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Walking speeds for timing of pedestrian walk and clearance intervals

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Abstract

Using suitable pedestrian crossing speeds for traffic signal design would have significant impacts on safety and efficiency at signalised intersections. This paper investigates pedestrian crossing speeds at signalised intersections for the Green Walk time and Flashing Red Don't Walk time. Video data of pedestrian crossings were recorded at two signalised intersections in Melbourne and analysed using Kinovea, an open-source motion video analysis software. Overall, results show that the average speed and 15th percentile crossing speed from all survey sites and crossing types are 1.49 m/s and 1.25 m/s respectively. The overall 15th percentile speed of 1.25 m/s is close to the normal walking speed (1.2 m/s) often adopted for both Green Walk and Flashing Red Don't Walk time design (e.g. Austroads' 2016 guide). However, the speeds of crossings started in Flashing Red Don't Walk time (average speed of 1.63 m/s and 15th percentile speed of 1.37 m/s) are significantly higher when compared to crossings started in Green Walk time (average speed of 1.45 m/s and 15th percentile speed of 1.25 m/s). Particularly, the 15th percentile speed of crossings started in Flashing Red Don't Walk time for the survey site in Hawthorn, Melbourne is 1.43 m/s, which is close to the design speed for Flashing Red Don't Walk time adopted by VicRoads (1.5 m/s). These findings suggest that a higher design speed can be adopted for Flashing Red Don't Walk time than for Green Walk time. Results also indicate that pedestrians who have already passed the middle of the road when the signal turned from Green Walk to Flashing Red Don't Walk have a lower speed during the rest of the crossing.

Keywords: pedestrian; speed; clearance time; walk time

1. Introduction

Pedestrian walking speeds are important parameters for designing traffic signals. Given the relatively long time that pedestrians require crossing a road, the pedestrian walk time and clearance time often represent a large proportion of the signal cycle that could have been used for other movements. Discussion on the impacts of different pedestrian walking speeds on the overall efficiency of signalised intersections can be found in LaPlante and Kaeser (2004). In the US, walking speeds of between 3.5 ft/s (or 1.07 m/s) and 4 ft/s (1.2 m/s), based on 15th percentile speeds, are often recommended for calculating the pedestrian clearance time (Fitzpatrick et al., 2006, FHWA, 2009). When there are concerns about older pedestrians, a walking speed of 3.0 ft/s (or 0.9 m/s) should be employed (Fitzpatrick et al., 2006).

In Australia, the walking speed used for determining the pedestrian walk time and pedestrian clearance time is usually 1.2 m/s (Austroads, 2016, TMR, 2014, Department of Transport, 2011, RMS, 2010). For areas with a greater number of slower pedestrians, e.g. the elderly, a clearance walking speed of 1.0 m/s would also be appropriate. In Victoria, walking speeds of 1.2 m/s and 1.5 m/s are employed for determining the pedestrian walk time and clearance time respectively (VicRoads, 2015). The higher allowable walking speed of 1.5 m/s is used for the calculation of clearance time to encourage pedestrians to complete a crossing in an efficient manner. Another reason for using a higher walking speed for the pedestrian clearance time is that pedestrians might increase their speeds due to the limited time to cross during the clearance time. In other words, the increased walking speed during the clearance time is generally due to the perceived urgency from pedestrians when they observe the Flashing Red Don't Walk signal.

A few studies in Japan have suggested that pedestrian walking speed is higher at the onset of the flashing green time (i.e. clearance time) than during the green time (i.e. walk time) (Zhang et al., 2013). It is noted that the pedestrian clearance time in Japan is quite short as the flashing green time is estimated as the time required to walk half of the crossing distance. Pedestrian crossing speed surveys at signalised intersections have been conducted in Victoria, which indicated the normal waking speed of 1.2 m/s is very close to the 15th percentile walking speed (Bennett et al., 2001). However, the effects of pedestrian signals on walking speeds were not examined in these surveys. Overall, there is a lack of empirical evidence on differences between walking speeds during the walk time and clearance time, particularly in Australia.

The objective of this paper is to conduct a survey to estimate pedestrian walking speeds relating the pedestrian walk time (Green Walk) and clearance time (Flashing Red Don't Walk) at signalised intersections. The survey provides empirical evidence of pedestrian walking speeds, which is essential to determining the Green Walk and Flashing Red Don't Walk time for traffic signals. Note that the Green Walk and the Flashing Red Don't Walk are referred to as, respectively, the Walk (Green) and the Flashing Don't Walk (Red) phase in the Guide to Traffic Management Part 9 (Austroads, 2016).

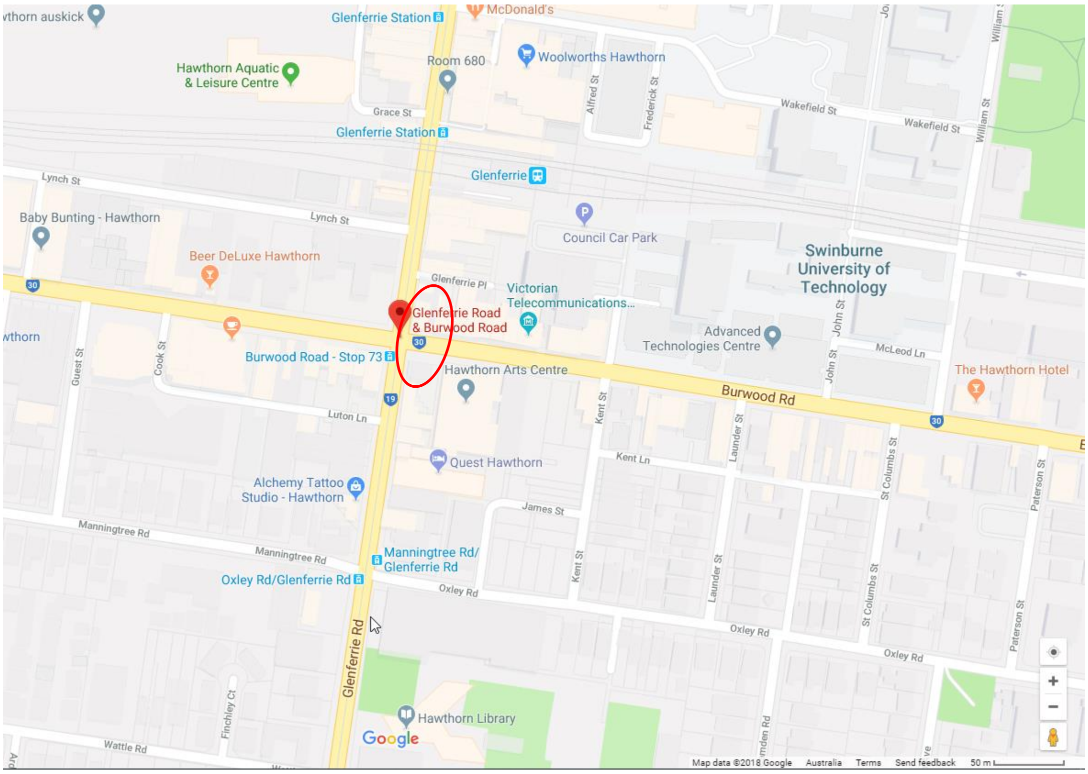
The remainder of this paper is organised as follows. The survey method is presented in Section 2, followed by descriptions of results and discussion in Section 3. Section 4 concludes the report with a summary of key findings.

2. Method

2.1 Survey

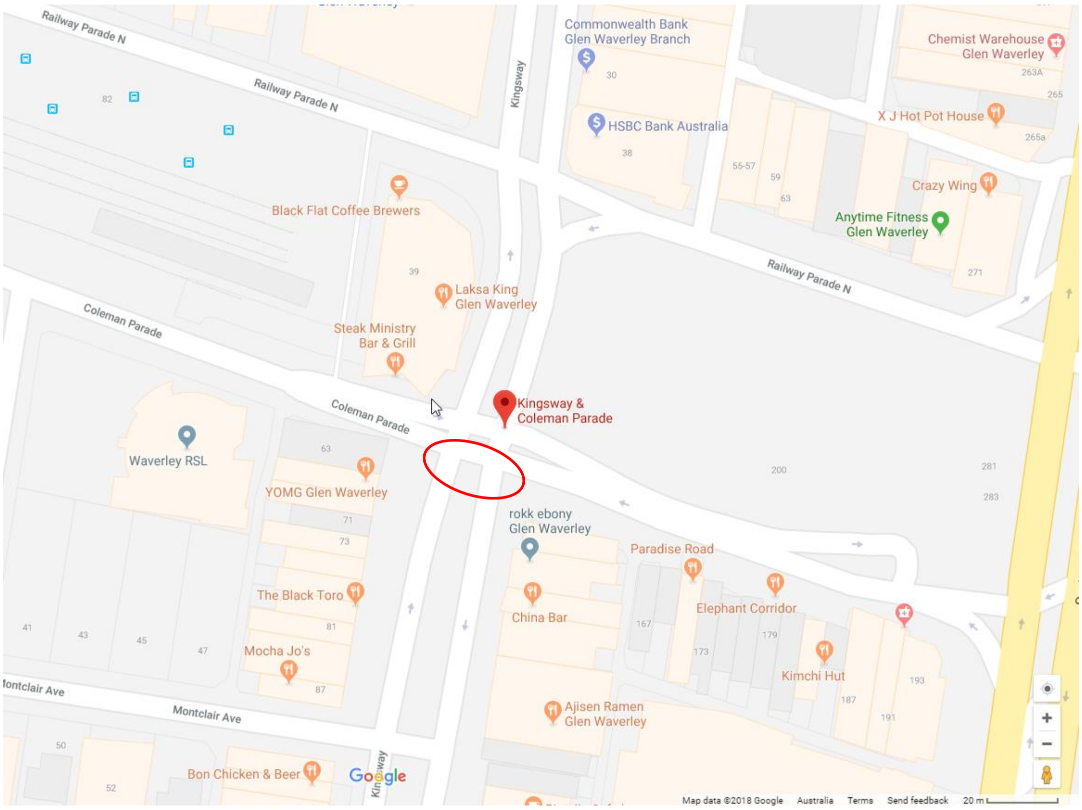
Surveys were undertaken at two signalised intersections in typical urban areas with slightly different characteristics. The first survey site was located on Burwood Road at the intersection between Burwood Road and Glenferrie Road in Hawthorn. Both Burwood and Glenferrie Roads have four lanes with relatively high vehicle flows. The second site was located on Kingsway at the intersection between Kingsway and Coleman Parade in Glen Waverley. Both survey sites are within in walking distances to train stations and shopping strips. The locations of the two survey sites are shown in Figure 1 and their key characteristics are summarised in Table 1. Fixed cameras were installed on light poles to record pedestrian crossing and the pedestrian signal status in Hawthorn and Glen Waverley for 4 hours (12:00 to 16:00) and 6.5 hours (10:30 to 17:00) respectively, on a weekday. The site in Glen Waverley was surveyed for a longer period as it was expected that pedestrian volume would be lower compared to the survey site in Hawthorn. Crossing distances, Green Walk times, and Flashing Red Don't Walk times from the two survey sites are also presented in Table 1. The weather during the survey was dry.

Figure 1 Survey locations



Source: Google Maps (2014), 'Victoria', map data, Google, California, USA

a) Burwood Road and Glenferrie Road



Source: Google Maps (2014), 'Victoria', map data, Google, California, USA

b) Kingsway and Coleman Parade

Table 1 Survey site characteristics

Characteristics	Burwood Road/Glenferrie Road (Hawthorn)	Kingsway/Coleman Parade (Glen Waverley)
Crossing distance (m)	16	23
Green Walk time (s)	variable (approx. 8 - 32)	8
Flashing Red Don’t Walk time (s)	10	15
Survey period	12:00 to 16:00, April 10, 2018	10:30 to 17:00, April 9, 2018
Average volume - two directions (peds/h)	357	110

2.2 Data analysis

Pedestrian and vehicle speeds have often been measured using video data in previous research (Dias et al., 2014, Iasmin et al., 2018). In this study, pedestrian crossing video data were processed using Kinovea, an open-source motion video analysis software (Kinovea, 2018). Video data were recorded with the frame rate of 12 frames per second, allowing the tracking of pedestrian positions at approximately 0.08 second intervals. In Kinovea, a perspective grid can be constructed and calibrated with actual distances measured using Nearmap (Nearmap, 2018). This approach has been validated in previous research looking at turning vehicle speeds (Iasmin et al., 2018). Figure 2 shows the perspective grids calibrated for the two survey sites, which were employed to estimate pedestrians’ walking distance when the signal status changed from Green Walk to Flashing Red Don’t Walk.

Figure 2 Video data analysis

a) Burwood Road/Glenferrie Road (Hawthorn) b) Kingsway and Coleman Parade (Glen Waverley)

Three types of pedestrian crossing were considered, including (i) crossings started and completed within the Green Walk time, (ii) crossings started in Flashing Red Don’t Walk time, and (iii) crossings occurred during both Green Walk time and Flashing Red Don’t Walk time. To estimate speeds for each of the three crossing types, time instances that a pedestrian started and completed the crossing and the associated signal status were extracted from the video data.

In addition, if a pedestrian started crossing in Green Walk time and completed crossing in Flashing Red Don’t Walk time, the time instance that the signal turned into Flashing Red Don’t Walk was recorded, and distance travelled during the Green Walk was estimated using the perspective grid. Thus, speeds during the Green Walk time and during the Flashing Red Don't Walk time can be calculated.

Bidirectional pedestrian volumes are presented in Table 1, with an average of 357 peds/h in Hawthorn and 110 peds/h in Glen Waverley. Overall, pedestrian flows on both directions were similar. A randomised approach was adopted to select pedestrians for the speed analysis when the flow rate was high, e.g. every second pedestrian from both directions. Pedestrian crossings that occurred outside the area between the crosswalk and the stop line were not analysed. Demographic information about pedestrians such as age group, gender and walking disability was also recorded. However, there were not enough samples of pedestrians with walking disability, thus this group was not analysed. Also, the age group was determined solely by observation to the best judgement of the survey team.

3. Results and Discussion

Overall, crossing speeds of 673 pedestrians were analysed, including 385 from Burwood Road/Glenferrie Road (Hawthorn) and 288 from Kingsway/Coleman Parade (Glen Waverley). Table 2 summarises results of the pedestrian speed analysis. Note that given the relatively short Green Walk time in the Glen Waverley site, there was no crossing completed within the Green Walk time.

Table 2 Summary of pedestrian crossing speed results

Site	Speed (m/s)	Pedestrian crossing types					Overall
		Start and finish crossing within Green Walk	Start during Green Walk and finish during Flashing Red Don't Walk			Start crossing during Flashing Red Don't Walk	
			Green Walk	Flashing Red Don't Walk	Both		
Burwood Road/ Glenferrie Road (Hawthorn)	Mean	1.50	1.38	1.56	1.44	1.67	1.50
	std.	0.26	0.41	0.39	0.19	0.30	0.26
	15th %tile	1.22	0.93	1.19	1.25	1.43	1.24
	Median	1.47	1.34	1.51	1.43	1.64	1.47
	85th %tile	1.75	1.80	1.90	1.61	1.86	1.75
	n	254			100	31	385
Kingsway/ Coleman Parade (Glen Waverley)	Mean		1.38	1.46	1.45	1.60	1.48
	std.		0.41	0.26	0.21	0.35	0.25
	15th %tile		0.95	1.23	1.25	1.36	1.26
	Median		1.35	1.44	1.45	1.52	1.46
	85th %tile		1.82	1.70	1.65	1.86	1.66
	n				237	51	288
All survey sites	Mean	1.50	1.38	1.49	1.45	1.63	1.49
	std.	0.26	0.41	0.31	0.20	0.33	0.25
	15th %tile	1.22	0.95	1.21	1.25	1.37	1.25
	Median	1.47	1.35	1.46	1.44	1.54	1.46
	85th %tile	1.75	1.80	1.75	1.64	1.87	1.71
	n	254			337	82	673

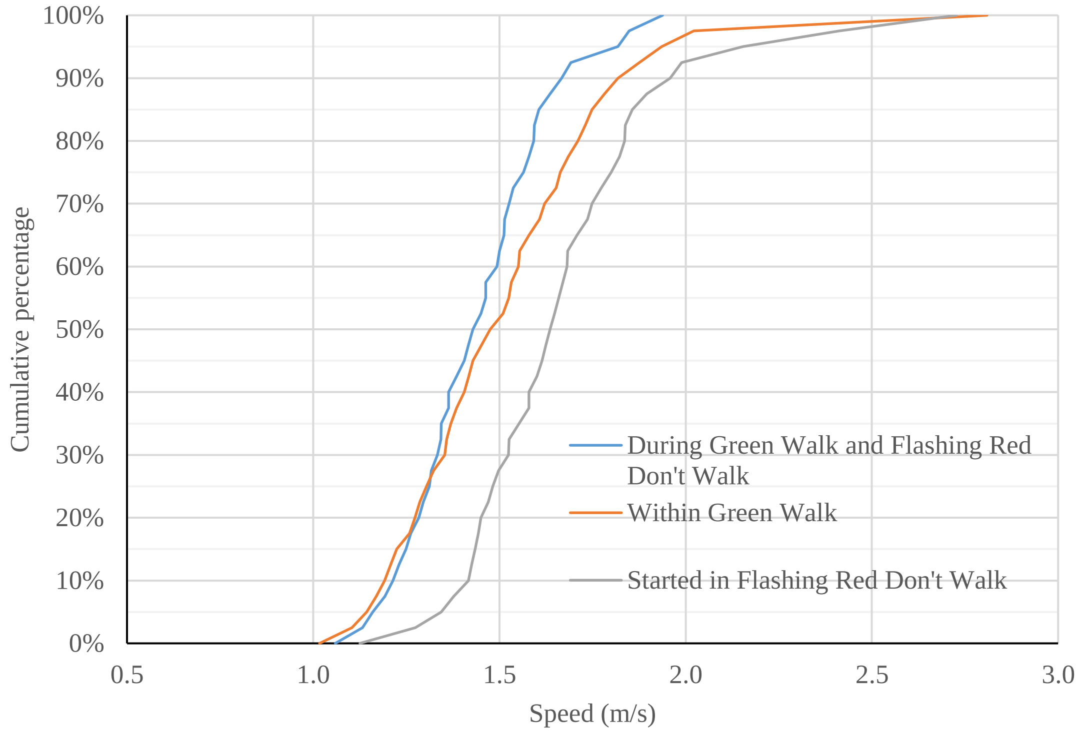
3.1 Burwood Road/Glenferrie Road (Hawthorn)

For crossings occurred during both Green Walk and Flashing Red Don't Walk time, results indicated an average speed of 1.44 m/s. The average speed during Green Walk time (1.38 m/s) was lower compared to that during Flashing Red Don't Walk time (1.56 m/s). Similarly, 15th percentile, 50th percentile, and 85th percentile speeds were higher during Flashing Red Don't Walk than during Green Walk time.

However, the average speed of crossings completed within Green Walk time (1.5 m/s) was slightly higher compared to that of crossings that occurred during both Green Walk time and Flashing Red Don't Walk time (1.44 m/s). This suggests there may be no effect of signal changes during the crossing on pedestrian speeds. A possible explanation for the slightly higher speed during Flashing Red Don't Walk time when compared to Green Walk time is that pedestrians could increase their speed slightly during the latter part of the crossing.

It was evident that the average speed of crossings started in Flashing Red Don't Walk time was significantly higher compared to those of crossings within Green Walk time or that occurred during both Green Walk time and Flashing Red Don't Walk time (1.67 m/s versus 1.5 m/s and 1.44 m/s respectively, statistically significant at $p<0.001$). Figure 3 illustrates cumulative percentages of speeds by crossing types, which further indicates a higher speed for crossings started when the signal had already turned into Flashing Red Don't Walk. Overall, the average pedestrian speed, 15th percentile speed, and 85th percentile speed for the survey site in Hawthorn were 1.5 m/s, 1.24 m/s, and 1.75 m/s respectively.

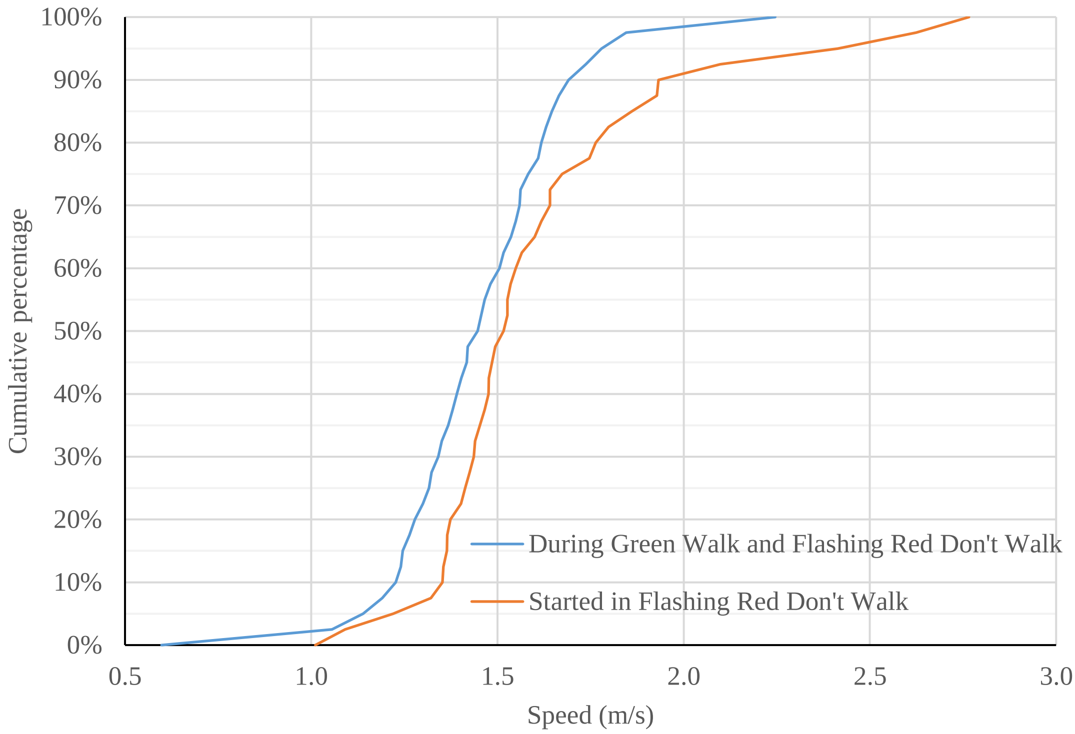
Figure 3 Cumulative percentage of pedestrian speeds by crossing types (Burwood Road/Glenferrie Road in Hawthorn)



3.2 Kingsway/Coleman Parade (Glen Waverley)

As shown in Table 2, speeds of crossing started in Flashing Red Don't Walk time were higher compared to speeds started in Green Walk time (an average of 1.6 m/s versus 1.45 m/s respectively, statistically significant at $p<0.001$). The distributions of speeds are further depicted in Figure 4. The average speed of crossings that occurred during both Green Walk time and Flashing Red Don't Walk time was 1.45 m/s, which is similar compared to the Hawthorn site. For this type of crossing, the average speed during Flashing Red Don't Walk was slightly higher than during Green Walk time (1.46 m/s versus 1.38 m/s). However, there was no crossing completed within the Green Walk time for comparison. Overall, results were consistent with those from the Hawthorn survey site. The average pedestrian speed, 15th percentile speed, and 85th percentile speed for the survey site in Glen Waverley were 1.48 m/s, 1.26 m/s, and 1.66 m/s respectively.

Figure 4 Cumulative percentage of pedestrian speeds (Kingsway/Coleman Parade in Glen Waverley)



3.3 Combined results from both survey sites

Combining results of the two survey sites, the average crossing speed, 15th percentile speed, and 85th percentile speed were 1.49 m/s, 1.25 m/s, and 1.71 m/s respectively. These speeds are close to findings of previous research in Melbourne (Bennett et al., 2001), which indicated an average walking speed of 1.63 m/s, 15th percentile speed of 1.24 m/s, and 85th percentile speed of 1.96 m/s. Particularly, the 15th percentile speed from both survey sites was very close to the normal walking speed of 1.2 m/s often used for traffic signal design.

Figure 5 and Figure 6 show distributions of speeds by survey sites and by crossing types. Speeds of crossing started when the signal was already Flashing Red Don't Walk were higher. Overall, the 15th percentile speed of crossings started in Flashing Red Don't Walk time was 1.37 m/s, which is slightly lower than the speed recommended for designing clearance time in Victoria (i.e. 1.5 m/s). The 15th percentile speed at the intersection between Burwood Road and Glenferrie Road, where pedestrian and traffic flows were relatively higher, was 1.43 m/s.

Figure 5 Cumulative percentage of pedestrian speeds by survey sites

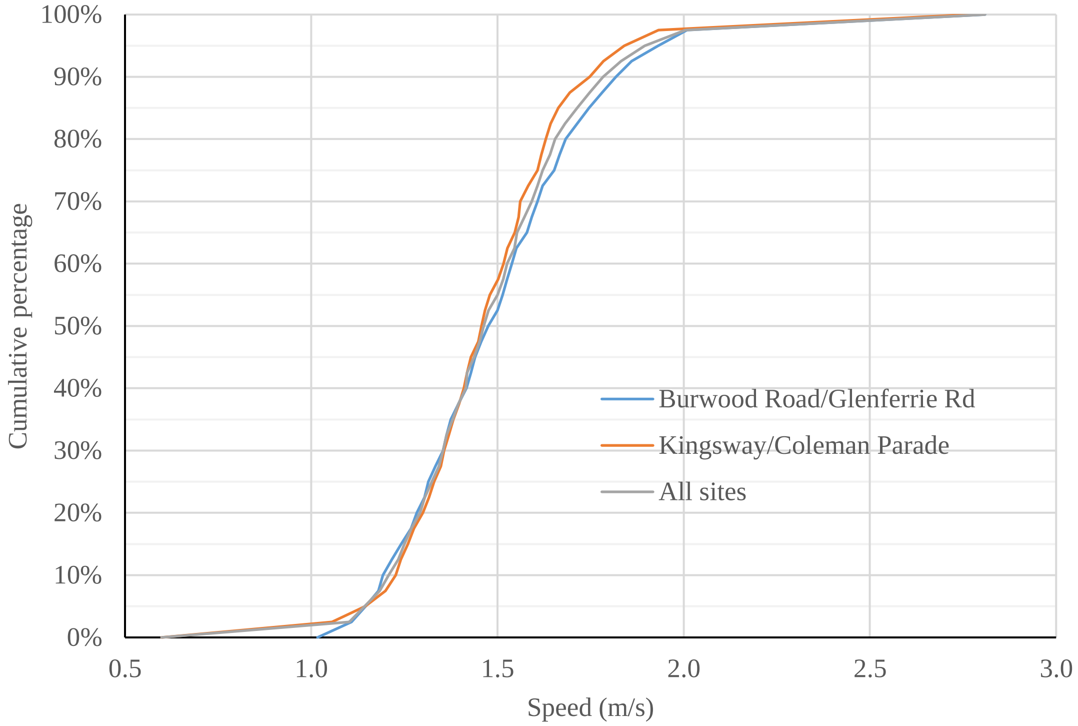
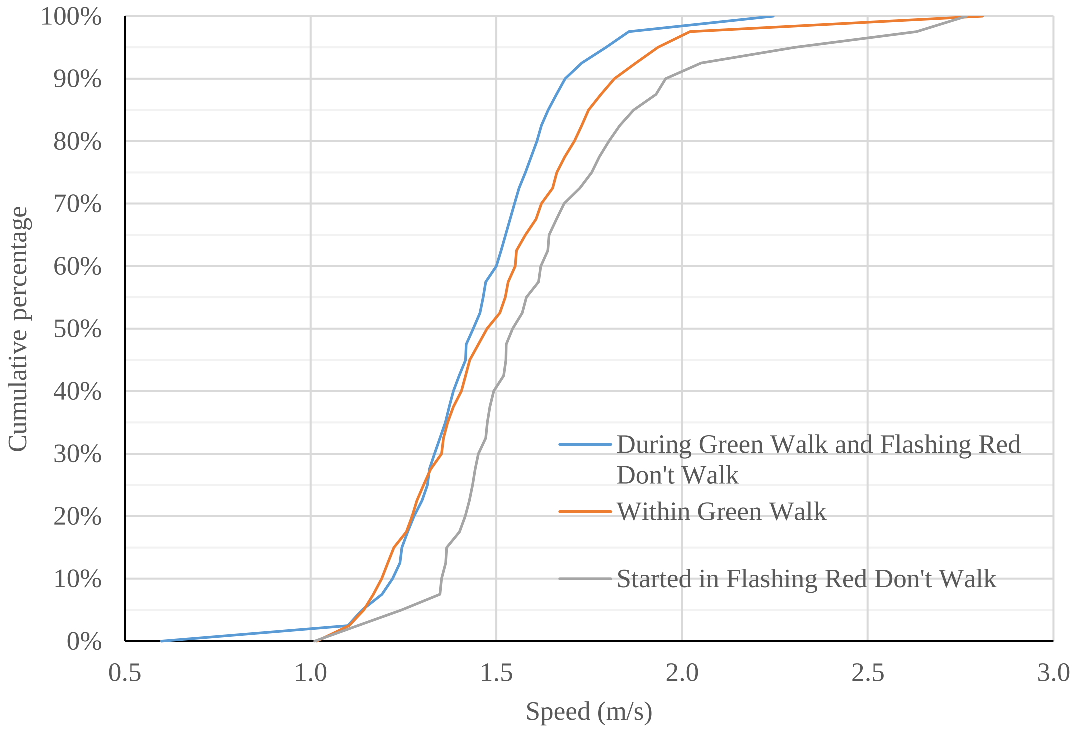


Figure 6 Cumulative percentage of pedestrian speeds (all survey sites)



3.4 Speed analysis

Table 3 shows that if pedestrians passed the middle of the road when the signal turned from Green Walk to Flashing Red Don't Walk, their speeds during the rest of the crossing (during Flashing Red Don't Walk time) tend to be lower (1.46 m/s versus 1.66 m/s, statistically significant at $p<0.01$). The reason might be that pedestrians who did not pass the middle of the road when the signal changed faced a longer distance to cross the road and therefore chose a higher speed to complete crossing safely. Note that the survey site in Glen Waverley was not selected for analysis since almost all pedestrians were in the first half of the crossing when the signal changed due to the relatively short Green Walk time.

Table 3 Pedestrian speed during the Flashing Red Don't Walk time (Burwood Road/Glenferrie Road in Hawthorn)

Speed (m/s)	Passed the middle of the road when signal turned to Flashing Red Don't Walk	
	Yes	No
Mean	1.46	1.66
std.	0.31	0.43
n	52	49

Table 4 indicates that males had a higher crossing speed than females. This observation is consistent for all crossing types. Overall, the average speeds of males and females were 1.54 m/s and 1.44m/s respectively (statistically significant at $p<0.001$).

Table 4 Pedestrian crossing speed by gender

Gender	Speed (m/s)	Pedestrian crossing types					Overall
		During Green Walk and Flashing Red Don't Walk			Within Green Walk	Started in Flashing Red Don't Walk	
		Green Walk	Flashing Red Don't Walk	Both			
Female (n=335)	Mean	1.35	1.46	1.43	1.44	1.57	1.44
	std.	0.39	0.28	0.20	0.22	0.37	0.23
Male (n=337)	Mean	1.42	1.52	1.47	1.56	1.66	1.54
	std.	0.42	0.34	0.20	0.29	0.31	0.26

Table 5 presents pedestrian crossing speed by age group. As expected, in general older pedestrians had a lower speed (1.33 m/s versus 1.5 m/s, statistically significant at $p<0.001$). Particularly, the difference in speeds of crossings started in Flashing Red Don't Walk time was larger (1.35 m/s versus 1.65 m/s, statistically significant at $p<0.001$).

Table 5 Pedestrian crossing speed by age group

Age group	Speed (m/s)	Pedestrian crossing types					Overall
		During Green Walk and Flashing Red Don't Walk			Within Green Walk	Started in Flashing Red Don't Walk	
		Green Walk	Flashing Red Don't Walk	Both			
Under 60 (n=633)	Mean	1.39	1.49	1.45	1.52	1.65	1.50
	std.	0.41	0.30	0.20	0.26	0.33	0.25
60 or above (n=40)	Mean	1.25	1.49	1.35	1.29	1.35	1.33
	std.	0.39	0.44	0.18	0.23	0.21	0.20

4. Conclusions

In this paper, a sample of 673 pedestrian crossings at two signalised intersections was collected using video recording and analysed using a motion video analysis software. Key findings are summarised as follows:

- Overall, the average speed, 15th percentile speed, and 85th percentile speed were 1.49 m/s, 1.25 m/s, and 1.71 m/s respectively. Results from each survey site also indicated a similar trend. These results are in alignment with previous research.
- The average speed of crossings started in Green Walk time and completed outside the Green Walk time was 1.45 m/s, which is very close to the average speed of crossings started and completed within Green Walk time (1.5 m/s). The 15th percentile speed of crossings started in Green Walk time from the two sites ranged between 1.22 m/s and 1.25 m/s.
- The speeds of crossings started in Flashing Red Don't Walk time were significantly higher compared to speeds of crossings started in Green Walk time (with the average speed of 1.63 m/s, the 15th percentile speed of 1.37 m/s, and 85th percentile speed of 1.87 m/s).
- At the signalised intersection between Burwood Road and Glenferrie Road in Hawthorn, the average and 15th percentile speeds of crossings started in Flashing Red Don't Walk time were 1.67 m/s and 1.43 m/s respectively. These results were higher when compared to the signalised intersection between Kingsway and Coleman Parade in Glen Waverley, which is partly contributed to by higher pedestrian and vehicle movements in the site in Hawthorn.
- Among pedestrians who started crossings in Green Walk time, but completed outside the Green Walk time, those who already passed the middle of the road when the signal turned into Flashing Red Don't Walk had a lower speed for the rest of the crossing (average speed of 1.46 m/s versus 1.66 m/s).

Survey results confirmed that the overall 15th percentile crossing speed was close to 1.2 m/s, which is the normal walking speed adopted for Green Walk time design. The 15th percentile speeds of crossings started in Flashing Red Don't Walk time was 1.43 m/s and 1.37 for the site in Hawthorn and for both sites respectively, which is close to the 1.5 m/s speed used by VicRoads for Flashing Red Don't Walk time design. An important and practical implication of the survey results is that a higher design speed can be used for Flashing Red Don't Walk time than for Green Walk time.

It is noted that whilst VicRoads bases the walk and clearance speed on 1.2m/s and 1.5m/s respectively, this is supplemented by an additional minimum period of 3-second Solid Red Don't Walk and a site inspection by a traffic signal engineer to confirm the appropriateness of the pedestrian timings. This provides for a conservative approach by providing a safety factor (3-second Solid Red Don't Walk prior to conflicting movements facing a green signal) and also allows the engineer to provide sound engineering judgement to further increase (never decrease) the pedestrian timings (e.g. when traffic signals are adjacent to a primary school with crossing supervisors or retirement village).

Although this paper has presented several meaningful findings, there are several areas for deeper investigation in future research. First, the analysis for walking disability was not conducted due to the very limited sample size of this group. In addition, the age group of pedestrians was estimated visually, which is not ideal. Finally, similar surveys could be conducted for a larger number of sites and for both weekdays and weekends for a greater generalisation of findings.

Acknowledgement

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