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https://hdl.handle.net/2324/25577

出版情報：九州大学工学紀要. 72 (4), pp.103-114, 2012-12-17. 九州大学大学院工学研究院
バージョン：

Memoirs of the Faculty of Engineering, Kyushu University, Vol.72, No.4, December 2012

Predicting Pedestrian Conflict Avoidance Behavior on the Roads Surrounding Schools When Children Are Coming to and from Schools

by

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(Received October 30, 2012)

Abstract

Road traffic accidents when children arrive and depart from schools are the major cause of childhood injuries. In China, the school roads are typical of roads with mixed pedestrian and automotive traffic. The roads are narrow, and also have a very high traffic during the start and finish of the school period, which creates a high risk for children. The intent of this paper is to investigate ways of securing the road and guaranteeing the safety of children. In this research we use typical pedestrian's avoidance behavior as an indicator of the dangers to the children and discrete choice model methods of predicting the dangers. Through this model, we quantitatively evaluate the dangers existing in school roads, develop an understanding of microscopic mechanisms of road traffic, and conclude by quantifying and evaluating the possible effects of traffic improvement measures.

Keywords: School road, Time of to-or-from school, Pedestrian, Motor vehicle, Pedestrian avoidance behavior, Mixed traffic

1. Introduction

According to the WHO statistics, 1,270,000 people die from traffic accidents every year. Nearly half (46%) of them are pedestrian and bicycle users. These are collectively referred to as "vulnerable traffic participants". Road traffic accidents in mixed traffic environments are the main cause of children injuries. In 2007, the International Children's Security Network in China published a survey of Chinese children road traffic accident investigation. It showed, more than 30,500 children under the age of fifteen (almost one hundred per day) injured of road traffic accident. For every ten traffic injuries, four of the victims are children in the age range of five to nine years of age. Students meeting traffic congestion in route to and from school is quite common. At least 44% of the children

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in China meet very high risk situations at the peak times on the roads surrounding the schools[1). Although many of these injuries are due to the children not developing good walking behavior and discipline, there still is an existing road environment factor. There is not enough safe space for pedestrian walking.

The roads surrounding most schools contain typical mixed traffic situations. With the drastic surge in car ownership in China, the number of motor vehicles used to drive children is also growing rapidly, causing massive traffic chaos. Furthermore most schools were built over fifteen years ago; they were established without consideration to motor vehicle traffic. Therefore the roads surrounding schools are very old and narrow, usually less than six meters wide. Moreover, there are a lot of vehicles parked on the side of the road. Whether moving or parked, motor vehicles will occupy pedestrian space, which increases the risk of walking. The conflicts between pedestrians and motor vehicles are hard to avoid, which necessitates the need for conducting analysis research on the existing conditions and problems.

Mixed traffic flow is the main mode of transportation for most developing countries[2)]. There has been significant research in this field, especially in the area of pedestrian behavior at traffic intersections. These studies gathered data for automobile's driving speed and avoidance distances. For example, King et al.[3)] was based on factors such as roads section's driving speed in the nearside lane, traffic flow data and pedestrian exposure risk. This was done using quantitative and qualitative comparisons to show that when crossing the intersection, if 85% of the cars reduced their speed by 2km/h, the risk to pedestrian will be reduced by 28%. Hakkert et al[4)], concluded that the use of warning signs can lower the vehicle speed by 2-5km/h, which reduces the pedestrian risk by 28%. Kaparias et al[5)] combine security, complexity and spatio-temporal factors to describe the microscopic conflict behavior based on pedestrian-vehicle conflicts analysis method. Shuming Feng et al[6)] studied the conflicts between pedestrians and double direction vehicles at intersections, which often lead to car delays and accidents. However, these researches pay more attention to motor vehicle collision avoidance behavior, instead of pedestrians.

Other research has used traffic accident data for analysis. Kim[7)]uses discrete choice models to analysis the pedestrian and non-motorized influencing factors, based upon 1997-2000 American Northern California pedestrian traffic accident data. Diogenes et al.[8)] established Poisson distribution to analyze safety factors which impact pedestrian, basing on the 1998-2006 Brazil Xuan Gerry Lane City pedestrian accident data. However accidents are relatively rare and in more dangerous conditions, individual behavior will become more careful and prudent. This results in difficulty in collecting accident observation data. To conclude although the relationship between pedestrians' avoidance behavior and traffic accidents have not been established, still it is easy and plentiful source for external observation. Therefore this study uses avoidance behavior as a risk assessment indicator.

China's mixed traffic has a definite influence in the roads surrounding schools. There have been very few studies regarding safety analysis in these schools. In this study, pedestrian conflict avoidance behavior is used as a direct indicator of the level of danger that walkers believed they face. The factors of the model are the car's motion and position relative to the pedestrian. Through this model, we can quantitatively evaluate the dangers on the roads surrounding schools; this provides a realistic understanding of microscopic mechanism of road traffic. With this data we can quantify and evaluate the possible effects of various traffic improvement measures.

2. Pedestrian Conflict Avoidance Behavior

2.1 The definition of pedestrian conflict avoidance behavior

When walkers perceive danger from approaching running motor vehicles, the normal behavior is as follows: a) Changing the walking direction, resulting in moving more closely to the roadside; b) slowing the walking speed; or c) stop walking.

The three behaviors mentioned in the above paragraph are the definition of pedestrian conflict avoidance behavior in this research. These actions or reactions of pedestrians can be readily observed. Reasons that cause the psychological pressure for pedestrian to engage in the above behavior are for example: a) the distance between the walker and running vehicle is too close, or b) the speed of motor vehicle is too fast. This study concentrates on analyzing these factors.

2.2 The survey sites

The study sites in this research are the roads surrounding two primary schools. In China, these types of roads have the following characteristics: a) Pedestrians and motor vehicles mix traffic; b) The roads are narrow, the width is almost always less than 6 meters; c) traffic is heavy, especially at the time students arrive and leave the school; and d) vehicles are parked along the side of the road.

Choosing the appropriate roads for data collection is crucial for the reliability of the study. Upon considering the efficacy of various roads, we chose two for the study, one road is near shanghai Huinan Town primary school attached to GongShang University and the other is near Nanhui No 2 primary school, the environment for observation are shown in **Fig.1** and **Fig.2**.

Fig.1 The first survey site.

Fig.2 The second survey site.

The width of both roads is very narrow. The first road is 4.5 meters wide, while the second road is 5.5 meters wide. Both roads are the major access to the schools. That means during the times of commuting to the school and leaving the school there will be a very high flow of pedestrians and automobiles with student passengers. The average traffic flow as well as pedestrians flow during the start of school time is higher than that during the end of school time, because different grade in the same school has different after school time in China. Results are illustrated in **Table 1** and **2**. Moreover, in the second road, maximum value of traffic flow reaches to 618 vehicles/ hour, while pedestrians flow reaches to 840 people/ hour.

Table 1 Average flow of traffic (vehicles/hour, including motorcycles).

	Start of school time	End of school time
First survey site	417	364
Second survey site	536	506

Table 2 Average flow of pedestrians (people/hour).

	Start of school time	End of school time
First survey site	458	392
Second survey site	676	540

2.3 Observation method

Figure 3 shows the shooting method. The observational interval is thirty meters long, and is divided into two parts. Physical objects were chosen as reference points for the two endpoints and the one midpoint. These objects were a telephone pole, a tree, and a drawing line on the ground. These markers were obvious and easily identifiable. The purpose of the markers was for counting the speed of the motor vehicles. The interval for the unit shooting time was 0.01 seconds. There was sixty minutes of video taken at each site during the peak hours of travel to and from the schools.

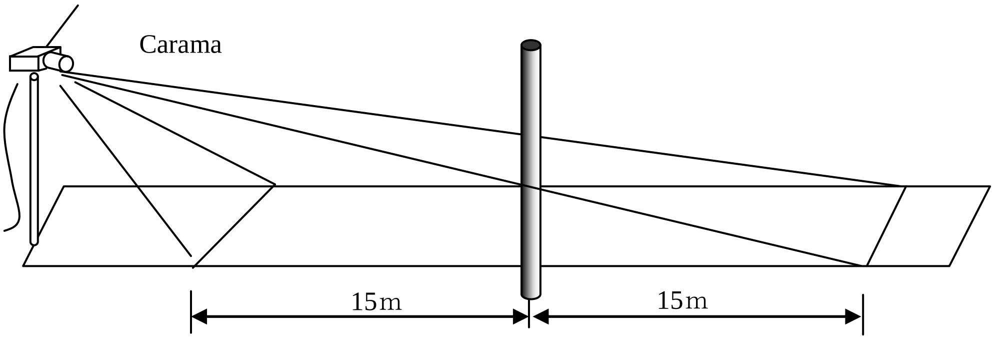

Fig.3 Shooting method.

2.4 Observation object

Because these roads have no legal restrictions for the flow and direction of traffic, the circumstances and situations for which pedestrians and vehicle will encounter each other are very complex. For instance motor vehicles driving from behind may come up to pedestrians or there could be head-on encounters with pedestrians. Situations where pedestrians meet oncoming motor vehicles are more dangerous than other situations. In this circumstance passengers can easily perceive the high risk and take avoidance behaviors. This is the point where observations are collected, as shown in **Fig.4** and **Fig.5**.

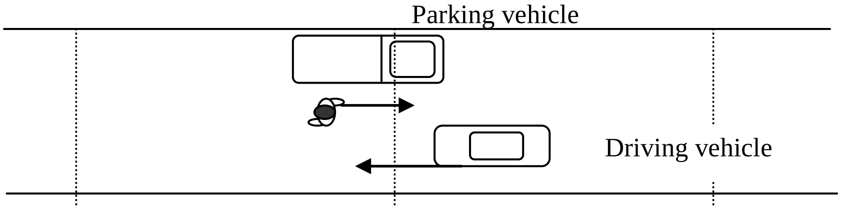

Fig.4 Head-on encounters with pedestrians who walking in the parking vehicle side.

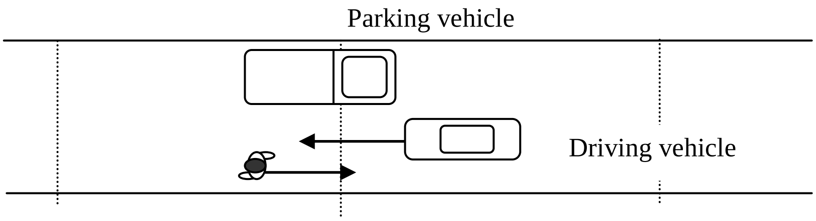

Fig.5 Head on encounters with pedestrians walking in the contrary of parking vehicle side.

2.5 Statistics

2.5.1 Statistical items

Data acquisition day was March 2012. The time periods were 8:20-8:50 AM (school arrival peak time) and 4:20-4:50 PM (school departure peak time).

There were 125 observations where chosen for the model, of which 49 were automobiles or larger vehicles and 76 were motorcycles. Of the 125 samples, a total 85 were observed to execute contact avoidance behavior. From the 85 samples that exhibited avoidance behavior, 72 samples changed directions to be closer to the roadside, five samples stopped, and eight samples slowed their speeds. Most avoidance behavior consists of changing direction to maintain a certain distance from the oncoming motor vehicle. The statistical items that were collected were the speed of the oncoming vehicle, the distance between the pedestrian and the vehicle when they passed each other, whether there was observable avoidance behavior, whether vehicles passed each other, and how the pedestrian was walking (for example individually, two people side-by-side and three side –by-side).

In this research, occurrences of vehicles passing other vehicles are depicted in **Fig.6** and **Fig.7**. Instances of passing, where vehicles are side by side, were recorded and are illustrated whether the vehicles were driving in different or the same direction. The two situations are all defined as “vehicle staggering”.

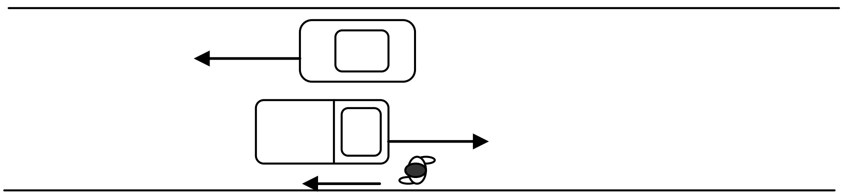

Fig.6 Situation one: vehicles driving in different directions.

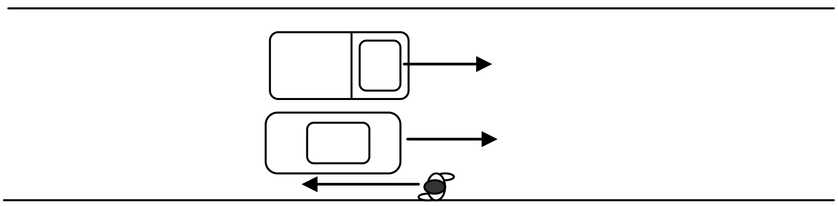

Fig.7 Situation two: vehicles driving in same direction.

Except for motor vehicle speed and the distance between passengers and vehicles, the value of the other factors can be obtained directly. The following methods were used to count the vehicle speed and the distance between the passengers and the vehicles.

Distance: The length of the distance between the passengers and the vehicles was calculated as a proportion to the width of the road.

Speed : The time points where the vehicles entered and left the observed road sections was calculated, through those collected times the period required to pass through the observed road section would be calculated, and then use the length of the defined observed road section to divide the time. This would yield a rate of speed.

2.5.2 Statistical result

(1) Effect of distance

The relationship between pedestrian avoidance choice behavior and the distance between passengers and vehicles is demonstrated in **Fig.8**.

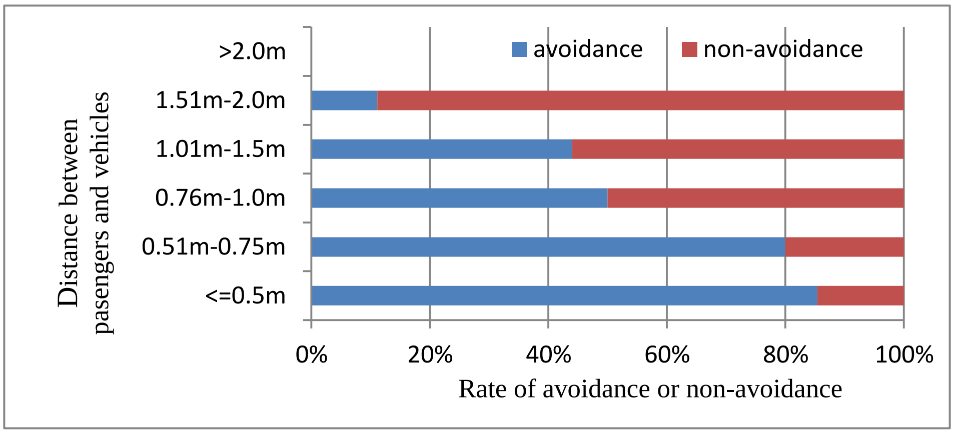

Fig.8 Distance-avoidance behavior diagram.

The vertical axis is the distance between sample pedestrians and moving motor vehicles when they pass each other. The horizontal axis is the rate of avoidance (blue) or non-avoidance (red). It can be seen from the figure that the shorter the distance, the greater the avoidance rate. When the distance is less than or equal to 0.5 meters, the avoidance rate reaches 85.4%. When the distance is 1.51 to 2 meters, the rate is only 11.1%. However when the distance is greater than two meters, the rate becomes zero. The average distance in the avoidance situations is 0.664 meters, but in non-avoidance situations the distance is 1.165 meters.

(2) Effect of speed of the motor vehicles

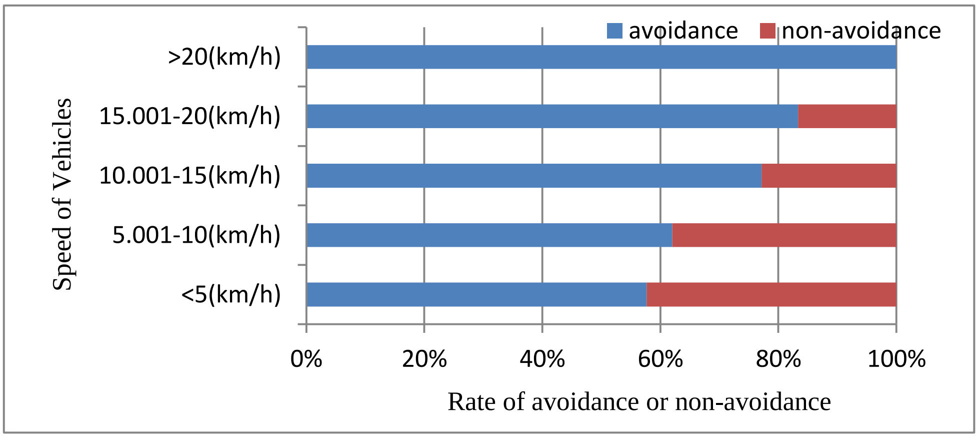

Fig.9 Speed-avoidance behavior diagram.

The relationship between amount of speed and the avoidance rate is demonstrated in **Fig 9**. The figure shows that the faster the speed, the higher the rate of avoidance. When the speed is greater than 20 km/h, the avoidance rate reaches 100%. Even when the speed is less than or equal to 5 km/h, the avoidance rate is still 57.7 %, because the roads are very congested with traffic. The speed of observed samples correlates to greater avoidance behavior. The average speed of vehicles where avoidance behavior is observed is 9.8 km/h, compared to an average of 7.5 km/h for where there is no avoidance behavior observed. The conclusion is that the faster the speed, the greater the avoidance behavior.

(3) Effect of vehicle staggering

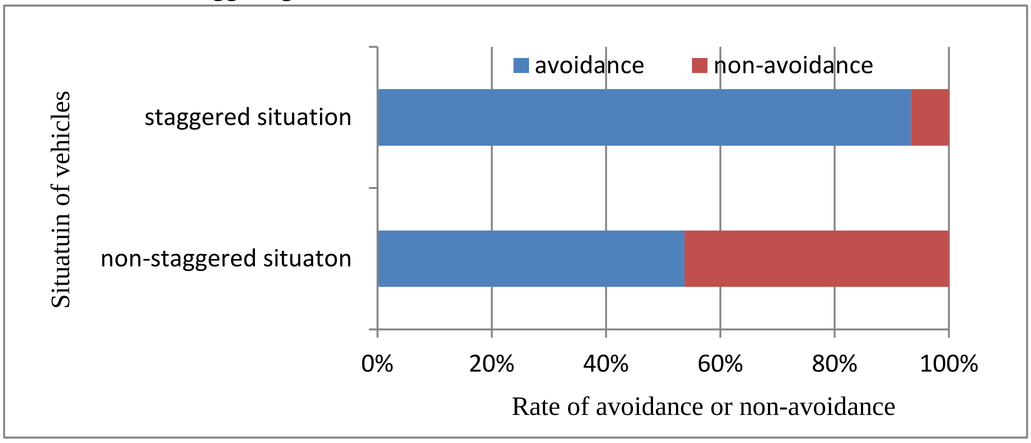

Fig.10 Staggering vehicles-avoidance behavior diagram.

The above figure shows the corresponding rate of avoidance conditions on whether vehicles pass side by side or not as the cases shown by **Fig.6** and **Fig.7**. In conditions of this vehicle staggering conditions, the avoidance rate is 93.3 % compared with 53.8 % in non-staggering conditions. The conclusion could be made that staggering vehicles produce an apparent, but still significant, effect on the avoidance rate. When vehicles drive side by side (in either the same or opposite directions), the vehicles will occupy a large portion of the walking space and necessitate pedestrian avoidance behavior.

(4) Effect of the type of the motor vehicles

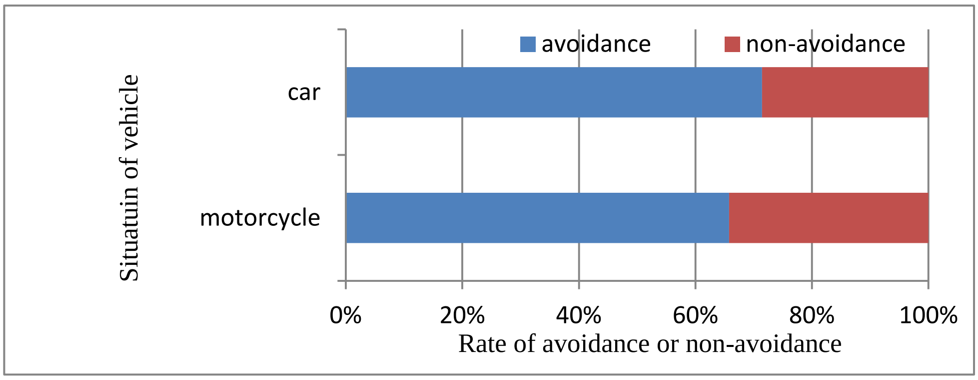

Fig.11 Vehicle type-avoidance behavior diagram.

There were just two types of motor vehicles observed in the study: cars and motorcycles. With observations involving cars, the avoidance rate was 72.4 %. This was slightly higher than the avoidance rate for motorcycles, which was 65.9 %. This result is logical and to be expected, as the cars volume and space displacement of the road would be greater than the motorcycle.

(5) Effect of different pedestrian walking situations

The following figure shows the avoidance rates on different states of walking situations. In this research all the observations involved three different situations of people walking. The research recorded 87 cases of individual people walking by themselves, had 34 cases of two people walking side by side, and only four cases of three people together walking side by side.

The avoidance rate of individuals was 67.8 %, where two people were walking together the avoidance rate was 64.7 % and when three people were walking together the avoidance rate was 100 %. In general it would seem logical that when more than one person is walking side by side, the avoidance rate would be higher, because multiple walkers occupy a larger road space. However in this study when two people are walking side by side, the number of motor vehicles on the road was less than with individual pedestrians, so that the level of the danger that two pedestrians perceived was apparently reduced. This resulted in a slightly smaller rate of avoidance behavior for paired pedestrians. If the observations for two and three people walking together are combined, this would be termed as group walking, the avoidance rate would be 68.4 %, which is a rate slightly greater than individual pedestrians.

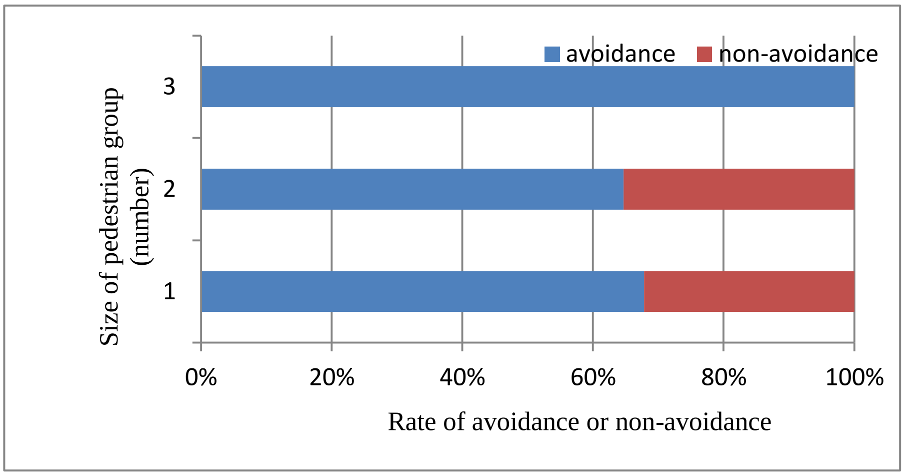

Fig.12 Walking situations-avoidance behavior diagram.

3. Conflict Avoidance Behavior Prediction Model

3.1 Model mechanism

The steps that pedestrians take leading up to avoidance behavior are as follows: pedestrians initiating such behavior are based on factors as the speed and distance of oncoming vehicles and the subjective identification of the danger presented by the vehicle. Based on this quick analysis the pedestrian would make a hurried determination on the need to generate yielding behavior or not. The yielding behavior occurred when passengers determined that the risk exceeded a certain threshold. In this study, a disaggregate behavioral logit model was used. This model is one of the method that has been used in psychophysical researches. This model was mathematically calibrated by this kind of subjective judgment caused by psychological factors. The formula used to calculate the utility of the degree of danger and its threshold is as follows.

The formula for the degree of danger (D) is represented as formula (1). The independent variables consist of road conditions, and other relevant factors such as motor vehicle speed and distance. These are called external factors.

$$D = \sum \alpha_i X_i \qquad (i = 1,2,3,4) \tag{1}$$

In the above formula, α_i are the parameters need to be estimated. X_1 is the distance between the pedestrian and the motor vehicle when they pass each other (m), X_2 is the presence or absence of vehicle staggering (one presence or zero absence), X_3 is the speed of the oncoming vehicles (m/s), and X_4 is the type of motor vehicle (one motorcycle or two cars).

The threshold value (D_0) consists of the factors relevant to the pedestrian status (internal factors), such as the walking situations. The avoidance behavior occurs on the condition that D exceeds D_0 .

$$D_0 = \beta_1 + \beta_2 Y_1 \tag{2}$$

In the above β_1 and β_2 are parameters need to be estimated. The walking situations are defined as $Y_1 = 1$ (single walking), $Y_1 = 2$ (two people walking side by side), and $Y_1 = 3$ (three people walking side by side).

The model has two selections, avoidance occurrence and non-occurrence. The probability of D exceeding D_0 (avoidance occurrence) is demonstrated on formula (3)[9].

$$P_{N1} = \frac{\exp(D)}{\exp(D) + \exp(D_0)} \tag{3}$$

The non-occurrences avoidance probability is demonstrated on formula (4) [9].

$$P_{N0} = \frac{\exp(D_0)}{\exp(D) + \exp(D_0)} \tag{4}$$

3.2 Estimation of parameters

An estimation of the parameters using the maximum likelihood method, the result is depicted in table (3). The next step was to determine the reasonableness of this model.

Table 3 Result of the estimation.

		parameters	T-value	Loglikelihood ratio	Consistent rate (%)	Number of samples
α_1	The distance between pedestrian and motor vehicles (m)	-2.23	-3.37***	0.38	84	125
α_2	Whether vehicles passing by each other or not	2.18	3.04***			
α_3	Speed of motor vehicle (m/s)	0.81	3.2***			
α_4	Type of motor vehicle (car or motor cycle)	0.96	1.8**			
β_1	Constant	1.92	1.24*			
β_2	Walking states	-0.71	1.32*			

Note: ***significant at 0.01 level. ** significant at 0.05 level, *significant at 0.15 level

3.2.1 Signs of the coefficients

Signs of the coefficient are within the scope of general knowledge.

(1): The distance between the motor vehicle and the pedestrian

If the distance is shorter, the greater the level of danger and pedestrians would be more prone to avoidance behavior. The sign should be negative. The statistical result is consistent with what would be expected with the actual conditions.

(2): Whether vehicles pass by each other or not

When pedestrians and motor vehicles pass by each other, there may be other vehicles that will pass the situation side by side, making the road more crowded and provide even less space for walking. This makes avoidance behavior more likely by the pedestrian.

The analysis of the data shows that most of these staggering samples involved avoidance behavior by the pedestrian. Therefore this circumstance should be positively correlated to the generation of avoidance behavior, the sign should be positive. The statistical result is consistent with what would be expected with the actual conditions.

(3): Speed of motor vehicles

The faster the oncoming vehicle, the greater the level of danger, and the probability of making appropriate avoidance behavior to maintain safety also increases. Therefore this statistics should be positively correlated to avoidance behavior generation. The sign should be positive. The result is consistent with what would be expected with the actual conditions.

(4): Type of vehicles

The volume of cars is greater than that of motorcycles. Therefore the avoidance ratio when a pedestrian encountered a car should be greater than when a pedestrian encountered a motorcycle. The sign should be positive.

(5): Walking situations

The larger the walking group, the more prone the group will be take avoidance behavior, the probability of a non-occurrence avoidance should be low. The sign should be negative. The result is consistent with what would be expected with the actual conditions.

3.2.2 T-test

The T-test is used to judge the degree of reliability with the coefficients. When the Degrees of Freedom (DOF) reaches infinity, it the T-value is greater than 1.6446, the reliability can reach 90%. Although the Degrees of Freedom in this study do not reach infinity, the t-Values are all high and significant. Therefore these results have a great degree of trust.

3.2.3 Log-likelihood ratio

After adjusting the degree of freedom, the log-likelihood ratio reaches 0.38. This indicates a high level of significance.

3.2.4 Hit-ratio

The consistency share between the theoretical selection probability and the actual choice reaches a level of 84%, which means the study and the model used in the study has a high degree of replication and consistency.

4. Discussions

In this study the mechanism used to identify risk is the pedestrian avoidance rate. This means the higher the pedestrian avoidance rate, the higher the degree of risk. The focus of this section is how to improve road safety and be able to reduce the pedestrian avoidance rate. This study focused on two factors, restriction of speed of vehicle and widening of road space .

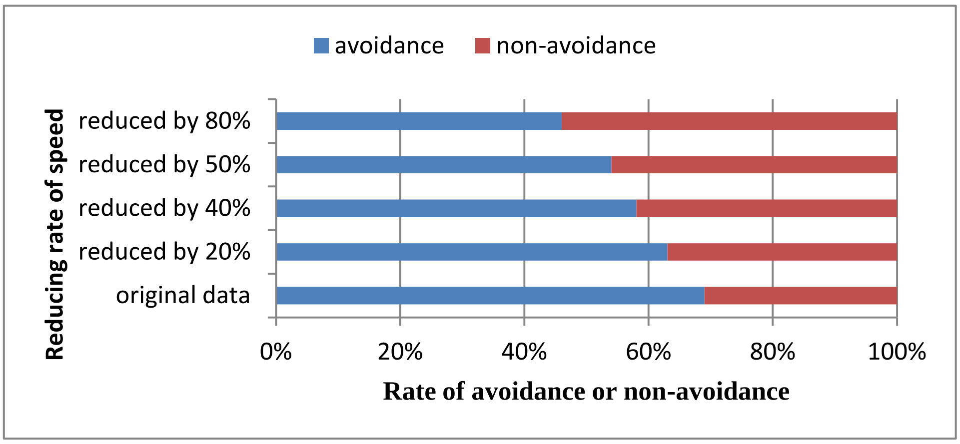

Fig.13 The avoidance ratio after reducing speed.

First, the effect of reducing motor vehicle speed was examined. Using all observed data in Chapter 2 as an original data in the previous model, and changing the speed by reducing at some rates, 20%, 40%, 80%, the rate of avoidance behavior was calculated at each speed. The effect of reducing motor vehicle speed is shown in **Fig.13**.

Second, the effect of the distance between pedestrian and vehicle was examined. Like the first examination, using the observed data as original data, and changing the distance between pedestrian and vehicle in the model, the effect of the distance was calculated. The result is shown in **Fig.14**. Generally, in situations where the flow of traffic and pedestrians are in the same or different direction, if the road becomes wider, there will be more room for walking. This additional space means the distances between vehicles and pedestrians will become greater also. This impact could be used to represent the effect of widening the road.

As the results show, the effect created from widening the road is almost same as by reducing the speed of the oncoming vehicle. But widening the road is better method than reducing speed, because during the peak hours, the flow of traffic and pedestrians is very heavy. At this point the roads are reaching the point of saturation. The speeds are already very slow and the degree of the reduction of space is minimal.

From this examination, broadening the width of the road in this case is the relatively better choice to optimize road safety. But in practice, there are some problems, estate for widening road space, construction cost and so on, with broadening the width of the road. There are also other factors to cause the change of people's behavior except vehicle speed and the distance between walker and vehicle. To do more detailed research, Those Factors should be combined with the proposed models in the future.

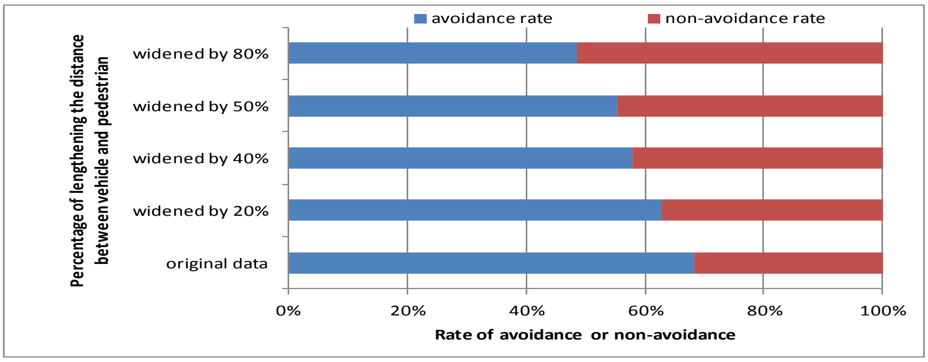

Fig.14 The avoidance ratio after expanding distances.

5. Conclusions

Guaranteeing the security of the roads surrounding schools is a significant and important way for reducing the frequency of traffic accidents involving children. This study uses the pedestrian conflict avoidance rate as the indictor to the pedestrian, through observing the behavior and road conditions during the start and finish of the schools day, in order to create a pedestrian conflict avoidance prediction model. The probability of this model is a function of the type of vehicle, speed, distance and pedestrian attributes. The results showed that the model has a reliable replicability. Finally in order to improve schools safety and reduce pedestrian avoidance behavior, policy analysis was made through this model. The conclusion was made that to widen the road would almost have the same beneficial impact as by a reduction of the speed of the oncoming vehicle. However the study also proposed that traffic flow, as well as parked vehicles; will also have a great impact on road safety. This study was not an in-depth exposition of these factors. Further research is required in this these areas of study and observation.

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