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Analysis of pedestrian-related accident risk factors considering various accident types in traffic analysis zone on non-arterial roads

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Abstract:

In this study, the relationship between pedestrian-related accident risk factors of "traffic characteristics," "road characteristics", "road environment characteristics" and the risk of pedestrian-related accidents was analyzed by accident type based on negative binomial model for pedestrian-related accidents on non-arterial roads in Chiba prefecture over a four-year period. As a result, there are some factors that commonly affect all types of accidents and uncommon factors that have a different impact depending on accident type. Specifically, it was shown that although "un-signalized intersection density" had a positive impact on all accident types, the impact of the "roadside characteristics" factor, which expresses more area-specific activity conditions, was different by accident types. Furthermore, it was shown that the risks of walking along roadway accidents and Unmarked crosswalk accidents at non-intersection roads tended to be higher in areas with a high tendency for "central business district type factors". In contrast, the "roadside characteristics" factor was non-significant for accidents at crosswalks.

1 INTRODUCTION

In recent years, pedestrian traffic safety has been one of the important traffic issues facing society. In the case of Chiba Prefecture in Japan, the number of traffic accidents in Chiba Prefecture was 13,564, about 60% of which occurred on non-arterial roads[1)]. The ratio of accidents involving people and vehicles on non- arterial roads is increasing trendy. In response to this situation, Japan has been promoting area-based measures to ensure safe traffic on non-arterial roads, such as speed restrictions using Zone 30 and physical devices such as humps to control speed. It is clear from the above that the importance of traffic accident countermeasures on non-arterial roads is high to further reduce the number of accidents involving pedestrians on non-arterial roads, and that it is important to identify the area where these countermeasures should be prioritized in Japan. The decision to implement a countermeasure is basically based on the number of traffic accidents that occur at a given area. When looking at the selection of safety areas, it is useful to identify areas with a high risk of traffic accidents and to model them based on past traffic accidents, for example, when prioritizing countermeasure projects. In the case of accidents involving pedestrians, it is considered that defining traffic accidents by considering not only the vehicle traffic exposure but also the influence of pedestrian distribution, will lead to safety assessments such as traffic demand management that are more in line with the actual situation. Consequently, to foster a safer environment, it is critical to comprehensively examine regional factors in the traffic analysis zone, including population and socio-economic characteristics, land use, road networks, and local built environments. Pedestrian related accidents analysis has been conducted by many previous studies in the past. Investigating the characteristics of pedestrian related accidents and predicting pedestrian related accidents through models were the issues focused on in these studies. Previous research [2)- 10)] has found that a wide range of factors may contribute to the occurrence of pedestrian accidents, including traffic exposure, roadway and environmental factors. The studies above suggested that pedestrian-related accidents are associated with several factors. Furthermore, an accurate understanding of the factors by accident types is important, because traffic engineers, policy makers and planners rely on this information to determine the most effective safety measures. However, many previous studies focus on modeling total accident frequency and model comparison while a few have looked at accident frequencies by type. In this study, the relationship between the accident factors of "traffic characteristics," "road characteristics", "road environmental characteristics" and the risk of pedestrian -vehicle accidents were analyzed by accident type based on non-arterial roads in Chiba Prefecture over four-years.

2 DATA AND METHODOLOGY

2.1 Target Study Area and Data

In this study, we used Traffic accident data, digital roadmap network data, probe data, road traffic census data, regional environment data traffic observation data and people flow data using smartphones. This study used traffic accident data provided by Chiba police department and incorporated 3,741 pedestrian -involved accidents that occurred in Japan between 2015 and 2018 at the target study area. There are five types of traffic accidents: (1) walking along roadway accidents, (2) accidents at crosswalks, (3) unmarked crosswalk at intersection, (4) unmarked crosswalk accident at mid-blocks and (5) other accidents. Figure 1 shows the distribution of developed traffic analysis zones (TAZs). To explore the spatial distribution of pedestrian related accidents, we developed 85 TAZs. TAZs are a mesh block approximation of the recognized boundaries of main arterial roads as defined in this study area as shown in figure 1.

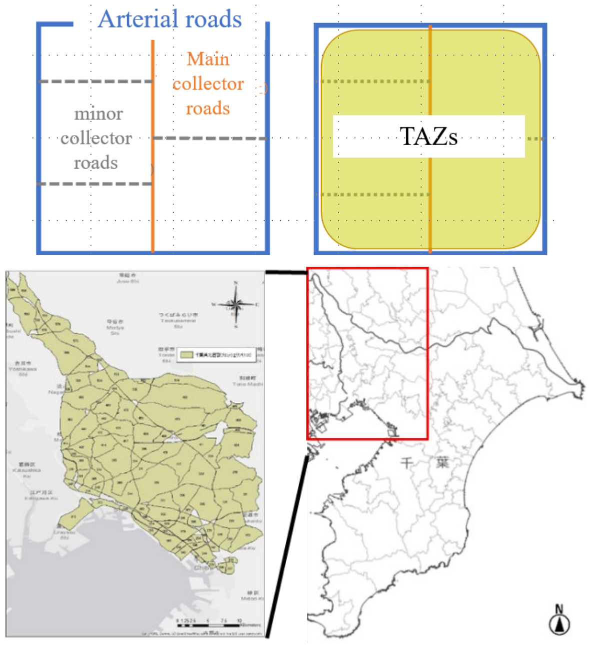

Figure 1:Target Study area and traffic analysis zones

Table 1: Variables used in this analysis

Explanatory variable	Meaning
Traffic characteristics	
Congestion level on surrounding arterial roads x 1	This variable quantifies the degree of traffic congestion on arterial roads adjacent to capture external traffic pressure influencing local road in TAZ.
Average travel speed (Main collector roads) x 2	These variables quantifies the degree for evaluating the traffic conditions in TAZ.
Average travel speed (minor collector roads) x 3	
Variance of travel speed (Main collector roads) x 4	
Variance of travel speed (minor collector roads) x 5	
Skewness of travel speed (Main collector roads) x 6	
Skewness of travel speed (Main collector roads) x 7	
Pedestrian characteristic	
Pedestrian spatial autocorrelation x 8	This variable measures the degree of pedestrian clustering within the TAZ to assess spatial concentration.
Road characteristics	
Density of signalized intersections x 9	These variables are used to capture road conditions in TAZ.
Density of unsignalized intersections x 10	
Percentage of zones with 30 km/h speed limits x 11	These variable assess the impact of traffic regulations in TAZ.
Percentage of one-way streets x 12	
Roadside characteristics	These variables were derived through factor analysis to represent underlying roadside patterns in TAZ. Factor analysis was performed on ten variables such as station, facility, and store density.
Central business district -type factor x 13	
Commercial-type factor x 14	
Medium sized station-type factor x 15	
Rural-type factor x 16	

2.2 Accident Risk Factor

Various factors are believed to influence pedestrian safety, including intersection configuration, demographic characteristics of both drivers and pedestrians, and traffic operational features, as shown in Table 1. In this study, these factors are expressed by 16 variables (x1-x16). The traffic characteristics are seven variables used to express the characteristics of vehicle traffic: congestion level on surrounding arterial roads; the average travel speed on main collector roads (5.5-13.0 m) and minor collector roads (less than 5.5 m) within the TAZs; variance of the average travel speed distribution on main collector roads and minor collector roads within TAZs; and the skewness of the area average travel speed main collector roads and minor collector roads within TAZs. The pedestrian characteristic index is the pedestrian spatial autocorrelation. This study uses Global Moran measure I, which is one of Moran's statistics, as the spatial autocorrelation. The

Global Moran measure takes a value between -1 and 1, with a value closer to 1 indicating the presence of positive autocorrelation and a value closer to -1 indicating the presence of negative autocorrelation. The following five variables are used as explanatory variables for road characteristics: "density of signalized intersections", "density of unsignalized intersections", "percentage of main roads", "percentage of zones with 30 km/h speed limits", and "percentage of one-way streets". In this study, we apply factor analysis to variables related to roadside characteristics and use the four factor loadings extracted as explanatory variables to aggregate information on facilities in each TAZ. These are the "central business district -type factor", "commercial-type factor", "medium sized station-type factor", and "rural-type factor".

2.3 Traffic Accident Risk Model Analysis

In this study, Poisson model ($y_i \sim \mathrm{Po}(\mu_{jm})$)and negative binomial model (($y_i \sim \mathrm{NB}(\mu_{jm}, \theta)$)) are applied to evaluate the effects of TAZs based variables on the frequency of pedestrian related accidents as shown in Equation (1).

$$\mu_{jm} = R_{jm} L_j = exp\left(\alpha + \sum \beta_i x_i\right) L_j \tag{1}$$

where μ_{jm}expected number of accidents of accident type m in TAZs j, θ is over-dispersion parameter, R_{jm} accident risk by pedestrian relate accident type m in TAZs j, L_j is total vehicle kilometers traveled in TAZs j, $x_i$is the feature variable, x is a set of feature values for a certain sample and $\alpha, \beta_i$are unknown parameters of feature i.

3 MODEL RESULTS

Table 2 shows the parameter estimation results for the negative binomial regression model for accidents between people and vehicles, by accident type. When looking at the effects of "Traffic characteristics", the average travel speed (main roads), average travel speed variance (minor collector roads), and average travel speed skewness (main roads, minor collector roads) were extracted as significant variables. The results of the "pedestrian characteristics" analysis showed that the spatial self-correlation of pedestrians had a significant positive effect on the risk of accidents at crosswalks, unmarked crosswalk accident at intersection and other accidents. This suggests that the risk of these types of accidents increases in areas where pedestrians are concentrated in one place. In addition to the area population density indicated in previous research, the results suggest that the spatial pattern of actual pedestrian flow also affects the risk of accidents occurring in an area. In the "road characteristics" category, the density of unsignalized intersections showed a significantly positive coefficient value in all five accident models. In contrast, the density of signalized intersections showed different positive and negative sign conditions depending on the accident type. The "roadside characteristics" showed the effects of the different factor scores for each type. Specifically, the coefficient values for the central business district type and medium-sized station types were positive, while the coefficients for the commercial type and rural type were negative, indicating that the trends in the effects of accidents differ between accidents that occur frequently at pedestrian crossings in intersections and accidents that occur frequently on non-intersections.

4 CONCLUSIONS

In this study, we set a non-arterial TAZs analysis of pedestrian related accidents that occurred on non-arterial roads in the northwestern part of Chiba Prefecture over a four-years (2015-2018). We also investigated the relationship between area-based factors and area accident risk using a negative binomial regression model analysis. The findings of the analysis are as follows. As a result, there are some factors that commonly affect all types of accidents and uncommon factors that have a different impact depending on accident type. For example, although "density of unsignalized intersections" has a positive impact on all accident types, the impact of the "roadside characteristics" factor, which substitutes for the pedestrian activity situation specific to the area, differs depending on the accident type. Specifically, compared to accidents involving pedestrians crossing at pedestrian crossings on non-arterial roads, the risk of walking along roadway accidents and unmarked crosswalk accidents at non-intersection roads tends to be higher in areas where the tendency of the "roadside characteristics" factor is stronger, such as central business district type factors and medium-sized station-type factors. This is thought to be because areas where transport nodes and business and commercial facilities are located close to each other have a diverse range of pedestrian activity and the activity itself is also active, and as a result, the number of opportunities for pedestrians to come into contact with each other or to cross the road in an unsafe manner also increases, resulting in a high accident risk value. In contrast, the "roadside characteristics" factor was shown to be non-significant only accidents at crosswalks. Therefore, unlike other types of accidents, it was suggested that this was due to factors not related to the characteristics of the roadside. From the above, when considering measures on a wide scale, it is effective to plan and implement a policy for traffic safety measures to be taken, considering the characteristics of the TAZs and the high accident risk in that area. These results have important implications for developing effective safety countermeasures.

Table 2: Model estimation results for the frequency of pedestrian accidents by accident types.

Explanatory variables \ Types of accidents	Walking along roadway accidents	Accidents at crosswalks	Unmarked crosswalk accident at intersection	Unmarked crosswalk accident at mid-blocks	Other accidents
Constant	-20.369 ***	-24.795 ***	-23.397 ***	-22.175 ***	-22.032 ***
Traffic characteristics					
Congestion level on surrounding arterial roads x 1				0.768 *	0.676 *
Average travel speed (Main collector roads) x 2	0.050 *	0.123 ***	0.120 ***	0.057 *	0.062 *
Average travel speed (minor collector roads) x 3					
Variance of travel speed (Main collector roads) x 4			-0.007 ***		-0.004 **
Variance of travel speed (minor collector roads) x 5	-0.003 ***	-0.003 ***	-0.002 **	-0.002 **	
Skewness of travel speed (Main collector roads) x 6			0.142 ***		0.107 *
Skewness of travel speed (Main collector roads) x 7		0.064 *			
Pedestrian characteristic					
Pedestrian spatial autocorrelation x 8		2.696 ***	1.940 ***		1.744 ***
Road characteristics					
Density of signalized intersections x 9	-1.214 **	1.464 ***		2.276 **	
Density of unsignalized intersections x 10	0.236 ***	0.409 ***	0.402 ***	0.200 **	0.224 ***
Percentage of zones with 30 km/h speed limits x 11		-2.566 *	-3.399 **	-7.194 ***	-4.591 ***
Percentage of one-way streets x 12				-3.058 ***	
Roadside characteristics					
Central business district -type factor x 13	0.341 ***			0.246 ***	
Commercial-type factor x 14			-0.212 **		
Medium sized station-type factor x 15	0.350 ***		0.161 *	0.171 *	0.207 **
Rural-type factor x 16	-0.221 **		-0.170	-0.244 **	-0.144
N			340		
ρ^2	0.04	0.04	0.04	0.03	0.03

Significance level of the Z-value: '***' p<0.01 '**' p<0.05 '*' p<0.1

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