Delays at Pedestrian Crossing Points

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ABSTRACT

Pedestrian delays at crossing points are an important aspect of urban traffic planning. Accurate determination of these delays is critical to the correct selection of appropriate pedestrian crossing treatments. A recent study aimed to develop models for estimating pedestrian delays at zebra crossings and mid-block signalised crossings, to add to the existing models in the NZTA Pedestrian Crossing Facilities Calculation Spreadsheet. This was achieved using field surveys of seven sites around Christchurch.

From the zebra crossing sites it was found that pedestrian delays increased as pedestrian volumes decreased and traffic volumes increased. This could be attributed to the relative awareness and compliance of drivers in each case. Pedestrians were also more cautious when present in lower numbers or when facing higher traffic volumes.

For the mid-block actuated signalised crossing sites, there were no clear trends observed in terms of volumes and delays. Therefore a SIDRA model was developed independently to show the relationship between pedestrian delay and traffic volume at varying pedestrian volumes. In general, pedestrian delays increased as traffic volumes increased. At lower pedestrian volumes the delays were significantly less, which is probably related to the infrequent crossing phase calls being more likely to be met on demand.

1. INTRODUCTION

The pedestrian delay at crossing points is an important aspect of traffic planning in an urban environment. The New Zealand Transport Agency (NZTA) puts an emphasis on the safety of not only on-road users but also pedestrians. As the pedestrian delay increases, the safety aspect becomes more critical as pedestrians become impatient. This provided motivation for the project aim which was to develop models for estimating pedestrian delays at Zebra Crossings and Mid-block Signalised Crossings (examples shown in Figure 1).

The project focus was to add the obtained model to the NZTA Pedestrian Crossing Facilities Calculation Spreadsheet. This spreadsheet currently assumes *zero delay* for pedestrians at Zebra Crossings and there is no model for Mid-block Signalised Crossings. This work was intended to provide a starting point for further research into pedestrian delays at crossings.

Figure 1: Typical zebra crossing (left) and midblock signalised crossing (right)

2. LITERATURE REVIEW

The NZTA *Pedestrian Planning Guide* (NZTA, 2009) was used as a primary basis for which to research the area for this project. A defining characteristic of pedestrian delay (particularly non-priority crossings) is the walking speed of pedestrians. In Section 3.4: Walking Speed (NZTA, 2009) the average walking speed of an average adult is taken to be 1.5m/s. The average walking speed of an elderly pedestrian is taken to be 1.2m/s. This can be used to find a weighted average of pedestrian speed and will influence the average pedestrian delay at each site.

The US Federal Highway Administration (FHWA, 2005) reported on the safety aspects of marked and unmarked crosswalks. It was found that pedestrians perceive zebra crosswalks and signalised crossings as ways to increase their safety and mobility. They view the white parallel lines as a sign that they have a right to share the roadway with other traffic (FHWA, 2005). Another part of this study showed that the rate of pedestrian crashes was found to be about twice as high at Zebra Crossings compared to locations that were signalised. Additionally, pedestrians aged 60 and above were most at risk, followed by pedestrians below age 16 (FHWA, 2005). This report provided some context on how crossings are managed in another country, although it should be noted that the crosswalk laws in North America differ from New Zealand in providing greater rights to the pedestrian.

A previous University of Canterbury study (Laurence, 2011), considered options for reducing pedestrian delay across a busy campus road, using a probabilistic risk method. Two factors relevant in this study were: crossing priority; and delay as a measure of safety. The first factor (crossing priority) showed the major difference between the two crossing types of Zebra Crossings and Signalised Crossings. In the first crossing type the pedestrian is normally given priority over all other traffic once they step out (assuming traffic stops), while a pedestrian at a Signalised Crossing has to wait for the crossing signal. The second factor (delay as a measure of safety) influences how pedestrians perceive and act on delay. The longer a pedestrian has to wait at a crossing, the higher the chance that they may risk a crossing irrespective of traffic. Depending on what type of Crossing it is (Zebra or Signalised) will affect how motorists expect this possible action and respond to it; for example motorists approaching a Zebra Crossing may be more likely to expect someone to just step out at any time.

The crossing length should be determined by the carriageway width that needs to be crossed by pedestrians. It should be minimised by making sure the crossing is at right angles to the carriageway. This length can be reduced by extending the footpath out or by providing central refuge islands so that the pedestrians can do a staged crossing (FHWA, 2005).

Warrants for crossings are commonly used to quickly identify the most efficient and equitable treatment for a site. A formal crossing is needed where there is considerable conflict between motorists and pedestrians. A crossing is needed outside public amenities that have the need to safely channel crossing pedestrians such as outside schools (Tate, 2007).

The current NZTA Pedestrian Crossing Facilities Calculation Spreadsheet (NZTA 2007) aims to help with this decision-making by assessing the relative benefits and costs (for both pedestrians and motorists) of different crossing types. Both delays and crash rates are assessed for each configuration and then compared with the likely cost to determine the most cost-effective and appropriate treatment. However, while the current spreadsheet provides detailed estimates of crossing delays for non-priority crossings, it makes a simplistic assumption of zero delay for pedestrians at Zebra Crossings (i.e. traffic stops immediately) and there is no built-in model for Mid-block Signalised Crossings, requiring analysts to use a tool like SIDRA for assessment. Therefore a gap was identified in the research to develop simple models for delays at these types of crossings.

3. METHODS AND MATERIALS

3.1. Materials

The following equipment was used to record the necessary data:

- **Hand-held Psions**: used to record the instantaneous pedestrian numbers waiting to cross at random intervals.
- **Clicker counters**: used to count pedestrian and traffic volumes during surveys.
- **Stopwatches**: used to keep track of survey period times and measure phase times for Mid-block Signalised Crossings.
- **Measuring wheel**: used to measure the dimensions of each crossing.

3.2. General Methodology

The intention was to survey three Zebra Crossings and three Mid-block Signalised Crossings to produce suitable variation in the data obtained. Data was collected for ten sets of 15-minute periods for the “Early” period between 2:30pm and 4:00pm and the (typically busier) “Late” period between 4:30pm and 6:00pm (with short breaks between each set). This was carried out over two days at each site to produce a reasonable data set.

The “Queue Delay Method” (Koorey, 2012) was used for this study. Based on a similar survey method for calculating traffic delays; it required the collection of two data types for each survey. The first data collected was the average number of pedestrians, **n**, waiting at a specific instant in time at random intervals between 10 to 30 seconds apart. The second was to record the total number of pedestrians using the crossing over the whole survey period and from this determine the flow rate, **q** (the number of pedestrians over the survey period is **qT**, where **T** is the survey period).

The Queue Delay Method requires other parameters to be calculated in the case of uncongested flow. Figure 2 shows the survey length, **L,** which is used for the vehicle delay survey. It is assumed the method can be applied to pedestrians in a similar way to that used for vehicles. In this case a survey length of 5m was used, to capture all pedestrians approaching the crossing from the adjacent footpath. The other parameter required is the uncongested walking speed, **v**. An assumed walking speed of approximately 1.5m/s was taken from NZTA (2009). These two parameters allow the expected number of pedestrians, **e**, to be calculated in the case of an uncongested flow in equation (1).

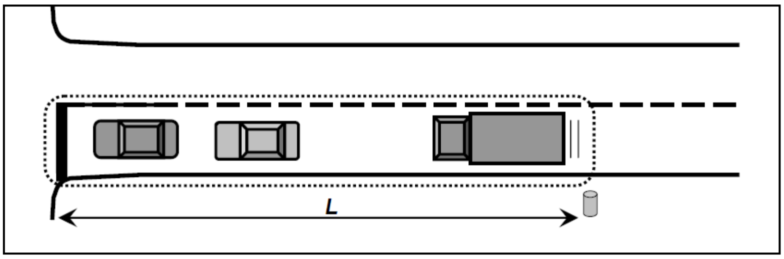

Figure 2: Queue length used for measuring vehicle queue delay

The delay experienced by pedestrians is shown with the difference between the average number of pedestrians, **n**, and the expected number of pedestrians, **e**. The total delay experienced by all pedestrians in the survey can be found by using equation (2).

The average delay experienced by each pedestrian, $\mathbf{d_{avg}}$, is calculated by taking the total delay, **d**, and dividing by the total number of pedestrians during the survey, **qT**. This is found by using equation (3).

The equations of the Queue Delay Method are shown below:

$$e = \frac{qL}{v} \tag{1}$$

$$d = T(n - e) \tag{2}$$

$$d_{avg} = \frac{d}{qT} \tag{3}$$

The parameters of these equations are stated explicitly below for clarity:

e = *Expected number of pedestrians in theoretical uncongested flow with no delay and uncongested speed,* ***v****.*

q = *Flow rate of pedestrians measured during survey.*

L = *A specified approach "queue" length over which instantaneous pedestrian volumes are measured (5m).*

v = *Uncongested walking speed of pedestrians (assumed 1.5m/s).*

d = *Total pedestrian delay for all pedestrians.*

T = *Length of survey period (15 minutes).*

n = *Average number of pedestrians measured instantaneously in survey length.*

d_{avg} = *Average delay per pedestrian.*

3.3. Development of Method

For the first two sites, the scope of the project was defined and the survey method tested and refined. This provided early guidance for the surveys of further sites. These sites showed whether the data collected was useful to analyse. It was found that the data collected from the first Zebra Crossing site produced negative delays. This did not reflect the expected outcomes, which were zero or positive delay. This came about because the 5m approach length was not properly taken into consideration. This resulted in ***e*** being greater than ***n***, which produced negative pedestrian delay. For the subsequent sites the pedestrians in the 5m approach length were recorded as being delayed if they were seen to stall. The method was suitable for the Mid-block Signalised Crossing sites as this required a higher level of randomness in the instantaneous counts, to remove the consistency in the phase times.

Despite the name of the survey method, it is not only the instantaneous number of pedestrians waiting that is recorded at regular intervals, but rather all pedestrians within the 5m queue length even if they were moving or experienced minimal delay. The Psion handheld enabled a random interval period to be generated for each observation; for similar traffic delay surveys this interval is often between 15s - 60s. The interval time between random observations for Zebra Crossings was changed to between 10 and 15s, as pedestrians were not able to be accurately recorded with a relatively large time between each instantaneous observation.

4. RESULTS AND DISCUSSION

4.1. Zebra Crossings Details

Rotherham Street Zebra Crossing

This site is a slightly raised crossing with a constrained street environment for approaching traffic. Riccarton (Westfield) Mall, a major shopping centre, is on the west side of the street and a commercial area is on the east side. Drivers were observed to be cautious and compliant. There is a moderate level of visibility for approaching traffic and a high level of visibility for pedestrians.

Pedestrian and traffic activity was largely generated by Riccarton Mall. There were similar pedestrian and traffic volumes of 250 to 350 per hour, per direction.

In the analysis of the data, shown in Table 1, negative pedestrian delays were obtained for all the periods surveyed. This implied that traffic delays resulted in fewer pedestrians present than without traffic, which is not realistic. It was identified later that some pedestrians, who were within the queue length of 5m, were not being recorded because they were not stationary. The surveys also used longer observation intervals, which resulted in many pedestrians not being recorded at all.

Table 1: Average Pedestrian Delays Observed at Rotherham Street Zebra Crossing

Average Pedestrian Delay	
Early	-1.82 s
Late	-0.90 s

An assumption of zero delay was made for the site because it was observed that the site layout restricted vehicles to low speeds, as the crossing was outside the mall entrance. Therefore, it can be assumed that drivers expected a pedestrian to be waiting when they approached the crossing. This environment would represent one end of the traffic spectrum where a zero delay assumption would seem appropriate.

Riccarton Road Zebra Crossing

This crossing is located on a busy arterial road that takes traffic to and from the City Centre (AADT>20,000). A residential area with motels is located near this crossing. Christchurch Girls High is to the north of the crossing. There is also a bus stop next to the crossing.

There were no significant differences in pedestrian volumes in each direction of travel. Pedestrian traffic was generated by Christchurch Girls High School during the peak period from 3.00pm to 3.30pm, and also from the bus stop. The pedestrian volumes were low at 10 to 30 per hour, per direction. The traffic volume was high at 650 to 950 per hour, per direction.

There was no significant difference in pedestrian delay between the two crossing directions. Table 2 shows an average delay of 5 seconds was observed for both periods and directions. However, it was noticed that on some occasions in the late periods, when traffic was congested, the pedestrians were able to cross by walking between the slowed vehicles. Therefore, these pedestrians had zero delay.

Table 2: Average Pedestrian Delays Observed at Riccarton Road Zebra Crossing

Average Pedestrian delay	
Early	5.3 s
Late	4.9 s

Chalmers Street Zebra Crossing

This is a relatively minor service street, with Hornby Mall on the south side, and a large car park on the north side. The site allows a high inter-visibility for approaching pedestrians and high visibility for approaching traffic. There is a suburban bus exchange located next to the crossing.

The volume of traffic was similar for both periods and directions of travel at 150 to 300 per hour, per direction. The volume of pedestrians was similar to traffic volume, ranging from 120 to 300 per hour, per direction. There were no recorded peaks in the traffic and pedestrian volumes.

Table 3 shows that the delays to pedestrians were low compared to the other sites. This can somewhat be explained by the observed behaviour of pedestrians following onto the road after each other when they crossed. The high visibility for both pedestrians and traffic would have also reduced the delay to pedestrians. The drivers were able to observe approaching pedestrians and hence stop accordingly.

Table 3: Average Pedestrian Delays Observed at Chalmers Street Zebra Crossing

Average Pedestrian Delay	
Early	1.7s
Late	1.8s

Williams Street Zebra Crossing

The site is on the main street in the Kaiapoi Town Centre, which is a major thoroughfare both through and to the town. There were road works nearby while the surveys were carried out, but these were not considered to affect the results observed.

There was no significant directional difference for both volume of pedestrians and volume of traffic. The volume of traffic ranged from 600 to 800 per hour, per direction. The volume of pedestrians was lower at 20 to 40 per hour, per direction.

Table 4 shows that the calculated pedestrian delay was greater in the early periods than the late periods. There is no obvious conclusion that can be made for this difference. The delays were similar to the delay values at the Riccarton Road Zebra Crossing. However, the traffic volumes were less than Riccarton Road and the pedestrian volumes were higher than Riccarton Road.

Table 4: Average Pedestrian Delays Observed at Williams Street Zebra Crossing

Average Pedestrian Delay	
Early	5.9 s
Late	3.7 s

4.2. Zebra Crossing Analysis – All Sites

The data obtained from all of the sites, except Rotherham Street, was collated to analyse any possible trends. Rotherham Street was discarded as the negative delays obtained were inconsistent and not useful to this analysis.

Firstly, pedestrian delays at sites were compared with the pedestrian volumes. This is shown in Figure 3; each data point represents one 15-minute period.

It can be seen from Figure 3 that as the pedestrian volume increases, the pedestrian delay decreases, but at a slowly flattening rate. Some caution is required with this result, because clearly there is a lot of variation within each site.

The relationship can be explained by the follow-on effect of pedestrians; the higher the number of pedestrians the more dominant their presence to oncoming traffic. The follow-on effect means that as some pedestrians start crossing, more pedestrians can directly follow on behind them while the traffic has stopped. These follow-on pedestrians experience no delay.

The greater the number of pedestrians, the more visible they are to approaching traffic, which will notice the pedestrians earlier and stop. This also results in lower pedestrian delay.

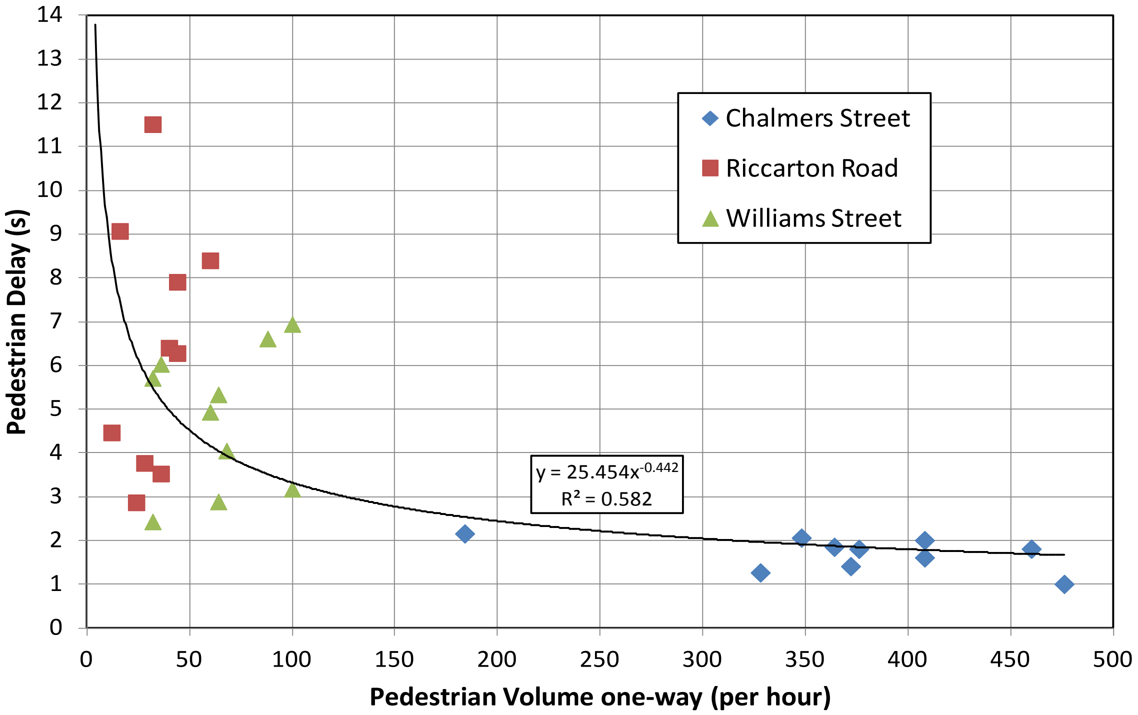

Figure 3: Pedestrian Delay versus Pedestrian Volume for All Zebra Crossing Sites

Next, pedestrian delays at sites were compared to the corresponding traffic volumes. It can be seen from Figure 4 that, as the traffic volume increases, the pedestrian delay increases. Although a linear relationship fits the data reasonably well, a greater number of sites would need to be surveyed to confirm this relationship, given the scatter evident within each site.

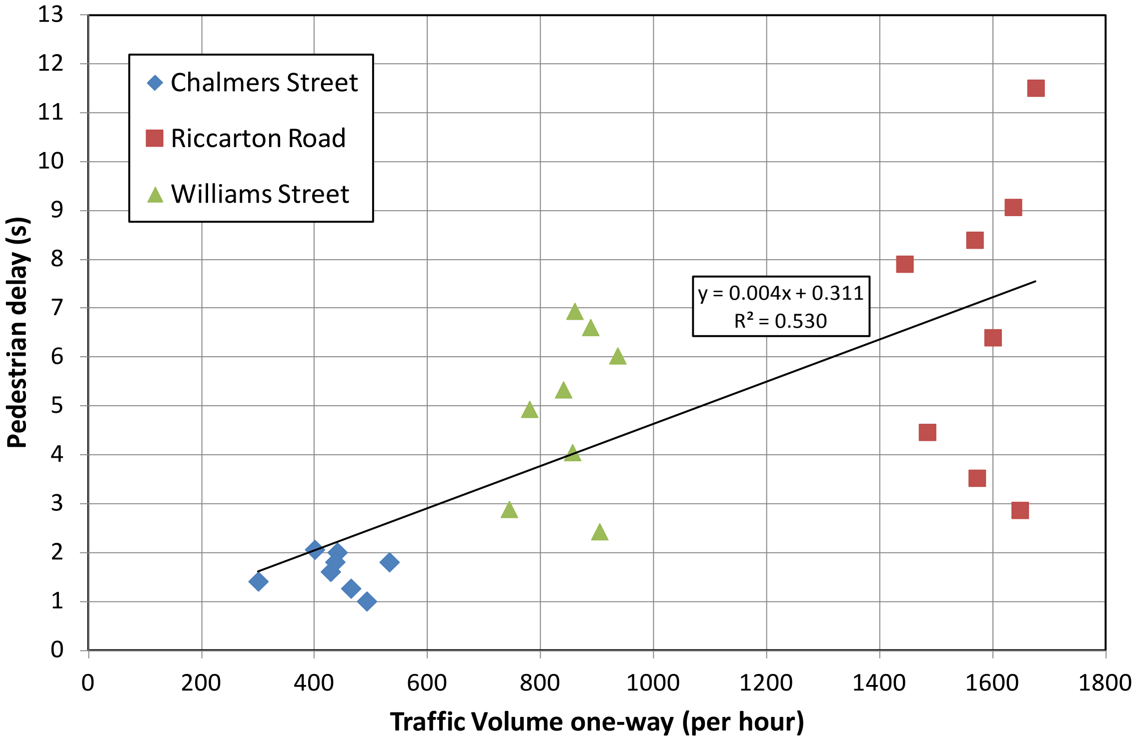

Figure 4: Pedestrian Delay versus Traffic Volume for All Zebra Crossing Sites

This relationship explains that the higher the traffic volume, the lower the number of opportunities for pedestrians to cross, and the more cautious the pedestrians will be. Traffic may also be inclined to follow the behaviour of the vehicle in front (or be pressured by the vehicles behind) and therefore not stop. This increased the overall pedestrian delays.

4.3. Mid-block Signalised Crossings Details

Riccarton Road Signalised Crossing

This site is located in a busy commercial area with Riccarton Mall close by. The adjacent commercial area generates most of the pedestrian traffic here. The two side streets of Rimu Street and Rotherham Street are located nearby on either side of the crossing. These have an influence on the flow of traffic through this Mid-block Signalised Crossing.

The signal phase times for traffic were measured and found to have a minimum time of 11s and a maximum time of 47s. The pedestrian phase time was consistent, with a length of 17s, and the expected time for the slowest pedestrian across the 11m-wide crossing was 11s (using a walking velocity of 1.00m/s for the 5% elderly/children pedestrian (NZTA, 2009). Using the maximum traffic phase time and the pedestrian phase time, a practical cycle time of 64s was determined for this site. This indicated the usual maximum length of the cycle time at this site.

The traffic volumes at Riccarton Road were typically in the range of 600 to 750 vehicles per hour, per direction. The pedestrian volumes were relatively high, typically in the range of 80 to 180 pedestrians per hour, per direction.

The pedestrian delays observed at this site are expressed in Table 5. These are average delays and do not show the variability of the delay measured in each survey run. Even though the average delays are shown to be 27-28s, the range of measured delays was anywhere from 15 to 40s. This was typical for all of the sites surveyed.

Table 5: Average Pedestrian Delays Observed at Riccarton Road Signalised Crossing

	Travelling North	Travelling South
Early	28.0s	27.6s
Late	26.8s	28.0s

Lincoln Road Mid-block Signalised Crossing

The Lincoln Road site is located next to a small commercial area in Addington. The relatively small size of this area means that not as much pedestrian traffic is generated in the area, despite local activity growth post-quakes. There are a couple of side streets near the site but the traffic from these can be considered negligible compared to the traffic volume on Lincoln Road.

The traffic phase times were measured and found to have a minimum time of 11s and a maximum time of 46s. The pedestrian phase time was consistent, with a length of 17s, and the expected time for the slowest pedestrian was 10s (10m-wide crossing). Using the maximum traffic phase time and the pedestrian phase time, a practical cycle time of 63s was determined for this site, i.e. very similar to Riccarton Road.

The traffic volumes at Lincoln Road were typically in the range of 600 to 850 vehicles per hour, per direction. The pedestrian volumes were relatively low, typically in the range of 30 to 60 pedestrians per hour, per direction.

The average delays are shown in Table 6. The pedestrian delays observed at this site were the lowest relative to the other signalised sites. From this analysis there appears to be some influence to the delay based on the much lower pedestrian volume seen here.

Table 6: Average Pedestrian Delays Observed at Lincoln Road Signalised Crossing

	Travelling NW	Travelling SW
Early	18.9s	16.6s
Late	18.9s	17.6s

Straven Road Signalised Crossing

The Straven Road site is located in a residential area in the suburb of Fendalton, located near Christchurch Boys High School and Christchurch Girls High School. Christchurch Boys High is located right next to the crossing and generates a peak of pedestrians and cyclists immediately at the end of the school day at 3pm. There is also a delayed peak of pedestrians using the crossing from Christchurch Girls High to the east. At all other times there are a relatively low number of pedestrians and cyclists using the crossing site.

The traffic phase times were measured and found to have a minimum time of 11s and a maximum time of 53s. There was no inherent consistency observed between phase time, which is why the range appears to be much greater. The pedestrian phase time was consistent, with a length of 19s, and the expected time for the slowest pedestrian was 12s (12m-wide crossing). Using the maximum traffic phase time and the pedestrian phase time, a practical cycle time of 72s was determined for this site. This cycle time was less reliable given the inconsistencies in phase time observed.

The traffic volumes at Straven Road were fairly high, typically in the range of 700 to 1050 vehicles per hour, per direction. Conversely, the pedestrian volumes were relatively low, typically in the range of 30 to 60 pedestrians per hour, per direction, with the exception of school peaks that were as high as 240 per hour. Cyclist numbers were generally very similar to pedestrian numbers.

The higher traffic volumes appeared to have a much more significant effect to the pedestrian delays as they were much higher than those at Lincoln Road. There was another influencing factor that caused this, which was the requirement for pedestrians to stand on a pad to activate the phase. There were several times when pedestrians did not stand on the pad, which meant the phase was not called, and the pedestrians were delayed for a longer period. These average delays are shown in Table 7.

Table 7: Average Delays Observed at Straven Road Signalised Crossing

	Pedestrian	Cycling
Early	31.3s	35.2s
Late	34.2s	35.8s

4.4. Mid-block Signalised Crossings Analysis

For data analysis of the Mid-block Signalised Crossing sites, a graph of pedestrian delay was plotted against pedestrian volume. Figure 5 shows no apparent correlation between the two variables and this is shown by the near-zero R^2 value of 0.038 (even worse for a linear regression). This means that a similar analysis cannot be carried out on the Mid-block Signalised Crossing sites as done for the Zebra Crossings. Evidently there are other factors involved that influence the delay observed by pedestrians.

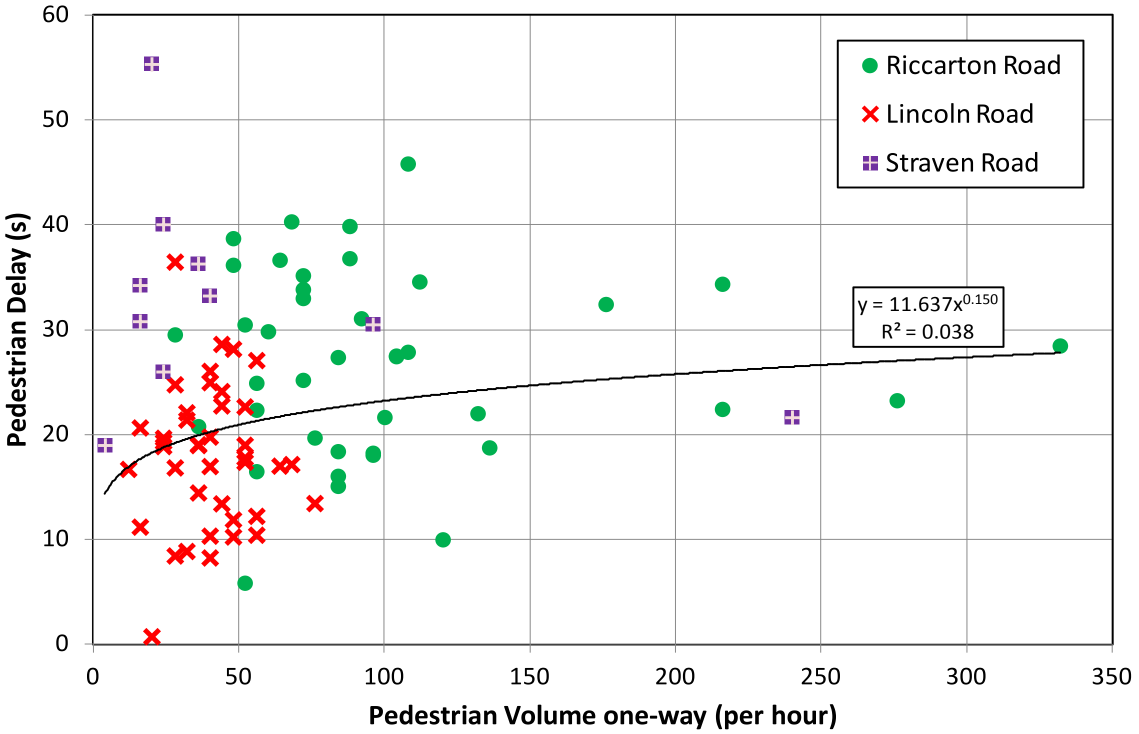

Figure 5: Pedestrian Delay versus Pedestrian Volume for All Signalised Sites

The other main data analysis for the Mid-block Signalised Crossing sites was to plot pedestrian delay against traffic volume. This is shown in Figure 6. Only limited traffic volume data was collected during each survey and this was plotted against the average delay data collected over the same period. The very weak R^2 value of 0.11 again shows that the two variables are unlikely to be strongly correlated for this type of site. This is also not likely to be influenced by matching data collected at different times, due to this weak fit.

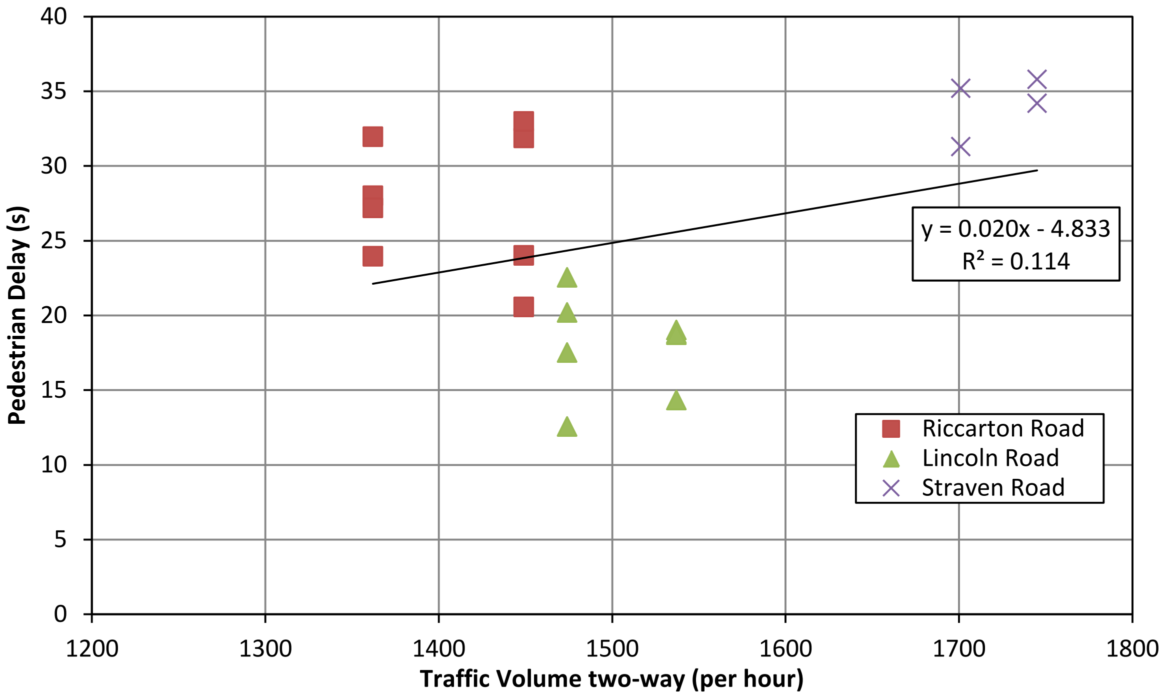

Figure 6: Pedestrian Delay versus Traffic Volume for All Signalised Sites

The underlying factor that influences the delay relationship here is the phasing of the traffic signals. The phase times observed were relatively consistent, regardless of what traffic volumes and pedestrian volumes were observed. This somewhat explains why there was little correlation in the previous two Figures discussed.

To help provide some guidance with modelling these sites, a detailed intersection analysis program known as SIDRA (Akcelik & Associates 2011), was used instead. SIDRA is designed to analyse single intersections with a variety of forms of control and layouts; its features include the ability to model mid-block signalised crossings.

A range of pedestrian volumes and traffic volumes were trialled in SIDRA to find a relationship between the pedestrian delay and these volumes. This is shown in Figure 7. SIDRA has used several assumptions in order to predict what types of delays would be expected for a particular pedestrian and traffic volume. In this graph a *fixed time* analysis was assumed (typical for a signalised intersection) where pedestrians would be given a particular time to cross, even if a phase was not called. The general trend was for pedestrian delay to increase more quickly at higher traffic volumes. The change in the pedestrian delay was shown to be less significant when comparing very large pedestrian crossing numbers.

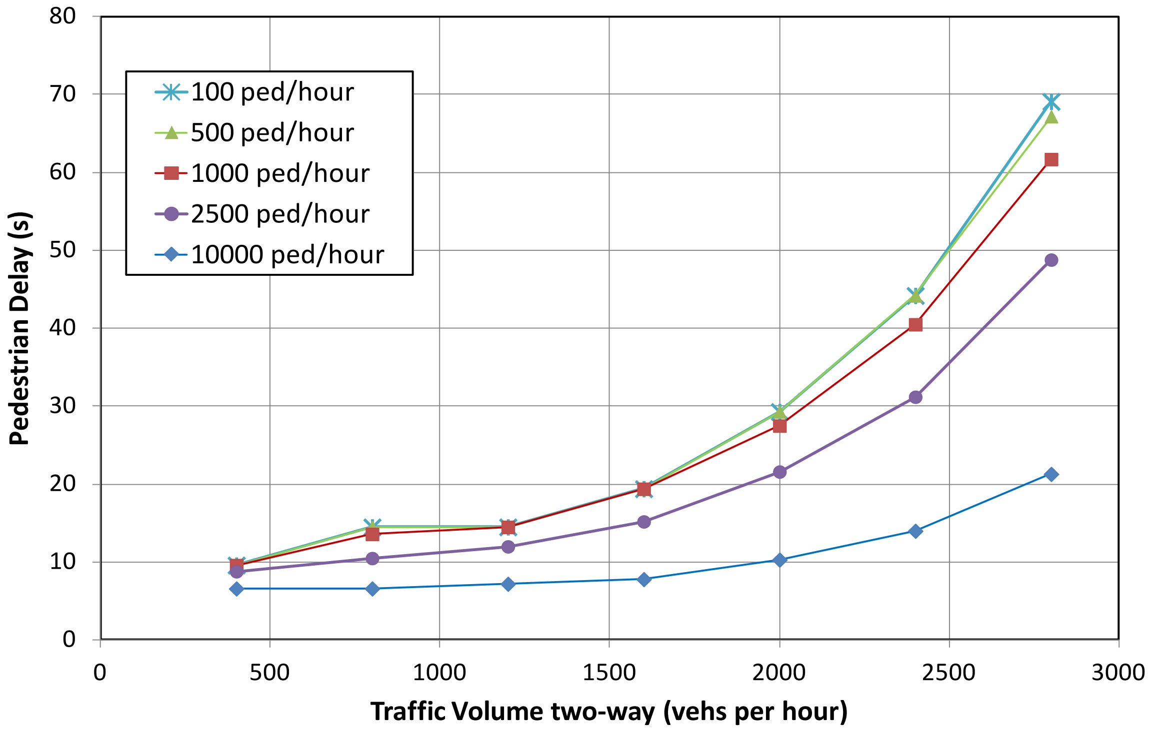

Figure 7: SIDRA Model: Pedestrian Delay versus Traffic Volume (Fixed Phase)

The second graph shown in Figure 8 is more realistic. This is due to the assumption of an *actuated phase* and reflects the situation where pedestrians push a button to call a phase. The same general increasing pattern can be observed; although, there is very little change observed between different pedestrian volumes. The only point to note is that at very low pedestrian volumes, the delay is relatively less, particularly at high traffic volumes. The underlying factor is again the length of the phase. This shows that, at low volumes, the pedestrian phase is likely to be more responsive as the time between calling a phase is likely to be much larger than the phase time itself. This means that the phase should be more on demand; therefore, the delay is reduced. At higher pedestrian volumes, pedestrians often have to wait longer because a crossing phase would have just recently been called.

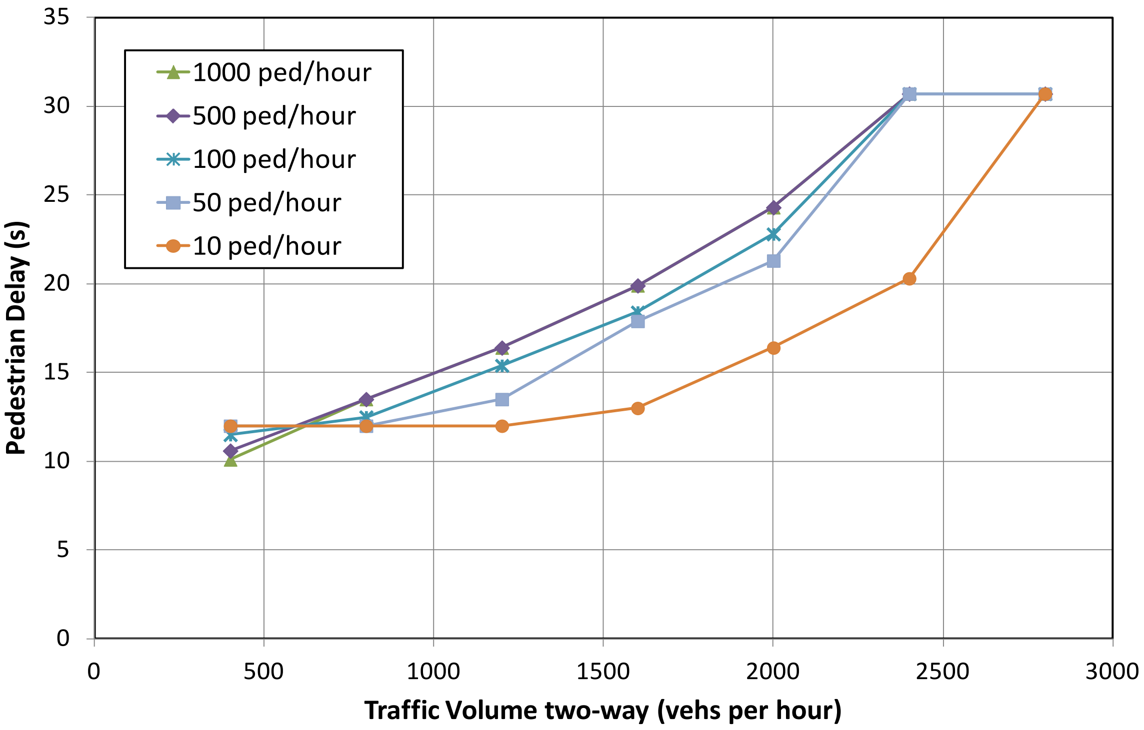

Figure 8: SIDRA Model: Pedestrian Delay versus Traffic Volume (Actuated Phase)

5. LIMITATIONS

5.1. Survey Method Assumptions

An assumed "queue length" of 5m was used for all sites. In practice, pedestrians typically did not queue behind each other when they waited to cross; rather they used the whole width of the crossing while they waited. It was only at the Straven Road Mid-block Signalised Crossing where the pedestrian number was high during the peak period that they had to queue behind each other. However, the fact that pedestrians don't queue doesn't affect the method since all pedestrians, waiting or moving, are recorded within the queue length.

For delay calculations, the pedestrian walking/crossing speed was assumed to be 1.46 m/s. This was a weighted average of the pedestrian walking speeds from NZTA (2009), which include standard adults and more sensitive pedestrians such as children and the elderly. There were also other pedestrians that may have been more time constrained.

The interval for recording observations was between 10 to 30s for Mid-Block Signalised Crossings, and 10 to 15 s for Zebra Crossings. In both cases the interval may have been too large as some pedestrians were often not able to be recorded when they were waiting to cross. Typically this is only an issue for very low flows when the random intervals may result in an unusually high or low calculated delay, due to the chance arrival times of the pedestrians.

5.2. Time Constraints

The sites tested were limited to three Mid-block Signalised Crossings and four Zebra Crossings. Therefore the models obtained for the two types of crossings may not be an accurate reflection for the performance of such crossings across all combinations of pedestrian and traffic volumes. Some additional zebra crossings have recently been studied in Dunedin to help build on this initial data.

Each of the sites was tested on Thursday and Friday from 2.30pm to 6.00pm. Because of the complexity of data recording, the majority of the traffic volume counts were carried out on Mondays. Therefore, the traffic volumes may have not always been an accurate reflection of the level of traffic on Thursdays and Fridays.

5.3. Pedestrian Behaviour

In the case of Mid-block Signalised Crossings there were some pedestrians that crossed before the start of the pedestrian green phase. Some pedestrians were also observed to increase their walking speed to enable them to cross during the green phase. In both of these cases the pedestrians experienced no delay. However, if they had continued at normal walking speeds then they would have experienced some delay. Such behavioural observations need to be considered when assessing the robustness under real-life conditions of the models developed.

6. CONCLUSIONS AND RECOMMENDATIONS

From the Zebra Crossing analysis there were two main trends observed.

1. In the first trend, it was shown that as the pedestrian volume increased, the pedestrian delay decreased. There was a reasonable fit shown by a power relationship. This relationship can be explained when pedestrians follow others already on the crossing at higher pedestrian volumes. It was found that as the pedestrian volume increased, their presence on the crossing improved. This resulted in improved safety to pedestrians and increased awareness to drivers.
2. In the second trend, it was shown that as the traffic volume increased, the pedestrian delay increased. There was a reasonable fit shown by a linear relationship of the data values. This implies that, as the traffic volume increased, the compliance of drivers decreased. The pedestrians were more cautious at crossings with higher traffic volumes. Both of these factors increased the calculated pedestrian delay.

For the Mid-block Signalised Crossing sites, there were no obvious trends observed in the same analysis carried out for the Zebra Crossings. This meant that SIDRA, a detailed intersection analysis program, had to be used instead.

A SIDRA model was developed to show the relationship between pedestrian delay and traffic volume at varying pedestrian volumes. This was carried out assuming a fixed phase time in the first case and an actuated phase in the second case. The second case was found to be more realistic as all of the sites in our surveys used actuated phases.

The main finding of the model showed a general increase to pedestrian delay as the traffic volume increased. There was no significant change in the relationship for the higher pedestrian volumes used. It was only at the lower pedestrian volumes where the delay was significantly less. This was related to the infrequent phase calls that were on average longer than the typical cycle length, which meant they were likely to be responded to on demand.

The two models obtained for Zebra Crossings are appropriate to be used to estimate the pedestrian delay at other sites. The model for the Mid-block Signalised Crossing is less developed due to the poor relationships found. This means that they are inappropriate for predicting pedestrian delays at other sites.

Both models require further development before they can be added to the NZTA Pedestrian Crossing Facilities Calculation Spreadsheet. Recent further zebra crossing studies in Dunedin are helping to refine the model for these crossings. More surveys and analysis is still needed to develop the equivalent model for signalised mid-block crossings.

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