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Pedestrian Conflict Risk Model at Unsignalized Locations on a Community Street

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Abstract: *Crossing a street at unsignalized location can be dangerous to pedestrians, especially the elderly. This paper evaluate the pedestrian-vehicle collision risk on specific roads to identify that the degree of Pedestrian safety requires pedestrian intervention such as road improvement. First, age was a significant variable in that older people tend to be at greater risk than the non-elder people. There was an insignificant difference between the PSM of approaching vehicles that were traveling at speeds less than 30 km/h and those traveling at speeds in the range of 30-50 km/h. Interestingly, conflicts when the speed of the vehicles exceeded 50 km/h, the risk of conflict risk was higher than it was for vehicles traveling at speeds below 30km/h. The ratio of conflict risk for crossing gradient topography road was about 21.7 times greater than that for the non-gradient topography area. Regarding safety facilities, the 30 km/h speed limit sign influenced the risk situation of conflict. The ratio of conflict risk for a road with the safety facility was about 0.395 times lower than that for an unmarked road.*

I. Introduction

Crossing a street at an unsignalized location can be dangerous to pedestrians, especially elderly people. The safety of pedestrian crossings requires interventions that include improvement of road safety facilities and assessment of the risk of collisions between pedestrians and vehicles. Such interventions are necessary to identify areas in which there is a risk of conflict between pedestrians and vehicles so that improvements can be made to avoid these conflicts. There are insufficient safety measures for non-signal areas of roadways, and there is a lack of research on the analysis of the risk of pedestrian-motor vehicle conflicts, especially in Korea. Models are needed in order to delve into the factors that influence the risk of such conflicts. Therefore, the purpose of this study was to identify situations that involved the risk of conflicts on roads without traffic signals and analyze the factors that affect pedestrians' ability to cross such roads safely. After initially reviewing the previous research, we developed a statistical model that can be used to explain the relationship between the possible risk of pedestrians' possible conflicts with vehicles and the factors that affect that possibility.

A. Literature Review

Researchers have investigated how pedestrians' demographic characteristics influence their crossing behavior. Ref. [1] analyzed the effect of pedestrians' ages on determining when to cross the road via a simulation technique in a virtual environment. Ref. [2] presented the pedestrian speed was influence in pedestrian behavior and analyzed pedestrians' gap acceptance behavior in the mid-block section without regulation. Studies have been conducted to determine the effect of a vehicle's velocity and the effect of the condition of the street on the occurrence crashes between vehicles and pedestrians. Ref. [3] provided an analysis of the relationship between the speed of a vehicle and the severity of the pedestrian injuries and the risk of death. Ref. [4] addressed the effects of environmental features, such as the availability of crossing facilities, the volume of traffic, and roadway geometry, on pedestrians' crossing behavior to determine the relationship between safety facilities on the road and pedestrians' safety in crossing the road. Ref. [5] provided the effect of the construction of traffic facilities on pedestrians' crossing behavior. Ref. [6] indicated that the purpose of constructing a pedestrian crossing was to avoid pedestrians' conflicts with vehicles and allow pedestrians to cross the road safely.

Several studies have been conducted that used various statistical models to estimate the impact of risk factors on the severity of crashes between vehicles and pedestrians at intersections. Ref. [7] used the Probit model to determine the risk factors that affect the severity of crashes at intersections in Singapore. Ref. [8] used a Bayesian hierarchical binomial logistic model to identify the significant factors that affect the severity of crashes at signalized intersections in Singapore. Ref. [9] used a logit model to examine the factors that affected crashes at intersections in Greensboro, North Carolina. Ref. [10] used Multi-level, Mixed effect Poisson models to determine the correlation of locations. Ref. [11] analyzed the risk factors associated with intersection crashes using logistic regression models. Ref. [12] identified the important factors that affect the severity of pedestrians' injuries in collisions with vehicles by using a mixed logit model. Ref. [13] applied a decision model and a motion model to simulate the interaction process between pedestrians and vehicles at uncontrolled, mid-block crosswalks. Although many studies have investigated the causes of and cures for crashes between people and vehicles at intersections, research related to determining the factors that contribute to crashes between pedestrians and vehicles on local streets without traffic signals is relatively rare. In this study, logistic regression and the Pedestrian Safety Margin index were used to model the significant factors that affect the risk of conflicts between vehicles and pedestrians at crosswalks with no traffic signals. Logistic regression is a reliable statistical approach for estimating the relationship between the response and explanatory variables in the traffic conflict field, as in [14][15]. The potential risk factors of crashes contain pedestrians' characteristics, the speed of vehicles, the features of the roads, and the features of any associated facilities in an actual situation. A study of the dangerous factors that affect the severity of pedestrian-vehicle conflicts in South Korea will lead to a better understanding of traffic safety issues.

II. Methods

B. Pedestrian Safety Margin

Pedestrian Safety Margin (PSM) has been defined in different ways in earlier papers [1] [16], and, in this research, we used the concept of the difference between the time at which a pedestrian crosses the street at a specific conflict point and the time at which the next vehicle arrived at that point [17]. PSM, which quantifies the degree of conflict between a vehicle and a pedestrian, was defined as shown in Fig.1. PSM is closely related to personal attributes, such as age or gender, the size of the group of pedestrians who are crossing the street, whether or not the pedestrians are vulnerable [18], how decisions are made about whether to cross the street or wait [19], and the average time delay until the next crossing opportunity.

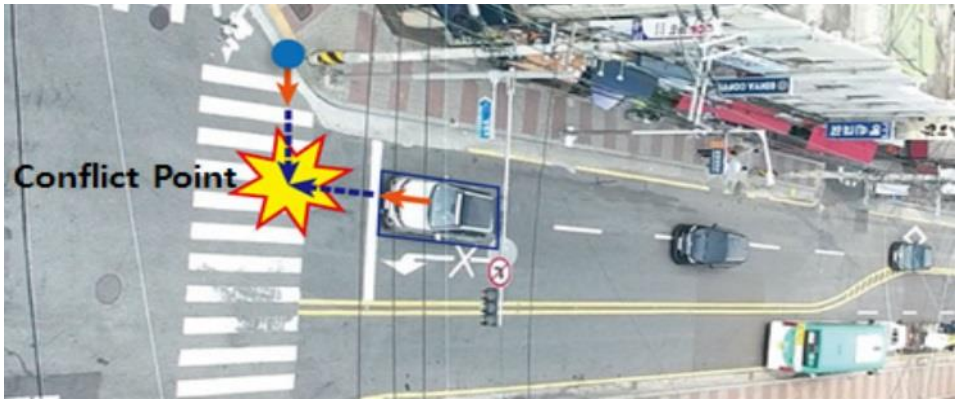

Figure 1. Concept of pedestrian safety margin

In this research, PSM is used as a measure to determine whether or not the risk of conflict exists. Normally, when providing warning of danger, the distance required to stop based on the speed of the vehicle is a crucial factor. The minimum time required for the driver to stop is based on the distance between the car and the pedestrian, the reaction time of the driver after perceiving the possibility of a collision, and the distance required to stop the vehicle with maximum braking. In this case, the speed at which the vehicle is traveling, the driver's perceived response time, and the friction coefficient of the roadway are important variables. In general, the driver's perceived response time is calculated by combining the risk factor judgment time of 1.5 seconds and 1 second required to activate braking. Therefore, in this study, we also analyzed the thresholds for more dangerous situations in which the PSM was less than 2.5 seconds.

C. Data Collection

Cross-sectional data were collected from different six locations at two sites, one in Suwon and one in Jeungpyeong, Republic of Korea. Both of the sites that were selected were local community streets that were identified as silver zones or school zones and had reported frequent traffic accidents. All collection points shown in Fig.2 are two-lane roads with traffic in both directions.

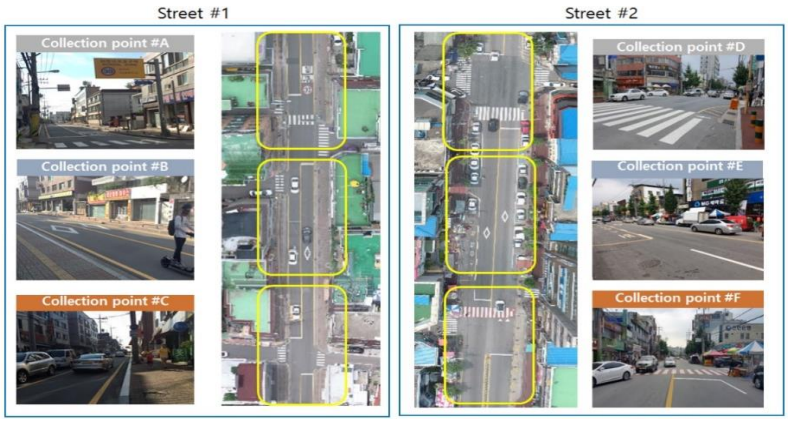

Figure 2. Survey location

The data were comprised of demographic characteristics, vehicle information, and video-recorded street information. The data required for modeling were extracted from these three sources of data, and they were used to calculate PSM, the speeds of the vehicles, the speeds at which pedestrians crossed the roadway. Based on the research method in reference [2], demographic characteristics, including age and gender, were assessed visually at research location. We made sure that the pedestrians were unaware that we were collecting data so that their behaviors would not be affected. We defined and collected indicators to assess the risk of pedestrian-vehicle conflicts, as in Table I, and the feature of the data collection point is revealed in Table II.

Table I Descriptive of the variable

Variables	Type	Unit or Code
Age	Discrete	0: Non-Elders, 1: Elders
Gender	Discrete	0: Women, 1: Men
Pedestrian platoon	Discrete	0: Single, 1: more than one
Jaywalking	Discrete	0: No, 1: Yes
Danger status	Discrete	0: No, 1: Yes
Pedestrian speed	Continuous	m/s
Vehicle speed	Continuous	Km/h
Pedestrian Safety Margin(PSM)	Continuous	Time in sec

Table II Survey area feature

		Feature of data collection point		Vehicle-related		Number of jaywalking	
Collection point		Facility	Topography	Average traffic per hour	Vehicle speed(km/h)	Elderly(%)	Non-Elderly(%)
Street #1	A	30 km/h speed limit sign +Unsignalized marked crosswalk	Flat	537	28.6±10.2	117(99.2)	185(91.0)
	B	No facility	Flat	639	39.9±12.2	171(100)	134(100)
	C	No facility	Gradient	611	40.1±20.8	66(100)	5(100)
Street #2	D	Unsignalized marked crosswalk	Flat	626	23.8±8.4	75(54.3)	41(33.9)
	E	No facility	Flat	567	30.1±9.8	34(100)	8(100)
	F	Unsignalized marked crosswalk	Flat	563	28.9±14.2	56(56.6)	2(28.6)
Summary				590	32.1±13.9	519(82.9)	375(78.5)

D. Logistic Regression Analysis

Logistic regression analysis can be used to illustrate the relationship between the binary response variable and the related factors, and this method was used to estimate the significance of the risk factors that influence traffic accidents. In this study, the response variable was defined if PSM is less than 2.5 sec considered as conflict risk status(Y=1) and if PSM over than 2.5 sec as non-danger status (Y=0). The probability of conflict risk is based on a linear combination function, as shown by equation (1).

$$logit(P) = ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_i x_i \quad (1)$$

where P is the probability of conflict risk, x is the explanatory variable, and beta is the coefficient of variables. The odds ratio (OR) illustrates the comparison of the risk status among different levels. The likelihood of the conflict risk status is defined as the probability of a conflict risk state divided by the probability of a non-danger conflict status.

III. Results

E. Descriptive Data

There were 1,104 conflict risk cases that were available for analysis, 17.7% of the total number of crossings occurred; 626 (56.7%) were elderly people, and 478 (46.3%) were non-elderly people. Table III shows the basic statistical information that was collected. The elderly people crossing speed was about 12.3% smaller than the non-elderly. PSM was calculated based on the analysis of the data of 1,104 pedestrian-vehicle conflicts. The results showed that there was a difference between the PSM of the elderly pedestrians and the non-elderly people. PSM is related to the speed of the vehicle, and the effects of the factors that could contribute to the risk of a collision were shown by the odds ratio against the reference level.

Table III Descriptive Statistics

		Number of conflict events			Pedestrian Safety Margin (sec)		Pedestrian crossing speed(m/s)	
Collection point		Total(%)	Elderly(%)	Non-Elderly(%)	Elderly(%)	Non-Elderly(%)	Elderly (Mean±StD)	Non-Elderly (Mean±StD)
Street #1	A	321(29.1)	118(36.8)	203(63.2)	3.93	4.39	1.44±0.41	1.61±0.39
	B	305(27.6)	171(56.1)	134(43.9)	3.63	3.96	1.48±0.44	1.52±0.46
	C	71(27.4)	66(93.0)	5(7.0)	1.54	1.78	1.37±0.45	1.45±0.48
Street #2	D	259(23.5)	138(53.3)	121(46.7)	3.79	3.83	1.27±0.40	1.42±0.37
	E	42(3.8)	34(81.0)	8(19.0)	3.41	3.71	1.48±0.47	1.55±0.48
	F	106(9.6)	99(93.4)	7(6.6)	3.24	3.27	1.05±0.21	1.04±0.24
Summary		1,104(100)	626(56.7)	478(43.3)	3.33	4.04	1.35±0.42	1.53±0.42

F. The Effect of Age and the Velocity of the Vehicle

This model shows the influence of age and the speed of the vehicle speed on the risk of conflict. The speed of the vehicle is a continuous variable that first must be categorized for convenient interpretation of the analysis, and, in this study, it was categorized into three groups, i.e., less than30 km/hr, 30-50 km/hr, and more than 50 km/hr. The descriptive statistics of the model are illustrated in Table IV, and the model shows that two variables, i.e., age and vehicle speed, are significantly influenced in the pedestrian safe road crossing. The probability of unsafe crossing increase when the elderly cross the road than the non-elderly does. The ratio of conflict risk for elderly people crossing is about 3.1 times higher than for non-elderly people. In terms of vehicle speed, the vehicle with less than 30km/h speed was used as reference, the ratio of conflict risk for vehicle with over than 50km/h speed is about 2.9 times higher than vehicle approaching with 30km/h, the difference between of vehicle speed 30~50km/h and less than 30km/h was found as insignificant in this model though.

Table IV Estimated coefficients

		B	S.E	t(p)	p-value	Exp(B)	95% Confidence Interval
Elderly		1.132	0.198	32.565***	0.000	3.101	2.102-4.573
Vehicle speed	30 km <= Speed < 50 km	-0.020	0.181	0.012	0.912	0.980	0.687-1.398
	50 km <= Speed	1.078	0.295	13.387***	0.000	2.919	1.650-5.237
Intercept		-2.519	0.188	178.639***	0.000	0.081	

Probability (Unsafe crossing) = -2.519 + 1.132(Elderly) + 1.078(Vehicle speed >= 50 km/h) (2)

The risk associated with elderly people crossing the road is higher than that of those less than age 55 as in Ref [20], and age had a positive correlation with PSM. In case of a collision with a pedestrian, the speed of the vehicle is one of the most important parameters that affect the result of the accident, and reference [3] identified the speed of the vehicle as the most influential factor. The velocity of

an approaching vehicle is the important factor that affects the risk of injuries to pedestrians in a collision, so we must consider safety measures, such as marked crosswalks when there is no traffic signal or speed limit signs to determine whether these measures can cause drivers to decrease the speed of their vehicles.

G. The Effect of Age, Road Facility, and Geometrical Features

The model aims to determine the effect of age, road facility, and geometrical features on the risk of conflict. Road facility variables are categorized into three groups, i.e., 1) non-facility zone, 2) unsignalized crosswalk zone, and 3) unsignalized crosswalk zone with a vehicle speed limit sign. The geometry feature is categorized into two groups regarding whether gradient topography or not. The descriptive statistics of the model are illustrated in Table V, and the model shows that two variables, i.e., age and gradient topography, have a significant positive influence on the probability of conflict risk with a vehicle.

Table V Estimated coefficients

		B	S.E	t(p)	p-value	Exp(B)	95% Confidence Interval
Elderly		0.657	0.216	9.256***	0.002	1.930	1.264 - 2.947
Gradient topography		3.076	0.346	78.943***	0.000	21.682	10.999 - 42.741
Safety facility	Unsignalized crosswalk	-0.241	0.221	1.187	0.276	0.786	0.509 - 1.212
	30 km/h speed limit sign + Unsignalized crosswalk	-0.928	0.290	10.235***	0.001	0.395	0.224 - 0.698
Intercept		-2.183	0.215	103.389***	0.000	0.113	

Probability (unsafe crossing) = -2.183 + 0.657(Elderly) + 3.076(Gradient topography) - 0.928(Speed limit sign) (3)

Compared to the non-elderly people, the probability of unsafe crossing is greater when elderly people cross the road. The ratio of conflict risk for elderly people crossing the road is about 1.93 times higher than the risk for non-elderly people, and the ratio of conflict risk of crossing at gradient topography road is about 21.7 times than non-gradient topography area. In terms of safety facility varible, no facility zone was used as reference. The vehicle speed limit sign showing 30 km/hr had an influence on the pedestrians being able to cross the road safely, and the ratio of conflict risk for a road with a speed limit sign at unsignalized crosswalk was about 0.395 times lower than no facility at an unmarked road. However, the effect of an unsignalized crosswalk was found to be insignificant in this model, so it can be concluded that a marked road without a signal does not have a positive effect on safe crossings.

IV. Conclusions

The aim of the present research was to identify the effect of age, vehicle speed, and road environmental factors on the risk of pedestrians' colliding with vehicles on the safety improvement of unsignalized roads by measuring the risk of conflict between pedestrians and vehicles. We acquired data using video equipment in order to extract the pedestrians' characteristics, and we extracted the secondary data to acquire the speed of an approaching car and the PSM between the pedestrian and the vehicle. Critical thresholds were classified for cases in which the PSM was less than 2.5 seconds. A total of 1,104 data with PSM were collected, and a logistic regression model was used to demonstrate the risk factors that affect the risk of conflict with a vehicle when pedestrians cross a local street that does not have any traffic signals. First, age was a significant variable in that older people tend to be at greater risk than the non-elder people, and this result was similar to that in [21]. There was an insignificant difference between the PSM of approaching vehicles that were traveling at speeds less than 30 km/h and those traveling at speeds in the range of 30-50 km/h. Interestingly, conflicts when the speed of the vehicles exceeded 50 km/h, the risk of conflict risk was higher than it was for vehicles traveling at speeds below 30km/h. The ratio of conflict risk for crossing gradient topography road was about 21.7 times greater than that for the non-gradient topography area. Regarding safety facilities, the 30 km/h speed limit sign influenced the risk situation of conflict. The ratio of conflict risk for a road with the safety facility was about 0.395 times lower than that for an unmarked road. However, the effect of a marked crosswalk without a traffic signal was found to be insignificant, so the result showed that a marked road without a signal has no effect on safe crossings.

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