IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Campus walkability: enhancing pedestrian safety through installation of raised crosswalks

To cite this article: A E Mohd Noor Azmi and B D Daniel 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1347** 012046

IOP Conf. Series: Earth and Environmental Science **1347** (2024) 012046 doi:10.1088/1755-1315/1347/1/012046

Campus walkability: enhancing pedestrian safety through installation of raised crosswalks

A E Mohd Noor Azmi[1] **and B D Daniel**[2*]

[1] Department of Civil Engineering, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400, Malaysia
[2] Smart Driving Research Center (SDRC), Universiti Tun Hussein Onn Malaysia, 86400, Malaysia
*Corresponding author: basil@uthm.edu.my

Abstract. Walking is one of the most common sustainable modes of transportation in university campuses. To ensure its sustainability, pedestrian facilities that are safe, comfortable and reliable must be adequately provided. Various traffic calming measures have been introduced to enhance the safety of pedestrians. In Universiti Tun Hussein Onn Malaysia (UTHM), 6 raised crosswalks (RCW) have been installed along Persiaran Tun Ghafar Baba. This study aimed to investigate the impact of RCWs on vehicular speed reduction. Speed data were collected at each RCW. Vehicle speeds were recorded before, at and after the RCWs. Speed profiles developed indicate that the 85th percentile speed difference of RCWs were 14 – 25 km/h, which meant that the percentage of speed reduction at RCWs were remarkably high (31 – 48% reduction). Statistical tests confirmed that all RCWs yielded significant drops in speed i.e., the peak mean travelling speed versus the operational speed at the device. Furthermore, it was found that the zones of influence were between 29 – 50 m. This shows that drivers start reducing their speeds from as far as 50 m from the RCWs. Based on these findings, it can be concluded that raised crosswalks are effective in reducing speed, thus enhancing pedestrian safety while crossing as drivers tend to be more aware of their surroundings at lower speeds.

1. Introduction

For the past decades, the majority of road users were pedestrians, due to limited availability of transportation facilities. However, since technology is evolving rapidly, it can be seen that motor vehicles are slowly dominating the road and pedestrians are becoming the minority as road users. Automobiles had become so dominant that civil engineers did not bother to include pedestrians in their first computer models to study traffic flow [1]. These changes have a significant influence on pedestrian safety and walkability. In 1951, Slough, England, was the first city to construct a crosswalk. Since then, crosswalks have been installed all around the world to enhance the safety of pedestrians. Despite the availability of crosswalks, the majority of drivers were unconcerned about the presence of a crosswalk and reluctant to reduce the speed that frequently results in injury or deaths. In order to reduce traffic accidents involving pedestrians, a few traffic calming devices have been invented; one of the devices is the raised crosswalk. Raised crosswalks (RCWs) is a combination of a road hump and a pedestrian crosswalk. Crosswalks contribute significantly to road safety by providing continuity to sidewalks on both sides of the road, reducing the speed of vehicles by interrupting long straights [2].

Speeding is a major threat to road safety in many countries, accounting for more than one-third of all fatal accidents [3]. In February 2022, while crossing a busy street near campus in Cleveland, Tenn, a Lee University student was hit by a car and injured [4]. Therefore, it can be seen that vehicle speeds have a significant impact on pedestrian safety. The study is conducted at Persiaran Tun Ghafar Baba, UTHM. Persiaran Tun Ghafar Baba was initially a two-way street. However, in early 2022, the university has installed 6 RCWs along the street and changed the two-way street to a one-way street. Nevertheless, due to the changes, the traffic flow has improved and less congestion has occurred at intersections. Even so, vehicular speeds are likely to increase compared to two-way streets. One-way road will increase the travel speed and decrease the road safety as most of the accidents are caused by the high travel speed [5]. Therefore, the installation of RCWs as traffic calming devices is likely to reduce vehicular speeds.

The aim of this study is to investigate the speed reduction of vehicles after the installation of RCWs. To achieve the aim of this study, the objectives of this study are to develop speed profile of vehicles traversing RCW and evaluate the impact of RCW on speed reduction. This study is primarily focused on light vehicles. Buses are excluded in data collection since the buses will stop at the bus stops where the RCWs are installed. Data collection is limited to 50 vehicles that travel across each crosswalk. On-site data will be acquired utilizing a video recording method and a mobile application to track vehicle speeds.

2. Raised crosswalks and safety

2.1. Effects of vehicle speed on pedestrian safety

Vehicle speed reportedly to be a huge threat to pedestrian safety. Higher vehicle speeds were found to be strongly associated with both a higher likelihood of pedestrian crash occurrence and a more serious resulting pedestrian injury [6]. The magnitude of the resulting changes in speed has a significant impact on the severity of pedestrian's injuries [7]. In theoretically, the higher the vehicle speed when it collides with a pedestrian, the greater the risk of severe injuries or fatalities. This assertion is supported by a case study on impact speed and pedestrian risk of severe injury. The study findings show that the average risk of light and medium injuries is at an impact speed of 26 km/h and 37 km/h, respectively. The average severity injury considered serious when the vehicle speed was 63 km/h, and causing fatality when the vehicle speed was 74 km/h [8]. As a result, it is possible to conclude that vehicle speed is an important factor that can have an impact on pedestrian safety.

2.2. Impacts of raised crosswalks on speed reduction

A study has been conducted at several locations in Lower Silesia (south-western Poland) to evaluate the selected devices (refugee islands, speed tables and RCWs) that will help reduce the vehicle speeds on pedestrian crossings. The effectiveness of the devices is mainly measured by the range of vehicle speed reduction. The findings show that RCW causes the greatest reduction in speed, as illustrated by positive values of the relative rate of speed change. Compared with refugee islands and speed tables, RCWs have the highest efficiency in terms of speed reduction and its reduction to pedestrian-safe values in the case of an accident [9]. Another study has achieved the reduction of vehicle speed of 40-45% with similar geometric parameters. Hence, the study concluded that RCWs is the most effective traffic calming device that can reduce the vehicle speed and thus maintaining the risk to pedestrians [10].

3. Research methods

3.1 Location of study and data collection

The study involved speed data collection at 6 RCWs along Persiaran Tun Ghafar Baba, University Tun Hussein Onn Malaysia. There are five RCWs located at every intersection of each faculty; Faculty of Technology Management and Business (FPTP), Faculty of Technical and Vocational Education (FPTV), Faculty of Civil Engineering and Built Environment (FKAAB), Faculty of Electrical and Electronic Engineering (FKEE), and Faculty of Computer Science and Information Technology

(FSKTM). Another one, RCW, is located at the intersection of the Tunku Tun Aminah Library where the crosswalk is installed near a bridge that connects the library to the Research Center.

The RCW were 50 mm in height and the length is fixed 5 m. The street widths range from 6.4 m to 7 m. On-site data are acquired utilizing a video recording method and a mobile application "Smart Speed" to track vehicle speeds. Data is collected during off-peak hours for 3 days. It is important to collect data during off-peak hours to make sure the obtained vehicle speeds are unhindered by other motorized or non-motorized traffic. A sample size of 50 vehicle speeds is collected at each RCW. The selected sample data includes motorcycles, cars, vans, and trucks. Buses are excluded from data collection since the observations have been done at bus stops. Observation is done for vehicles that travel on the straight road, while vehicles that cross the faculty intersection will be ruled out. All data are collected in clear and dry conditions in order to eliminate factors that affect driving, such as poor visibility and wet road surfaces.

The road is measured 20 m before and 20 m after the RCW. The observation distance has been determined 20 m before and after the device considering the geometric road design of Persiaran Tun Ghafar Baba that is curvy. Poles are placed at every 5 m interval in the 20 m range as marks to collect the data. Data collection is done by using mobile application "Smart Speed" to measure the speed of vehicles travel across each pole. The distance between observer and vehicles needs to be computed accurately to minimize the error of the obtained reading. Figure 1 shows the plan view of the observation area.

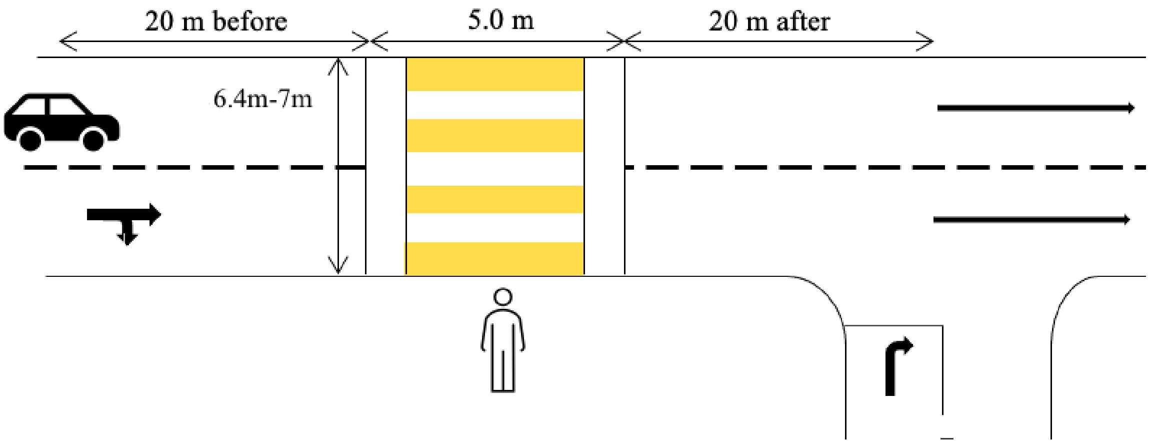


Figure 1. Plan view of observation area.

3.2 Validation of data

Validation of data is done to determine the credibility of the mobile application in order to obtain the accurate reading of vehicular speeds. Therefore, the speed recorded using mobile application "Smart Speed" has been compared with stopwatch method. 30 vehicle speeds are observed and both methods are performed at the same time. The distance between start and end for the stopwatch method is derived by assuming the length based on the performance of observer reaction times. A z-test with a 95% level of confidence was performed in Microsoft Excel to determine the significance of the difference in mean between the two samples. The null hypothesis, H_o, and alternate hypothesis, H_a, have also been stated to conclude about whether H_o is rejected or accepted. The result obtained determined whether a correction factor was needed for the Smart Speed application.

3.3 Data analysis

3.3.1 Speed profiling

To compare the speed-reducing effect of each RCW, the 85th percentile speed and mean speed profiles have been plotted. Figure 2 represents the typical speed profile on a traffic-calmed street using

85th percentile speeds at varying distances. The profiles helped researchers better understand how drivers react to horizontal shifts. From the speed profile, the speed difference can be obtained and the percentage of speed reduction can be determined. Therefore, the impact of RCW on speed reduction can be analyzed. Significant speed difference testing is required to determine the impact or effectiveness of RCWs in speed reduction. Thus, a z-Test is done to calculate the significance of the mean between peak speed and speed at RCW with a 95% level of confidence. The results obtained show whether speed differences at every RCW are significant or not, as well as concluding the effectiveness of RCW in reducing vehicular speed.

3.3.2 Zone of influence

From the developed speed profiles, speeds at different distances from the devices and between devices could be studied. From figure 2, it can be seen that the speed profiles also yielded influence zones generated by calming devices [11]. The zone of influence denotes the distance at which drivers began to slow down before approaching the traffic calming device. Due to the limitation of study length, the 85th percentile speed has been forecasted 30 m backward by using a polynomial trendline in Microsoft Excel to assume the zone of influence. The zone of influence at each RCW has been analysed and further discussed along with the results of speed differences to evaluate the impact of RCWs on speed reduction

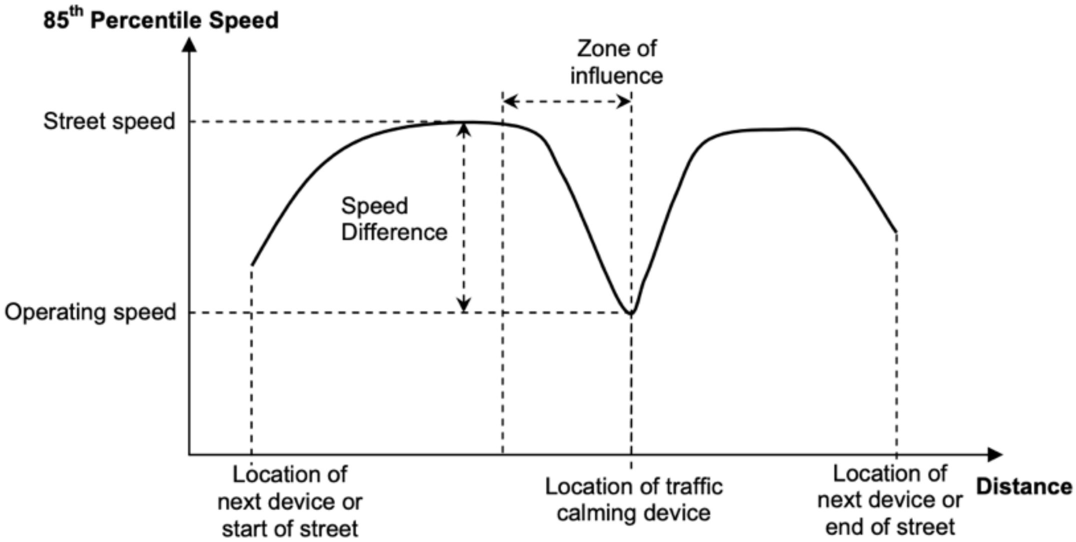


Figure 2. Typical speed profile on a traffic calmed street [11].

4. Results and discussion

4.1 Data validation between stopwatch method and Smart Speed application

Validation of data has been done to determine the credibility of the mobile application in order to obtain the accurate reading of vehicular speeds. The null hypothesis, Ho, and alternate hypothesis, Ha, have been determined as below:

H_o: There is no difference in mean between stopwatch method and Smart Speed app in tracking vehicle speed,

H_a: There is difference in mean between stopwatch method and Smart Speed app in tracking vehicle speed.

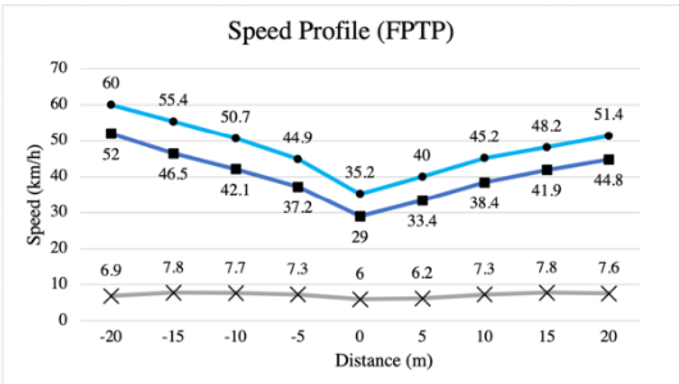
Based on the obtained results, z-test is performed to determine the significant of data collected using Smart Speed app compared to the stopwatch method. Results shows the calculated z-value (-0.24) is less than the z-critical (1.96). Hence, Ho is accepted. Based on the calculated results, there is no significant difference in mean between the two methods in tracking vehicle speed (p-value > 0.05). Thus, no correction factor is needed.

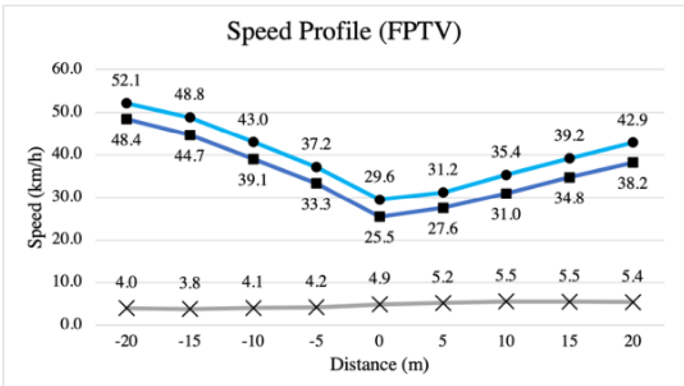
Table 1. Significance testing result between stopwatch method and Smart Speed app using z-test.

	Sample size	Mean	Standard deviation	p-value	z-critical (two tail)	z-value
Stopwatch Method	30	66.95	13.07	0.8134	1.96	-0.24
Smart Speed App	30	67.79	14.47			

4.2 Speed profiles and speed differences

Speed profiles have been developed using the mean, 85th percentile, and standard deviation of vehicular speeds as shown in Figure 3. The speed difference between the street and a traffic calming device is used to indicate RCWs' speed-reduction impact. Every location has showed a reduction in speed before approaching RCW. Table 2 shows the differences in mean and 85th percentile speed at every location of RCWs, percentage of mean speed reduction, and result of significant testing of speed difference. By referring to the table, it has been shown that the range of speed differences in terms of the mean and 85th percentile is 14 – 23 km/h and 14 – 25 km/h, respectively. All RCWs has obtained a reduction in speed between 31% – 48%. Results show that RCW at every studied location has a significant difference between peak mean speed and speed at the device (p-value > 0.05).





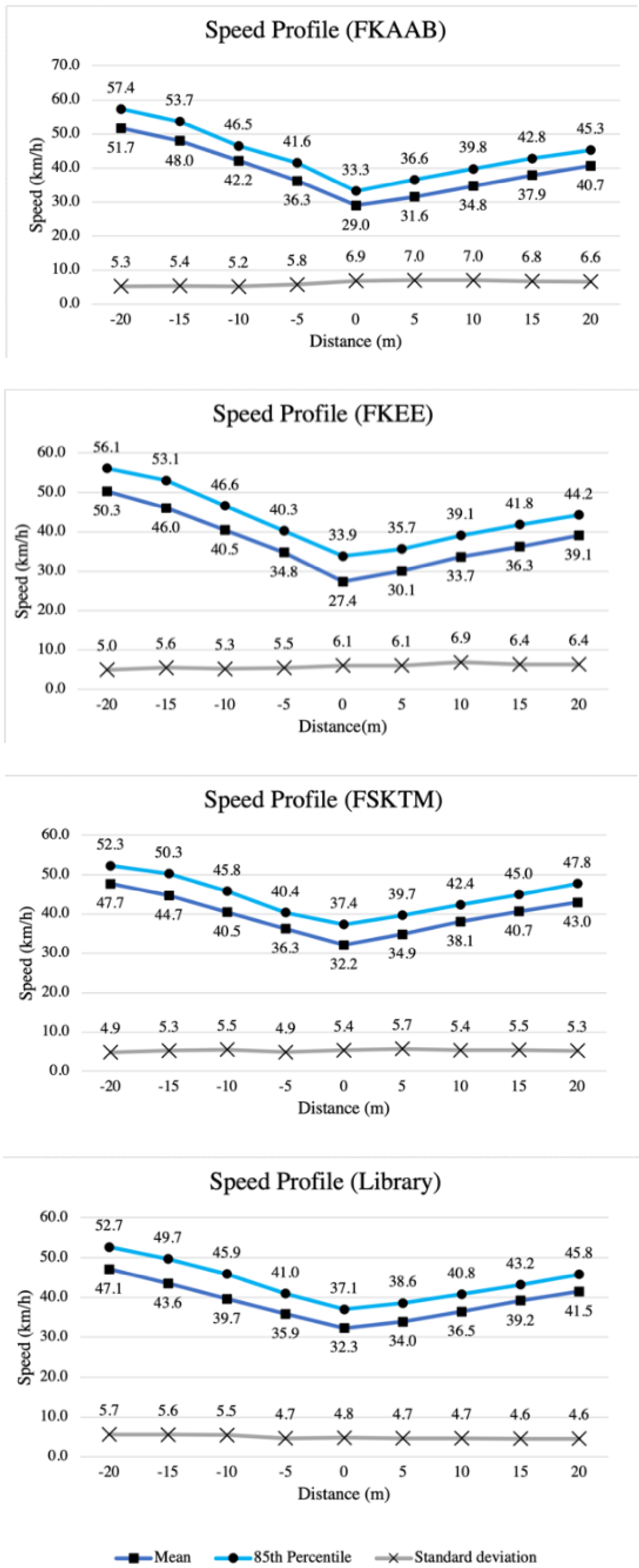


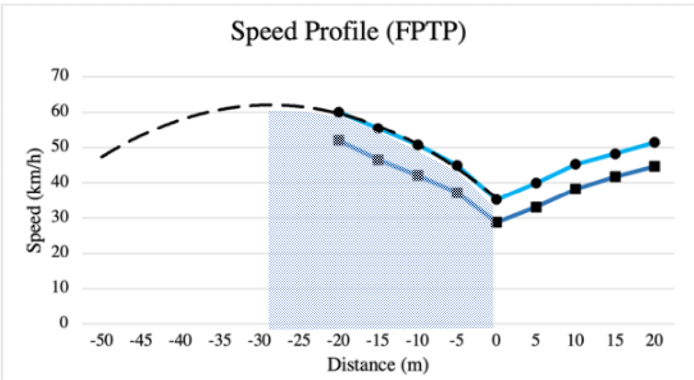
Figure 3. Speed profiles and standard deviation plots.

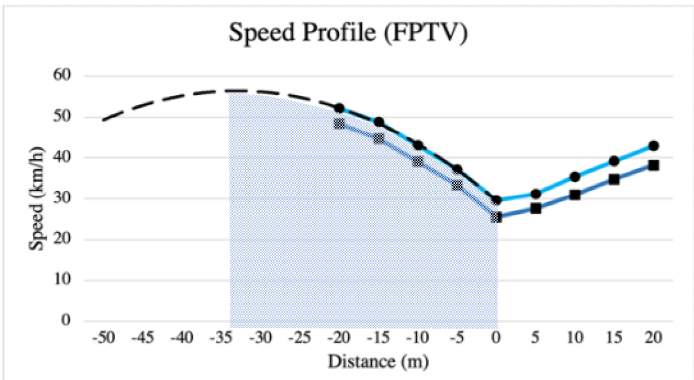
Table 2. Speed difference and z-test results for significance.

Location	Speed Difference (km/h)		Mean Speed Reduction (%)	z-critical	Significance
	Mean	85th Percentile			
FPTP	23.0	24.8	44.2	17.68	Significant ($p < 0.05$)
FPTV	22.9	22.5	47.3	25.75	Significant ($p < 0.05$)
FKAAB	22.7	24.1	43.9	18.41	Significant ($p < 0.05$)
FKEE	22.9	22.2	45.5	20.55	Significant ($p < 0.05$)
FSKTM	15.5	14.9	32.5	15.09	Significant ($p < 0.05$)
Library	14.8	15.6	31.4	14.04	Significant ($p < 0.05$)

4.3 Zone of influence

From the developed speed profiles, the zone that influenced vehicles to slow down can be determined. Figure 4 shows the 85th percentile speed profiles that have been developed at each location of RCW and have been forecasted 30 m backward. Therefore, from the constructed trendlines, assumptions can be made to determine the distance with the highest vehicular speed. The shaded region indicates the zone of influence of RCW. Table 3 shows the zone of influence at every study location, with a distance range of 29 – 50 m. A study conducted at the intersection of FPTP shows the shortest zone of influence. Meanwhile, RCWs located at the intersection of FSKTM and the library exerted the most extensive zone of influence as drivers began reducing their vehicle speeds by 50 m before approaching the devices. The shortest zone of influence indicates that drivers reduced their vehicle speed when they approached the traffic calming device. Meanwhile, longer distances for speed-reducing effect show drivers slow down their vehicles early.





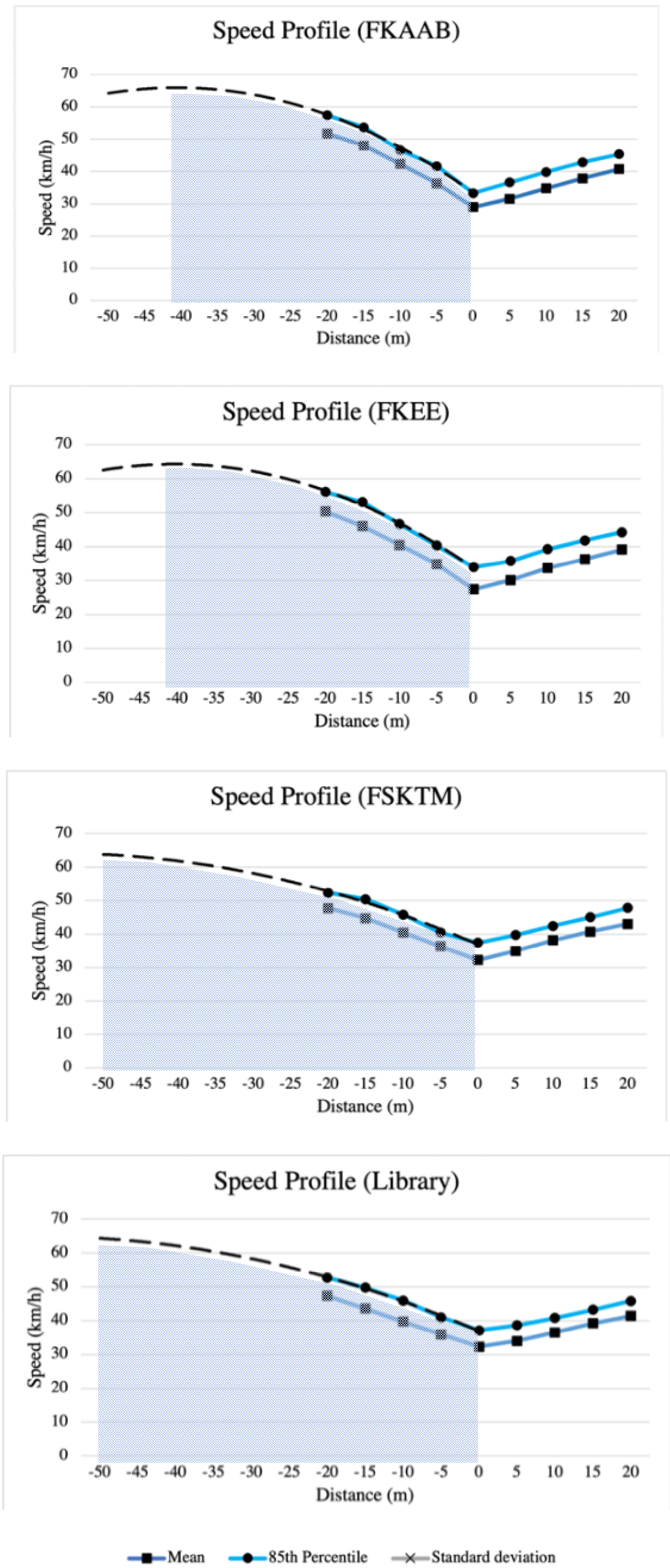


Figure 4. Speed profiles and zones of influence.

Table 3. Zone of influence.

Location	Zone of Influence (m)
FPTP	29
FPTV	34
FKAAB	41
FKEE	41
FSKTM	50
Library	50

4.4 Discussion

The developed speed profiles show a pattern of speed decreasing when vehicles approaching RCWs at every studied location. Although the street speed recorded at every location is above the regulated speed limit (40 km/h), the operating speed is lower than the permitted speed limit at RCW (35 km/h). Among 6 locations of RCWs, the RCW at the intersection of FPTP has the highest 85th percentile speed difference of 24.8 km/h. The street speed at 20 m before approaching the device can be considered high due to the road geometry that is straight compared to other locations which make the drivers tend to overspeed. However, most road users managed to slow down their vehicle speeds when they approached RCW. The results of speed difference at other location can be affected by the road users behaviour since they have been aware of RCW and slow down the speed after the first bump at the intersection of FPTP. RCW at FSKTM shows the lowest 85th percentile speed difference compared to other locations. Assumption of factor affecting the result can be made due to the road geometry at FSKTM that is less curvy. Hence, the road users are not likely to reduce the vehicle speed lower than the speed limit at RCW. Other than that, the street speed at FSKTM is among the lowest compared to other location, and it can be defined the reason why the speed difference is low. This reduction in speed ensuing from the installation of RCWs has also been reported by previous research conducted in Italy [2], Poland [9], New Zealand [11] and United States [12].

5. Conclusion

Speed is a crucial element for road safety issue. It has been determined that it is a major contributing factor in all fatal accidents. Compared to the conventional pedestrian crosswalk, a raised crosswalk is more visible to the road users and they tend to reduce the speed. Based on the discussion of the results and findings in the previous chapter, the range of mean speed and 85th percentile speed differences at RCWs are between 14 – 23 km/h and 14 – 25 km/h, respectively. The zone of influence at RCWs recorded range of 29 – 50 km/h. The mean speed reduction of each RCW has been calculated and has an average of 40.8%, which can be considered acceptable since the difference in speed is quite large and has been proven through significant testing. Hence, it can be concluded that raised crosswalks are effective in reducing vehicular speeds along Persiaran Tun Ghafar Baba.

This study has shown the effectiveness of RCWs in speed reduction along Persiaran Tun Ghafar Baba. However, the outcomes from this study also show that the street speed is still high and exceeding the speed limit. From the observations made during the data collection process, it can be seen that many students instead of using the proper marked crosswalks, they tend to jaywalk to reduce the walking distance. Hence, ensuring the safety of pedestrians might be a difficult task considering human behaviour. It is suggested that future researchers investigate students' crossing behaviour at raised crosswalks.

6. References

[1] Thompson C 2014 *When Pedestrians Ruled the Streets* Retrieved on February 20, 2023 from https://www.smithsonianmag.com/innovation/when-pedestrians-ruled-streets-180953396

[2] Pratelli A, Pratali R and Rossi M 2011 Raised Crosswalks Efficacy on the Lowering of Vehicle Speed. *Urban Transport* **116** 541-552

[3] Distefano N and Leonardi S 2019 Evaluation of the Benefits of Traffic Calming. On Vehicle Speed Reduction *Civil Engineering and Architecture* **7(4)** 200-214
[4] Benninghoff E 2022 *Dangerous Path: After Student Struck, Petition Calls to Change Lee University Crosswalk* Retrieved on 22 February 2022 from https://newschannel9.com/ /local/dangerous-path-after-student-struck-petition-calls-to-change-lee-university-crosswalk-cleveland-bradley-county-pedestrian
[5] Florea, D, Covaciu, D and Timar, J 2016 Analysis of the Influence of One-Way Streets on the Urban Road Networks Connectivity. *CONAT 2016 International Congress of Automotive and Transport Engineering*, pp 653–667
[6] Leaf W A and Preusser D F 1999 *Literature Review on Vehicle Travel Speeds and Pedestrian Injuries* Report No. DOT-HS-809-021;NTIS-PB2000103347 (Washington: National Highway Traffic Safety Administration) pp 6-10
[7] Davis G A 2001 Relating Severity of Pedestrian Injury to Impact Speed in Vehicle-Pedestrian Crashes: Simple Threshold Model. *Transportation Research Record: Journal of the Transportation Research Board* **1773** 108-113
[8] Tefft B C 2011 Impact Speed and a Pedestrian's Risk of Severe Injury or Death *AAA Foundation for Traffic Safety* **50** 871-878
[9] Kruszyna M and Matczuk-Pisarek M 2021 The Effectiveness of Selected Devices to Reduce the Speed of Vehicles on Pedestrian Crossings *Sustainability* **13** 9678
[10] Alavi S H 2007 Analyzing Raised Crosswalks Dimensions Influence on Speed Reduction in Urban Streets *Proc. 3rd Urban Street Symposium* (Seattle) (Washington: Transportation Research Board) pp 1-15
[11] Daniel B D, Nicholson A and Koorey G 2011 Investigating Speed Patterns and Estimating Speed on Traffic-Calmed Streets *Proc. IPENZ Transportation Group Conference* (Auckland) Volume 2011 (Wellington: Institute of Professional Engineers New Zealand) pp 1-14
[12] Federal Highway Authority 2018 *Raised Crosswalks – Safe Transportation for Every Pedestrian: Countermeasure* Technical Sheet No. FHWA-SA-18-063 (Washington: United States Department of Transportation) pp 1-2

Acknowledgement
The authors would like to thank Universiti Tun Hussein Onn Malaysia for funding this research under Tier 1 Research Grant (Q346).