travel speeds on neighborhood roads has a significant positive impact on accident risk. As (2) road characteristics, signalized intersection density (medium × small) and unsignalized intersection density (small × small) show a positive impact, with the impact of intersection density shown to differ depending on the type of roads that intersect. Furthermore, although accident risk increases in areas with higher road density, accident risk tends to decrease in block areas with a high share of major community roads. As for (3) surrounding environment characteristics, accident risk increases in areas with dense concentrations of amusement facilities such as retail stores, restaurants, and movie theaters. Conversely, accident risk tends to decrease in areas with high ratios of 30 km/h zones, as is the case with vehicle-vehicle accidents.

Table 2. Model estimation results

Variable	Vehicle-vehicle accidents		Pedestrian-vehicle accidents	
	Coefficient value	Z-value	Coefficient value	Z-value
	2.58	18.2***	0.76	2.67**
Traffic characteristics				
Average degree of congestion (census links)	0.34	8.19***	0.48	5.93***
Average travel speed (main community roads)	-0.03	-11.29***	-0.03	-5.10***
Average travel speed (neighborhood roads)	-0.02	-4.68***	-0.03	-4.20***
Variance of average travel speed (main community roads)	$-1.55*10^{-4}$	-1.57		
Variance of average travel speed (neighborhood roads)	$-9.55*10^{-5}$	-1.70*	$2.54*10^{-4}$	3.48***
Road characteristics				
Signalized intersection density (medium × medium)				
Signalized intersection density (medium × small)	1.36	9.12***	0.86	3.19***
Signalized intersection density (small × small)	-3.51	-2.59***		
Unsignalized intersection density (medium × medium)	-0.20	-6.47***	-0.14	-2.67***
Unsignalized intersection density (medium × small)	0.03	1.48		
Unsignalized intersection density (small × small)	0.08	10.44***	0.10	6.82***
Road density	0.02	9.69***	0.03	5.67***
Ratio of major community roads	-0.90	-6.57***	-1.34	-4.88***
Connection density with arterial roads	-0.42	-5.61***		
Surrounding environment characteristics				
Ratio of 30 km/h zones	-0.69	-3.03***	-1.21	-3.04***
School density	0.77	3.64***	0.83	2.09**
Station density	-5.08	-8.05***		
Large shopping mall density	3.77	7.33***		
Medical institution density	-0.15	-3.23***	0.41	5.88***
Convenience store density	1.04	8.22***	0.80	3.60***
Sample size *N*	1026		1026	
AIC	5763		3196	
Likelihood ratio *ρ2*	0.40		0.36	

Significant level: '***': p<0.01, '**': p<0.05, '*': p<0.1

Note: Signalized intersection density (small = width less than 5.5 m, medium = width 5.5 m or more and less than 13 m)

4. Conclusion

In this research, we focused on macro traffic characteristics of residential roads in Chiba Prefecture and comprehensively analyzed the impact of area-determining factors on traffic accident risk. Specifically, a residential road block area surrounded by arterial roads was selected based on the coverage of areas in which safety measures have been implemented, with relationships between determining factors, including traffic characteristic indicators, and the traffic accident risk of each area being analyzed using the Poisson regression model. As a result, we found that accident risk for both vehicle-vehicle accidents and pedestrian-vehicle accidents was higher in areas with a high density of arterial roads around the area's periphery which also had decreased average travel speeds on its main community roads and neighborhood roads than in the case of areas without such features. Our results also showed that the greater the variance of the average travel speed on neighborhood roads, the higher an area's accident risk for pedestrian-vehicle accidents would be. Furthermore, it was found that accident risk for pedestrian-vehicle accidents is higher in areas where facilities in which people gather are concentrated, while accident risk is lower in areas with high ratios of 30 km/h zones. As an issue for the future, we believe other efforts will be necessary including the use of information based on individual vehicle history such as trip length and driving speed to consider differences due to the traffic characteristics of each link.

<References/Sources>

(1) 千葉県警察本部 HP：交通事故統計資料集 (https://www.police.pref.chiba.jp/kotsusomuka/traffic-safety_hakusyo.html).

(2) 千葉県警察本部 HP：「ゾーン 30」の概要 (https://www.police.pref.chiba.jp/kotsukiseika/traffic-safety_defend-08.html）.

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