Comparative Analysis of Pedestrian Walking Speed at Crosswalk and Non-Crosswalk Locations in Mixed Traffic Flow

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Received: 1 April 2025 | Revised: 1 May 2025 and 17 May 2025 | Accepted: 25 May 2025

 DOI: https://doi.org/10.48084/etasr.11241

ABSTRACT

The objective of this study is to analyze the pedestrian walking speed at crosswalk and non-crosswalk locations on urban roads. The investigation utilizes real-world data collected at various sites to examine walking speed in different types of crossings, including informal crossings, which occur at mid-block segments, and zebra crossings, which occur at designated crosswalks. The paper develops simulation scenarios in VISSIM to analyze the walking speed for the studied cases. The data analysis reveals that the speed influence level—defined as the influence of vehicle traffic flow on pedestrian walking speed—is lower at zebra crossings (24.2%) compared to informal crossings (32.3%). The simulation scenarios in VISSIM validate pedestrian walking behavior, implying the psychological stability of pedestrians when crossing at the designated crossings. The walking speed at zebra crossings demonstrated greater stability, exhibiting a mean change of 1.3%, in contrast to the less stable behavior observed at informal crossings, where the mean change was 17.7%. The findings of the research confirm the role of zebra crossings in improving traffic safety on urban roads.

Keywords-pedestrian; traffic flow; simulation; motorcycle; walking speed

I. INTRODUCTION

Crossing the street at locations not designated for crossing is a common phenomenon in Vietnam. This behavior poses a risk of traffic accidents involving vehicles and pedestrians [1-5]. Although the authorities have recommended using crosswalks to ensure safety, not all pedestrians use them due to negligent or shortcut behavior [1, 6, 7]. Many studies have been conducted on this topic [8-14]. Authors in [14] analyzed pedestrian crossing behavior patterns at intersections and suggested methods to reduce traffic accidents. The authors proposed behavioral models to describe four modes of crossing the road. However, the paper has certain limitations related to traffic characteristics or the interaction between pedestrian and vehicle flow. Authors in [15] analyzed pedestrian behavior at intersections and suggested policies to improve road traffic safety in urban areas, by conducting surveys on pedestrian crossing behavior. The study determined pedestrian travel time and speed by considering traffic lights and illegal overtaking behavior. Pedestrian crossing behavior in mixed traffic conditions is an important factor for studying to improve safety and reduce accidents, especially in urban areas [16]. Authors in [16] concluded that pedestrian behavioral characteristics, such as rolling clearance, reproductive behavior, and attempt frequency, play an important role in forming crossing behavior. These conclusions are useful for designing pedestrian facilities as well as for improving pedestrian safety at uncontrolled intersections. Regarding the evaluation of human factors in crossing, authors in [17] evaluated internal factors based on data collected at 20 different locations. They built a model to predict the walking position of pedestrians when crossing the street, considering different environmental variables. Authors in [18] analyzed the crossing behavior at intersections to provide suggestions for improving traffic safety. In addition, they analyzed how the characteristics of pedestrians, such as age and gender, influence pedestrian behavior. Authors in [19] evaluated behavioral changes in drivers and pedestrians due to changes in the road environment, traffic enforcement activities, and public information campaigns. The researchers used a four-stage analysis to evaluate changes in pedestrian behavior at study sites in the city of Shoreline.

In Vietnam, the flow of motorcycle traffic has shaped the characteristics of the traffic environment [20]. To facilitate analysis, mixed traffic flow is often converted into equivalent Passenger Car Units (PCUs) or Motorcycle Equivalent Unit (MEUs) [20, 21]. Unlike in developed countries, mixed traffic significantly impacts road users, including pedestrians [6, 7]. Despite the numerous research studies on pedestrian crossing issues in Vietnam, important points of concern remain unaddressed. Indeed, some studies [6, 7] have evaluated behavior in motorcycle traffic flow with limitations in sample size, interaction factors, and human factors. Additionally, pedestrian behavior and the interaction between vehicles and pedestrians have been studied [6, 7], yet the analysis of pedestrian crossing speed at locations with and without lines has not. Crossing the road at locations without crosswalks has consequences in terms of traffic accidents and jams, which affect traffic flow efficiency. Analyzing pedestrian speed at crosswalk and non-crosswalk locations is necessary to improve understanding of pedestrian behavior for future traffic policy improvements.

II. DATA COLLECTION AND ANALYSIS

The research team collected data on 30 Thang 4 Street, an urban street in Can Tho City, Vietnam. This two-way road is 13 m wide on each side and is separated by a wide median strip. The study focuses on analyzing pedestrian crossing speeds at locations with crosswalks and locations without crosswalks (informal crossing) in only one direction of the street. The location is shown in Figure 1.

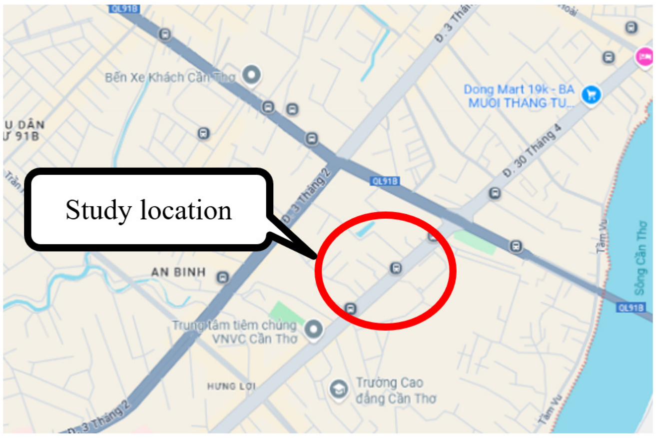


Fig. 1. The study location at 200 D.30 Thang 4 street, Can Tho city, Vietnam, map data ©2025 Google.

To collect the data, the research team used two cameras mounted on the hotel buildings to observe traffic flow and pedestrians crossing roads [6]. The first camera was positioned on the fourth-floor balcony of the Mai Lan Hotel, and the second camera was placed on the fourth-floor terrace of the Thanh The Hotel. The research team collected data during the peak and off-peak hours on normal days. The recorded videos were analyzed using Speed Estimation by Video (SEV) software [21] to collect necessary information about pedestrian speed and travel time. Figure 2 illustrates the site extracted from the videos using the SEV program.

To facilitate data analysis, a 2D coordinate system was created in SEV [21] using four base points that were determined in the study area, as shown in Figure 2. The study focused on analyzing pedestrian walking speed on this section of road at locations with and without crosswalks (zebra crossings). At zebra crossing locations, pedestrians tend to feel safe when crossing the street. In contrast, at non-crosswalk locations, pedestrians cross the road illegally, which increases the risk of traffic accidents. Figure 3 illustrates these two crossing locations.

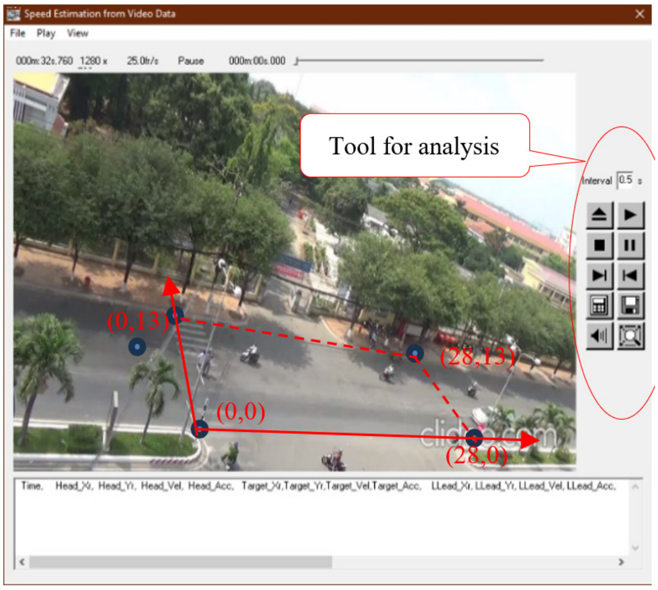


Fig. 2. Study location in SEV program.

Fig. 3. Crossing with and without a crosswalk.

The data collected for each pedestrian crossing the street include walking speed, coordinates every 0.5 s, traffic flow composition, volume, speed, travel time, etc. Crossing speed includes periods of waiting for gaps in traffic. The analytical data exported to an Excel file will be used to analyze and compare the crossing behavior in the two cases mentioned. This dataset is available upon request.

III. METHODOLOGY

A. Crossing Speed Analysis Method

Using the collection method above, the author collected 160 samples at informal crossings and 392 samples at zebra crossings. To examine pedestrian behavior at zebra and non-zebra crossings, this study proposes the concept of the speed influence level (I). This is defined as the ratio of the difference in speed between pedestrians crossing the road with and without vehicle traffic flow. The definition is expressed in the following formula:

$$I = \left|\frac{S_{t,i} - S_{0,i}}{S_{0,i}}\right| \times 100\% \quad (1)$$

where:

- $S_{t,i}$: the real speed of person i crossing the road, influenced by traffic flow at time t (m/s).

- $S_{0,i}$: the average speed of person i crossing the road, unaffected by traffic flow (m/s).
- I: the speed influence level (%).

B. Simulation Analysis Method

To evaluate crossing behavior, a model was built using the VISSIM simulation software [22] to simulate scenarios involving pedestrians crossing at a zebra or informal crossing. Figure 4 illustrates these two locations including the traffic volume and number of traffic lanes at the survey location.

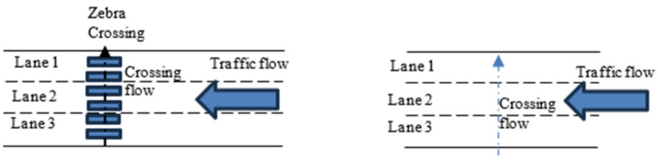


Fig. 4. Crossing flow with and without zebra crossings.

VISSIM, developed by PTV in Germany, is a microscopic, multimodal traffic flow simulation software package [22]. It can set up simulations based on real-world data to model traffic or pedestrian flow, or the interaction between them. In addition to the vehicle traffic model parameters, such as acceleration, headway, speed, and safety distance, pedestrian behavior parameters were also set. Key parameters affecting the model were applied, including the rear influence on pedestrian behavior (λ_mean) and the reaction time (τ), which was set to 0.4 s. Additionally, the $ReacToN$ parameter that represents the influence caused by the n nearest pedestrians was set to 0.5 s. The $ASociso$ and $BSociso$ parameters, which govern the force between pedestrians, were set to 2.04 and 0.2, respectively. Acceleration (a), an important parameter for simulating pedestrian behavior that is determined based on the desired speed (v_0) and the current speed (v), is defined by the following equation:

$$a = \frac{(v_0 - v)}{\tau} \quad (2)$$

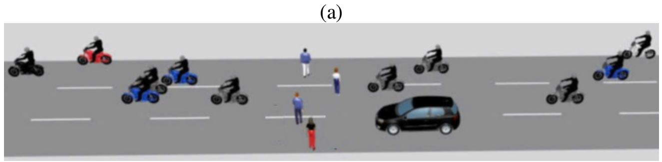
This study used VISSIM to create a transportation system with tools such as links and nodes. The simulation runs under the rules of the car-following and car lane-changing models developed by Wiedemann in 1974 [23]. Using 2D/3D tools in VISSIM, the author simulated the scenarios of traffic flow and crossing pedestrians at the study site. The interface of the simulation scenarios is shown in Figure 5.

IV. RESEARCH RESULTS

A. Traffic Analysis

The real-world road segment observed in this study recorded a traffic volume of 1,350 vehicles per typical hour. The pedestrian crossing rate is 98 people per typical hour. Most of the traffic consists of motorcycles, at 97%. Cars and trucks account for 2.5% and 0.5%, respectively. The traffic composition at the site is illustrated in Figure 6.

(a)



(b)

Fig. 5. Simulation scenarios in VISSIM: (a) crossing at a crosswalk (zebra crossing), and (b) crossing at a non-crosswalk location (informal crossing).

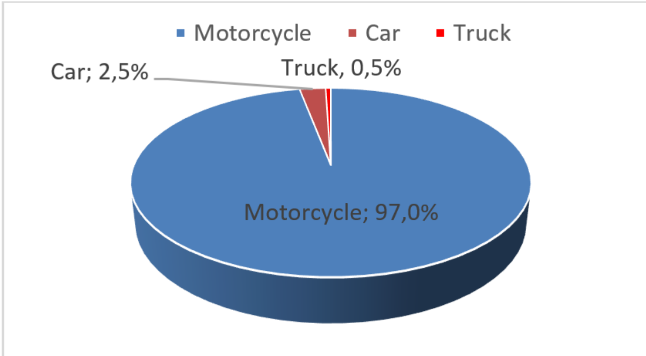


Fig. 6. Traffic composition at the study site.

B. Crossing Speed Analysis

Based on the collected data, the study analyzed and determined the distribution of pedestrian walking speeds at the zebra and informal crossings [7]. The resulting speed distributions are presented in Figures 7 and 8.

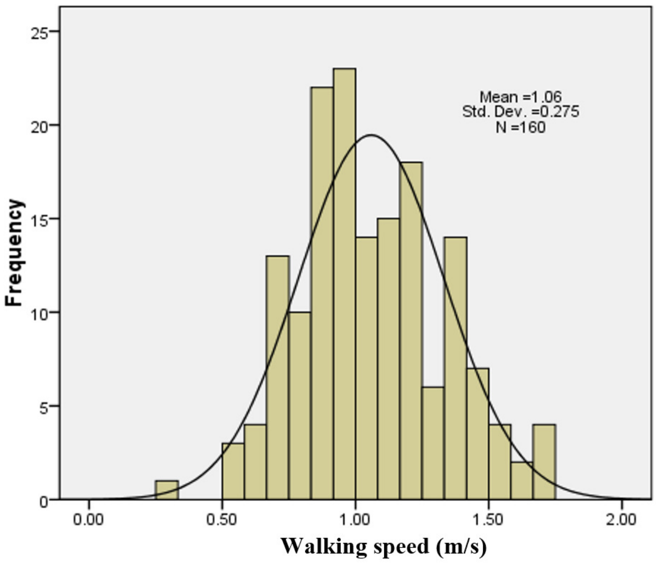


Fig. 7. Walking speed distribution for informal crossing.

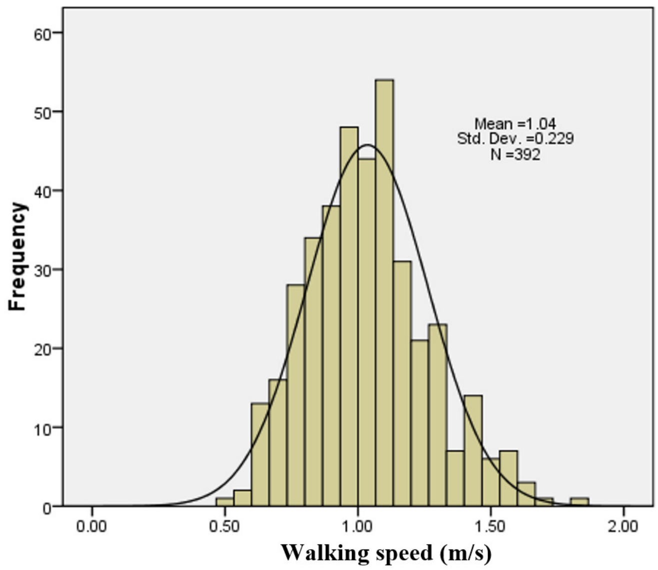


Fig. 8. Walking speed distribution for zebra crossing.

As shown in Figures 7 and 8, the mean walking speeds differ slightly between the two cases. For the informal crossing, the figure is 1.06 m/s, and for the zebra crossing, it is 1.04 m/s. The speed influence levels (I) for the two cases are illustrated in Figure 9.

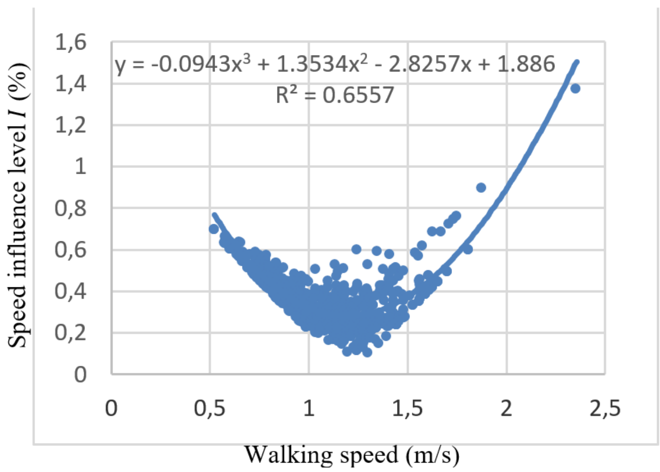


Fig. 9. Speed influence level (I) for informal and zebra crossings.

As shown in Figure 9, the curve representing the relationship between speed and influence for the two cases is a cubic concave parabola. Due to the influence of road traffic volume, pedestrians crossing the street will adjust their speed to ensure safety. The relationship between speed influence level and walking speed is highly reliable, with 65.57% of the sample size being explained (R^2=0.6557). Taking the derivative of the functions to find the bottom of the curve yields the following relationship:

$$\frac{dy}{dx} = -0.2829x^2 + 2.7068x - 2.8257 \quad (3)$$

$$\frac{dy}{dx} = 0 \quad (4)$$

$$x = 1.193 \quad (5)$$

The result shows that $x = 1.193$ and that the value of the speed influence level is $y = 0.253$. This means that the minimum value of speed influence level is 25.3% at the walking speed of 1.193 m/s.

The study conducted an in-depth analysis for each individual case of informal or zebra crossings. Figure 10 shows the speed influence levels (I) for the informal crossings, and the derivative of the functions to find the bottom of the curve yields the following relationship:

$$\frac{dy}{dx} = -0.8157x^2 + 3.9466x - 3.3884 \quad (6)$$

$$\frac{dy}{dx} = 0 \quad (7)$$

$$x = 1.12 \quad (8)$$

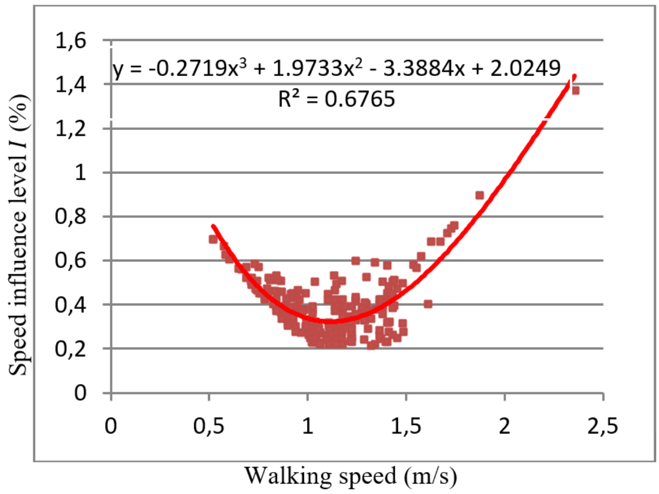


Fig. 10. Speed influence level (I) for informal crossing.

The result shows that $x = 1.12$ and that the value of the speed influence level is $y = 0.323$. This means that the minimum value of speed influence level is 32.3% at the walking speed of 1.12 m/s for the case of informal crossings.

Figure 11 shows the speed influence levels (I) for the zebra crossings, and the derivative of the functions to find the bottom of the curve yields the following relationship:

$$\frac{dy}{dx} = 1.3377x^2 - 0.984x - 0.8888 \quad (9)$$

$$\frac{dy}{dx} = 0 \quad (10)$$

$$x = 1.26 \quad (11)$$

The result shows that $x = 1.26$ and that the value of the speed influence level is $y = 0.242$. This means that the minimum value of speed influence level is 24.2% at the walking speed of 1.26 m/s for the case of zebra crossings.

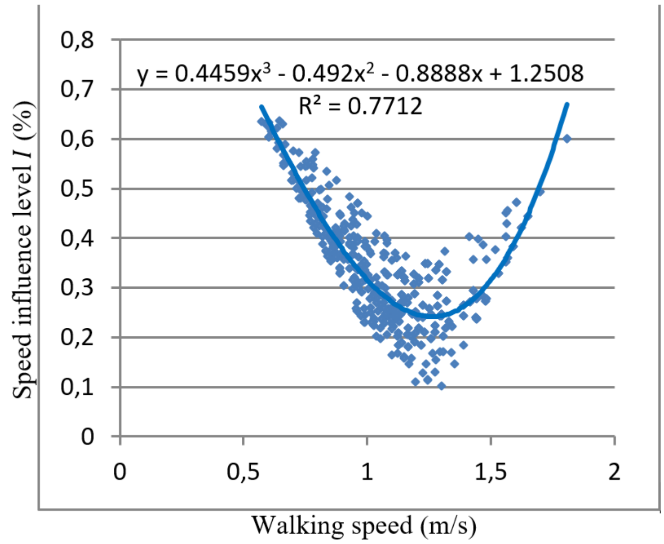


Fig. 11. Speed influence level (*I*) for zebra crossing.

The analysis results reveal that:

- The relationship between speed influence level and walking speed follows the law of the third-order parabolic function, as shown in Figure 9.
- The influence of vehicle flow on pedestrian crossing speed is smallest when the difference between pedestrian crossing speed with and without vehicle traffic flow is 32.3% and 24.2% for the cases of informal and zebra crossing, respectively.
- In the cases where traffic flow has the least impact on pedestrians, pedestrian speeds at zebra crossings are always greater than at informal crossings.
- Pedestrians tend to have less variation in walking speed at zebra crossings than at informal crossings.

C. Simulation Analysis

To validate the simulation model in VISSIM, the behavior of vehicles and pedestrians traveling on the road was checked. Figure 12 shows the model validation in terms of traffic volume.

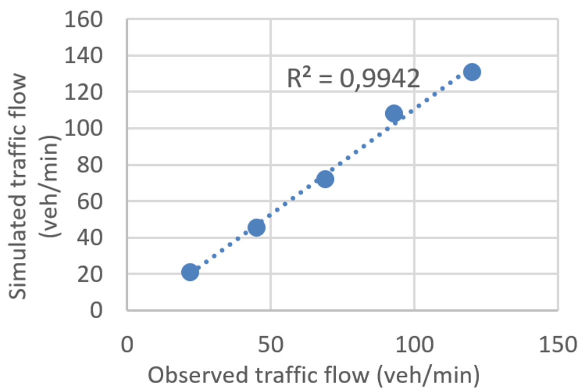


Fig. 12. Traffic flow validation in the simulation model.

As shown in Figure 12, the observed value of real-world traffic flow is close to the VISSIM simulation, with a high R^2 value. This implies that the model is validated and can be used for further analysis. To achieve a variety of travel behaviors, the researchers ran simulation scenarios with different simulation seeds. The observed average walking speeds for informal and zebra crossings were entered into the simulation model. The changes in walking speed were then compared between the two cases, and the results are depicted in Figure 13.

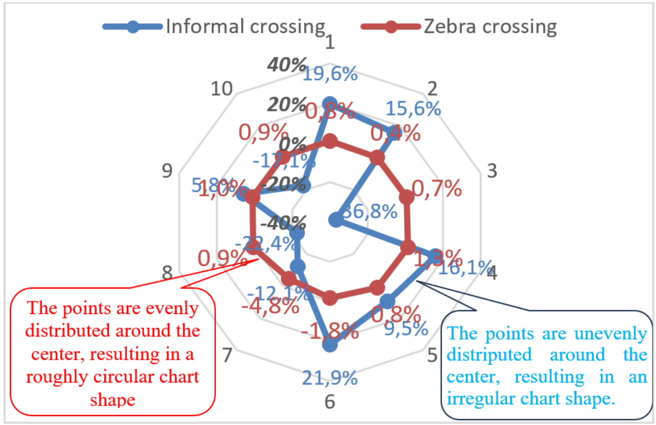


Fig. 13. Speed influence level (*I*) for informal and zebra crossing.

As shown in Figure 13, the changes in walking speed at zebra crossings are more stable and smaller than at informal crossings, as illustrated by the shape of the equidistant distribution graph. The mean margin of the change for informal crossings is 17.7%, whereas the margin for zebra crossings is 1.3%. This indicates that pedestrians feel safer using designated crosswalks because they do not need to significantly adjust their speed to find safe gaps in traffic, unlike at informal crossings.

The author investigated the effect of pedestrian volume on by proposing a definition for speed change, denoted as A_i, as follows:

$$A_i = \left|\frac{S_{100} - S_i}{S_{100}}\right| * 100\% \quad (12)$$

$$Difference = \left|\frac{S_{zebra,i} - S_{informal,i}}{S_{zebra,i}}\right| * 100\% \quad (13)$$

where:

- S_{100}: the walking speed at a pedestrian crossing volume of 100 pedestrians per hour (m/s).
- S_i: the walking speed at a pedestrian crossing volume of i pedestrians per hour (m/s).
- $S_{zebra,i}$: the walking speed at a pedestrian crossing volume of i pedestrians per hour at a zebra crossing (m/s).
- $S_{informal,i}$: the walking speed at a pedestrian crossing volume of i pedestrians per hour at an informal crossing (m/s).

The simulation results for pedestrian flow volumes are illustrated in Figure 14. The results demonstrate that, as the volume of pedestrians crossing increases, the changes in walking speed tend to be greater at the informal crossing (red curve) than at the zebra crossing (blue curve). This finding indicates that crossing the road at a zebra crossing provides a more stable walking speed compared to informal crossings. This outcome demonstrates the pedestrians' comfort with regard to priority and safety when crossing the road at a zebra crossing. Furthermore, the difference in walking speed between zebra and informal crossings (green curve) tends to increase as the volume of pedestrian flow increases.

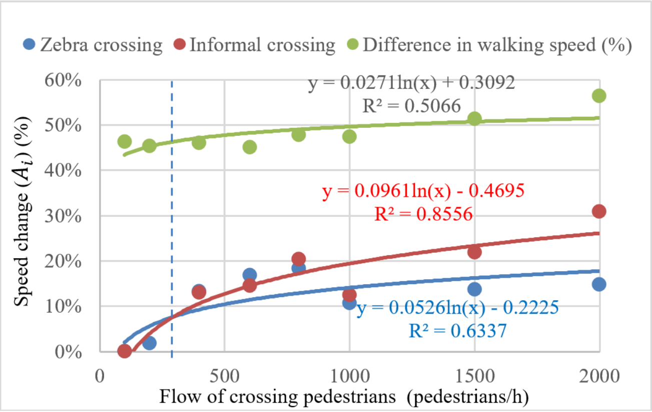


Fig. 14. The effects of pedestrian flow volume on walking speed.

V. CONCLUSION

The present paper is composed of two main components. The first focuses on analyzing pedestrian crossing behavior in terms of walking speed, whereas the second aims to analyze pedestrian walking speed by using simulation models. The investigation utilizes real-world data collected at sites with motorcycle-dominated traffic flow to examine walking speed, considering two types of crossing: informal and zebra. The paper develops simulation scenarios in VISSIM to analyze the walking speed for the studied cases. The data analysis indicates that the speed influence level for the case of zebra crossing is lower than that for the case of informal crossing, with the figure of 24.2% and 32.3%, respectively. The simulation scenarios in VISSIM validate the walking behavior, thereby supporting the conclusion that pedestrians experience greater psychological stability when using designated crossings. The mean margin of change in walking speed at zebra crossings was found to be 1.3%, indicating stability in this context. In contrast, the mean margin of change in walking speed at informal crossings was 17.7%, suggesting greater variability.

While other studies have examined related topics, including crossing safety [3, 12], road crossing behavior in relation to flashing green beacons [4], pedestrian crossing time [6], and the impact on traffic flow [7], this study offers a unique analysis focusing on the aspect of crossing speed. The findings of this research indicate that maintaining a consistent walking speed is indicative of a high level of safety and security. Conversely, frequent and continuous changes in walking speed with large fluctuations negatively impact walking psychology, traffic flow, and the likelihood of accidents. Based on these results, the paper proposes several measures to increase safety, encourage walking, and protect the environment. These measures include implementing pedestrian crosswalks, configuring traffic signals to facilitate pedestrian crossings, and increasing the number of crosswalks on streets. The government should implement solutions that reduce informal crossings without affecting the main traffic flow and minimize traffic accidents by deploying hard separators at the median of roads. The research results confirm the role of the zebra crossing in improving traffic safety on urban roads. Pedestrians feel safer crossing the street at crosswalks than at non-crosswalk locations. They do not need to hurry to find a safe gap in traffic when crossing the road as they would at an informal crossing. Although the presented model is relatively simple, future research should explore more sophisticated models and larger datasets to enhance realism. Furthermore, in-depth studies on how gender influences crossing behavior at crosswalks and informal crossings would provide valuable insight into crossing behavior and help develop reasonable traffic solutions.

ACKNOWLEDGMENT

The author extends profound gratitude to Mr. Huynh Hoai Son from the Economic and Infrastructure Department of My Tu district in Soc Trang province, Vietnam, for his indispensable support in orchestrating the data collection process.

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