Analysis of School-Age Children's Street-Crossing Behavior at Signalized Intersections

Bo Li, Lei Wang, Delong Zou

Abstract— **School-age children, due to their physiological and psychological immaturity and relatively limited traffic experience, face higher risks when crossing signalized intersections. To gain a deeper understanding of the characteristics of school-age children's street-crossing behavior, this study focused on signalized intersections near elementary schools. Field video surveys were conducted to collect videos of children crossing the streets. The collected video data were processed using SIMI Motion software to extract parameters related to crossing behavior, including walking trajectories, crossing speed, crossing time, and horizontal and vertical displacement. Furthermore, combined with manual calibration methods, different types of crossing behavior, such as normal crossing and delayed crossing, were classified. Corresponding speed analysis charts were created using Origin. SPSS software was used to perform significance analysis on the differences in crossing behavior parameters among different types of crossings, quantifying the similarities and differences between them. The research results help to understand school-age children's street-crossing behavior and provide targeted improvements for crossing facilities and traffic signal timing at signalized intersections around elementary schools.**

Index Terms— **pedestrian traffic; school-age children crossing the road; traffic safety; significance analysis**

I. Introduction

With the rapid development of the economy, the number of automobiles has been continuously increasing, traffic volume has been steadily growing, and traffic safety issues have gained increasing attention. Pedestrians are relatively vulnerable in traffic; among them, school-age children, due to their physiological and psychological immaturity and relatively limited traffic experience, face significant risks when crossing streets at signalized intersections. School-age children exhibit different crossing behaviors and characteristics compared to the general population. For the above reasons, observing and studying the crossing behaviors of this group at signalized intersections and taking targeted measures can help reduce traffic accidents and has practical significance for ensuring pedestrian safety.

A large amount of research has been conducted both domestically and internationally on pedestrian crossing issues at signalized intersections. Leidy Marcela Barón Acela and others analyzed pedestrian behavior at intersections in two culturally diverse cities based on factors such as walking speed, distance between pedestrians, group size, and gender composition, exploring how cultural and social differences in each city affect group walking speeds and mobility [1]. Nóra Krizsik and colleagues recorded several parameters about drivers and pedestrians and used descriptive statistics and discrete choice models to analyze the data, demonstrating that drivers' willingness to stop is influenced by pedestrian distractions [2]. Japanese scholar Mio Suzuki and others studied elementary school students' crossing behavior at signalized crosswalks, finding that violations not only result from misjudgment of traffic conditions but may also be influenced by factors such as prioritizing group actions, lack of attention, and following adults' violations [3]. Vasudevan Vinod and others conducted an exploratory study using LiDAR to examine crosswalk speeds at mid-block crossings in India and concluded that pedestrians are more willing to engage in risky crossing behaviors in front of electric bicycles than in front of cars [4]. Peng Jinshuan and others studied the impact of signal countdown displays on pedestrians' physiological load when crossing, finding that the start interval of crossing significantly affects pedestrians' physiological parameters [5]. An Shi conducted research on pedestrian crossing control strategies at parallel-flow intersections, proposed a pedestrian crossing mode with vehicle-pedestrian overlap phase, and provided signal control strategies for two pedestrian crossing modes to address conflicts between pedestrians and motor vehicles at parallel-flow intersections [6]. Xu Yinfeng applied the theory of traffic flow traversable gaps to establish a model of the impact of pedestrian herd crossing behavior on road traffic delays, studying the effect of pedestrian herd crossing on vehicle flow delays [7]. Pei Yulong and others defined the risk levels of pedestrian crossing under different conditions and proposed a method for calculating these risk levels [8]. Based on existing research findings, scholars both domestically and internationally have conducted extensive studies on the street-crossing behavior of the general population, but there is relatively little research focusing specifically on the street-crossing behavior of school-aged children. Current road traffic facilities and signal timings at intersections near schools may no longer meet the conditions necessary for the safe crossing of students. This study, based on traffic surveys, thoroughly analyzes the psychological and behavioral habits of school-aged children when crossing streets, providing certain reference value for optimizing signal timings and reasonably setting up pedestrian crossing facilities. The research findings are significant for guiding schools and families in traffic safety education for school-aged children and helping them develop good street-crossing habits.

II. Traffic Survey and Data Processing

A. Traffic Survey Plan

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This study selected the intersection next to the Experimental School in Tinghu District, Yancheng City, Jiangsu Province, namely the intersection of Taihu Road and Changting Road, as shown in Figure 1. This intersection has two-way motor vehicle lanes in both directions (east, west, south, and north), along with bicycle lanes separated by barriers, and sidewalks are located on the road shoulders. The intersection is controlled by traffic lights, and pedestrian crossing facilities include crosswalks.

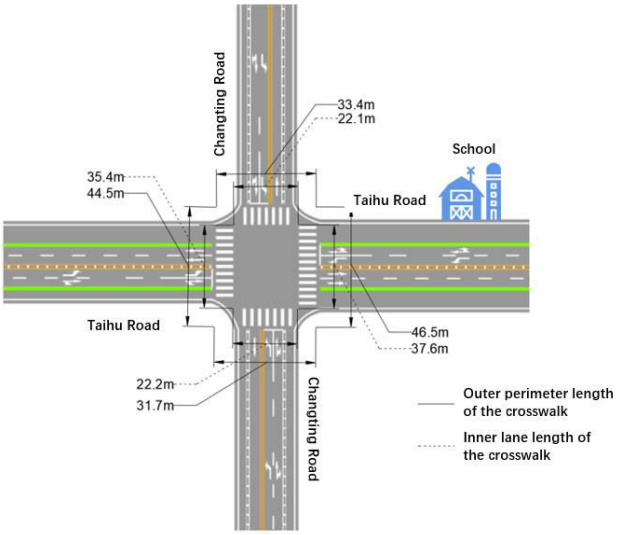

Figure 1. Signal Intersection of Changting Road and Taihu Road

Considering that the afternoon dismissal time for students on campus is 16:00, the period from 16:00 to 16:30 is the peak time for pedestrians crossing the street after school. In order to fully reveal the temporal distribution characteristics of university students crossing streets, this study chose to conduct observations on Friday. Using video recording methods, pedestrian crossing data at this intersection were obtained for the period from 15:30 to 17:30.

B. Data Processing

Using video data obtained from traffic surveys, combined with manual calibration, data collection and processing were performed using SIMI Motion software. A world coordinate system was established, with frame-by-frame processing every 0.1 seconds, and data grouped according to one traffic light cycle interval. Pedestrian crossing flow, motor vehicle flow, lateral displacement, longitudinal displacement, lateral speed, and longitudinal speed were obtained. The signal timing for each phase at the signalized intersection is shown in Figure 2. According to statistical analysis, a total of 596 valid pedestrian samples were collected, including 239 school-age children. The traffic parameters for pedestrians crossing straight on the left side of Taihu Road are shown in Table 1.

Table 1. Pedestrian parameters for each cycle period of one-way street crossing

Cycle Number	Pedestrian flow per unit period	Average speed(km/h)
1	20	4.12
2	16	4.74
3	12	4.09
4	4	4.98
5	4	4.37
6	4	4.19
7	12	4.52
8	4	4
9	12	5.32
10	8	4.51

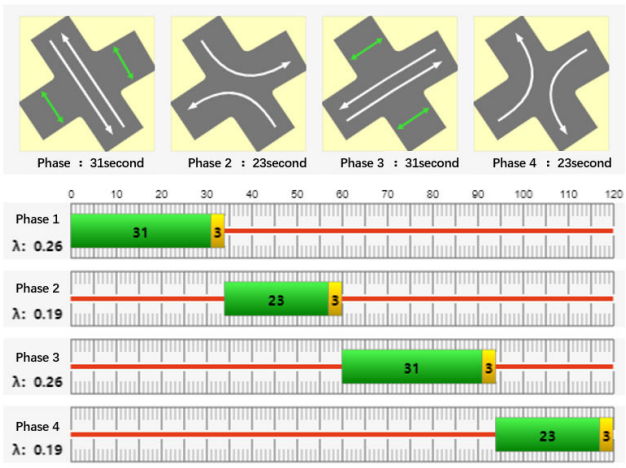

Figure 2. Timing of each phase signal

III. Analysis of Pedestrian Crossing Characteristics

A Pedestrian Crossing Trajectory Analysis

Import the video into the software to obtain pedestrian crossing trajectory maps for each cycle. Taking the pedestrian crossing trajectory map of one cycle as an example, see Figure 3. It can be seen that the pedestrian crossing trajectories exhibit a fluctuating pattern. Due to different purposes after crossing, pedestrians' movement trajectories at the signalized intersection show lateral deviations. The maximum curvature calculated numerically is 1.66/m, and the average curvature is 0.31/m. Some trajectories deviate from the normal route, possibly due to reasons such as encroaching on motor vehicle lanes or not following the marked lines.

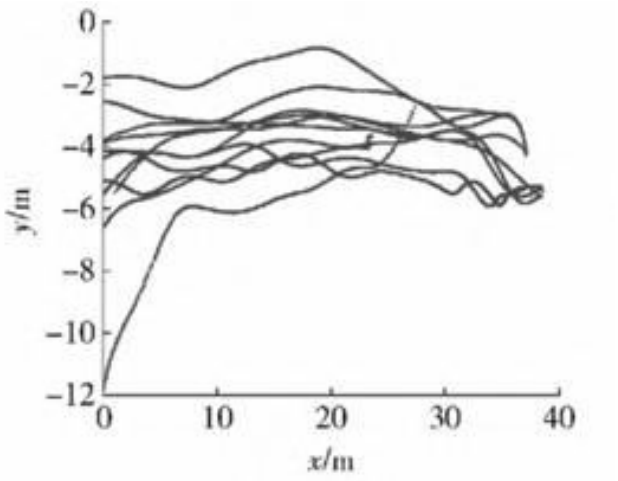

Figure 3 Pedestrian Crossing Trajectory

B Pedestrian Crossing Flow and Speed Analysis

Using the data obtained from traffic surveys, it is processed and analyzed with software. The data is grouped according to the traffic light cycles at signalized intersections, and for

analysis, pedestrian crossing traffic parameters during 10 consecutive cycles within a selected time period are temporarily chosen, resulting in Figure 4.

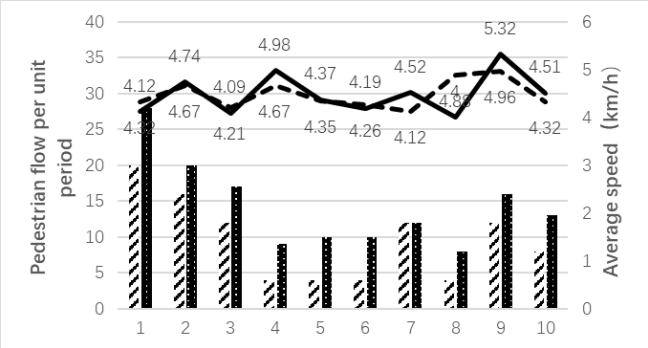

Figure 4. Pedestrian crossing flow and speed

Figure 4 shows the distribution of pedestrian flow and speed for crossing on both the left and right sides of Taihu Road. It can be seen that pedestrian crossing flow has no obvious relationship with the signal cycle, indicating that pedestrian crossing flow exhibits irregularity over time. Since the school is located on the right side, the number of pedestrians crossing on the right side is significantly higher. However, there is no significant difference in crossing speed between the two sides, reflecting the complexity of crossing patterns for school-age children.

IV. Analysis of Crossing Types at Intersections

According to the obtained video, when recording pedestrian crossing trajectories, pedestrian crossings are divided into two types. The first type is normal crossing, defined as including pedestrians who arrive at the waiting area to cross before the green light countdown starts, those who reach the waiting area just as the green light begins to cross, and those who enter the intersection within 5 seconds after the green light countdown starts. The second type is delayed crossing, that is, crossing behavior in which pedestrians enter the intersection more than 5 seconds after the green light countdown starts.

Figure 5 shows the distribution curve of pedestrian speed over time during normal crossing at a signalized intersection. It can be seen from the figure that at the beginning of normal crossing, pedestrian speeds are concentrated in two ranges: one below 3 km/h, which is presumed to represent pedestrians who arrive at the waiting area early or just in time to wait for crossing, and the other concentrated above 4 km/h, presumed to be pedestrians who already have a relatively high initial speed and enter the intersection within 5 seconds of the green light turning on. However, regardless of the type, once the final speed stabilizes, it basically remains within the [3-5 km/h] range. The average pedestrian crossing speed was then calculated to be 4.2 km/h, or 1.17 m/s. This speed is below the standard speed of 1.2 m/s. Crossing time is generally around 35 seconds.

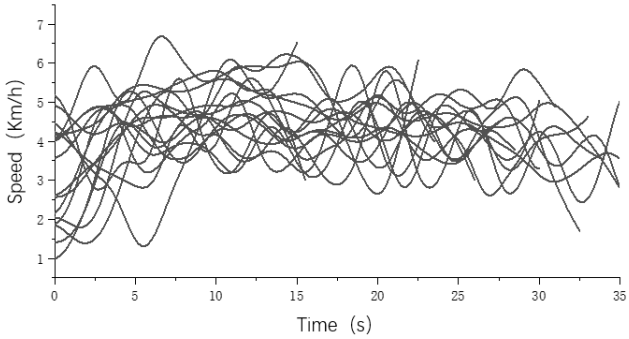

Figure 5. Distribution Curve of Normal Street-Crossing Speed

Figure 6 shows the distribution curve of pedestrian speed over time when delayed at a signalized intersection. It can be seen that under delayed crossing conditions, pedestrians have relatively high initial speeds and greater speed fluctuations. The initial speed generally exceeds 4 km/h, indicating that pedestrians perceive the green light countdown to be ending soon and worry that they may not be able to cross the signalized intersection safely, thus increasing their walking speed; in some cases, speeds approach 12 km/h, suggesting that pedestrians run across the street. Due to the higher speeds, crossing times are concentrated within 25 seconds, far below the normal crossing time. The average speed is 5.27 m/s.

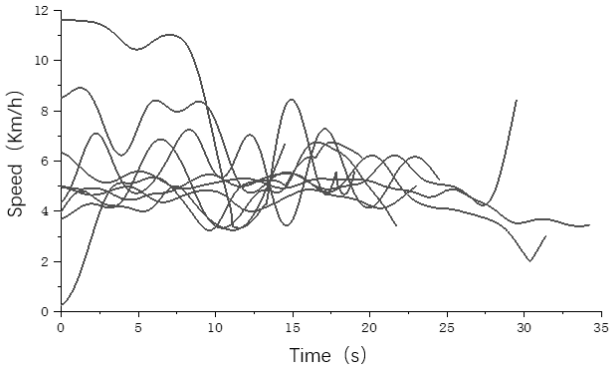

Figure 6. Delay Pedestrian Crossing Speed Distribution Curve

A significance test was conducted on the speed differences between normal crossing and delayed crossing. The results are shown in Table 2. The average speed for normal crossing was 4.2 m/s, which is lower than the average speed of 5.27 m/s for delayed crossing, with a significance level of 0.001, less than 0.005. This indicates that there is a difference between normal crossing and delayed crossing for pedestrians at signalized intersections.

A differential analysis of the two types of crossing times is shown in Table 3. Normal crossing time ranges within 35 seconds, while delayed crossing time is within 25 seconds. The significance test results indicate that there is a difference between the two. This suggests that children, due to psychological or physiological immaturity, are more concerned about whether they can cross safely when crossing is delayed, which is reflected in the considerable difference in crossing times.

Table 2. Results of Significance Test for Speed Differences

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	825.300	1	825.300	890.216	<.001
Within Groups	2272.269	2451	0.927		
Total	3097.57	2452			

Table 3. Results of the Significance Test for Time Differences

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	374.411	1	825.300	890.216	<.001
Within Groups	311.017	12	25.918		
Total	685.429	13			

TRAFFIC IMPROVEMENT MEASURES

Considering that primary school students are not yet fully developed physically, generally walk at slower speeds, and that some pedestrian crossings around school areas are designed overly long due to road width limitations, there often exists the risk of insufficient green light duration or signal changes while students are crossing, which can easily lead to conflicts with passing vehicles and seriously threaten travel safety. To effectively strengthen the safety barrier for primary school students crossing streets, it is recommended to systematically optimize from four aspects: First, install safety islands by planning sufficiently wide buffer zones in the middle of pedestrian crossings, using non-slip materials to provide second stopping points for students, preventing dangers caused by fatigue or panic during continuous crossing. Second, precisely optimize signal timing by investigating the average crossing time of primary school students during peak school commute hours and adjusting pedestrian green light duration accordingly, ensuring signal timing matches students' crossing pace. Third, scientifically increase the all-red interval to ensure that after the green light ends, vehicles in the intersection are completely cleared, preventing overlap between vehicle movements and pedestrian crossing, thus improving intersection order. Fourth, standardize pedestrian safety waiting areas by using physical barriers, colored markings, and other isolation measures to designate exclusive waiting zones, guiding students away from vehicle lanes, reducing safety risks during the waiting stage from the source. The coordinated implementation of these measures can comprehensively enhance street-crossing safety around schools and safeguard the travel of primary school students.

CONCLUSION

(1) The pedestrian flow of school-age children crossing the street has no obvious relationship with the signal cycle over time.
(2) The crossing trajectories of school-age children show fluctuation patterns, and there are behaviors such as occupying motor vehicle lanes and not following road signs.
(3) There is a lateral deviation when crossing, which is relatively significant, and future studies can focus on this direction separately.
(4) Normal crossing and delayed crossing types have a significant impact on school-age children's street crossing, especially crossing speed and time, which have a significant effect..

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