Akcelik & Associates Pty Ltd

TECHNICAL REPORT

An Investigation of Pedestrian Movement Characteristics at Mid-Block Signalised Crossings

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An Investigation of Pedestrian Movement Characteristics at Mid-Block Signalised Crossings

Contents

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Executive Summary

This report presents findings of a research project that investigated pedestrian movement characteristics at pedestrian actuated mid-block signalised crossings on four-lane undivided roads in Melbourne, Australia. The surveys were conducted at three signalised crossings. Two surveys were carried out at each site, one on a weekday and one on the weekend. A survey method was developed and used as part of this project. The main objective of the study was to obtain information on crossing speeds of pedestrians for signal timing purposes, and pedestrian movement start loss and clearance time gain parameters for pedestrian delay and queue calculations. Other information obtained from surveys included the proportions of pedestrians using different signal intervals (Walk, Flashing Don't Walk). The study also investigated characteristics of pedestrians with walking difficulties.

Data for all sites combined indicate an average crossing speed of 1.42 m/s (in the range 1.36 to 1.52 m/s for individual sites and periods), and a 15th percentile speed of 1.18 m/s (in the range 1.14 to 1.34 m/s for individual sites and periods). The 15th percentile speed for all sites combined is very close to the general design speed of 1.2 m/s recommended by the Australian and US design guides.

For pedestrians with walking difficulty (using data for all sites combined), the average crossing speed is 1.29 m/s and the 15th percentile speed is 1.00 m/s. The 15th percentile speed for pedestrians with walking difficulty is very close to the design speed of 1.0 m/s recommended by the Australian and US design guides for sites with higher populations of slower pedestrians. In the data set for all pedestrians with and without walking difficulty, the crossing speed of 1.0 m/s corresponds to the 4th percentile speed.

The ratio of the 15th percentile speed to the average crossing speed is fairly constant (the average value is 0.86). The use of a simple factor of 0.85 could be useful as a rough rule to convert the average crossing speeds to the 15th percentile speed for design speed purposes.

Data for all sites combined as well as data for individual sites indicate that crossing speed characteristics of pedestrians are similar during weekdays and weekends. Data for all sites combined shows that the crossing speed characteristics of queued and unqueued pedestrians are similar although data for individual sites indicate some differences. Pedestrian speeds for the first half of the crossing were higher than the speeds in the second half. The average and 15th percentile crossing speeds decrease with increased pedestrian flow rate. This result is based on the pedestrian flow rate counted in the study direction.

Average start loss is 1.3 s (in the range 1.2 to 1.4 s for individual sites and periods) and average clearance time gain is 2.9 s (in the range 1.5 s to 3.3 s for individual sites and periods). These pedestrian movement parameters are close to the default values used in aaSIDRA 1 (1 s and 3 s, respectively).

Data for all sites combined indicate that the majority of users (87 %) crossed during the Walk interval. The remaining pedestrians crossed during the Flashing Don’t Walk or steady Don’t Walk intervals (13%). It appears that the improper use increases with increased pedestrian flow and decreases with increased vehicle flow. Pedestrians choosing not to use the crossing also appear to increase with increased pedestrian flow and decrease with increased vehicle flow. These results are based on the pedestrian flow rate counted in the study direction and the vehicle flows counted in both directions.

Similar studies of pedestrian movement characteristics are recommended for intersection signalised crossings, mid-block Pelican crossings and Zebra (unsignalised) pedestrian crossings.

Acknowledgements

The work described in this report is based on data collection and initial analyses carried out by Erika Seidel and Andrew Hill as a final year student project towards a Bachelor of Engineering degree at Monash University, Civil Engineering Department during 2000. The Hill and Seidel families assisted in the collection of survey data. The Monash University project was supervised by Adjunct Professor Rahmi Akçelik and Professor Bill Young.

Further work was commissioned by Akcelik & Associates (Research & Development) Pty Ltd to carry out additional data analyses and further develop the survey method. This report was prepared by Rahmi Akcelik in association with Erika Seidel and Andrew Hill using material from the student project and the results of the A&A (R&D) project.

1 Introduction

This report presents findings of a research project that investigated pedestrian movement characteristics at mid-block signalised crossings on four-lane undivided roads. The main objective of the study was to obtain information on crossing speeds of pedestrians for signal timing purposes, and pedestrian movement start loss and clearance time gain parameters for pedestrian delay and queue calculations (Akcelik & Associates 2000). An important aspect of the study was the development of a survey method and its use to conduct surveys at mid-block signalised crossings in Melbourne, Australia.

Other information obtained from surveys included the proportions of pedestrians using different signal intervals (Walk, Flashing Don't Walk), and the extent of pedestrians misusing the signalised crossing or choosing not to use the crossing.

Surveys were conducted at pedestrian actuated mid-block signalised crossings. Such crossings are usually located where high pedestrian activity is concentrated along short sections of road carrying high traffic volumes (AUSTROADS 1993, 1995). For example busy suburban shopping strips with high volumes of vehicle traffic would warrant this type of facility.

Traffic management and planning policies need to give more emphasis to the design of pedestrian facilities in view of the vulnerability of pedestrians and their importance in the overall traffic system. This research aimed to help towards this purpose by improving the understanding of the nature of pedestrian behaviour at signalised crossings.

The study did not investigate the effect of age or sex of pedestrians, although attempt was made to investigate characteristics of pedestrians with walking difficulties.

The survey method is described in *Section 2* including a description of preliminary work undertaken, the survey technique developed and the study sites characteristics. Results of the analyses of survey data are presented in *Sections 3 to 5*.

Section 3 presents the crossing speeds of pedestrians obtained from surveys at three sites. Comparisons of speed profiles for different sites, weekdays vs weekends, queued pedestrians vs unqueued pedestrians, dependence of crossing speed on pedestrian flow, crossing speeds of pedestrians with walking difficulty, and comparison with published data are given. Conclusions of the study are summarised and recommendations for further research are given in *Section 6*.

2 Survey Method

This section describes the survey method including a description of preliminary work and pilot study undertaken, the survey technique developed, study site selection and site characteristics.

2.1 Stages of Project

The first stage of the project involved the development of workable survey forms for data collection in an effective way. This process involved identifying the relevant parameters required by conducting a pilot study and undertaking trial analyses of the data. The forms were improved as a result of trial surveys.

The second stage of the project involved selecting study sites suitable for collecting the data required. Site selection was aimed at finding mid-block pedestrian actuated signalised crossings on undivided four-lane roads with sufficient pedestrian flow. The sites eventually selected for the study were located on Maroondah Highway in Lilydale, Burke Road in Camberwell, and High Street in Ashburton.

Data collection comprised the third stage of the project. Two surveys were carried out at each site, one on a weekday and one on the weekend.

Finally, the raw data were transferred from survey forms to a Microsoft Excel spreadsheet file for processing and analyses. Analyses of crossing speeds for individual sites during weekdays and weekends, and for various combinations of these were carried out. Other information derived from data included pedestrian movement start loss and clearance time gain parameters, the proportions of pedestrians using different signal intervals (Walk, Flashing Don't Walk), and the extent of pedestrians misusing the signalised crossing or choosing not to use the crossing.

2.2 Preliminary Work

A significant amount of time was spent in drafting survey data collection forms that would effectively capture the data required. The development of these forms provided a clear, sequential and workable layout that would enable easy and accurate recording of data. This included taking into consideration the following key points:

1. *Standardisation*: The forms were constructed into a clear and coherent style making it easy for an inexperienced person to quickly understand their requirements in order to facilitate easy recording of data with minimum error.
2. *Observer's workload*: To ensure accurate results, it was seen as vital that too high a workload was not placed on the observer. The balance sought was to keep them active with just enough responsibility to remain busy, but not overloading with too much information.
3. *Sequential listing*: Designing the forms with a logical and sequential order of events was of a high priority. This ensured that the observer was recording data sequentially from the left-hand towards the right hand side of the form for each signal cycle.

2.3 Pilot Study

With the survey forms drafted, a pilot survey was conducted at the Lilydale (Maroondah Highway) site (see *Section 2.5*). From this preliminary study, limitations and inefficiencies of the survey forms were identified, and demand on observers were quantified. The survey method was refined accordingly.

2.4 Site Selection

The following criteria were used for site selection:

(i) Pedestrian-actuated mid-block signalised crossing.

(ii) Undivided four-lane road with a uniform width (and similar width between sites). Different pedestrian behaviour is expected at signalised crossings on divided roads due to some pedestrians stopping in the median area, or due to the use of staged crossings.

(iii) Sufficient pedestrian flow. A balance of judgement was applied between flows too high or too low to ensure the integrity of the data was maintained. Excessive flows would overwhelm the surveyor causing data to be missed. On the other hand, flows that are very low could have the reverse effect of the observers being under-worked and becoming distracted.

With these factors in mind a list of possible sites was formed, eventually leading to the following appropriate sites being selected for the study.

- Burke Road, Camberwell.
- High Street, Ashburton, and
- Maroondah Highway, Lilydale,

Only these three sites were chosen due to the limited time available for the project. However, a good range of conditions was achieved with different levels of pedestrian flows at these sites.

2.5 Site Characteristics

The characteristics of the sites selected for this study are given below. All sites are on undivided four-lane roads in 60 km/h speed limit zones.

Camberwell Site (*Figures 2.1 and 2.2*)

- Location: Burke Road, Camberwell, between Camberwell junction and the intersection of Burke Road and Prospect Hill Road.
- Melways map reference: 45 J12.
- VicRoads Reference Number: 4039.
- Tram flows in both directions.
- Sensor instead of pedestrian push button (audible tone and LED display indicating register of request).
- Traffic slow and generally congested from Camberwell junction.
- Busy strip shopping on both sides of the roadway.

Ashburton Site (*Figures 2.3 and 2.4*)

- Location: High Street, Ashburton, between Summerhill Road and Ashburn Grove.
- Melways map reference: 60 C9.
- VicRoads Reference Number: 3816.
- Parking on both sides of the roadway leading up to the signalised crossing.
- Busy strip shopping on both sides of the crossing.
- Vehicle traffic varies between free-flowing and highly congested within the survey period.

Lilydale site (*Figures 2.5 and 2.6*)

- Location: Maroondah Highway, Lilydale, between Anderson and Clarke Streets.
- Melways map reference: 38 E4.
- VicRoads Reference Number: 144.
- Strip shopping located immediately on the Northern side of the crossing. Southern side shopping strip is separated by a car park from the crossing.
- Pedestrians channelled through the crossing due to surrounding garden area.
- High volume of heavy-vehicle traffic (trucks and buses).
- The crossing is on an uphill grade (approximately 5 %) in the study direction.

Figure 2.1 - Views of the Camberwell site

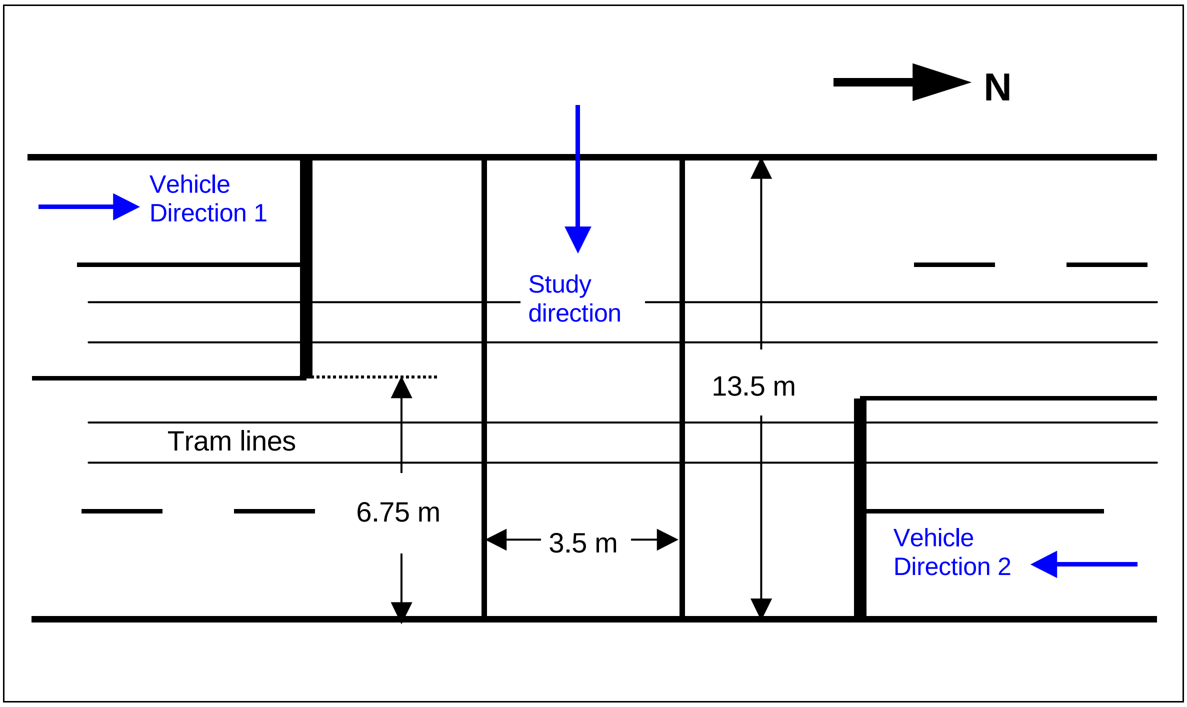

Figure 2.2 - Plan view of the Camberwell site and dimensions

Figure 2.3 - Views of the Ashburton site

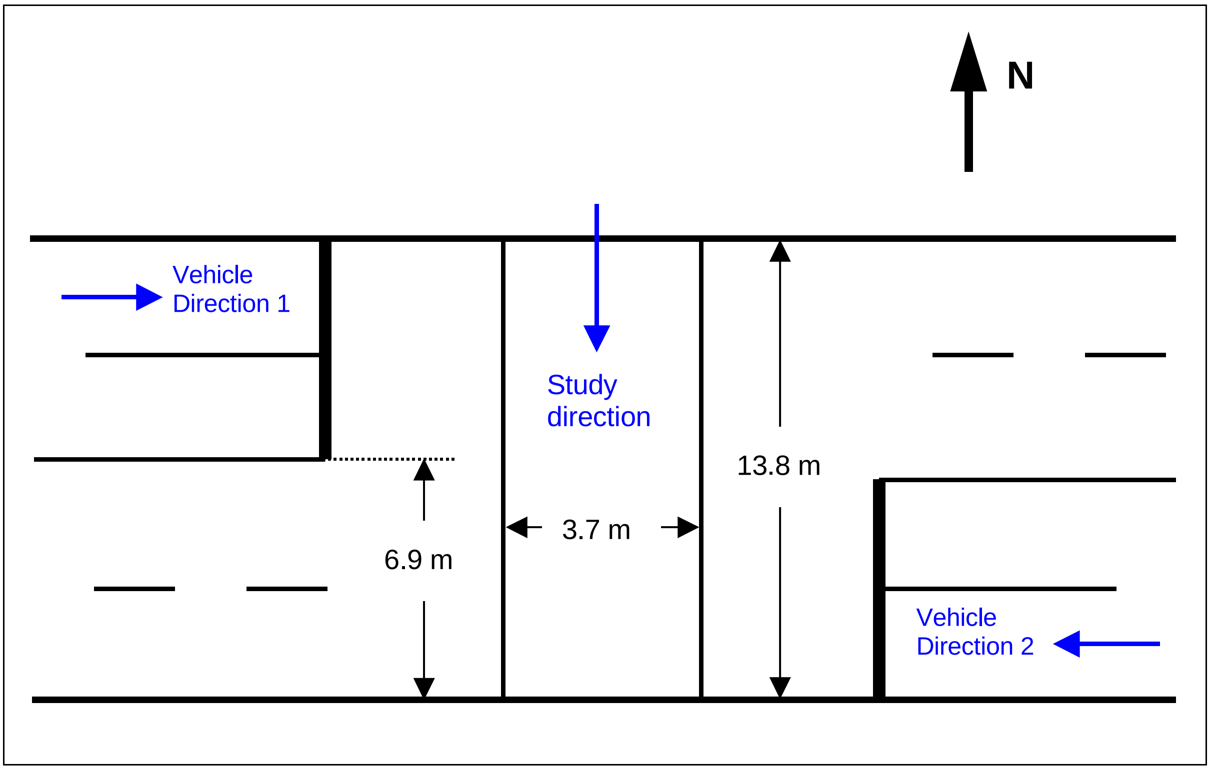

Figure 2.4 - Plan view of the Ashburton site and dimensions

Figure 2.5 - Views of the Lilydale site

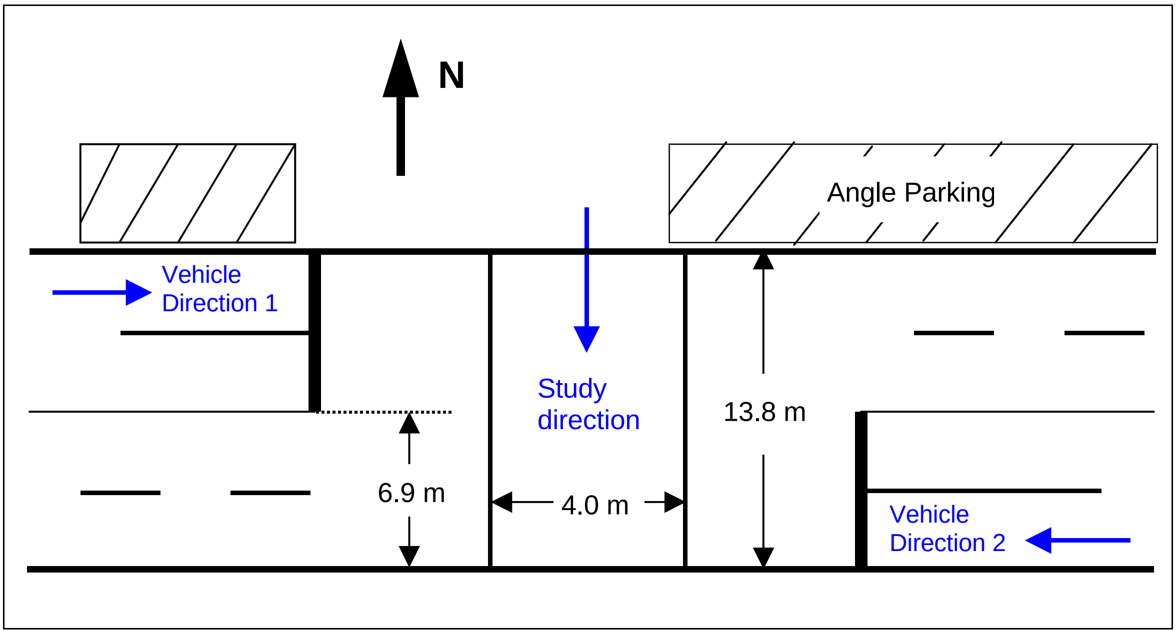

Figure 2.6 - Plan view of the Lilydale site and dimensions

2.6 Data Collection

Two surveys were conducted at each study site, one on a weekday and the other on the weekend. The weekday surveys were conducted on either Tuesdays or Thursdays (1 pm - 4 pm) to get an emphasis on pedestrian traffic associated with office and shopping activities. The weekend surveys were carried out on Saturday mornings (10 am - 1 pm) to capture pedestrian traffic associated with shopping and recreational activities. A sample size corresponding to approximately 50 signal cycles was used for each survey.

The resources needed for the surveys were two stopwatches, a distance-measuring wheel and the survey forms. The availability of a sufficient number of observers ensured that a significant amount of data was recorded to a high degree of accuracy. This allowed the observers to capture the data required efficiently and also be able to pay attention to other more general occurrences of pedestrians behaviour.

Video taping was considered as an alternative survey method during the preliminary stages of the project, but rejected on the grounds of resource constraints.

The need for five observers was not realised during the pilot study phase until the first research survey was conducted at Camberwell. With higher pedestrian flow rates than the Lilydale site, it was difficult to accurately quantify how many pedestrians were not choosing to use the crossing. As a result, this survey was repeated with five surveyors to capture this information.

During the survey it was also an important consideration for the presence of observers to be of low key and isolated from the main flow of pedestrians. This was essential to ensure that pedestrian flows were not impeded and any effects on pedestrian behaviour were minimised.

Although technically the crossing is defined as the area bound within the crosswalk lines, the crossing was taken to the boundary of the vehicle stop lines for the purpose of this study (see *Figure 2.7*). This was considered necessary since a large proportion of pedestrians used this area rather than being confined between the pedestrian line markings.

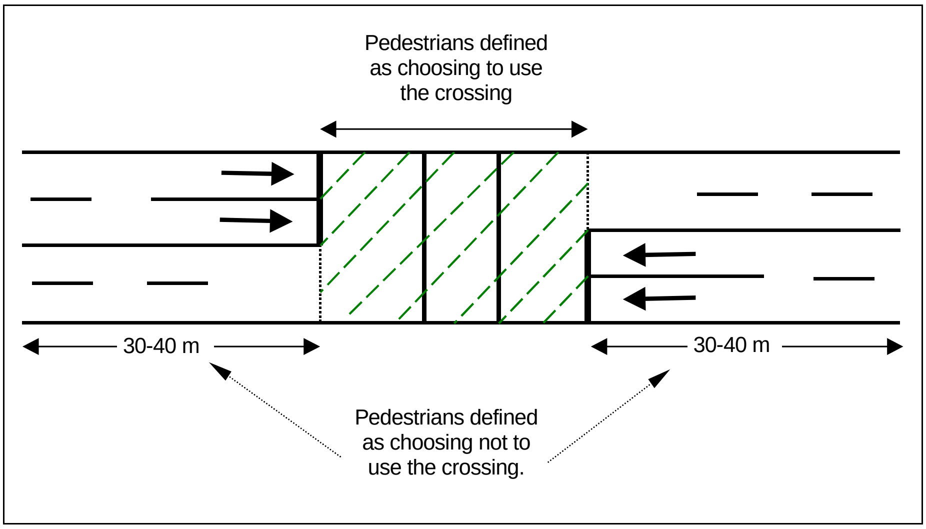

Figure 2.7 - Signalised crossing definition for the purpose of this study

For the collection of crossing speed data, a pedestrian was selected at random in each signal cycle, at the same time trying to obtain a representative distribution of "Queued" and "Unqueued" pedestrians crossing during the green “Walk” phase (see *Section 3.3*).

If the selected pedestrian crossed just prior to the display of the “Walk” signal, then another pedestrian was selected so that only pedestrians beginning on the “Walk” signal were selected.

Initially, it was also intended to collect speed data for pedestrians arriving and crossing during the Flashing Don’t Walk interval. These pedestrians were very difficult to survey because of their unpredictable nature. It was therefore decided not to include these pedestrians in the speed survey.

Pedestrian flows were observed in one direction only (*study direction*). Vehicle counts were performed in each direction by two observers.

3 Crossing Speeds

This section presents the results for crossing speeds of pedestrians obtained from surveys at the three sites described in *Section 2.5*. Comparisons of speed profiles for different sites, weekdays and weekends, queued pedestrians and unqueued pedestrians are given in *Sections 3.1 to 3.3*. Dependence of crossing speed on pedestrian flow, crossing speeds for pedestrians with walking difficulty, and a comparison with published data are discussed in *Sections 3.4 to 3.6*.

Average values, standard deviations and various percentile values of the crossing speeds determined considering the entire crossing distance are given in *Table 3.1*. Crossing speeds for the first half (from step-on to the mid-point) and the second half (from mid-point to the step-off point) of the crossing are given in *Table 3.2.*

In *Figures 3.1 to 3.6*, speed profiles are presented in the form of cumulative frequency graphs of crossing speeds given as the percentage of pedestrians crossing below a given speed.

Figure 3.1 shows the speed profile for data representing all sites combined including data for both weekdays and weekends. The 16^{th} and 4^{th} percentile speeds shown in *Figure 3.1* correspond to the crossing speeds of 1.2 m/s and 1.0 m/s used for determining duration of pedestrian clearance intervals (AUSTROADS 1993, 1995; TRB 2000). The lower value of 1.0 m/s is usually recommended for sites with higher populations of slower pedestrians.

The results given in *Table 3.2* indicate that pedestrian speeds for the first half of the crossing were higher than the speeds in the second half (1.51 m/s vs 1.36 m/s).

Figure 3.2 shows the speed profiles for the three sites with weekday and weekend data combined for each site. Speed profiles for weekday and weekend data for each site are shown in *Figures 3.3 and 3.4*. Speed profiles for weekdays and weekends with data for individual sites combined are shown in *Figure 3.5*. Speed profiles for all sites including weekend and weekday results are given together in *Figure 3.6*. The results presented in these figures are discussed in *Sections 3.1 and 3.2*.

Table 3.1

Crossing speeds at three mid-block signalised crossings (overall speed across entire crossing, m/s)

	Average speed	Standard deviation	**15th percentile**	30th percentile	50th percentile	70th percentile	85th percentile
Camberwell Weekday	**1.36**	0.26	**1.14**	1.27	1.35	1.47	1.63
Camberwell Weekend	**1.37**	0.24	**1.18**	1.24	1.38	1.48	1.54
Camberwell Combined	**1.36**	0.25	**1.15**	1.25	1.37	1.47	1.58
Ashburton Weekday	**1.39**	0.23	**1.14**	1.27	1.40	1.46	1.60
Ashburton Weekend	**1.39**	0.22	**1.17**	1.25	1.39	1.50	1.65
Ashburton Combined	**1.39**	0.23	**1.16**	1.26	1.39	1.49	1.64
Lilydale Weekday	**1.52**	0.28	**1.34**	1.42	1.50	1.61	1.71
Lilydale Weekend	**1.49**	0.19	**1.32**	1.38	1.47	1.56	1.67
Lilydale Combined	**1.50**	0.24	**1.32**	1.39	1.48	1.60	1.70
All Weekdays Combined	**1.42**	0.27	**1.16**	1.33	1.43	1.53	1.65
All Weekends Combined	**1.42**	0.22	**1.20**	1.29	1.42	1.51	1.63
All sites combined	**1.42**	0.24	**1.18**	1.31	1.42	1.52	1.65

* Standard deviations for "combined" cases are based on aggregate data

Table 3.2

Crossing speeds at three mid-block signalised crossings (speeds to the mid-point of crossing and from mid-point to step-off, m/s)

	Speed from step-on to the mid-point		Speed from mid-point to step-off	
	Average speed	Standard deviation	Average speed	Standard deviation
Camberwell Weekday	1.45	0.30	1.29	0.24
Camberwell Weekend	1.55	0.30	1.26	0.24
Camberwell Combined	1.49	0.32	1.28	0.24
Ashburton Weekday	1.45	0.28	1.35	0.24
Ashburton Weekend	1.46	0.25	1.36	0.28
Ashburton Combined	1.45	0.26	1.35	0.26
Lilydale Weekday	1.58	0.33	1.47	0.28
Lilydale Weekend	1.56	0.26	1.43	0.20
Lilydale Combined	1.57	0.29	1.45	0.24
All Weekdays Combined	1.50	0.32	1.37	0.26
All Weekends Combined	1.52	0.27	1.35	0.25
All sites combined	1.51	0.30	1.36	0.26

* Standard deviations for "combined" cases are based on aggregate data

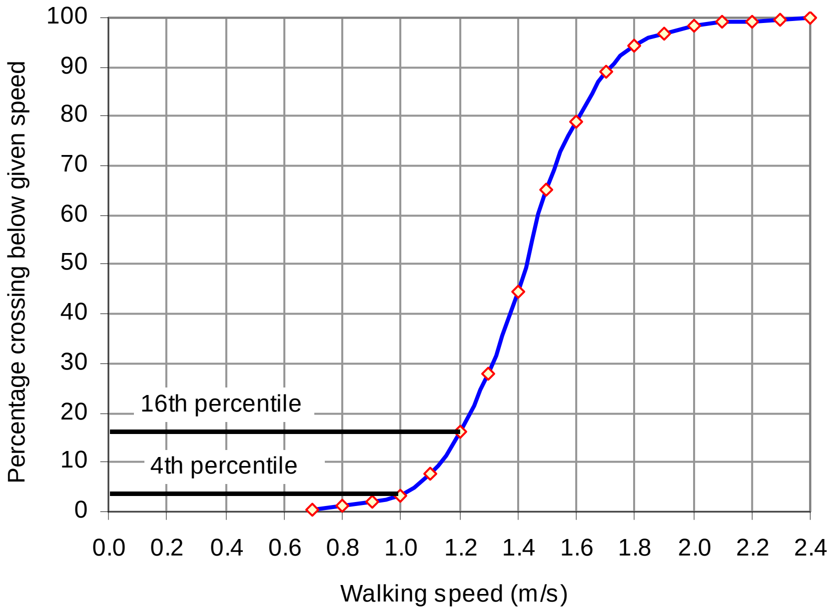

Figure 3.1 - Pedestrian speed at mid-block signalised crossings: data for all sites combined

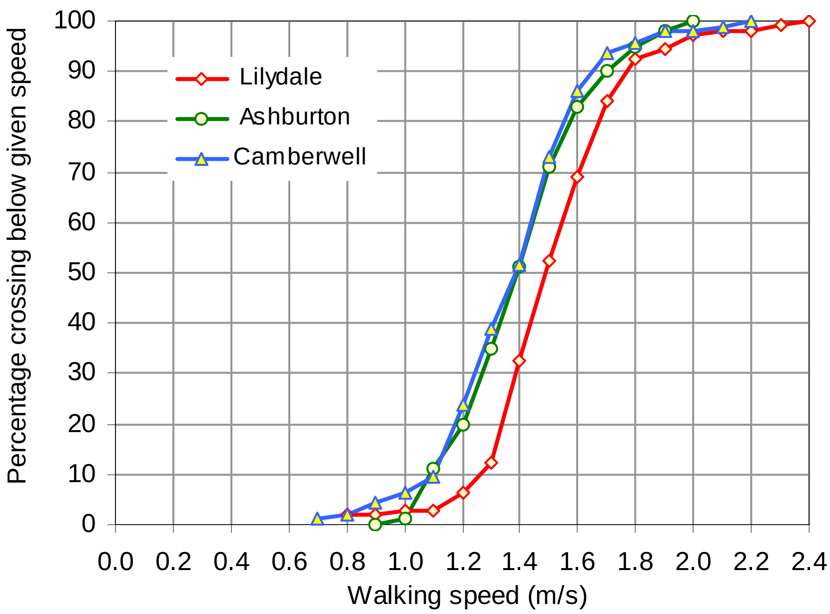

Figure 3.2 - Pedestrian speeds at individual mid-block signalised crossings: weekday and weekend data combined for each site

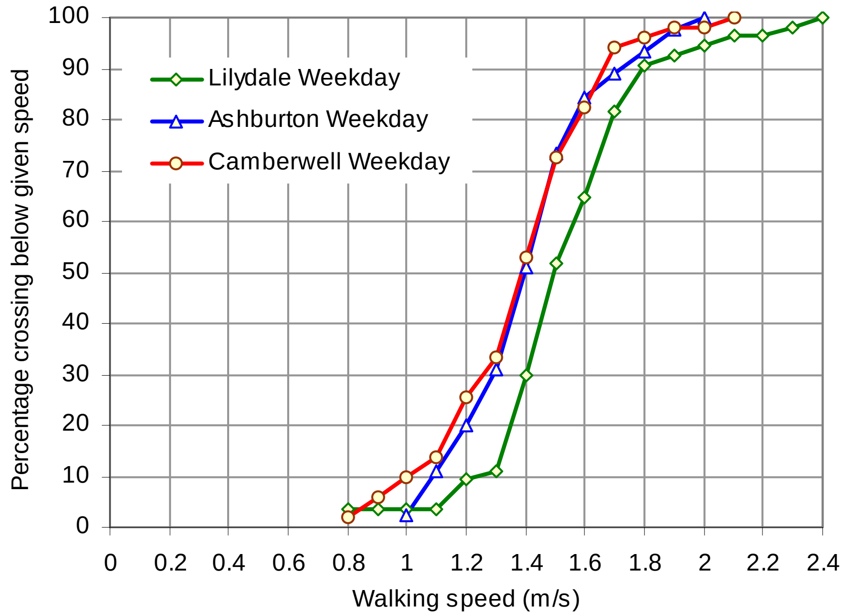

Figure 3.3 - Pedestrian speeds at individual mid-block signalised crossings: weekday data

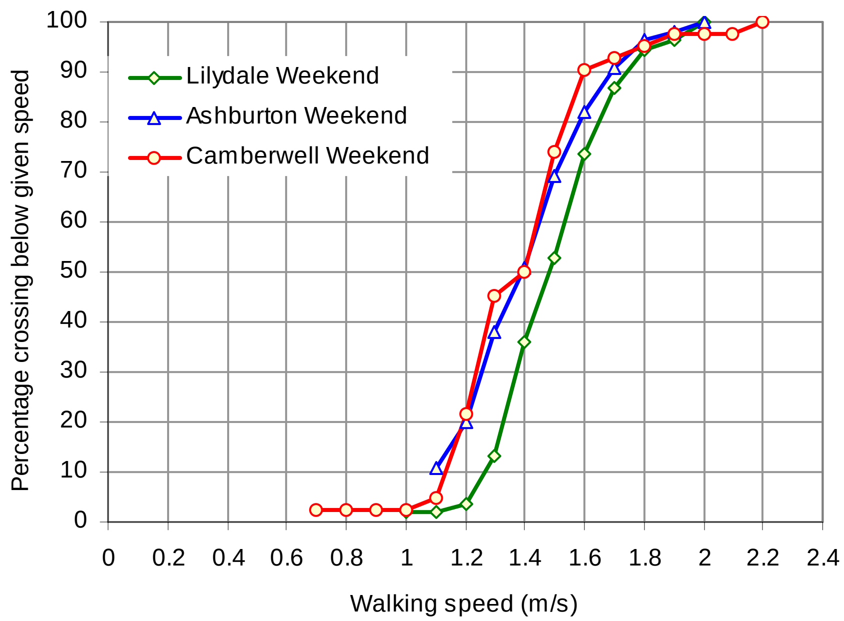

Figure 3.4 - Pedestrian speeds at individual mid-block signalised crossings: weekend data

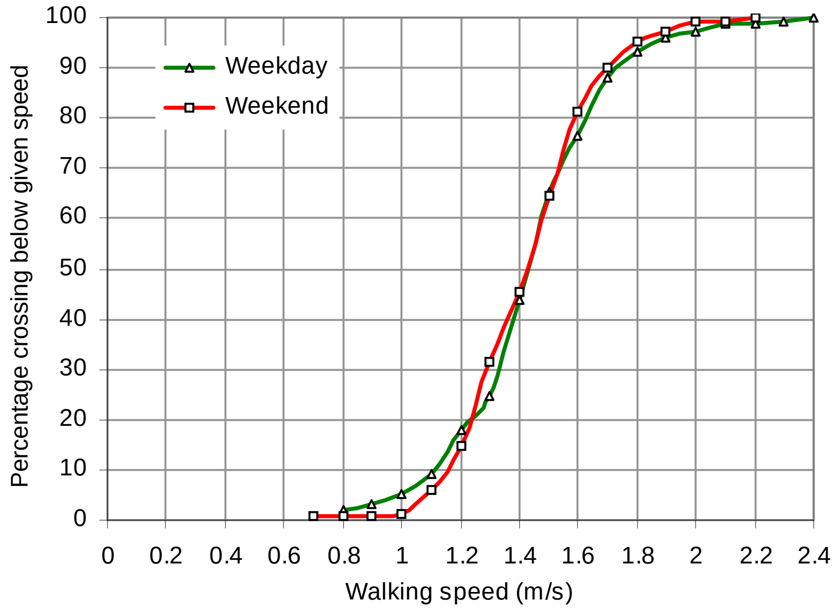

Figure 3.5 - Pedestrian speeds for weekdays and weekends: data for individual mid-block signalised crossing sites combined

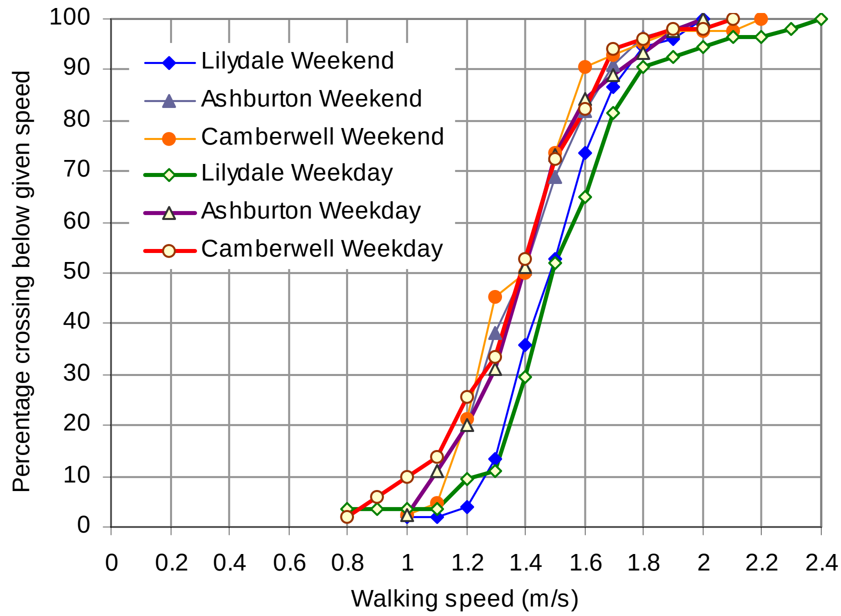

Figure 3.6 - Pedestrian speeds at individual mid-block signalised crossings: all data

3.1 Comparison of Crossing Speeds for Different Sites

Data presented in *Figures 3.2 to 3.4* and *Table 3.1* indicate that the crossing speed characteristics for the Ashburton and Camberwell sites are close (average speed = 1.4 m/s, 15th percentile speed =1.2 m/s) whereas the results for the Lilydale site indicate higher crossing speeds (average speed = 1.5 m/s, 15th percentile speed =1.3 m/s). Possible reasons for this difference include:

(i) The population within the Camberwell and Ashburton areas may be older as reflected in the survey sample.

(ii) The pedestrian flow rates for the Lilydale site were much lower (97 peds/h) than the Camberwell (390 peds/h) and Ashburton (187 peds/h) flows, which allows the pedestrians to walk more freely as discussed in *Section 3.4*.

(iii) At the Lilydale site, the Walk signal display time is longer and the Flashing Don't Walk display time is shorter than other sites (see *Table 5.3* in *Section 5*).

(iv) Vehicle speeds are higher at the Lilydale site (although speed limits are the same at all sites, this is less restricted environment for vehicles).

(v) The design of the signalised crossing at the Lilydale site forces pedestrians to cross in a direct route within the crossing lane due to the barriers formed by the planted areas on both sides of the crossing (*see Figure 2.5*). At the Camberwell and Ashburton sites, significant numbers of pedestrians cross diagonally or take a curved path for the second half of the crossing as shown in *Figure 3.7*.

To compensate for increased walking distances due to the curved paths at the Camberwell and Ashburton sites, a factor of 1.1 was used as a general adjustment factor. This could be further investigated in future studies to determine whether a more suitable adjustment factor exists.

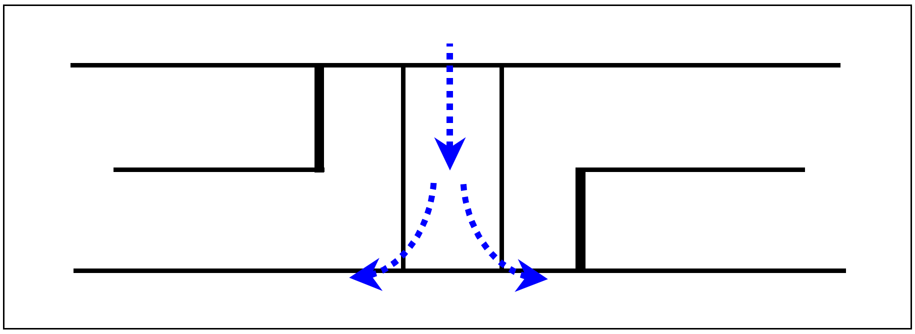

Figure 3.7 - Walking paths of pedestrians crossing in a curved path

3.2 Comparison of Crossing Speeds for Weekday and Weekend

Data presented in *Figures 3.5 and 3.6* and *Table 3.1* for all sites combined and for individual sites indicate that crossing speed characteristics of pedestrians are similar during the weekdays and weekends.

Thus, it could be concluded that the crossing speed characteristics were not affected by the type of activity that generated the pedestrian flows, i.e. retail and work during weekdays vs retail and recreational activities at the weekends.

3.3 Comparison of Crossing Speeds for Queued and Unqueued Pedestrians

Crossing speeds of pedestrians who arrived before the Walk signal (therefore "queued") and those who arrived during the Walk interval (therefore "unqueued") were compared.

Although the speed profiles of queued and unqueued pedestrians based on the weekday or weekend data at individual sites indicate some differences (as shown in *Figure 3.8* as an example), there is little difference for individual sites when the weekday and weekend data are combined.

Figure 3.9 for all sites combined shows that the crossing speed characteristics of queued and unqueued pedestrians are similar.

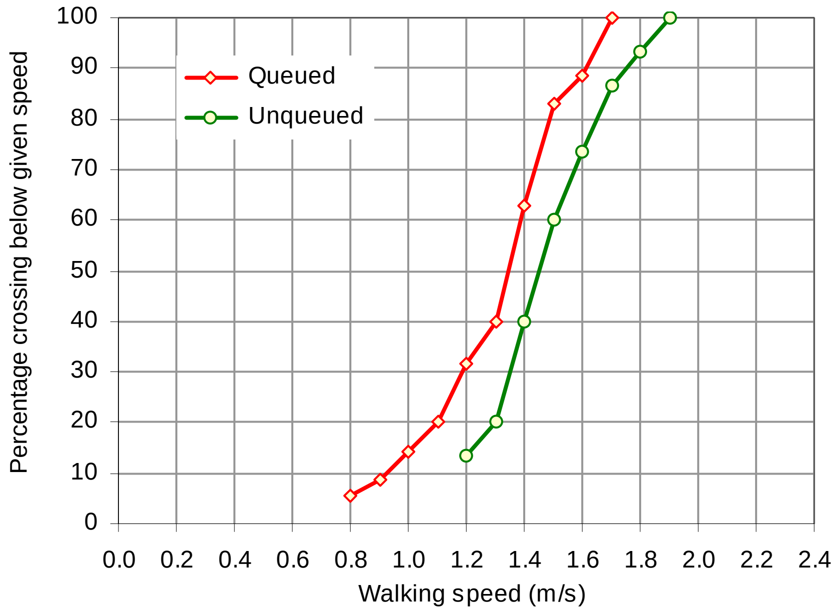

Figure 3.8 - Comparison of queued and unqueued pedestrian crossing speeds: Camberwell site (weekday data)

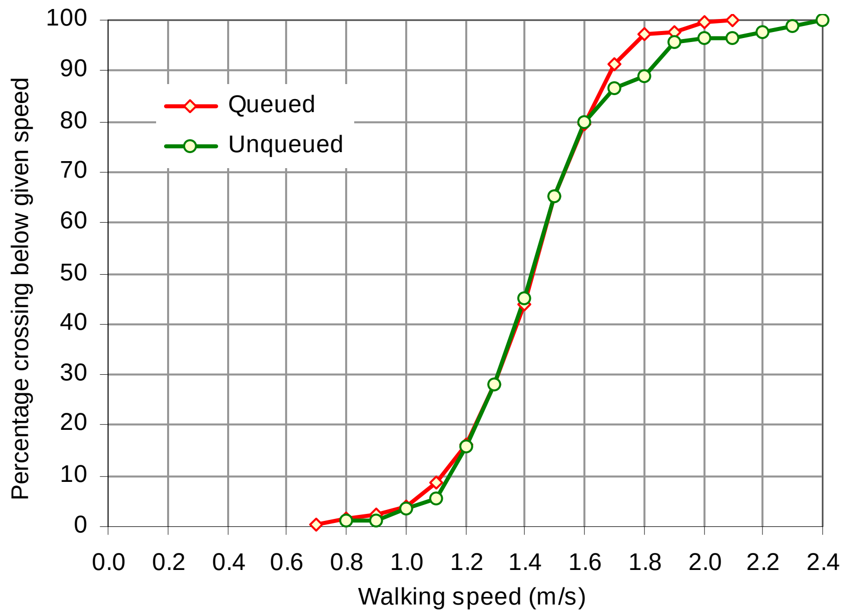

Figure 3.9 - Comparison of queued and unqueued pedestrian crossing speeds: all sites combined

3.4 Dependence of Crossing Speed on Pedestrian Flow

The relationship between the pedestrian flow rate and the crossing speed was investigated. *Table 3.3* shows the pedestrian flow rate (in the study direction), the average and 15th percentile crossing speeds, as well as the ratio of the 15th percentile speed to the average speed.

Figure 3.10 shows the average and 15th percentile crossing speeds plotted against the pedestrian flow rate. The linear trendlines for the speed - flow relationships indicate that a reasonably strong relationship exists between the average crossing speed and the pedestrian flow rate although the relationships for the 15th percentile speed is weaker.

It is seen from *Figure 3.10* and *Table 3.3* that the crossing speed decreases with increased pedestrian flow rate. This result is based on the pedestrian flow rate in the study direction available from the survey data, although the pedestrian flow rate in the opposite direction (not included in survey data) would also have affected the crossing speeds.

It is interesting to observe that the ratio of the 15th percentile speed to the average crossing speed is fairly constant (the average value is 0.86). Therefore, the use of a simple factor of 0.85 could be useful as a rough rule to convert the average crossing speeds that can be obtained from simple speed surveys to the 15th percentile speed for design speed purposes (0.85 x 1.4 m/s = 1.2 m/s).

Table 3.3

Crossing speeds (m/s) and pedestrian flow rates

Sites	Camberwell Weekday	Camberwell Weekend	Ashburton Weekday	Ashburton Weekend	Lilydale Weekday	Lilydale Weekend
Pedestrian flow rate (ped/h)	424	356	128	246	94	100
Average speed (m/s)	1.36	1.36	1.39	1.39	1.52	1.49
15th percentile speed (m/s)	1.14	1.18	1.14	1.17	1.34	1.32
Ratio of the 15th percentile speed to average speed	0.84	0.87	0.82	0.84	0.88	0.89

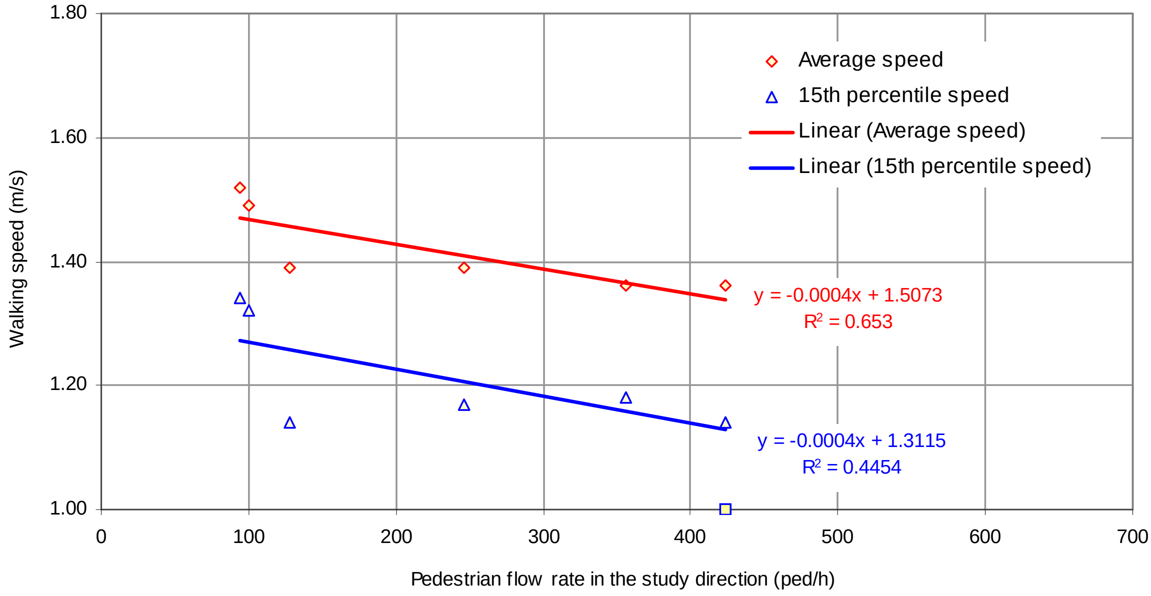

Figure 3.10 - Relationship between walking speed and pedestrian flow (study direction only)

3.5 Crossing Speeds of Pedestrians With Walking Difficulty

This study noted the "pedestrians with walking difficulty" irrespective of their age. This group included elderly persons, people with physical disability, parent pushing a pram and paying attention to a young child walking alongside.

Pedestrians with walking difficulty constituted 8 per cent of the total sample size.

The results for this group are summarised in *Tables 3.4a and 3.4b*, and shown in *Figure 3.11*.

It is interesting to note that, as seen from *Table 3.4a* and *Figure 5.11*, the 15th percentile speed (1.0 m/s) for pedestrians with walking difficulty is very close to the design speeds recommended by AUSTROADS (1993, 1995) and TRB (2000) for accommodating slow pedestrians. Similarly, the 15th percentile speed (1.2 m/s) was found to be very close to the general design speeds of 1.2 m/s recommended by AUSTROADS (1993, 1995) and TRB (2000).

This indicates that the use of the *15th percentile speed* for all pedestrians would be an appropriate crossing speed for signal timing purposes.

Table 3.4a

Crossing speeds of pedestrians with and without walking difficulty (overall speed across entire crossing for all sites combined, m/s)

	Average speed	Standard deviation	**15th percentile**	30th percentile	50th percentile	70th percentile	85th percentile
Pedestrians with walking difficulty	**1.29**	0.28	**1.00**	1.15	1.31	1.41	1.52
Pedestrians without walking difficulty	**1.45**	0.22	**1.23**	1.34	1.44	1.54	1.66
All pedestrians	**1.42**	0.24	**1.18**	1.31	1.42	1.52	1.65

Table 3.4b

Crossing speeds of pedestrians with and without walking difficulty (speeds to the mid-point of crossing and from mid-point to step-off, m/s)

	Speed from step-on to the mid-point		Speed from mid-point to step-off	
	Average speed	Standard deviation	Average speed	Standard deviation
Pedestrians with walking difficulty	1.40	0.34	1.21	0.26
Pedestrians without walking difficulty	1.54	0.28	1.39	0.24
All pedestrians	1.51	0.30	1.36	0.26

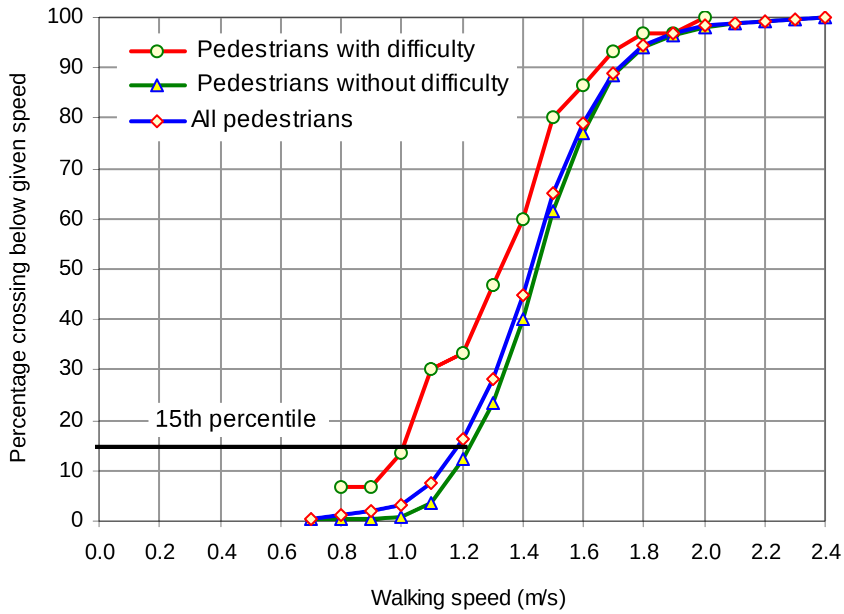

Figure 3.11 - Crossing speeds for pedestrians with and without crossing difficulties. and for all pedestrians (all sites combined)

3.6 A Comparison with Published Data

A limited comparison of the crossing speeds obtained from this study with published data was conducted. For this purpose, speed profiles given in AUSTROADS (1993, Appendix A.4), based on a Swedish study reported in an article by Sleight (1972) were considered. These are shown in *Figure 3.12* together with the speed profile from this study (data for all sites combined as in *Figure 3.1*). Speed profiles for pedestrians with and without difficulty (as in *Figure 3.11*) are shown together with data from Sleight in *Figure 3.13*.

As seen in *Figures 3.12 and 3.13*, Sleight gave speed profiles for three different categories of pedestrians, namely Elderly, Adults and Children. It is seen that the speed profile for this study (all data combined) is very close to the profile for the Elderly group in the Swedish study. The average crossing speed for the Adult and Elderly groups in the Swedish study was 1.4 m/s, which is the same value as the average speed found in this study (all data combined) as seen in *Table 3.1*.

In the Swedish study, the 15th percentile speed for the Adults group is slower than the values for the Elderly group. Sleight noted that "… many elderly walked more rapidly or more slowly than did typical adults. Most children consistently moved considerably more rapidly …".

Unlike the Swedish study, which categorized pedestrians by age, this study noted "pedestrians with walking difficulty" irrespective of their age (*Section 3.5*). *Figure 3.13* shows that this group has generally slower speeds than those in the Swedish study.

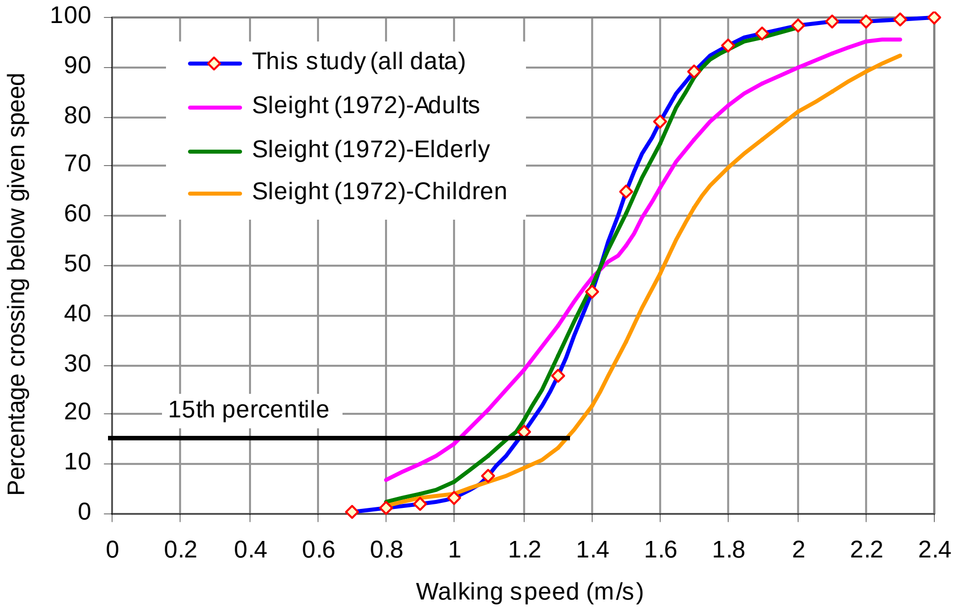

Figure 3.12 - Pedestrian speeds at individual mid-block signalised crossings: results of this study (all sites combined) compared with published date (Sleight 1972)

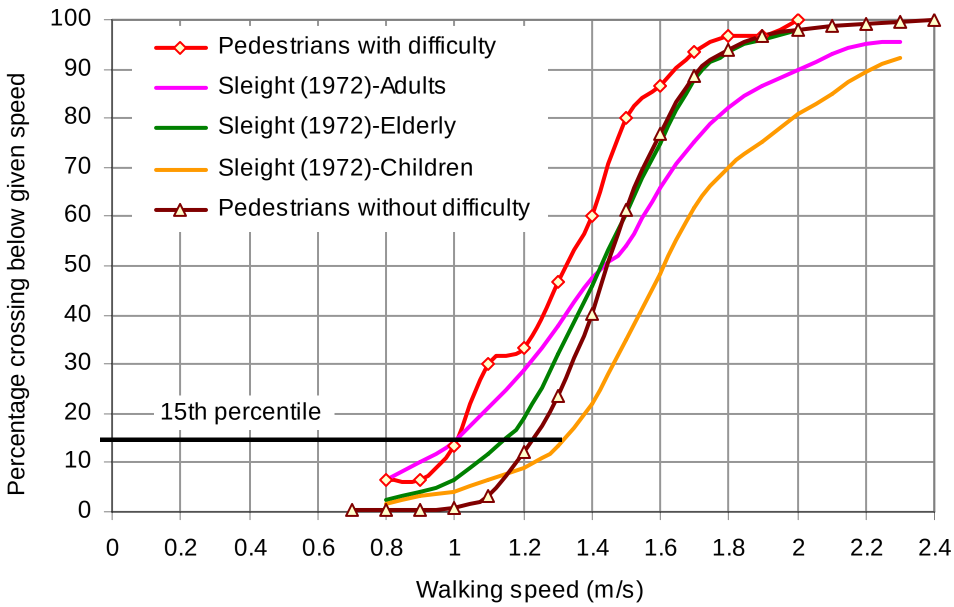

Figure 3.13 - Pedestrian speeds at individual mid-block signalised crossings: results of this study (pedestrians with and without walking difficulty) compared with published date (Sleight 1972)

4 Pedestrian Movement Start Loss and Clearance Time Gain

The aaSIDRA software package (Akcelik & Associates 2000) applies the *effective green time* concept for determining performance characteristics (delay, queue length, etc.) for pedestrians at signalised crossings. This requires the determination of *start loss* and *end gain* parameters for pedestrian movements. The concept is illustrated in *Figure 4.1* for mid-block signalised crossings.

As shown in *Figure 4.1*, total pedestrian phase time is $t_W + t_F + t_{ar1}$ where t_W is the Walk time, t_F is the Flashing Don't Walk time and t_{ar1} is the all-red time (= intergreen time, I_p) before vehicle green (i.e. at the start of the steady Don't Walk display). Total vehicle phase time is $G_v + I_v$ where G_v is the vehicle green time and I_v is the vehicle intergreen time ($I_v = t_y + t_{ar2}$ where t_y is the yellow time and t_{ar2} is the all-red time before Walk display). Steady Don't Walk time is $t_D = t_{ar1} + G_v + t_y + t_{ar2}$, and the vehicle red time is $R_v = t_{ar2} + t_W + t_F + t_{ar1}$. Cycle time is found as $c = t_W + t_F + t_D = G_v + t_y + R_v$.

For pedestrians, the start loss parameter (t_s) represents the average step on time when the pedestrian signal display changes to Walk.

Most of the Flashing Don't Walk (clearance) time is treated as an effective loss or *negative end gain* (t_e). Pedestrians make some use of the clearance period. The first part of the Flashing Don't Walk interval that is used by pedestrians is called the *clearance time gain* (t_g). Thus, the effective green time for a pedestrian movement is determined as $g_p = t_w - t_s + t_g = t_w + t_F - t_s + t_e$ where the negative end gain value is calculated from $t_e = -(t_F - t_g)$. The effective red time for a pedestrian movement is $r_p = t_D + t_s - t_e = t_F + t_D - t_g + t_s$. Cycle time can also be found as $c = g_p + r_p$.

In aaSIDRA 1, the default values of the start loss and clearance time gain parameters for pedestrians are t_s = 1 s and t_g = 3 s. These values result in an effective green time for the pedestrian movement that is 2 s longer than the Walk time ($g_p = t_w + 2$). Highway Capacity Manual 2000 (TRB 2000, p 18-13) specifies a clearance end gain value of 4 seconds.

The results for the surveys conducted at the three sites are given in *Table 4*.1. This indicates an average start loss value of t_s = 1.3 s (in the range 1.2 to 1.4 s) and an average clearance time gain value of t_g = 2.9 s (in the range 1.5 s to 3.3 s). These parameters are close to the default values used in aaSIDRA 1, and would result in an effective green time that is 1.6 s (range: 0.1 s to 2.1 s) longer than the Walk time ($g_p = t_w + 1.6$). Interestingly, the clearance time gain at the Lilydale site is small (resulting in an effective green time that is the same as the Walk time) while the crossing speeds were seen to be higher than other sites.

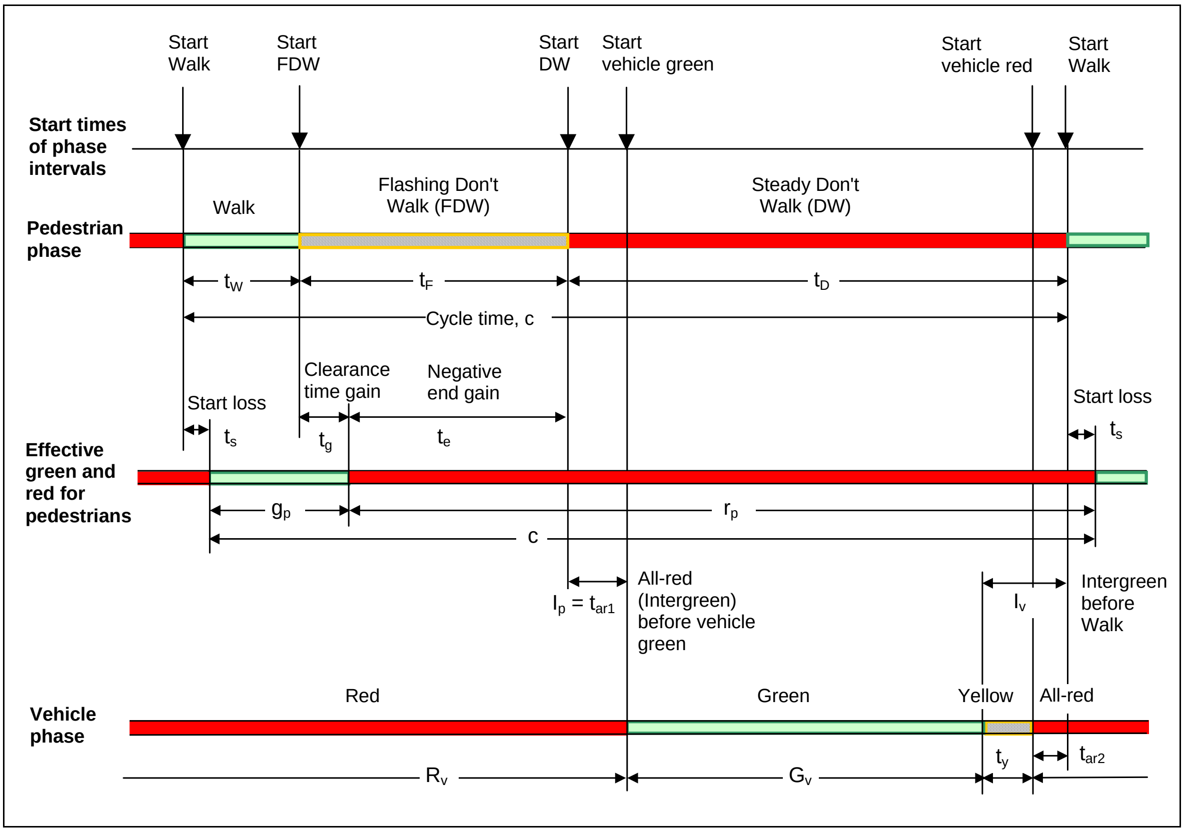

Figure 4.1 - Pedestrian and vehicle phase intervals, and effective timings for pedestrian movements at mid-block signalised crossings

Table 4.1

Pedestrian movement start loss and clearance time gain times (seconds)

	Start loss, t_s		Clearance time gain, t_g			Average clearance time gain less start loss, t_g - t_s
	Average	Standard deviation	Average	Standard deviation	Largest in any cycle	
Camberwell Weekday	1.26	0.48	3.00	2.70	9	1.7
Camberwell Weekend	1.28	0.63	3.29	1.68	7	2.0
Camberwell Combined	1.27	0.56	3.14	2.23	9	1.9
Ashburton Weekday	1.46	0.64	2.33	0.57	3	0.9
Ashburton Weekend	1.29	0.50	3.13	3.04	8	1.8
Ashburton Combined	1.36	0.56	2.91	2.59	8	1.6
Lilydale Weekday	1.37	0.60	1.50	0.71	2	0.1
Lilydale Weekend	1.23	0.43	1.50	0.71	2	0.3
Lilydale Combined	1.30	0.52	1.50	0.58	2	0.2
All Weekdays Combined	1.35	0.57	2.75	2.38	9	1.4
All Weekends Combined	1.27	0.53	3.08	2.17	8	1.8
All sites combined	1.30	0.55	2.93	2.25	9	1.6

5 Use of Crossing

The use of signal phase intervals by pedestrians, as well as the pedestrians who did not use the crossing were recorded at three survey sites. "Improper use" was considered as being pedestrians who use the crossing but begin crossing outside the Walk interval, i.e. during the Flashing Don't Walk or steady Don't Walk intervals. As shown in *Figure 2.7* in *Section 2.6*, pedestrians crossing within the boundary of the vehicle stop lines on each side of the crossing were defined as "using the crossing", and those crossing outside this area but within a distance up to 30-40 m from the vehicle stop lines were defined as "not using the crossing".

The use of signal phase intervals was recorded in terms of pedestrians crossing during the following intervals (see *Figure 5.1*):

(i) Walk (queued and unqueued, i.e. those arriving before and during the Walk signal, recorded separately),

(ii) Flashing Don't Walk (FDW), and

(iii) steady Don't Walk (DW).

The proportions of pedestrians using these signal intervals (including the corresponding pedestrian flow rates) are given in *Table 5.1*. The results for all sites combined are shown in *Figure 5.1*. It is seen that the majority of users (87%) crossed during the Walk interval. The remaining pedestrians used the crossing improperly, i.e. crossed during the Flashing Don't Walk or steady Don't Walk intervals (13%). Various other statistics are given in *Table 5.2*, including the number of pedestrians choosing not to walk when arrived during Walk and those choosing not to use the crossing.

The durations of signal phase intervals observed at the three survey sites are summarised in *Table 5.3*. The use of considerably longer Walk and shorter Flashing Don't Walk intervals at the Lilydale site is noted in view of different crossing speed characteristics at this site (*Section 3.1*).

It appears that the improper use increases with increased pedestrian flow (study direction) and decreases with increased vehicle flow (both directions) as seen in *Figures 5.2a and 5.2b*. Pedestrians choosing not to use the crossing also appear to increase with increased pedestrian flow (study direction) and decrease with increased vehicle flow (both directions) as seen in *Figures 5.3a and 5.3b*. However, the speed environment is likely to have played a more important role than the vehicle flow rates in the use of crossing. For example, the Lilydale site had higher vehicle speeds while it had the highest vehicle flow rates, whereas the speeds were low at the Camberwell site (a restricted environment) although vehicle flow rates were lower.

Table 5.1

Use of signal phase intervals by pedestrians at mid-block signalised crossings

	During Walk (Queued)		During Walk (Unqueued)		During Flashing Don't Walk		During steady Don't Walk		Pedestrian flow rate (ped/h)
	Total	%	Total	%	Total	%	Total	%	
Camberwell Weekday	282	66.5	62	14.6	21	5.0	59	13.9	424
Camberwell Weekend	259	72.8	49	13.8	24	6.7	24	6.7	356
Camberwell Combined	271	69.4	56	14.2	23	5.8	42	10.6	390
Ashburton Weekday	97	75.8	18	14.1	6	4.7	7	5.5	128
Ashburton Weekend	178	72.4	53	21.5	10	4.1	5	2.0	246
Ashburton Combined	138	73.5	36	19.0	8	4.3	6	3.2	187
Lilydale Weekday	67	71.3	21	23.0	4	4.3	2	2.1	94
Lilydale Weekend	76	76	17	17.0	6.0	6.0	1	1.0	100
Lilydale Combined	72	73.7	19	19.6	5	5.2	1.5	1.5	97
All Weekdays Combined	149	69	34	15.6	10	4.8	23	10.5	215
All Weekends Combined	171	73.1	40	17.0	13	5.7	10	4.3	234
All sites combined	160	71.1	37	16.3	12	5.3	16	7.3	225

"Total" values indicate pedestrian flows as hourly rates (ped/h). The values for "combined" cases are average values of data for individual cases.

Table 5.2

Various survey results for pedestrians at mid-block signalised crossings

	Number of pedestrians who chose not to walk when arrived during Walk	Number of pedestrians who DID NOT USE the signalised crossing (see *Fig. 2.7*) (ped/h)	Number of pedestrians who USED the signalised crossing (see *Fig. 2.7*) (ped/h)	Ratio of pedestrians who do not use the crossing to those who use the crossing	Total vehicle flow rate (both directions) veh/h
Camberwell Weekday	11 (2.6%)	110	424	0.26	1139
Camberwell Weekend	3 (0.8%)	114	356	0.35	1062
Camberwell Combined	7 (1.8%)	112	390	0.30	-
Ashburton Weekday	0 (0.0%)	36	128	0.24	1449
Ashburton Weekend	1 (0.4%)	52	246	0.32	1521
Ashburton Combined	1 (0.3%)	44	187	0.29	-
Lilydale Weekday	2 (2.1%)	7	94	0.09	1676
Lilydale Weekend	7 (7.0%)	10	100	0.11	2247
Lilydale Combined	5 (4.6%)	9	97	0.10	-
All Weekdays Combined	4 (2.0%)	51	215	0.23	-
All Weekends Combined	4 (1.6%)	59	234	0.30	-
All sites combined	4 (1.8%)	55	225	0.27	-

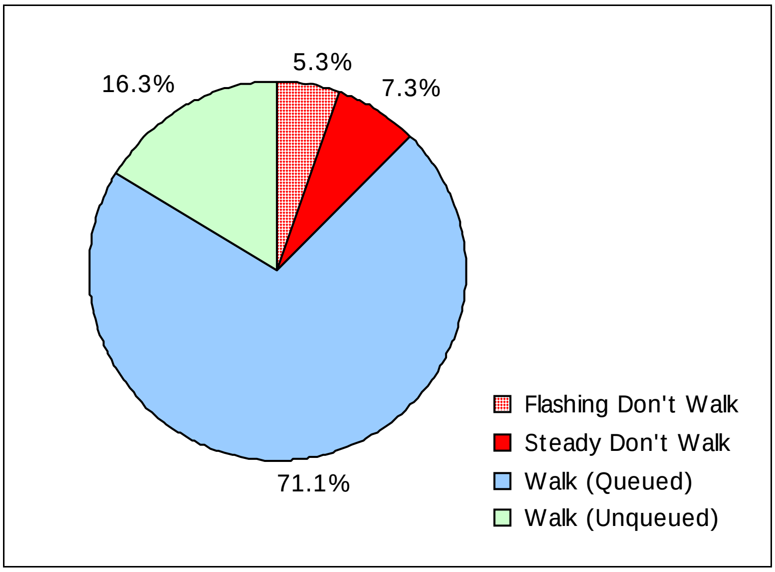

Figure 5.1 - Use of signal stages by pedestrians at Mid-Block Signalised crossings (all sites)

Table 5.3

Signal timing data (average values)

	Walk (t_W)	Flashing Don't Walk (t_F)	All-red (before vehicle green) (t_{ar1})	Vehicle green plus yellow ($G_v + t_y$)	All-red (before Walk display) (t_{ar2})	Vehicle red (R_{vy})	Total steady Don't Walk (t_D)	Signal cycle time (seconds) (c)
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6 = 1+2+3+5)*	*(7 = 3+4+5)*	*(1+2+7 = 4+6)*
Camberwell Weekday	10.3	10.4	2.7	47.9	3.4	26.8	54.8	74.7
Camberwell Weekend	10.3	10.4	2.7	47.9	3.4	26.8	54.8	74.7
Ashburton Weekday	8.1	9.4	2.7	69.2	3.4	20.3	75.3	92.8
Ashburton Weekend	8.1	9.4	2.7	69.2	3.4	20.3	75.3	92.8
Lilydale Weekday	13.2	5.2	3.9	54.4	2.7	25.0	61.1	79.5
Lilydale Weekend	13.2	5.2	3.9	54.4	2.7	25.0	61.1	79.5

The timings given in this table are average values based on a sample of 7 signal cycles at each site.
See *Figure 4.1* for signal intervals.

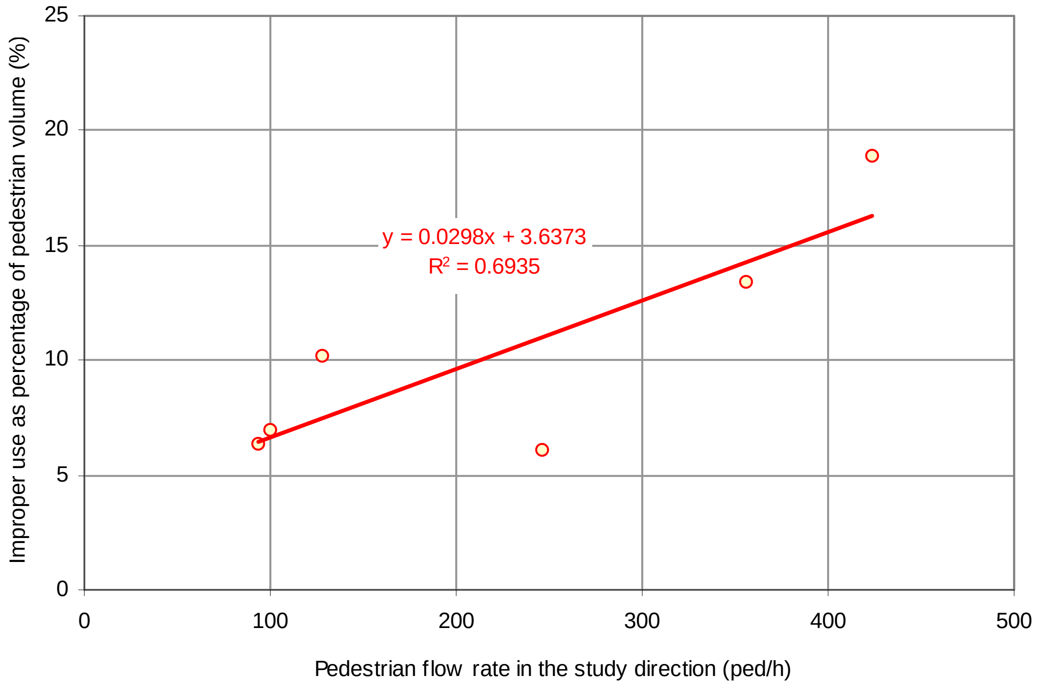

Figure 5.2a - Relationship between improper use of the crossing and pedestrian flow (study direction only)

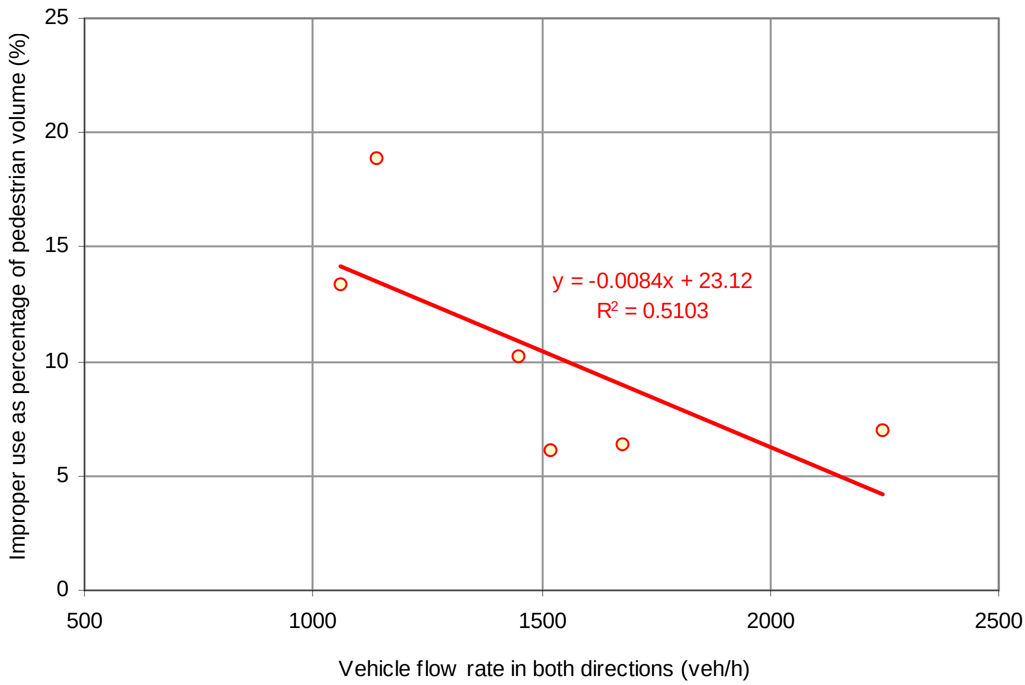

Figure 5.2b - Relationship between improper use of the crossing and vehicle flow (both directions)

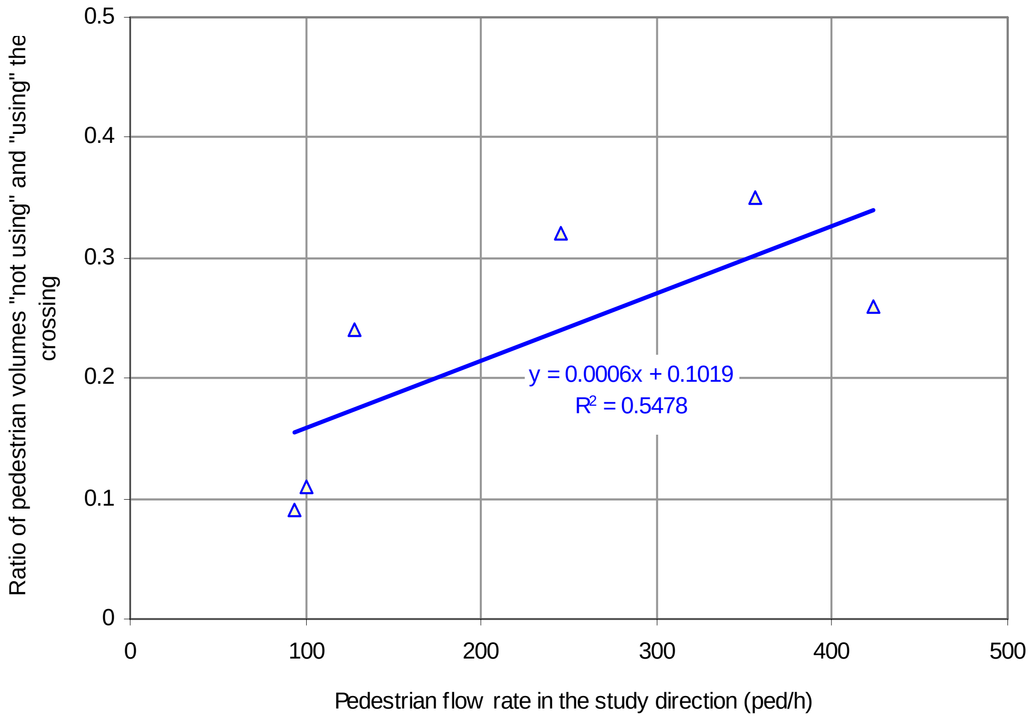

Figure 5.3a - Relationship between non-use of the crossing and pedestrian flow (study direction only)

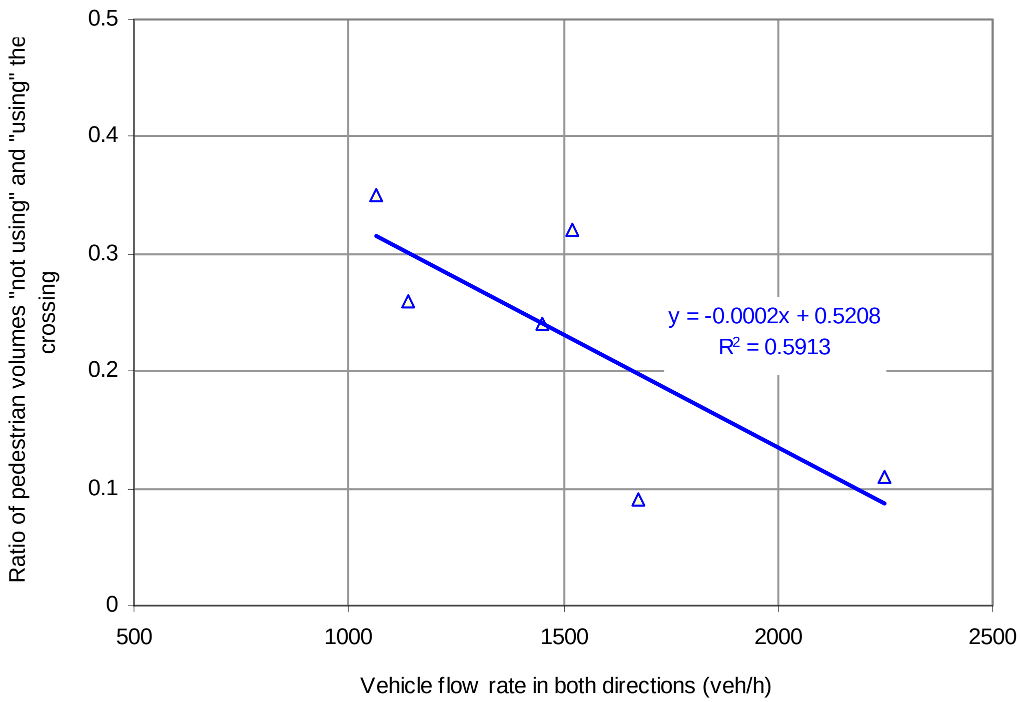

Figure 5.3b - Relationship between non-use of the crossing and vehicle flow (both directions)

6 Conclusions

The main findings of this study can be summarised as follows:

1. Data for all sites combined, including data for both weekdays and weekends, indicate an average crossing speed of 1.42 m/s (in the range 1.36 to 1.52 m/s for individual sites and periods), and a 15th percentile speed of 1.18 m/s (in the range 1.14 to 1.34 m/s for individual sites and periods).
2. The 15th percentile speed for all sites combined is very close to the general design speed of 1.2 m/s recommended by the Australian and US design guides (AUSTROADS 1993, 1995; TRB 2000).
3. For pedestrians with walking difficulty (using data for all sites combined), the average crossing speed is 1.29 m/s and the 15th percentile speed is 1.00 m/s.
4. The 15th percentile speed for pedestrians with walking difficulty is very close to the design speed of 1.0 m/s recommended by the Australian and US design guides (AUSTROADS 1993, 1995; TRB 2000) for sites with higher populations of slower pedestrians. In the data set for all pedestrians with and without walking difficulty, the crossing speed of 1.0 m/s corresponds to 4th percentile speed.
5. The ratio of the 15th percentile speed to the average crossing speed is fairly constant (the average value is 0.86). The use of a simple factor of 0.85 could be useful as a rough rule to convert the average crossing speeds, which can be obtained from simple speed surveys, to the 15th percentile speed for design speed purposes (0.85 x 1.4 m/s = 1.2 m/s).
6. Data for all sites combined as well as data for individual sites indicate that crossing speed characteristics of pedestrians are similar during the weekdays and weekends.
7. Data for all sites combined shows that the crossing speed characteristics of queued and unqueued pedestrians are similar although data for individual sites indicate some differences.
8. Pedestrian speeds for the first half of the crossing were higher than the speeds in the second half.
9. The average and 15th percentile crossing speeds decrease with increased pedestrian flow rate. This result is based on the pedestrian flow rate counted in the study direction.
10. Average start loss is 1.3 s (in the range 1.2 to 1.4 s for individual sites and periods) and average clearance time gain is 2.9 s (in the range 1.5 s to 3.3 s for individual sites and periods). These pedestrian movement parameters are close to the default values used in aaSIDRA 1 (1 s and 3 s, respectively).
11. Data for all sites combined indicate that the majority of users (87 %) crossed during the Walk interval. The remaining pedestrians crossed during the Flashing Don't Walk or steady Don't Walk intervals (13%). It appears that the improper use increases with increased pedestrian flow and decreases with increased vehicle flow. Pedestrians choosing not to use the crossing also appear to increase with increased pedestrian flow and decrease with increased vehicle flow. These results are based on the pedestrian flow rate counted in the study direction and the vehicle flows counted in both directions.

Similar studies of pedestrian movement characteristics are recommended for intersection signalised crossings, mid-block Pelican crossings and Zebra (unsignalised) pedestrian crossings. A greater variety of conditions should be covered including different road types, different locations, staged crossings, and sites with higher populations of slower pedestrians.

REFERENCES

AKCELIK & ASSOCIATES (2000). *aaSIDRA User Guide.* Akcelik and Associates Pty Ltd, Melbourne, Australia.

AUSTROADS (1993). *Traffic Signals*. Guide to Traffic Engineering Practice, Part 7. Association of Australian State Road and Transport Authorities, Sydney.

AUSTROADS (1995). *Pedestrians*. Guide to Traffic Engineering Practice, Part 13. Association of Australian State Road and Transport Authorities, Sydney.

SLEIGHT, R.B. (1972). *The Pedestrian*. In: T.W. Forbes (Ed.), *Human Factors in Highway Traffic Safety Research*, Wiley-Interscience, New York, pp. 224-253.

TRB (2000). *Highway Capacity Manual.* Transportation Research Board, National Research Council, Washington, DC, USA.