Logical Definition and Application of Expressway Network Guide Sign System

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Abstract

During the design and administration of expressway traffic signs, people always treat one single sign, instead of thinking about the relationships of signs on an entire network composed of different expressways. In fact, traffic signs, especially the guide signs, act as a system, which seems to have great logic. Their locations, types and information on the panels are reasonable and correlative. The paper designs the topology model of the expressway network, with the consideration of exits, entrances, interchanges and nodes of expressways, makes a logical definition of the guide signs, and discusses the relationship between the guide signs' logical definition and expressway network topology. With the logical definition, there are a lot of applications, such as automatically choosing as well as altering the guide signs that are related to the added expressway or the dropped one, and altering the relative guide signs with the adjustments of the topology of the expressway network during the expressway rebuilding and traffic administration.

Key words: *guide signs, expressway network, topology, information management system, traffic administration*

1 Introduction

As the expressway system develops as a network, it is more and more difficult to add guidance for expressway users. Guide signs, which contain the most important parts of the traffic information, are becoming quite complicated in their information and locations. Guide signs help drivers to choose their routes, show them where to get into the expressway and where to get off, and also tell them how far are their destinations. So the information and locations of guide signs have a close relationship with the topology of the expressway system. In the meanwhile, it is necessary to set guide signs in groups to give enough information to the drivers and help them to make decisions during their journeys. It is of great use to study the logic of the information and locations of guide signs to make correct guidance for the drivers, as well as making the work easier and more effective for the expressway administrators.

2 The Expressway Network Topology Structure

As the location and information setting on guide signs are decided by the expressway network topology, it is necessary to build the topology structure of the expressway network before studying the logical definition of guide signs. The route is the basic element of an expressway, and then there will be primary reference points, such as exits, entrances, the starting point, and the end point. In the end, there should be shifting information, which mainly consists of information of interchange ramps and ramps of exits and entries.

2.1 Expressway network and nodes

There should be two nodes (the starting point and the end point) for the radial expressways and more for the annular ones. The basic topology (see Figure1.) could be built by lines referencing the routes and points referencing the nodes. Then, there should be KM-number system put on the lines. After this, there should be the relationship between the Descartes coordinates and the linear coordinates within the precision. For each node, there should be a pointer in the database to indicate which expressway it belongs to.

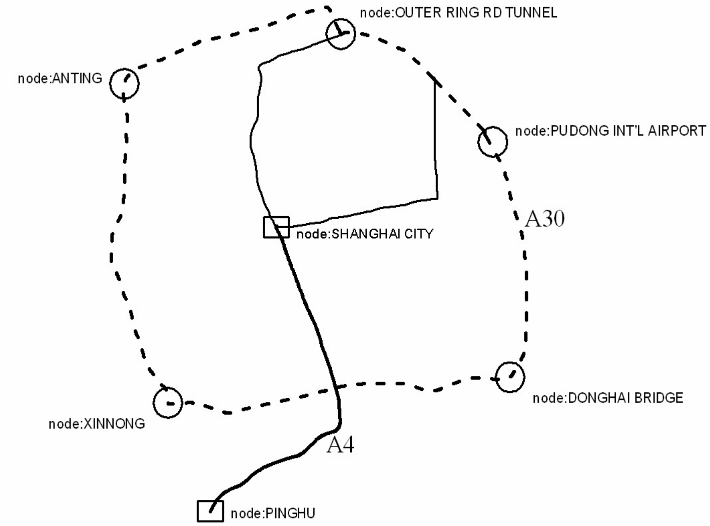

Figure 1. Basic Expressway Topology

2.2 Topology of exit, entry and interchange ramp systems

In the basic expressway topology, each expressway is treated separately. There is neither the information of showing how to get into or off the expressway nor the information of shifting between expressways. So the topology information of entries, exits and interchange ramps should be added to the topology model (see Figures 2 and 3), and Tables 1, 2 and 3 show which kinds of information should be involved.

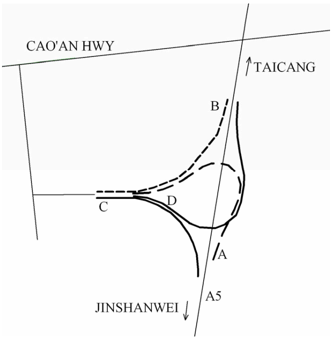

Figure 2. Topology of Exit and Entry Systems

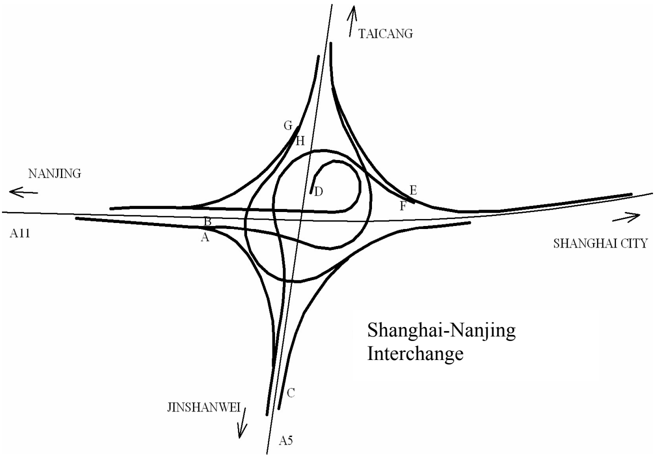

Figure 3. Topology of Interchange Ramps

Table 1. Topology Information of Exit System

Exit_NO	Exit_Name	Expwy_NO	KM-number	Ramp_ID	Expwy_Node	Ramp_Type
5	CAO’AN HWY	A5	23000	A	TAICANG	Left
5	CAO’AN HWY	A5	22750	B	JINSHANWEI	Right

Table 2. Topology Information of Entry System

Entry_NO	Entry_Name	Expwy_NO	KM-number	Ramp_ID	Expwy_Node	Ramp_Type
15	CAO'AN HWY	A5	23000	C	TAICANG	Left
15	CAO'AN HWY	A5	22375	D	JINSHANWEI	Right

Take Exit ramp A in Figure 2 for example. Table 1 shows that the exit number is 5; the exit name is CAO'AN highway; the exit belongs to the A5 expressway; the KM-number on A5 of the starting point of the ramp is K23+000; the ramp of the exit is named A; the ramp starts from A5 with the direction of to-Taicang; and the ramp type is left-turn.

Table 3. Topology Information of interchange Ramps

ID	Name	Exit_NO	RP_ID	S_EPX	E_EPX	S_KM	E_KM	S_Node	E_Node	RP_Type
12	Shanghai -Nanjing	2A	A	A11	A5	11400	11625	SHANG-HAI City	JIN-SHAN-WEI	Y-Right
12	Shanghai -Nanjing	2A	B	A11	A5	11400	10650	SHANG-HAI City	TAI-CANG	Y-Left
12	Shanghai -Nanjing	6	C	A5	A11	12000	3097	TAI-CANG	SHANG-CITY	A (of AB)
12	Shanghai -Nanjing	6	D	A5	A11	11125	11400	TAI-CANG	NAN-JING	B(of AB)
12	Shanghai -Nanjing	2A	E	A11	A5	3097	10575	NAN-JING	TAI-CANG	Y-Right
12	Shanghai -Nanjing	2A	F	A11	A5	3097	11625	NAN-JING	JIN-SHAN-WEI	Y-Left
12	Shanghai -Nanjing	6	G	A5	A11	10575	11400	JIN-SHAN-WEI	NAN-JING	Y-Right
12	Shanghai -Nanjing	6	H	A5	A11	10575	3097	JIN-SHAN-WEI	SHANG-CITY	Y-Left

Take ramp A in Figure 3 for example. Table 3 shows that the ramp belongs to the interchange named Shanghai-Nanjing with the ID of 12 in the database and the exit number is 2A; the ramp name is C; it takes the function of making shift-driving from A11 with the to-Shanghai-city direction to A5 with the to-Jinshanwei direction; the ramp starts from A11 K11+400 and ends at A5 K11+625; the ramp type is turn-right of the Y-type.

3 Logical Definition of Guide Signs on the Expressway Network

When the topology is built, it is time to make the logical definition of guide signs follow the relative design and plan rules. In the topology model of the expressway network, the reference points (consisting of exits, entries, interchanges and the nodes), divide an expressway into several sections. Within each section, there are rules to set a group of guide signs. Figure 4 shows how to set guide signs on a section (on the A5 expressway, with the to-Taicang direction, from the reference point of Cao'an highway to the reference point of Bao'an highway).

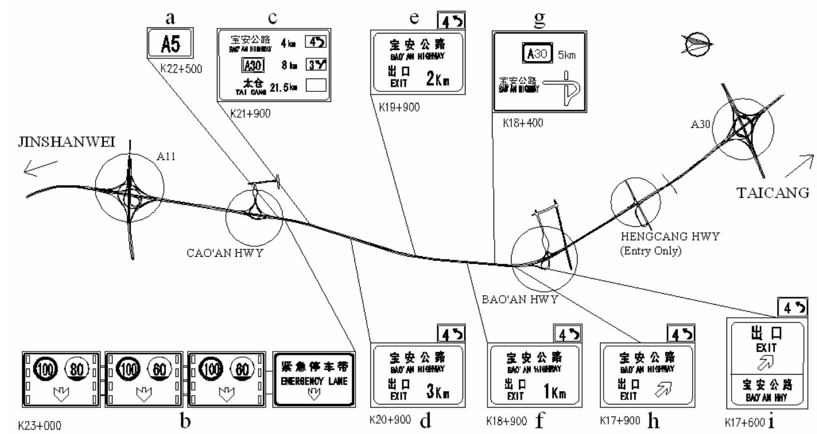

Figure 4. Guide Signs on an Expressway Section

There are rules for the setting of these guide signs according to the section topology. As shown in Figure 4, at the end of the entry ramp, where one gets into the expressway, there should be an Expressway-Number sign (Sign a in figure 4) announcing the number of the expressway, which is A5 in this instance. Then there should be a group of Lane-Speed-limit signs (b) to advise expressway users about the permitted speed range or function of each lane. Also there should be a Destination-Distance sign (c) to give users the information of the next exit, the exit past the next, and the node to arrive in the current direction on the expressway. The information of each destination consists of name, distance, exit-number and exit ramp type (for the next exit and the exit past the next). The information has close relationship with the expressway topology information, for the destination is either a reference point or a node; the distance is decided by the KM-number on the road, and the exit number is decided by the exit number system of the entire expressway. The exit-ramp type just represents the exit topology. When it comes to the zone near the exit, there should be Exit-Advance signs (d,e,f), and they should be placed at 3km, 2km and 1km in advance of the beginning of the decelerating lane carrying the distance information. At 0.5km before the beginning of the decelerating lane, there should be a Diagram-Advance sign (g), and a diagram giving the shape of the interchange, or exit ramps should be placed on the sign panel with the name of the exit and next exit or the number of the expressway to shift to, as well as the distance to the next exit or expressway. At the beginning of the decelerating lane, there should be an Exit-Direction sign (h) with the same face-design as the Exit-Advance signs, except that there should be an arrow instead of the distance information. An Exit-Gore sign (i) should be located where the ramp branches from the main road. For the Exit-Advance sign, the Exit-Direction sign and the Exit-Gore, there should be a small panel carrying the information of the exit number and the exit type on the right top of the main panel.

4 Application of the logical definition

In the situation of dropping the exit ramp of the reference point of Bao'an highway on A5 expressway with the direction of to-Taicang (see Figure 4), in this direction, the section of Cao'an highway to Bao'an highway and the section of Bao'an highway to Hengcang highway would combine into one, and the guide signs placed on the primary two sections should be modified. As shown in Figure 4, Sign a and Sign b would get no change, while the others would be updated or dropped and some new signs should be placed. On the panel of Sign b, the information on the first line would be of the primary information of the second line(A30), and the second line would carry the information of the exit past A30(for Hengcang highway has only entries), and the bottom line of the node information would remain unchanged. Signs d, e, f, g, h and i would be dropped for they carry the topology information of Bao'an highway exit. There would also be some modification on other sections for their signs to carry information of the dropped exit.

5 Conclusions

As the expressway network becomes more and more complicated, it is getting harder and harder to set guide signs to guide road users clearly, and the administration of the signs is becoming a difficult job. With the logical definition of guide signs based on the topology model of the expressway network, an information management system of expressway guide signs could be built which will help to make efficient administration of guide signs.

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Research on Pedestrian-Vehicle Collision Model and Simulation Calculation

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Abstract: In recent years vehicle-pedestrian crash is significant, and pedestrian safety has been a serious problem all over the country. The conflict between the vehicle and the pedestrian is the key to the pedestrian safety research and a road layout safety plan. Based on the traffic conflict technology, this paper sets up the vehicle-pedestrian conflict model and vehicle-pedestrian crash model in the condition of one pedestrian crossing a single lane. In addition, the Monte-Carlo system simulation is used to calculate the probability of vehicle-pedestrian collision. With the tool of spatial analytic geometry, the Volume-Speed curve is built as the condition of setting pedestrian safety device.
Key words: *Pedestrian Vehicle System, Pedestrian Safety, Conflict Technology, Pedestrian-Vehicle Collision Model, Monte-Carlo Simulation*

1 General

In the recent years, the vehicle-pedestrian accident rate has been high in China. During 2003-2005, 53407 pedestrian casualties happened due to their violation behavior. Pedestrian accidents make up 17% of all the road traffic accidents [3]. Pedestrian safety has been a significant problem in China, and it is essential to provide a safe walking environment.

The conflict between pedestrian and vehicle is the key to the pedestrian safety research. Historical data shows that careless pedestrian rushing into the vehicle lane is one of the main causations for the pedestrian vehicle accident [6]. From the viewpoint of pedestrian safety, it is very dangerous for a single pedestrian to cross a free traffic flow [4]. There is neither an effective method to evaluate pedestrian's crossing behavior nor a standard to set pedestrian protection devices such as zebra crossings, traffic control signals etc. in China. Such problems could be solved by studying the probability of pedestrian vehicle conflict rate.

Road traffic accident especially the pedestrian-vehicle accident is such a random issue that it is almost impossible to get the traffic flow character when the accident happened. Thus it is more feasible to set up a simulation model to study the situation.

Ashton induced the relationship between speed distribution and pedestrian-vehicle collision in 1982 and the probability of being collided to death was calculated to illustrate the contribution of vehicle speed to the casualty [8]. Pasanen developed Ashton's model and Gray used the model to evaluate the effectiveness of Local Traffic Calming Device [4]. Xiaoliang Ma utilized the pedestrian vehicle conflict simulation to evaluate the Intelligent Speed Adaption System [8]. Ashton and Pasanen's conflict and collision possibility model pays more attention to the speed variation. However, the traffic volume is not involved. Secondly, the road traffic environment and pedestrian's behavior in foreign countries differs widely from that in China so that the model could not be fully applied. Moreover a pedestrian's critical gap which represents his safety perception is not included in the above models, which is essential.

Based on the traffic conflict technique, the pedestrian vehicle conflict and collision model when a single pedestrian crosses a free-flow traffic lane is built and Monte—Carlo simulation is used to calculate the probability of pedestrian conflict and collision in different traffic condition. According to the calculation result, the justification for setting a pedestrian control device is discussed in the end.

2 Pedestrian-Vehicle collision model

2.1 Conflict mechanism

The procedure of pedestrian vehicle conflict when a pedestrian crossing the street is shown in Figure. 1.The vehicle and pedestrian's characters are described by t_p and t_v which represent the time they take to reach the conflict point. V_v is the initial speed of vehicle, d_v the distance from the conflict point, V_p the pedestrian's walking speed, and d_p the pedestrian's distance from the conflict point. Therefore $t_v = d_V / V_v$ and $t_p = d_p / V_p$, and the time gap needed by the pedestrian to cross the street $t_{cross} = W / V_p$

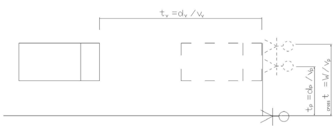

Figure 1. Pedestrian's crossing procedure

In the case $t_v > t_{cross}$, the vehicle is far enough from the pedestrian that no conflict occurs. In the case $t_v < t_p$, the vehicle reaches the conflict point before the pedestrian and the pedestrian will stop in front of the vehicle to avoid collision. In both two situations, the vehicle will not slow down. While $t_p < t_v < t_{cross}$, the vehicle must decelerate or it will collide the pedestrian who is crossing the street. Therefore the conflict between the pedestrian and vehicle comes into being. Considering the pedestrian's safety perception (critical cross gap) t_c=4.5s[7] , the probability of the conflict is shown as in Eq.1.

$$P_{conflict} = P(t_p < t_v < t_{cross}, t_v > t_c) \qquad (1)$$

2.2 The probability model of collision

Conflict is the direct cause that induces the accident and collision is the most serious conflict[9]. It is supposed that t_{dv} is the time that the decelerating vehicle approaches the conflict point and t_r is the pedestrian's reaction time. Thus 3 possible situations exist when a conflict occurs:

Case1 $t_p>t_r+t_{dv}$, The driver finds the pedestrian dashing into the crosswalk and steps on the brake, and the vehicle stops completely in front of the conflict point.

Case2 $t_r+t_{dv}>t_{cross}$ The driver finds the pedestrian dashing into the crosswalk and steps on the brake, and the pedestrian reaches the end of the crosswalk before the vehicle comes.

Case3 $t_{cross}>t_r+t_{dv}\geq t_p$, The driver finds the pedestrian dashing into the crosswalk and step on the brake, and the vehicle could not entirely stop in front of the conflict point and will bump into the pedestrian. .

Therefore in the conflict condition, the probability model of pedestrian vehicle accident is shown as the following function

$$P = P(t_{cross} > t_r + t_{dv} > t_p, t_p < t_v < t_{cross}, t_v > t_c) \qquad (2)$$

The relationship between conflict and collision could be described as Eq.3.

$$P(A_{collision}|B_{conflict}) = P(A_{collision}, B_{conflict}) / P(B_{conflict})$$

$$= P(A_{collision}) / P(B_{conflict})$$

Therefore

$$P(A_{collision}) = P(B_{conflict}) P(A_{collision}|B_{conflict}) \qquad (3)$$

2.3 Parameter establishing

The parameters of the model consult the reference [1], [5], [8], [9].

The distance from the pedestrian's starting point to the conflict point d_p obeys uniform distribution d_p (d_p~U(2,6)). The minimum distance 2m is considered by the width of the bicycle lane. The pedestrian's walking speed conforms to normal distribution (v_p~N(1.5,1),$v_{p\ min}$=0.5). While the pedestrian is confronted by the conflict his running speed conforms to (v_p~N(3.02,0.51) which is calculated through the national 4×10m shuttle racing standard

The vehicle's arrival time conforms to negative exponential distribution.

The driver's reaction time conforms to logarithm normal distribution (t_r~LnN(1.2,1)).

The vehicle's minimum brake time t_{dv} refers to middle vehicle brake effect in sun time.

2.4 Hypothetic condition of the model

The model comes into existence under the following 4 conditions.

(1) The model object is to calculate the collision probability when a single pedestrian crosses a free traffic flow.

(2) The model neglects the situation that pedestrian goes back to the footpath when he feels threatened.

(3) Although the bicycle lane width is considered, the model supposes that there is no

bicycle when the pedestrian is crossing the street.
(4) It is assumed that the vehicle decelerates and keeps original trace when it is exposed to the conflict. But the vehicle sometimes swerves to evade the pedestrian in the real world.

3 Simulation calculation

Because most variables in the model are random and conform to a certain contribution model, Integral calculation on Eq.2 is complex and Monte-Carlo Simulation is used. The simulation procedure is shown in Figure. 2. The input data in the model are the operating speed from 30km/h to 70km/h and traffic volume 200PCU/h to700PCU/h. According to the distribution characters of the different parameters in the model, The tool of MATLAB is used to generate the random. When combining different vehicle rates of speed and traffic flow and simulating N time, the probability pedestrian-vehicle conflict could be obtained as shown in Figure. 3 and the pedestrian-vehicle collision probability calculation result is shown in Table1. When n=30000, the result tends to convergent.

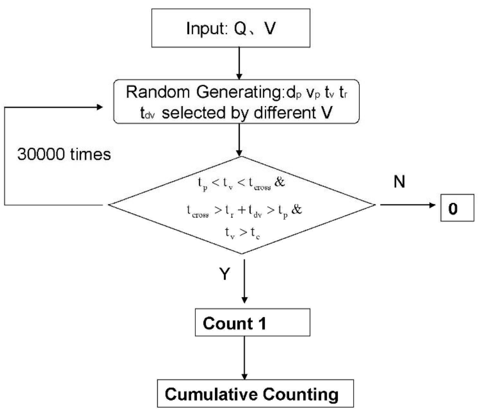

Figure 2. The simulation procedure

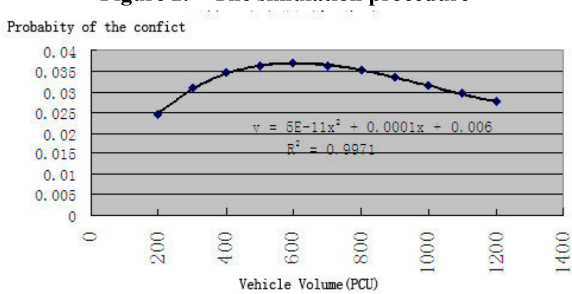

Figure.3. The relationship between traffic flow and conflict probability