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The behavior analysis of pedestrian-cyclist interaction at non-signalized intersection on campus:Conflict and interference

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Abstract

Pedestrian-cyclist interaction is closely relative with traffic safety on campus intersection. The relationships of flow, speed, Level of Service(LOS)with pedestrian-cyclist conflict and interference were studied. Studying pedestrian-cyclist interaction was using collected video data which recorded the behaviorsof pedestrians and cyclists at a non-signalized intersection on campus.The pedestrians and cyclists' flowswere recorded by video statistic software, the collected videos were decoded into image frames, their trajectory and distance data wereacquired by image processing software,the data was converted into numbers as a VCNXY(Video number, Current frame no, Pedno, Pedx, Pedy) database,thentheir speeds were computedby Euler's formula.The LOS is classified with three levels under different traffic density and road traffic capacity. Through the analysing of pedestrians and cyclists' flows and their average speeds at different time, andanalysing the relationships with pedestrian-cyclist interaction and their flow, speed, LOS.Results showed that campus' transportation is much different from city transportation, the proportion of pedestrians and cyclists are much higher, the average speeds of pedestrians and cyclistsare lower.Experimental results show that flow, speed and LOS are very strongly related to pedestrian-cyclist interaction.

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*Keywords:*Pedestrian-cyclist interaction; Conflict; Interference;Level of Service(LOS)

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1. Introduction

Pedestrian-cyclist interaction is usually happen on campus intersections, especially in class time, thepedestrian-cyclist interaction at no-signalized intersections has become one of the main causes of traffic congestion and accident on campus network[1]. Therefore, studying of the pedestrian-cyclist interaction at intersections is very important for every university student, faculty and stuff safety. Conflict and interference are the two class description in pedestrian-cyclistinteraction. Traffic conflict isdefinedthat two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged[2]. So the traffic conflict is mainly useful to evaluate road safety,serious conflict would be result in accident. Traffic interference is described that two or more road users run trajectory are interact or parallel. So the traffic interference is mainly reflecting these road users' influence on each other [3], serious interference would be result in conflict.Level of Service(LOS) reflects the road traffic capacity, which is relative with road's width, condition and traffic flow. LOS is also influence on Pedestrian-cyclist interaction.

Researches and applications at home and abroad are mainly centered on analyzing the behaviorof vehicle-vehicle, cyclist-vehicle and pedestrian-vehicleinteraction at signalized intersections. A number of published studies have analyzed the behavior of pedestrians and cyclists, but they are mainly researching on macroscopic study, such as the relationship of LOS and flow, the relationship of speed and flow, etc.Few studies have researched on pedestrian-cyclist interaction. Taylor and Davis [4] noted in their review of current bicycle research that cyclist speed distribution studies, a development that would enable the creation of a composite LOS for a mixed flow of intersections and eliminate the use of motor vehicle equivalents for cyclists. Cheng et al.[5] proposed that higher vehicle volume might lead to more pedestrian-vehicle conflict because pedestrians' waiting time will increase and exceed their tolerance limits, higher vehicle speed results in a higher collision probability between pedestrians and vehicles. Jia et al. [6] analyzed the vehicle's velocity distribution frequency under the cyclist's friction interference and block interference, the study showed that the block interference is bigger influence than friction interference in vehicle's velocity. SayedT [7] presented an automated safety diagnosis approach for evaluating cyclist-vehicle conflicts using video analysis, for identifying and analyzing serious events such as traffic accidents and violations.Himanen and Kumala [8] analyzed 799 events of pedestrian-vehicle conflict, their results indicated that the most important explanatory variables included pedestrian distance from the curb, city size, number of pedestrians, vehicle speed, and vehicle platoon size. This study was researching on pedestrian-cyclist interaction at no-signalized intersection on campus, it is extend the behavior of mixed traffic interaction research.

Unlike vehicle-vehicle, cyclist-vehicle and pedestrian-vehicle interaction, pedestrian-cyclist interaction cannot be easily formulated because of the random behavior of pedestrians and cyclists on campus, which depend on many uncertain factors [9], such as the randomization of pedestrian's walking and cyclist's driving, the uncertainty of their temporal and spatial distribution, the complexity of their walking psychology and riding psychology.Contrast to vehicle, bicycle's braking system can be rapidly applied, the bicycleturn direction mucheasier.Non-signalized intersection on campus is much more complex than at a signalized intersection, because the pedestrians and cyclists usually needn't comply with trafficregulations on campusintersections, most of the roads do not have signal light, and the roads do not divide into stable lanes, forthe pedestrians can walk and cyclist ride freely. In this paper, studying on the macroscopic and microscopic characteristics within campus mixed traffic flow at non-intersection have been carried out , analyzing macroscopic variable of flow, microscopic variable of speed and LOS arerelative with microscopic behavior of pedestrian-cyclist conflict and interference,studying the behavior of pedestrian-cyclist interaction will be helpful to deeply understand campus traffic.

Thisstudy used video recording to collect pedestrian, cyclist and pedestrian-cyclist interaction data at a non-signalized marked intersection in Wuhan University of Technology, China, including statistics flows, trajectory, speeds of pedestrians and cyclists through intersections. The authors recorded the flow of reaching pedestrians and cyclists every minute by video software, and the relationship of flow and time was analyzed. The videos were framed with images, the pedestrian and cyclist's trajectory were recorded by image processing software, and the data was saved by VCNXY(Video number, Current frame no, Pedno, Pedx, Pedy) database, then the average speed of every pedestrian and cyclist was computed by Euler's formula.Finally, analyzing the relationship of flow, speed, LOSwith pedestrian-cyclist conflict and interference.

Fig.1. Location of study area.

This paper makes two contributions. The first is analyzing the relationship with pedestrian-cyclist interaction at different flow and speed.The second is analyzing the pedestrian-cyclist interaction relationship with different LOS, which would be helpful for campus transportation agencies to meet pedestrian and cyclist's time-cost and comfort needs in crossing intersections when they design pedestrian and cyclist facilities at intersections on campus, and which would be improving for campus transportation safety.

2. Materials and methods

2.1. Study area and data

It was selected Wuhan University of Technology as study area, the road users of intersections are mainly pedestrians and cyclists, especially in time of class and after time of class. Fig. 1 shows the plan map and data collected road sections by videos.

The pedestrians and cyclists data were collected by video graphic survey on Nanhu campus premises in March, 2014. The vertical direction and horizontal direction both included 13 mark lines, the intersection's length is 14m, width is 13m, and the area is 182m^2.

For analyzing the pedestrian-cyclist interaction at intersection, we selected to capture mixed traffic flow 270 minutes from 7:30 to 12:00 on the intersection. For more accurately reflecting the campus traffic situation, every one minute video data was counted, such as the pedestrian and cyclist's flow, velocity, and so on.

2.2. Pedestrian-cyclist interaction type analysis

Analyzing pedestrian-cyclist conflict and interference, which mainly depend on their interaction direction, speed, behavior characters, and so on.As shown in table 1, if they run opposite direction or vertical direction, and run higher speed, they mainly happenconflict, the other situations mainly happen interference.

Table 1.Pedestrian-cyclist interaction type.

Interaction Type	Description
1	Straight cyclist and right pedestrian happen conflict and interference
2	Straight cyclist and left pedestrian happen conflict and interference
3	Turn right cyclist and straight pedestrian happen conflict and interference (same direction)
4	Turn right cyclist and straight pedestrian happen conflict and interference (opposite direction)
5	Turn left cyclist and straight pedestrian happen conflict and interference (same direction)
6	Turn left cyclist and straight pedestrian happen conflict and interference (opposite direction)

The intensity of the avoidance behavior taken by the cyclist at the decision point can reflect the seriousness of the interaction and can be determined from pedestrian-cyclist interaction features: emergency braking, rapid deceleration and erratic steering indicate a conflict.

When pedestrian and cyclist run the same direction, the cyclist displays a relatively gentle slowdown or sign at the decision-making point to avoid the interaction, the interaction is often interference. Their interference divides into friction interference and block interference [10].

2.3. Trajectory extraction and coordinate transformation

This study decoded the both collected videos into frames, and synchronized them manually. Since the frame rates of these videos were the same (i.e. 25fps), the synchronized error of time between these videos is about 0.04 seconds(=1/(25-1)). Based on the collected videos, this study identified the pedestrians and cyclists of these in manual. In the collected videos, for analyzing pedestrian-cyclist interaction, the authors chose 239 cyclists and 190 pedestrians from 7:30 to 12:00,their locations were recorded by the time tags of video frames.

In many previous studies on mixed traffic interaction, observers were repeatedly trained using video images to remove the subjectivity of the data collection, and their interaction observation results were compared with the results from the video images. After the training, interactions were detected through the observers' eyes. This method would cause many practical problems including observation errors in field applications, and is possible only in a laboratory and almost impossible in the field where very complicated traffic maneuvers exist, as the observers must be able to observe the diverse and complex traffic flows simultaneously and judge the type of the interaction during the long-term observation. To avoiding these problems, in this paper, OpenCV and its built-in algorithm were used do video processing.

The video data collection is related to the simulation through VCNXY (Video number, Current frame no, Pedno, Pedx, Pedy) database[11]. Real world data is captured and digitized by the MVDC(Microscopic Video Data Collection) into a VCNXY database. Using a simple viewer program, this database can be viewed back as a simulation of the real world.

It is an observation point where the position of a pedestrian or a cyclist at a time is recorded. The database consists of five fields, which are video number, current frame number, pedestrian or cyclist number, pedestrian or cyclist coordinate location. Pedestrian or cyclist number is a unique number for each pedestrian or cyclist and a new pedestrian or cyclist number is given to a new pedestrian or cyclist who enters the system.

Using the VCNXY database, the movement data of pedestrian and cyclist in the video are converted into numbers. The rest of the process can then be done by a computer, which reduces the processing cost and improves accuracy and speed.

2.4. Distance and speed computation

The authors usedEuler's formula for computing pedestrian and cyclist's distance. To a pedestrian's distance change, the pedno1's first distance s1=SQRT((H3-H2)^2+(G3-G2)^2), so we can attain the pedestrian's instant speed in different time. Finally, we can get the pedestrian's average speed, etc. The method of computing cyclist speed is as the same the pedestrian's speed. It reflects the relationship of their speed with pedestrian-cyclistinteraction; when a cyclist is interacted with a pedestrian, the cyclist's behavior usually change, for example, deceleration, steer, etc. When a pedestrian is interacted with a cyclist, he usually takes deceleration, stop, etc.

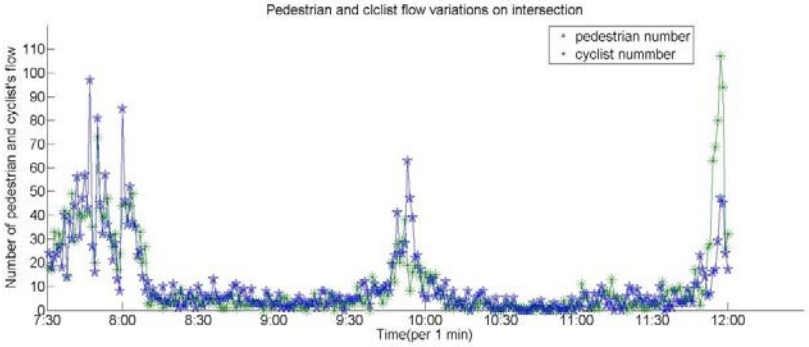

Fig.2.The relationship of flow and different time.

3. Statistical results

3.1. Pedestrian and cyclist's flow are relation with pedestrian-cyclist interaction

3.1.1. Pedestrian and cyclist's flow at different time

Between 7:30-12:00, the max flowwas 97 per min, the average flow was 10.92 per min, and the total number of pedestrian is 2948. The number of pedestrian's flow was relative with school schedule, the first lesson starting at 8:00, the second lesson and forth lesson ending at 9:40 and 11:50 respectively. As shown in the Fig. 2, from 7:30 to 8:00, the pedestrian flow was the highest, the total flow was 1110 pedestrians, the intersections was not only include students and teachers, but also include the other persons whose worked in around the campus and doing morning exercise persons, etc. From 9:30 to 10:00, the pedestrian flow was the second highest, the total was 506 pedestrians, and thetraffic flow was mainly including students. From 11:30 to 12:00, the pedestrian flow was the third highest, the total was 330 pedestrians.

Bicycle is a flexible and practical transportation tool, it is fit for short distance trip, which is very common on campus roads, especially in large area universities, which is dorm, teaching building is usually far from with each other, so many students choose bicycle to go to class.

Based on statistics analysis, between 7:30-12:00, the max flow of cyclistwas 107 per min, the average flow was 10.65 per min, and the total number was 2875. So as the same of pedestrian flow, as shown in the Fig. 2, the cyclist flow peaks was three time periods, from 7:30 to 8:00, 9:30 to 10:00 and 11:30 to 12:00.

3.1.2. The relationship with flow and pedestrian-cyclist interaction

Based on the real videos and above analysis, the bigger of pedestrian and cyclist's flow, the more probability happen pedestrian-cyclist interaction, especially in the class time, the pedestrian-cyclist interaction is the most, and the interaction is not only include conflict, but also include interference, and the bigger the flow, the probability happen pedestrian-cyclist conflict, even result in traffic congestion and accident, so the road mark and guide are very important for campus safety.

3.2. Pedestrian and cyclist's speeds are relation with pedestrian-cyclist interaction

3.2.1. Pedestrian and cyclist's average speed analysis

The SPSS's descriptive was used to test the normality of pedestrian speed data. The results indicated that Skewness=0.797, Kurtosis=1.550, so the pedestrian speed didn't differ from normality at the 5% significance level. So the campus intersection is much different from city transportation. In normal transportation condition, the pedestrian's speed isn't change at all. Based on the statistical analysis, the highest speed of pedestrian is mainly in 7:30-8:00, because some students got up after 7:30, and have breakfast before 8:00, so they were very urgent in the first class, some of them even running to class.

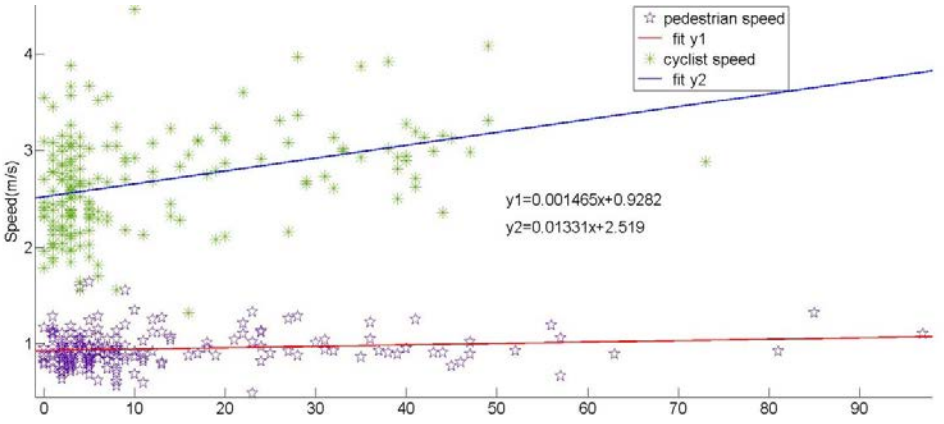

Fig. 3.The relationship of speed and flow on campus.

Contrast to vehicle, bicycle is a randomness, unsteadiness swing, slow speedtransportation tool. Contrast to pedestrian, cyclist's speed are usually higher, cyclist's behavior is much same as pedestrian. Through the statistics analyzing, the results indicated that Skewness=0.362, Kurtosis=0.367, so the cyclist's speed also didn't differ from normality at the 5% significance level, their speed was relative with student schedule, flow, etc.

3.2.2. The relationship with speed and flow

The relationship of speed and flow on the intersection is shown in Fig. 3. If the road is in normalcondition, the speed of pedestrian and cyclist are not too much change;the speeds are relative with student schedule and flow.

3.2.3. The relationship with speed and pedestrian-cyclist interaction

Based on the real videos and above analysis, the pedestrian and cyclist speed are relative with pedestrian-cyclist interaction directly, the higher speed of the pedestrians and cyclists, the more probability happen pedestrian-cyclist interaction. Especially in the beginning of the first class and after the fourth class, most of students run to class and canteen, the pedestrian-cyclist conflict is the most, and it is very dangerous.

3.3. LOS is relationship with pedestrian-cyclist interaction

LOS is the most important transportation safety indicator for evaluating the road traffic capacity, which is relative with pedestrian-cyclist interaction. Through the observation and computation of pedestrian-cyclist interaction, thepercentage of conflict and interference occurrence, $P_{conflict}$ and $P_{interference}$ are calculated as:

$$P_{conflict} = \frac{N_{conflict}}{N_{interaction}} \quad (1)$$

$$P_{interference} = \frac{N_{interference}}{N_{interaction}} \quad (2)$$

Where $N_{conflict}$ is the number of conflicts,$N_{interference}$ is the number of interferences, $N_{interaction}$ is the total number of pedestrian-cyclist interactions.

Details about conflict and interference percentage in different LOS are summarized in Table2.

Table 2.Conflict and interference percentage in different LOS.

Number Of pedestrian	Number Of cyclist	Conflict percentage	Interference percentage
[6, + ∞)	[6, + ∞)	37.21%	9.30%
[3, 6)	[3, 6)	13.43%	25.37%
[1, 3)	[1, 3)	10.34%	27.59%

Based on the real videos observation and analysis, we can obtain the relationship pedestrian-cyclist interaction with different LOS:

1. Low LOS (Over 6 pedestrians, over 6 cyclists)
   Pedestrian-cyclist interaction is mainly conflict, such as turn direction suddenly, stop suddenly, and so on.
2. Middle LOS (nearly 4 pedestrians, nearly 4 cyclists)
   Pedestrian-cyclist interaction is not only including conflict, but also including interference, such as turn direction, slow down, etc.
3. HighLOS (nearly 2 pedestrians, nearly 2 cyclists)
   Pedestrian-cyclist interaction is mainly conflict, such as turn direction slightly, slow down slightly, etc.

In general, conflicts occurred most frequently in lowLOS, interference occurred most frequently in highLOS.

3.4. Contrast to city transportation

City road transportation have vehicle lanes, cyclist lanes, trafficlights and clear traffic regulations, it's easily confirm the conflict and interference area,usually is the crossing area,the TTC (Time to conflict) [12] and PET(Post-encroachment time) [13] usually take as conflict severity indicator,it's possible to quantity the conflict and interference severity level. Campus road transportation haven't vehicle lanes and cyclist lanes, no signal, no clear traffic rules, it's very difficult to confirm the conflict and interference zone, and it's very hard to choose suitable safety indicator for quantifying the conflict and interference severity; further research should be conform the safety indicator and quantify the interaction severity level.

4. Conclusions

This study is focused on the pedestrian-cyclist interaction with mixed traffic at non-signalized intersections on campus. The result can be used for campus traffic simulation and traffic evacuation guidance. Following are the main conclusions:

1. The peak of traffic flow is associated with student schedule. Only during going to class and leaving class with appears flow peak, at other times, traffic flow is very little, less than 30 road users per min. So the pedestrian-cyclist interaction usually happens in class time, the bigger the traffic flow, the moreprobabilityhappen pedestrian-cyclist interaction, especially at noontime, most of students choose go to have lunch in canteen, pedestrian-cyclist conflict would be the most, would be result in serious conflict.
2. Pedestrian and cyclist's speed are faster during the early morning and noontime compared to other times; their speeds are relative with student schedule and flow. The higher speed of the pedestrians and cyclists, the more probability happen pedestrian-cyclist interaction.
3. Pedestrian-cyclist interaction is relative with LOS, under lowLOS, the interaction is mainly conflict; under middle LOS, the interaction is both conflict and interference; under highLOS, the interaction is mainly interference.

In general, analyzing the pedestrian-cyclist interaction is very import for campus safety, which would be helpful for campus transportation designers when they design and plan campus intersections.For example, based on the analyzing of the behavior of pedestrian-cyclist interaction, the teach managers can adjust student schedule for reducing pedestrian-cyclist interaction; the road managers can set suitable sign and mark for pedestrians and cyclist choosingappropriate path. Finally, these analysis data and experiment result would be useful of building microscopic model for pedestrian-cyclist interaction.

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