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*Pedestrian-Vehicle Accident Review: Human Factors Behavioural Assessment*

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# Contents

# 1 Introduction

## 1.1 Overview of the Pedestrian-Vehicle Accident Study

Wellington City Council is conducting an investigation into pedestrian-vehicle accidents in the Wellington Central Business District. This investigation includes stages 1-3 below, with the possibility of option 4 (to monitor success) to be considered.

1. **Crash analysis study**, including a full CAS and site analysis (Companion Report by GHD);
2. **Observational study** of pedestrian and vehicle behaviour to understand how pedestrians are interacting within different road environments;
3. **Intervention phase** that will be informed by the recommendations of Stages 1 and 2 in conjunction with an expert steering group evaluation. Potential interventions could include engineering interventions, perceptual countermeasures, an exploration of behavioural motivation and social marketing solutions, or a vehicle study (e.g. examining features that may make vehicles more easily detected by pedestrians), and;
4. **Evaluation phase** to proactively examine intervention success by observing behavioural success measures post-intervention.

The current report relates to the Stage 2 of this investigation, the Observational Study and Human Factors assessment, which is being undertaken in conjunction with GHD, who have performed the Stage 1 Crash Analysis.

This report uses naturalistic observation techniques to examine pedestrians at different infrastructure and explore the effects of a number of explanatory factors (such as demographics and individual differences, pedestrian activity and clothing) on a number of performance factors. Performance factors assessed will include variables such as gap acceptance and conflict, as well as looking and crossing behaviour.

## 1.2 Objectives

The objectives of this part of the investigation include:

- Explore the effects of a number of explanatory factors on performance factors to identify the correlates of safe/unsafe pedestrian behaviour, and
- Identify effective interventions and countermeasures for implementation to reduce unsafe pedestrian behaviours and therefore reduce pedestrian injury.

## 1.3 Report content and structure

Section 1: Introduction

Section 2: Previous literature and background

Section 3: Research methodology

Section 4: Observational findings

# 2 Previous Literature

A short, non-exhaustive review was conducted to examine:

- International pedestrian-vehicle safety studies (particularly observational studies) to inform the methodology and performance measures examined in this observational study.
- Pedestrian safety relating to distraction and vehicle visibility
- Previous intervention options

See Martin (2006) for a more detailed review of factors influencing pedestrian accidents, including behavioural factors and some of the possible engineering interventions.

## 2.1 Pedestrian safety

### 2.1.1 Distraction

**Evidence for the role of distraction in pedestrian injury**

A survey of the causes of road and roadside pedestrian slip, trip and fall injuries in the Wellington region of New Zealand between 2008 and 2010 found that approximately 45% of participants agreed or strongly agreed they had some level of distraction at the time of their accident (Frith & Thomas, 2010). The most often reported reason for this distraction was being 'lost in thought' (23%), with a further 13.2% reporting being distracted by conversation.

Only 9% of these pedestrians were engaged in another activity (e.g. listening to music or walking a dog) at the time of their accident. Overall, 3.7% of pedestrians were listening to a music player at the time of their accident, with 0.6% and 0.4% respectively using a cell phone for texting or talking (Frith & Thomas, 2010).

Route familiarity can lead to low perceived risk and low attentiveness. About 87% of these pedestrians also indicated they were familiar with the route they were travelling at the time of their slip, trip or fall.

Anecdotal observations of pedestrian behaviour during a safety audit along the Golden Mile route in 2011 also indicated that pedestrian behaviour typically infers a lack of attention (Beca Infrastructure, 2011). It was suggested that low perceived risk due to the pedestrian-friendly environment may be a contributing factor (Beca Infrastructure, 2011).

**Distraction by mobile phones and portable music devices**

Both media and research interest has recently been directed towards the effect of distraction by technologies such as cell phones and portable music players on pedestrian safety, particularly due to the well-documented negative safety implications for drivers (e.g. Nasar, Hecht & Wener, 2008; Stavrinos, Byington &

Schwebel, 2011; Neider, McCarly, Crowell, Kaczmarski & Kramer, 2010). Crossing the street requires cognitive attention; therefore it has been hypothesised that the use of mobile phones and music players may distract pedestrians from this cognitive demand, reducing situational awareness and increasing the risk of accidents (e.g. Nasar et al., 2008; Hatfield & Murphy, 2007).

Cell phone usage does have negative implications for pedestrian safety, having an association with decreased cautionary behaviour and a slowed walking pace when crossing the road (Nasar et al., 2008; Hatfield & Murphy, 2007; Neider et al., 2010). An association has also been found between mobile phone use and reduced looking and waiting behaviour for female pedestrians (Hatfield & Murphy, 2007). Pedestrians conversing on phones may also be less likely to recognise and act on crossing opportunities (Neider et al., 2010).

These negative safety implications may be more pronounced for older pedestrians (Neider, Gaspar, McCarley, Crowell & Kacsmarski, 2011) and may vary depending on the cognitive complexity of the use of the phone (Stavrinos et al., 2011). For example, in a study of College students in the US, Stavrinos et al., (2011) found those participating in a cognitively demanding conversation or completing demanding tasks over the phone performed more poorly on safety measures than others participating in mundane conversations or less complex tasks. This moderation effect was not observed in relation to non-safety related variables however; pedestrians were equally distracted on these variables regardless of task complexity.

In contrast, research exploring pedestrian distraction by portable music players has not shown the same trend; the use of portable music devices by pedestrians has not been linked to poorer performance on safety measures and in some cases has been linked to increased cautionary behaviour (e.g. increased rates of looking before crossing the road), at least for males (Walker, Lanthier, Risko & Kingstone, 2012; Neider et al., 2011; Neider et al., 2010). Though, as Walker et al. (2012) emphasise, it is unclear whether such behavioural effects translate into increased safety or a lack of negative safety implications for pedestrians. The data reported above (Frith & Thomas, 2010) indicates that in a New Zealand context the use of portable music devices may have a larger role to play in pedestrian injury than cell phone use, at least for non-motor accidents. This issue therefore requires further exploration. Given the current evidence, however, mobile phones and portable music players need to be considered as different distracters with potentially varying safety consequences for pedestrians.

### 2.1.2 Detection of vehicles

Accurate motion detection of vehicles with concurrent self-motion is an important dynamic task in vehicle collision avoidance for pedestrians making crossing decisions and manoeuvres (Santos, Noriega & Albuqerque, 1999). A number of studies have explored what factors influence the motion detection of vehicles, including varying road surfaces (e.g. Santos et al., 1999) and individual differences (e.g. Santos et al., 1999; Scialfa, Guzy, Leibowitz, Garvey & Tyrrell, 1991; Tom & Granie, 2011; Humphry & Kramer, 1997).

In relation to road surfaces, Santos et al. (1999) found evidence that different road surfaces affect the accuracy of motion detection of vehicles. Vehicle motion detection was more impaired in the situation of bitumen pavement with chromatic bands[1], a pavement with high optical flow density (which increases visual motion of the scene around the vehicle; see Figure 1), compared to other road surfaces such as bitumen or concrete without chromatic bands (see Figures 2 and 3 respectively; Santos et al., 1999). This finding led the authors to conclude that over-signalised roads could have dangerous implications for motion detection, meaning the number and type of signals required on a road should be carefully considered to ensure a safe environment (e.g. chromatic bands should be used where required to signalise designated crossings but excessive signage should be avoided).

Individual differences were also found with regard to motion detection; females had advanced detection skills, however with age the time required to accurately detect vehicles increased. Males on the other hand required less time to detect vehicles, but with age showed an increased error rate (Santos et al., 1999).

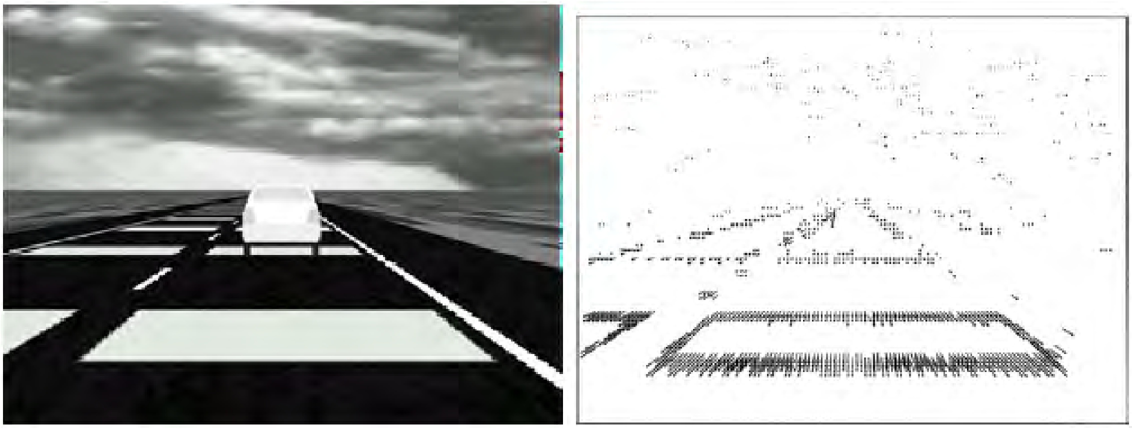

**Figure 1: Bituminous pavement with chromatic bands, including global optical flow representation (Santos et al., 1999)**

[1]Chromatic bands are rectangles of contrasting coloured pavement within the road surface, as seen in Figure 1. Real world examples of contrasting horizontal colour on the road surface can include road markings or paved locations.

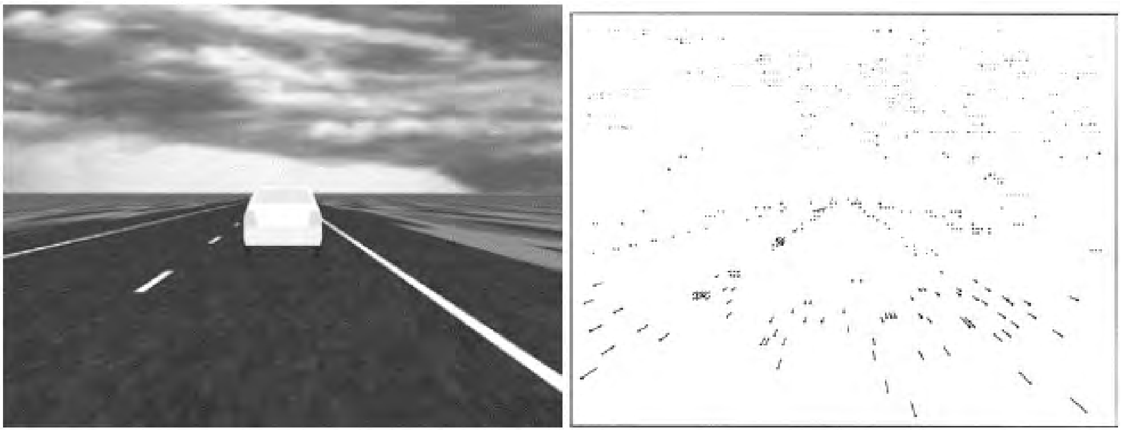

**Figure 2: Bituminous pavement without chromatic bands, including global optical flow representation (Santos et al., 1999)**

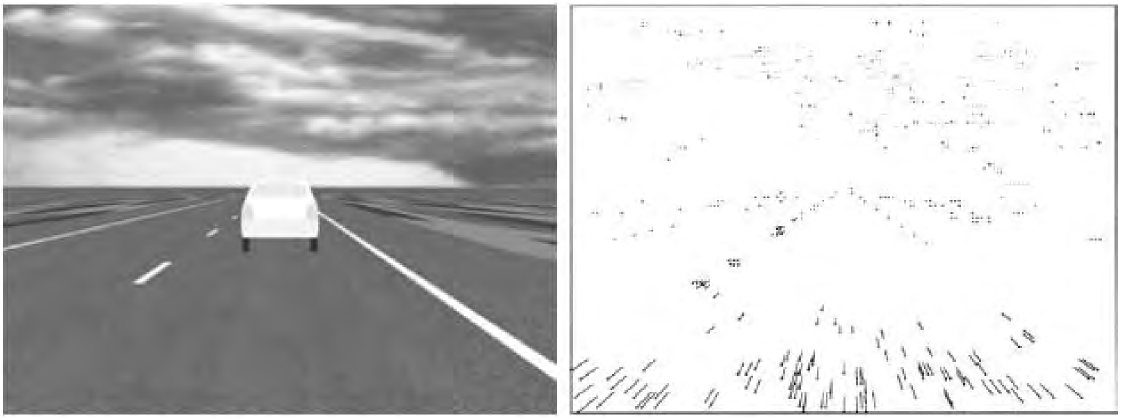

**Figure 3: Concrete pavement without chromatic bands, including global optical flow representation (Santos et al., 1999)**

Tom and Granie (2011) found additional gender differences; this time in relation to gaze targets for pedestrians crossing the road. Females were more likely to focus their gaze on other pedestrians whereas males were more likely to focus their gaze on traffic (Tom & Granie, 2011). Such differences may have implications for the accuracy of motion detection of vehicles between male and female pedestrians.

Gender differences in crossing compliance were additionally found; temporal crossing compliance was lower among male pedestrians whereas spatial crossing compliance did not differ between genders (Tom & Granie, 2011). Finally, spatial crossing compliance and gaze targets were modulated by the crossing type. Spatial crossing compliance was higher at signalised crossings, especially for males. In addition, gaze targets for females varied by crossing type; on signalised crossings female pedestrians are more focused on the traffic light before crossing, while during crossing their gaze shifts to other pedestrians. Female pedestrians' focus on other pedestrians was found to increase at unsignalised crossings. Males, in contrast, were focused on moving vehicles regardless of crossing type (Tom & Granie, 2011). Therefore, interventions aimed at the types of crossings provided (e.g. altering the number of signalised crossings) may have important safety implications.

In regard to age-related variation in motion detection, Scialfa et al. (1991) found older pedestrians had more difficulty in judging changes in the speed of cars compared to younger age groups. In addition, the older pedestrians tended to overestimate lower speeds and underestimate higher speeds (the highest in the trial being 50mph, or around 80km/h), which obviously has potential safety implications for older pedestrians, especially when making crossing decisions on higher speed roads. Humphry and Kramer (1997) additionally established that older pedestrians find it more difficult than younger adults to rapidly and accurately locate and identify objects in cluttered environments. This finding is important as Scialfa et al.'s (1991) study involved velocity assessments of an isolated vehicle, hence, older pedestrians' disadvantages may be more pronounced in a real world context involving multiple stimuli.

Thus, older pedestrians may be at increased injury risk compared to younger pedestrians due to comparative difficulties in the speed and accuracy of detecting vehicles and their relative velocities. This is supported by evidence that shows a disproportionate number of both pedestrian and driver accidents involving older people may involve errors in velocity estimation (e.g. Faulkner, 1975; Sheppard & Pattison, 1986 cited in Scialfa et al., 1991).

The current evidence therefore shows road surfacing is an important consideration when aiming to improve motion detection of vehicles and therefore pedestrian safety. Research shows contrast (e.g. between concrete pavement and bitumen pavement) is of low importance to this with optical flow instead having important implications; over signalised roads potentially pose a hazard (Santos et al., 1999). Age related deficiencies in vehicle motion detection are well documented and vary by gender. Gender differences are also apparent in gaze targets and crossing compliance and these additionally vary by crossing type.

**Vehicle type, perceived risk and detection**

Hamed (2001) suggests that pedestrians have lower perceived risk around buses, finding that pedestrians were more likely to cross if the oncoming vehicle was a bus (Cited in Zhuang & Wu, 2012). It is suggested that this may be because buses are perceived to be slower than cars, such that pedestrians accept smaller gaps when crossing. Further, typical visual detection cues regarding speed may be hampered with a bus, where many of the speed detection cues (such as the spacing of roadside infrastructure) may be blocked by the larger size of the vehicle.

In terms of actual detection, visual theory would suggest that larger objects are easier to detect as they take up a greater visual angle. A possible corollary to this is that modern bus design may mean that the proportion of highly visible bus frontage is so low that pedestrians may simply be better at detecting cars (e.g. see Harris, 2011).

## 2.2 Interventions

There are three main types of interventions aimed at improving pedestrian safety by influencing road user (e.g. driver or pedestrian) behaviour. These include:

- Engineering or physical interventions,
- Enforcement interventions, and
- Educational and social marketing interventions.

This review will focus on interventions aimed at pedestrians which have either been suggested for, or have potential applications to, the Wellington CBD.

### 2.2.1 Physical interventions

**Guard rails**

Guard rails are generally installed along roads with high foot and vehicle traffic and are designed to increase separation between pedestrians and drivers by keeping people or vehicles from entering areas not designated for them. Guard rails are often suggested as a quick fix for unsafe pedestrian behaviours and high pedestrian injury rates; however, evidence for their effectiveness is at best mixed. In addition, research in this area has generally been plagued with problems such as small sample sizes and resulting statistical robustness issues.

A small handful of studies have explored pedestrian collision statistics in relation to railing availability (e.g. Zheng & Hall, 2003; Simmonds, 1983 cited in Martin, 2006). Zheng and Hall (2003) completed an observational study of pedestrian behaviour and conflicts at sites with and without guard railing in London after concluding a review of the available literature provided an unclear picture. For example, evidence from the Molasses database, a database of UK safety studies which includes 20 sites where guard railing has been installed, does show an average reduction in collisions and pedestrian injury of 40%. However, it was concluded these findings may be biased due to a tendency to selectively report successful sites to Transport for London (TRL). In addition, at the majority of sites, railing was used in conjunction with other interventions, meaning the effectiveness of the railing alone is unclear (Zheng & Hall, 2003).

Zheng and Hall's (2003) research could not follow a before-and-after methodology due to time restraints, therefore similar sites with and without railing were instead observed. Thirty-seven sites across five London boroughs in total were selected as observation sites. Analysis showed that across all sites, those with guard railing did have lower average levels of pedestrian conflict, lower total collisions and statistically significant lower pedestrian collisions (Zheng & Hall, 2003). The safety effect varied by site type however, which led Martin (2006) to conclude that the findings may have been due to small sample sizes. Zheng and Hall (2003) emphasise their findings reiterate the importance of carefully selecting sites for the erection of guard railings; installation at link/junction sites may increase risky behaviour (e.g. jumping over railings) whereas installation at school and transport interchanges may provide safety benefits.

Simmonds (1983, cited in Martin, 2006) completed a before-and-after study of guard rail installation, also in London. This study found a reduction in collisions when guard railings were installed, however, this may have been an artefact arising from selection bias (e.g. Martin, 2006). Finally, a more recent study conducted by the Department for Transport (DfT, 2009) found no statistically significant differences between sites surveyed with/without railing for total and pedestrian collisions (sites selected were outside of London for this study). DfT (2009) conclude these results are, at best, indicative and should be interpreted with caution. A survey within this project of attitudes towards walking and guard railing in particular also revealed that while participants saw the provision of railing as a necessary road safety device offering protection from traffic, over three-quarters felt the use of railing should be restricted to where 'absolutely necessary' (DfT, 2009).

Arguments against guard rails imply negative side effects associated with their installation (Gehl, 2004 cited in Martin, 2006; Stewart, 1983; Zheng & Hall, 2003). Typical arguments include:

- Pedestrians becoming trapped by the railing;
- Downstream problem behaviour shift if only used as "spot" solutions;
- Increased pedestrian injury risk if vehicle crashes through the railing and the railing becomes stuck to the front of the vehicle;
- Creation of an unpleasant, restrained pedestrian environment; and
- Increased vehicle speeds in the presence of railing.

Consequently, a number of authors argue there is little evidence to suggest the provision of railing is associated with reduced pedestrian injury or collision risk (e.g. Hall, 1986; Taylor, Hall & Chatterjee, 1996 cited in Martin, 2006).

Railings may provide modest safety benefits when sites for installation are carefully selected based on evidence-supported criteria. However, there is also the potential for an increase in hazardous pedestrian behaviours following their provision, particularly if site selection is poor. It is also argued that systemic pedestrian network solutions are required rather than localised or "spot" solutions if there is to be a significant improvement in pedestrian safety (e.g. Gitelman, et al. 2012). In addition, surveys of public attitudes have emphasised a preference for restricting the use of this intervention. Overall, this appears to be a last resort option, when all other interventions fail.

### 2.2.2 Enforcement interventions

**"Jaywalking" laws**

Research on the effectiveness of "jaywalking" laws (laws defining legal crossing behaviour) in terms of reducing casualty rates is not available to the best of the author's knowledge. There is some evidence that conducting warning campaigns for jaywalking laws can result in an increase in the number of legal crossings (based on research carried out in the US and South Africa; Martin, 2006). However, research in the UK, where no jaywalking laws are in place, also shows that the presence of a police officer can have a beneficial effect on both pedestrian and driver behaviour at automatic traffic lights (Martin, 2006). Therefore, it is unclear whether improvements in pedestrian safety and compliance behaviour found during warning campaigns are due to the presence of police officers or concern for complying with law.

Pedestrian crossing compliance statistics from studies based in countries with jaywalking laws in place also show that pedestrians are willing to make non-compliant crossings and therefore break the law. For example, Sisiopiku and Atkin (2003) found, in an observational study of pedestrian behaviours at various urban crosswalks, that 28.6% of pedestrians on average at different crosswalk types were spatially non-compliant (see Table 2 for further detail). Non-striped midblock crosswalks showed the highest level of non-compliance, with signalised intersection crosswalks showing the lowest. Temporal compliance rates at signalised crosswalks were lower than spatial compliance rates, with nearly 50% on average of those observed making non-compliant crossings. It is important to note that these statistics should be interpreted with care due to small sample sizes.

**Table 1: Pedestrian spatial crossing compliance rates from Sisiopiku & Atkin (2003)**

| Location | Number of observations | Mean (%) | SD |
|---|---|---|---|
| Signalised intersection x-walks | 36 | 82.8 | 8.321 |
| Midblock x-walks | 28 | 71.2 | 11.062 |
| Unsignalised intersection x-walks | 14 | 67.5 | 6.348 |
| Non-striped midblock x-walk | 12 | 64.2 | 3.487 |
| **Average** | | **71.4** | |

**Table 2: Pedestrian temporal crossing compliance rates from Sisiopiku & Atkin (2003)**

| Location | Number of observations | Mean (%) | SD |
|---|---|---|---|
| Signalised intersection x-walk 1 | 8 | 43.4 | 9.020 |
| Signalised intersection x-walk 2 | 8 | 46.8 | 9.432 |
| Signalised intersection x-walk 3 | 8 | 57.6 | 7.999 |
| Signalised intersection x-walk 4 | 6 | 52.1 | 8.214 |
| Signalised intersection x-walk 5 | 6 | 54.5 | 12.338 |
| **Average** | | **50.9** | |

Anecdotal evidence additionally suggests that enforcement of jaywalking laws can be both resource intensive and of limited effect. For example, Fijian authorities recently initiated a zero-tolerance campaign with relation to jaywalking (Gopai, 2011), however, it became apparent pedestrians were only following the laws when they were being watched (Narayan, 2011). This provides support for the conclusion drawn above that it is difficult to assess whether pedestrian behavioural improvements observed in previous research are due to (a) being watched or the presence of a police officer, or (b) regard for the law.

The resource requirement to enforce this law, coupled with its lack of overall effectiveness, meant that Fijian authorities abandoned the campaign just months after its initiation (Narayan, 2011). An important point to note here is citizens felt enforcement of the law was unfair given a perceived lack of adequate crossings provided (e.g. Karan, 2011). Therefore, a focus on providing a road network which reduces the perceived need to “jaywalk” (or crossing in violation of the law, for example, increasing the number of crossings, improving the quality of crossings) may be a more effective strategy for reducing unsafe pedestrian behaviours and therefore pedestrian injury/collision rates.

### 2.2.3 Educational and social marketing interventions

While outside the scope of this study, any pedestrian education interventions should be informed by the demographic and behavioural findings within both the GHD crash analysis report and this behavioural report. Social marketing interventions are more effective when the demography of the at-risk population is known (for example, see Clancy, 2006). Similarly, increasing knowledge of the specific behaviours that lead to reduced safety may be of benefit in persuading people to adopt safer behaviour.

Typically these interventions aim to achieve behavioural change by:

- Increasing road safety knowledge
- Make road users aware of the implications of unsafe behaviour
- Promoting desirable attitudes
- Providing/teaching people strategies to minimise the risk of being involved in a road traffic collision, and
- Increasing awareness of the needs of other road users
- Also, there is typically greater traction if aimed at younger (e.g. pre-adolescent) children

# 3 Research methodology

## 3.1 Observational studies

The observational studies focused on indicators of pedestrian and vehicle performance relating to safe crossing behaviour and the relationship between performance and potential causative factors.

The following studies were conducted:

1. Exploratory study of bus footage: Where a camera was mounted on a trolley bus travelling regularly through the "Golden Mile".

2. Exploratory study of pedestrian behaviours over time: Where footage of pedestrian crossing behaviours over multiple crossings was observed. .

3. Fixed site observations: Footage was examined from fixed cameras mounted at four key sites.

## 3.2 Exploratory footage

### 3.2.1 Bus footage

An exploratory bus footage study was conducted by mounting a camera on a trolley bus travelling regularly through the "Golden Mile". This footage provided some assistance in identifying appropriate sites for the four fixed observation sites.

### 3.2.2 Pedestrian footage

An exploratory observation study was used to observe pedestrians over a number of crossings to explore pedestrian behaviours prior to crossing (which may have been missed by a narrow video viewpoint) and examine individual trends in crossing compliance.

## 3.3 Fixed site evaluation criteria and selection process

Fixed camera sites are shown on Figure 4. Sites were selected based on several key criteria:

1) High relative number of pedestrian crashes at the sites;
2) Uncertainty over the mechanics of pedestrian behaviour (based on the crash reports);
3) Historic changes in infrastructure (e.g. alteration of one-way to two-way road traffic direction)
4) Variation in infrastructure at site (street furniture, sight distances, road width)
5) Variation in traffic flow (bus-only vs mixed traffic)

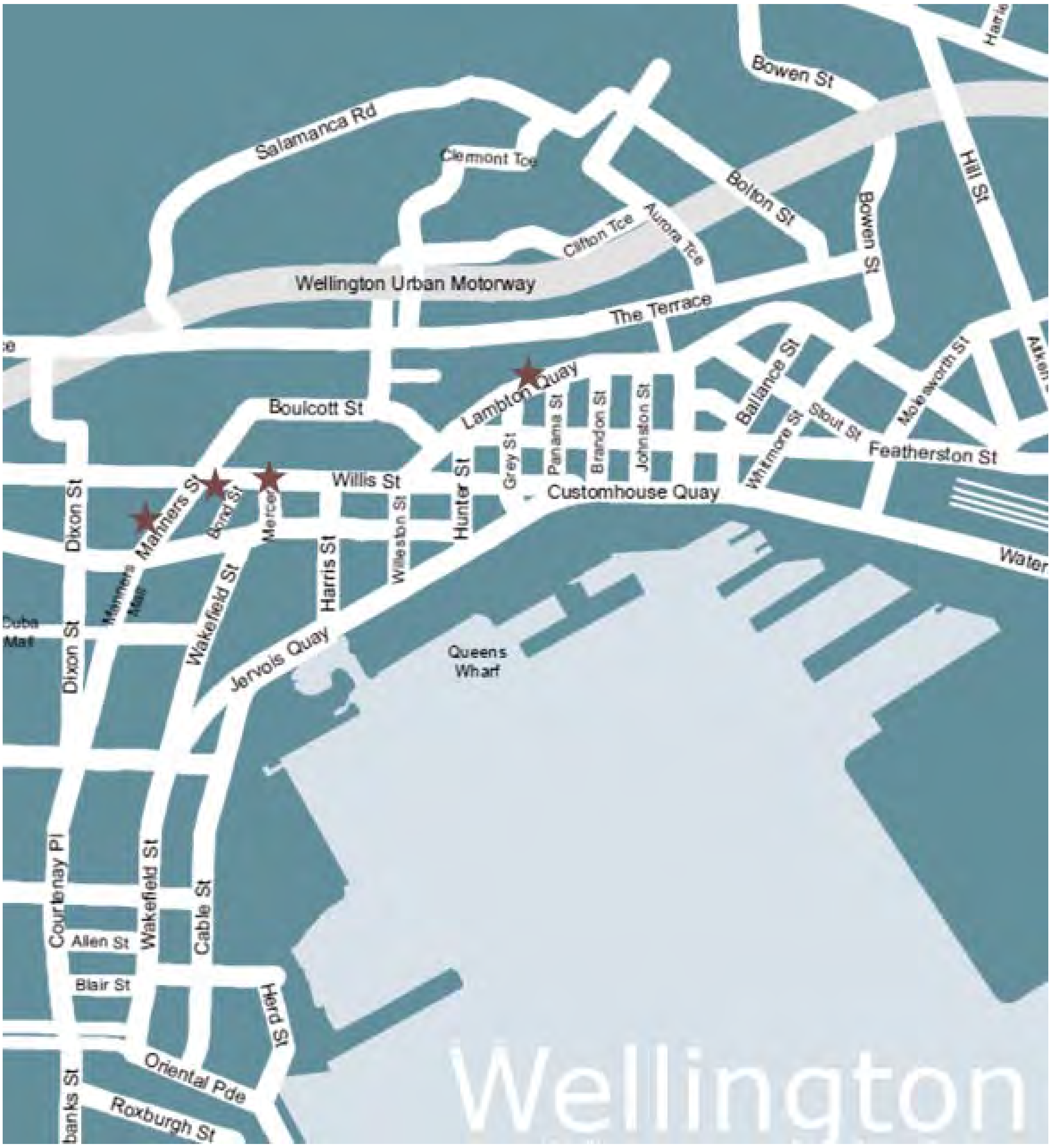


**Figure 4: Street map of Wellington with fixed camera site locations indicated by stars (Source: Wellington City Council)**

### 3.3.1 Site 1: Signalised intersection site

**Location:** Mercer Street (intersection of Mercer Street and Willis Street)

**Key Site Characteristics:** Ability to examine temporal compliance and looking behaviour at signalised crossings with set pedestrian phases, with a particular focus on the beginning and end-of-phase of the signal. A key benefit of this site is that is has similar infrastructure and layout to Site 3.

#### 3.3.2 Site 2: Bus only site

**Location:** Manners Street (between Victoria Street and Willis Street)

**Key Site Characteristics:** High pedestrian accident site, with bus-only traffic, some vertical roadside furniture limiting visual detection, and natural variation in kerb approach direction. There is also a historical change in traffic direction from one-way to two-way.

#### 3.3.3 Site 3: Traffic exposure variation site

**Location:** Willis Street (between Boulcott Street and Bond Street)

**Key Site Characteristics:** Historical traffic direction change from 1-way to 2-way traffic. Disproportionate traffic density and vehicle type, with low density bus only traffic heading South and high density mixed car and bus traffic heading North. There is also a variation in roadside infrastructure that allows examination of pedestrian desire lines. This site also has similar infrastructure to Site 1.

#### 3.3.4 Site 4: Median strip site

**Location:** Lambton Quay (immediately North of the Grey Street Pedestrian Lights)

**Key Site Characteristics:** This site was chosen due to its relatively low pedestrian crash numbers and due to variation in pedestrian refuge type, as the site contains a raised pedestrian island and a level painted median. There is a bus stop on one side. There is also a natural variation in roadside infrastructure, where one side has infrastructure that can block visual detection and one side that has no visual infrastructure barriers.

#### 3.3.5 Additional site footage

There is additional site footage that has been captured, but has not been analysed, that could be utilised as "before" footage if interventions were undertaken at these sites in the future.

*Site 5: Desire line site*

Video footage at Manners Street (between Taranaki Street and Cuba Street), where the angled desire lines may encourage left look only behaviour.

*Site 6: Long wait times site*

CCTV footage at the signalised crossing at the intersection of Taranaki Street/Manners Street

### 3.4 Video and CCTV observation method

Video and CCTV footage was used to capture pedestrian-vehicle interactions. Direct human observation was used initially at sites to select appropriate camera locations. Video footage was identified as the best method for data collection, as this allowed replay of the footage to accurately capture the multitude of complex behaviours in real-time. Direct observation of these behaviours would have been too demanding on the observers.

### 3.5 Observation measures

Pedestrians were observed at each of the four sites until the number of crossings was enough to ensure statistically robust results. Morning and afternoon footage was collected at each of the sites. A range of measures were gathered, which are summarised in Tables 3, 4 and 5. The focus was on collecting a large range of behaviours for each individual rather than attempting to measure a large numbers of crossings.

**Table 3: Pedestrian and site characteristics**

| Measure | Categories/Description |
|---|---|
| *Pedestrian characteristics* | |
| Age | Age was divided into three broad categories: youth (up to 25 years), middle-aged (25-65 years) and older/elderly (65 years and over) |
| Gender | Male or female |
| Body type | Normal or overweight |
| Clothing | Sport, business/work, casual or school uniform |
| Footwear | High-heel, running shoe, sneaker or other |
| Headwear | None, present but not blocking vision or hearing, covering ears, blocking peripheral vision or covering ears and blocking peripheral vision |
| Activity | None, audio activity, visual activity, physical activity, or both audio and visual activity. Physical activities were defined as those that were laborious or may have affected pedestrian ability to cross the road safely (such as carrying a heavy load, eating, pushing a pram). Where a pedestrian was observed performing an activity the specific activity (e.g. carrying bags, texting) was noted. |
| *Site characteristics* | |
| Engineering factors | Measures of road width, lane separation, kerb height, colour contrast, street furniture and sight distance were collected for each site |
| Road and roadside environment alterations | Any recent alterations that may alter behaviour (e.g. speed zone changes, signage, use of colour, changing from one-way to two-way roads) were also taken into account |

The compliance characteristics relate to compliance with intended use as opposed to legal compliance. The definition of compliance used in the current study differs from the legal requirements. Legally, a pedestrian is only spatially non-compliant if a crossing is completed within 20 meters of a designated crossing. However, previous research suggests crossing at non-designated locations places pedestrians at higher injury risk, which is why this different definition was employed. For example, Ghee et al. (1998) found that there were 150 risk events recorded per 1000 crossings in non-designated crossing points, compared with 30 risk events per 1000 crossings at designated crossings.

**Table 4: Measures of potential conflict, actual conflict and vehicle behaviours**

| | |
|---|---|
| *Conflict characteristics and vehicle behaviour* | |
| Potential conflict | This measure relates to gap acceptance to the closest variable. Following Cairney and Diamantopoulou (1999), the following categories were used to distinguish potential conflicts: no potential conflict (vehicle stationary or stopping), low potential conflict (vehicle over 3 – 7 seconds away), medium potential conflict (vehicle within 3 seconds), high potential conflict (vehicle within 2 seconds) or very high potential conflict (within with 1 second) |
| Actual conflict | No accident or accident. No actual conflicts were observed during the study. |
| Vehicle behaviour | No change, vehicle swerves, vehicle brakes/slows, vehicle already stationary or NA (no vehicle present) |

**Table 5: Crossing, looking and compliance behaviours**

| | |
|---|---|
| *Crossing characteristics* | |
| Crossing direction* | This was divided into two measures. The first indicated whether the pedestrian was crossing towards or away from the camera. The second recorded whether the pedestrian approached the point of crossing from the left, right or straight on. |
| Zone* | These were recorded as indicated in Figures 8 and 9 below. |
| Tempo to kerb | Slows down, stops, false start, regular walking rhythm or jog/run |
| Number when arrive | Alone or group |
| Wait time | Second count of wait time prior to crossing |
| Number crossing | Alone or group |
| Speed | Walk, partial run or run |
| Partial Crossing | No partial crossing or partial crossing |
| Crossing type | Lights, zebra, midblock or raised crossing |
| Time of day | Morning or afternoon |
| *Looking behaviour* | |
| Prior looking behaviour | No look, partial look, full look, passive full look or passive partial look. Passive looking is where pedestrians are already facing in the direction of oncoming traffic as they move to cross. |
| Distance first look right* | Estimate of meters from kerb when pedestrian first looked right |
| Number of times look left* | Count of number of times pedestrian looked left |
| Number of times look right* | Count of number of times pedestrian looked right |
| During cross looking behaviour | No look, partial or full look |

| *Compliance characteristics* | |
|---|---|
| Spatial compliance | This measure relates to where pedestrians chose to cross. Crossings completed at designated crossings (e.g. signalised or zebra crossings) were recorded as compliant, whereas midblock crossings and crossings completed outside the designated area at lights and other actual crossings were recorded as non-compliant. |
| Temporal compliance | This measure relates to the timing of pedestrian crossings for crossings completed at signalised lights. Crossings started in the green pedestrian phase were recorded as compliant. Crosses that were started during the red phase, flashing red clearance phase or the inactive phase (when no signal was present) were recorded as non-complaint[2]. Temporal compliance was recorded as not applicable for crossings completed midblock or on zebra and raised crossings. |

Note: Where indicated with an asterisk this measure was not collected for Site 1.

### 3.5.1 Observational reliability

Inter-rater reliability was examined on a small sample of the observations to check that the observational measures were being consistently and accurately coded. The reliability of measures between observers was assessed using the Kappa statistic and the results are displayed in Table 6. Only one measure (number when arrive) showed moderate agreement (.60) between observers, with all other measures showing either substantial (.61 - .80), almost perfect (.81 - .99) or perfect (1.00) agreement (Viera & Garrett, 2005).

[2] This also differs from the legal requirements; pedestrians are legally able to cross when no man is present (e.g. the inactive phase). However, this type of crossing requires the same looking and risk behaviours as crossing during the red phase, hence this was defined as non-compliant for the purposes of this study.

**Table 6: Inter-rater reliability statistics**

| Variable | Kappa | % agreement | Significance |
|---|---|---|---|
| *Pedestrian characteristics* | | | |
| Age | .77 | 86.7% | *** |
| Gender | .93 | 96.7% | *** |
| Body type | - | 100.0% | - |
| Clothing | .73 | 86.7% | *** |
| Footwear | .64 | 80.0% | *** |
| Headwear | - | 96.7% | - |
| Activity | .68 | 83.3% | *** |
| *Crossing characteristics* | | | |
| Crossing towards or away from camera | 1.00 | 100.0% | *** |
| Zone | 1.00 | 100.0% | *** |
| Crossing direction | .95 | 96.7% | *** |
| Tempo to kerb | .76 | 83.3% | *** |
| Number when arrive | .60 | 80.0% | *** |
| Wait time | .81 | 90.0% | *** |
| Number crossing | 1.00 | 100.0% | *** |
| Speed | .91 | 96.7% | *** |
| Partial crossing | - | 96.7% | - |
| Crossing type | - | 100.0% | - |
| *Looking behaviour* | | | |
| Prior looking behaviour | .89 | 93.3% | *** |
| Distance first look right | .75 | 80.0% | *** |
| Number of times look left | .70 | 76.7% | *** |
| Number of times look right | .87 | 90.0% | *** |
| During cross looking behaviour | .76 | 83.3% | *** |
| *Compliance characteristics* | | | |
| Spatial compliance | - | 100.0% | - |
| Temporal compliance | - | 100.0% | - |
| *Conflict characteristics and vehicle behaviour* | | | |
| Potential conflict | .83 | 90.0% | *** |
| Actual conflict | - | 100.0% | - |
| Vehicle behaviour | 1.00 | 100.0% | *** |

*** $p < .001$. Note: where the kappa statistic is not reported this could not be calculated because the measure was constant in at least one set of observer data.

# 4

# 5 Exploratory Study 1: Bus footage

## 5.1 Purpose

The bus footage was collected to:

1. Aid in the identification of potential problem sites;
2. Examine typical pedestrian behaviour immediately preceding a bus; and
3. Examine behaviours across the entire length of the Golden Mile.

## 5.2 Method

A camera was mounted inside a bus and footage recorded for one full day (see Figure 5 for a screenshot of the view from this camera). Over the course of the day, the bus travelled a number of routes, including travelling the length of the 'Golden Mile'[3] around ten times. Some of this footage was compromised due to heavy rain and condensation build-up on the inside of the windscreen. Footage of two full passages through the Golden Mile was reviewed and pedestrian behaviour recorded. Only pedestrians crossing in front of the bus in question were observed and their behaviour coded.

**Figure 5: Screenshot of view from bus camera**

As previously stated, potential conflicts were defined as possible when the vehicle occupied a space previously occupied by a pedestrian in the previous three seconds (in line with

[3] The 'Golden Mile' route is a passage through Wellington City CBD consisting of Lambton Quay, Willis Street, Manners Mall and Courtney Place.

Cairney and Diamantopoulou, 1999). Calculations were therefore made of the average meters per second travelled by a bus travelling the speed limit through the Golden Mile (8.33 meters per second for a bus travelling at 30 kms an hour) and this distance was mapped on the footage for 1, 2, 3 and more than 3 seconds, based on measurements taken along the side of the road on Lambton Quay.

The following results do not include any significance tests due to the small sample size producing unreliable findings (e.g. expected cell frequencies less than 5 in chi square tests).

## 5.3 Findings

In total, 104 pedestrian crossings were observed. Of these crossings, 59.6% (N=62) were spatially compliant (e.g. the crossing was completed on a designated crossing such as at a zebra crossing or at lights), leaving 40.4% (N=42) non-compliant. Of these spatially non-compliant crossings, 4 (9.5%) were close to lights, with the remaining 38 crossings being mid-block (90.5%). In relation to temporal compliance, 37.5% (N=39) of crossings were compliant, with 20.2% (N=21) being non-compliant. Temporal compliance was not applicable or unknown for 42.3% (N=44) of the crossings (e.g. because the crossings were completed mid-block or at a zebra crossing rather than at lights). Overall, 55.8% (N=58) of crossings observed were at lights, 7.7% (N=8) were at zebra crossings and 36.5% (N=38) were mid-block.

### 5.3.1 Gender, age and crossing compliance

The data showed that equal proportions of males and females were location compliant in their crossings (around 63% for each group), meaning that the males and females observed were spatially non-compliant at equal rates. Temporal compliance proportions were also similar between males and females (see Table 7). Crossing types were also chosen by each gender at similar rates.

**Table 7: Temporal compliance rates split by gender**

| | Males | Females |
|---|---|---|
| Not compliant | 13 (25.0%) | 7 (16.3%) |
| Compliant | 18 (34.6%) | 20 (46.5%) |
| Not applicable | 21 (40.4%) | 16 (37.2%) |
| Total | 52 (100.0%) | 43 (100.0%) |

Some slight variation in spatial compliance rates by different age groups was observed. As displayed in Table 8, the oldest age group was spatially compliant at a higher rate than the other two groups. The data additionally showed that the oldest age group chose to cross the road at the lights (88.9%) at a higher rate than both the youngest and middle age groups (66.7% and 55.8% respectively). In line with this trend, this older age group also chose to cross mid-block at a lower rate (11.1%) than the other two groups (33.3% and 32.7% respectively). In contrast, pedestrians belonging to the oldest age group were found to be temporally non-compliant at the highest rate (44.4%) of the three groups (18.5% and 19.2% respectively). These trends should be treated with caution here due to low numbers, but if they are statistically significant this should become apparent within the main four sites.

**Table 8: Spatial compliance rates split by age**

| | Younger/Youth | Middle-aged | Older/Elderly |
|---|---|---|---|
| Not compliant | 10 (37.0%) | 19 (36.5%) | 2 (22.2%) |
| Compliant | 17 (63.0%) | 33 (63.5%) | 7 (77.8%) |
| Total | 27 (100.0%) | 52 (100.0%) | 9 (100.0%) |

### 5.3.2 Looking behaviour

Where looking behaviour could be viewed[4], 32.5% (N=13) failed to look before entering the roadway, and 80.7% (N=71) failed to look during crossing.

There is some evidence that pedestrians trust the signalised crossings, such that they are less alert at these crossing points. In one instance, a pedestrian was observed reading while crossing the road during the green pedestrian phase at signalised traffic lights. This pedestrian's looking behaviour prior to crossing is unknown (due to the angle of the lens), however, during crossing the pedestrian failed to look, instead focusing their attention on their reading material.

### 5.3.3 Potential conflict

Only two crossings out of the 104 observed were deemed to constitute a potential pedestrian-bus conflict. These crossings were both completed on the south end of Lambton Quay, shortly after the Willis Street/Lambton Quay intersection at the only single lane section of the Golden Mile. This indicates that sites where pedestrians perceive it is easier to cross could elicit higher risk pedestrian behaviour.

All other crossings were either completed when the bus was already stationary (e.g. at lights or a bus stop) or outside of the three second threshold. Both of the crossings were within the three second threshold (e.g. 25 meters from the bus) but outside of the two second threshold (e.g. 16.66 meters from the bus). In one of these potential conflict crossings the pedestrian had made the decision to follow immediately behind another pedestrian that crossed just outside the conflict zone, indicating the influence of other pedestrians on individual behaviour.

While potential conflicts with the bus in question were rare, other potentially risky pedestrian behaviours were observed in the footage. In one instance, a pedestrian darted out in front of the bus while it was parked at a stop, failing to look for oncoming traffic. Research shows that when pedestrians enter the roadway between parked vehicles their risk level for conflict is greatly increased, as their field of vision is generally impeded, as is the oncoming driver's (Tom & Granie, 2001).

In a number of cases observed, crossings were also completed outside of the allocated time at lights (e.g. after the flashing red phase had finished). In these cases the bus was

[4] Looking behaviour prior to crossing was unknown for many pedestrians (61.5%, N=64) due to the angle of the camera.

required to accelerate at a slower rate than generally observed in order to allow these pedestrians time to pass.

# 6 Exploratory Study 2: Consistency of Pedestrian Behaviour

## 6.1 Purpose

To examine pedestrian footage for the same pedestrians over time to:

1. Identify any individual consistency in behaviour across sites; and
2. Identify any relevant "lead-up" behaviour prior to the crossing point (that may have been missed in the fixed video/CCTV sites).

## 6.2 Method

Individual pedestrians were observed over time to examine pedestrian crossing behaviour over a number of crossings.[5]

## 6.3 Findings

In total, 19 pedestrians were observed in the footage. All pedestrians crossed at least once, with one pedestrian crossing four times. In total, 37 crossings were observed. Crossing type choices and spatial and temporal compliance rates for these pedestrians over crossings are displayed in Table 9.

[5] No individual pedestrians were identified during this process (i.e. their behavioural data could not be linked back to them in any way). Also, observations were made in public areas performing public behaviours that were intended for that space (i.e. walking).

**Table 9: Spatial and temporal compliance and crossing type over crossings**

| | Crossing 1 | | | Crossing 2 | | | Crossing 3 | | | Crossing 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Participant | Crossing | Spatial | Temporal | Crossing | Spatial | Temporal | Crossing | Spatial | Temporal | Crossing | Spatial | Temporal |
| 1 | Lights | Comp | Comp | Lights | Comp | Comp | Lights | Comp | Comp | -- | - | - |
| 2 | Lights | Comp | Comp | Lights | Comp | Comp | Lights | Comp | Comp | - | - | - |
| 3 | Midblock | Non | N/A | - | - | - | - | - | - | - | - | - |
| 4 | Lights | Non | Non | Lights | Non | Non | Lights | Comp | Non | - | - | - |
| 5 | Lights | Comp | Comp | Lights | Comp | Comp | Raised | Non | N/A | Lights | Comp | Comp |
| 6 | Zebra | Comp | N/A | - | - | - | - | - | - | - | - | - |
| 7 | Zebra | Comp | N/A | Lights | Comp | Comp | Raised | Non | N/A | - | - | - |
| 8 | Lights | Comp | Non | Lights | Comp | Comp | - | - | - | - | - | - |
| 9 | Midblock | Non | N/A | - | - | - | - | - | - | - | - | - |
| 10 | Midblock | Non | N/A | - | - | - | - | - | - | - | - | - |
| 11 | Lights | Comp | Non | - | - | - | - | - | - | - | - | - |
| 12 | Lights | Comp | Non | - | - | - | - | - | - | - | | - |
| 13 | Lights | Comp | Non | - | - | - | - | - | - | - | - | - |
| 14 | Lights | Non | Comp | - | - | - | - | - | - | - | - | - |
| 15 | Midblock | Non | N/A | Midblock | Non | N/A | - | - | - | - | - | - |
| 16 | Midblock | Non | N/A | Midblock | Non | N/A | - | - | - | - | - | - |
| 17 | Lights | Comp | Comp | - | - | - | - | - | - | | - | - |
| 18 | Zebra | Comp | N/A | Lights | Comp | Comp | Lights | Comp | Comp | - | - | - |
| 19 | Zebra | Comp | N/A | Lights | Comp | Comp | Lights | Comp | Comp | - | - | - |

### 6.3.1 Consistent individual crossing compliance behaviour

Pedestrians who were compliant in their original crossings were generally compliant in subsequent crossings (see Table 9). In line with this trend, pedestrians who were non-compliant remained non-compliant in subsequent crossings. This indicates that spatial and temporal compliance may be related to individual attributes as opposed to situational characteristics; however, this is based on an extremely small sample of pedestrians so these findings should be treated with caution. Group behaviour may also have a role to play in non-compliant crossings, with 8 of the 11 non-compliant crossings being completed in groups.

Patterns in crossing type choice for those who made more than one crossing are also evident in the above table. Those who chose to cross at allocated crossing sites (e.g. lights, zebra crossings) always selected these sites in subsequent crossings. Similarly, those who chose to cross at non-designated sites (e.g. midblock) repeatedly chose such sites for subsequent crossings. This again indicates that spatial compliance may in some way be related to personal preference, however, it could also be related to the location at which participants were observed (e.g. on quieter or one-way streets as opposed to those with multiple lanes and heavier traffic flow).

### 6.3.2 Inconsistent individual looking behaviour

The looking behaviour of the non-compliant pedestrians varied within subjects, indicating that looking behaviour may be more influenced by changes in infrastructure. For example:

- Pedestrian number four (a middle-aged male in casual clothing and listening to an MP3 player as well as carrying grocery shopping) failed to look during his second and third crossings, and only partially looked during his first.
- Pedestrians nine and ten (a younger female and middle-aged male respectively, both in casual clothing) looked prior to crossing but then failed to look during.
- Participant number fourteen (a younger male in casual clothing) failed to look before entering the roadway but then partially looked during his crossing.
- Only participants fifteen and sixteen (a young female and young male, both in casual clothing) looked fully before starting to cross and in addition, partially looked while crossing.

### 6.3.3 Non-compliant wait times were shorter

The mean wait time across all crossings was 8.6 seconds, ranging from 0 to 60 seconds. For those who generally crossed compliantly, the mean wait time was raised to 11.8 seconds (ranging from 0 to 60 seconds). For those who generally crossed non-compliantly, however, the mean wait time was only 0.3 seconds (ranging from 0 to 3 seconds).

# 7 Fixed camera observation findings: Individual differences

The data for this section include all four fixed camera sites.

## 7.1 Demographics and clothing

In total, 1386 pedestrian crossings were observed across the four sites. Sample demographics, body type and clothing are reported in Table 10.

**Table 10: Total sample demographics, body type and clothing (N = 1386)**

| Sample characteristic | Frequency |
|---|---|
| *Age* | |
| Up to 25 years | 300 (23.0%) |
| 25 to 65 years | 899 (69.0%) |
| 65 years and over | 104 (8.0%) |
| Total | 1303 (100.0%) |
| *Gender* | |
| Male | 757 (56.4%) |
| Female | 585 (43.6%) |
| Total | 1342 (100.0%) |
| *Body type* | |
| Normal | 1226 (92.0%) |
| Overweight | 107 (8.0%) |
| Total | 1333 (100.0%) |
| *Clothing* | |
| Sport | 26 (2.1%) |
| Business/work | 492 (39.1%) |
| Casual | 718 (57.1%) |
| School uniform | 21 (1.7%) |
| Total | 1257 (100.0%) |
| *Footwear* | |
| High-heel | 66 (7.3%) |
| Running shoe | 75 (8.3%) |
| Sneaker | 142 (15.7%) |
| Other | 619 (68.6%) |
| Total | 902 (100.0%) |
| *Headwear* | |
| None | 1247 (96.3%) |
| Not blocking vision or hearing | 39 (3.0%) |
| Covering ears | 5 (0.4%) |
| Blocking peripheral vision | 3 (0.2%) |
| Covering ears and blocking peripheral vision | 1 (0.1%) |
| Total | 1295 (100.0%) |

Against expectation, there were fewer female pedestrians in this sample. Previous research indicates that the level of walking in the Wellington CBD is higher amongst females (Frith & Thomas, 2010), so this may be a function of the Golden Mile route.

Pedestrians that were wearing running shoes, sports clothing and running prior to crossing were identified as joggers, but only three pedestrians fit this criteria, so no further analyses of their behaviour was examined.

### 7.2 Activities

Activities across all four fixed sites were examined to gain an idea of the proportion of pedestrians that were engaged in behaviours that may impact either perception, level of fatigue or even crossing time. Overall 20.7% (n = 286) of pedestrians were observed to be engaged in an activity. Only 1.4% (n = 19) of these were engaged in an audio or visual activity (see Table 11) with the remaining pedestrians engaged in a physical activity (see Table 12).

**Table 11: Audio and visual activities observed (N = 19)**

| Activity | Frequency | Percentage of total sample |
|---|---|---|
| *Audio activity* | | |
| Talking on cell phone | 5 (26.3%) | 0.4% |
| Listening to portable music device | 4 (21.1%) | 0.3% |
| *Visual activity* | | |
| Texting/looking at phone | 7 (36.8%) | 0.5% |
| Reading | 1 (5.3%) | 0.1% |
| *Audio and visual activity* | | |
| Listening and looking at portable music device | 2 (10.5%) | 0.1% |
| Total | 19 (100%) | 1.4% |

Physical activities were defined as those that were laborious or may have affected pedestrian safety behaviour. Generally this constituted the pedestrian carrying objects such as bag(s), books, boxes, large backpacks or other large objects. A number of pedestrians were also observed pushing/pulling potentially difficult objects (e.g. sack barrows, courier trolleys, suitcases or prams). Carrying and/or drinking coffee was also observed regularly and incorporated into this measure.

**Table 12: Physical activity types observed by frequency (N = 267)**

| Physical activity | Frequency | Percentage of total sample |
|---|---|---|
| Carrying bag(s) | 137 (51.3%) | 9.9% |
| Carrying/drinking coffee | 32 (12.0%) | 2.3% |
| Carrying books | 28 (10.5%) | 2.0% |
| Pushing/pulling something* | 20 (7.5%) | 1.4% |

| **Physical activity** | **Frequency** | **Percentage of total sample** |
|---|---|---|
| Carrying briefcase | 17 (6.4%) | 1.2% |
| Carrying boxes and large objects** | 16 (6.0%) | 1.2% |
| Carrying a baby/pushing a pram | 6 (2.2%) | 0.4% |
| Carrying food/eating | 6 (2.2%) | 0.4% |
| Large backpack | 4 (1.5%) | 0.3% |
| Applying makeup | 1 (0.4%) | 0.1% |
| Total | 267 (100.0%) | 19.2% |

* includes sack barrows, courier trolleys and suitcases; ** includes guitars and ladders

A summary of characteristics of the crossings observed is provided in Table 13. Wait times for the full sample across the four sites ranged from 0 to 64 seconds, with a mean of 4.20 seconds[6].

**Table 13: Total sample crossing characteristics**

| **Crossing characteristic** | **Frequency** |
|---|---|
| *Crossing direction** | |
| From left | 123 (21.8%) |
| From right | 155 (27.5%) |
| Straight on | 285 (50.6%) |
| Total | 563 (100.0%) |
| *Tempo to kerb* | |
| Stops | 286 (29.2%) |
| Slows down | 107 (10.9%) |
| False start | 1 (0.1%) |
| Regular walking rhythm | 569 (58.2%) |
| Jog/run | 15 (1.5%) |
| Total | 978 (100.0%) |
| *Number when arrive at kerb* | |
| Alone | 726 (71.0%) |
| Group | 296 (29.0%) |
| Total | 1022 (100.0%) |
| *Number crossing* | |
| Alone | 737 (53.3%) |
| Group | 646 (46.7%) |
| Total | 1383 (100.0%) |
| *Speed* | |
| Walk | 1305 (94.2%) |
| Partial run | 49 (3.5%) |
| Run | 31 (2.2%) |
| Total | 1385 (100.0%) |

[6] Wait time was observed for 971 pedestrians.

| Crossing characteristic | Frequency |
|---|---|
| *Partial crossings* | |
| No partial crossing | 943 (95.3%) |
| Partial crossing | 46 (4.7%) |
| Total | 989 (100.0%) |

* This measure was not collected at the signalised intersection at Site 1

### 7.3 Overall looking behaviour

Examination of looking behaviour prior to crossing reveals that pedestrians looked left once on average, ranging from 0 to 7 times[7]. Sixty-eight pedestrians looked passively left (e.g. they were walking in that direction when approaching the kerb to cross).

Pedestrians looked right 1.5 times on average, ranging from 0 to 8 times. Seventy-four pedestrians passively looked right before crossing. Twenty-five pedestrians failed to look right before crossing. Pedestrians first looked right 2.5 meters from the kerb on average, ranging from 0 to 10 meters.

A significant relationship was found between wait time and pedestrian looking behaviour. Longer wait times were related to a higher frequency of looking both left ($r$ (447) = .59, $p < .01$) and right ($r$ (438) = .65, $p < .01$) prior to crossing.

### 7.4 Compliance and conflict

Crossing compliance rates for the sample are reported in Table 14. Most crossings (64.6%) across the four sites occurred at mid-block locations, as opposed to at signalised lights (35.4%), where timing compliance was applicable.

**Table 14: Compliance rates**

| Compliance characteristic | Frequency |
|---|---|
| *Spatial compliance* | |
| Non-compliant | 963 (69.5%) |
| Compliant | 423 (30.5%) |
| Total | 1386 (100.0%) |
| *Temporal compliance* | |
| Non-compliant | 94 (6.9%) |
| Compliant | 376 (27.5%) |
| Not applicable (not at signalised crossing) | 895 (65.6%) |
| Total | 1365 (100.0%) |

Table 15 displays vehicle behaviour and conflict measures for the crossings observed. As can be seen, across the four sites, 53 individual potential conflict incidents were observed (potential conflicts were recorded when a vehicle occupied space previously occupied by a pedestrian with three seconds or less). Only one vehicle took evasive action in these

[7] The number of times pedestrians looked left and right and the distance at which pedestrians first looked right were not collected at Site 1.

incidents, and this was a cyclist. All other vehicles did not appear to alter their speed or path when faced with a potential conflict. No actual conflicts were observed within the observations.

The rate of potential conflict was 3.8% (using the 3 second rule of thumb), which is lower than previously reported rates. For example, in Sydney, Australia, 10% of observed crossings were deemed to represent potential conflicts (defined as present if either the car or the pedestrian changed their behaviour to avoid an incident; Hatfield & Murphy, 2007). When using a similar definition to Hatfield and Murphy (2007) (e.g. combined frequency of partial crossings, partial running, pedestrian false starts and vehicle swerving) the rate of potential conflicts for the current study increased to 6.6% (N = 92). Analysis shows potential conflicts (using the 3 second rule of thumb) were significantly higher for those who partially ran compared to those who walked or ran across the entire road ($p < .001$)[8]. The same relationship was not evident for partial crossings ($p = .47$), however, this could be because pedestrians who partially crossed were avoiding narrow gaps with vehicles, and therefore avoided potential conflict.

**Table 15: Vehicle behaviour and conflict measures**

| | **Frequency** |
|---|---|
| *Vehicle behaviour* | |
| No change | 249 (18.1%) |
| Vehicle swerves | 1 (0.1%) |
| Vehicle stationary | 173 (12.6%) |
| NA (no vehicle present) | 952 (69.2%) |
| Total | 1375 (100.0%) |
| *Potential conflicts* | |
| No potential conflict | 1198 (86.5%) |
| Low potential conflict (3-7 seconds away) | 134 (9.7%) |
| Medium potential conflict (within 3 seconds) | 40 (2.9%) |
| High potential conflict (within 2 seconds) | 13 (0.9%) |
| Very high potential conflict (within 1 second) | 0 (0.0)% |
| Total | 1385 (100.0%) |
| *Actual conflicts* | |
| No conflict | 1386 (100.0%) |
| Conflict | 0 (0.0%) |
| Total | 1386 (100.0%) |

[8] Fisher's Exact test is reported here due to low expected cell frequencies (e.g. < 5).

## 7.5 Behavioural differences by gender, age and body type

### 7.5.1 Gender

Females were less likely to look prior to crossing, whereas males were more likely to passively look ($\chi^2$ (4, *N* = 908) = 12.98, p = .01). The lower female level of looking behaviour does align with some of the pedestrian-vehicle crash findings, where there is a gender bias towards females. However, females are more likely to cross at lights (as opposed to mid-block), such that females were just as likely to look prior to crossing at non-signalised crossings. Therefore, the higher accident rate does not appear to align with looking behaviour.

### 7.5.2 Age

The older (65 or more years) age group were no more likely to choose signalised crossings than mid-block crossings, but when they do use signalised crossings they have less looking behaviour prior to crossing than any other age group ($\chi^2$ (1, *N* = 387) = 4.51, p < .05).

The younger (25 years or younger) age group was more likely to choose mid-block crossings than the middle (25-65 years) age group ($\chi^2$ (2, *N* = 1303) = 38.24, p < .001).

### 7.5.3 Body type

There is some indication that overweight pedestrians are more cautious in their road crossing behaviour, such that they were more likely to:

- Avoid activities or headwear that impaired their perception ($\chi^2$ (1, *N* = 1333) = 4.91, p < .05)
- Avoid physical activities that could cause fatigue or reduce crossing speed ($\chi^2$ (1, *N* = 1314) = 6.60, p = .01)
- Use signalised crossings ($\chi^2$ (1, *N* = 1333) = 41.02, p < .001)
- Stop prior to crossing ($\chi^2$ (2, *N* = 927) = 9.64, p < .01)
- Wait significantly longer prior to crossing (*t (*93.5) = -2.81, p < .01)

From these findings you could imply that those with less cautious behaviour may also perceive themselves to be more agile. This is supported by the finding that younger pedestrians are more likely to choose mid-block crossings.

# 8 Site 1: Willis Street/Mercer Street Intersection

## 8.1 Site description

The CCTV camera at this intersection is mounted on the Central Library building, providing a view of both the crossings at the end of Mercer Street, as displayed in Figure 6. As can be seen, the lights on the far side of Willis Street (Crossing A) are visible from this angle, therefore it was possible to accurately record whether pedestrian crossings were temporally compliant on this crossing. Light phase timings could also therefore be accurately observed from this view. The light on the front intersection (Crossing B) was not visible, however, which meant recording of temporal compliance and light phases for this crossing was slightly more difficult.

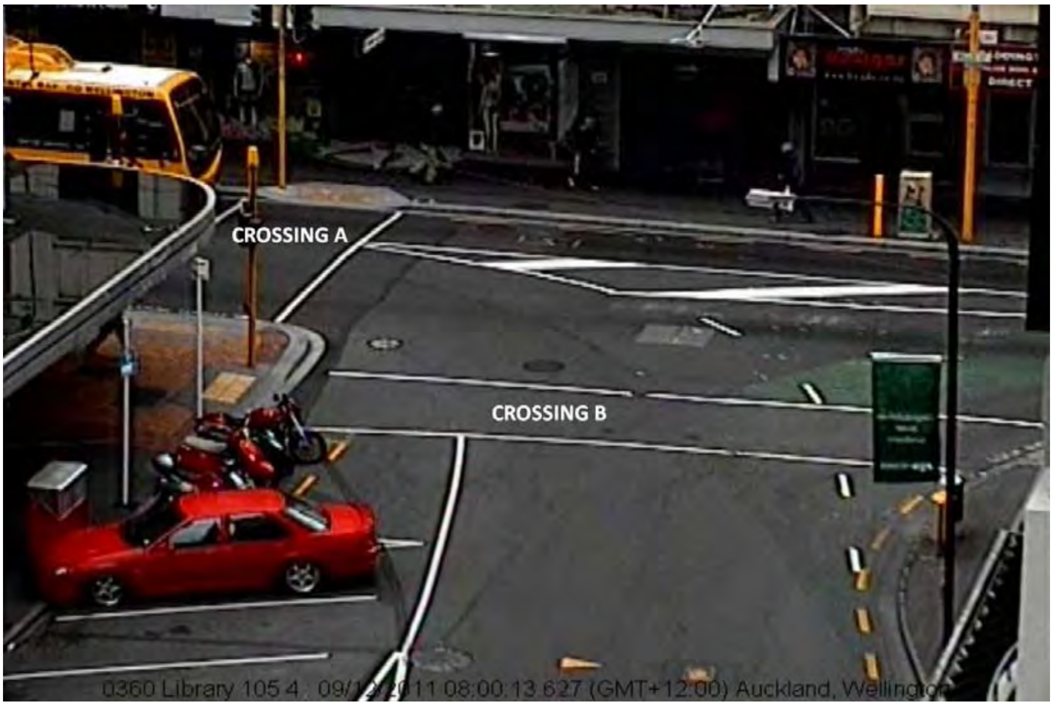


**Figure 6: Screen shot of CCTV view of Mercer Street/Willis Street intersection.**

Light phases for both crossings are displayed in Table 16. As can be seen, the total cycle time for Crossing B was shorter than for Crossing A, meaning green phases were more regular for this crossing. Green phases between the two crossings overlapped in that when Crossing A was green, Crossing B was generally green (although as mentioned, Crossing B had additional green phases that were not in time with Crossing A).

**Table 16: Average timings in seconds for light cycles for both crossings at both time slots**

| | 8am – 8.10am | | 2pm – 2.10pm | |
|---|---|---|---|---|
| **Light phase** | **Crossing A** | **Crossing B** | **Crossing A** | **Crossing B** |
| Red phase | 58 | 20 | 53 | 20 |
| Green phase | 12 | 15 | 16 | 18 |
| Flashing red phase | 12 | 12 | 12 | 12 |
| Total cycle time | 82 | 47 | 81 | 50 |

Footage was analysed at both 8am and 2pm. In total, 194 pedestrian crossings were observed during the 8am time slot, and 274 during the 2pm time slot. The date at which the footage was recorded (Friday, December 9th, 2011) provides a potential explanation for the higher number of pedestrians during the afternoon period, with Christmas shopping potentially attracting more people to the city centre. Rates of clothing types support this assumption, with a higher proportion of pedestrians being dressed in business clothing during the 8am time slot (36.1% versus 15.3% respectively) and a correspondingly lower proportion of people dressed in casual clothing compared to during the 2pm time slot (23.2% versus 57.7% respectively).

## 8.2 Findings

In total, 468 pedestrian crossings were observed at the Mercer/Willis Street intersection. The majority of pedestrians did not look either before or during crossing, with only 14.9% of the sample looking prior to crossing and 3.5% looking during crossing. Most of the observed pedestrians were not participating in any activity during crossing, with physical activities being the most common for those who were. Carrying bag(s) was the most common physical activity participated in this group, followed by carrying other items (e.g. briefcase or guitars), wheeling suitcases, or pushing prams or trolleys. Visual activities observed included one pedestrian who was reading and two pedestrians who were using their cell phones (e.g. texting).

The mean wait time for the total sample was 7.18 seconds, ranging from 0 to 64 seconds (SD = 12.96). No significant difference in wait time was evident between those crossing in the morning versus the afternoon ($t$ (410) = -.28, $p$ = .65). A significant difference was found between male and female pedestrians' average wait times ($t$ (357.2) = -1.97, $p$ < .05), with males waiting a shorter time on average than females. However, there were no significant differences between males and females in relation to either spatial compliance ($\chi^2$ (1, $N$ = 424) = .348, p = .56) or temporal compliance ($\chi^2$ (1, $N$ = 404) = .85, p = .36).

### 8.2.1 Compliance behaviour

Rates of spatial and temporal compliance are reported in Table 17. A cross-tabulation of these two variables is provided in Table 18. Temporal non-compliance was overall more common than spatial non-compliance, however, this finding may be a product of the angle of the camera lens (e.g. because only a small section of road not designated as a crossing was visible, see Figure 6). Additionally, nearly three times as many pedestrians were spatially compliant but temporally non-compliant as the other way around.

Of those who were temporally non-compliant, 7.3% (n = 6) started just before the green phase, 6.1% (n = 5) started once the broken red phase had begun and the remaining 86.6% (n = 71) completed their crossing entirely during the red phase.

**Table 17: Spatial and temporal compliance rates**

| | **Frequency** |
|---|---:|
| *Spatial compliance* | |
| Non-compliant | 45 (9.6%) |
| Compliant | 423 (90.4%) |
| Total | 468 (100.0%) |
| *Temporal compliance* | |
| Non-compliant | 82 (18.3%) |
| Compliant | 365 (81.7%) |
| Total | 447 (100.0%) |

**Table 18: Spatial compliance and temporal compliance cross-tabulation**

| | | Temporal compliance | | |
|---|---|---:|---:|---:|
| | | Non-compliant | Compliant | Total |
| Spatial compliance | Non-compliant | 20 | 21 | 41 |
| | Compliant | 62 | 344 | 406 |
| | Total | 82 | 365 | 447 |

Significant differences with regard to looking behaviour were found between those who crossed compliantly versus non-compliantly. Those who were not spatially compliant were significantly more likely to look prior to (p=.001)[9] and during crossing (p<.001) than those who were spatially compliant. In line with this, those who crossed non-compliantly in relation to timing were also significantly more likely to look prior to ($\chi^2$ (1, *N* = 373) = 88.17, p < .001) and during crossing (p<.05) than those who were temporally compliant.

Contrary to expectation, those who were non-compliant in relation to timing did not wait a significantly shorter time on average than those who were compliant (*t* (109.2) = -1.85, *p* > .05). Again, no significant differences were found in relation to spatial compliance (*t* (42.7) = -1.44, *p* > .05).

Differences in crossing compliance by time of day were also found. Pedestrians crossing during the afternoon were significantly more likely to be spatially compliant than those crossing in the morning ($\chi^2$ (1, *N* = 468) = 8.85, p < .01), however, no such relationship was found for temporal compliance ($\chi^2$ (1, *N* = 447) = .003, p =

[9] Fisher's Exact Test is reported here because expected cell frequencies are less than 5. This is the appropriate test to use this situation because Fisher's test makes no assumption regarding expected cell values, but is instead based on observed cell values.

.96). This may explain why no significant differences in average wait times were observed between the two time periods.

No differences in prior looking behaviour were found between the two data collection times ($\chi^2$ (1, *N* = 394) = .61, p = .43). Looking behaviour during crossing did differ significantly between observation times however ($\chi^2$ (1, *N* = 438) = 15.51, p < .001), with those crossing in the morning being more likely to look than those crossing during the afternoon.

Another descriptive variable of interest is clothing type. A significant difference was found in that those dressed in business clothing were more likely to cross non-compliantly in relation to location (e.g. not at the crossing) than those dressed in casual clothing ($\chi^2$ (1, *N* = 315) = 11.07, p = .001). However, those dressed in business clothing were not significantly more likely to cross non-compliantly in relation to timing ($\chi^2$ (1, *N* = 296) = 1.35, p = .25). This provides a mixed result if you were try to infer whether people in business attire were in more of a hurry.

### 8.2.2 Conflict

An incident table of potential conflicts observed is provided below (Table 19). In total, 12 potential conflicts were observed, with another four people crossing just outside of the three second threshold. All other crossings were completed either when no vehicle was present or while vehicles were already stationary at the lights.

All potential conflict crossings were temporally non-compliant, indicating that such non-compliance placed pedestrians at a higher risk of conflict than those who were compliant. As expected, pedestrians who were temporally non-compliant were significantly more likely to have potential conflict than those who were compliant (p < .001). No significant differences in potential conflicts were found between those who were spatially compliant versus non-compliant, however (p = .62).

The majority of these pedestrians crossed in groups indicating that poor group behaviour can have negative safety implications for pedestrians. Potentially unsafe trends in looking behaviour are also unveiled in the table, with all pedestrians failing to look while crossing, and one additionally failing to look prior to entering the roadway.

**Table 19: Incident table of observed potential conflicts[10]**

| | Time | Age | Gender | Clothing | Headwear | Activity | No. when arrive | Wait time | No. crossing | Prior look | During look | Speed | Spatial comp. | Temp. comp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low potential conflict (over three seconds from vehicle) | | | | | | | | | | | | | | |
| Case 1 | PM | Mid | Female | Casual | None | None | Alone | 0 | Alone | Full | None | Walk | Comp. | Non |
| Case 2 | PM | Mid | Female | Casual | Present | None | Alone | 0 | Group | Full | None | Walk | Comp. | Non |
| Case 3 | PM | Mid | Male | Casual | None | None | Group | 0 | Group | Partial | None | Walk | Comp. | Non |
| Case 4 | PM | Mid | Female | Casual | None | None | Group | 0 | Group | Partial | None | Walk | Comp. | Non |
| Medium potential conflict (within three seconds from vehicle) | | | | | | | | | | | | | | |
| Case 5 | AM | Youth | Female | - | - | None | Alone | 11 | Alone | - | None | Walk | Comp. | Non |
| Case 6 | PM | - | Male | - | - | None | Alone | 0 | Group | Partial | None | Walk | Comp. | Non |
| Case 7 | PM | - | Female | - | - | None | Alone | 0 | Group | Partial | None | Walk | Comp. | Non |
| Case 8 | PM | - | - | - | - | None | - | - | Group | - | None | Walk | Comp. | Non |
| Case 9 | PM | - | - | - | - | None | - | - | Group | - | None | Walk | Comp. | Non |
| Case 10 | PM | Mid | Male | Work | None | None | Alone | 0 | Alone | Partial | None | Walk | Comp. | - |
| Case 11 | PM | Mid | Female | Casual | None | Phys. | Alone | 20 | Group | - | None | Walk | Comp. | Non |
| Case 12 | PM | Mid | Male | Casual | None | None | Group | 2 | Group | Partial | None | Walk | Comp. | Non |
| Case 13 | PM | Mid | Male | Work | None | None | Group | 0 | Group | None | None | Walk | Comp. | Non |
| High potential conflict (with two seconds from vehicle) | | | | | | | | | | | | | | |
| Case 14 | PM | - | - | - | - | None | - | - | Group | - | None | Walk | Comp. | Non |
| Case 15 | PM | - | - | - | - | Phys. | - | - | Group | - | None | Walk | Comp. | Non |
| Case 16 | PM | Mid | Male | Casual | None | None | - | 0 | Group | - | None | Walk | Comp. | Non |

[10] Where cells are empty this characteristic was not discernible from the footage.

# 9 Site 2: Manners Street

## 9.1 Site description

A camera was mounted on a lamppost on Manners Street where traffic previously was one way. Markers to remind pedestrians to look right before crossing into the new bus lane in the opposite direction are on the footpath (see Figure 7), however, this site has been identified as a problem site for pedestrian behaviour. Looking behaviour when crossing into this new lane was of most interest at this site, and as such the camera was placed to provide the best view possible of this behaviour. A screenshot of the view from this camera is provided in Figure 7.

The traffic on Manners Street is bus only. Visibility prior to crossing in the section selected is relatively high, with average gaps of about 4.37m between the vertical roadside furniture.

Pedestrians were observed at this site between 7.30am and 1pm, yielding a total sample of 315 pedestrians. Both busy times and quiet times were captured in this period.

**Figure 7: Screenshot of camera view at Manners Street site**

## 9.2 Findings

Analyses were undertaken to explore variation in behaviour based on approach angle prior to crossing, more specifically this included either a straight on approach (transverse approach) or an approach from the left or right (parallel approach) to the road. In total, 126 pedestrians crossed towards the camera during the observation period. A breakdown of the direction to the kerb these pedestrians travelled at is provided in Table 21.

**Table 20: Approach direction prior to crossing**

| | Frequency |
|---|---|
| Travelling from left* | 25 (19.8%) |
| Travelling from right* | 15 (11.9%) |
| Travelling from straight on | 86 (68.3%) |
| Total | 126 (100.0%) |

* These categories were combined for the analyses due to low expected cell frequencies

### 9.2.1 Approach direction findings

- Those crossing from the left or right were significantly more likely to display passive prior looking behaviour, where as those who approached the kerb straight on were significantly more likely to look fully prior to crossing ( 2 (2, N = 114) = 46.36, $p < .001$)[11]. No differences in partial prior looking behaviour were evident between the two groups (see Table 21).

- Those approaching from the left or right first looked right at a significantly shorter distance to the kerb (mean = 1.6m) than those crossing from straight on (mean = 5.8m) ($t$ (52.9) = -8.68, $p < .001$).

- Pedestrians travelling from straight on also looked right at a significantly higher rate (mean = 1.5) than those travelling from either the left or right (mean = 1.0) ($t$ (43.1) = -3.52, $p = .001$). However, there was no difference in the frequency these pedestrians looked left.

- Those approaching from the left or right had significantly shorter wait times (mean = 0.08 seconds) than those crossing from straight on (mean = 0.81 seconds) ($t$ (100.9) = -2.77, $p < .01$).

**Table 21: Prior looking behaviour by direction to kerb**

| | Approached kerb from left or right | Approached kerb straight on |
|---|---|---|
| Partial look | 5 (16.1%) | 14 (16.9%) |
| Full look | 8 (25.8%) | **66 (79.5%)** |
| Passive full look* | **12 (38.7%)** | 3 (3.6%) |
| Passive partial look* | **5 (19.4%)** | 0 (0.0%) |
| Total | 31 (100.0%) | 83 (100.0%) |

* These categories were combined due to low expected cell frequencies

[11] It should be noted that, due to the angle of the camera, observation of prior looking behaviour for those travelling to the kerb from the left or right may have been obscured in some cases.

The following factors did not differ by approach direction:

- Looking behaviour during crossing (p = .46).
- Tempo to kerb prior to crossing (p = .82). In other words, neither group slowed down, stopped or continued at a regular walking rhythm at a higher rate than the other based on approach.

# 10 Site 3: Willis Street

## 10.1 Site description

A camera was mounted on a tree along Willis Street. A screenshot of the view from this camera is provided in Figure 8. As can be seen, this site was divided into two zones for observational purposes.

The zones provide a natural variation within the site, as Zone 2 has a greater level of roadside furniture (park benches and trees). This furniture may reduce detection of pedestrians and vehicles (although the widths of the vertical infrastructure are typically smaller, with trees that are only 6-7cm wide), and may also reduce travel within this zone compared with Zone 1. Zone 1 is approximately 12.75m wide (and 94% of this horizontal space is open), whereas Zone 2 is approximately 12.7m wide (and 50% of this horizontal space is open). All crossings completed beyond Zone 2 were not recorded in the data set (due to reduced visibility for the observer).

Traffic on Willis Street heading South is bus-only (see left lane in Figure 8) and traffic on Willis Street heading North (see middle and right lanes) is a mix of vehicle types. North-bound traffic is higher in frequency than South-bound, so there is also interest in any expectation effect, such that pedestrians may be more focussed on the North-bound traffic.

Pedestrians were observed at this site in the morning between 7.30am and 9am and in the afternoon between 3pm and 4pm. This yielded a total sample of 299 pedestrian crossings and covered both busy and quieter times.


**Figure 8: Screenshot of camera view at Willis Street site**

## 10.2 Findings

### 10.2.1 Presence of furniture and desire lines

Comparison of zone use was examined to determine how the presence of furniture can be used to filter walking traffic to other locations (i.e. influence desire lines). Table 22 shows that overall Zone 2 was only used by about 20% of pedestrians. Therefore, the majority of pedestrians (about 4 in 5) will select a crossing location that is relatively clear of infrastructure.

**Table 22: Incident Frequency of crossings within Zones 1 and 2 from both sides of Willis Street**

| | Crossing towards camera | Crossing away from camera | Overall |
|---|---|---|---|
| Zone 1 | 145 (83.3%) | 93 (74.4%) | 238 (79.6%) |
| Zone 2 | 29 (16.7%) | 32 (25.6%) | 61 (20.4%) |
| Total | 174 (100.0%) | 125 (100.0%) | 299 (100.0%) |

Note: Pedestrians using Bond Street were not included in these crossings as they did not have the same level of opportunity to use either crossing point.

### 10.2.2 Presence of furniture on safe crossing behaviour

The evidence suggests that pedestrians that chose to cross at the high infrastructure location of Zone 2 were typically less safe prior to crossing:

- Prior to crossing passive full looking behaviour is higher and full looking behaviour is reduced ($\chi^2$ (1, *N* = 70) = 4.21, p < .05; see Table 23)

- Average frequency of looking left was lower (Zone 2 M = 0.9 looks; Zone 1 M = 1.4 looks)

- Average frequency of looking right was lower (Zone 2 M = 0.8 looks; Zone 1 M = 1.6 looks), and the distance from kerb when they first looked right was shorter (Zone 2 M = 0.7m; Zone 1 M = 1.2m)

- Average wait times prior to crossing were shorter (M = 0.5 seconds) compared with the low infrastructure zone (M = 1.8 seconds)

In contrast, looking behaviour during crossing for the Zone 2 pedestrians was better for vehicle detection, with a greater likelihood of looking in both directions than those in Zone 1 ($\chi^2$ (1, *N* = 75) = 5.45, p < .05). Potential conflict did not vary between zones.

**Table 23: Crossing characteristic by zone**

| Characteristic | Zone 1 | Zone 2 |
|---|---|---|
| *Looking behaviour prior to crossing* | | |
| Partial look | 2 (3.5%) | 2 (8.3%) |
| Full look* | 26 (45.6%) | 4 (16.7%) |
| Passive full look* | 26 (45.6%) | **14 (58.3%)** |
| Passive partial look | 3 (5.3%) | 4 (16.7%) |
| Total | 60 (100.0%) | 24 (100.0%) |
| *Looking behaviour during crossing* | | |
| No look | 5 (8.5%) | 1 (4.5%) |
| Partial look* | 29 (49.2%) | 5 (22.7%) |
| Full look* | 25 (42.4%) | **16 (72.7%)** |
| Total | 59 (100.0%) | 22 (100.0%) |
| Average looks left prior to crossing | 1.4 | 0.9 |
| Average looks right prior to crossing | 1.6 | 0.8 |
| Distance from kerb when first looked right | 1.2m | 0.7m |
| Average wait time | 1.8s | 0.5s |

* These categories were included in the chi square analysis. Other categories had to be excluded due to low expected cell sizes.

# 11 Site 4: Lambton Quay

## 11.1 Site description

A camera was mounted on a lamppost along Lambton Quay. A screenshot of the view from this camera is provided in Figure 9. This site was divided into three zones for observational purposes. All crossings completed beyond Zone 3 were not recorded in the dataset due to poor visibility for the observer. Crossings completed within the first two zones were recorded as midblock, whereas crossings completed within Zone 3 were deemed close enough to the designated crossing to constitute a spatially non-compliant lights crossing. Temporal compliance was therefore recorded for pedestrians crossing within Zone 3.

Traffic on Lambton Quay is a mix of buses and private vehicles. As can be seen in the figure below, visibility is impeded for pedestrians crossing from the left within Zone 2. Within Zone 1 there is also some visibility impairment on the median strip. Stationary buses at the stop on the right hand side also create a visibility issue for pedestrians crossing from this side within all three zones (depending on the number of buses present).

Pedestrians were observed at this site in the morning between 8am and 8.30am and 10am and 10.30am. Parked trucks and vans obscured the camera's view between 8.30am and 10am. The afternoon observation period was between 4pm and 4.30pm. In total, these hours of observation yielded a sample of 304 pedestrian crossings.


**Figure 9: Screenshot of camera view at Lambton Quay site**

## 11.2 Findings

### 11.2.1 Pedestrian refuge findings

Analyses were undertaken to explore the influence of a pedestrian refuge (or median) on risk-related behaviour. As displayed in Table 24, the majority of crossings observed at the Lambton Quay site were completed with Zone 1, where there was a wider, raised median (or pedestrian refuge).

**Table 24: Frequency of crossings by Zone**

| **Refuge type** | **Crossing towards camera** | **Crossing away from camera** | **Overall** |
|---|---|---|---|
| Zone 1 – Raised refuge | 38 (55.9%) | 188 (79.7%) | 226 (74.3%) |
| Zone 2 – Wide painted refuge | 19 (27.9%) | 33 (14.0%) | 52 (17.1%) |
| Zone 3 – Narrow painted refuge | 11 (16.2%) | 15 (6.3%) | 26 (8.6%) |
| Total | 68 (100.0%) | 236 (100.0%) | 304 (100.0%) |

The evidence suggests that people altered their behaviour depending on the zone used for crossing (and therefore the median available to them):

- Pedestrians crossing within Zone 1 were more likely to use this larger median for partial crossings ($\chi^2$ (1, $N$ = 197) = 5.29, $p < .05$) than those crossing in Zone 2[12]
- Pedestrians crossing in Zone 1 were more likely to only look partially prior to crossing, where as those crossing in Zones 2 and 3 were more likely to display passive full looking behaviour ($\chi^2$ (2, $N$ = 216) = 14.76, $p = .001$)
- Those crossing in Zone 1 looked right prior to crossing at a higher frequency on average than those crossing in Zone 2 ($F$(2, 223) = 4.19, $p < .05$; see Table 25)
- Those crossing in Zone 1 first looked right at a significantly longer distance to the kerb than those crossing in Zone 3 ($F$(2, 199) = 3.27, $p < .05$; see Table 25)
- Those crossing in Zone 1 were more likely to look fully during crossing, where as those crossing in Zones 2 and 3 were more likely to partially look ($\chi^2$ (2, $N$ = 298) = 20.94, $p < .001$; see Table 26)
- The mean wait time for those crossing in Zone 1 was 1.4 seconds, compared to 0.2 seconds for those in Zone 2 and 0.9 seconds for those in Zone 3. However, these differences were not statistically significant.

Overall, these findings suggest that a pedestrian's ability to engage safely in two partial crossings, with full looking increases as a consequence of having a raised, wide median (compared with a painted median, where the perceived safety of waiting during a partial crossing is likely to be lower).

**Table 25: Mean, minimum and maximum prior looking behaviours by Zone**

[12] Zone 3 had to be excluded from this analysis due to small expected cell frequencies.

| Zone | N | Mean | Minimum | Maximum | SD |
|---|---|---|---|---|---|
| *Frequency looked left* | | | | | |
| Zone 1 | 155 | 0.4 | 0 | 3 | .64 |
| Zone 2 | 28 | 0.5 | 0 | 3 | .75 |
| Zone 3 | 15 | 0.6 | 0 | 2 | .63 |
| *Frequency looked right* | | | | | |
| Zone 1 | 165 | 1.4 | 0 | 5 | .81 |
| Zone 2 | 37 | 0.9 | 0 | 3 | .60 |
| Zone 3 | 24 | 1.1 | 0 | 2 | .45 |
| *Distance first looked right (m)* | | | | | |
| Zone 1 | 151 | 1.6 | 0 | 4 | 1.34 |
| Zone 2 | 30 | 1.5 | 0 | 4 | 1.17 |
| Zone 3 | 21 | 0.9 | 0 | 3 | 0.73 |

**Table 26: Looking behaviour during crossing by Zone**

| | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|
| No look | 2 (0.9%) | - | - |
| Partial look* | 89 (40.1%) | 36 (69.2%) | 19 (73.1%) |
| Full look* | 131 (59.0%) | 16 (30.8%) | 7 (26.9%) |
| Total | 222 (100.0%) | 52 (100.0%) | 26 (100.0%) |

* These categories were included in the chi square analysis. Other categories had to be excluded due to low expected cell sizes.

### 11.2.2 Bus stop findings

The Lambton Quay site was compared to the other sites to examine the effect of a bus stop on pedestrian safety behaviours.

Analysis showed that pedestrians entering the road from behind stationary buses was significantly more common at the Lambton Quay site compared to the other three sites ($\chi^2$ (3, N = 1379) = 83.83, $p < .001$; see Table 27). In contrast, pedestrians at the Manners Street and Mercer Street sites were significantly more likely to enter where the road was clear.

**Table 27: Road entry characteristics by site**

| | Mercer St | Manners St | Willis St | Lambton Q |
|---|---|---|---|---|
| Side of road clear | 466 (99.6%) | 311 (98.7%) | 288 (96.3%) | 266 (87.5%) |
| Stepped out between buses | - | 2 (0.6%) | - | 2 (0.7%) |
| Stepped out between cars | 2 (0.4%) | - | - | - |
| Stepped out behind bus | - | 2 (0.6%) | 11 (3.7%) | **35 (11.5%)** |
| Stepped out behind van | - | - | - | 1 (0.3%) |
| Total | 468 (100.0%) | 315 (100.0%) | 299 (100.0%) | 304 (100.0%) |

Differences between pedestrians who entered the road from behind stationary buses versus from clear road at the Lambton Quay site were explored. Key findings include:

- Pedestrians who stepped out behind buses were significantly more likely to be females ($\chi^2$ (1, *N* = 301) = 5.59, p < .05).Analysis showed there were not significantly more females at this site compared to the other three; therefore the finding cannot be explained by a higher rate of females at this site.

- Pedestrians crossing from a bus-free section of the road were more likely to passively look prior to crossing, where as those crossing from behind buses were more likely to look fully ($\chi^2$ (2, *N* = 213) = 6.38, p < .05). No differences in partial looking between these two groups were evident.

- It is important to note that while pedestrians crossing from behind buses may have moved their heads to look in both directions, their view of oncoming traffic may have been blocked by the bus. It was observed that these pedestrians frequently leaned out past stationary buses to look for oncoming traffic, indicating their view prior to crossing was obscured. As expected, these pedestrians were significantly more likely to look fully during crossing (e.g. once past the bus) than those crossing from clear road ($\chi^2$ (1, *N* = 287) = 27.47, p < .001).

- There were no significant differences in wait times between those who entered the road from behind buses versus from clear road (p = .08).

- No significant differences in potential conflicts were found between these two groups (p = .17).

### 11.2.3 Furniture presence analysis

Analyses were undertaken to explore the behavioural effects of the presence of wide vertical furniture on risk behaviours. Those crossing within Zones 2 and 3 from either side of the road were compared (as shown in Figure 9, furniture is present on the left side of the road and no furniture is present on the right side of the road) on key safety behaviours (e.g. wait times, stopping and looking behaviour and potential conflicts).

The evidence shows that pedestrians crossing from the left side (with furniture present) did not increase their safety behaviours:

- No differences in prior looking behaviour ($\chi^2$ (2, *N* = 53) = 5.55, p = .062) or looking behaviour during crossing ($\chi^2$ (1, *N* = 78) = 2.11, p = .15) were found for pedestrians crossing from either side of the road.

- Those crossing from the left versus right also looked left and right at equivalent rates and first looked right at equivalent distances from the kerb.

- No differences in tempo to kerb were evident between the two groups ($\chi^2$ (1, *N* = 73) = .08, p = .78; e.g. no group stopped, slowed down or continued at a regular walking rhythm at a higher rate than the other).

- Wait time was significantly shorter for those crossing from the left side (mean = 0 seconds) compared to the right (mean = 0.80 seconds; *t* (44.0) = -2.7, p < .01).

However, there were no differences in potential conflicts between the two groups ($\chi^2$ (1, *N* = 78) = .77, p = .38).

# 12 Comparison between sites

## 12.1 CAS analysis

Based on the CAS analysis, the section of road where Pedestrian Risk is relatively low is Site 4, Pedestrian Risk is medium at Sites 1 and 3 and high at Site 2 (see Table 28).

**Table 28: Crash frequency, density and vehicle and pedestrian crash risk by relevant street segment (Source: GHD companion report)**

| Risk measure | Mercer St | Manners St | Willis St | Lambton Quay |
|---|---|---|---|---|
| *Crash frequency (2006-2011)* | | | | |
| Fatal | 1 | 0 | 1 | 1 |
| Serious | 0 | 7 | 0 | 5 |
| Minor | 6 | 4 | 6 | 11 |
| Non-injury | 0 | 0 | 0 | 1 |
| Overall | 7 | 11 | 7 | 18 |
| *Crash exposure* | | | | |
| Crash density (crash/km/year) | 8.24 | 7.27 | 8.24 | 2.5 |
| Vehicle risk (crash/vehicle trip) | 72.36 | 342.52 | 72.36 | 68.75 |
| Pedestrian risk (crash/pedestrian trip) | 19.84 | 44.46 | 19.84 | 12.2 |

## 12.2 Site measurements

All sites are located in a 30kph speed zone. Characteristics that do vary by site are number of traffic lanes, road width, footpath width, and roadside infrastructure. Roadside infrastructure is of particular interest as it could influence:

- Footpath flow (and possibly impatience)
- Crossing point selection (possible ability to alter pedestrian desire lines)
- Sight distance
- Ability to detect vehicles and be detected by vehicles

The gaps, widths and distances from the kerb for all vertical roadside objects are outlined in Table 29. The purpose of collecting this information relates to the impeded view of drivers and pedestrians to detect each other due to objects such as trees, poles and phone booths. Objects over 1.4m tall were included, as these were most likely to cause visual barriers based on the height and eye height of adult New Zealanders (see Appendix A for more information).

**Table 29: Vertical roadside infrastructure measurements**

| Vertical roadside infrastructure | Descriptive | Distance from kerb (cm) | Width (cm) | Gap (m) |
|---|---|---|---|---|
| Manners (Site 2) | Mean | 82.08 | 21.36 | 4.37 |
| (N = 12) | Median | 83.50 | 22.00 | 5.55 |
| | SD | 12.06 | 8.78 | 1.91 |
| Willis (Site 3) | Mean | 110.29 | 21.75 | 4.59 |
| (N = 17) | Median | 97.00 | 18.00 | 4.10 |
| | SD | 35.45 | 23.11 | 2.11 |
| Lambton Quay (Site 4) | Mean | 58.14 | 20.33 | 5.40 |
| (N = 7) | Median | 58.00 | 20.00 | 5.70 |
| | SD | 14.39 | 5.51 | 2.51 |
| Overall | Mean | 90.75 | 21.47 | 4.66 |
| (N = 36) | Median | 90.75 | 21.47 | 4.66 |
| | SD | 91.14 | 21.07 | 4.64 |

Note: Sight distance details were not collected for Site 1 (looking behaviour was infrequent at this signalised crossing).

## 12.3 Colour contrast at the road threshold

Colour contrast at the road threshold at all four fixed sites (and for most of the Golden Mile) was reasonably high (see Figure 10), with the use of:

- Tactile surfaces at the signalised crossing
- Strong use of coloured pavers
- Bus lane colour
- Bold messages (signalling the need to look)


| Mercer: Site 1 | Manners: Site 2 | Willis: Site 3 | Lambton Quay: Site 4 |
|---|---|---|---|

**Figure 10: Colour contrast photos at the kerb-street threshold by site.**

## 12.4 Wait times between sites

A comparison of wait times between the four sites is provided in Table 30. The mean wait time was the longest at the Mercer Street/Willis Street signalised intersection site (Mean = 7.2 seconds), again attributable to the fact that this site was a lighted intersection. Crossings at the other sites were at non-signalised locations with shorter wait times (Mean = 2.0 seconds) ($t$ (531.1) = 7.57, $p < .001$).

**Table 30: Minimum, maximum and mean wait times in seconds between sites**

| | N | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|
| Mercer St | 412 | 0 | 64 | 7.2 | 12.96 |
| Manners St | 124 | 0 | 10 | 0.6 | 1.99 |
| Willis St | 183 | 0 | 59 | 4.1 | 8.82 |
| Lambton Quay | 253 | 0 | 24 | 1.2 | 3.24 |
| Overall | 972 | 0 | 64 | 4.20 | 9.84 |

## 12.5 Looking behaviour between sites

A comparison of looking behaviour prior to and during crossing between the four sites is provided in Table 31. As can be seen, looking behaviour was poorer at the Mercer Street/Willis Street intersection site than at the other three sites. The majority of crossings completed at this site were compliant crossings at lights and in groups, which provides an explanation for this observed trend.

**Table 31: Comparison of looking behaviour between sites**

| | Mercer St | Manners St | Willis St | Lambton Q |
|---|---|---|---|---|
| *Prior looking behaviour* | | | | |
| No look | 335 (85.0%) | 0 (0.0%) | 0 (0.0%) | 9 (3.7%) |
| Partial | 21 (5.3%) | 19 (16.7%) | 5 (2.9%) | 111 (45.3%) |
| Full | 38 (9.6%) | 74 (64.9%) | 117 (66.9%) | 57 (23.3%) |
| Passive full* | - | 15 (1.32%) | 44 (25.1%) | 48 (19.6%) |
| Passive partial* | - | 6 (5.3%) | 9 (5.1%) | 20 (8.2%) |
| Total | 394 (100.0%) | 114 (100.0%) | 175 (100.0%) | 245 (100.0%) |
| *During cross looking behaviour* | | | | |
| No look | 423 (96.6%) | 10 (9.6%) | 27 (9.4%) | 2 (0.7%) |
| Partial look | 6 (1.4%) | 55 (52.9%) | 133 (46.5%) | 144 (48.0%) |
| Full look | 9 (2.1%) | 39 (37.5%) | 126 (44.1%) | 154 (51.3%) |
| Total | 438 (100.0%) | 104 (100.0%) | 286 (100.0%) | 300 (100.0%) |

* These categories were added after Site 1 (Mercer St) data collection

Minimum, maximum and mean looking behaviours are reported in Table 32. These measures were not collected for Site 1; hence this site is omitted from the table.

**Table 32: Minimum, maximum and mean looking behaviour between sites**

| | N | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|
| *Distance in meters first look right* | | | | | |
| Manners St | 100 | 0 | 10 | 4.9 | 3.12 |
| Willis St | 86 | 0 | 8 | 2.2 | 1.49 |
| Lambton Quay | 202 | 0 | 4 | 1.5 | 1.28 |
| *Frequency look left* | | | | | |
| Manners St | 103 | 0 | 3 | 0.9 | 0.58 |
| Willis St | 154 | 0 | 7 | 1.8 | 1.30 |
| Lambton Quay | 198 | 0 | 3 | 0.4 | 0.66 |
| *Frequency look right* | | | | | |
| Manners St | 107 | 0 | 3 | 1.4 | 0.65 |
| Willis St | 113 | 0 | 8 | 2.1 | 1.30 |
| Lambton Quay | 226 | 0 | 5 | 1.3 | 0.76 |

## 12.6 Signalised versus non-signalised crossing comparisons

Pedestrians at signalised crossings were significantly less likely to look prior to crossing compared to those at non-signalised crossings, who were more likely to look either partially or fully ($\chi^2$ (2, $N$ = 786) = 546.44, p < .001; see Table 33). In line with this trend, those at signalised crossings were significantly less likely to look during crossing, whereas those at non-signalised crossings were more likely to partially and fully look ($\chi^2$ (2, $N$ = 1128) = 916.00, p < .001).

**Table 33: Looking behaviour prior to and during crossing by crossing type**

| | Signalised crossings | Non-signalised crossings | Total |
|---|---|---|---|
| *Prior looking behaviour* | | | |
| No look | 335 (85.0%) | 9 (1.7%) | 344 (37.1%) |
| Partial look | 21 (5.3%) | 135 (25.3%) | 156 (16.8%) |
| Full look | 38 (9.6%) | 248 (46.4%) | 286 (30.8%) |
| Passive full look* | - | 107 (20.0%) | 107 (11.5%) |
| Passive partial look* | - | 35 (6.6%) | 35 (3.8%) |
| Total | 394 (100.0%) | 534 (100.0%) | 928 (100.0%) |
| *During crossing looking behaviour* | | | |
| No look | 423 (96.6%) | 39 (5.7%) | 462 (41.0%) |
| Partial look | 6 (1.4%) | 332 (48.1%) | 338 (30.0%) |
| Full look | 9 (2.0%) | 319 (46.2%) | 328 (29.1%) |
| Total | 438 (100.0%) | 690 (100.0%) | 1128 (100.0%) |

* These categories were not collected at Site 1.

Other than looking behaviour, pedestrian behaviour at signalised crossings was typically aligned with lower risk behaviours:

- Pedestrian tempo to the kerb showed that those at signalised crossings were more likely to stop compared to those at non-signalised crossings who were more likely to slow down ($\chi^2$ (3, *N* = 977) = 54.12, p < .001).

- Those at signalised crossings were significantly more likely to walk during crossing, where as those at non-signalised crossings were more likely to either partially run or run the length of the road ($\chi^2$ (2, *N* = 1385) = 23.35, p < .001).

- Prior to crossing, those at signalised crossings were more likely to wait on the footpath compared to those at non-signalised cross points, who were more likely to wait on the road ($\chi^2$ (2, *N* = 1386) = 4.49, p < .05).

- Those at signalised crossings were significantly less likely to have potential conflicts with vehicles ($\chi^2$ (2, *N* = 1385) = 68.09, p < .001).

## 12.7 Potential conflicts

Significant differences in the likelihood of pedestrians being in potential conflicts were found between the four sites ($\chi^2$ (6, *N* = 1385) = 183.26, p < .001). Pedestrians at the Mercer St and Manners St sites were significantly less likely to be in potential conflict with a vehicle compared to the other sites. Pedestrians at the Willis Street and Lambton Quay sites, in contrast, were significantly more likely to experience low (4-7 seconds away) and medium risk (within 3 seconds) potential conflicts compared to these sites (see Table 34).

**Table 34: Potential conflicts by site**

| | **Mercer St** | **Manners St** | **Willis St** | **Lambton Quay** |
|---|---|---|---|---|
| No potential conflict* | 452 (96.6%) | 302 (95.6%) | 199 (66.8%) | 245 (80.6%) |
| Low potential conflict (3-7 seconds away)* | 4 (0.9%) | 9 (2.9%) | **78 (26.2%)** | **43 (14.1%)** |
| Medium potential conflict (within 3 seconds)* | 9 (1.9%) | 2 (0.6%) | **17 (5.7%)** | **12 (3.9%)** |
| High potential conflict (within 2 seconds) | 3 (0.6%) | 2 (0.6%) | 4 (1.3%) | 4 (1.3%) |
| Very high potential conflict (within 1 second) | - | - | - | - |
| Total | 468 (100.0%) | 315 (100.0%) | 298 (100.0%) | 304 (100.0%) |

* These categories were included in the analysis. The high potential conflict category had to be excluded due to low expected cell sizes.

## 12.8 Factors that relate to potential conflict

### 12.8.1 Looking behaviour

Pedestrians performed some form of looking prior to conflict 97% of the time, indicating that people were aware of the road and the change to vehicle priority, such that they were scanning for vehicles when they decided to cross ($\chi^2$ (1, *N* = 927) = 16.40, p < .001).

Previous accident findings suggest that some problem behaviour relates to not seeing the vehicle at all, such as looking left and stepping into the path of a vehicle coming from the right. Those that crossed at locations without pedestrian signals and engaged in a partial look (rather than actively looking in both directions as they crossed) were more likely to be in potential conflict ($\chi^2$ (2, *N* = 666) = 6.30, p < .05).

### 12.8.2 Waiting to cross while on road

Those pedestrians that waited to cross on the road instead of on the footpath were more likely to accept smaller gaps in traffic ($\chi^2$ (1, *N* = 1385) = 11.69, p < .01). This may imply they needed to enter the road as their view of other traffic may have been blocked, or this may be an indicator of impatience.

### 12.8.3 Speed prior and during crossing

The sample of people jogging prior to the crossing was too small (n = 15) to robustly state that there is a statistical relationship with potential conflict behaviour. About 7% of potential conflicts at mid-block locations occurred when pedestrians were jogging prior to crossing.

Pedestrians that increased their speed part way through crossing were also more likely to have potential conflicts ($\chi^2$ (1, *N* = 1353) = 100.99, p < .001). Further inspection reveals that pedestrians increase their crossing speed in 29.4% of potential conflict situations. This reveals that either the pedestrian has misjudged the speed or distance of the approaching vehicle or simply did not observe them prior to starting the crossing.

### 12.8.4 Signalised pedestrian crossings

Potential conflict only arose at signalised crossings when pedestrians were temporally non-compliant with the green pedestrian phase (p < .001). Not enough variation in timing was established to determine how conflict behaviour could be reduced. However, the literature suggests that shorter wait times and mid-block PUFFIN crossings are very effective at improving pedestrian compliance behaviour.

## 12.9 Factors that do not relate to potential conflict

There is no relationship between the following variables and potential conflict (as measured by the gap acceptance of pedestrians):

- Individual differences, such as age, gender and body type ($\chi^2$ (1, $N$ = 1341) = 1.65, p = .20; $\chi^2$ (1, $N$ = 1303) = .62, p = .43; $\chi^2$ (1, $N$ = 1332) = 1.08, p = .30 respectively). In fact, there is some evidence to suggest that there is behavioural compensation here, such that:
  - o Younger pedestrians may choose mid-block crossings more frequently
  - o Overweight pedestrians choose signalised intersections more frequently and are less likely to engage in activities that may impair their walking or perceptual performance (e.g. cell phone use, carrying loads or poor footwear)
- Eyesight and visually detecting vehicles. If you used age as a proxy of ability to detect vehicles then older pedestrians are no more likely be in conflict or attempt to adjust for any visual difficulty by increasing the frequency of their looking behaviour.
- Footwear type (from running shoe/flat soled shoe/ high heel) which implies walking stability and potentially crossing speed ($\chi^2$ (2, $N$ = 901) = 2.54, p = .28).
- Clothing, such that those in business attire may be in more of a hurry ($\chi^2$ (1, $N$ = 1256) = .37, p = .54).
- Perceptual impairment due to audio-visual activities or physical impairment due to physical load ($\chi^2$ (1, $N$ = 1385) = .001, p = .97).
- Time of day (morning peak compared with afternoon; $\chi^2$ (1, $N$ = 1385) = .11, p = .74).
- Group size (alone compared with crossing as a group; $\chi^2$ (1, $N$ = 1382) = .11, p = .74).
- Spatial path deviation at signalised crossings did not increase conflict (p = .62).
- Vehicle type (bus compared with car; $\chi^2$ (1, $N$ = 43) = .61, p = .43; see Table 35).

**Table 35: Potential conflict by vehicle type**

| | Medium potential conflict (with 3 seconds) | High potential conflict (within 2 seconds) |
|---|---|---|
| Bus | 16 (40.0%) | 7 (53.8%) |
| Car | 16 (40.0%) | 4 (30.8%) |
| Cyclist | 5 (12.5%) | 2 (15.4%) |
| Van | 2 (5.0%) | 0 (0.0%) |
| Truck | 1 (2.5%) | 0 (0.0%) |
| Total | 40 (100.0%) | 13 (100.0%) |

# 13 Discussion and Recommendations

Based on these findings and a brief examination of best practice intervention options we present the following recommendations for discussion with the steering group. The discussion points are focussed on solutions regarding:

1) Individual interventions
2) Vehicle interventions
3) Engineering interventions

## 13.1 Individual behaviour solutions

### 13.1.1 Safe crossings are typical

Across the four sites all 1386 crossings were completed without a crash, and only 3.8% (n = 53) of crossings had potential conflict, where a vehicle occupied the same space as the pedestrian within 2-3 seconds of that pedestrian leaving (following a definition of conflict provided by Cairney & Diamantopoulou, 1999).

The rate of potential conflicts increases from 3.8% to 6.6% (n = 92), when following a definition that also includes conflict avoidance behaviours (such as vehicles swerving or braking, pedestrian false starts, partially running, or partially crossing). This rate of potential conflict is still lower than other cities, such as Sydney, Australia, where the rate of potential conflict was 10% (Hatfield & Murphy, 2007).[13]

Looking right prior to crossing occurred on average 1.5 times per crossing (higher than left-looking behaviour), indicating that pedestrians are typically aware that the immediate risk of traffic is to their right.

Most people recognise a change in pedestrian priority, as seen by their looking behaviour. Poor looking behaviour, in the form of not looking at all during mid-block crossings, was only observed in 1.7% of crossings.

**Recommendation:**

- Emphasise the relationship between positive pedestrian behaviours and safety outcomes in social marketing campaigns.

### 13.1.2 Social marketing/educational interventions

Problematic attitudes towards crossing occur because pedestrians cross at greater potential risk but without injury on a frequent basis. An attitudinal campaign could focus on a paradigm shift to move the measure of success for crossing away from the perceived benefits of poor behaviour (e.g. saves time, prevents boredom and prevents inconvenience) and to a safety-focussed crossing.

[13] It is important to note that this comparison does not account for differences in exposure to conflict.

- Highlight positive normative behaviour. For example, that the majority of pedestrians do look before they cross.

- Promotion of specific positive behaviours:

  - Assertive or active looking strategies (over passive or lazy looking strategies)
  - Encouraging pedestrians to pause at kerbs
  - Encouraging pedestrians to cross in more open locations (as opposed to locations where there is visual or physical intrusion from roadside furniture)
  - Encouraging pedestrians to cross at designated crossing locations

**Recommendation:**

- Promote the benefit of more high-effort or active looking and waiting behaviour prior to crossing

#### 13.1.3 Individual consistency in higher risk pedestrian behaviour

While most crossings are completed safely, it is worth noting that there is evidence that some individuals are consistently engaging in low-effort behaviour prior to crossing, and consistently choosing to cross non-compliantly with regard to signalised crossings.

These behaviours may be difficult to alter, such that interventions may have to focus on vehicle or engineering interventions that either:
1) Make the environment more forgiving when pedestrians behave poorly (such as the use of vehicle speed or signal timing interventions); or
2) Take away current paths of least resistance (for example, the use of roadside infrastructure that alters desire lines).

### 13.2 Vehicle solutions

#### 13.2.1 Car vs bus and pedestrian behaviour

Vehicle type does not influence the likelihood that a pedestrian will enter a situation of high potential vehicle conflict. It could be that different elements are competing here, such that pedestrians perceive they have:

- An increased ability to detect larger vehicles (both visual and auditory detection, even though electric buses can be reasonably quiet).

- A perception that buses are slower than other vehicles.

These factors compete with:

- An increased understanding of the severity of a bus accident if the vehicle does hit them.

Stepping out from behind vehicles is more of an issue with buses as this does occur in about 12% of crossings where there is a bus stop, and means that pedestrians are crossing in a situation where they cannot view the road until they move their body beyond the bus. Research shows that when pedestrians enter the roadway between parked vehicles their risk level for conflict is greatly increased, as their field of vision is generally impeded, as is the oncoming driver's (Tom & Granie, 2001). This supports the findings of the crash analysis.

In addition to stepping out between buses, anecdotal evidence suggests that buses may even induce a stepping out effect, such that pedestrians may be more likely to cross immediately behind a bus. One rationale for this behaviour is related to a localised traffic search strategy, where pedestrian behaviour only relates to the vehicles in their immediate visual zone. If this is a real trend then pedestrians may have a reduced consideration for vehicles they are not aware of because they are blocked from view by the larger size of the bus. Consequently, pedestrians may be more likely to partially cross the road prior to considering the traffic beyond the immediate lane, or may assume there is a gap in the immediate vehicle lane, as their view of the next vehicle is blocked.

**Recommendation:**

- Bus drivers (as well as other drivers) could be trained to adopt a strategy of increasing the gap between them and any bus immediately ahead of them (such that they are more visible to pedestrians). However, social pressures from following (or "tailgating") drivers if a gap is provided (not to mention travel time pressures) typically means that this will be practically difficult to achieve.

- Education around less localised pedestrian search strategies could be used. However, it is important to note that this type of behaviour change can also be difficult to achieve.

#### 13.2.2 Vehicle speed countermeasures

Pedestrians appear to have trouble judging vehicle speed (as evidenced by many pedestrians increasing their speed part-way through crossing). Any vehicle speed countermeasure should therefore be focused not only on reducing speed, but also on encouraging less variation in vehicle speed. Typical speed countermeasures to consider with caution:

- Fixed speed cameras: Which may be most effective within 250m, potentially shifting speed problems to other locations

- Intelligent Speed Adaptation (ISA): ISA is effective at applying an area-wide speed solution. For example, placing ISA in buses will slow speeds, but unless it is applied within the entire vehicle fleet, could cause problems with pedestrians habituating to ISA-implemented vehicle speeds when they encounter a non-ISA vehicle in free-flow traffic.

**Recommendation:**

- Evaluate any vehicle speed countermeasures more closely in relation to overall speed consistency prior to adoption.

### 13.2.3 Innovative vehicle technology solutions

Potential vehicle technology solutions, particularly for larger mass vehicles such as buses, could include:

- Increased visibility solutions: Where more of the vehicle front has higher visibility (e.g. see Harris, 2011). The accident and observation data do not suggest there is a consistent "looked but did not see" or inattention blindness issue, however, these can be quite easily-adopted, cost-effective changes, so may be worth considering.
- Impact reduction solutions, with a technology focus on pedestrian safety. This includes innovations such as external airbag systems (e.g. see the Volvo V40 to see the first pedestrian airbag; http://autos.sympatico.ca/auto-news/13304/volvo-unveils-pedestrian-airbag). The technology here is still in development.

The GHD companion report makes additional suggestions regarding improved vehicle detection and the ability to reduce pedestrians stepping out from between buses.

**Recommendation:**

- Impact reduction solutions should be examined as technology improves in the longer term.
- In the interim, increased visibility solutions could be investigated further where they are cost-effective.

## 13.3 Engineering solutions

### 13.3.1 Self-explaining footpaths and consistent infrastructure

Infrastructure surrounding the pedestrian should naturally encourage the correct user behaviour, such that higher vehicle conflict sites should encourage pedestrians to look for drivers (and vice versa) more actively. The use of consistent design features can improve the visual and tactile environment for pedestrians.

**Recommendation:**

- Use of consistent infrastructure to signal different levels of crossing point and signal timings. For example, the signalised, mid-block crossing at Lambton Quay and Grey Street has the benefit of low wait times, but there is very little to distinguish this from crossings at major intersections (with much longer wait times).

- Give pedestrians consistent visual cues to help detect vehicle speed and distance. More specifically, placing consistent gaps between obvious vertical infrastructures (as is done in best practice highway design).
- Use of consistent kerb heights should reduce tripping hazards at kerb locations. Current heights can vary quite dramatically even from one side of the road to another. For example, bus stops and drainage areas can have higher kerb heights (at about 20cm high) compared with other locations (where the kerb is reasonably consistently 13cm high).
- Naturally filter pedestrians towards open locations that encourage active looking behaviour.

### 13.3.2 Perceptual threshold barriers

Visual barriers at the kerb threshold could be used to either heighten perceived risk at problem locations or intuitively signal a change in priority without causing the problems associated with physical barriers. However, at most sites the existing colour contrast was good and in most instances the looking behaviour of pedestrians suggests that they have detected the change in environment. The effectiveness of additional increments in perceptual interventions is relatively unknown.

Horizontal lines with high contrast (typically used at give way intersections for a driver) have a strong association with stopping behaviour, such that they have been found to reduce perceived pedestrian priority (Thomas and Tate, 2004). Therefore, even stronger colour contrast lines around the gutter would likely send a stronger signal to pedestrians that there has been a reduction in pedestrian priority, such that they should temporarily increase attention. This may have the added benefit of helping drivers maintain a low speed (as this may enhance the narrowness of the road).

**Recommendation:**

- Consider the use of stronger colour contrast lines around the kerb/gutter to send a stronger signal to pedestrians that there has been a reduction in pedestrian priority

### 13.3.3 Signalised crossings: Pedestrian trust, expectation and habit

There is evidence that pedestrians rely on their prior crossing experience to inform future decisions to cross. This is particularly evident at signalised crossings, where there is strong trust that the pedestrian light phase is safe, with only 15% of pedestrians looking for vehicles prior to crossing and 3.5% looking during crossing.

There is also an indication that some pedestrians rely on their prior knowledge of the signal phasing to time their crossing, with 7% of temporally non-compliant crossings occurring immediately prior to the green phase. Interventions aimed at improving knowledge of the pedestrian wait time has had mixed success. For example, the use of pedestrian countdown technology can increase the number of late starters, late finishes and overall temporal non-compliance (Wanty & Wilkie, 2010).

The only additional potential conflict crossings (that occurr just outside of the observation zone, so are only anecdotally noted) happen based on pedestrian reliance on a light phase change, and a driver running an orange light. Multiple errors are often required before there is conflict. The latent error in this system is that many pedestrians rely on drivers to comply explicitly with the signal timings, where they should still be actively looking for traffic.

Consequently, a change to the environment may not cause an appropriate change in pedestrian behaviour if pedestrians have low situation awareness and strong habitual behaviour. The fact that none of the pedestrian-vehicle accidents on the Golden Mile since 2006 involved tourists is minor evidence that the pedestrian issues are occurring in those that are familiar with the walking environment. Previous slips, trips and falls within the Wellington region also indicate that most accidents are by pedestrians who are highly experienced with the location, many of which are caused because they are simply not attentive to a change in their environment (e.g. elevation change or unexpected infrastructure damage; Thomas & Frith, 2004).

**Pedestrian wait time thresholds**

Maintaining low pedestrian wait times is another known technique for improving crossing compliance. Martin (2006) reviewed several studies on the effect of waiting times on pedestrian behaviour, including video observations conducted in Japan by Asaba & Saito (1998). This observational study suggests that pedestrian temporal non-compliance peaks at around 40-45 second wait times (Asaba & Saito, 1998). Pedestrians also reported to become impatient at 21-28 seconds waiting time, and that when they became impatient they would move to the front row of pedestrians and rely on gaps in the traffic to cross (Asaba & Saito, 1998).

**Recommendation:**

- Interventions aimed at better enforcement of red-light running by vehicles (such as the use of cameras) would be of benefit where these accident types are observed. Pedestrian trust in signals means that vehicle compliance with light timings is critical.
- Ensuring pedestrian wait times are below 40 seconds will reduce pedestrian crossings due to impatience (with best practice for pedestrian priority routes suggesting maximum waiting times of 30 seconds).
- Where late crossings are problematic these can be reduced by longer clearance times (i.e. a longer flashing red phase).

### 13.3.4 Desire lines: Altering problematic passive and partial looking behaviour

While pedestrians do look for traffic, their looking strategies are often low effort or even lazy. Only 46% of pedestrians engaged in full active looking, turning their heads in both directions immediately prior to crossing. Partial looking in one direction accounts for 25% of looking behaviour.

Passive looking behaviour occurred in about 27% of mid-block crossings, with 20% passive full looks (where pedestrians passively looked in the direction they were walking and actively turned their head to look in the opposite direction to check for traffic), and 7% passive partial crossings (where they did not make any effort to actively look).

Passive behaviour is much less likely when pedestrians' approach direction is straight on to the kerb (as opposed to walking in parallel to the road). Altering the desire lines of pedestrians to adopt a transverse rather than parallel approach, or even shifting them back from the kerb, so their parallel path changes to a transverse path immediately prior to their crossing could reduce passive looking behaviour.

The placement of roadside infrastructure does influence the desire lines of pedestrians. For example, low height roadside infrastructure (such as benches) encourage pedestrians to cross at more open locations, without impeding vision of those that do choose to cross between infrastructure. Similarly, using raised pedestrian refuges (islands) helps focus pedestrians to certain crossing points and can be utilised as appropriate, taking into account possible constraints, such as road width or heavy foot traffic.

**Recommendation:**

- Consider the use of roadside infrastructure that deters pedestrians walking in parallel to the road at the kerb. Currently furniture placement leaves a gap that averages about 88cm that could be seen as a pedestrian path. However, any use of roadside infrastructure that occasionally limits the width of this gap (and breaks up the pathway) could also cause some pedestrians to choose to step out onto the kerb or road, so any change would need to carefully consider this potential side effect.
- Placement of low, visible infrastructure or narrow vertical infrastructure within this path could be used to break up the kerbside pathways and move these pedestrians back from the kerb.

### 13.3.5 The use of clear zones around infrastructure

Clear zones have the benefit of high visibility. Another positive aspect of clear zones is that pedestrian behaviour prior to crossing at these locations appears to be safer, with more active looking strategies and greater likelihood of pausing prior to crossing. The use of permeable physical barriers, using wide, low infrastructure (such as park benches) can help filter foot traffic to the clear zone. GHD (2012) produced the following depiction of a clear zone (see Figure 11).

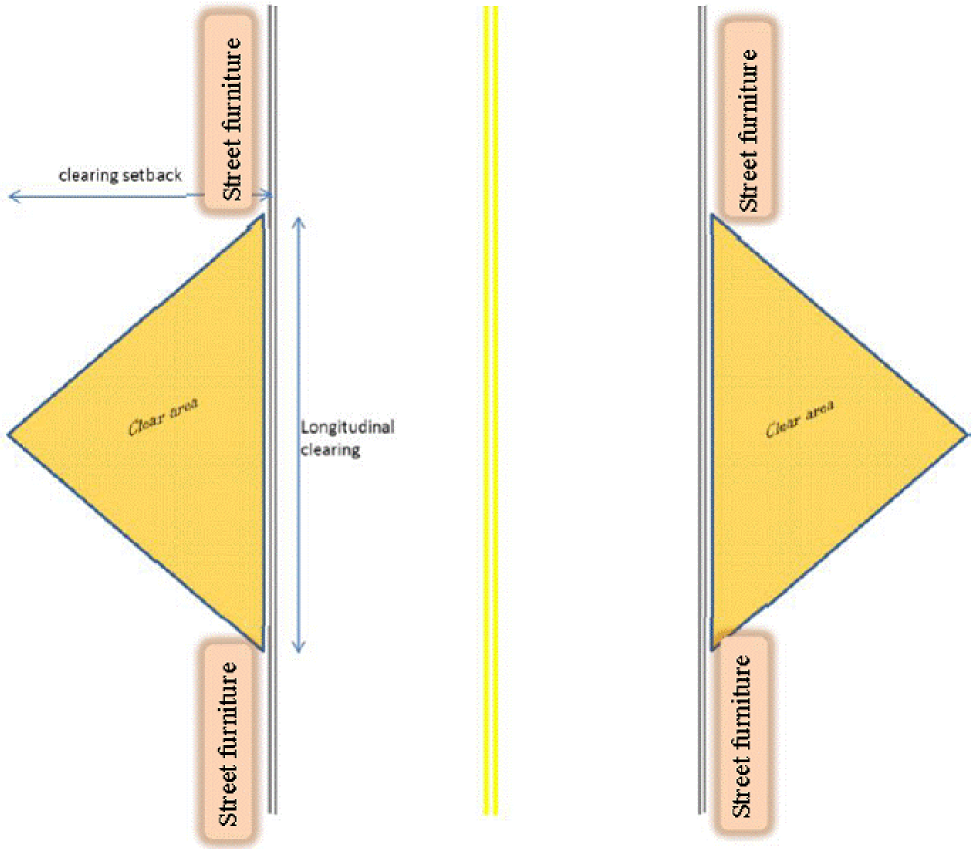


**Figure 11: Clear zone treatment (Source: GHD companion report)**

Safer behaviour occurs in the Willis Street Site in Zone 1, an area that is 94% clear of furniture (it contains one pole and one tree) and is approximately 12 meters in length. Therefore, the clear zone does not need to be completely free of infrastructure, nor does it need to be a particularly large area of clearance.

Infrastructure placement prior to the clear zone could signal a perceptual width change to give the appearance of increasingly wider footpath lines (and therefore narrower vehicle paths) around preferred crossing points fulfilling the dual purpose of:

- Encouraging pedestrians to approach the kerb at a more transverse angle; and
- Naturally reducing vehicle speeds at the crossing point.

**Recommendation:**

- Ensure any clear zones developed are mostly (about 95%) empty of infrastructure, and have reasonable gaps between any infrastructure present.
- Incorporate the use of high infrastructure zones surrounding the clear zone to filter pedestrians to these zones. Preferably with wide, low infrastructure that does not impair sight lines (particularly to the right).
- Trial any clear zone option with before and after analysis of behaviour prior to making systemic changes to the network.

### 13.3.6 High infrastructure zones surrounding clear zones

High infrastructure zones (such as Site 3, Zone 2) do filter foot traffic away from them, but this does raise the issue of the safety of the pedestrians that continue to use these zones.

Counter-intuitively, infrastructure that fills up 50% of the kerb-side space does not appear to have the benefit of heightening risk perception and encouraging safer behaviour prior to crossing. Other studies have found improved safety follows from sight restrictions, where reduced driver view has reduced speed and improved gap acceptance (i.e. accepting only larger gaps) behaviour at intersections (e.g. Charlton, 2003). Even at Site 4 (Zones 2 and 3) there are no differences in looking behaviour between an area clear of infrastructure compared with an area with wide vertical infrastructure that limits sight distances.

It is relatively unknown what level of space or vision restriction will induce a higher perceived level of risk. Space restriction is likely to be a more effective intervention than visual restriction here, as visual restriction has the additional implication that it may increase actual risk. Different spatial gaps between infrastructure, or even long sections with no gaps, could be trialled to see how these variations influence pedestrian behaviour.

**Recommendation**

- Trial variation in high roadside infrastructure zones (such as continuous, high infrastructure with no gaps and high infrastructure with small gaps) to see which leads to safer behaviour prior to crossing.

### 13.3.7 Workshop Engineering Recommendation

These findings (alongside the GHD companion report findings) were presented in two steering group workshops made up of road safety experts and stakeholders. Based on the recommendation of this steering group a pilot trial of the clear zone intervention was suggested for the first intervention phase.

The pilot involved a roadside infrastructure reversal around a clear zone, where the infrastructure immediately adjacent to an existing clear zone was shifted into the clear zone (making the immediately adjacent high infrastructure zone into a clear zone). Behaviours would be measured before and after the intervention, ensuring a method that would control for all other site characteristics and determine the effectiveness of the infrastructure solution in isolation.

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# 16 Appendices

**Appendix A: Infrastructure and street furniture height as a visual detection barrier**

Anthropometric data indicates that infrastructure over 1.4m could cause visual barriers for some pedestrians, making vehicle detection more difficult (see Table A). Likewise, infrastructure over 1.5m is likely to make it more difficult to detect pedestrians[14].

Table A. Anthropometric data showing the approximate height and eye height of New Zealanders by gender and age group. *Source: Wilson, Russell, Wilson (1993). Size and shape of New Zealanders.*

| Group | | | Height (cm) (Pedestrian detection) | Eye height (cm) (Vehicle detection) |
|---|---|---|---|---|
| Males | 19-45 years | | | |
| | | 5th | 1665 | 1560 |
| | | 50th | 1770 | 1660 |
| | | 95th | 1870 | 1760 |
| | 45-65 years | | | |
| | | 5th | 1650 | 1545 |
| | | 50th | 1745 | 1635 |
| | | 95th | 1840 | 1730 |
| Female | 19-45 years | | | |
| | | 5th | 1555 | 1450 |
| | | 50th | 1650 | 1550 |
| | | 95th | 1750 | 1650 |
| | 45-65 years | | | |
| | | 5th | **1525** | **1425** |
| | | 50th | 1630 | 1530 |
| | | 95th | 1765 | 1635 |

Note: 5th, 50th and 95th refers to the percentile height range for each group. The most visually disadvantaged group is highlighted in bold.

[14] This does not take into account the variability in height of the vehicle. For example, sedan style cars would be more difficult to detect (with vehicle heights between 1.4-1.5m), when compared with vehicles that are elevated in height, such as bus, van or truck drivers. Similarly, sedan drivers would have greater difficulty detecting pedestrians as their eye height is likely to be closer to 1.3m.

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