A STUDY OF PEDESTRIAN CHARACTERISTICS AT TRAFFIC SIGNALS

Author/Presenter: **Eddie Cook**, NZCE (Civil), Dip. Transport (Massey)
Senior Traffic Management Officer, Invercargill City Council
Email: *Eddie.cook@icc.govt.nz*

Author: **Glen Koorey**, PhD(Trptn), ME(Civil), BE(Hons), BSc, MIPENZ
Senior Lecturer, Dept. of Civil and Natural Resources Engineering
University of Canterbury, Christchurch
Email: *Glen.Koorey@canterbury.ac.nz*

ABSTRACT

Pedestrian and motor vehicle activity varies both spatially and temporally throughout all transportation networks. A recent Engineering Masters study analysed pedestrian behaviours and characteristics at three signalised intersections in Invercargill during different periods of the day and week. The study achieved the following findings:

1) The determination of 5th and 15th percentile walking speeds for different width signalised crosswalks. The current setting used by practitioners in NZ is 1.2 m/s.
2) The determination of average pedestrian delay intervals for non-compliant and compliant pedestrian movements at different width signalised crosswalks during various times of the day. These values have been compared with results from a similar NZTA research project for other cities in NZ.
3) The determination of values for the percentage of non-compliant pedestrian movements at different width signalised crosswalks. A measure of risk for these non-compliant pedestrian movements was also assigned , based on estimated time to collision Surveys were also undertaken of motivations behind non-compliance and general understanding of pedestrian facilities in NZ.

The findings indicate that pedestrian age, road width, time of day and trip purpose can all affect compliance rates, delay lengths and walking speeds at signalised crosswalks. This has implications for future design of pedestrian facilities.

1 INTRODUCTION

Pedestrian and motor vehicle activity varies by time of week and time of day. A recent Engineering Masters study (Cook 2013) analysed pedestrian behaviours and characteristics at three signalised intersections in the City of Invercargill during different vehicle flow, time of day and time of week periods.

The study aimed to achieve the following objectives:

1. To recommend 5th and 15th percentile walking speeds for different width roads and three age group classifications for traffic signal crosswalks within New Zealand. Previous research shows that road width can affect walking speeds at both intersection and midblock locations.
2. To measure average pedestrian delay times for non-compliant and compliant pedestrian activities during different times of the day. Pedestrian delay at signalised intersections can be affected by many different factors. These results will be calculated for each of the intersections studied and compared with average pedestrian delay survey findings for New Zealand.
3. To determine the extent of non-compliant crossing behaviour within Invercargill for different times of the day at each of the intersections studied. Non-compliant road crossings by pedestrians at signalised crosswalks are prevalent throughout the world. A measure of "risk" for these non-compliant crossings is also approximated.

These results may aid in defining the risks involved for pedestrians crossing the road at traffic signals during different times of the day and in characterising and defining pedestrian attributes at traffic signals with respect to gender, age and trip purpose. Insight into the causes and reasons for non-compliant behaviour at traffic signals may also be found.

2 LITERATURE REVIEW

2.1 Walking Speed

The speed of pedestrians is a major factor in the design and provision of pedestrian facilities. For example, Australasian traffic signal guidelines (Austroads 2003) discuss Pedestrian Walk Times and Pedestrian Clearance Times.

The purpose of the Pedestrian Walk Time setting is to give pedestrians sufficient time to begin their crossing. This setting determines the duration of the Green Man display. New Zealand follows the Austroads guide and uses a Walk Time setting of six seconds at traffic signals. The purpose of the Pedestrian Clearance Time is to allow pedestrians who have stepped off the kerb at the commencement of the Pedestrian Clearance interval to complete their crossing with safety. The Pedestrian Clearance interval is implemented using the flashing DON'T WALK display.

The pedestrian walking speed for determining this clearance time is 1.2 metres per second (m/s). A clearance speed of 1.0 m/s may be appropriate for intersections with higher populations of slower pedestrians. These values are currently used by New Zealand Traffic signal design practitioners.

This research aims to validate these walking speed values for Invercargill's road, pedestrian demographic and traffic conditions. Walk time and pedestrian clearance time settings contribute to the overall delay experienced at intersections, particularly at the side road approaches to wider carriageways during off-peak flow periods. Validation of these walking speed values will justify the vehicle delays being incurred.

Akcelik and Associates (2001) derived these walking speed values from a pedestrian walking speed survey conducted at three mid block signalised crossings in Melbourne. The results of this survey indicated that the recommended clearance speeds of 1.0 m/s and 1.2 m/s correspond to the 5th and 15th percentile speeds respectively i.e. approximately 5% of pedestrians were observed to cross with speeds below 1.0 m/s and 15% of pedestrians were observed to cross with speeds below 1.2 m/s. For dual carriageway roadway widths in the vicinity of 30 metres and more the total clearance time and walk time settings combined can equate to 30 seconds or more. FHWA (1988) recommends a pedestrian walking speed of 1.22 m/s (4.0 ft/s) for pedestrian clearance interval settings. FHWA (1983) indicated that nearly one third of pedestrians walk slower than 1.22 m/s and nearly 15% of pedestrians walk at or below 1.06 m/s (3.5 ft/s). FHWA (1983) also stresses the moral and legal right of slower pedestrians to complete crossing once they have entered the intersection.

Chandra *et al* (2012) observed pedestrian crossing speeds at three Indian Cities, Chandigarh, Hyderabad and Delhi. They suggested that characteristics such as age and gender of the pedestrian, pedestrian movement singly or in a group, traffic volume, size of the urban area and width of the road can influence pedestrian speeds. It was observed that the 15th percentile speeds for pedestrians were in the range of 0.83 to 1.02 m/s, which was less than their recommended design crossing speed of 1.2 m/s for pedestrian facilities. They suggested using 0.95 m/s as the pedestrian crossing speed for facility design. This could be modified to 0.79 m/s if the proportion of older or female pedestrians was high.

Table 1 summarises the various 5th and 15th percentile walking speeds from the Literature Review.

Reference	5th % (m/sec)	15th % (m/sec)
FHWA (1983)		1.06
Knoblauch *et al* (1996)		0.97 (elderly) 1.25 (young)
Tarawneh (2001)	0.97	1.11
AustRoads (2003)	1.0	1.2
Feng & Wu (2004)	1.07	1.19
Bill *et al* (2006)	1.0	1.15
Chandra *et al* (2012)	0.79	0.95

Table 1 - Recommended 5th/15th Percentile Walking Speeds from various studies

Many researchers also commented that the width of streets had an effect on walking speeds. The wider streets tended to induce faster walking speeds.

2.2 Pedestrian Delays

Pedestrian delay is recognised as one of the greatest reasons for pedestrian non compliance and acts of risk taking at traffic signals.

Bubb *et al* (2012) applied a human reliability analysis method to study the safety of pedestrians crossing at traffic signals at five selected signalised crosswalks in Beijing, China. They concluded that apart from the risk takers who are not willing to wait for the traffic lights (about 10% of their sample) the likelihood of non-compliant pedestrian behaviour increases with waiting time at the traffic lights. They also indicated two important time durations for pedestrian waiting time. Most risk takers cross the street within 3 seconds of their arrival. The time duration of 50 seconds reflects the endurance ability of most pedestrians. After this time period, most pedestrians began looking for suitable opportunities to cross the road. The calculated risk rate for pedestrians crossing with in 3 seconds and after 50 seconds was very high. The calculated risk rate for pedestrians crossing between 3 and 50 seconds was relatively low.

Bangdiwala *et al* (2007) observed pedestrian behaviour at seven selected intersections in Delhi, India. The results indicated that the mean waiting time for females were 27% more than males, while the waiting time of 90% of female pedestrians are 44% more than the corresponding value for males. They concluded that pedestrians who become impatient because of long delays are not willing to wait. The pedestrians who do wait for the signals are risk adverse and more likely to be female. They recommended that intersection geometry and signal cycle timings should be checked at all intersections to encourage safe pedestrian behaviour.

Turner and Vallyon (2011) Observed 1465 pedestrians at 14 intersections in Auckland (5) Wellington (2) and Christchurch (7) within New Zealand. Average pedestrian delays were measured at each intersection, which derived average waiting times for each city. Table 2 summarises the average delay findings from this study. Pedestrian surveys were also carried out. Respondents at each intersection were asked how long they felt they had to wait before crossing the road.

The average perceived delay time was found to be double the actual average delay time for the intersection. Waiting time being a subjective experience and frustrating experience were the main reasons given for this higher than actual quantifiable loss of time. Time waiting is also an unproductive use of a person's time.

Their results concluded that after about 20-30 seconds of delay the pedestrian's level of frustration grows disproportionately to the actual delay itself and this has implications for traffic safety should these pedestrian's violate the pedestrian signals. It was also concluded that improvements to delays for pedestrians at signalised crossings are necessary, from both a delay and a safety perspective.

Location	Average Delay (seconds)
Christchurch	25
Wellington	45
Auckland	53

Table 2 – Results of Average Pedestrian Delay Surveys (Turner & Vallyon 2011)

2.3 Compliance Rates

Across the world, pedestrians who enter the crosswalk at a signalised intersection are legally bound to comply with the particular traffic signal regulations for that country. Those pedestrians who do not obey these pedestrian crossing regulations are performing an illegal traffic movement and for the purposes of this paper are termed non-compliant.

The reasons for and the percentages of non-compliant behaviour at intersections can vary spatially from intersection to intersection within a city, from city to city within a country and from country to country. Similarly, temporal variations of a non-compliant behaviour can also occur.

Turner *et al* (2006) collected continuous pedestrian flow count data over a period of a year from May 2003 to May 2004 at various signalised CBD and suburban intersections in Christchurch, New Zealand (the period from the end of September 2003 to the start of December 2003 was excluded from the pedestrian counts).

An analysis of the pedestrian count data indicated that the proportion of pedestrians crossing on the "green man" at traffic signals was lowest before the morning peak period and following the evening peak periods. The percentage of people who crossed on the "red man" for all intersection types is around 40% before the AM peak and 60% following the PM peak.

Table 3 summarises the various compliance rate findings from this Literature Review.

	% Compliant	Comments	Country
Ke-Ping & Ying (2011)	56%	11 Intersections	China
Barker *et al* (1991)	29%	33 Intersections	-
Ghafourian *et al* (2009)	80%	6 Intersections	Australia
Keegan & Mahoney (2003)	76%	Countdown Timer	Ireland
Keegan & Mahoney (2003)	64%	Before Installation of Countdown Timer	Ireland
Turner *et al* (2006)	60%	Before AM Peak	New Zealand
Turner *et al* (2006)	40%	After PM Peak	New Zealand

Table 3 - Pedestrian Compliance Rates at Traffic Signals Summary Table

3 METHODOLOGY

3.1 Intersection Selection

To obtain a varied cross section of pedestrian characteristic results, three intersections with varying road width, land use, traffic composition and pedestrian composition were selected within Invercargill for the observational surveys.

The three intersections selected were:

<u>Kelvin Street / Esk Street</u>

This intersection is located in one of the busiest sections of the Central Business District. The carriageway widths are both 13.8 metres and pedestrian flow is constant throughout the middle portion of shopping hours. Kelvin Street typically carries 9500 vehicles per day and Esk Street 5000 vehicles per day. A recent pedestrian survey observed 555 pedestrians crossing this intersection during the 12.15pm to 1.15pm period.

<u>Tay Street / Kelvin Street</u>

This intersection is located on the southern periphery of the Central Business District where traffic and pedestrian volumes are constant throughout the middle of the day. Significantly the carriageway width on Tay Street is 24.6 metres with a 1.5 m solid median landscaped strip in the road centre. Kelvin Street is 11.5 metres wide. Kelvin Street typically carries 9500 vehicles per day and Tay Street 12000 vehicles per day through this intersection.

A recent pedestrian survey observed 398 pedestrians crossing this intersection during the12.30pm to 1.30pm period.

<u>Tay Street / Elles Road</u>

This intersection is located in the southeast corner of the Central Business District and is Invercargill's busiest signalised intersection for vehicle movements. Many school students and Polytechnic students use this intersection in the morning and afternoon 'before and after' periods. Pedestrian volumes at this intersection are not as high as the other two intersections being studied. Tay Street is 30.9 metres wide with solid central medians that provide little or no pedestrian refuge.

3.2 "Near Miss" Interval

For non-compliant pedestrians, the time interval was measured between the nearest vehicle colliding with them and that pedestrian moving out of their vehicle path. This is to attempt to provide a gauge for the "riskiness" of non-compliant crossing actions.

3.3 City of Dunedin Pedestrian Observational Studies

The intersection of George Street and St Andrew Street, which is located in the middle of Dunedin's Central Business District, was surveyed on one separate day by Dunedin City Council staff. The survey period was from 8.12am to 10.15am and covered the morning peak period for this location. The raw survey data was analysed and included in the results below. The results from the Dunedin observational surveys may be useful for comparison purposes with the Invercargill City results.

4 RESULTS

4.1 Survey Sizes

618 pedestrian movements were recorded at the three signalised intersections in Invercargill during the months of June, July and October 2012. A further 63 pedestrian movements were recorded at the signalised intersection in Dunedin on 31 August 2012.

4.2 Walking Speed Results

An average 5th percentile speed of 1.1 m/s and 15th percentile speed of 1.3 m/s was attained in Dunedin. These values are lower than the respective Invercargill values of 1.3 m/s and 1.4 m/s. The mean speed for Dunedin was 1.6 m/s.

The mean speed for Invercargill at this time period was 1.7 m/s. Overall the walking speed characteristics of pedestrians in Dunedin and Invercargill were very similar with Invercargill pedestrians showing a tendency to be marginally faster in all measures.

4.3 (Student) t-Tests and F-Tests for Walking Speeds

The results from (Student) t-Tests and F-Tests performed in relationship to walking speeds, age groups and road widths are used in Section 5 of this paper to formulate conclusions. The 11.5 m and 13 m wide crosswalks were classified as narrow width roads. The 22.5 m, 24.6 m and 30.9 m width roads were classified as wider width roads.

The 10 to 60 year old age groups were compared with the 61 years and over age group. The compliant pedestrian flow groups were split into less than one vehicle per minute and greater than one vehicle per minute categories. The non-compliant pedestrian vehicle flow groups were split into less than six and greater than six vehicles per minute groups. The tests showed that wider roads, do have significantly greater walking speeds, than the narrower roads and younger pedestrians have significantly greater walking speeds, then older pedestrians. Table 4 shows these results: Large vehicles flow rates did not have significantly greater walking speeds than small vehicle flow rates.

	Width 11.5m		Width 13.8m		Width 22.5m		Width 24.6m		Width 30.9m	
	5% Speed	15% Speed	5% Speed	15% Speed	5% Speed	15% Speed	5% Speed	15% Speed	5% Speed	15% Speed
10 to 30 years	1.1	1.3	1.3	1.4	1.5	1.6	0.8	1.3	1.6	1.8
31 to 60 years	1.0	1.2	1.3	1.4	1.6	1.7	1.3	1.4	1.7	2.2
61+ years	1.0	1.0	1.0	1.1	1.5	1.5	0.7	1.0	1.5	1.5

Table 4 – Age Range Walking Speed, for Varying Widths of Crosswalks.

4.4 Walking Speed Data Distributions

Many of the data distributions attained for walking speeds in comparison to road width, vehicle flow and age group were bi-modal in nature.

The distributions contained two peaks in most instances. There was usually more than one dominant walking speed within the distribution. This bi-modal phenomenon reflects the many factors influencing walking speeds.

When analysing the compliant walking speed data for the narrower width road grouping of 11.5 m and 13.8 m crosswalks, the varying ages of pedestrians within this group have created a lower peak mode for the more elderly pedestrians and a higher peak mode for the younger pedestrians within this group. In effect, there are sub groups present within the main group that are creating this bi-modal effect in many of the data distributions. The distribution data attained for the older age groups walking speeds was more representative of a normal distribution spread.

This result reflects that there are no sub groups within this age group class and hence the tendency for this distribution to be more approaching a normal fit.

4.5 Average Pedestrian Delays

Table 5 shows the range of walking speeds for varying width of crosswalks and age ranges.

Pedestrian Class	All Roadwidths	Width 11.5m	Width 13.8m	Width 22.5m	Width 24.6m	Width 30.9m
Compliant Male	23	20	20	29	24	38
Compliant Female	24	22	22	48	24	39
Non-compliant Male	8	6	7	27	1	35
Non-compliant Female	7	3	6		13	35
All Classes	**19**	**14**	**17**	**38**	**19**	**38**

Table 5 – Pedestrian delays for varying width of crosswalks and compliance classes

Average pedestrian delays were calculated for both compliant and non-compliant pedestrian classes for the different width crosswalks. The overall average delay attained for the non-compliant pedestrians were smaller than the average delay for compliant pedestrians. (7 seconds compared to 23 seconds) Male and female delays for both compliant and non-compliant pedestrians were very similar in comparison.

The average delays were highest at the more difficult to cross crosswalk widths of 22.5 m and 30.9 m. Average delays were approximately twice the value at these two wider crosswalks when compared to the narrower crosswalk group (38 seconds and 17 seconds respectively).

4.6 Pedestrian Delay Results from the Dunedin City Survey

The average compliant pedestrian delay from the 8.12am to 9.15am period and 9.15am to 10.15am periods were 19 and 22 seconds respectively. Nine pedestrians were non-compliant during this period and the average delay for this group was 17 seconds. There was very little difference in pedestrian delays between the compliant and non-compliant pedestrians at 20 and 17 seconds respectively.

4.7 Delay Comparisons between New Zealand Cities

Table 2 from Turner and Vallyon (2011) has been amended to include the findings from this research in Invercargill and Dunedin. Table 6 portrays these inclusions.

City	Number of Intersections	Observed Pedestrians	Average Pedestrian Waiting Time (secs)
Christchurch	5	289	25
Wellington	2	333	45
Auckland	7	843	53
Invercargill	3	618	19
Dunedin	1	63	19
Combined Results	**18**	**2146**	**32**

Table 6 - Average pedestrian waiting time surveys (Turner & Vallyon 2011, Cook 2013)

Most notably the average pedestrian waiting times incurred in the less heavily trafficked cities are smaller in value than those cities with greater traffic volumes and traffic flows. The results obtained for Invercargill and Dunedin are the same; however, it should be recognised that the Dunedin survey was limited in sample size and survey duration.

4.8 (Student) t-Tests and F-tests for Pedestrian Delays

The same groupings applied to the various F- and t-tests for walking speeds have been applied to the F- and t-tests for pedestrian delays. All tests were considered at the 99% level of confidence. The results from these tests are used in Section 5 of this paper to formulate conclusions. The tests showed that wide roads have significantly greater pedestrian delays than the narrow roads and age had no significant effect on pedestrian delay. Vehicle flow rate had no significant effect on compliant pedestrian delay but did have a significant effect on non-compliant pedestrian delay.

4.9 Pedestrian Delay Data Distributions

Many of the pedestrian delay data distributions were either skewed to the lower end of the delay scale (0 to 3 seconds) or bi-modal in nature with a peak delay at the lower end of the delay scale (0 to 3 seconds) and another peak delay usually in the mid-range of the delay scale for that group.

The skewing effect mostly occurs for the non-compliant pedestrian who is anxious to depart the kerbside within 5 seconds of their arrival time. 104 out of the 193 non-compliant pedestrians departed the kerbside within 0 to 5 seconds of their arrival time.

This represents 54% of the total sample. At the other end of the distribution, delays of up to 68 seconds were recorded. The bi-modal distributions are not prevalent in the compliant pedestrian tables and this is caused largely by the “randomness” of the compliant pedestrian delay, which is dependent to a large extent on the time of arrival to the kerb by that pedestrian in relation to the next activation of the green man symbol. The non-compliant pedestrian has more control over their delay interval as they are not constrained by waiting for the next green man symbol

4.10 Pedestrian Compliance

Table 7 shows the pedestrian compliance rates for different road widths.

Road Width (m)	Sample Size (N)	Compliant Pedestrians	Compliance Rate %
11.5	126	71	56%
13.8	357	258	72%
22.5	26	24	92%
24.6	61	35	57%
30.9	48	37	77%
All Roads	**618**	**425**	**69%**

Table 7 – Pedestrian Compliance Rates

An overall pedestrian compliance rate of 69% was obtained for this survey. 92% compliance was recorded at the difficult-to-cross 22.5 m-wide crosswalk at Elles Road. In contrast, the narrowest crosswalk on Kelvin Street at 11.5 m wide has the lowest compliance rate of 56%. Road width and the difficulty of the crossing task appears to influence compliance rates. This compliance rate for Invercargill of 69% compares closely with some of the values in Table 3 of this paper; Keegan & Mahoney (2003) – 64% Ke-Ping & Ying (2011) – 56% and Ghafourian *et al* (2009) – 80%. These findings validate previous research undertaken by Barker *et al* (1991) and Ke-Ping & Ying (2010).

4.11 Dunedin City Pedestrian Compliance Rates

The pedestrian compliance rate for the Dunedin survey during the 8.15 to 9.00 am period was 78% compared to 33% for Invercargill. The compliance rate during the 9.00am to 10.00 am period for Dunedin was 88% compared to 67% for Invercargill. The compliance rates between the two cities differed greatly and the intersection geometry in Dunedin may be a factor in this.

The intersection is not wide at 13.8 m but could be more heavily trafficked at this period of the day. This would explain the vast difference in compliance levels. The staff member from Dunedin City Council did also comment that many pedestrians were aware of her presence and this could have modified their pedestrian crossing behaviours.

4.12 "Time to Collision" Results

The average "Time to Collision" value attained for the 193 non-compliant pedestrians was 12 seconds.

This represents approximately 150 m of average conflict distance between the pedestrian and the conflicting vehicle travelling at 50km/h. Table 8 provides the distribution pattern of these "Time to Collision" intervals.

Road Width (m)	11.5m		13.8m		22.5m	24.6m		30.9m	
Gender	Male	Female	Male	Female	Male	Male	Female	Male	Female
Average Time to Collison Gap for Non-Compliant Pedestrian (secs)	9	7	17	17	10	15	12	11	11

Table 8 - "Time to Collision Intervals" Distribution Table

The average result attained of 12 seconds does not cause much reason for concern. (150 m is the length of one and half rugby fields) Of more reason for concern are the following results:

- 5% "Time to Collision" interval = 1 second
- 15% "Time to Collision" interval = 5 seconds
- 9% of the sample size experienced a 3 second or less "Time to Collision" interval, representing a conflict distance of 41 metres at 50km/h.
- 2.1% of the sample size experienced a car braking and stopping to let them cross safely. (four pedestrians).
- 2.1% of the total sample size for Invercargill's non-compliant pedestrian population at Traffic Signals could equate to at least 1000 pedestrians each year.

4.13 Crash Analysis Results

Analysis of New Zealand Transport Agency Crash Analysis System (CAS) provides the following information on pedestrians involved in accidents at traffic signals in Invercargill over the last 5 year period 2007-2011.

- 6 accidents involving non-compliant pedestrians at traffic signals.
- 2 serious injuries, 2 minor injuries, 3 non injuries.
- 5 accidents involved through vehicle movements and pedestrian crossings from the left.

- 1 accident involved right turn vehicle movement and pedestrian crossing from the left.

4.14 Risk Analysis

The non-compliant pedestrian percentage for the Invercargill study is 31%. A 31% non-compliance rate at Invercargill's 28 cross roads signalised sites, over a 5 year period could easily equate to approximately 75,000 non-compliant pedestrians over a 5 year period (assuming a modest average of 144 pedestrians a day at Invercargill's 28 cross road intersections, an average of 18 pedestrians per hour during the 8am to 4pm period).

This total sample size equates to approximately one accident involving a non-compliant pedestrian at a signalised intersection for every 12,500 non-compliant pedestrians.

Based on these assumptions, there is a 0.008% chance of a non-compliant pedestrian being involved in an accident with a vehicle at a signalised intersection in Invercargill.

2.1% of the non-compliant pedestrians observed in this study experienced a car braking and stopping to physically let them cross the road safely (4 pedestrians). It was observed that all of the vehicles involved stopped safely and were also travelling slowly at the time of braking. Field observations and analysis of the crash data and approximated non-compliant pedestrian population for a 5-year period indicates that the risk of being involved in a crash as a non-compliant pedestrian at traffic signals in Invercargill is very low.

4.15 Chi-Square Tests

Chi-square tests were performed to compare the compliance rates of the divided crosswalks (of all widths) against the wider undivided crosswalks, and also the compliance rates for the younger age groups against the older (>60 yrs) age group.

Both tests rejected the null hypothesis that Sample 1 was the same as Sample 2 to $p=0.001$, i.e. it is likely that there are significant differences in the compliance rates of these samples.

4.16 Pedestrian Walk Time (Green Man) Settings

It was observed in the field on most occasions that a surplus amount of pedestrian walk time (green man) was available for pedestrians who were beginning their crossing.

The purpose of the pedestrian walk time setting is to give pedestrians sufficient time to begin their crossing.

The six seconds of green man time currently available for pedestrians who are beginning their crossing appears to be too long in duration. Whilst the actual time of surplus time was not measured for every field observation, it would have been in most cases, at least two seconds. Four seconds of green man time, based on these field observations, would appear to be a more appropriate time setting for the pedestrian volumes measured during this study. A four second green man time interval concurs with Kochevar & Lalani (1985) and broadly relates to Austroads (2003), which does permit a green man setting of five seconds and minimum setting of four seconds where the signalised crossing is on a very narrow carriageway.

There needs to be more research applied to this area to ascertain the amount of surplus and insufficient green man time for differing pedestrian volumes and demographics.

A reduction in the green man time for six to four seconds will potentially reduce vehicle delays by two seconds in those instances where the next signal phase is waiting only for the pedestrian movement to end.

This reduction in "green man" time may induce higher rates of non-compliant pedestrian activity as those pedestrians who are some distance from the crosswalk at the onset of the "green man", now have more difficulty in reaching the crosswalk during the "green man" signal. This reduction in time may also have the effect of modifying pedestrian behaviour as some choose to wait for the next cycle and "green man" signal. This pedestrian characteristic will need to be observed and measured at the locations where this initiative is trialled.

5 CONCLUSIONS

The conclusions made from this study are grouped into the following sections,

- Walking Speeds
- Pedestrian Delay
- Pedestrian Compliance
- Traffic Signal Rule Comprehension
- Pedestrian Risk
- 'Green Man' time

The conclusions made in this study are based on the analysis of the raw field data and are reinforced by observations made during the field surveys and findings from the Literature Review.

5.1 Walking Speeds

- Wide undivided crosswalks (22 m and greater) had significantly greater walking speeds observed than the narrower crosswalks
- Vehicle flow rate was observed to not affect walking speeds at all of the crosswalks surveyed
- The younger age group (60 years and below) had significantly greater walking speeds observed than the older age group (61 years and above)
- The 15th percentile speed for all age groups increased with road width.

5.2 Pedestrian Delay

- Wide, undivided crosswalks (22 m and greater) had significantly greater pedestrian delays observed than the narrower crosswalks
- Vehicle flow rate was observed to not affect compliant pedestrian delay at all of the crosswalks surveyed
- Larger vehicle flow rates (6 vehicles/minute and greater) had significantly greater non-compliant pedestrian delays observed than the smaller vehicle flow rates (less than 6 vehs/min) at all of the crosswalks surveyed.
- Pedestrian age was observed to not significantly affect pedestrian delay at all of the crosswalks surveyed.

5.3 Pedestrian Compliance

- Wide, individual crosswalks (22 m and greater) had significantly greater pedestrian compliance observed than the narrower (less than 22 m) and wide, divided crosswalks.
- Older pedestrians observed were significantly more compliant than the younger pedestrians.
- Compliance was lowest during the very low traffic periods of the day. (Many of these pedestrians crossed during the "OFF" period when no symbol was displayed).

5.4 Traffic Signal Rule Comprehension

- The Green Man symbol is fully understood by pedestrians.
- The Red Man solid symbol is mostly understood by pedestrians (93% understanding).
- The Red Man flashing symbol is not fully understood by many pedestrians (79% understanding).

5.5 Pedestrian Risk

- The risk of a non-compliant pedestrian being involved in a crash with another vehicle in Invercargill is very low. (Approximately 0.008% chance)

5.6 "Green Man" Time

- A four second "green man' time is a more appropriate time setting for the pedestrian volumes measured in this study.

5.7 Original Objectives and Relative Confidence

The relative confidence in the findings and conclusions from this study are reinforced by my own field observations and previous research conducted in these areas.

5th and 15th Percentile Walking Speeds

The study aimed to recommend 5th and 15th percentile walking speeds for different width roads and age group classifications for the three signalised intersections surveyed. The study has achieved this objective with a good level of confidence for the population sampled in Invercargill. These results could be further validated with surveys performed in other New Zealand Cities.

Average Pedestrian Delays

This study aimed to measure average pedestrian delay times for non-compliant and compliant pedestrian activities during different times of the day. These results would be compared with other pedestrian delay survey findings for New Zealand.

This Study has achieved this objective with a good level of confidence for the population sampled in Invercargill. These results could be further validated with surveys performed in other New Zealand Cities.

Non-compliant Pedestrian Behaviour

This study aimed to measure the extent of non-compliant pedestrian behaviour for different times of the day at the three signalised intersections surveyed. The study has achieved this objective with a good level of confidence for the population sampled in Invercargill. These results could be further validated with surveys performed in other New Zealand Cities.

6 RECOMMENDATIONS

The following recommendations are made based on the literature review findings and conclusions drawn from this study.

6.1 Less Pedestrian Clearance Interval time

A **1.5 m/s walking speed** should be used to calculate the pedestrian clearance interval on wide (22 m or greater) undivided carriageways and a 1.3 m/s walking speed rate used on narrow (22 m or less) carriageways. This could be trialled at suitable sites within New Zealand.

6.2 Two pedestrian Clearance Interval Options on Pedestrian Call Facilities

To allow for the fact that less able pedestrians may still wish to safely use a signalised crossing, we suggest introducing "dual-speed" crossings. This would be achieved by modifying the pedestrian call facility used at trial locations to still allow a longer pedestrian clearance interval for those less able and slower pedestrians (e.g. by pushing a "secret" button or holding for longer).

6.3 Four Second "Green Man" Time

A four second "green man" interval could be used at crosswalks where pedestrian volumes are low, (i.e. no more than one row of pedestrians forms at the crosswalk kerb). This could be trialled at suitable sites within New Zealand.

6.4 Education on the Pedestrian Crossing Rules at Traffic Signals

More education is required on the pedestrian crossing rules for traffic signals, particularly in the area of the Pedestrian Clearance Interval (Flashing Red Man). NZTA should initiate this education campaign.

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