# Pedestrian Guard Railing: A Review of Criteria for Installation

by **P. Zheng** and **R.D.Hall**
(Transportation Research Group)

Contract No: 1505

This report has been produced by the Transportation Research Group (University of Southampton) for Transport for London. Any views expressed are not necessarily those of Transport for London.

# Pedestrian Guard Railing: A Review of Criteria for Installation

**FINAL REPORT**

to

**Transport for London**

Contract No: 1505

by **P. Zheng** and **R.D.Hall**

**Transportation Research Group**
**University of Southampton**

**October 2003**

Transportation Research Group
School of Civil Engineering and the Environment
University of Southampton, Highfield, Southampton, SO17 1BJ
Tel: 023 8059 2192 Fax: 023 8059 3152 email: mm7@soton.ac.uk
Web: www.trg.soton.ac.uk

# CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# EXECUTIVE SUMMARY

Pedestrian guard railing has been used throughout London at many types of location, as a road safety measure and for highway management purposes. However, guard railing can have an adverse effect on the convenience for pedestrians and the attractiveness of the street scene. The Mayor of London's Transport Strategy places emphasis on providing good facilities for pedestrians, eliminating street clutter and improving the street scene to make London one of the most walking friendly cities.

Transport for London commissioned this research to review how guard railing is used in London and to develop criteria for the installation of pedestrian guard railing that promotes road safety and pedestrian access. This report presents the findings of the research which investigated pedestrian movement characteristics and safety records at different types of site with and without railing in London.

A review of the existing national and London custom and practice in the installation of guard railing was carried out. Literature reviews revealed that there was no dedicated UK document defining the criteria for the installation of pedestrian guard railing. However some recommendations on the installation of guard railing are contained in some standards and guidance for the design of particular highway and pedestrian facilities, though decisions about installation of guard railing are mainly based on good engineering judgement (in conjunction with any available guidance).

A survey of pedestrian behaviour was carried out using video cameras at 37 sites in London - 19 sites with railing and 18 sites without. The selection covered a range of different types of sites including pelicans, zebras, refuges, signal junctions, priority junctions, roundabouts, busy streets, central reservations, transportation interchanges and schools. The survey at each site lasted for about 4 hours covering either the morning or evening peak hours. A pedestrian movement recording method was developed and used as part of this research. Vehicle speeds and counts were also made, and 85% vehicle speed and traffic flow were calculated to characterise the traffic conditions of the sites. Pedestrian conflicts were also observed and analysed from the video recordings, using an operational definition of a conflict developed for this research. The main objective of the behaviour survey was to obtain information on pedestrian movement characteristics in the presence of and lack of guard railing under varying traffic and pedestrian flow situations. The main objective of the conflict analysis was to obtain information on the safety implications as a result of the pedestrian behaviour adopted in the presence or absence of guard railing.

Accident records for the three years 2000-2002 were obtained and analysed for all sites surveyed. For each type of site comparisons were made of the average number of accidents per year at sites with and without railing. All accidents including pedestrian accidents within a section of about 50 metres centred on the main pedestrian crossing place were counted and used as safety indices of sites.

The effect of guard railing was analysed using behaviour effectiveness and safety effectiveness indices. For the behaviour effect of guard railing, indices needed to be defined according to the type of site. These included the Utilisation Rate, Correct Use Rate and Formal Use Rate for pedestrian crossing and junction sites; Activity Rate for central reservation and link sites; Directly Crossing Rate for transportation interchange and school sites. These indices were constructed to take account of the intended purposes of the guard railing at each type of site. The safety effect of guard railing was indicated by pedestrian conflict rate, accident rate and pedestrian accident rate for all types of site.

Data for all the sites combined indicated that (Para. 5.3, 5.4):

- Traffic speed, traffic flow and pedestrian flow did not differ significantly between sites surveyed with and without guard railing.
- Conflicts at sites without railing were 1.2 times that at sites with railing, though the difference is not statistically significant.
- The all accidents rate at sites without railing was almost the same as that at sites with railing, the difference being not statistically significant.
- The pedestrian accident rate at sites without railing was 2.5 times that at sites with railing, and the difference is statistically significant.

Of all the sites with and without guard railing (Para. 5.4):

- Pedestrian crossings and junction sites have a higher than average rate of conflicts, accidents and pedestrian accidents.
- Transportation interchange and school sites have a lower than average rate of conflicts, accidents and pedestrian accidents.
- Central reservation sites have a higher than average rate of accidents but a lower than average rate of pedestrian conflicts and pedestrian accidents.
- Link sites have a higher than average rate of conflicts but a lower than average rate of accidents and pedestrian accidents.

Site type specific analysis indicated that the effectiveness of guard railing is likely to be different at different types of sites (Para. 5.5):

- For the pedestrian crossing sites, an average of 88.8 percent of pedestrians were found to cross within the designated crossing area at sites with railing, compared with 73.5 percent at sites without railing, the difference being statistically significant. The accident total and pedestrian accidents were fewer at sites with railing, while pedestrian conflicts were fewer at sites without railing, but the difference is not statistically significant.
- For the junction sites, an average of 86.9 percent of pedestrians were found to cross within the designated crossing area at sites with railing, compared with 79.8 percent at sites without railing, and the difference was statistically significant. Pedestrian conflicts and pedestrian accidents were fewer at sites with railing, while accidents were much the same at sites with and without railing, the differences being not statistically significant.
- For the link and central reservation sites combined, an average of 19 pedestrian activities per hour was observed compared with 109 per hour at sites without railing. Pedestrian conflicts and pedestrian accidents were fewer at sites with railing, while accidents were higher, though the differences were not statistically significant.
- For the transportation interchange and school sites combined, none of the pedestrians were found to cross directly at the entrance/exit at sites with railing compared with an average of 1.4 percent at sites without railing. Pedestrian conflicts, accidents and pedestrian accidents were fewer at school sites with railing than without. Accidents were fewer at the transportation interchange sites with railing, while pedestrian conflicts and pedestrian accidents were higher.

The results of the analysis show that the likely purpose for the erection of the guard railing had generally been achieved, i.e. increase the formal use rate at pedestrian crossing and junction sites, reduce the activity rate at link and central reservation sites, and reduce pedestrian accident rates. However, it was also found that the differences in most of the effectiveness indices between sites with and without guard railing were not statistically significant, and at some types of site, a higher rate of accidents and pedestrian conflicts were found at sites with guard railing. A decrease in pedestrian accidents by the introduction of guard railing could be counterbalanced by an increase in accidents at some types of sites.

In light of the above results, guidelines for the erection/removal of guard railing were developed. It is recommended that two warrants, the behaviour effectiveness warrant and the safety effectiveness warrant, be used in considering the erection of new guard rails or removal of existing guard rails. The general philosophy is that the erection of new guard rails should not be considered if alternative safety measures could be used. Guard railing should only be considered when the expected effectiveness is significant, and unnecessary guard rails should be removed. Both general and site specific guidelines will be made available as a separate document.

# 1 INTRODUCTION

Pedestrian guard railing has been erected throughout London at many different types of location including:

- along the kerb-line of high-density shopping streets
- at the entrances and/or exists to transport interchanges
- at road intersections
- at pedestrian crossings.

Guard railing has also been introduced at a number of sites as a way of keeping vehicles off the footway and to discourage parking where there was evidence of pedestrians being masked by parked cars.

Generally, there are two types of barriers that offer protection to road users. One is a crash barrier that is used to retain and redirect vehicles upon impact, and the other is pedestrian guard railing to separate pedestrians from vehicle traffic. In some situations, guard railing can create an unpleasant constrained environment for pedestrians, stopping them from crossing where they want to. Improper use of guard railing can even create safety problems, e.g. visibility of children through the railing from approaching vehicles may be reduced, cyclists may be squashed between the railing and the motor vehicle, etc.

The Mayor's Strategy (para 41.11) places emphasis on providing good facilities for pedestrians, eliminating street clutter and improving the street scene. An objective of the Strategy is to make London one of the most walking friendly cities by 2015.

The Living Streets Initiative (formerly the Pedestrians Association) and others have advocated reducing the use of railing to improve the character of the street. Guard rails can take pedestrians away from their 'desire lines' (preferred pedestrian routes from one location to another), may encourage higher vehicle speeds because of the lower perceived risk, can degrade the street scene and, in areas of high demand, take valuable footway space from the pedestrian. This latter effect is because guard railing has to be set back from the kerb edge to provide clearance from vehicles, reducing the effective width of the footway by much more than the thickness of the railing.

In the light of this, it is appropriate to review how guard railing is used in London and whether the removal of railing could reduce pedestrian safety.

The main aims of this study were:

- to review the current practice/criteria for the installation of Pedestrian Guard Railing.
- to identify the effect of guard railing on pedestrian behaviour and accidents.
- to develop criteria for the installation of pedestrian guard railing that promote road safety and pedestrian access.

The research began with a review of existing national and London custom and practice with regard to the installation of guard railing. This involved a literature search and interviews with a number of London traffic engineers. The effects of guard railing were examined through a series of surveys of pedestrian behaviour at a range of different types of sites with and without railing in London, together with an analysis of conflicts and injury accidents at theses sites. The findings from all this work were then drawn together in order to develop the new criteria.

# 2 CURRENT GUIDELINES AND PRACTICE FOR INSTALLATION

## 2.1 INTRODUCTION

Pedestrian Guard Rail is generally used along the edge of footways to provide guidance to pedestrians. Other names, e.g. pedestrian safety barrier, pedestrian fence etc. [DOT, 2001], have also been used to refer to such railing systems.

It is commonly believed that pedestrian guard railing can reduce accidents by preventing pedestrians from walking on the carriageway or crossing at dangerous places. Guidance for pedestrians in the Highway Code states that:

> '*It is safer to cross at subways, footbridges, islands, Zebra and traffic light crossings, or where there is a police officer, school crossing patrol or traffic warden'*. (para.7a)

Where there are pedestrian safety barriers, the Highway Code advises pedestrians to

> '*cross the road only at the gaps provided for pedestrians. Do not climb over the barriers or walk between them and the road.*' (para.9)

The underlying philosophy on the provision of guard railing is to protect pedestrians by preventing them from:

- walking on the carriageway (e.g. in a shopping street, at a transport interchange etc)
- crossing at unsafe places (e.g. close to a pelican crossing or junction).

## 2.2 GUIDELINES ON INSTALLATION

There is no dedicated UK document concerning the installation of pedestrian guard railing. However, some recommendations are included in highway design standards and guidance for particular highway and pedestrian facilities. The guidance generally recommends the installation of pedestrian guard rail at locations deemed hazardous. The following is a summary of the references which include such recommendations:

***'The Design of Pedestrian Crossings' (Local Transport Note 1/95 and 2/95)***
***'The Installation of PUFFIN Pedestrian Crossings' (Traffic Advisory Leaflet 1/02)***
***'A Road Safety Good Practice Guide' (DOT)***
***'A Guide to Best Practice on Access to Pedestrian and Transport Infrastructure' (DOT)***
***'Guidelines for the safety audit of highways' (IHT 1987)***
***'Pedestrian Facilities at Traffic Signal Installations' (DOT Advice Note TA15/81)***

### 2.2.1 At Pedestrian Crossings

When a crossing is installed the site becomes a focus of drivers' concentration and areas of carriageway either side of the crossing become potentially more hazardous for pedestrians crossing the road. Therefore it is commonly considered necessary to erect guard railing to channel the pedestrians to the crossing. Some guidance regarding the installation of pedestrian guard railing at pedestrian crossings is given in 'The Design of Pedestrian Crossings' [DOT, 1995(2)].

> *2.1.3.1 it may be necessary in urban areas, where large numbers of pedestrians are present, to provide guard rails or other means of deterring pedestrians to prevent indiscriminate crossing of the carriageway.*

> *2.2.1 if there is an existing school crossing within 100 metres then a mutually convenient site should be found to accommodate both the patrol and other pedestrians. It may be necessary to install a greater number of guard rail sections to achieve a suitably safe site.*

*2.5.1 Many accidents at pedestrian crossings occur at the approach to the crossing. The provision of guard railing at such positions should be considered. Guard railing may also provide useful guidance for blind and partially sighted pedestrians.*

*2.5.2 Guard railing manufactured to British Standard (BS) 3049 should be used. Intervisibility is important and should be a major factor in deciding whether guard railing should be provided, the physical layout of railing and its specific type.*

*2.5.3 The effectiveness of guard railing is lessened if gaps have to be left for access for vehicles and the loading/unloading of goods. Where possible, crossings should be sited to avoid the necessity for such gaps.*

*2.5.4 Guard railing, at signal controlled crossings, should start at the signal post but not encroach past the push button position.*

*3.5 Pedestrians can be tempted to cross near or in the 'shadow' of the refuge. This can be potentially dangerous. In these cases, if the refuge cannot be located where there is a clear desire line, measures such as guard railing should be considered.*

For PUFFIN pedestrian crossings, Traffic Advisory Leaflet 1/02 [DOT, 1995(1)] states that

'*short sections of guard railing will normally be required in order to discourage pedestrians from crossing in the shadow of the crossing, often a cause of accidents. This should help to ensure that pedestrians cross within the range of the on-crossing detectors. The crossing will not function properly if pedestrians cross outside the limits of the crossing. Guard railing may also be helpful in guiding blind and partially sighted people to the crossing area. Any pedestrian guard rail should extend up to but not beyond the signal pole in the direction of the crossing'.*

The necessity for the installation of guard railing needs to be properly justified according to 'A Road Safety Good Practice Guide' of DOT [DOT, 2001], as there are also disadvantages.

*4.36 Guard rail or fencing to channel pedestrians to the designated crossing may be deemed necessary on **busy roads**. However, their use should only be considered where the risks of walking onto the carriageway are very high, as they have a number of disadvantages. They are visually intrusive, reduce footway width, can obscure children, and can cause access difficulties to commercial premises.*

*4.52 The problems associated with pedestrians stepping out from bus stops onto the main carriageway can be limited by the use of pedestrian guard-rails at strategic locations. Pedestrian refuges to the rear of the stopped bus deter vehicles from overtaking and offer additional protection to the alighted passengers.*

### 2.2.2 At Intersections

'Pedestrian Facilities at Traffic Signal Installations' [DOT, 1981] provides the guidance for installation of pedestrian guard railing at such intersections.

*6.6 (Guard Rails) It is desirable in some cases to restrict the crossing of pedestrians to certain approaches at an intersection and guard rails can be used to prevent pedestrians crossing at dangerous places (for example where filtering traffic may be moving at times unexpected by pedestrians).*

*Guard rails should always be provided on large islands where staggered pedestrian movements are allowed.*

### 2.2.3 At Other Places

Pedestrian guard railing has also been erected along high-density shopping streets and at the entrances and/or exists to transport interchanges. Specific recommendations for installation were not found for these types of site. However, more general guidance given in 'A Road Safety Good Practice Guide' may be applicable [DOT, 2001], where it states that

> '*guard rail or fencing to channel pedestrians to the designated crossing may be deemed necessary on **busy roads'***.

Crash barrier is used as a vehicle restraint system on central reservations to prevent cross over accidents. For pedestrian guard railing on central reservations, no specific recommendations have been found.

### 2.2.4 Safety Audit Requirements

Installation or removal of pedestrian guard rails may be decided as a result of a safety audit. The general guidelines are prescribed in 'Guidelines for the safety audit of highways' [IHT 1987].

> *5.4.5 The object of pedestrian guard rails used in urban areas is to segregate the pedestrian from the vehicle on the carriageway, not to stop an errant vehicle. They should not be so high or opaque as to obscure the driver's sight of the pedestrian waiting to cross at a crossing, or at the end of the guard rail if this is a location at which a pedestrian might cross. Particular provision should be made to ensure the visibility of children.*
>
> *5.5.3 (iii) in general, the most dangerous part of the road for pedestrians is within 50 m of light controlled crossings, where use of guard rails may be appropriate.*

### 2.2.5 Design and Construction Requirements

Local Transport Note (1/95) specifies that guard railing manufactured to British Standard (BS) 3049 should be used. Intervisibility is important and should be a major factor in deciding whether guard railing should be provided, the physical layout of railing and its specific type. The same requirement has also been quoted in 'Pedestrian Facilities at Traffic Signal Installations (TA 15/81)', which states that '*Guard railing used should comply with the requirements of British Standard 3049/1976 which sets out the requirements for installing metal rail*'.

A more detailed requirement is contained in 'A guide to best practice on access to pedestrian and transport infrastructure' [DfT, 2002]. Here are the relevant excerpts.

> *3.3 Fences and guard rails*
> *If there is a steep slope or drop at the rear of the footway, precautions must be made to prevent wheel-chair users running over the edge or blind or partially sighted people walking over it. Guard rails and barriers at the side of or across footways should be at least 1100mm high, preferably 1200 mm measured from ground level.*
>
> *In common with other street furniture on or close by footways, guard rails should be clearly colour contrasted from their surroundings: simple galvanized railings are not acceptable. If, for reasons of economy, this type of railing has to be used it should at minimum have colour contrasted markings on it. These requirements also apply to rails around street works.*

*Guard rails should also be designed to prevent guide dogs from walking under the rails, but there should be sufficient openings between vertical members to ensure that children and wheelchair users can see, and be seen, through the railings. The top rail should have a smooth profile and, if intended to provide support, should be circular with a diameter of between 40 and 50 mm.*

*There should also be an upstand a minimum of 150mm in height at the rear of the paved area, which can then act as a tapping rail for long cane users as well as a safeguard for wheelchair users.*

*3.5 Barriers on footways*
*Where it is necessary to provide staggered barriers across footways and footpaths in order to prevent conflict with other forms of traffic (for example at junctions with main roads) the barriers should be constructed of vertical bar sections 1200mm high and colour contrasted with their surroundings. An offset between the two barriers of 1200mm allows wheelchair users convenient passage but discourages the riding of bicycles. Requirements to give visibility through the railings, as mentioned in Section 3.3, also apply to barriers.*

### 2.2.6 Maintenance

The highway authority is responsible for the maintenance of the guard railing according to ‘The Highways Act 1980 (section 66)’, where it is stated:

> *"(3) A highway authority may provide and maintain in a highway maintainable at public expense by them which consists of a footpath, such barriers, rails or fences as they think necessary for the purpose of safeguarding persons using the highway."*

## 2.3 INTERVIEWS WITH TRAFFIC ENGINEERS

Telephone interviews were conducted with six London borough and Transport for London Engineers with responsibility for guard railing installation.

They all confirmed that there was little published guidance available apart from a few paragraphs in DfT Standards and Advice Notes. However, some of the boroughs had recently produced (or were drafting) a street furniture manual/guide, though these were largely concerned with the style of railing.

Responsibility for deciding whether or not to install guard railing lies with the site or route engineer concerned. It is very dependent on the particular site, but safety is the dominant consideration. Until fairly recently there has been no specific policy or practice that has been followed, but during the last year or two in some boroughs there has been a change towards trying to minimise the amount of railing put in. This was reported from a few of the engineers, but particularly from the Royal Borough of Kensington & Chelsea where there is now a specific strategy in place to reduce all forms of street clutter and guard railing is included in this.

Safety audit was reported to occasionally have an influence on whether guard railing is installed. A recommendation to install is likely to bear significant weight in the decision, but there are reported instances where this has also helped to make the engineer clarify the issues involved and make an exception report, whereby no guard rail was installed.

# 3 RESEARCH ON THE SAFETY EFFECTS OF GUARD RAILING

## 3.1 INTRODUCTION

Guard railing has generally been introduced to protect pedestrians, but it can also create an unpleasant constrained environment for pedestrians. It is important therefore that the safety benefits of guard railing are clarified so that installation is confined to locations where it can provide a clear safety benefit.

A comprehensive literature search was made, but little published research into the effectiveness of guard railing was found. The following provides a summary of the few relevant studies.

## 3.2 MOLASSES DATABASE

The Transport Research Laboratory maintains the MOLASSES database of U.K. safety studies. This contains just 20 sites where guard rails were erected as the only measure or part of other measures. Before-and-after accident numbers (three years before and after respectively) were reduced at all of the sites with an average reduction of 40 per cent (Table 3.1). However, there may be some bias in the reporting of the effects of these schemes because there may be a tendency to report to TRL only the successful ones.

**Table 3.1: Before-after Accidents at 20 Sites from MOLASSES Database**

| Site Type | Was Guard Railing the Only Measure? | Cost (£) | Completion Date | Accidents in 3yrs (before[after]) |
|---|---|---|---|---|
| Conventional roundabout (4 arm) | No | 5500 | 30/11/1989 | 11[6] |
| Grade separated intersection (4 arm) | No | 25000 | 31/05/1990 | 21[16] |
| Pelican crossing | No | 6000 | 01/12/1989 | 19[6] |
| Pelican crossing | No | 3509 | 29/10/1986 | 23[21] |
| Pelican crossing | Yes | 6641 | 01/12/1986 | 11[3] |
| Zebra crossing | No | 5738 | 16/04/1987 | 14[4] |
| Signal controlled jct (4 arm) | No | 15000 | 01/02/1992 | 12[4] |
| Zebra crossing | Yes | 3300 | 06/05/1992 | 8[3] |
| Conventional roundabout (4 arm) | No | 1600 | 01/09/1993 | 16[6] |
| Priority junction (3 arm) | No | 8100 | 01/06/1995 | 10[9] |
| Priority junction (3 arm) | No | 7500 | 01/01/193 | 15[9] |
| Priority junction (3 arm) | No | 9920 | 02/04/1994 | 12[8] |

| | | | | |
|---|---|---|---|---|
| Priority junction (4 arm) | No | 23225 | 14/06/1994 | 7[1] |
| Priority junction (3 arm) | Replace guard railing | 550 | 31/01/1995 | 13[11] |
| Priority junction (4 arm) | Yes | 5400 | 18/01/1995 | 16[8] |
| Priority junction (4 arm) | Yes | 1400 | 13/12/1993 | 12[9] |
| Priority junction (3 arm) | No | 1500 | 30/09/1994 | 4[3] |
| Priority junction (3 arm) | No | 3500 | 07/02/1995 | 10[4] |
| Priority junction (3 arm) | No | 120 | 03/11/1994 | 12[8] |
| Other | No | 65000 | 25/06/1992 | 30[26] |
| Reduction Rate | | | | 40.2% |

## 3.3 WOLVERHAMPTON STUDY

Table 3.2 shows before-and-after accident rates (three years before and after respectively) at four sites in Wolverhampton, where a significant reduction of accidents (76 % accidents and 79% causalities) was reported.

**Table 3.2: Wolverhampton Road Safety Plan: 1996-99 3rd Review**

| Location | Measures | Completion Date | Scheme Cost (£) | Accidents (casualties) [before], [after] |
|---|---|---|---|---|
| Highfields Road/Bank St. | Guard railing at crossing | 31.03.95 | 3,000 | [1(1)], [0(0)] |
| Newhampton Road/Hunter St. | Guard railing at traffic signals (narrowing at pelican Xing) | 31.03.96 | 36,000 | [9(12)], [1(1)] |
| Wednesfield Road/Coronation St. | Guard railing at pelican Xing | 31.03.96 | 1,750 | [6(8)], [1(1)] |
| Stafford Road/Church Road | Additional guard railing at pelican crossing | 31.03.96 | 1,750 | [5(7)], [3(4)] |
| Overall Reduction Rate | | | | 76% (79%) |

## 3.4 LONDON STUDY

The London Accident Analysis Unit (1983) conducted a before-and-after study at 16 sites in the Greater London area, where guard rail was the only accident remedial measure. Of 16 sites, eight already had enough guard rail to affect crossing patterns before the safety scheme was implemented (existing sites), six had none and two only a small amount in relation to the total amount erected under the scheme (new sites). An overall fall in all accidents of 12.6% and pedestrian accidents of 26.7% was reported. The overall fall of pedestrian accidents at eight 'new sites' and eight 'existing sites' was 16.0% and 40.6% respectively. The results indicated that extending and/or renewing guard rail at existing sites resulted in a greater fall in pedestrian accidents than did erecting guard rail at new sites. This finding seems counter-intuitive and there appears to be no logical reason for it.

Stewart (1983, 1988) examined the accident data of the London study by distinguishing adult and child pedestrian accidents. It was found that the traditional guard railing reduced adult pedestrian casualties but increased child pedestrian casualties because children were masked from drivers by the railings. An evaluation of the use of high-visibility guard rail (Visirail) was conducted using 18 sites. At 12 of these the high-visibility guard rail had replaced conventional guard rail. It was found that the reduction of casualties using Visirail was 3 times greater than that for the conventional guard rails.

## 3.5 PELICAN CROSSINGS STUDY

Bagley (1985) assessed the effect of the provision of pedestrian guard rails at pelican crossing sites on accidents. 55 sites were sub-divided into four categories: zebra conversions (to pelican) with railing, and those without railing, and completely new pelicans with railing and without railing. It was found that pedestrian accidents increased at new pelican sites without railing, whereas in the other three situations there were reductions in the number of pedestrian accidents.

## 3.6 ACCIDENT MODELLING STUDIES

A series of studies for TRL have been undertaken concerning the development of accident predictive models for junctions and links. Studies which included testing the effects of the presence of pedestrian guard railing are as follows:

- Accidents at 3-arm traffic signals on urban single-carriageway roads (Taylor, Hall and Chatterjee, 1996)
- Accidents at 4-arm single carriageway urban traffic signals (Hall, 1986)
- Accidents at 3-arm priority junctions on urban single carriageway roads (Summersgill, Kennedy and Baynes, 1996)
- Accidents at urban priority crossroads and staggered junctions (Layfield, Hall and Chatterjee, 1996)
- Accidents at junctions on one-way urban roads (Summersgill, Kennedy, Hall, Hickford and Bernard, 2001)
- Non-junction accidents on urban single-carriageway roads (Summersgill and Layfield, 1996)
- Accidents at urban mini roundabouts (Kennedy, Hall and Barnard, 1998)

In each study the effect on accident rates of the presence of guard railing (either guiding or deterring) on the entry or exit side of an arm or on the corner between two arms was examined.

At 3-arm traffic signal junctions about one-sixth of the junction arms had guard railing on the entry corner (Figure 3.1), about one-sixth had railing on the entry side and about one-sixth had it on the exit side. Deterring guard railing (designed to discourage pedestrians from crossing) on one or both sides of arm 2 (the right major arm) was associated with increased risk of pedestrian accidents with vehicles entering on arm 1; guiding guard railing (designed to encourage pedestrians to cross at a particular point) on the exit side of arm 2 was associated with increased risk of pedestrian accidents with vehicles entering on arm 2, and of total pedestrian accidents; guiding guard railing on either side of the minor arm was associated with increased risk of pedestrian accidents on that arm.

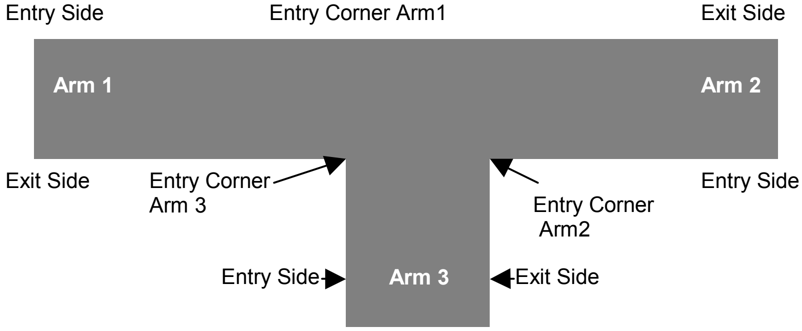



**Figure 3.1: Diagram of a Three-arm Junction**

At 4-arm traffic signals pedestrian guard rail was present on the nearside or offside of some 11% of the junction arms and at the corners at 15%. Factors representing the presence of pedestrian guard rails along the sides of the arm or at the corners did not prove significant in any of the pedestrian accident group models. The presence of the near and offside corner guard rails on the opposite arm, however, was significant for single vehicle accidents, but indicated higher accident rates at arms with such railings, though the reason is not known.

At 3-arm and 4-arm priority junctions the presence of guard rails was recorded by arm and side of road, and around 4% of arms of each junction type had such a feature. However, the presence of guard rails did not appear in any of the models.

The study of junctions on one-way roads included both signalised and priority junctions with 3 or 4 arms. About 18% of arms had guard railing on the entry corner. The study found that "The presence of guard railing on the entry corner or on either side of the arm was associated with increased accident risk for a number of accident groups, particularly pedestrian accidents", but the reason for this is not known. It concluded that "For all junction types, there was no evidence that the presence of pedestrian guard railing was associated with fewer pedestrian accidents. This suggests therefore that there may be scope for improvement in the design of these facilities to achieve their objectives."

On urban single carriageway links the presence and proportion of guard rails was recorded by side of road, and around 4% of links had guard rails present. However, the presence of guard rails did not appear in any of the models.

The only accident predictive modeling study which showed a decreased accident risk where guard railing was present is the study of urban mini-roundabouts. At these sites about 14 percent of arms had guard railing on or adjacent to the entry corner. The study found that the presence of guard railing (either guiding or deterring) on the exit side of an arm at 4-arm mini-roundabouts was associated with a reduction of about 30% in pedestrian with exiting vehicle accidents on that arm.

In summary, the above studies indicated that apart from the one accident type at 4-arm mini roundabouts, there was no evidence that the provision of guard railing resulted in reduced pedestrian accidents and indeed it was associated with increased accident rates for a few types of accidents at particular types of site.

## 3.7 CONCLUSION

Although much of the before-and-after research indicates that provision of pedestrian guard railing improves safety, there is little or no such evidence from the modelling studies. It is therefore hard to draw definite conclusions from these few studies without knowing the cause and nature of the accidents in relation to the site conditions and location of the guard railing.

# 4 SITE SURVEY DATA COLLECTION

In order to identify the effect of guard railing on pedestrian behaviour and safety, observations of pedestrian behaviour and conflicts in the presence of guard railing need to be made. For comparison purposes, a before-and-after observation at the same site would be desirable but was found to be infeasible, as sites that involved the erection/removal of guard railing within the short period of the study were not available. Instead, similar sites with and without railing were observed.

## 4.1 SITE SELECTION

To provide the breadth of information required, observations were needed at a selection of all the main types of site where guard railing is used. Table 4.1 summarises the desired distribution (number and type) of sites for the observational study. The number of sites included was limited by the resources available. A reconnaissance survey was conducted in December 2002 within the boroughs of Ealing, Westminster, Hammersmith & Fulham, Kensington & Chelsea and Hillingdon to identify potential sites (with and without guard railing).

**Table 4.1: Desired Numbers of Sites for Behaviour Study**

| Site Type | Number of Sites | |
|---|---|---|
| | With Railing | Without Railing |
| Kerb-line, High Density Retail Shopping streets | 3 | 3 |
| Entrance/exit of Transport interchanges | 2 | 2 |
| School Entrances | 3 | 3 |
| At Road Intersections | 5 | 5 |
| At Pedestrian Crossings | 5 | 5 |
| Central Reserve Railing | 2 | 2 |

The reconnaissance survey was carried out using a car equipped with a wide-angle camera recorder. The streets were filmed and potential sites were identified by analysing the video recording.

It was not possible to find enough school sites without railing in the reconnaissance survey. The final selected school sites included two sites with railing and one site without railing.

In total 37 sites were selected out of more than 200 sites identified. The final selection is summarised in Table 4.2. The sites were selected using the following criteria to give a good range of site conditions within each site type.

- Traffic volume
- Pedestrian volume
- Land use
- Complexity of junctions

An additional criterion concerned the ease with which video data could be collected and only sites with a conveniently situated lamppost were included (see section 4.2).

For the sites selected, detailed site visits were conducted and photographs were taken. A detailed description was made for each site, with such information as geometry (sketch map of the site), Ordnance Survey Co-ordinate, guard railing use, land use etc.

### Table 4.2: Summary of Selected Survey Sites

| Guard Rail | Site Number* | OS Coordinate | Location |
|---|---|---|---|
| **PEDESTRIAN CROSSINGS:** without=5, with=5 | | | |
| **Pelican** | | | |
| without | 1P03 | 204801 | Acton High St. near Grove Rd. / Acton Lane |
| without | 3P10 | 249794 | Kensington High St. near Melbury Road |
| with | 1P02 | 178807 | The Broadway (Ealing) near Haven Green |
| with | 2P11 | 302792 | Millbank near College St. |
| **Refuge** | | | |
| without | 2R03 | 294792 | Victoria St. near Buckingham Gate |
| with | 1R04 | 143827 | Oldfields Lane near Croyd Ave. |
| **Zebra** | | | |
| without | 1Z06 | 129824 | Lady Margaret Road near Kenilworth Gdns |
| without | 2Z07 | 302791 | Millbank / Dean Stanley St. |
| with | 1Z08 | 167799 | Northfield Ave. / Seaford Rd. |
| with | 1Z09 | 172789 | Northfield Ave. / Windmill Rd. |
| **JUNCTIONS:** without=5; with=5 | | | |
| **Signals** | | | |
| without | 2J11 | 292792 | Victoria St. / Palace St. |
| without | 4J16 | 240787 | Hammersmith Rd. / Brook Green |
| without | 2J19 | 289815 | Regent St./ Cavendish Place. |
| with | 1J05 | 144822 | Ruislip Rd./ Greenford Ave. |
| with | 1J06 | 176807 | New Broadway / Bond St. (Ealing) |
| with | 2J12 | 268819 | Edgware Rd. / Church St. |
| **Priority T junctions** | | | |
| without | 2J18 | 297793 | Victoria St. / Abbey St. |
| with | 1J17 | 167803 | Northfield Ave. / Mattock Lane |
| **Roundabouts** | | | |
| without | 1J20 | 128809 | Lady Margaret Rd / Carlyle Ave. |
| with | 1J21 | 130827 | Ruislip Rd / Lady Margaret Rd. |
| **KERB-LINE, HIGH DENSITY SHOPPING STREETS (LINKS)**, without =3; with=3 | | | |
| without | 2L03 | 293792 | Victoria St. near Palace St. |
| without | 2L07 | 275812 | Edgware Road near Kendall St. |
| without | 1L08 | 164804 | Uxbridge Road near Leeland Rd. |
| with | 1L01 | 199801-202801 | Acton High St. near Church Rd. / Horn Lane. |
| with | 3L05 | 256797 | Kensington High St. near Hornton St. |
| with | 1L06 | 178807-179808 | The Broadway (Ealing) near High St. |

**CENTRAL RESERVATION**, without= 2; with= 2

| | | | |
|---|---|---|---|
| without | 2C08 | 304807 | The Strand near Adam St. |
| without | 5C09 | 102812 | Uxbridge Road near Shakespeare Ave. |
| with | 2C04 | 275813 | Edgware Road near Kendal St. |
| with | 5C10 | 104811 | Uxbridge Road near Central Ave. |

**TRANSPORT INTERCHANGES**, without=2, with =2

| | | | |
|---|---|---|---|
| without | 2T08 | 297796 | Tothill St. / Broadway |
| without | 2T09 | 259808 | Queensway Rd. near Inverness Place |
| with | 1T03 | 188804 | Uxbridge Road near Granville Gdns. |
| with | 2T06 | 297796 | Tothill St. / Queen Annes Gate |

**SCHOOLS** without = 1, with=2

| | | | |
|---|---|---|---|
| without | 1S05 | 132827 | Ruislip Road near Ferrymead Ave. |
| with | 1S01 | 152820 | Greenford Ave. near Brookbank Ave. |
| with | 1S03 | 144829 | Oldfield Lane near Costons Lane. |

* Four digit Site number consists of:
(1) Borough number, 1=Ealing, 2=Westminster, 3=Kensington & Chelsea, 4=Hammersmith & Fulham, 5=Hillingdon
(2) Type: L= retail street (link), T= Transport interchange, J= Junction, P= pelican, Z= zebra, R= Refuge, S= School, C= Central Reservation
(3) Serial number (two digit) of the site

## 4.2 SITE OBSERVATIONS

For the study, traffic and pedestrian behaviours at the selected sites were observed. The observation was focused on the following aspects:

- Pedestrian and vehicle movements, to characterise the effect of guard railing in regulating pedestrian behaviour
- Pedestrian conflict, to provide an index of the pedestrian safety at the site.


**Figure 4.1: Snapshot of a Video Image (Site 1P02)**

Video recording is very useful for tracking the movement of both pedestrians and traffic, so was used in this research for the behavioural observations. All of the video surveys were undertaken by a specialised video survey company (SkyHigh Traffic Data Ltd.) in April 2003. The video surveys lasted for about 4 hours at each site (typically 0700-1100 a.m. or 1400-1800 p.m.), covering either the morning or afternoon peak hours. A Panasonic M50 video camera was used to record the activity. The camera was installed on a lamppost near to the observation area so that the videotape provided a bird's eye view. Figure 4.1 is a snapshot from a video recording, which covers a Pelican crossing with railing.

The video recordings (1 tape per site) were sent to the Transportation Research Group (TRG) for subsequent analysis.

## 4.3 ACCIDENT DATA COLLECTION

Accident data was sought from the London Accident Analysis Unit (LAAU) at TfL. All recorded personal injury accidents occurring at each site in the three years 2000 to 2002 were obtained.

Accidents occurring within the areas defined below were extracted:

- for pedestrian crossing sites: 25 metres each side of the crossing
- for junction sites: 25 metres from the crossing on the observed arm and the central part of the junction adjacent to the observed arm
- for link and central reservation sites: 25 metres each side from a central point of observation
- for transportation interchange and school sites: 25 metres each side from the entrance/exit.

The locations of the accidents were plotted on site plans and are shown in Appendix C.

Accidents involving one or more pedestrians were specially indicated as pedestrian accidents. For each site, the safety record was characterised using the number of all accidents and the number of pedestrian accidents.

Changes had been made at two sites during the three year accident study period. Site 3P10 originally had guard railing but this was removed. It was treated as a without-railing site in the behaviour observations, but was excluded from the accident analysis. Part of the railing at site 3L05 was removed before the survey, but there was still guard railing remaining within the observation area, so it was treated as a with-railing site in the behaviour and accident analysis.

# 5 ANALYSIS

The effect of guard railing on the behaviour of pedestrians has been evaluated by comparing pedestrian movements at sites with and without railing. Other factors, such as type and geometry of the site, vehicle speed and flow, and pedestrian flow, can also affect pedestrian behaviour. For example, high traffic speed may encourage more pedestrians to use a formal crossing; pedestrian crossings located along the desire line of pedestrians may be used correctly by a high proportion of pedestrians.

In order to make comparisons between sites with and without railing, the following pedestrian and traffic attributes were used to characterise each site:

- pedestrian movements
- pedestrian flow
- vehicle speed
- vehicle flow

Although many other attributes could be derived, the use of traffic/pedestrian flow rate and the associated traffic speed were believed to be appropriate as traffic flow rate should have been used in determining the installation of pedestrian crossings ($pv^2$) and traffic speed in determining the suitable type of pedestrian crossings (e.g., for zebra, below 30 mph).

The observation area was defined for each type of site to ensure consistent comparison:

- for pedestrian crossing sites: crossing itself and 25 metres each side
- for junction sites: designated crossing area, 25 metres on observed arm side, and central part of the junction
- for link and central reservation sites: 25 metres each side of the central point of observation
- for transportation interchange and school sites: 25 metres each side from the entrance/exit

These areas are identical with that used in the accident data extraction.

For each site, about 4 hours of video recording, covering both peak and off-peak periods, was available for analysis. Since the traffic and vehicle conditions could vary during this period, a sampling scheme was adopted in the data analysis. Vehicle attributes (speed and counts) were sampled every 30 minutes for 5 minutes, e.g. 7:01-7:05, 7:31-7:35 etc. Pedestrian attributes were usually sampled every 30 minutes for 10 minutes because there was usually less pedestrian activity than vehicle flow. At some sites where pedestrian activities were infrequent, all of the data were sampled every 30 minutes to give 8 samples from 4 hours. At some sites with extremely low pedestrian activity during the observation period (e.g. central reservation with railing), the whole recording was analysed to give 4 one-hour samples and enabled reasonable numbers of pedestrian activities to be observed.

## 5.1 VEHICLE ATTRIBUTES

Vehicle speeds were measured using a computer controlled video recording play-back system. The working principle is illustrated in Figure 5.1. Two reference lines a known distance apart on the site were first drawn on the TV screen. By measuring the time spent for a vehicle to travel between the two reference lines, the speed of the vehicle could be calculated. The time measurement method using the computer controlled video recording play-back system is detailed in Appendix A.


**Figure 5.1: Reference Lines used for Speed Measurement**

The speed of each vehicle passing the observed pedestrian crossing route, including turning vehicles, was measured in the sample period. The 85%ile and the average traffic speeds were calculated for each direction of traffic (different lanes but the same direction). This is because traffic speeds in opposite directions could be significantly different even on the same road. The overall one-directional mean and 85%ile speeds were then calculated by averaging 8 samples, and the overall two-directional mean and 85%ile were obtained by averaging the 2 one-directional mean and 85%ile speeds.

Five-minute traffic counts by vehicle type and direction of movement (including turning vehicles) were made for all vehicles passing the observed pedestrian crossing route in each sample time. The overall one-directional mean, the maximum and the minimum flow were calculated by converting the 5-minute counts to an hourly flow rate and averaging 8 samples. The overall two-directional mean vehicle flow (2Dmean), the maximum and the minimum flow (2Dmax and 2Dmin) were obtained by averaging the 2 one-directional flows.

## 5.2 PEDESTRIAN ATTRIBUTES

Pedestrian movements and pedestrian counts were derived from the video recordings. A pedestrian movement was represented by the origin and destination of the movement using a grid coordinate system developed in this research. The grid coordinate systems used for enumerating the pedestrian movements were tailored to the different types of site. The systems are introduced by the type of site in the subsequent analysis detailed below.

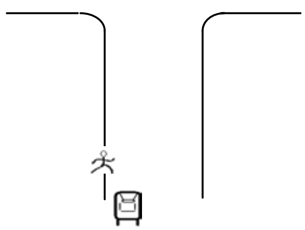
### 5.2.1 Pedestrian Conflicts

Traffic conflict data was traditionally collected by trained observers stationed at selected sites. Conflicts and events were recorded as they happened. In order to normalise conflict and event rates for different traffic volume conditions, traffic counts were generally made at the same time. The procedures for conducting a traffic conflict survey are well documented for surveyors using different conflict techniques. Using this method, however there is no way of reviewing the recorded conflicts and analysing the conflicts using another definition at a later stage.

With the advances in camera technologies, it is now possible to derive time-space trajectories of vehicles and pedestrians from video images, i.e., time-series position of vehicles and pedestrians within the coverage of the camera can be measured. A general definition of the pedestrian conflict is given in Appendix B. If we can measure the time-series position and speed of vehicles and pedestrians, not only can the conflict be identified from video recordings but also further analysis of the severity of the conflicts will be possible.

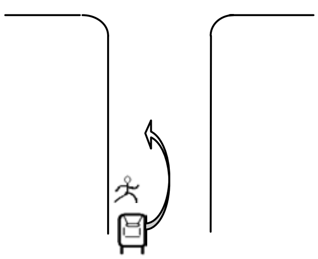
In this research, pedestrian conflicts were identified from video recordings (by playing the video at normal speed) based on subjective judgement of evasive actions in accordance with the operational definition developed for this research. This has been summarised in Figure 5.2 and detailed in Appendix B. A conflict was identified if evasive actions were evident. When the evasive actions were hard to judge, Time To Collision (TTC) was measured and a fixed TTC criterion of 1.5 seconds (Hyden, 1987) was applied in order to justify a conflict. A pedestrian conflict event was registered by its occurrence time and type of conflict.

All pedestrian conflicts identified within the observation area at each site in four hours of observation were counted. The number of conflicts is used as a surrogate index to characterise the safety of a site.



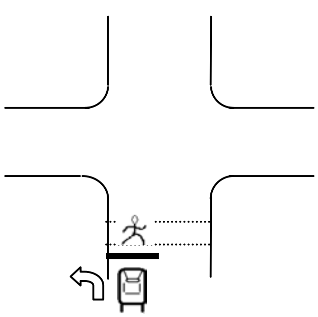
**Sudden-Appearance Conflict**

A pedestrian walking on the pavement stepped on to the carriageway abruptly, caused an approaching vehicle to brake severely or swerve to avoid collision.



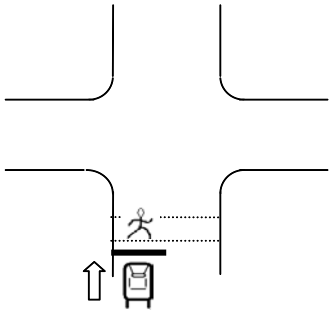
**Clearance Conflict**

A pedestrian walking on the carriageway caused an overtaking vehicle to swerve out of its lane, or brake to give up overtaking.



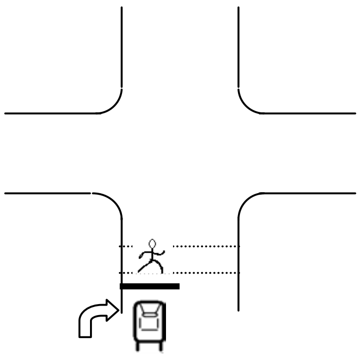
**Conflict with nearside, left-turn traffic**

A pedestrian crossing in the path of a vehicle that is going to turn left causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.



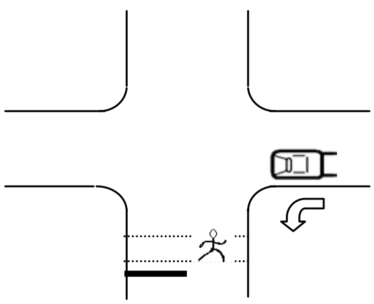
**Conflict with nearside, through traffic**

A pedestrian crossing in the path of a through vehicle coming from the right causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.



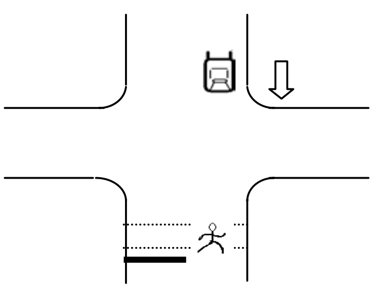
**Conflict with nearside, right turn traffic**

A pedestrian crossing in the path of a vehicle that is going to turn right causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.



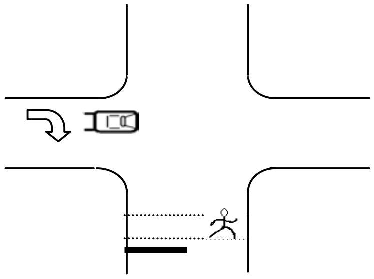
**Conflict with far-side, left turn traffic**

A pedestrian crossing in the path of a left turning vehicle causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions. If the vehicle is turning into a side road, the pedestrian has the right of way; therefore, the action that the vehicle stops to wait for the clearance of pedestrians is not an evasive action.



**Conflict with far-side, through traffic**

A pedestrian crossing in the path of a through vehicle coming from the left causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.



**Conflict with far-side, right turn traffic**

A pedestrian crossing in the path of a right turning vehicle causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.

**Figure 5.2: Operational Definition of a Conflict**

## 5.3 OVERALL TRAFFIC CONDITIONS AT SURVEYED SITES

It would be desirable if the overall traffic conditions at sites with railing and without railing were similar so that influencing factors other than guard railing are minimised. The overall average traffic conditions at sites with and without guard rails are shown in Figure 5.3 and Figure 5.4. Detailed information is shown in Table 5.1 (without railing) and Table 5.2 (with railing).

There are strong correlations between the mean and 85%ile vehicle speeds, so the 85%ile vehicle speed was used in the subsequent analysis.

t-tests were conducted to determine if there is a significant difference in traffic conditions between sites with and without railing. In this report, the 5% significance level is used as the level at which a statistic is considered to be statistically significant or not. For the flow and speed mean differences (with 16 samples), a t-value of about 2.12 is required for significance at the 5% level.

- Sites without railing (2D mean Flow 1164 vph, '2D' refers to two-directional) have lower average traffic flow than sites with railing (2D mean Flow 1392 vph), but the difference is not statistically significant (t=-1.20).
- Sites without railing (85%ile Speed 24.4mph) have lower average vehicle speed than sites with railing (85%ile Speed 26.3 mph), but the difference is not statistically significant (t=-0.95).
- Sites without railing (Ped. Flow 265 pph) have higher average pedestrian flow than sites with railing (Ped. Flow 207 pph), but the difference is not statistically significant (t=0.67).

The conclusion is that the observed sites with and without railing do not differ significantly in terms of traffic flow, traffic speed and pedestrian flow.

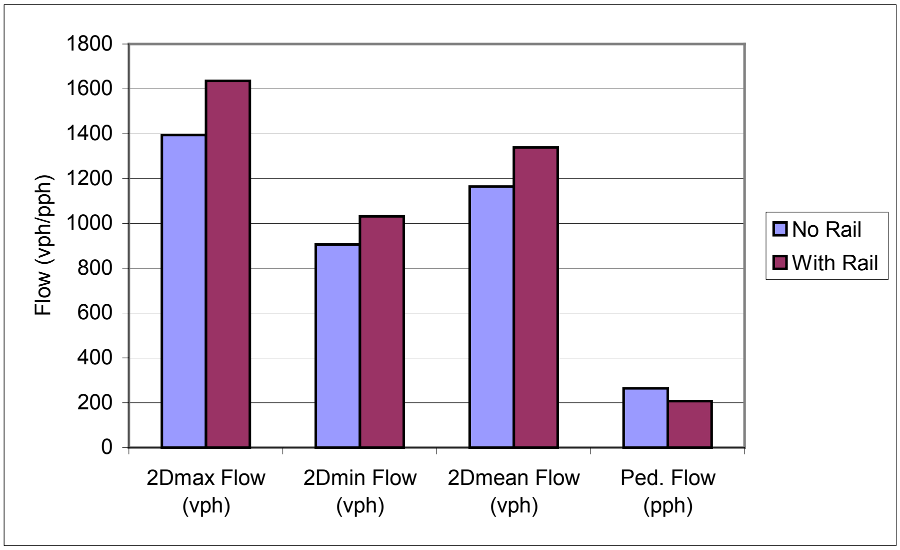



**Figure 5.3: Traffic and Pedestrian Flows at Sites with and without Guard rails**

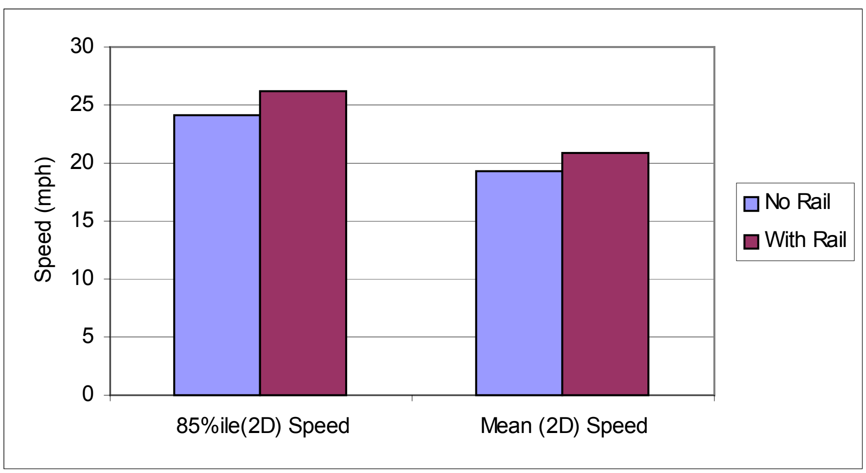



**Figure 5.4: Traffic Speeds at Sites with and without Guard rails**

### Table 5.1: Traffic Conditions at Sites Without Railing

| | Site | Vehicle Flow (vph) | | | Vehicle Speed (mph) | | Mean Ped. Flow (pph) |
|---|---|---|---|---|---|---|---|
| | | 2Dmax | 2Dmin | 2Dmean | 85%ile(2D) | mean(2D) | |
| Pelican | 1P03 | 1956 | 1284 | 1589 | 23.2 | 18.1 | 71 |
| | 3P10 | 1572 | 1056 | 1379 | 36.2 | 31.7 | 70 |
| Refuge | 2R03 | 1416 | 984 | 1201 | 27.6 | 21.7 | 541 |
| Zebra | 1Z06 | 1680 | 1188 | 1493 | 37.6 | 32.2 | 27 |
| | 2Z07 | 1740 | 1260 | 1488 | 36.9 | 28.9 | 210 |
| Junction | 2J11 | 312 | 156 | 233 | 12.3 | 9.9 | 1133 |
| | 4J16 | 1404 | 852 | 1226 | 22.8 | 18.2 | 94 |
| | 2J18 | 228 | 84 | 144 | 11.0 | 9.0 | 387 |
| | 2J19 | 1068 | 348 | 842 | 19.4 | 16.3 | 749 |
| | 1J20 | 1644 | 936 | 1221 | 25.2 | 20.1 | 36 |
| Central Reservation | 2C08 | 1824 | 1296 | 1541 | 22.2 | 16.3 | 165 |
| | 5C09 | 2640 | 1368 | 1986 | 32.6 | 28.1 | 52 |
| Link | 2L03 | 1380 | 972 | 1209 | 28.0 | 22.5 | 170 |
| | 2L07 | 1680 | 1296 | 1433 | 15.6 | 12.3 | 33 |
| | 1L08 | 1332 | 708 | 1107 | 23.8 | 18.7 | 127 |
| Transport Interchange | 2T08 | 660 | 516 | 572 | 17.3 | 13.8 | 305 |
| | 2T09 | 660 | 516 | 570 | 17.0 | 12.1 | 249 |
| School | 1S05 | 1908 | 1476 | 1728 | 25.1 | 18.6 | 346 |
| | Mean | 1395 | 905 | 1164 | 24.1 | 19.4 | 265 |
| | STD. | 614 | 428 | 507 | 8.0 | 7.1 | 291 |

### Table 5.2: Traffic Conditions at Sites With Railing

| | Site | Vehicle Flow (vph) | | | Vehicle Speed (mph) | | Mean Ped. Flow (pph) |
|---|---|---|---|---|---|---|---|
| | | 2Dmax | 2Dmin | 2Dmean | 85%ile(2D) | mean(2D) | |
| Pelican | 1P02 | 1968 | 1236 | 1637 | 22.8 | 17.1 | 558 |
| | 2P11 | 1836 | 1176 | 1529 | 38.1 | 28.7 | 233 |
| Refuge | 1R04 | 900 | 420 | 693 | 33.0 | 27.1 | 43 |
| Zebra | 1Z08 | 1260 | 792 | 1010 | 30.3 | 24.9 | 85 |
| | 1Z09 | 1608 | 768 | 1206 | 23.6 | 19.0 | 306 |
| Junction | 1J05 | 1776 | 1200 | 1541 | 21.9 | 20.4 | 656 |
| | 1J06 | 792 | 396 | 620 | 19.7 | 15.5 | 536 |
| | 2J12 | 2400 | 1536 | 1889 | 24.5 | 20.1 | 214 |
| | 1J17 | 1368 | 780 | 1125 | 27.1 | 21.0 | 3 |
| | 1J21 | 3300 | 2472 | 2813 | 23.4 | 18.1 | 54 |
| Central Reservation | 2C04 | 2628 | 2016 | 2379 | 20.9 | 15.6 | 2 |
| | 5C10 | 3072 | 1884 | 2381 | 38.7 | 30.2 | 2 |
| Link | 1L01 | 1512 | 996 | 1293 | 26.6 | 21.4 | 70 |
| | 3L05 | 1716 | 1404 | 1587 | 23.1 | 17.1 | 18 |
| | 1L06 | 1584 | 804 | 1259 | 25.7 | 21.7 | 5 |
| Transport Interchange | 1T03 | 1692 | 1128 | 1472 | 26.4 | 20.0 | 278 |
| | 2T06 | 564 | 300 | 425 | 17.3 | 12.6 | 512 |
| School | 1S01 | 1308 | 840 | 1016 | 30.4 | 25.2 | 41 |
| | 1S03 | 804 | 348 | 575 | 25.8 | 21.8 | 324 |
| | Mean | 1689 | 1079 | 1392 | 26.3 | 20.9 | 207 |
| | STD. | 744 | 591 | 644 | 5.7 | 4.7 | 220 |

## 5.4 OVERALL SAFETY EFFECT OF GUARD RAIL

The average number of accidents and conflicts at sites with and without guard railing are shown in Figure 5.5. The general result is the same in that the number of both accidents and conflicts is higher at sites without railing:

- Pedestrian accidents at sites without railing are 2.5 times that at sites with railing, and the difference is statistically significant (at 5% level, t=2.1).
- The total of all accidents at sites without railing are the same as that at sites with railing, and the difference is not statistically significant (t=0.01).
- Conflicts at sites without railing are 1.2 times that at sites with railing, but the difference is not statistically significant (t=0.51).

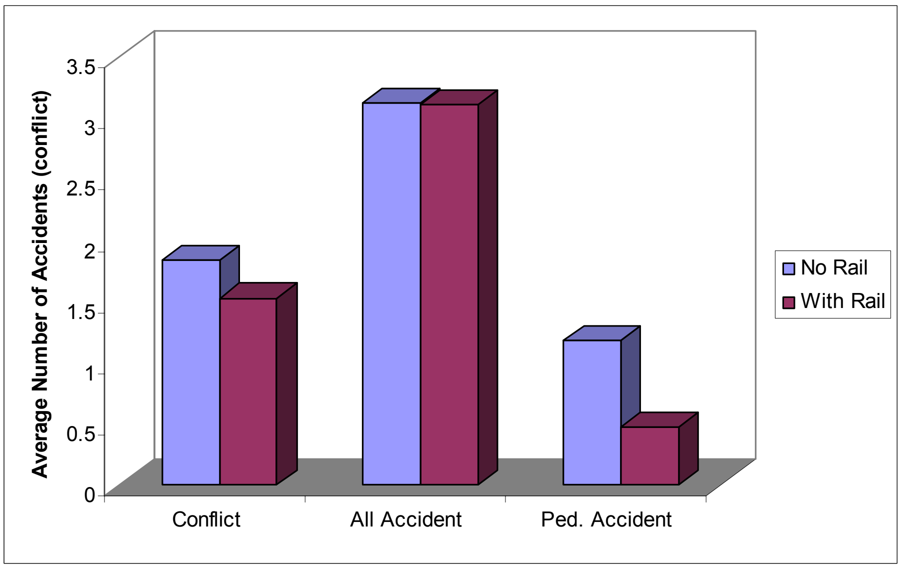



**Figure 5.5: Average Numbers of Accidents and Conflicts at All Sites**

### 5.4.1 Accidents and Conflicts at Sites with/without Guard Rail by Type of Site

For each type of site, comparison of accidents and conflicts at sites with and without guard rail is shown by the accident and conflict ratios in Figure 5.6. The accident or conflict ratio is the ratio of the average number of conflicts or accidents at sites with railing to that at sites without railing. So a ratio of less than one indicates that there are fewer conflicts/accidents at sites with railing than at sites without railing. The ratios show that:

- Conflicts are lower at sites with railing for all types of site except pedestrian crossings where the conflict rate is slightly higher than at sites without railing.
- Accident rates are much higher at link sites and slightly higher at central reservation sites with railing, than at sites without railing.
- Pedestrian accidents are fewer at all types of sites with railing.
- At transportation interchange sites without railing, there were no pedestrian accidents and conflicts, so the ratios will be infinite and are not depicted.
- At school sites with railing, no conflicts or accidents were recorded, and at central reservation sites with railing, no pedestrian conflicts or pedestrian accidents were recorded, so the ratios are all zero.

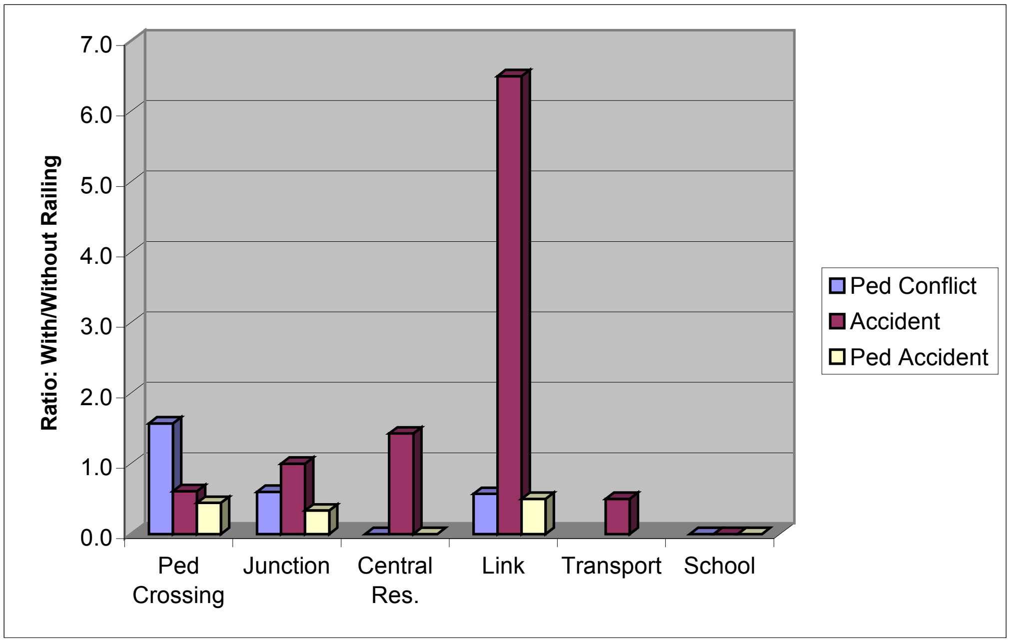



**Figure 5.6: Accident and Conflict Ratios (with/without guard railing)**
(Note: values less than 1.0 indicate railing is beneficial)

### 5.4.2 Comparing Site Types to the Overall Average

Figure 5.7 shows the ratio of the conflict and accident rates for each type of site (with and without railing) to the average over all types of site (with and without railing). A ratio of one is equivalent to the average number of conflicts/accidents over all sites. It can be found that:

- At pedestrian crossing and junction sites, conflicts, accidents and pedestrian accidents are more than the average of all types of sites.
- At transportation interchange and school sites, conflicts, accidents and pedestrian accidents are lower than the average.
- Pedestrian crossing sites have the highest pedestrian accident rate.
- Link sites have the highest conflict rate.
- Central reservation sites have the highest accident rate.

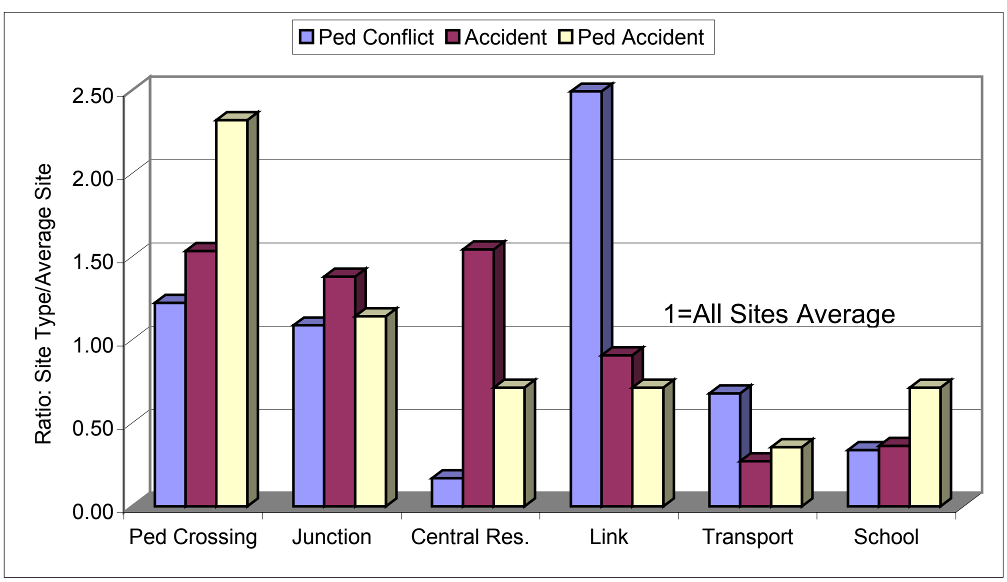



**Figure 5.7: Accident and Conflict Rate Ratios of Site Type to the Average Site**

## 5.5 SITE SPECIFIC EFFECTIVENESS OF GUARD RAILS

The effectiveness of guard railing was analysed by comparing pedestrian behaviour and safety records at sites with and without railing. The safety effect was quantified using:

- total accident rate
- pedestrian accident rate and
- pedestrian conflict rate

However, pedestrian behaviour in the presence of guard railing is different at different types of sites, and may be difficult to quantify using consistent indices. For example, most pedestrians are guided by guard railing to a designated crossing position at a pelican site, while other pedestrians may avoid guard railing by crossing outside the railing or by taking a short-cut route. The effectiveness of guard railing at this type of site may be quantified by the proportion of pedestrians who cross at designated crossing position. However, at central reservation sites with railing, most pedestrians have to detour to a nearby crossing while a few others may avoid the guard railing by climbing over it and crossing. The effectiveness of guard railing may better be quantified by counts of pedestrians who use the road section either by crossing or walking on it. For this reason, site-specific effectiveness indices were developed in a way that was pertinent to the objectives concerning the erection of the guard railing.

Only pedestrian movements (and associated pedestrian flow) that can be directly affected by guard railing were taken into account in the analysis. For example, only crossing pedestrians at pedestrian crossing sites were considered as they will be directly affected by the guard railing while through pedestrians will not be directly affected. The analysis was therefore focused on site-specific pedestrian groups, which varied by type of site as detailed below.

### 5.5.1 Pedestrian Crossings

The pedestrian groups analysed included all those who crossed the road in the observation area, as guard railing might affect their movements.

Pedestrian movements were recorded using a grid coordinate system. Figure 5.8 shows the grid coordinate used at a zebra crossing site. The zigzag lines were used as natural coordinate markings. The zigzag lines were labelled numerically to the right of the crossing point and alphabetically to the left. Pedestrian movements were recorded using an origin-destination grid coordinate. For example, ‘20’ was used to represent a pedestrian’s movement from the second zigzag on the left side to the zebra area on the right side. At refuge sites, there were no zigzag lines as natural markings so a slightly different grid coordinate system was used. The observation area was divided into three grids, the refuge section itself, and two road sections of 25 metres length (or 5 metres from the end of the guard rail) each side of the refuge.

Three types of pedestrian movements were counted:

(A) Pedestrian movements with both origin and destination at the crossing (grid coordinate 0-0), i.e., pedestrians who crossed at the crossing.
(B) Pedestrian movements with origin or destination at the crossing, but not both, i.e., pedestrians who either started or ended crossing at the crossing but did not cross fully at the crossing.
(C) Pedestrian movements with both origin and destination not at the crossing, i.e., pedestrians who crossed elsewhere.

The crossing was fully used in the first type of movement and partly used in the second type of movement. It was not used at all in the third type of movement. With the erection of guard railing, the first and the second type of pedestrian movements should be expected to increase while the third type of movements should reduce.

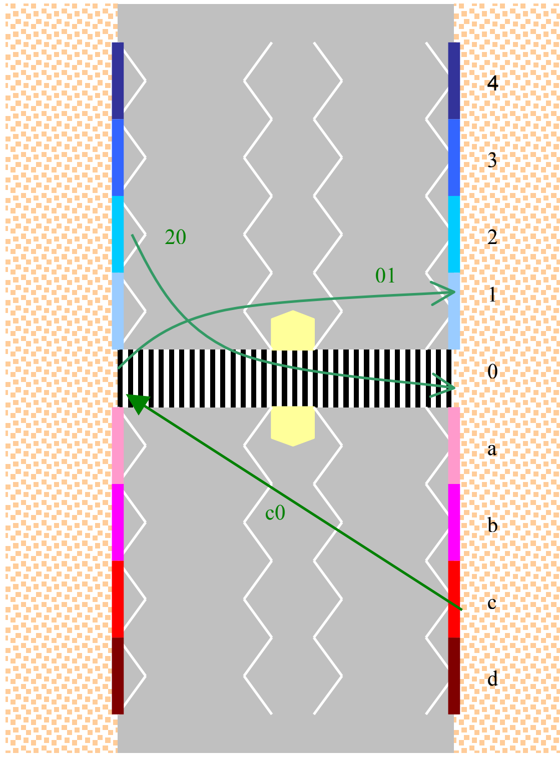



**Figure 5.8: Grid Coordinate System used for Pedestrian Crossing Sites**

Three effectiveness indices were constructed for pedestrian crossing sites:

- **Utilisation rate (UR)**. This is the proportion of pedestrians who used the crossing fully or partly to all crossing pedestrians. This was calculated as the ratio of the sum of the first and second types of pedestrian movements to all pedestrian movements (i.e. *(A+B)/(A+B+C)*), and is an indicator of the effectiveness in increasing the overall use.
- **Correct use rate (CUR).** This is the proportion of pedestrians who used the crossing fully to those pedestrians who used the crossing fully or partly. This was calculated as the ratio of the first type of pedestrian movement to the sum of the first and second types of pedestrian movements (i.e. *(A)/(A+B)*).
- **Formal use rate (FUR)**. This is the proportion of pedestrians who used the crossing fully to all crossing pedestrians. This was calculated as the product of the utilisation rate and the correct use rate (i.e. *(A)/(A+B+C)*).

As can commonly be observed, pedestrians sometimes avoid using a designated crossing by crossing elsewhere (e.g., at the end of railing away from the crossing). Pedestrians who use the crossing may also deviate from the designated crossing position (0-0), to take a short-cut route. The first index is an indication of the effectiveness of the guard railing in increasing the overall use of the crossing while the second index is an indication to the effectiveness in guiding pedestrians within a safe area. The third index is closely related with utilisation rate and can be taken as an indication of the overall effectiveness of guard rails in guiding pedestrians to cross within the designated crossing area.

#### 5.5.1.1 Behaviour Effect

The average values of traffic and pedestrian attributes at each pedestrian crossing site are shown in Table 5.3. Sites with railing have higher utilisation, correct use and formal use rates than sites without railing. The difference is more than 10% in terms of utilisation rate, i.e. over 10% more people use the crossing when there is guard railing.

**Table 5.3: Traffic and Pedestrian Attributes at Pedestrian Crossing Sites**

| Site | | Traffic | | Pedestrian | | | |
|---|---|---|---|---|---|---|---|
| Guard Rail | Site ID | Veh Flow (vph) | 85%ile Speed (mph) | Ped Flow (pph) | UR (%) | CUR (%) | FUR (%) |
| Pelican | | | | | | | |
| without | 1P03 | 1589 | 23.2 | 71 | 86.1 | 91.3 | 78.6 |
| without | 3P10 | 1379 | 36.2 | 70 | 84.3 | 93.2 | 78.5 |
| with | 1P02 | 1637 | 22.8 | 558 | 92.9 | 99.2 | 92.1 |
| with | 2P11 | 1529 | 38.1 | 233 | 93.0 | 92.4 | 86.0 |
| Refuge | | | | | | | |
| without | 2R03 | 1201 | 27.6 | 541 | 55.6 | 97.6 | 54.2 |
| with | 1R04 | 693 | 33.0 | 43 | 93.0 | 100.0 | 93.0 |
| Zebra | | | | | | | |
| without | 1Z06 | 1493 | 37.6 | 27 | 93.4 | 90.3 | 84.3 |
| without | 2Z07 | 1488 | 36.9 | 210 | 90.1 | 85.8 | 77.3 |
| with | 1Z08 | 1010 | 30.3 | 85 | 93.7 | 78.9 | 74.0 |
| with | 1Z09 | 1206 | 23.6 | 306 | 98.3 | 100.0 | 98.3 |
| All crossings | | | | | | | |
| Mean (without rail) | | 1430 | 32.3 | 184 | 81.9 | 91.6 | 74.6 |
| Mean (with rail) | | 1215 | 29.6 | 245 | 94.2 | 94.1 | 88.7 |

UR: Utilisation Rate; CUR: Correct Use Rate; FUR: Formal Use Rate

t-tests of the differences between means for sites with and without railing (assuming unequal variances) were conducted for the Utilisation Rate, Correct Use Rate and Formal Use Rate. The results are given below. It should be noted that the average rates shown in Table 5.3 are calculated from site means, while the average rates in the t-tests are calculated from individual observations, so they are slightly different because the number of observations made at each site was different:

- Sites with railing have a higher Utilisation Rate (94.3%) than those without railing (80.6%), and the difference was found to be significant (at 0.1% level, t=4.56)
- Sites with railing have a slightly higher Correct Use Rate (94.1%) than those without railing (91.8%), but the difference was found to be not significant (t=1.12).
- Sites with railing have a higher Formal Use Rate (88.8%) than those without railing (73.5%), and the difference was found to be significant (at 0.1% level, t=4.89).

Correlation coefficients between the five pedestrian crossing attributes, i.e., Utilisation Rate, Correct Use Rate, vehicle flow, vehicle speed and pedestrian flow, were calculated for sites with and without railing respectively, and are shown in Table 5.4. From the correlation between Utilisation Rate and traffic flow (UR vs. V-Flow), it can be found that at sites without railing more pedestrians tend to use the pedestrian crossings at higher traffic flow than at lower traffic flow (correlation coefficient = 0.76). The plot is shown in Figure 5.9. It is likely that crossing opportunities are easier to find at low traffic flow so pedestrians could be tempted to cross at a more convenient place. At sites with railing, pedestrian flow is higher when traffic speed is low (P-Flow vs. 85%ile Speed, correlation coefficient = - 0.51). This seems to be reasonable as traffic speed could be restricted at some busy pedestrian crossings. No other strong correlations were found.

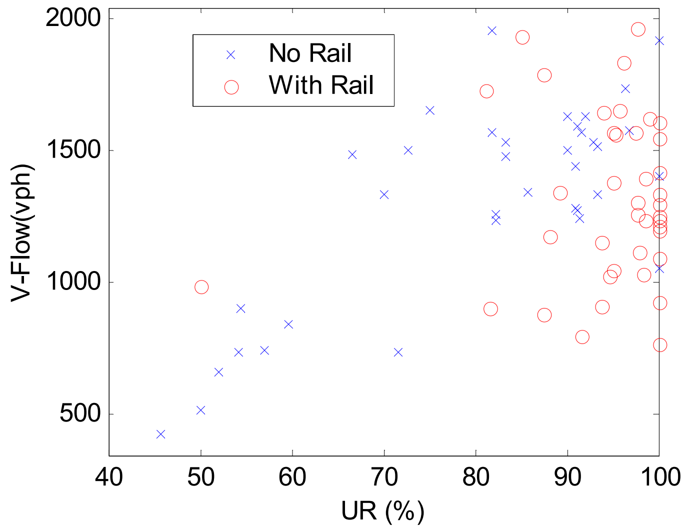



**Figure 5.9: Plot of Utilisation Rate vs. Vehicle Flow at Pedestrian Crossing Sites**

**Table 5.4: Correlation Coefficients (Pedestrian Crossings)**

| | | UR | CUR | V-Flow | 85%ile Speed | P-Flow |
|---|---|---|---|---|---|---|
| No Rail | **UR** | 1 | | | | |
| | **CUR** | -0.36 | 1 | | | |
| | **V-Flow** | **0.76** | -0.23 | 1 | | |
| | **85%ile Speed** | 0.37 | -0.17 | 0.17 | 1 | |
| | **P-Flow** | -0.38 | 0.00 | -0.47 | -0.07 | 1 |
| With Rail | **UR** | 1 | | | | |
| | **CUR** | 0.06 | 1 | | | |
| | **V-Flow** | 0.09 | 0.29 | 1 | | |
| | **85%ile Speed** | -0.28 | -0.28 | -0.11 | 1 | |
| | **P-Flow** | 0.28 | 0.08 | 0.20 | **-0.51** | 1 |

### 5.5.1.2 Safety Effect

As shown in Figure 5.10, at the pedestrian crossing sites, there are fewer pedestrian conflicts, but more accidents and pedestrian accidents if guard railing is not present. The conflict figure seems to be counter-intuitive as more conflicts generally means more accidents. However, the differences are not statistically significant (t=-0.54 for conflicts, t=0.92 for accidents, t=1.37 for pedestrian accidents).

The pedestrian crossing sites have the highest overall pedestrian accident rate (Figure 5.7), and there are fewer accidents and pedestrian accidents at the sites with railing than at sites without railing. Overall, installation of guard railing may be of benefit by helping to guide pedestrians to the designated crossing place.

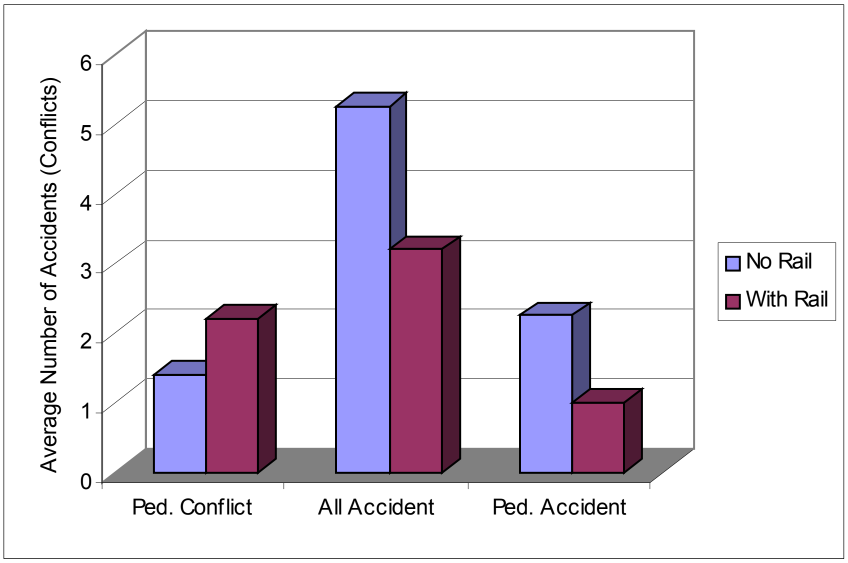



**Figure 5.10: Average Numbers of Accidents and Conflicts at Pedestrian Crossing Sites**

### 5.5.2 Junctions

The pedestrian groups analysed included all those who crossed the observed arm of the junction, as guard railing could affect their movements.

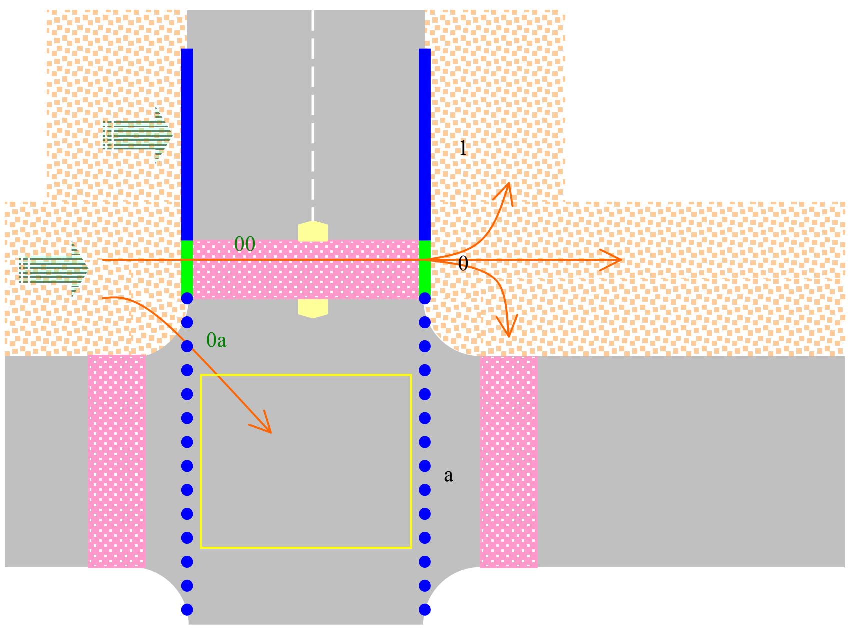



**Figure 5.11: Grid Coordinate System used for Junction Sites**

Figure 5.11 shows the grid coordinate system used at a four-arm junction site. Three grids were defined for the designated crossing area, the arm side section and the node section. Pedestrian movements were recorded using an origin-destination grid coordinate. For example, ‘0a’ was used to denote a pedestrian’s diagonal movement from the designated crossing to the node.

Three types of pedestrian movements were counted:

(A) Pedestrian movements with both origin and destination at the designated crossing (grid coordinate 0-0), i.e. pedestrians who crossed at the crossing.

(B) Pedestrian movements with origin or destination at the designated crossing, but not both, i.e., pedestrians who either started or ended at the crossing but did not cross fully at the crossing.
(C) Pedestrian movements with both origin and destination not at the designated crossing, i.e., pedestrians who crossed elsewhere.

The same effectiveness indices as for pedestrian crossing sites were used:

- **Utilisation rate (UR)**, i.e. the proportion of pedestrians who used the crossing fully or partly to all crossing pedestrians *(i.e. (A+B)/(A+B+C))*.
- **Correct use rate (CUR),** i.e. the proportion of pedestrians who used the crossing fully to those pedestrians who used the crossing fully or partly *(i.e .(A)/(A+B))*.
- **Formal use rate (FUR)**, i.e., the proportion of pedestrians who used the crossing fully to all crossing pedestrians *(i.e. (A)/(A+B+C))*.

### 5.5.2.1 Behaviour Effect

The average values of traffic and pedestrian attributes at each junction site are shown in Table 5.5. Sites with railing have higher utilisation, correct use and formal use rates, though the overall differences are all less than 10%.

**Table 5.5: Traffic and Pedestrian Attributes at Junction Sites**

| Site | | Traffic | | Pedestrian | | | |
|---|---|---|---|---|---|---|---|
| Guard Rail | Site ID | Veh Flow (vph) | 85%ile Speed (mph) | Ped Flow (pph) | UR (%) | CUR (%) | FUR (%) |
| without | 2J11 | 233 | 12.3 | 1133 | 96.4 | 81.2 | 78.3 |
| without | 4J16 | 1226 | 22.8 | 94 | 83.8 | 94.7 | 79.4 |
| without | 2J18 | 144 | 11.0 | 387 | 71.2 | 98.9 | 70.4 |
| without | 2J19 | 842 | 19.4 | 749 | 91.4 | 96.5 | 88.2 |
| without | 1J20 | 1221 | 25.2 | 36 | 81.4 | 100.0 | 81.4 |
| with | 1J05 | 1541 | 21.9 | 656 | 88.8 | 99.4 | 88.3 |
| with | 1J06 | 620 | 19.7 | 536 | 91.4 | 99.9 | 91.4 |
| with | 2J12 | 1889 | 24.5 | 214 | 97.3 | 100.0 | 97.3 |
| with | 1J17 | 1125 | 27.1 | 3 | 93.8 | 100.0 | 93.8 |
| with | 1J21 | 2813 | 23.4 | 54 | 69.7 | 98.1 | 68.4 |
| All Junction sites | | | | | | | |
| Mean (without rail) | | 733 | 18.1 | 480 | 84.8 | 94.3 | 79.5 |
| Mean (with rail) | | 1597 | 23.3 | 293 | 88.2 | 99.5 | 87.8 |

UR: Utilisation Rate; CUR: Correct Use Rate; FUR: Formal Use Rate

t-tests of the differences between means for sites with and without railing (assuming unequal variances) were conducted for the Utilisation Rate, Correct Use Rate and Formal Use Rate. It should be noted that the average rates shown in Table 5.5 are calculated from site means, while the average rates in the t-tests are calculated from individual observations and are slightly different because the number of observations made at each site was different. The results are as follows:

- Sites with railing have a higher Utilisation Rate (87.2%) than those without railing (85.2%), but the difference was found to be not significant (t=0.64).
- Sites with railing have higher Correct Use Rate (99.4%) than those without railing (94.1%), and the difference was found to be significant (at the 1% level, t=3.74).
- Sites with railing have higher Formal Use Rate (86.9%) than those without railing (79.8%), and the difference was found to be significant (at the 5% level, t=2.36).

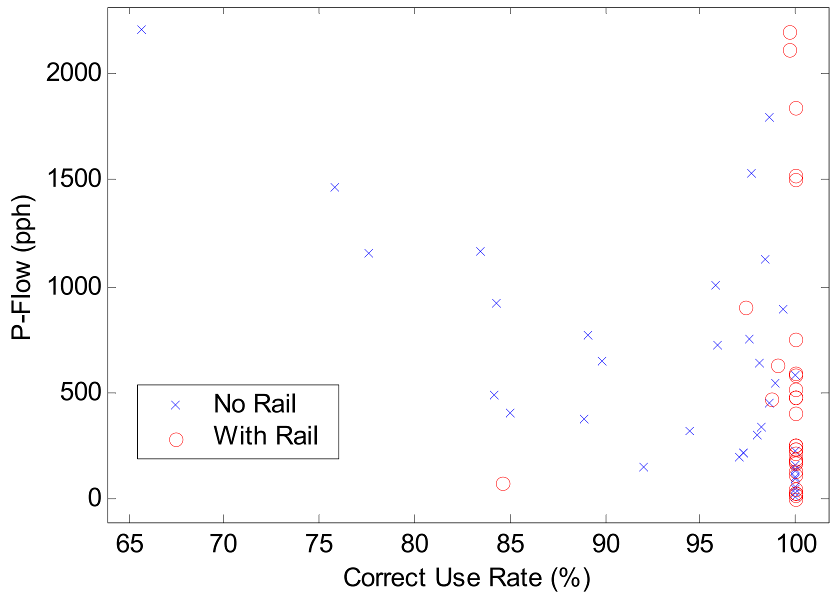



**Figure 5.12: Plot of Correct Use Rate vs. Pedestrian Flow at Junction Sites**

**Table 5.6: Correlation Coefficients (Junctions)**

| | | UR | CUR | V-Flow | 85%ile Speed | P-Flow |
|---|---|---|---|---|---|---|
| **No Rail** | **UR** | 1 | | | | |
| | **CUR** | -0.46 | 1 | | | |
| | **V-Flow** | 0.06 | 0.35 | 1 | | |
| | **85%ile Speed** | -0.14 | 0.41 | **0.84** | 1 | |
| | **P-Flow** | 0.23 | **-0.61** | **-0.54** | **-0.64** | 1 |
| **With Rail** | **UR** | 1 | | | | |
| | **CUR** | **0.56** | 1 | | | |
| | **V-Flow** | **-0.52** | -0.16 | 1 | | |
| | **85%ile Speed** | -0.02 | -0.16 | 0.27 | 1 | |
| | **P-Flow** | 0.22 | 0.09 | **-0.65** | **-0.53** | 1 |

Correlation coefficients between the five junction attributes, i.e., Utilisation Rate, Correct Use Rate, vehicle flow, vehicle speed and pedestrian Flow, were calculated for sites with and without railing respectively, and are shown in Table 5.6. From the correlation between Correct Use Rate and pedestrian flow (CUR vs. P-Flow), it can be found that at sites without railing, a lower proportion of pedestrians tend to use the crossing correctly at higher pedestrian flow than at lower pedestrian flow (correlation coefficient =-0.61, Figure 5.12). This may partly explain why the ‘Correct Use Rate’ at junction sites is significantly different between sites with and without guard railings, as with the increase of the pedestrian flow, more people are crossing outside the designated crossing area. The installation of guard railings could effectively guide pedestrians within the designated crossing area.

Pedestrian flow is found to be correlated with traffic flow and 85%ile speed at sites with and without railing (correlation coefficient between –0.53 to –0.65). Busy sites (in terms of pedestrian flow) have lower traffic flow and speeds.

It is interesting to note that at those observed junctions without railing, 85%ile traffic speeds are lower when vehicle flow is low (correlation coefficient =0.84). This cannot be interpreted as a kind of single lane speed-flow relationship as the vehicle flow used here is multi-lane two directional and multi-lane roads have much higher flow rate. The relationship may be an indication that speed on multi-lane roads is higher.

At sites with railing, the utilisation rate is found to decrease at higher traffic flow (correlation coefficient =-0.52). This may be a reflection of the geometry property of junctions and seems to indicate that at junction sites with railing, the effectiveness of guard railing is likely to be decreased at high traffic flow.

#### 5.5.2.2 Safety Effect

The numbers of conflicts, accidents and pedestrian accidents at the junction sites are shown in Figure 5.13. The accident rates are the same for sites with and without railing. There are fewer conflicts and pedestrian accidents at sites with railing, but the difference is not statistically significant (t=1.79 for conflicts, t=1.46 for pedestrian accidents).

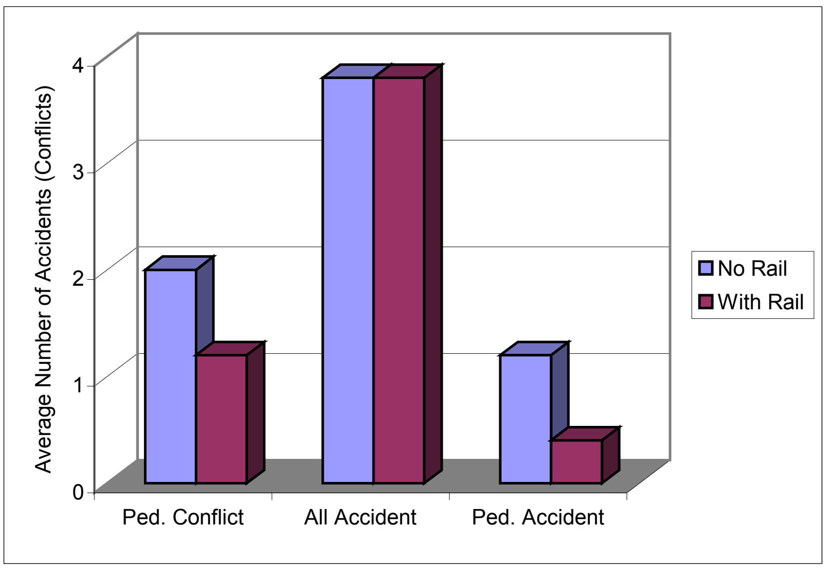



**Figure 5.13: Average Numbers of Accidents and Conflicts at Junction Sites**

Pedestrian accidents account for 10.5% and 31.6% of all accidents at the junction sites with and without railing respectively. While the total number of accidents remains unchanged, vehicle accident rate is higher at the junction sites with railing (89.5%) than at the sites without railing (68.4%). The effectiveness of guard railing on improving pedestrian safety may therefore be counterbalanced by an increase in vehicle with vehicle accidents.

### 5.5.3 Links and Central Reservations

The guardrails at central reservations and links are usually set in a long stretch to discourage pedestrians from crossing the carriageway. Within an observation area, four kinds of pedestrian activities can be distinguished (Figure 5.14 for central reservation sites and Figure 5.15 for link sites):

1) Pedestrians enter and leave the carriageway within the observation area (O, D where O=Origin, D=Destination).
2) Pedestrians walk into the observation area on the carriageway or central reservation and leave the carriageway within the observation area (~O, D).
3) Pedestrians enter the carriageway within the observation area and walk out of the observation area on the carriageway or the central reservation (O, ~D).
4) Pedestrians walk through the observation area on the carriageway or the central reservation (~O, ~D).

At central reservation sites, pedestrians can enter and leave the observation area on the carriageway or on the central reservation, while at link sites, they can only enter or leave on the carriageway. The pedestrian groups analysed included those observed in the observation area whose movements fell into one of the four categories defined above.

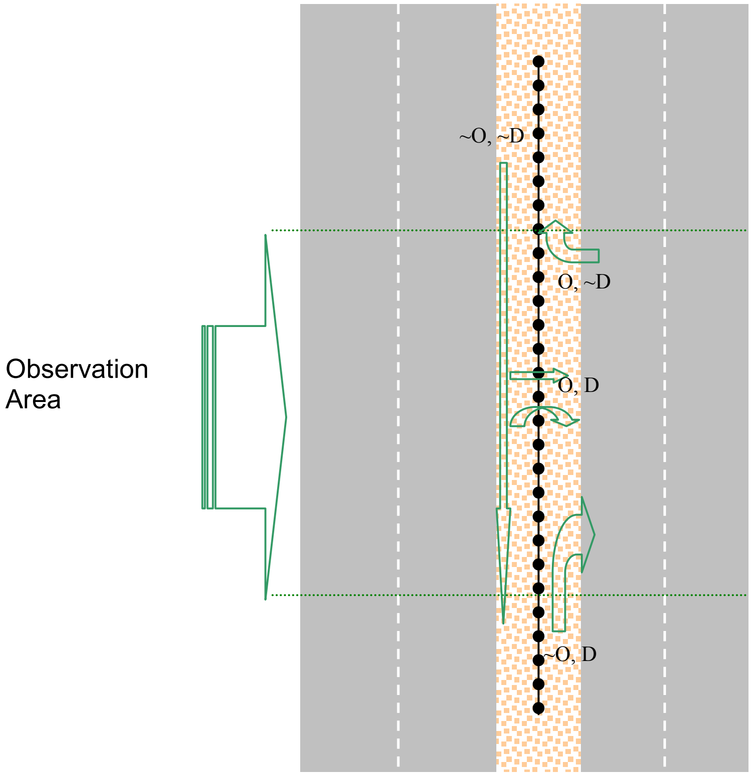



**Figure 5.14: Pedestrian Movements at Central Reservation Sites**

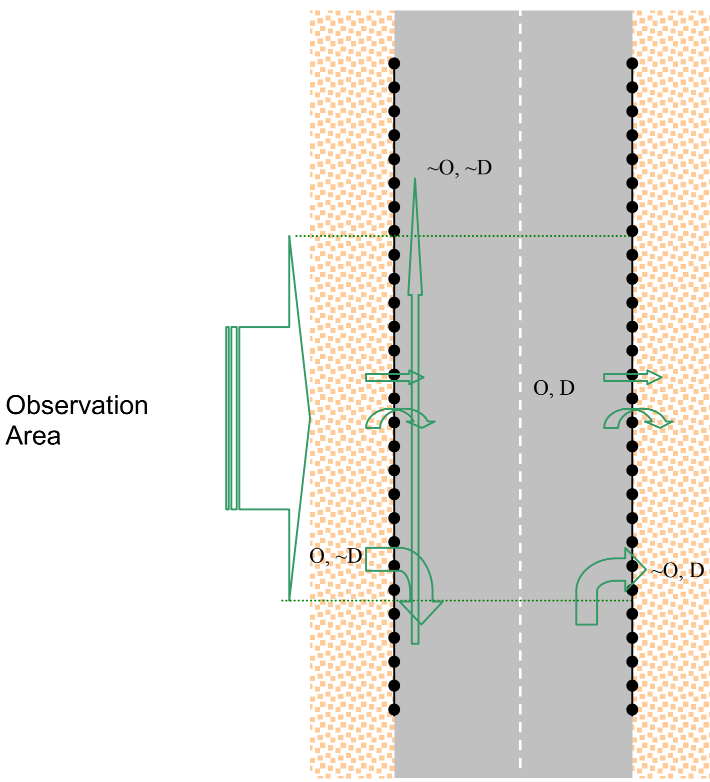



**Figure 5.15: Pedestrian Movements at Link Sites**

As pedestrians are not encouraged to cross or enter the carriageway at link and central reservation sites, the effectiveness index constructed was the **Activity Rate (AR)**. This was calculated as the sum of the counts of the four types of pedestrian movements.

### 5.5.3.1 Behaviour Effect

The traffic and pedestrian attributes at the link and central reservation sites are shown in Table 5.7. Sites with railing have slightly higher average traffic flow and speed.

The average hourly pedestrian activity rate at sites with railing (19 pph) is much lower than that at sites without railing (109 pph), and the difference is statistically significant (at the 5% level, t=-2.88). Very little pedestrian activity was observed at sites with guard railings. A comparison of the average activity rates for sites with and without railing is shown in Figure 5.16.

Counts of people climbing over the railing were also made. In total 29 rail-climbing activities were observed at three of the five sites with railing. Of the two sites with railing where no climbing events were observed, one site (1L03) has some gaps within the guard railing.

The time distribution of the rail-climbing activities is shown in Figure 5.17. At site 5C10, rail-climbing activities happened mainly in the morning peak hours, while at the other two sites, this is not so. It is difficult to draw any conclusion about the occurrence of rail-climbing from a very small sample, except that clearly some pedestrians are not willing to accept the added inconvenience created by a long stretch of guard railing, and instead will cross by climbing the rail at the nearest convenient location.

**Table 5.7: Traffic and Pedestrian Attributes at Link and Central Reservation Sites**

| Site | | Traffic | | Pedestrian | |
|---|---|---|---|---|---|
| Guard Rail | Site ID | Veh Flow (vph) | 85%ile Speed (mph) | Activity Rate (pph) | Total Number Climbing |
| Central Reservation | | | | | |
| without | 2C08 | 1541 | 22.2 | 165 | |
| without | 5C09 | 1986 | 32.6 | 52 | |
| with | 2C04 | 2379 | 20.9 | 2 | 0 |
| with | 5C10 | 2381 | 38.7 | 2 | 9 |
| Link | | | | | |
| without | 2L03 | 1209 | 28.0 | 170 | |
| without | 2L07 | 1433 | 15.6 | 33 | |
| without | 1L08 | 1107 | 23.8 | 127 | |
| with | 1L01 | 1293 | 26.6 | 70 | 0 |
| with | 3L05 | 1587 | 23.1 | 18 | 5 |
| with | 1L06 | 1259 | 25.7 | 5 | 15 |
| All Res. and Link sites | | | | | |
| Mean (without rail) | | 1455 | 24.5 | 109 | |
| Mean (with rail) | | 1780 | 27.0 | 19 | |

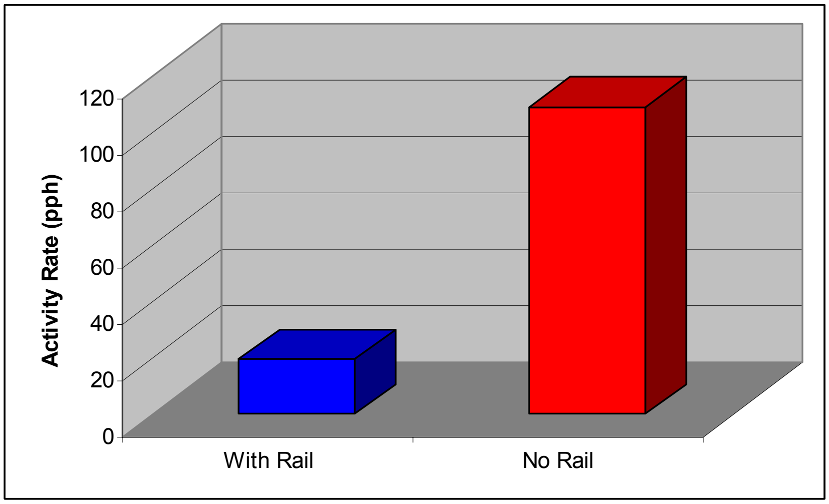



**Figure 5.16: Comparison of Activity Rate at Sites with and without Railing**

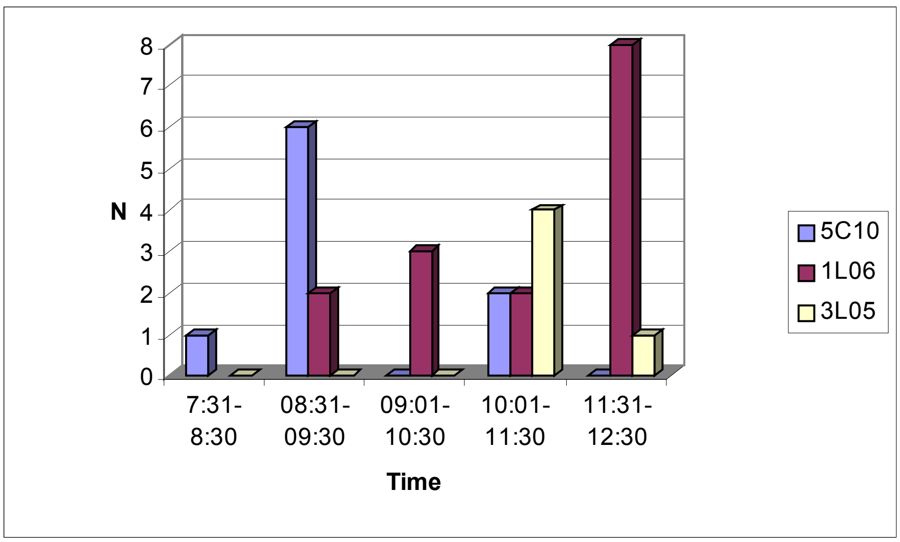



**Figure 5.17: Time Distribution of Climbing Railing Activities**

### 5.5.3.2 Safety Effect

The number of conflicts, accidents and pedestrian accidents at the observed central reservation sites is shown in Figure 5.18. While the conflicts and pedestrian accidents are fewer at the sites with railing than the sites without railing, overall accident rates are higher at the sites with railing.

Of the two observed central reservation sites with railing, no pedestrian conflicts and accidents were recorded. Of the two sites without railing, two pedestrian accidents and one conflict were recorded at one site. No statistical comparison has been made because of small samples, though the indication is that at the sites surveyed, pedestrian accidents and conflicts are lower at sites with railing, but total accidents are higher.

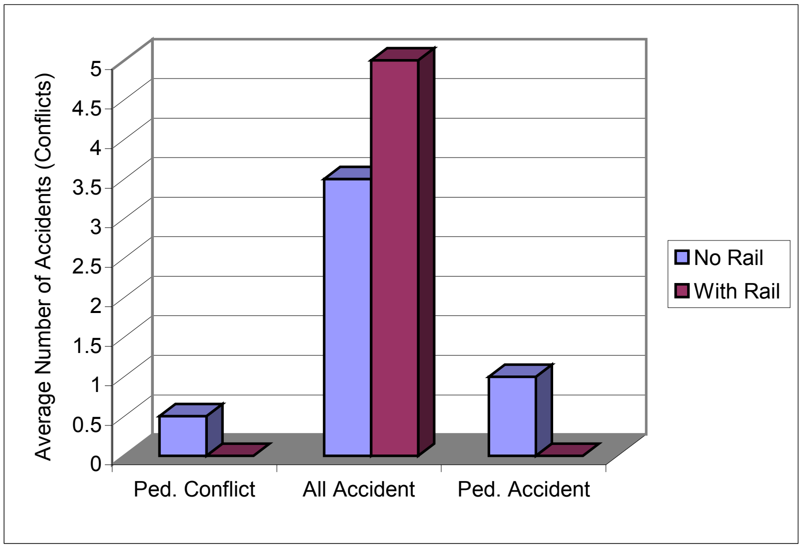



**Figure 5.18: Average Numbers of Accidents and Conflicts at Central Reservation Sites**

At the Link sites, the observed conflicts and pedestrian accidents are fewer at sites with railing than at sites without railing, as shown in Figure 5.19, though the number of accidents is higher at sites with railing. However, none of these differences are statistically significant at 5% confidence level (t=1.81 for conflicts, t=-2.29 for accidents, t=0.45 for pedestrian accidents).

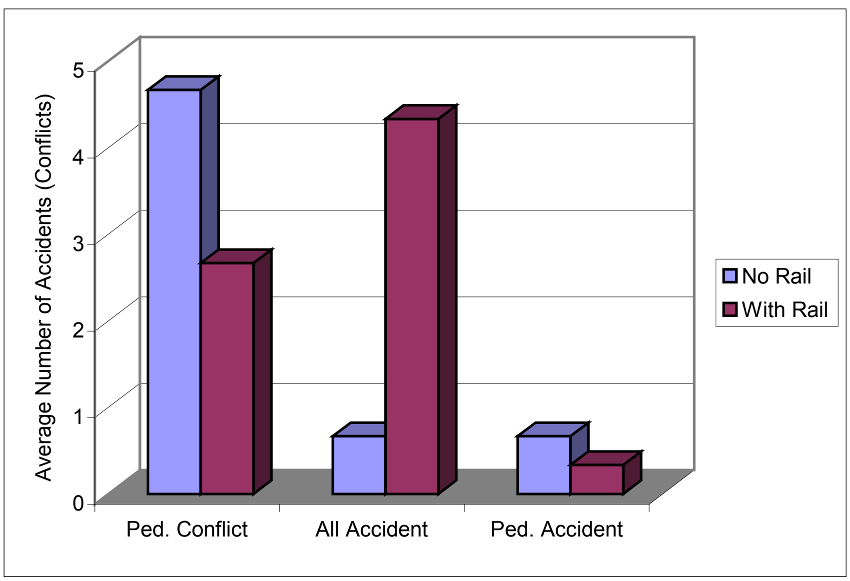



**Figure 5.19: Average Numbers of Accidents and Conflicts at Link Sites**

Accidents at observed link sites with railing are 6.5 times that at sites without railing, and the difference is very close to significance at the 5% level (5.3%). Compared with the marginal difference in pedestrian accident rates, the number of accidents at the observed sites with railing was very high, which indicates a possible adverse effect of guard railing on the overall safety at the observed link sites.

### 5.5.4 Transportation Interchanges and Schools

The purpose of guard rails at transportation interchanges and schools are two fold; the first is to prevent users from directly stepping into the carriageway without looking. The second is to guide users to a nearby pedestrian crossing. The typical arrangement at a transportation interchange is that guard rails are erected along the kerbside directly in front of the entrance/exit and extended to a nearby pedestrian crossing at one end. If a pedestrian crossing is aligned with the entrance/exit of a transportation interchange, then no guard rails are usually erected.

At school sites, entrances/exits are often far from a pedestrian crossing. At some sites, long guard rails are erected which extend to a pedestrian crossing, while at some other sites, only a short section of guard rail is installed directly in front of the school entrance/exit.

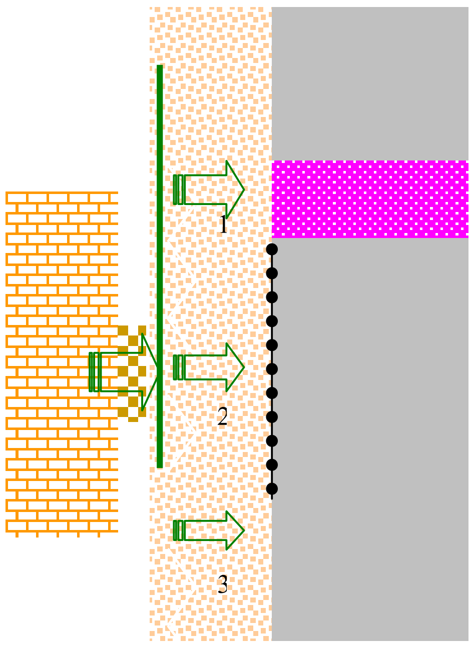



**Figure 5.20: Pedestrian Movements at Transportation Interchange and School Sites**

The pedestrians analysed were limited to the users of transportation interchanges or schools:

- For transportation interchange sites, only users who accessed the interchange by crossing the road were counted, i.e., users who accessed the interchange from the nearside pavement were excluded as they were not likely to be affected by this type of guard railing.
- For school sites, it was found that very few pupils crossed the road within the camera coverage, and many pupils used pedestrian crossings that were far from the school entrance/exit. It was difficult to judge whether pupils had accessed the entrance/exit from the opposite side pavement because of the limited coverage of the cameras. So, all pupils using the entrance/exit were counted, and those who did not cross within the observation area were assumed to use the formal pedestrian crossings.

Movements of three groups of interchange users/pupils were counted (Figure 5.19):

(A) Those who accessed the interchange/school using a nearby formal pedestrian crossing.
(B) Those who accessed the interchange/school directly not using a formal pedestrian crossing.
(C) Those who accessed the interchange/school by crossing elsewhere.

Three effectiveness indices were constructed:

- **Directly Crossing Rate (DCR),** which is the proportion of transportation interchange users/pupils who crossed the road directly in front of the entrance/exit (accessing the interchange/school directly not using a pedestrian crossing) to the all users who used the entrance/exit
  *(i.e. B/(A+B+C))*.
- **Crossing Rate at the associated pedestrian Crossing (CRC)**, which is the proportion of the transportation interchange users/pupils who used the associated pedestrian crossing to all users who used the entrance/exit
  *(i.e. A/(A+B+C)*.
- **Crossing rate at other locations (CRO),** which is the proportion of transportation interchange users/pupils who crossed at other locations (i.e., who crossed not directly in front of the entrance/exit and not using the associated pedestrian crossing) to all users who used the entrance/exit
  *(i.e. C/(A+B+C))*.

It is worth noticing that of the four observed transportation interchange sites, two sites with guard railing have a staggered arrangement between the entrance/exit and the associated pedestrian crossing. The CRC (crossing rate at the associated pedestrian crossing) is therefore an indication to the effectiveness of guard railing in guiding pedestrians to the crossing. The DCR (direct crossing rate) is an indication of the effectiveness of guard railing in preventing transportation interchange users from crossing directly to/from the entrance/exit. At the two sites without railing, the associated pedestrian crossing is aligned with the entrance/exit of the transportation interchange so the crossing is in the desire line of the crossing users. At these sites it is not possible to cross directly while not using the associated pedestrian crossing. The DCR will be zero, so may not be directly comparable with that at sites with railing.

#### 5.5.4.1 Behaviour Effect

The traffic and pedestrians conditions at the observed transportation interchange and school sites are shown in Table 5.8. One school site surveyed does not have guard rails, but bollards are used instead. Of the two school sites with rails, one site (1S01) has only a short section of railing while the other one (1S03) has guard rails extended to pedestrian crossings at both ends.

Sites with railing have higher average traffic speed. The directly crossing rates (DCR) are all very low. Sites without railing have higher traffic and pedestrian flow, but the differences are all small.

Direct crossings not using a pedestrian crossing are only observed at the school site (1S05) without railing. At the two transportation interchange sites, zebra crossings are aligned with the entrance/exit, so direct crossing not using a pedestrian crossing is not possible.

t-tests (assuming unequal variances) were conducted for the crossing rate at the pedestrian crossing (CRC), the crossing rate at other location (CRO) and the directly crossing rate (DCR). No statistically significant differences were found (CRO: t=-0.05; CRC: t=-0.32; DCR: t=1).

**Table 5.8: Traffic and Pedestrian Attributes at Transportation Interchange and School Sites**

| Site | | Traffic | | Pedestrian | | | |
|---|---|---|---|---|---|---|---|
| Guard Rail | Site ID | Veh Flow (vph) | 85%ile Speed (mph) | Ped Flow (pph) | CRO (%) | CRC (%) | DCR (%) |
| Transport Interchange | | | | | | | |
| without | 2T08 | 572 | 17.3 | 305 | 8.6 | 91.4 | - |
| without | 2T09 | 570 | 17.0 | 249 | 11.8 | 88.2 | - |
| with | 1T03 | 1472 | 26.4 | 278 | 5.6 | 94.4 | 0.0 |
| with | 2T06 | 425 | 17.3 | 512 | 15.2 | 84.8 | 0.0 |
| School | | | | | | | |
| without | 1S05 | 1728 | 25.1 | 346 | 0.0 | 95.7 | 4.3 |
| with | 1S01 | 1016 | 30.4 | 41 | 7.3 | 92.7 | 0.0 |
| with | 1S03 | 575 | 25.8 | 324 | 0.0 | 100.0 | 0.0 |
| All above sites | | | | | | | |
| Mean (no rail) | | 957 | 19.8 | 300 | 6.8 | 91.8 | 1.4 |
| Mean (with rail) | | 872 | 25.0 | 289 | 7.0 | 93.0 | 0.0 |

CRO: Crossing rate at Other Locations; CRC: Crossing Rate at the Associating Pedestrian Crossing; DCR: Directly crossing Rate;

### 5.5.4.2 Safety Effect

The average number of conflicts, accidents and pedestrian accidents at the observed transportation interchange and school sites are shown in Figure 5.21 -22. The overall rate of conflicts, accidents and pedestrian accidents is low. No pedestrian accidents and conflicts are observed at transportation interchange sites without railing and at school sites with railing. The number of conflicts and pedestrian accidents is higher at transportation interchange sites with railing than at sites without railing. School sites with railing show a better safety record in terms of conflicts, accidents and pedestrian accidents. However, these results are based on a very small sample, and should be interpreted with caution.

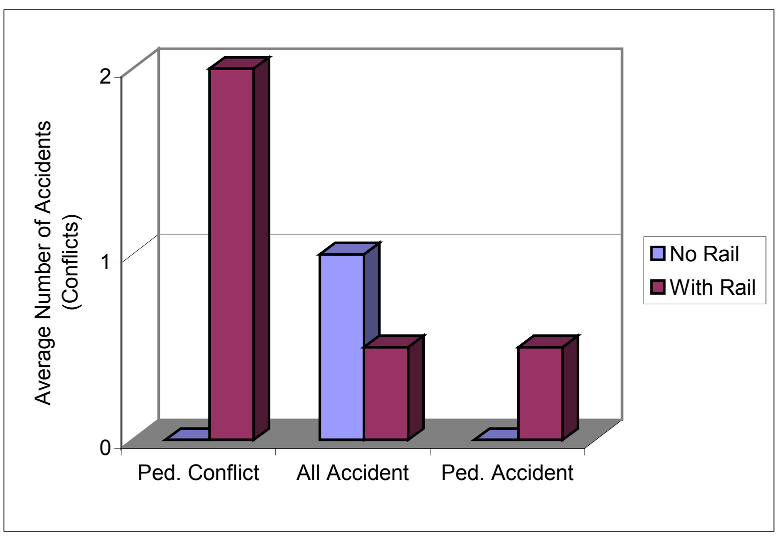



**Figure 5.21: Average Numbers of Accidents and Conflicts at Transportation Interchange Sites**


**Figure 5.22: Average Numbers of Accidents and Conflicts at School Sites**

## 5.6 EFFECTS OF TRAFFIC CONDITIONS AND PEDESTRIAN BEHAVIOUR ON SAFETY

Correlation coefficients between safety related attributes (conflict rate, accident and pedestrian accident rate) and traffic attributes (vehicle flow, 85%ile speed, pedestrian flow) at all sites were calculated to examine whether factors other than guard rails have a significant influence on safety (Table 5.9).

Guard rails are weakly related with pedestrian accident rate (correlation coefficient =-0.34). The negative coefficient indicates that pedestrian accidents are fewer at sites with railing than at sites without railing. Pedestrian flow is also weakly related with pedestrian accidents (correlation coefficient =0.34). The positive coefficient indicates that pedestrian accidents are fewer when pedestrian activities are lower.

**Table 5.9: Correlation Coefficients between Safety and Traffic Attributes**

| | Conflict | Accident | Ped. Accident | Guard Rail | V-Flow | 85%ile Speed | P-Flow |
|---|---|---|---|---|---|---|---|
| **Conflict** | 1 | | | | -0.02 | -0.08 | 0.01 |
| **Accident** | -0.12 | 1 | | | 0.26 | 0.08 | 0.12 |
| **Ped. Accident** | 0.22 | 0.41 | 1 | | -0.01 | -0.02 | **0.34** |
| **Guard Rail** | -0.12 | -0.06 | **-0.34** | 1 | 0.20 | 0.22 | -0.14 |

Correlation coefficients between safety related attributes (conflict rate, accident and pedestrian accident rate) and pedestrian behaviour indices (Utilisation Rate, Correct Use Rate, Formal Use Rate) at pedestrian and junction sites were also calculated and are shown in Table 5.10.

Guard rails are found to be positively correlated with pedestrian Formal Use Rate (correlation coefficient =0.53). The positive coefficient indicates that Formal Use Rate is higher at sites with railing than at sites without railing. It is also found that guard rails are weakly related with pedestrian accident rate (correlation coefficient =-0.42). The negative coefficient indicates that pedestrian accidents are fewer at pedestrian crossing and junction sites with railing than at sites without railing. Of three behaviour effectiveness indices, the Utilisation Rate, Correct Use Rate and Formal Use Rate, the correlation coefficients with guard rail are 0.37, 0.30 and 0.52 respectively. The Formal Use Rate has the highest correlation with the presence of guard rail so can be regarded as a suitable behaviour effectiveness index.

**Table 5.10: Correlation Coefficients between Safety and Behavioural Attributes**

| | Conflict | Accident | Ped. Accident | Guard Rail | UR | CUR | FUR |
|---|---|---|---|---|---|---|---|
| **Conflict** | 1 | | | | -0.48 | 0.40 | -0.24 |
| **Accident** | -0.15 | 1 | | | 0.06 | -0.08 | 0.01 |
| **Ped. Accident** | 0.07 | 0.46 | 1 | | -0.02 | -0.41 | -0.23 |
| **Guard Rail** | -0.06 | -0.16 | **-0.42** | 1 | 0.37 | 0.30 | **0.52** |

UR: Utilisation Rate; CUR: Correct Use Rate; FUR: Formal Use Rate

A regression analysis was carried out for conflict rate against accident rate and pedestrian accident rate. As shown in Figure 5.23, they do not show a definitive relationship. The general trend is that pedestrian accident rate increases in proportion with conflict rate.

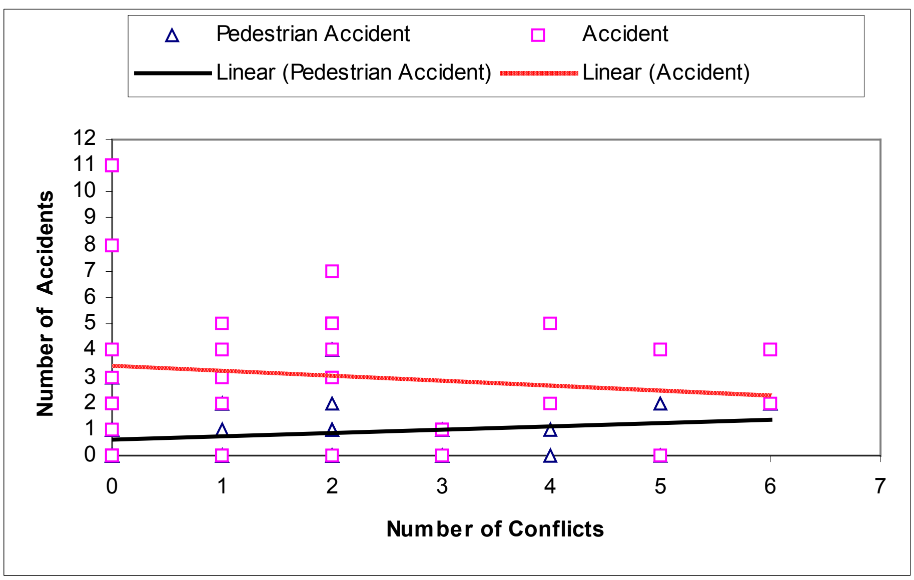



**Figure 5.23: Relationship between Accident and Conflict Rates**

The poor correlations between many of the affecting factors is likely to arise from the small sample sizes and the large random effect in the conflict and accident data, although erection of guard rails shows some effectiveness in increasing the formal use of the crossings and decreasing pedestrian accidents.

## 5.7 CONCLUSIONS

It has been shown that the effectiveness of guard railing is likely to be different at different types of sites. For example, at pedestrian crossings, installation of guard railing can effectively channel pedestrians to the crossing as indicated by the significant difference of utilisation rate between sites with and without railing. The same is not statistically significant at junction sites. This may be explained by the fact that pedestrian crossings are usually perpendicular to the direction of pedestrian movements, and pedestrians are found to cross outside the crossing if a suitable gap is available at sites without railing. On the other hand, pedestrian crossings at junctions are usually in the direction of the movements of the majority of pedestrians, even at sites without railing, so most pedestrians use the crossing whether or not there is guard rail and the difference has been shown to be insignificant. The correct use rate does not show a significant difference for the pedestrian crossing sites whilst it does for the junction sites.

At both pedestrian crossing and junction sites, the formal use rate is significantly higher at sites with railing than at sites without railing. This implies that at sites where guard rails are used to guide pedestrians to a desired crossing location, the effectiveness can be achieved both through guiding pedestrians to a crossing and guiding pedestrians on the crossing route.

Both accidents and pedestrian accidents are fewer at pedestrian crossing sites with railing. However, the accident rate is the same at junction sites with and without railings although pedestrian accidents are fewer at sites with railing. This indicates that guard railing could be generally worth erecting at pedestrian crossing sites, but this may not be always the case for junction sites as there could be a potential increase in vehicle accidents when guard rails are erected.

At link and central reservation sites, pedestrian activities on the carriageway are found to be significantly different. This is intuitively reasonable in that with the presence of guard railings, fewer pedestrians would either access or cross at these areas. However, some pedestrians avoid the restraints of the guard railing by climbing over it, and this could be potentially more dangerous.

Although pedestrian accident and conflict rates are lower at link and central reservation sites with railing, there are more accidents in total. While the all accident and pedestrian accident rate at the link and central reservation sites is below the all sites average, it may generally not be effective to erect guard railings at these sites.

At transportation interchange and school sites, no significant differences in behavioural indices are found between sites with and without railing. Pedestrian accidents are found to be more at transportation interchange sites with railing although accidents are fewer. The reason may be that the arrangements of the pedestrian crossings at observed transportation interchanges with railing are different from those without railing. The results may be indicating that a similar effect of guard rails may be achieved by a different arrangement of the pedestrian crossing with regard to entrance/exit of the transportation interchange.

At the observed school sites without railing, direct crossing events were observed although the number was small, while no such events were observed at the sites with railing. No conflicts, accidents and pedestrian accidents were found at school sites with railing. The effect of guard railing at school sites is evident.

# ACKNOWLEDGEMENTS

The authors would particularly like to thank Mr. Jonathan Fray of Transport for London for his valued guidance and discussion throughout the course of this research project.

We are also very grateful for the information and assistance provided by TfL Engineers and by the Engineers and Officers of the London boroughs, particularly in the London Borough of Ealing, London Borough of Hammersmith and Fulham, London Borough of Hillingdon, Royal Borough of Kensington and Chelsea and the City of Westminster.

## REFERENCES

Bagley, J. 1985. An assessment of the Safety Performance of Pelican Crossings in Relation to Criteria Value. P.T.R.C. Summer Annual Meeting, University of Sussex.

Department for Transport, 2002. Inclusive Mobility: A Guide to Best Practice on Access to Pedestrian and Transport Infrastructure, DfT Traffic Advisory Leaflet 6/02.

Department of Transport 1981. Pedestrian Facilities at Traffic Signal Installations, DOT Advice Note TA15/81.

Department of Transport, 1995(1). The Assessment of Pedestrian Crossings, Local Transport Note 1/95.

Department of Transport, 1995(2). The Design of Pedestrian Crossings, Local Transport Note 2/95.

Department of Transport, 2001. A Road Safety Good Practice Guide.

DTLR, 2002. The Installation of PUFFIN Pedestrian Crossings. Traffic Advisory Leaflet 1/02.

Erke, H. 1984. The Traffic Conflict Technique of the Federal Republic of Germany. International Calibration Study of Traffic Conflicts, NATO ASI Series Vol. F5, pp. 107-120, Springer-Verlag, Heidelberg, Germany.

Glauz, W.D. and D. J. Migletz. 1984. The Traffic Conflict Technique of the United States of America.

Hyden, C. 1987. The Development of a Method for Traffic Safety Evaluation: The Swedish Traffic Conflicts Technique. Bulletin 70, Department of Traffic Planning and Engineering, Lund Institute of Technology.

Hall, R. D. 1986. Accidents at four-arm single carriageway urban traffic signals. TRRL Contractor Report CR65, Transport and Road Research Laboratory, Crowthorne.

The Institution of Highways & Transportation (IHT). 1987. Guidelines for the safety audit of highways.

Kennedy J.V., R.D.Hall and S.R.Barnard, 1998. Accidents at urban mini roundabouts. TRL Report 281. Transport Research Laboratory, Crowthorne

Kittelson & Associates Inc. 1999. Traffic Conflict Studies Report – Working Paper 5. pp. 35.

Kou, C. C. and R. B. Machemehl. 1997. Modeling Driver Behaviour During Merge Manoeuvres. Southwest Region University Transportation Centre Report (SWUTC/97/472840-00064-1), pp305

Layfield R.E., R.D.Hall and K.Chatterjee, 1996. Accidents at urban priority crossroads and staggered junctions. TRL Report 185. Transport Research Laboratory, Crowthorne.

Parker, M. R. and C. V. Zegeer. 1989. Traffic Conflict Techniques for Safety and Operation – Observers Manual. FHWA Publications FHWA-IP-88-027, pp. 40.

Perkins, S. R. and J. L. Harris. 1968. Traffic Conflict Characteristics – Accident Potential at Intersections. Highway Research Record, Vol. 225, pp.35-41.

Simmonds, A. G. 1983. The effects of the erection of guard rail. Report ATWP 77, London Accident Analysis Unit, London.

Stewart, D. 1983. Pedestrian guard rails and Accidents, Traffic Engineering+Control, 29(9), pp. 450-455

Stewart, D. 1988. Visibility and Accidents at Pedestrian Guard rails, Vision in Vehicles II, A. G. Gale et al. (Ed.), Elsevier Science Publishers

Summersgill I.and R.E.Layfield, 1996. Non-junction accidents on urban single-carriageway roads. TRL Report 183. Transport Research Laboratory, Crowthorne

Summersgill I, J.V. Kennedy and D.Baynes, 1996. Accidents at 3-arm priority junctions on urban single carriageway roads. TRL Report 184. Transport Research Laboratory, Crowthorne

Summersgill I, J.V. Kennedy, R.D. Hall, A.J.Hickford and S.R.Bernard, 2001. Accidents at junctions on one-way urban roads. TRL Report TRL510. Transport Research Laboratory, Crowthorne

Taylor J.V., R.D.Hall and K.Chatterjee, 1996. Accidents at 3-arm traffic signals on urban single-carriageway roads. TRL Report 135. Transport Research Laboratory, Crowthorne

# APPENDIX A: SPEED MEASUREMENT FROM VIDEO RECORDING

## A.1 Method

A video recording is a sequence of frame images taken consecutively at a constant time interval, usually 0.04 seconds (25 frames per second). The position of a moving object changes frame by frame when a video recording is taken using a fixed video camera. The speed of a moving object can therefore be measured by comparing positions of the moving objects in different frames.

However, the position of a moving object in a frame image is difficult to measure accurately because of the reduced size of the image and the optical deformation. A practical way is to draw reference lines on the display screen, which are a known distance apart on the ground. The average speed of a moving object between the two reference lines can be obtained if the traveling time can be measured. The speed measurement problem is then converted to the measurement of event time when a moving object passes a reference line. As illustrated in Figure A.1, using a pair of reference lines a known distance apart *D*, if we can measure the two event times of passing each reference line, $t_1$ and $t_2$, then the speed of the moving object can be estimated using Equation A.1:

$$\tilde{v} = \frac{D}{t_2 - t_1} \qquad \text{(A.1)}$$

where $t_1$ and $t_2$ are the event time of passing a reference line which are estimations of the precise time of passing the reference lines by a moving object.

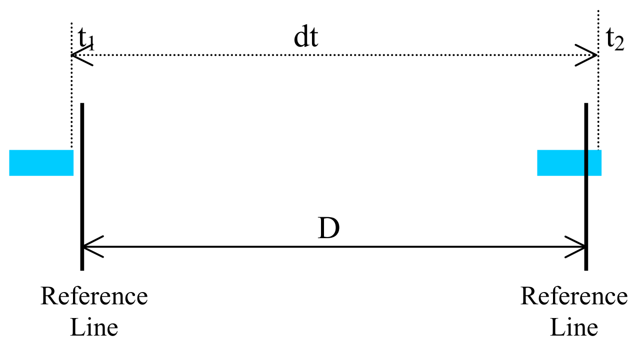



**Figure A.1: Speed Measurement using Event Times at Reference Lines**

An event time logging system, which was developed at the Transportation Research Group (TRG) of the University of Southampton, was used for the speed measurement. The core of the system is a Videocassette Recorder (VCR) controlled by a computer program, the Lane Monitor. Figure A.2 shows the hardware architecture and Figure A.3 is a screen shot of the Lane Monitor. The operator watches the monitor while playing the video frame by frame. If an event of interest happens (e.g., passing a reference line), he/she pushes a button. The computer program will register the event time and the button code, which will be saved into a text file at the end of a data reduction session. The system has a time-resolution of 1/25 second (25 frames per second).

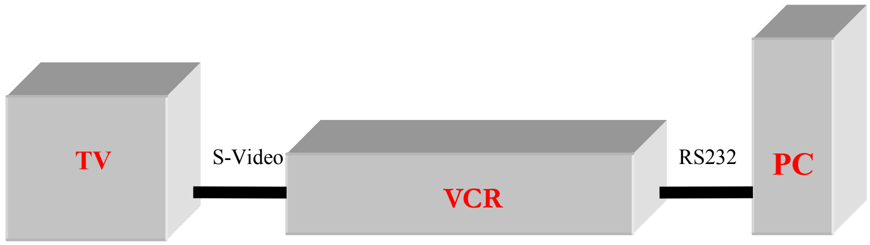



**Figure A.2: Hardware Architecture of Event Time Logger**

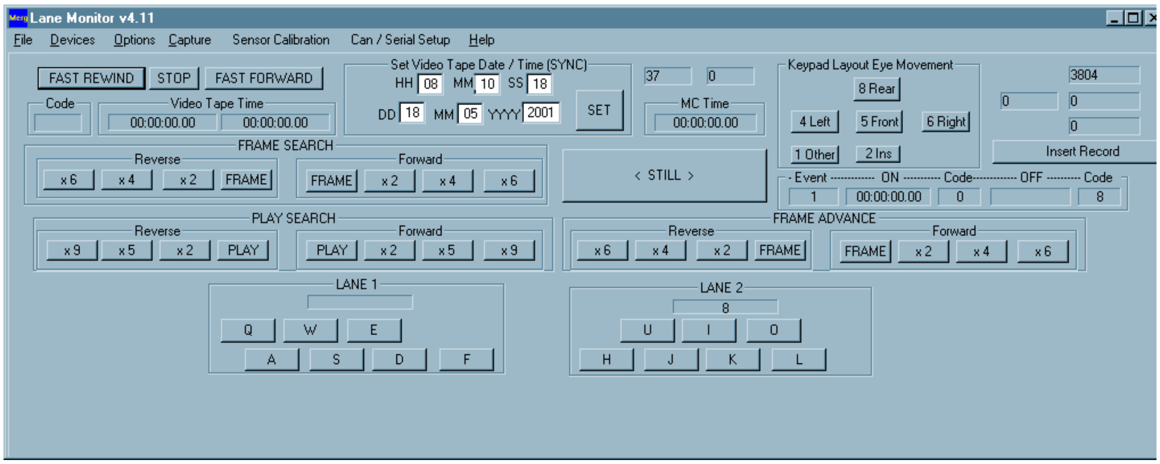



**Figure A.3: A Screenshot of Lane Monitor**

The speed of a moving object can then be calculated according to Equation A.1 based on two event times of passing the pair of reference lines.

## A.2 Measurement Error

A theoretical analysis of error in speed measurement using camera technology has been given by Kou (1997). Supposing the time base resolution of the video recorder/playback system is $k$, ($k$ frames per second), then a recorded event (such as passing a reference line) can occur at any time of $[t\text{-}1/k, t+1/k]$ with equal probability.

Therefore, the distribution of recorded time $t_1$, $t_2$ is

$$f(t_1)=k;\quad -1/2k<=t_1<=1/2k$$
$$f(t_2)=k;\quad -1/2k<=t_2<=1/2k$$

Let $t = ( t_2 - t_1) - D/v,$

where $v$ is the actual speed of the moving object to be measured and
$D$ is the distance between two reference lines.

The distribution of $t$ will be:

$$f(t) = k + k^2 t;\quad \text{for } -1/k<=t<=0;$$
$$f(t) = k - k^2 t\quad \text{for } 0<=t<=1/k;$$

Accordingly, the speed measurement error will be:

$$\varepsilon = \frac{D}{t + \frac{D}{v}} - v = \frac{-v^2 * t}{D + v * t} \qquad \text{(A.2)}$$

Using the variable transformation method, the distribution of speed measurement error can be obtained:

$$f(\varepsilon) = [k - \frac{k^2}{v}(\frac{\varepsilon D}{v+\varepsilon})]\frac{D}{(v+\varepsilon)^2} \qquad (for \quad 0 \le \varepsilon \le \frac{v^2}{kD - v}) \qquad \text{(A.3)}$$

$$f(\varepsilon) = [k + \frac{k^2}{v}(\frac{\varepsilon D}{v+\varepsilon})]\frac{D}{(v+\varepsilon)^2} \qquad (for \quad \frac{-v^2}{kD + v} \le \varepsilon \le 0) \qquad \text{(A.4)}$$

Figure A.4 shows the speed measurement error when k=25 frames/sec and D=9 m. The error will be within 1 m/s under 95% probability at a typical traffic speed of 30 mph (13.4 m/s). Increasing the distance intervals between adjacent reference lines, *D*, can reduce the measurement error of the average speed.

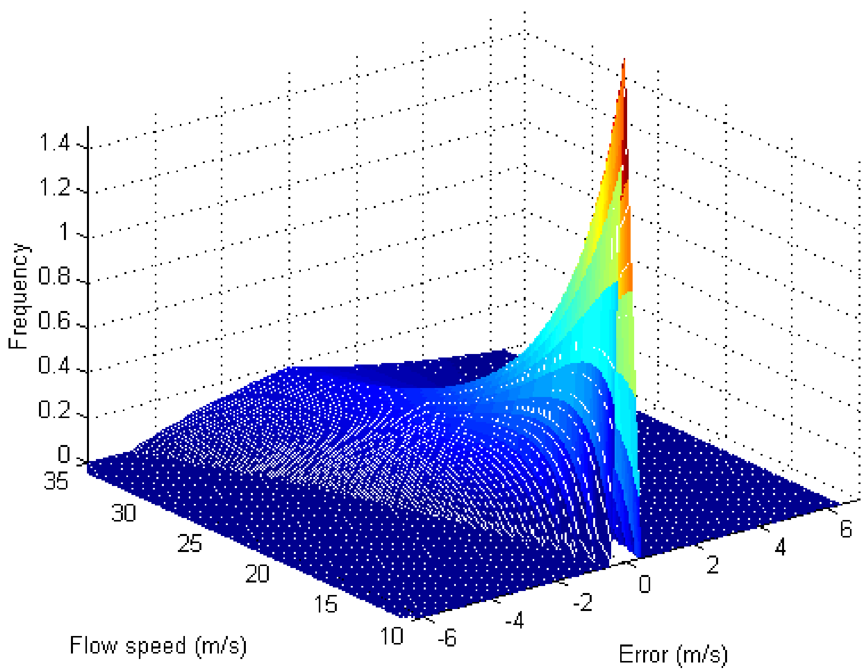



**Figure A.4: Distribution of Speed Measurement Error**

The position measurement error at the time-resolution of k is between [-v/2k, v/2k] supposing the reference line position is accurate enough, which equals about $\pm$1m. Measurement of the higher time derivatives such as acceleration rate is virtually impossible given the low accuracy of speed measurement. Theoretically, the acceleration rate measurement error is:

$$\eta = \frac{\varepsilon_2 - \varepsilon_1}{t + D/v} \qquad \text{(A.5)}$$

where: *a* is the actual acceleration to be measured,
$\varepsilon$ is speed measurement error with a distribution of Equation (A.3) and (A.4),
v is the actual average speed,
t and D are the same as defined above.

It is clear that the error will be larger than that of speed measurement error at normal traffic speed. That is to say, the acceleration measurement error will be greater than 2 $m/s^2$ given a speed measurement error of 2 m/s. A measured acceleration rate with an error of 2 $m/s^2$ will be meaningless, as it is large than the typical acceleration/deceleration rate a driver will use in merging. In conclusion, video camera technology is able to measure position and average speed with sufficient accuracy, but not acceleration.

# APPENDIX B: PEDESTRIAN CONFLICTS

## B.1 Overview

Traffic conflicts can be generally defined as traffic situations involving the interactions of two or more road users (vehicle, cyclist, pedestrian) where one or both take evasive action to avoid a collision. Several conflict analysis techniques have been developed since the 1960s, including the well-known US conflict technique and the Swedish conflict technique.

The US technique originated from the pioneering work conducted by Perkins et al. (1968) who developed a set of formal definitions and procedures for observing traffic conflicts that consisted of examining evasive actions or sudden braking. The definitions and observation procedures were further refined by Glauz et al. (1984) through extensive field testing in 1980, which eventually resulted in the publication of the Observers Manual and Engineers Manual for conducting traffic conflict analysis using the US technique (Parker et al., 1989).

The Swedish Conflict Technique has been developed and refined during a twenty-year period at the Department of Technology and Society, Lund University in Sweden. The definition was based on time-to-collision (TTC) which could be calculated from the speed and the distance between the two road users at the time of evasive action. According to Hyden (1987), conflicts under this definition could be considered dangerous by two means: a fixed TTC below 1.5 second or a speed-dependent TTC.

Conflicts could be also classified according to the severity of the evasive actions, e.g., German practice is to judge conflicts according to a predetermined severity scale of light, moderate and serious (Erke, 1984). It is clear that the definition for the conflict is not unique. The primary requirement of a traffic conflict is that the action of one user places the other user on a collision path unless evasive action is taken to avoid the accident.

A pedestrian conflict is one type of traffic conflict where one of road users involved is a pedestrian. According to the US technique (Glauz, et al., 1984), pedestrian conflicts occur when a pedestrian (the road user causing the conflict) crosses in front of a vehicle that has the right-of-way, thus creating a possible collision situation. However, pedestrian movements having the right-of-way, such as during a WALK phase, are generally not considered to create conflict situations.

For the purpose of this research, we are interested in the safety implication of guard railing on pedestrian activities. Such activities include but are not limited to crossing the carriageway, e.g., walking along the carriageway can also result in evasive action on the part of through traffic and thus forms a pedestrian conflict. Accordingly, we need to develop specific definitions and observation procedures of pedestrian conflicts within the general framework of traffic conflicts.

## B.2 Definition

### B.2.1 GENERAL DEFINITION

A pedestrian conflict is defined as a traffic situation involving a vehicle and a pedestrian in which either or both of them have to take evasive action to avoid a collision.

Figure B.1 illustrates the settings of possible conflicts between pedestrians and vehicles. The path of a vehicle is not necessarily straight as the vehicle in question may be making a turning manoeuvre. To constitute a pedestrian conflict, either vehicle or pedestrian must take evasive actions to avoid potential collision. The evasive action could be:

On the part of the vehicle
- Braking
- Acceleration
- Swerving

On the part of the pedestrian
- Sudden stop in the middle of carriageway
- Run to reach other end (e.g. footpath or island) from carriageway
- Back to footpath from carriageway

The pre-requisite for associating an evasive action with a pedestrian conflict is that such action must be necessary to avoid a collision.

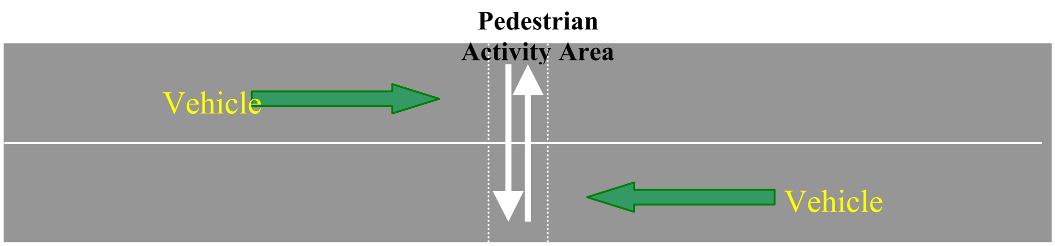



**Figure B.1: Pedestrian Activities in the Path of Traffic**

### B.2.2 OPERATIONAL DEFINITIONS

Within the general definition of a pedestrian conflict, a set of conflict definitions have been developed for operational purposes based on pedestrian activities.

Two types of pedestrian activities can be distinguished according to the purpose of movement:
- Walking on the carriageway, which may be observed when pavements are congested, obstructed, etc.
- Crossing the carriageway, which may happen at formal pedestrian crossings or at other road sections. If the crossing involves more than one stage because of the existence of a pedestrian refuge or central reservation, each stage is treated separately.

Pedestrians have the right of way at zebra crossings, during the pedestrian phase at traffic signals and in crossing the minor road of a junction into which a vehicle is turning. Otherwise, pedestrians are required to give way to traffic. Pedestrian conflicts can happen when pedestrians do not have the right of the way. For example, a pedestrian crossing against a pedestrian signal may cause a conflict. It can also happen when pedestrians have the right of the way. For example, a vehicle failing to stop for a pedestrian crossing at a zebra crossing may be forced to swerve to avoid a collision. Conflicts resulting from violations by one of the road users are basically the same as those resulting from non-violation behaviour in terms of the evasive actions taken.

In this research, conflicts are judged by the purpose of the evasive action taken by the road users. If an evasive action is taken to avoid an imminent collision, a conflict will be registered. Otherwise, no conflict will be registered. For example, if a pedestrian walking on the carriageway responds to an approaching vehicle by stepping back onto the pavement, the behaviour is not interpreted as an evasive action and no conflict will be registered. Also, a vehicle braking to stop for a pedestrian in accordance with a traffic signal or at a zebra crossing will not be identified as a conflict. On the other hand, if the vehicle having the right of way takes evasive action to avoid a collision with a pedestrian, a conflict will be registered. In total, 8 types of pedestrian conflicts are defined:

**Sudden-appearance Conflict** (Figure B.2)
A pedestrian walking on the pavement stepped on to the carriageway abruptly, caused an approaching vehicle to brake severely or swerve to avoid collision.

**Clearance Conflict** (Figure B.3)
A pedestrian walking on the carriageway caused an overtaking vehicle to swerve out of its lane, or brake to give up overtaking.

**Conflict with near-side, left turn traffic** (Figure B.4)
A pedestrian crossing in the path of a vehicle that is going to turn left causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.

**Conflict with near-side, through traffic** (Figure B.5)
A pedestrian crossing in the path of a through vehicle coming from the pedestrian's right causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.

**Conflict with near-side, right turn traffic** (Figure B.6)
A pedestrian crossing in the path of a vehicle that is going to turn right causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.

**Conflict with far-side, left turn traffic** (Figure B.7)
A pedestrian crossing in the path of a left turning vehicle causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions. If the vehicle is turning into a side road, the pedestrian has the right of way; therefore, the action that the vehicle stops to wait for the clearance of pedestrians is not an evasive action.

**Conflict with far-side, through traffic** (Figure B.8)
A pedestrian crossing in the path of a through vehicle coming from the pedestrian's left causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.

**Conflict with far-side, right turn traffic** (Figure B.9)
A pedestrian crossing in the path of a right turning vehicle causing the vehicle to take evasive action, or the pedestrian who has left the pavement takes evasive action, or both take evasive actions.

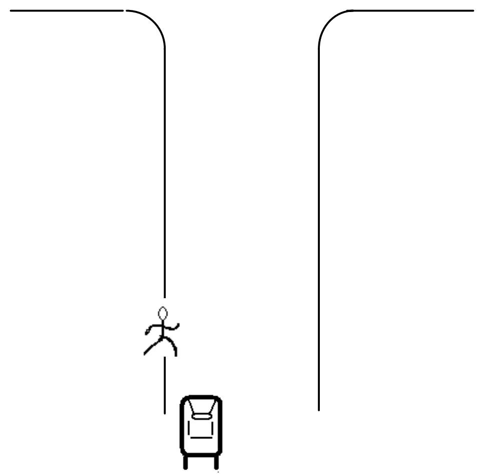


**Figure B.2: Sudden-Appearance Conflict**

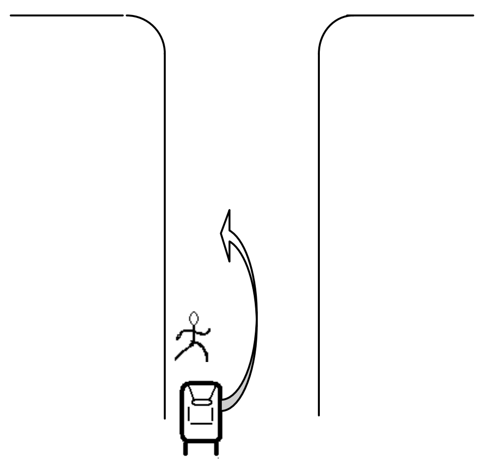


**Figure B.3: Clearance Conflict**

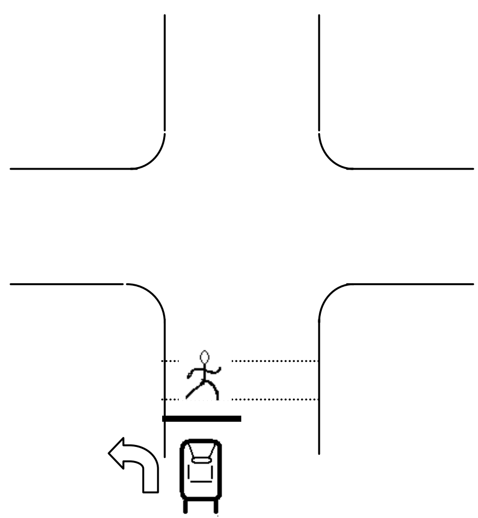


**Figure B.4: Conflict with near-side, left-turn traffic**

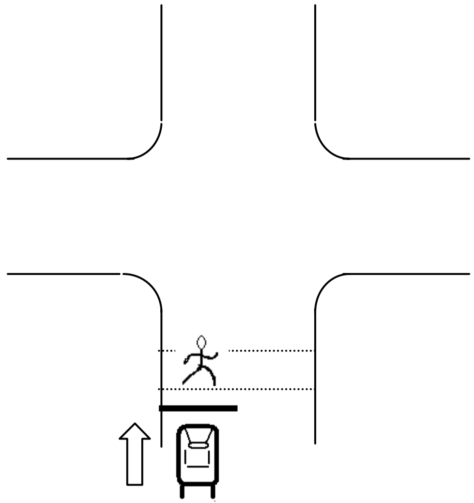


**Figure B.5: Conflict with near-side, through traffic**

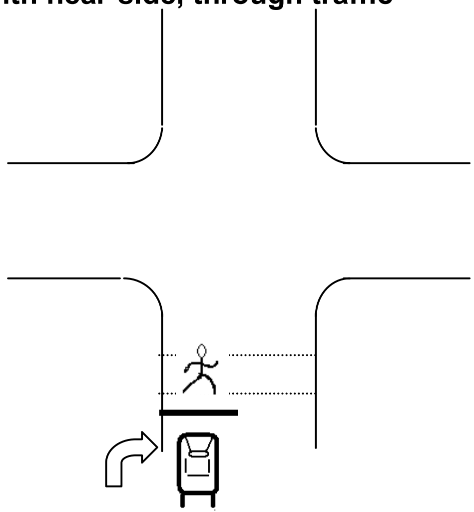


**Figure B.6: Conflict with near-side, right turn traffic**

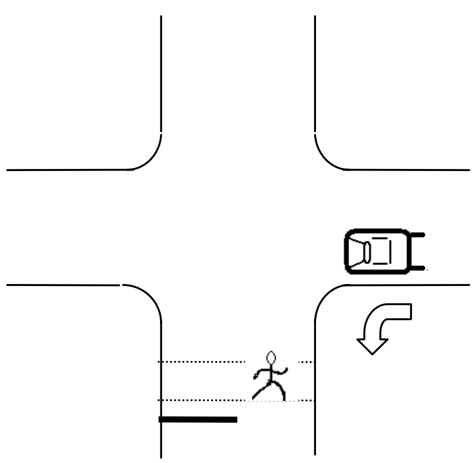


**Figure B.7: Conflict with far-side, left turn traffic**

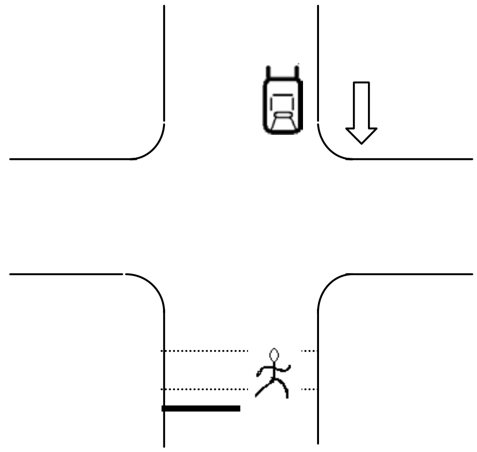


**Figure B.8: Conflict with far-side, through traffic**

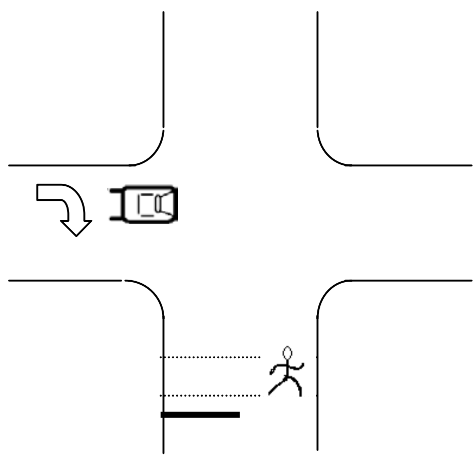


**Figure B.9: Conflict with far-side, right turn traffic**

B.3 Conflict Identification

Pedestrian conflicts were judged subjectively. By playing the videotape at normal speed, evasive actions by both pedestrians and vehicles can be observed. If they fall into the conflict definitions, a conflict will be registered.

It can sometimes be difficult to distinguish an evasive action from a planned response. For example, it can be observed that some pedestrians walk quicker or run in the latter stage of crossing in order not to impede an on-coming vehicle, although the driver has noticed the pedestrian and is able to slow down if the pedestrian keeps a constant walking speed. Another difficult situation involves the stopping of pedestrians in the middle of road. Some pedestrians cross the road in two stages especially when the traffic is heavy. They first arrive in the middle part of the road by accepting a gap in the nearside traffic, and then stop there while waiting for another gap in the far side traffic. This kind of stopping could be a planned response so does not constitute a conflict.

Under these difficult situations, subjective judgements are made to determine whether an action is not planned and instead constitutes collision avoidance. This has sometimes been supplemented by a quantitative Time To Collision (TTC) criteria. A TTC of 1.5 seconds has been adopted to help judge conflicts in this research. The TTC of a conflicting vehicle to pedestrian can be derived from the videotape, which is calculated according to:

$$TTC=D/V,$$

where D is the distance between the conflicting vehicle and the pedestrian and
V is the speed of the vehicle at the time of conflict.

Alternatively, TTC can be measured approximately by counting the time elapsed between the evasive action and arrival at the projected collision position. This method is suitable if the speed change of the road users involved in a potential conflict is not significant.

The registered conflicts are those which either meet the subjective criteria or the quantitative TTC criteria.

# APPENDIX C: SITE INFORMATION

This appendix details the sites surveyed in this research. The information provided includes:

- Traffic speed and flow rate
- Pedestrian behaviour indices
- Number of Pedestrian Conflicts (in 4 hours)
- Number of accidents and Pedestrian Accidents (3 years) within the observation area
- A photo giving an overview of the geometry of the site
- A graph showing location of all the accidents in an area wider than the observation area

For each type of site, averages of the above quantitative attributes have been given in the main body of the report. The sites are presented in the order given in Table 4.2.

These sites could be used as reference sites when applying guidelines for the erection/removal of guard railing developed in this research. The quantitative attributes provided could be used to determine the expected behaviour and safety effectiveness of guard railing for similar sites under consideration.

It should be noted that the number of Pedestrian Conflicts is based on 4 hours of observation at each site. Accidents refer to all accidents recorded in the three years 2000-2002. Brief definitions of the pedestrian behaviour indices are given below; please refer to the main report for detailed definitions.

Pedestrian Crossings and Junctions

- **Utilisation rate (UR)**: the proportion of pedestrians who used the crossing fully or partly to all crossing pedestrians.
- **Correct use rate (CUR):** the proportion of pedestrians who crossed used the crossing fully to those pedestrians who used the crossing fully or partly.
- **Formal use rate (FUR)**: the proportion of pedestrians who used the crossing fully to all crossing pedestrians.

Links and Central Reservations

- **Activity rate (AR)**: count of pedestrian activities on the carriageway (crossing, walking etc.) within the observation area.

Schools and Transportation Interchanges

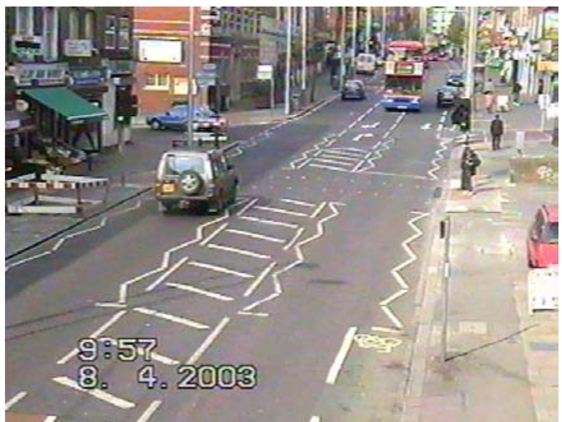
- **Directly crossing rate (DCR):** the proportion of transportation interchange users/pupils who crossed directly in front of the entrance/exit to the all users who used the entrance/exit.
- **Crossing rate at the associated pedestrian crossing (CRC):** the proportion of the transportation interchange users/pupils who used the associated pedestrian crossing to all users who used the entrance/exit.
- **Crossing rate at other locations (CRO):** the proportion of transportation interchange users/ pupils who crossed at other locations (i.e., who crossed not directly in front of entrance/exit and not using the associated pedestrian crossing) to all users who used the entrance/exit.

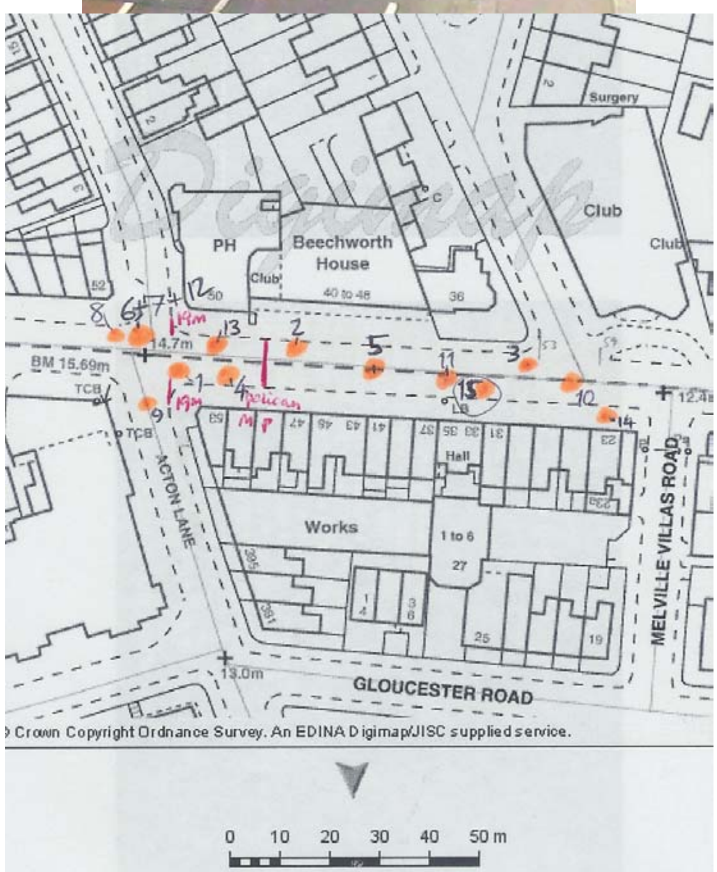
Note that the 4-digit Site number consists of:

(4) Borough number, 1=Ealing, 2=Westminster, 3=Kensington & Chelsea, 4=Hammersmith & Fulham, 5=Hillingdon
(5) Type: L= retail area (link), T= Transport interchange, J= Junction, P= pelican, Z= zebra, R= Refuge, S= School, C= Central Reservation
(6) Serial number (two digits) of the site

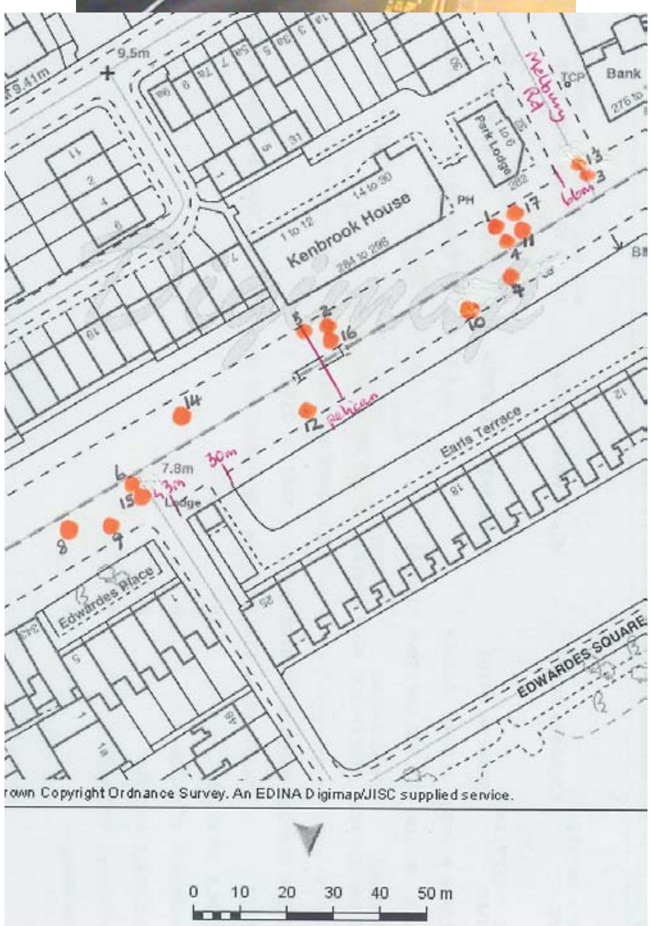
## Pelicans without railing

| Site | 1P03 | Pelican | |
|---|---|---|---|
| Location | Acton High Street near Grove Rd / Acton Lane | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1589 vph | | |
| 85%ile Speed | 23.2 mph | | |
| Crossing pedestrian flow | 71 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 2 | | |
| All Accidents (3 years) | 5 | | |
| Pedestrian Accidents (3 years) | 4 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 86.1% | 91.3% | 78.6% |



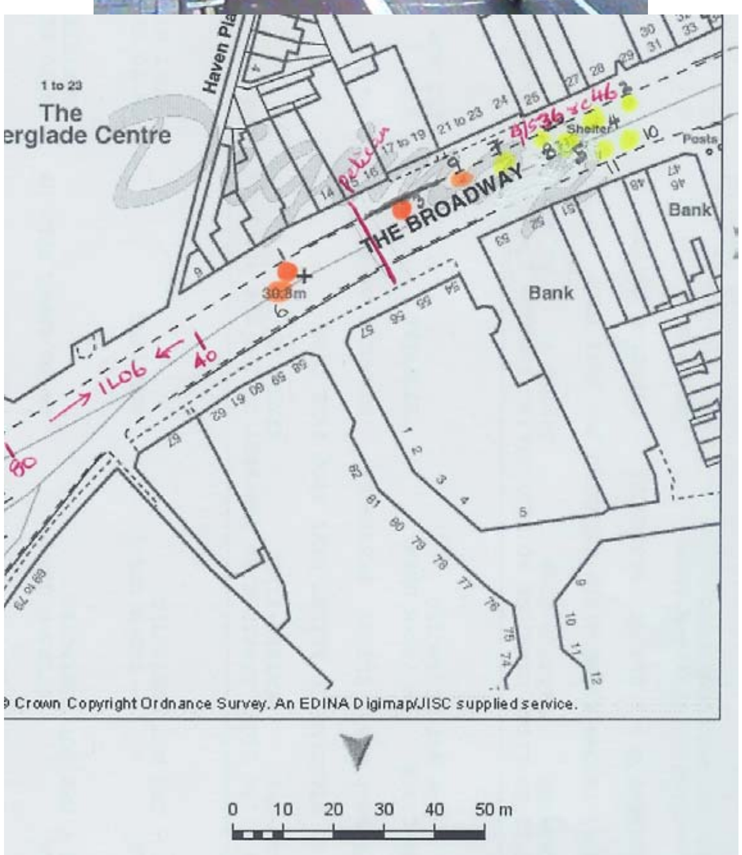



| **Site** | **3P10** | **Pelican** | |
|---|---|---|---|
| Location | Kensington High Street near Melbury Road | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1379 vph | | |
| 85%ile Speed | 36.2 mph | | |
| Crossing pedestrian flow | 70 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 4 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 84.3% | 93.2% | 78.5% |

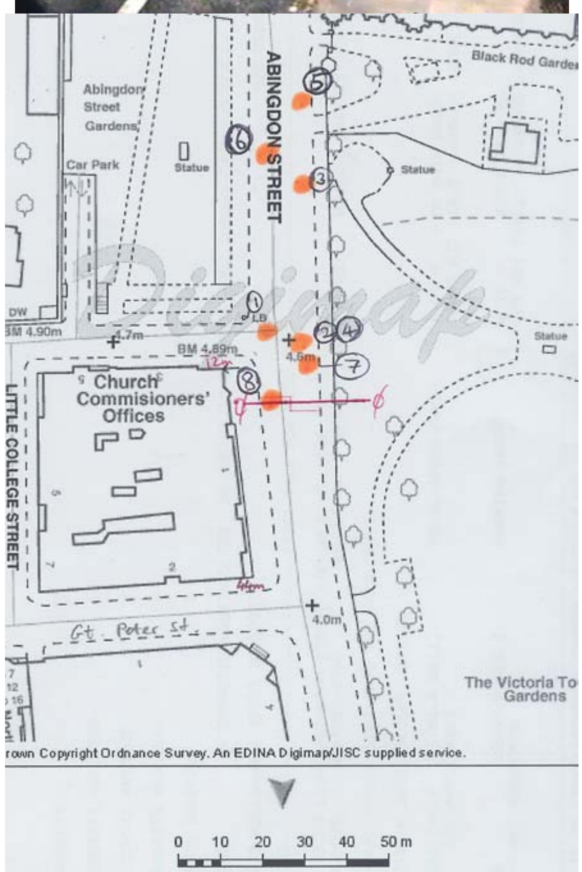



## Pelicans with railing

| **Site** | **1P02** | **Pelican** | |
|---|---|---|---|
| Location | The Broadway (Ealing) near Haven Street | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1637 vph | | |
| 85%ile Speed | 22.8 mph | | |
| Crossing pedestrian flow | 558 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 6 | | |
| All Accidents (3 years) | 4 | | |
| Pedestrian Accidents (3 years) | 2 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 92.9% | 99.2% | 92.1% |

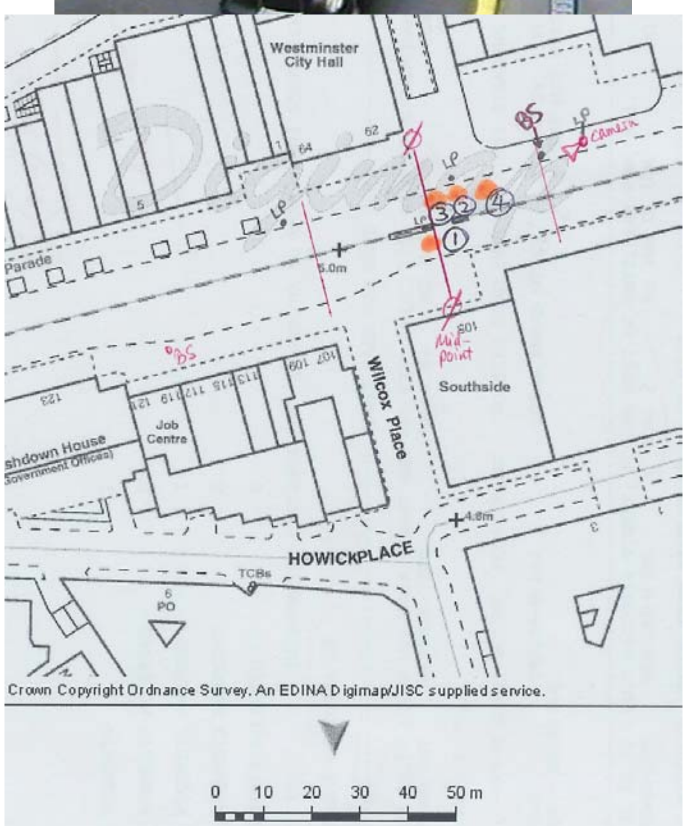



| **Site** | **2P11** | **Pelican** | |
|---|---|---|---|
| Location | Millbank near College Street | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1529 vph | | |
| 85%ile Speed | 38.1 mph | | |
| Crossing pedestrian flow | 233 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 2 | | |
| All Accidents (3 years) | 5 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 93.0% | 92.4% | 86.0% |

## Refuge without railing

| Site | 2R03 | Refuge | |
|---|---|---|---|
| Location | Victoria Street near Buckingham Gate | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1201 vph | | |
| 85%ile Speed | 27.6 mph | | |
| Crossing pedestrian flow | 541 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 5 | | |
| All Accidents (3 years) | 4 | | |
| Pedestrian Accidents (3 years) | 2 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 55.6% | 97.6% | 54.2% |

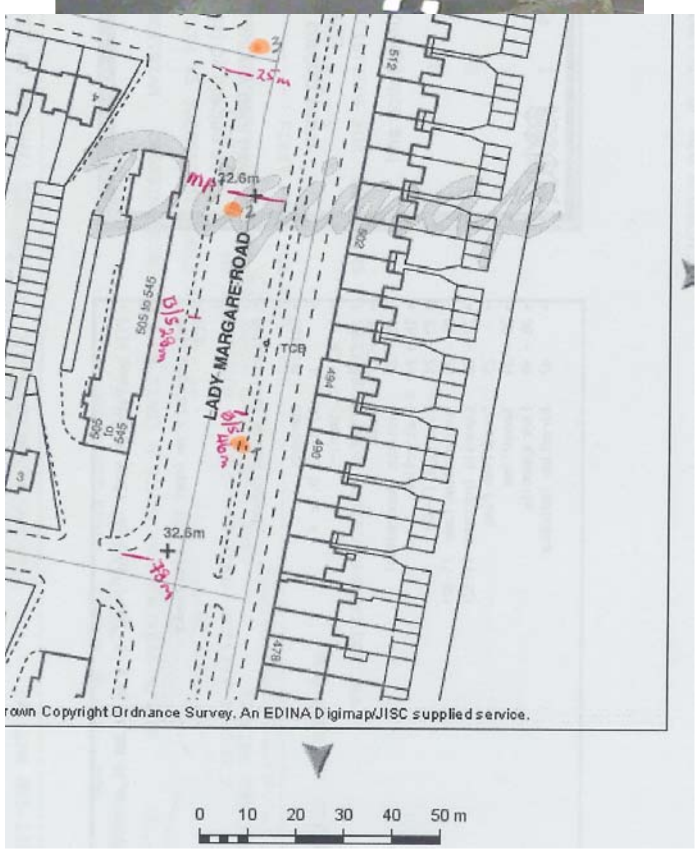



## Refuge with railing

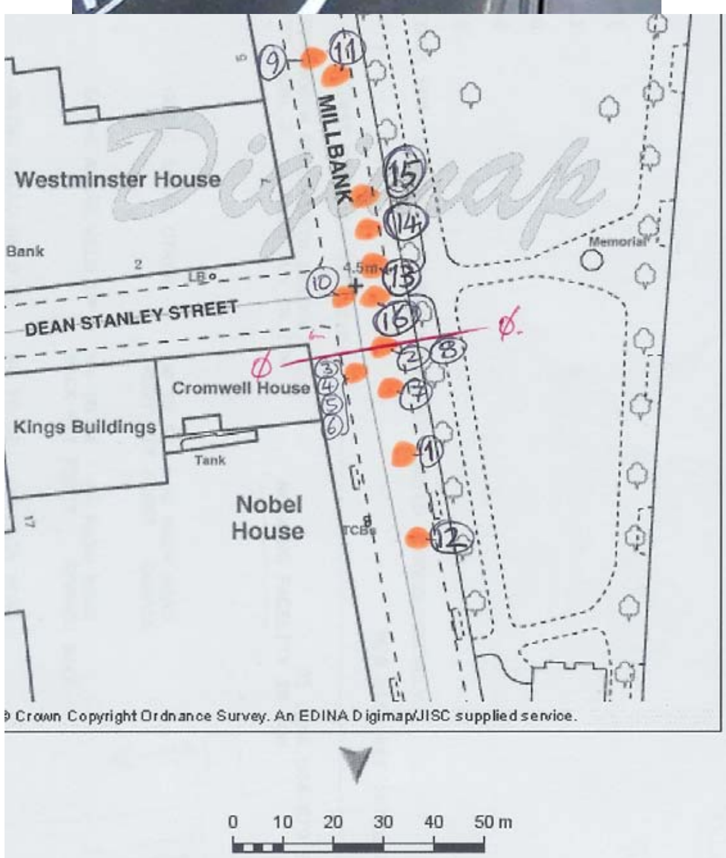
| **Site** | **1R04** | **Refuge** | |
|---|---|---|---|
| Location | Oldfields Lane near Croyd Avenue | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 693 vph | | |
| 85%ile Speed | 33.0 mph | | |
| Crossing pedestrian flow | 43 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 3 | | |
| All Accidents (3 years) | 1 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 93.0% | 100% | 93.0% |


## Zebras without railing

| **Site** | **1Z06** | **Zebra** | |
|---|---|---|---|
| Location | Lady Margaret Road near Kenilworth Gardens | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1493 vph | | |
| 85%ile Speed | 37.6 mph | | |
| Crossing pedestrian flow | 27 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 1 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 93.4% | 90.3% | 84.3% |

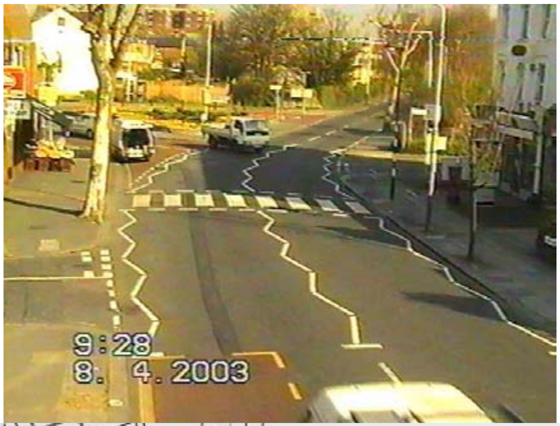



| **Site** | **2Z07** | **Zebra** | |
|---|---|---|---|
| Location | Millbank / Dean Stanley Street | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1488 vph | | |
| 85%ile Speed | 36.9 mph | | |
| Crossing pedestrian flow | 210 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 11 | | |
| Pedestrian Accidents (3 years) | 3 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 90.1% | 85.8% | 77.3% |

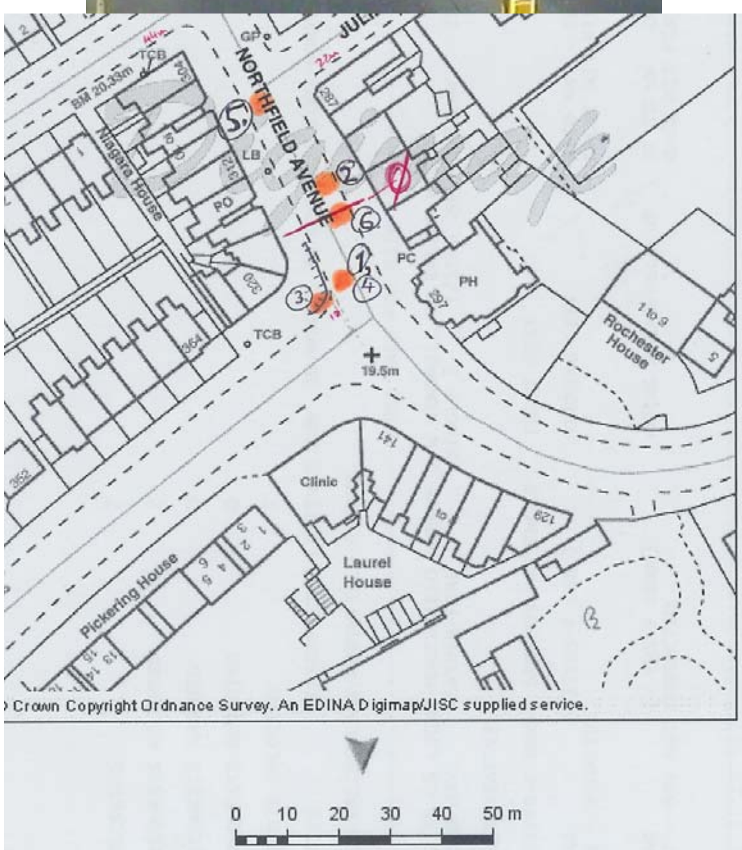



## Zebras with railing

| **Site** | **1Z08** | **Zebra** | |
|---|---|---|---|
| Location | Northfield Avenue / Seaford Road | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1010 vph | | |
| 85%ile Speed | 30.3 mph | | |
| Crossing pedestrian flow | 85 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 2 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 93.7% | 78.9% | 74.0% |

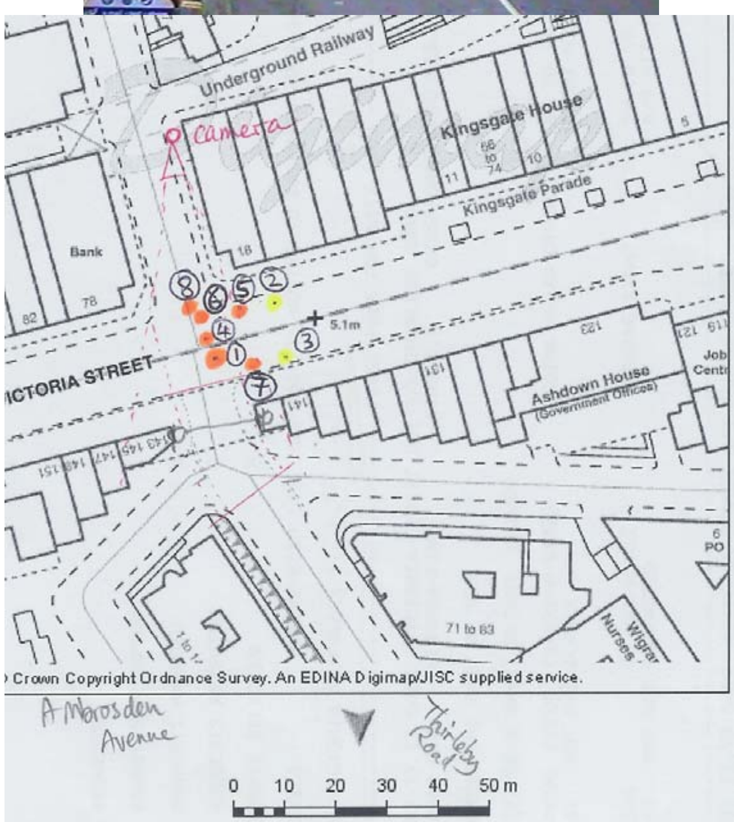



| | | | |
|---|---|---|---|
| **Site** | **1Z09** | **Zebra** | |
| Location | Northfield Avenue / Windmill Road | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1206 vph | | |
| 85%ile Speed | 23.6 mph | | |
| Crossing pedestrian flow | 306 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 4 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 98.3% | 100.0% | 98.3% |

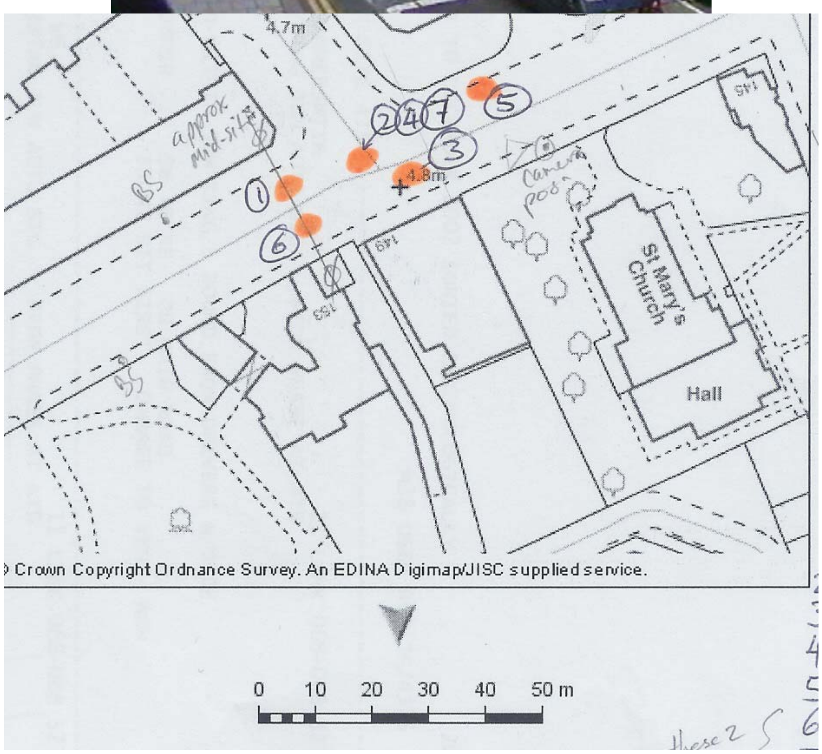



## Signalised Junction without railing

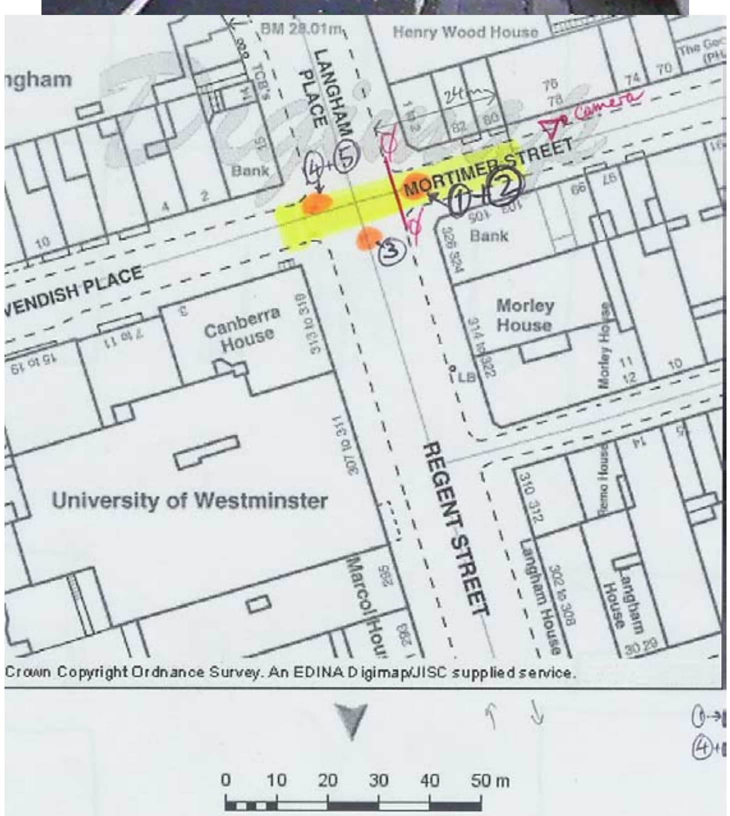
| **Site** | **2J11** | **Junction - Signals** | |
|---|---|---|---|
| Location | Victoria Street / Palace Street | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 233 vph | | |
| 85%ile Speed | 12.3 mph | | |
| Crossing pedestrian flow | 1133 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 1 | | |
| All Accidents (3 years) | 3 | | |
| Pedestrian Accidents (3 years) | 2 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 96.4% | 81.2% | 78.3% |

| **Site** | **4J16** | **Junction** | |
|---|---|---|---|
| Location | Hammersmith Road / Brook Green | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1226 vph | | |
| 85%ile Speed | 22.8 mph | | |
| Crossing pedestrian flow | 94 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 2 | | |
| All Accidents (3 years) | 5 | | |
| Pedestrian Accidents (3 years) | 2 | | |
| | | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 83.8% | 94.7% | 79.4% |

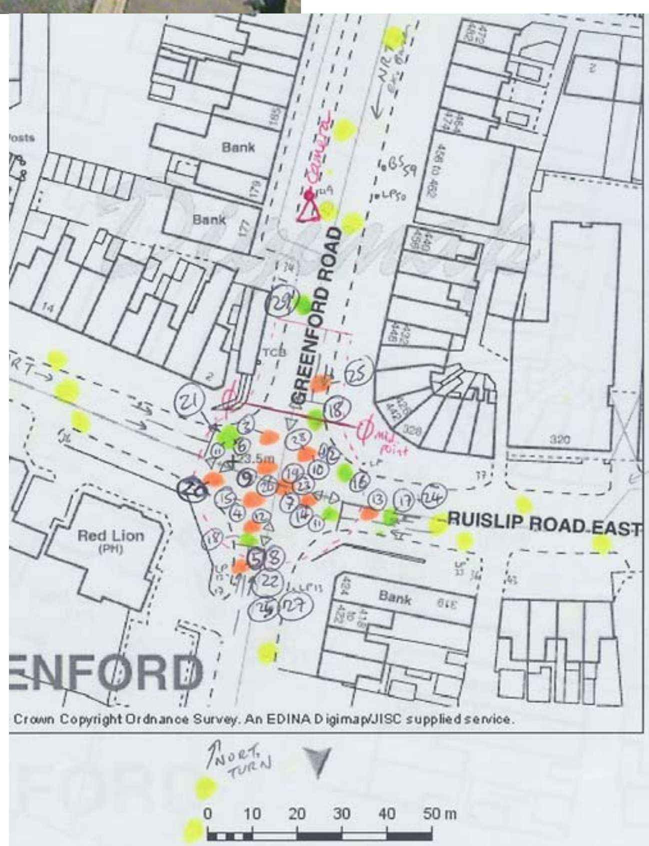



| **Site** | **2J19** | **Junction** | |
|---|---|---|---|
| Location | Regent Street / Cavendish Place | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 842 vph | | |
| 85%ile Speed | 19.4 mph | | |
| Crossing pedestrian flow | 749 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 1 | | |
| All Accidents (3 years) | 3 | | |
| Pedestrian Accidents (3 years) | 2 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 91.4% | 96.5% | 88.2% |

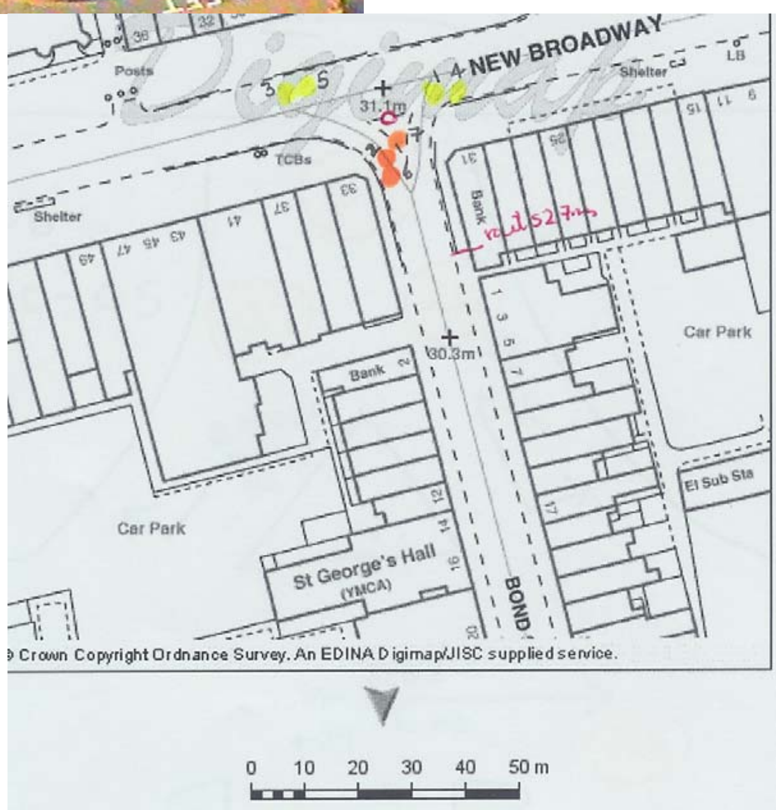



## Signalised Junction with railing

| Site | 1J05 | Junction | |
|---|---|---|---|
| Location | Ruislip Road / Greenford Avenue | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1541 vph | | |
| 85%ile Speed | 21.9 mph | | |
| Crossing pedestrian flow | 656 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 11 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 88.8% | 99.4% | 88.3% |

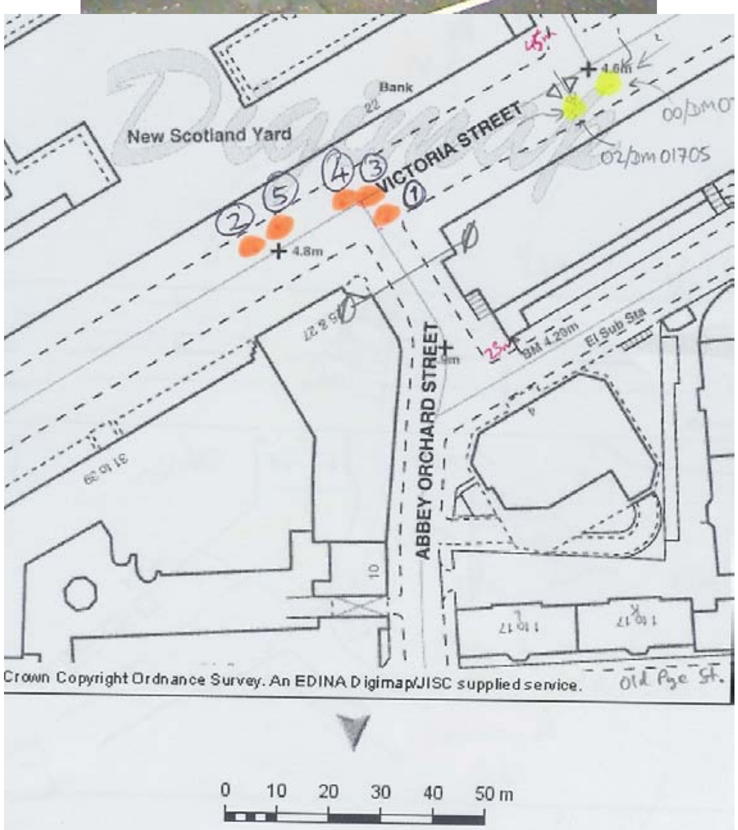
| **Site** | **1J06** | **Junction** | |
|---|---|---|---|
| Location | New Broadway / Bond Street (Ealing) | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 620 vph | | |
| 85%ile Speed | 19.7 mph | | |
| Crossing pedestrian flow | 536 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 2 | | |
| All Accidents (3 years) | 3 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 91.4% | 99.9% | 91.4% |

| **Site** | **2J12** | **Junction** | |
|---|---|---|---|
| Location | Edgware Road / Church Street | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1889 vph | | |
| 85%ile Speed | 24.5 mph | | |
| Crossing pedestrian flow | 214 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 1 | | |
| All Accidents (3 years) | 5 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 97.3% | 100.0% | 97.3% |

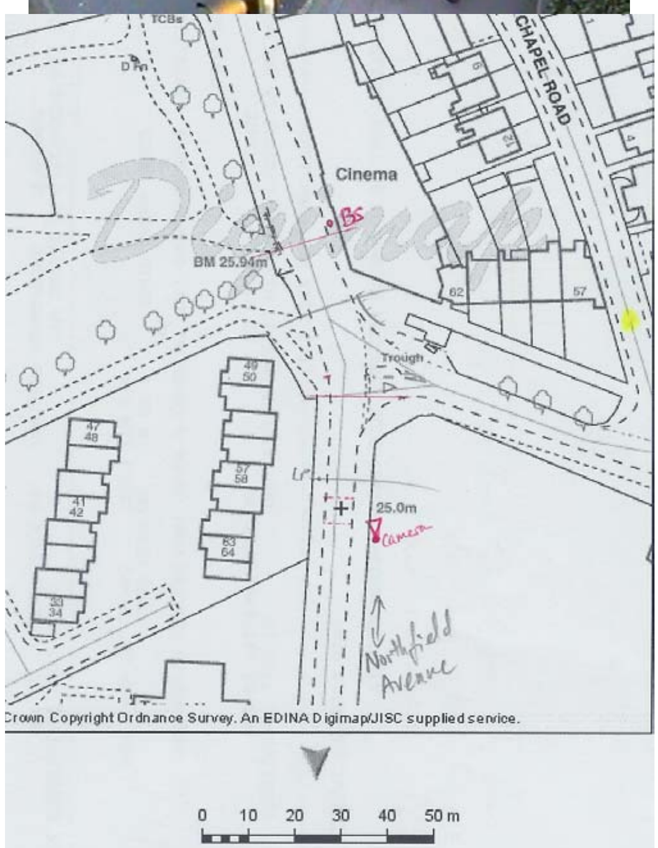

## Priority T Junction without railing

| Site | 2J18 | Junction | |
|---|---|---|---|
| Location | Victoria Street / Abbey Street | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 144 vph | | |
| 85%ile Speed | 11.0 mph | | |
| Crossing pedestrian flow | 387 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 2 | | |
| All Accidents (3 years) | 3 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 71.2% | 98.9% | 70.4% |

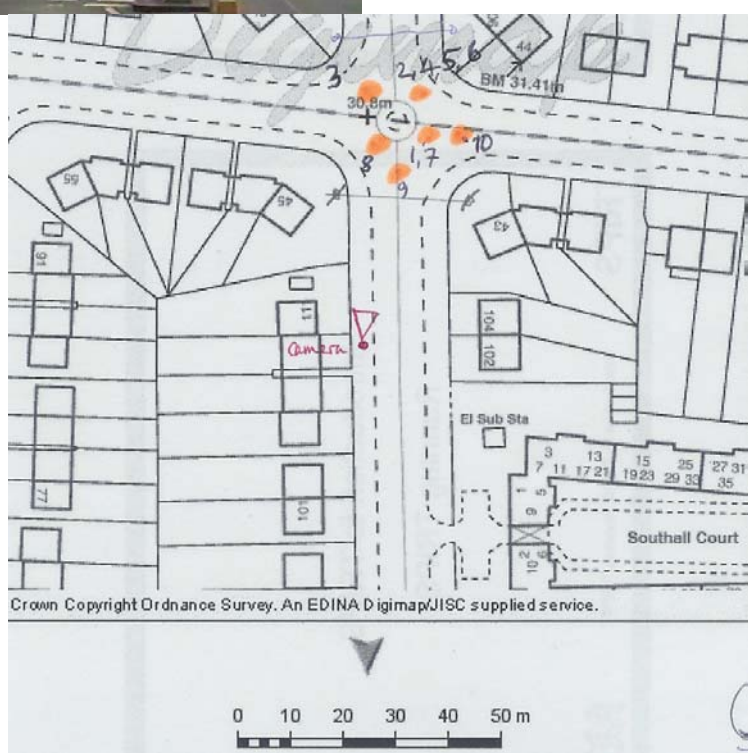
## Priority T Junction with railing

| Site | 1J17 | Junction | |
|---|---|---|---|
| Location | Northfield Avenue / Mattock Lane | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1125 vph | | |
| 85%ile Speed | 27.1 mph | | |
| Crossing pedestrian flow | 3 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 1 | | |
| All Accidents (3 years) | 0 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 93.8% | 100.0% | 93.8% |

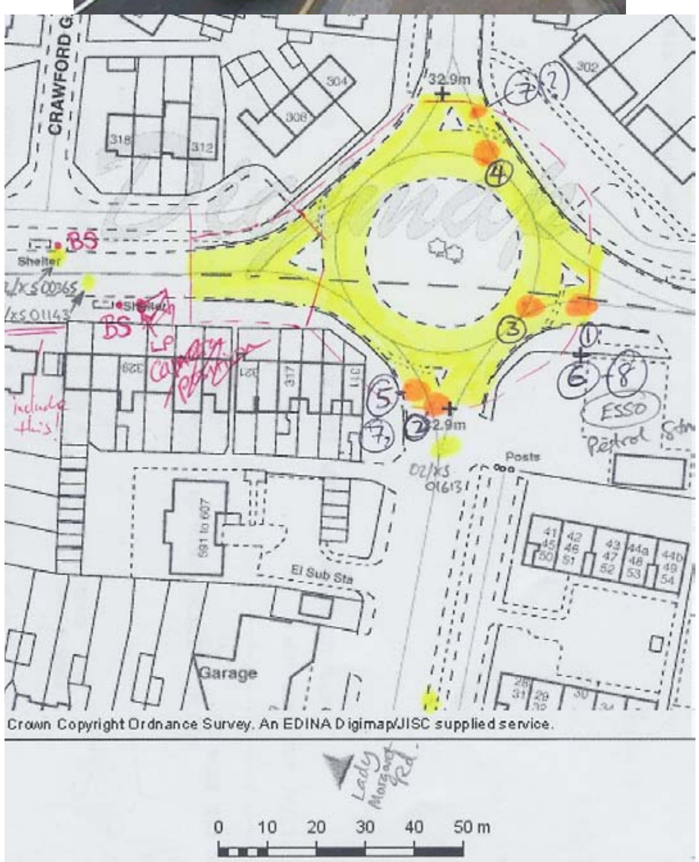
## Roundabout without railing

| Site | 1J20 | Junction | |
|---|---|---|---|
| Location | Lady Margaret Road / Carlyle Avenue | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1221 vph | | |
| 85%ile Speed | 25.2 mph | | |
| Crossing pedestrian flow | 36 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 4 | | |
| All Accidents (3 years) | 5 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 81.4% | 100.0% | 81.4% |

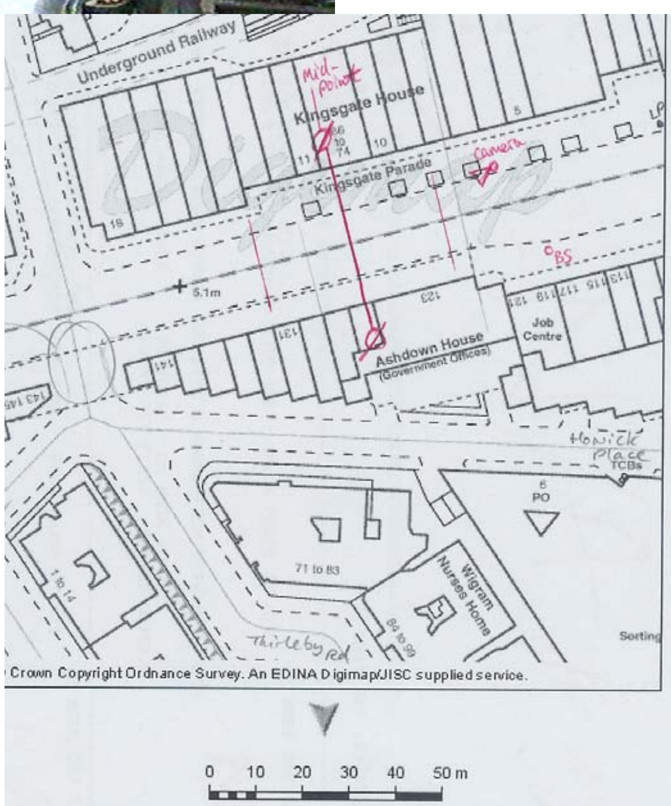
## Roundabout with railing

| **Site** | **1J21** | **Junction** | |
|---|---|---|---|
| Location | Ruislip Road / Lady Margaret Road | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 2813 vph | | |
| 85%ile Speed | 23.4 mph | | |
| Crossing pedestrian flow | 54 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 2 | | |
| All Accidents (3 years) | 0 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | UR(%) | CUR(%) | FUR(%) |
| | 69.7% | 98.1% | 68.4% |

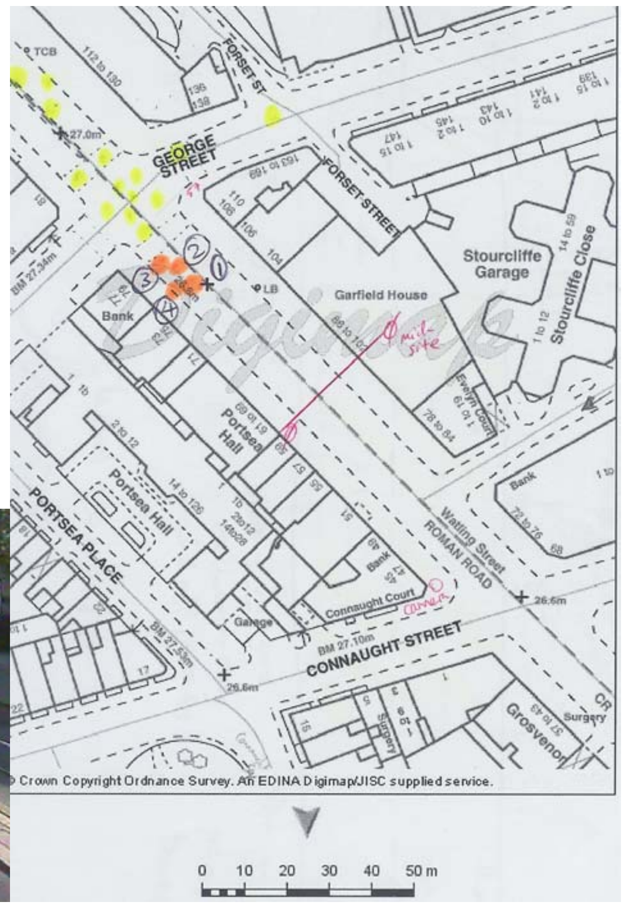



### Links without railing

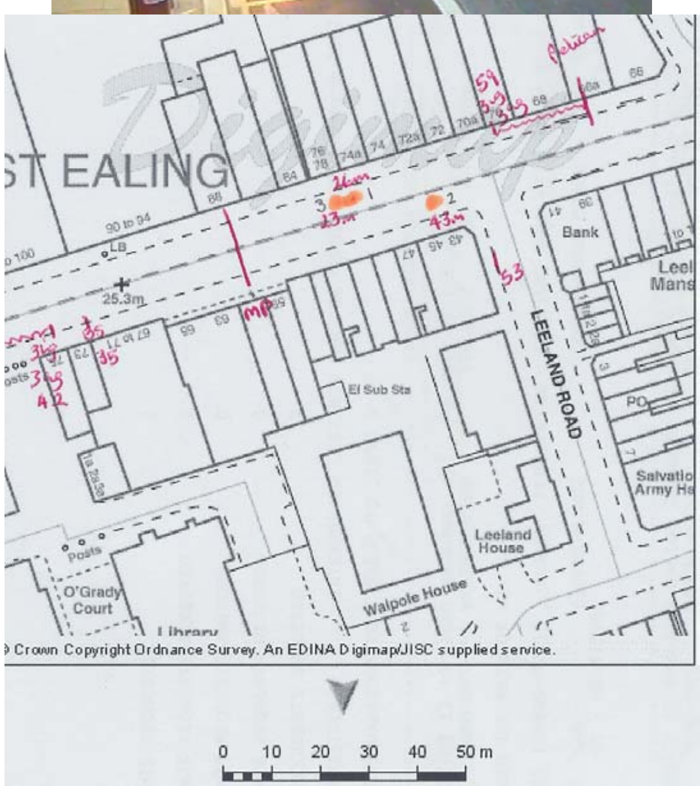
| **Site** | **2L03 Link** |
| --- | --- |
| Location | Victoria Street near Palace Street |
| Guard Rail | No |
| | |
| Vehicle flow | 1209 vph |
| 85%ile Speed | 28.0 mph |
| Crossing pedestrian flow | 170 pph |
| | |
| Pedestrian Conflicts (in 4 hours) | 5 |
| All Accidents (3 years) | 0 |
| Pedestrian Accidents (3 years) | 0 |
| Behaviour indices | AR |
| | 170 pph |

| | |
|---|---|
| **Site** | **2L07 Link** |
| Location | Edgware Road near Kendal Street |
| Guard Rail | No |
| | |
| Vehicle flow | 1433 vph |
| 85%ile Speed | 15.6 mph |
| Crossing pedestrian flow | 33 pph |
| | |
| Pedestrian Conflicts (in 4 hours) | 3 |
| All Accidents (3 years) | 0 |
| Pedestrian Accidents (3 years) | 0 |
| Behaviour indices | AR |
| | 33 pph |

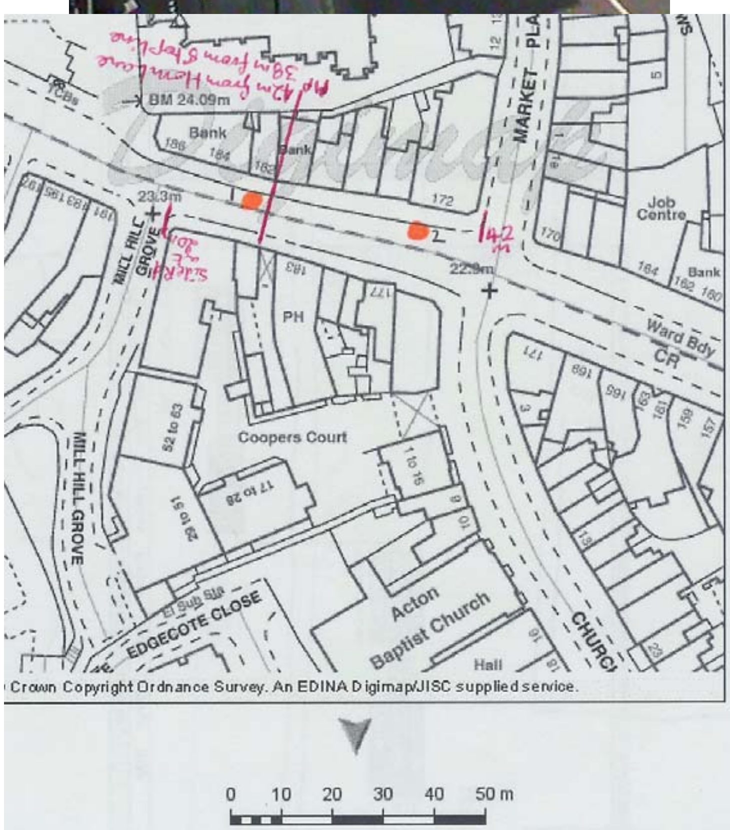



| | |
|---|---|
| **Site** | **1L08 Link** |
| Location | Uxbridge Road near Leeland Road |
| Guard Rail | No |
| | |
| Vehicle flow | 1107 vph |
| 85%ile Speed | 23.8 mph |
| Crossing pedestrian flow | 127 pph |
| | |
| Pedestrian Conflicts (in 4 hours) | 6 |
| All Accidents (3 years) | 2 |
| Pedestrian Accidents (3 years) | 2 |
| Behaviour indices | AR |
| | 127 pph |

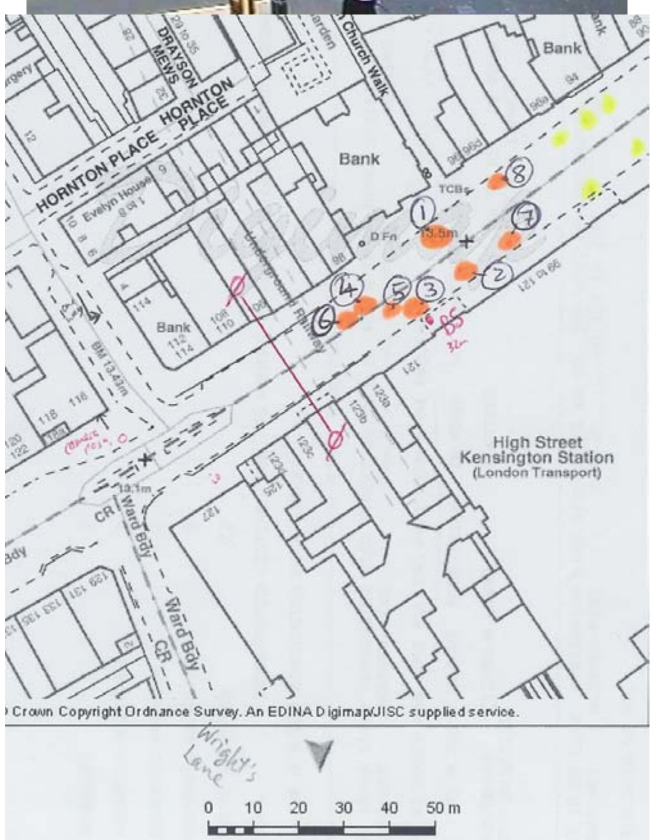



## Links with railing

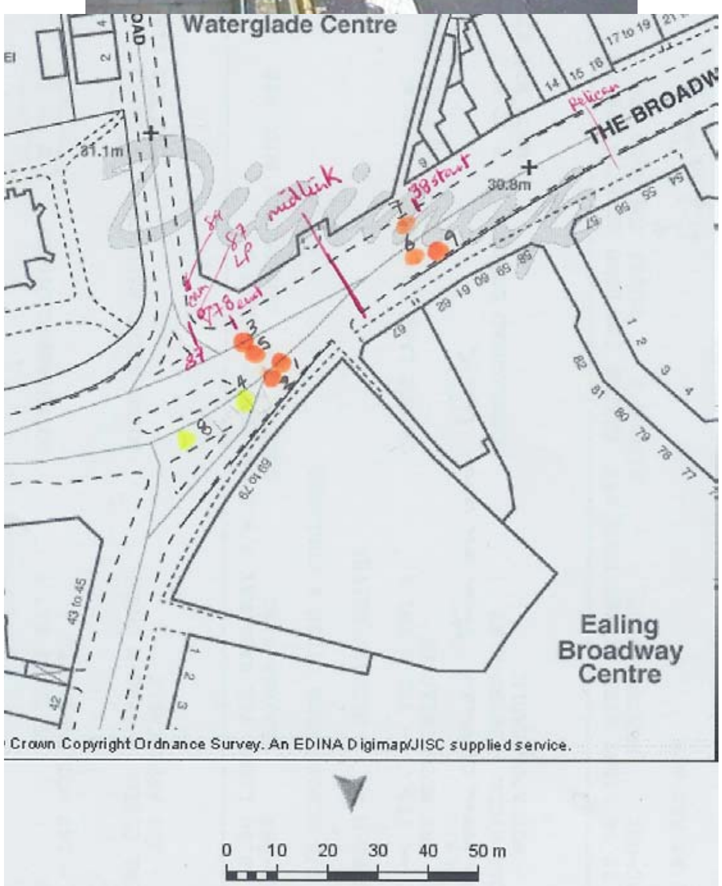
| **Site** | **1L01** | **Link** |
|---|---|---|
| Location | Acton High Street near Church Road / Horn Ln. | |
| Guard Rail | Yes | |
| | | |
| Vehicle flow | 1293 vph | |
| 85%ile Speed | 26.6 mph | |
| Crossing pedestrian flow | 70 pph | |
| | | |
| Pedestrian Conflicts (in 4 hours) | 4 | |
| All Accidents (3 years) | 2 | |
| Pedestrian Accidents (3 years) | 1 | |
| Behaviour indices | AR | Total Climbing |
| | 70 pph | 0 |

| **Site** | **3L05** | **Link** |
|---|---|---|
| Location | Kensington High Street near Horton Street | |
| Guard Rail | Yes | |
| | | |
| Vehicle flow | 1587 vph | |
| 85%ile Speed | 23.1 mph | |
| Crossing pedestrian flow | 18 pph | |
| | | |
| Pedestrian Conflicts (in 4 hours) | 2 | |
| All Accidents (3 years) | 4 | |
| Pedestrian Accidents (3 years) | 0 | |
| Behaviour indices | AR | Total Climbing |
| | 18 pph | 5 |

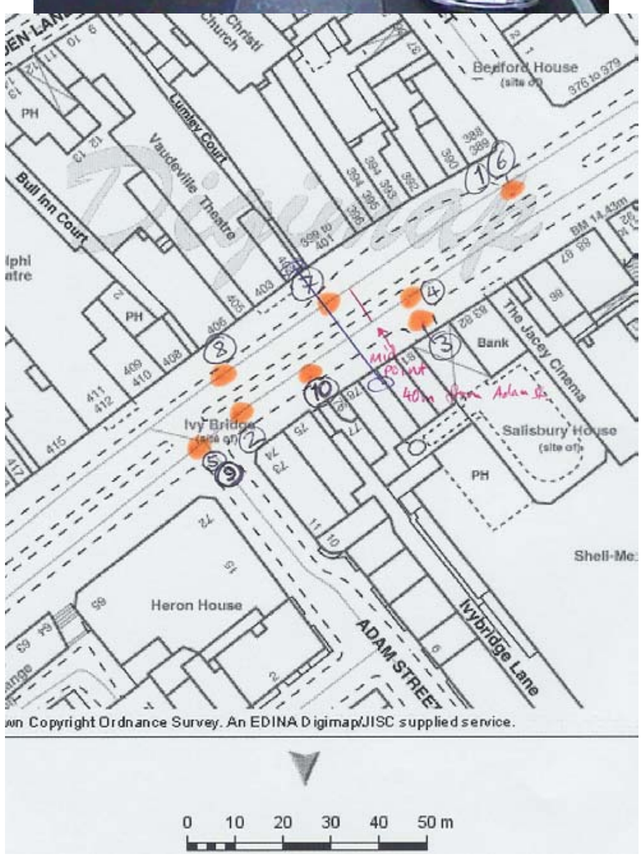



| Site | 1L06 | Link |
|---|---|---|
| Location | The Broadway (Ealing) near High Street | |
| Guard Rail | Yes | |
| | | |
| Vehicle flow | 1259 vph | |
| 85%ile Speed | 25.7 mph | |
| Crossing pedestrian flow | 5 pph | |
| | | |
| Pedestrian Conflicts (in 4 hours) | 2 | |
| All Accidents (3 years) | 7 | |
| Pedestrian Accidents (3 years) | 0 | |
| Behaviour indices | AR | Total Climbing |
| | 5 pph | 15 |

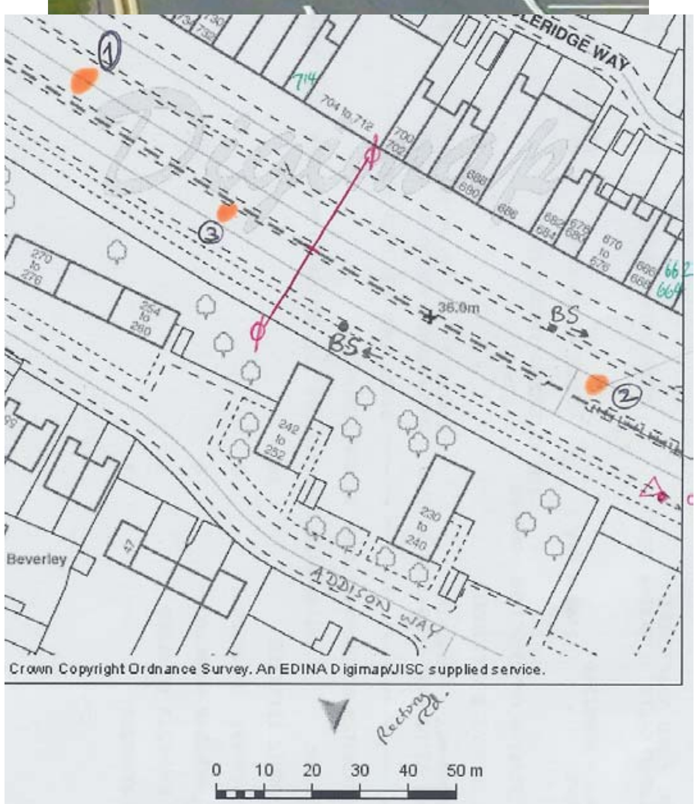



## Central Reservations with railing

| **Site** | **2C08 Central Reservation** |
|---|---|
| Location | The Strand near Adam Street |
| Guard Rail | No |
| | |
| Vehicle flow | 1541 vph |
| 85%ile Speed | 22.2 mph |
| Crossing pedestrian flow | 165 pph |
| | |
| Pedestrian Conflicts (in 4 hours) | 1 |
| All Accidents (3 years) | 6 |
| Pedestrian Accidents (3 years) | 2 |
| Behaviour indices | AR |
| | 165 pph |

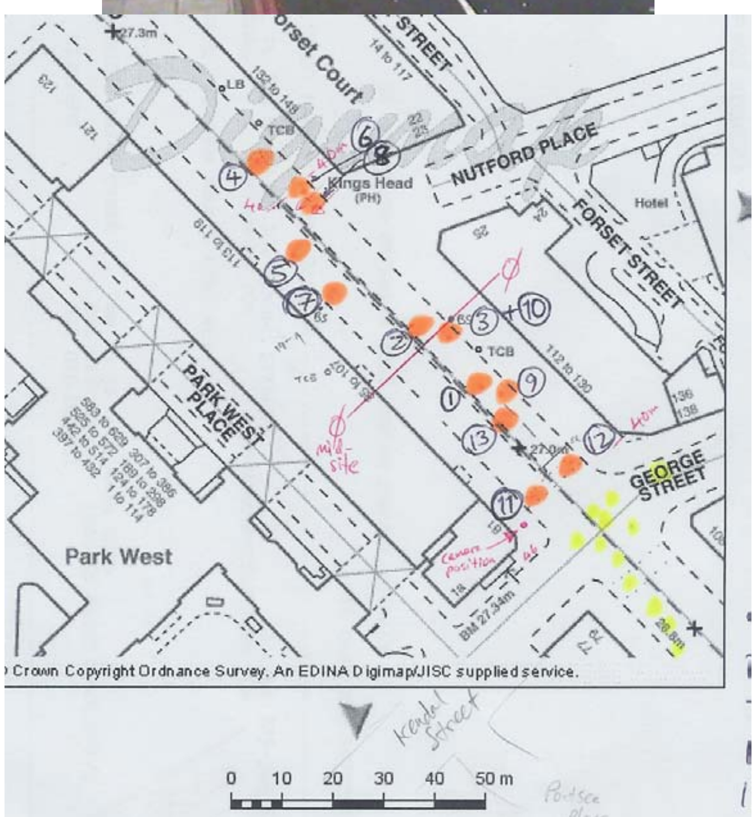



| **Site** | **5C09** | **Central Reservation** |
|---|---|---|
| Location | Uxbridge Road near Shakespeare Avenue | |
| Guard Rail | No | |
| | | |
| Vehicle flow | 1986 vph | |
| 85%ile Speed | 32.6 mph | |
| Crossing pedestrian flow | 52 pph | |
| | | |
| Pedestrian Conflicts (in 4 hours) | 0 | |
| All Accidents (3 years) | 1 | |
| Pedestrian Accidents (3 years) | 0 | |
| Behaviour indices | AR | |
| | 52 pph | |

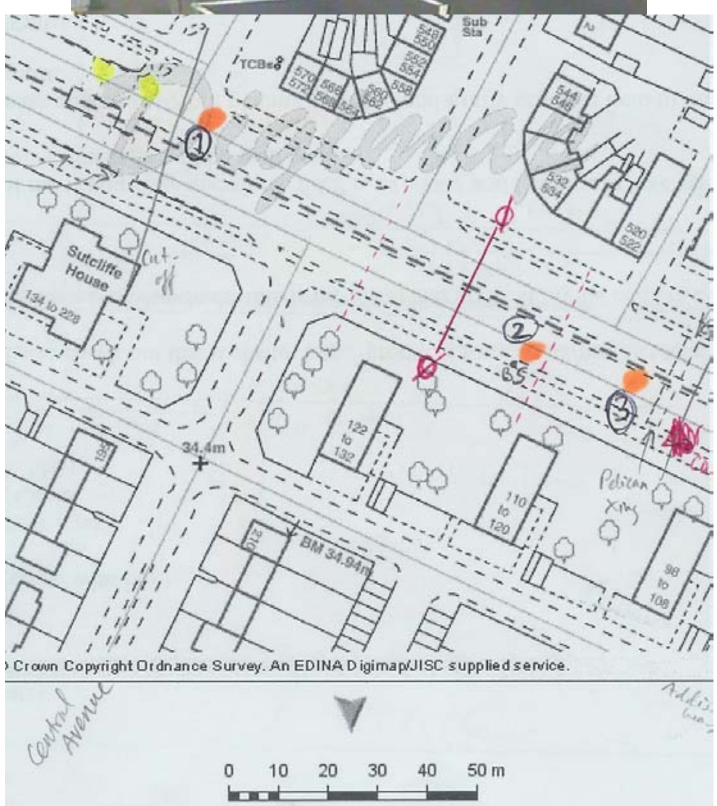



## Central Reservations with railing

| Site | 2C04 | Central Reservation |
|---|---|---|
| Location | Edgware Road near Kendal Street | |
| Guard Rail | Yes | |
| | | |
| Vehicle flow | 2379 vph | |
| 85%ile Speed | 20.9 mph | |
| Crossing pedestrian flow | 2 pph | |
| | | |
| Pedestrian Conflicts (in 4 hours) | 0 | |
| All Accidents (3 years) | 8 | |
| Pedestrian Accidents (3 years) | 0 | |
| Behaviour indices | AR | Total Climbing |
| | 2 pph | 0 |

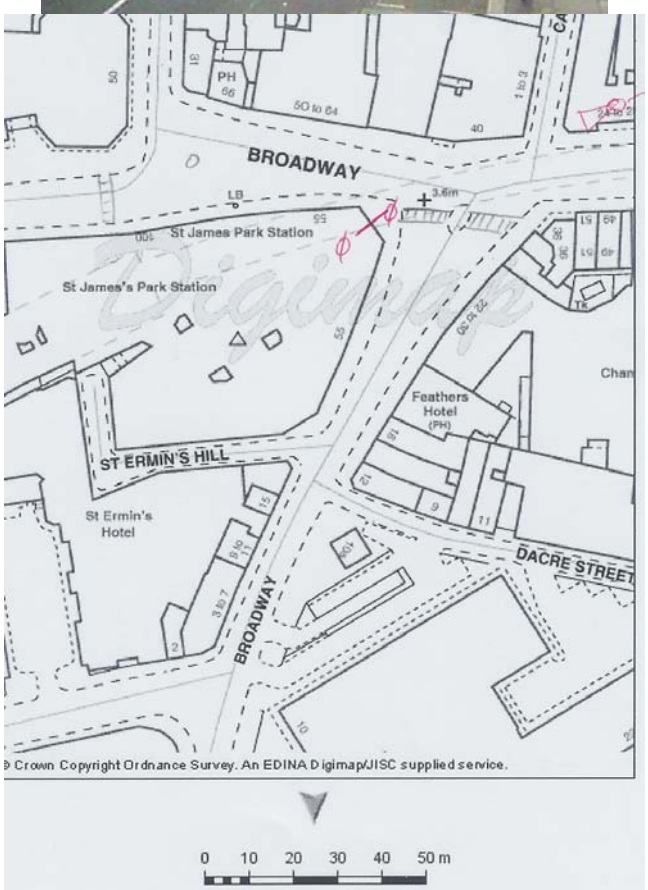



| **Site** | **5C10** | **Central Reservation** |
|---|---|---|
| Location | Uxbridge Road near Central Avenue | |
| Guard Rail | Yes | |
| | | |
| Vehicle flow | 2381 vph | |
| 85%ile Speed | 38.7 mph | |
| Crossing pedestrian flow | 2 pph | |
| | | |
| Pedestrian Conflicts (in 4 hours) | 0 | |
| All Accidents (3 years) | 2 | |
| Pedestrian Accidents (3 years) | 0 | |
| Behaviour indices | AR | Total Climbing |
| | 2 pph | 9 |

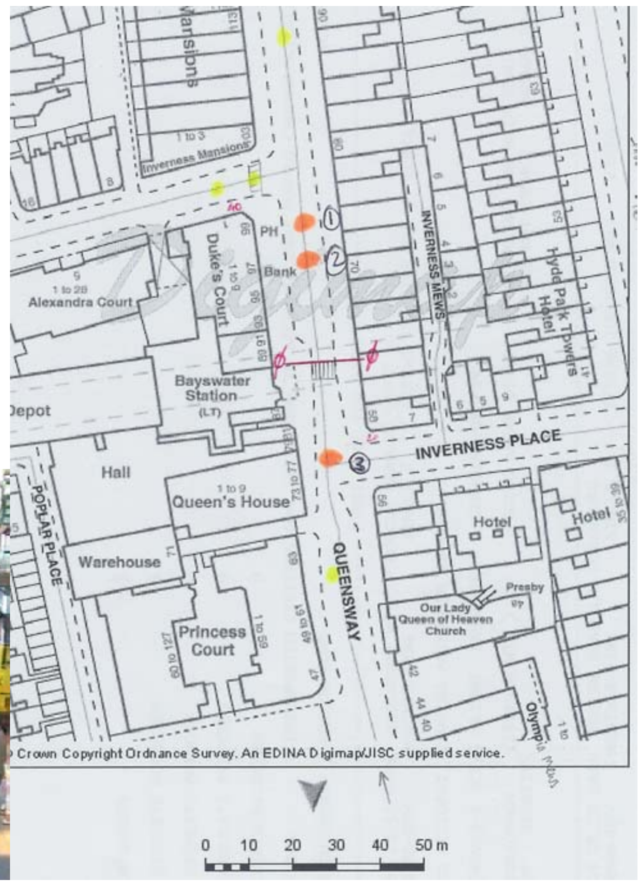



## Transportation Interchanges without railing

| **Site** | **2T08** | **Transport Interchange** | |
|---|---|---|---|
| Location | Tothill Street / Broadway | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 572 vph | | |
| 85%ile Speed | 17.3 mph | | |
| Crossing pedestrian flow | 305 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 0 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 8.6% | 91.4% | 0.0% |

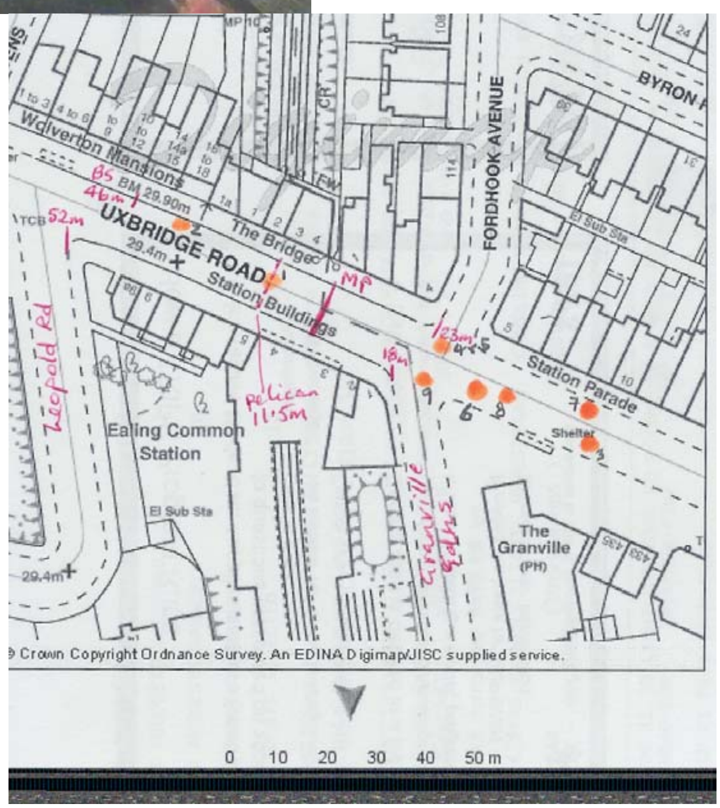



| **Site** | **2T09** | **Transport Interchange** | |
|---|---|---|---|
| Location | Queensway Road near Inverness Place | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 570 vph | | |
| 85%ile Speed | 17.0 mph | | |
| Crossing pedestrian flow | 249 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 2 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 11.8% | 88.2% | 0.0% |

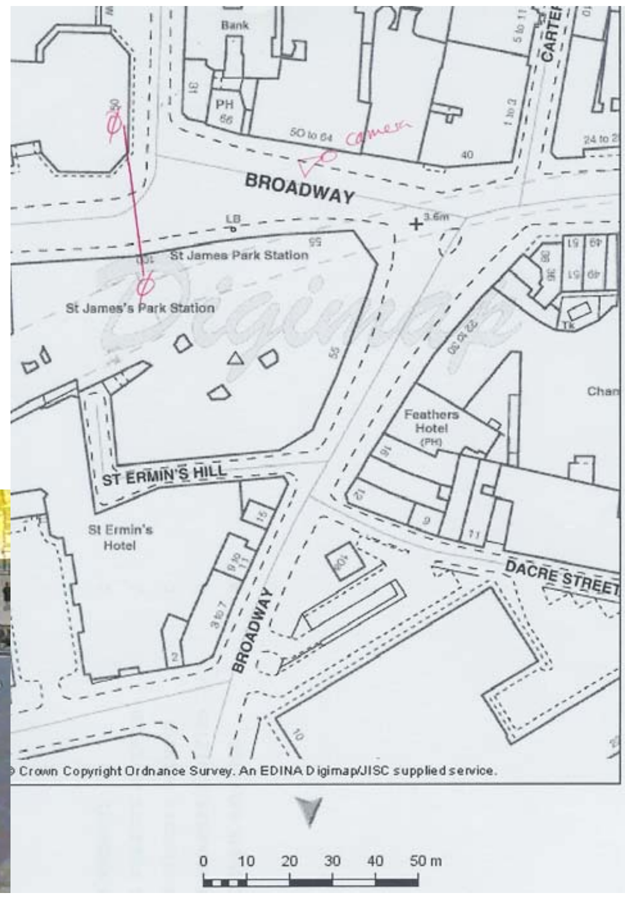



## Transportation Interchanges with railing

| **Site** | **1T03** | **Transport Interchange** | |
|---|---|---|---|
| Location | Uxbridge Road near Granville Gardens | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1472 vph | | |
| 85%ile Speed | 26.4 mph | | |
| Crossing pedestrian flow | 278 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 3 | | |
| All Accidents (3 years) | 1 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 5.6% | 94.4% | 0.0% |

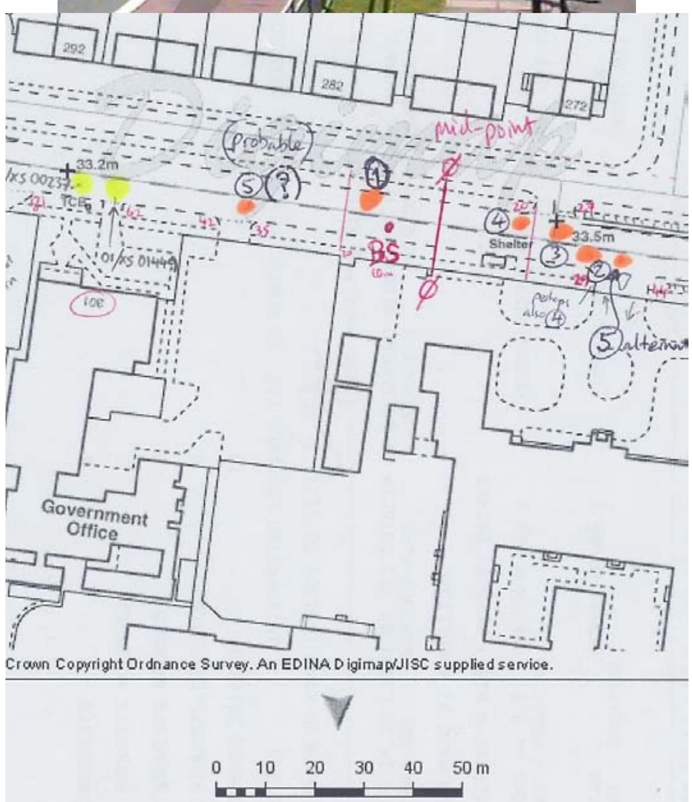



| **Site** | **2T06** | **Transport Interchange** | |
|---|---|---|---|
| Location | Tothill Street / Queen Annes Gate | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 425 vph | | |
| 85%ile Speed | 17.3 mph | | |
| Crossing pedestrian flow | 512 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 1 | | |
| All Accidents (3 years) | 0 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 15.2% | 84.8% | 0.0% |

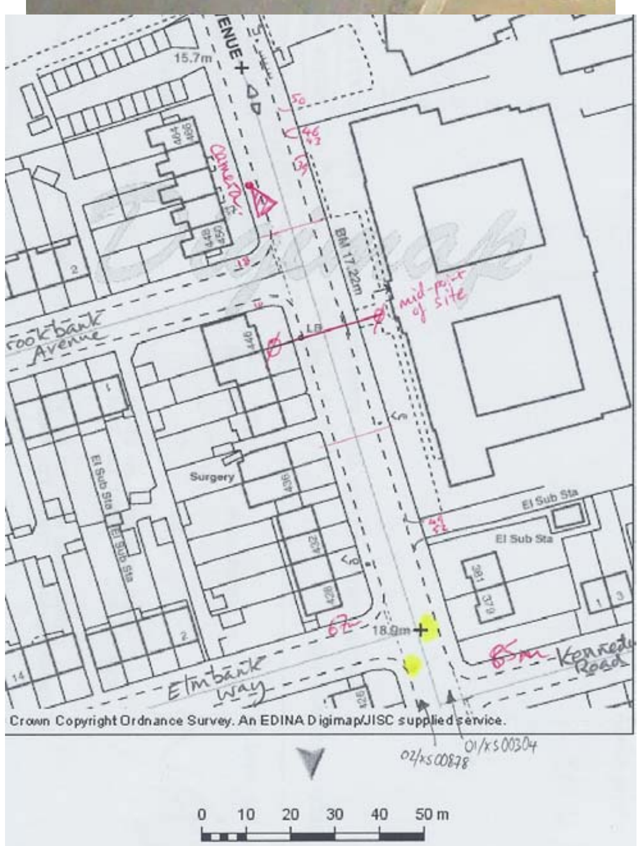
## School without railing

| **Site** | **1S05** | **School** | |
|---|---|---|---|
| Location | Ruislip Road near Ferrymead Avenue | | |
| Guard Rail | No | | |
| | | | |
| Vehicle flow | 1728 vph | | |
| 85%ile Speed | 25.1 mph | | |
| Crossing pedestrian flow | 346 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 1 | | |
| All Accidents (3 years) | 2 | | |
| Pedestrian Accidents (3 years) | 1 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 4.3% | 95.7% | 0.0% |

## Schools with railing

| Site | 1S01 | School | |
|---|---|---|---|
| Location | Greenford Avenue near Brookbank Avenue | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 1016 vph | | |
| 85%ile Speed | 30.4 mph | | |
| Crossing pedestrian flow | 41 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 0 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 0.0% | 92.7% | 7.3% |

| **Site** | **1S03** | **School** | |
|---|---|---|---|
| Location | Oldfield Lane near Costons Lane | | |
| Guard Rail | Yes | | |
| | | | |
| Vehicle flow | 575 vph | | |
| 85%ile Speed | 25.8 mph | | |
| Crossing pedestrian flow | 324 pph | | |
| | | | |
| Pedestrian Conflicts (in 4 hours) | 0 | | |
| All Accidents (3 years) | 0 | | |
| Pedestrian Accidents (3 years) | 0 | | |
| Behaviour indices | CRO(%) | CRC(%) | DCR(%) |
| | 0.0 % | 100.0 % | 0.0 % |