Factors influencing pedestrian safety: a literature review

by A Martin (TRL Limited)

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FACTORS INFLUENCING PEDESTRIAN SAFETY: A LITERATURE REVIEW

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Executive summary

Although there has been a decline in the popularity of walking, it remains a very commonly employed mode of travel. People of almost all ages, both sexes and in all walks of life, walk, set against a background of steadily increasing vehicle numbers and traffic levels. Londoners are believed to demonstrate both relatively high walking distances per person and high casualty rates compared to other British people, as they have a lower car use and therefore spend more time walking to the bus stop and train station.

Walking almost inevitably involves crossing a road, where the desire line of the pedestrian conflicts with the higher speed and lesser vulnerability of motor vehicles. Where speeds and/or flows are high, this can result in either delay or risk for the pedestrian. In fact, recent decades have seen an overall fall in pedestrian injuries due to several factors, including:

- Better vehicle design
- Effective speed management
- Traffic re-routing
- Reduction in walking

However, pedestrians still comprise around a quarter of those who die in road collisions and statistics published by the Department for Transport (2004) show that in Great Britain in 2003 over 290,000 people were killed or injured in road traffic collisions (36,405 were pedestrians). The majority of collisions occurred on roads where the speed limit was at most 40 mph (Department for Transport, 2004). In London, there were 38,340 casualties with more than 5,000 involving fatal or serious injuries (Transport for London, 2004). Of the casualties 7,127 were pedestrians and almost 1,500 were killed or seriously injured.

Most research studies investigating the crossing behaviour of pedestrians have focused on behaviour at, or close to, mid-block pedestrian crossings (i.e. crossings that are on a link rather than a junction). Various different techniques (either video observation or self-report data obtained via surveys and qualitative interviews or focus groups) have been used, but all produced similar findings with respect to pedestrian road crossing behaviour.

When crossing the road, pedestrians could potentially behave in a number of ways. They could follow safe rules and procedures by e.g. waiting for the signal to indicate that they should cross or waiting for a large enough gap in the traffic to negotiate the road safely. Alternatively, they could, for example, cross without waiting for the signal. They could accept only small gaps in traffic and/or could walk to the middle of the road and wait there for a gap in the traffic. The same pedestrian may adopt different strategies on different occasions e.g. they are less likely to take care when the weather is bad or they are in a hurry.

It is known that walking speeds can be affected considerably by the age of the pedestrian, whether s/he is encumbered by carrying a heavy object or by accompanying a child, or whether s/he has a disability. The time taken to cross a road will also be affected by its width.

An important factor at signal-controlled crossings is whether pedestrians comply with the signals or not. In addition to pedestrians who cross on the red man, many commonly anticipate the green man when they see the amber signal to traffic. It is likely that both motorist and pedestrian attitudes and behaviour are behind the relatively poor UK pedestrian collision record, with pedestrians in the UK more likely to ignore traffic signs and signals (such as the red man at signal crossings) than those in continental Europe (due to differences in traffic regulations).

Social pressure is an important variable in determining pedestrians' crossing decisions, particularly children and adolescents. This may lead to pedestrians crossing between parked cars, not using nearby crossings and running across the road without looking properly.

From the driver viewpoint, large vehicles at the stop line of signal-controlled junctions may not be able to see pedestrians, who are therefore at particular risk if they cross at or before the amber signal to traffic.

This report presents the results of a review of the relevant technical literature that was undertaken by TRL on behalf of Transport for London (TfL) to investigate in what ways pedestrian behaviour might be influenced (in ways most acceptable to pedestrians and other road users) to reduce the numbers of casualties on London's roads.

The main conclusions were as follows:

General

There are no simple universal solutions that would reduce pedestrian casualties in London, particularly because of the large numbers of pedestrians and the high traffic flows on London roads. The problem should be addressed at a strategic level and a hierarchical approach based on hot spots but also aimed at systematically improving pedestrian safety is needed.

Enforcement measures such as safety cameras (and, in the longer term, in-car speed limiters) are best applied on strategic routes where physical traffic calming measures would reduce capacity.

Education is probably best targeted at a particular behaviour (e.g. speeding) or a particular group (e.g. school children or older people)

Enhancement of pedestrian crossings

- Skid-resistant surfacing on the approaches to enable drivers to stop more easily
- Moving the stop line a few metres back at signalised crossings and junctions, to enable drivers of large vehicles to see pedestrians more easily
- Widening crossings so that pedestrians are less likely to walk off the crossing
- Reducing road width at pedestrian crossings so that pedestrians have a shorter distance to cross. (The use of build-outs makes pedestrians more visible)
- Flashing road studs to alert drivers to the presence of the crossing
- Re-locating the crossing to coincide with pedestrian desire lines to encourage pedestrians to use the crossing
- Raising crossings so that drivers have to slow down as they approach them
- Adding refuges so that pedestrians have fewer lanes to cross at a time
- Considering the need for guard railing to encourage pedestrians to use the crossing (although in some situations, it will be important to ensure that a situation in which pedestrians walk outside the guard rails does not occur)
- Increasing the responsiveness of signal-controlled crossings so that pedestrians may be more likely to wait for the green man
- Keeping cycle times short or having two green periods within the cycle so that again the responsiveness of the signals is improved
- Converting zebras and pelicans to Puffins can also be beneficial, either at an isolated hot spot or as a systematic policy over a period of years.

Measures at signal-controlled junctions

Pedestrian collisions at signal-controlled junctions account for a surprisingly high proportion of the total. Suitable measures to adopt are signal strategies that shorten waiting times for pedestrians, the provision of pedestrian phases, and all-red periods. This may be achieved as in the list of possible enhancements to pedestrian crossings by using shorter cycle times or increasing the window of opportunity for the pedestrian phase. Clearly these proposals will tend to increase delay to vehicles and they will only be possible in suitable locations.

Measures suitable for use in residential areas

An area wide consideration of residential areas, to determine the route hierarchy and hence which streets should have traffic calming measures and 20mph speed limits and where home zones or play zones could best be implemented. On the latter, pedestrian crossings should be informal or zebra crossings depending on the flow. Simple measures such as road narrowings (e.g. build-outs) will allow pedestrians to cross safely.

Measures suitable for use in shopping areas

Shopping streets are good candidates for pedestrianisation or semi-pedestrianisation. Where this is not possible, suitable crossings should be introduced at frequent intervals. These could be enhanced e.g. by the use of raised crossings or wide crossings with a central refuge. The use of pedestrian priority signals could also be considered.

Measures suitable for use outside schools

As far as possible, 20mph zones should be located around schools. Other possibilities are the use of intelligent road studs or vehicle-activated signals that work on 30mph most of the time but 20mph at school times, or pedestrian priority signals. The introduction of play zones may be appropriate.

Measures suitable for use in historic areas with high pedestrian and vehicle usage

In historic areas, it is important to maintain the aesthetic appearance. For example, the use of coloured surfacing should be avoided and high quality materials adopted.

Where there are large numbers of tourists, reminders on the road surface reminding foreign tourists in particular to look left / right, and wide crossings are appropriate. Timings should minimise delay to pedestrians as far as possible without increasing congestion. All red periods are easy to understand and decrease pedestrian delay.

Measures suitable for use on mixed priority routes

Reducing the amount of parking (e.g. by red routes) will allow drivers a clear view of pedestrians (although they may also encourage speeding), but generally zebra or Puffin crossings will be required. These should have short cycle times to minimise pedestrian delay. The use of countdown timers should also be considered. Speed cameras may be needed on the busier routes.

1 Introduction

Although there has been a decline in the popularity of walking, it remains a very commonly employed mode of travel. People of almost all ages, both sexes and in all walks of life, walk, set against a background of steadily increasing vehicle numbers and traffic levels. In particular, Londoners are believed to demonstrate both relatively high walking distances per person and high casualty rates compared to other British people, as they have a lower car use and therefore spend more time walking. Statistics for 2004 show that, in London, the number of trips (one-way movements from one place to another) and journeys (parts of a trip made by a single mode of transport) done by foot has increased from 5.2 million per day, on average, in 1993 to 5.6 million per day, on average, in 2004 (Transport for London 2005).

Walking in Britain today almost inevitably involves crossing a road, where the desire line of the pedestrian conflicts with the higher speed and lesser vulnerability of motor vehicles. Where speeds and/or flows are high, this results in either delay or risk for the pedestrian, unless specific provision has been made. In fact, recent decades have seen an overall fall in pedestrian injuries due to several factors, including:

- Better vehicle design
- Effective speed management
- Traffic re-routing
- Reduction in walking

However, pedestrians still comprise around a quarter of those who die in road collisions and statistics published by the Department for Transport (2004) show that in Great Britain in 2003 over 290,000 people were killed or injured in road traffic collisions (36,405 were pedestrians). The majority of collisions occurred on roads where the speed limit was at most 40 mph (Department for Transport, 2004). In London, there were 38,340 casualties with more than 5,000 involving fatal or serious injuries (Transport for London, 2004). Of the casualties 7,127 were pedestrians and almost 1,500 were killed or seriously injured.

Most research studies investigating the crossing behaviour of pedestrians have focused on behaviour at, or close to, mid-block pedestrian crossings (i.e. crossings that are on a link rather than a junction). Various different techniques (either video observation or self-report data obtained via surveys and qualitative interviews or focus groups) have been used, but all produced similar findings with respect to pedestrian road crossing behaviour.

When crossing the road, pedestrians could potentially behave in a number of ways. They could follow safe rules and procedures by e.g. waiting for the signal to indicate that they should cross or waiting for a large enough gap in the traffic to negotiate the road safely. Alternatively, they could, for example, cross without waiting for the signal. They could accept only small gaps in traffic and/or could walk to the middle of the road and wait there for a gap in the traffic. The same pedestrian may adopt different strategies on different occasions e.g. they are less likely to take care when the weather is bad or they are in a hurry.

It is known that walking speeds can be affected considerably by the age of the pedestrian, whether s/he is encumbered by carrying a heavy object or by accompanying a child, or whether s/he has a disability. The time taken to cross a road will also be affected by its width.

An important factor at signalised crossings is whether pedestrians comply with the signals or not. In addition to pedestrians who cross on the red man, many commonly anticipate the green man when they see the amber signal to traffic. It is likely that both motorist and pedestrian attitudes and behaviour are behind the relatively poor UK pedestrian collision record, with pedestrians in the UK more likely to ignore traffic signs and signals (such as the red man at signal crossings) than those in continental Europe (due to differences in traffic regulations). This subject is discussed further in Section 5.2

Evans and Norman (1998) found that social pressure is an important variable in determining pedestrians' crossing decisions. Social pressure can mean a number of different things. It does not necessarily have to reflect the feeling that 'other people would want me to behave in this way'. It could manifest itself in a more overt manner. For example, it was found in the recent TRL research into adolescent road user behaviour that children's perceived peer pressure influenced them to engage in a number of unsafe road crossing behaviours, such as crossing between parked cars, not using nearby crossings and running across the road without looking properly (Elliott, 2004). From the driver viewpoint, TRL research into pedestrians at signals indicated that large vehicles at the stop line may not be able to see pedestrians who are therefore at particular risk if they cross at the start of green to traffic.

This report presents the results of a review of the relevant technical literature that was undertaken by TRL on behalf of Transport for London (TfL) to investigate in what ways pedestrian behaviour might be influenced (in ways most acceptable to pedestrians and other road users) to reduce the numbers of casualties on London's roads. A list of all the literature reviewed can be found at the back of the report and literature summaries of key pieces of literature can be found in Appendix A.

2 Aims

The specific objectives of the review are detailed below.

Identifying the Problems

- **What underlying factors** influence pedestrian behaviour on the streets *vis a vis* pedestrian safety? (e.g. age, gender, ethnicity, social disadvantage, familiarity, pedestrian flows, drink and drugs, size of groups, trip purpose etc.)
- **In what way(s)** do the factors identified influence pedestrian behaviour, particularly with reference to pedestrian safety? (e.g. what are the impacts on attentiveness, changes in speed of movement, adherence to rules and signs, attitudes to safety, route choice, trip frequency etc.).
- **At what locations** does this behaviour (and the factors underlying it) affect the safety of pedestrians and other users of the streets? (i.e. what are the characteristics of the locations at which pedestrian behaviour is most important to address to decrease risk? E.g. pedestrian crossings, particular junction types, or along pavements; particular land uses such as shopping or residential streets; near pedestrian zones or transport interchanges; roads with or lacking bus lanes; certain road classes or widths etc.).

Evaluating Potential Solutions

- **What methods** have been used to exert influence over any identified behaviours (or the factors underlying them) that increase pedestrian risk (advertising and education programmes, physical interventions, signage, road markings etc.)
- **How successful** have the methods identified above been from a road safety perspective? (ideally, this will report on degrees and types of casualty and collision reductions, as well as pedestrian and other road user acceptance etc. and will be evaluated by target group where possible and appropriate, particularly age and gender)

Suitability of Measures to London

- **How appropriate** for London are these methods? The objective here is to evaluate the methods, given the road infrastructure along with the make-up of London's pedestrian casualties (information on which will be made available by LRSU).

Section 3 of this report describes the methods that were used to identify appropriate literature for inclusion in the review. Subsequent sections outline the main findings. Section 4 discusses the literature found relating to types of pedestrian and casualty data. Section 5 reviews pedestrian attitude and behaviour, Section 6 evaluates the measures reviewed in the available literature, and section 7 deals with the suitability of these measures for London.

3 Literature Searches

Searches of the TRL Knowledge Base were conducted in order to identify literature to be reviewed. The Knowledge Base comprises a number of databases, including the Transport Research Abstracting & Cataloguing System (TRACS). This is the main catalogue of publications held both in the TRL library and elsewhere. It contains bibliographic references and abstracts of English and foreign language articles from journals, books and research reports. It is the English language version of the world-wide ITRD database (International Transport Research Documentation) and contains abstracts from publications in the USA, Australia, Scandinavia, the Netherlands and Canada in addition to UK material. The database has been updated daily since 1972 and now comprises some 260,000 items. This is the prime literature resource for transport research. The Knowledge Base also includes the PROJEX database that contains summaries of current and recently completed research projects undertaken in ITRD member countries. The searches of the Knowledge Base were conducted using a number of combinations of the following key words, including: pedestrian, pedestrian casualties, pedestrian behaviour, collision measures, collision prevention and evaluation.

As well as searching the TRL Knowledge Base, studies were identified by browsing (e.g. using the reference lists of other publications to identify relevant pieces of work) and, where possible, researchers working in the field of pedestrian safety were contacted for advice and assistance with identifying appropriate literature.

4 Types of Pedestrian and Casualty Data

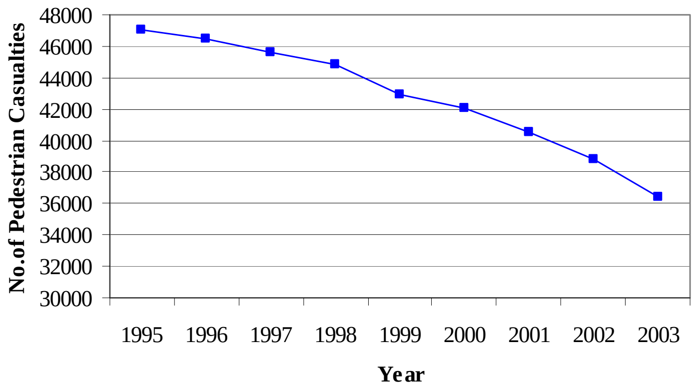
This section will set out the types of pedestrians who are involved in collisions, by examining government statistics and results of surveys conducted over the last ten years. The aim of this section is to provide background information on pedestrian casualty data. Information on (a) the demographic characteristics of pedestrians who are involved in collisions and (b) the circumstances under which those collisions occur (e.g. locations and time of day) is included.

4.1 Pedestrian Collision Statistics

Pedestrian casualties accounted for 13% of road collisions in 2003 (36,405 casualties) and 22% of all road deaths in the UK. Despite the figure falling, it still remains a high collision rate compared to most other European countries (TRL unpublished research undertaken as part of study by Wall, 2000). Results from the National Travel Survey indicated a decline in the average distance walked of about 2% (compared with averaged taken from 1994-1998) which indicates that reduced exposure may have had an influence on the apparent casualty reduction.

Figure 1 below show how the casualty figures for Great Britain have fallen since 1995. However despite the figures showing that the number of casualties is falling each year, the absolute number of casualties remains high.

Figure 1: No. of Pedestrian Casualties in Great Britain 1995-2003



Source: Road Casualties Great Britain 2004: Annual Report (Department for Transport/National Statistics)

Although collisions and casualties have reduced over the last decade, absolute numbers remain high and ways to improve pedestrian safety need to be identified.

4.2 The Location of Pedestrian Collisions

4.2.1 Pedestrian Crossings

It has been well documented that most pedestrian collisions occur when pedestrians are crossing a road, and most research finds that risk is much higher away from crossing facilities compared with on a crossing (AA Foundation, 1994 and Ghee et al, 1998). National statistics show that approximately 40% of pedestrian collisions in 2003 occurred whilst the pedestrian was crossing the road away from a pedestrian crossing (Department for Transport, 2004). Only 9% of pedestrian collisions occur on a pedestrian crossing and nearly 8% occur within 50m of a crossing (Department for Transport, 2004).

National figures suggest that more collisions occur at mid-block signalised crossings compared with other types of pedestrian crossing (such as zebra crossings, signal-controlled junctions and crossings with human control e.g. school crossing patrols) (Department for Transport, 2004). This, however, may be misleading as is takes no account of the numbers of each type of crossing.

It has been argued that the use of signalised crossings halves the risk compared with crossing without these facilities (AA Foundation, 1994), and that the lack of crossing facilities affects older women more than anyone else as they were found to have difficulties understanding and monitoring the sequence of traffic movements and a tendency to monitor nearside and far side traffic independently as they cross the road (Ghee et al, 1998).

In terms of collisions that do occur at crossings, one study has shown that the flashing pedestrian green phase at Pelican crossings has high collision rates (Ghee et al, 1998).

4.2.2 Type of Road

National statistics show that most pedestrian collisions occur on built-up roads (96%), that is roads with a speed limit of 40mph or less (Department for Transport, 2004). It should be noted that these figures do not take in to account exposure, and therefore it is possible that risk is not higher, but that there are higher pedestrian flows on, for example built-up roads with speed limits of 30mph or less.

Research conducted by the AA Foundation (1994) found that in their study area, the highest proportion of pedestrian casualties occurred on 'District Distributor' roads which were A or B roads with speed limits of 40mph of less.

According to one study, road width plays an important part in collision risk, with risk increasing with the width of the road (MVA, 1999).

4.2.3 One-Way Streets

Studies from America and Canada have suggested that there are lower pedestrian collision rates on one-way streets as compared with two-way streets and have therefore suggested that this may be a relatively low cost pedestrian collision countermeasure (Zegeer, 1991). Zegeer (1991) reported that one-way streets can have a 40-60% reduction on pedestrian collisions. However, Summersgill and Layfield (1998) showed no difference in the level of pedestrian collision risk between one-way roads and two-way roads with the same cross-section.

4.2.4 Roads with On-Street Parking

Official statistics and other studies show that casualty rates are high when crossing is masked by parked cars on local distributor and residential roads, and this is particularly true for young people (Transport for London, 2003, AA Foundation, 1994). Statistics for Great Britain in 2003 show that nearly 17% of all pedestrian collisions occurred when the pedestrian was masked by a stationary vehicle and the figures are particularly high for pedestrians aged between 8 and 15 years (Department for Transport, 2004).

However a report by Christie (1998) argues that most collisions occur amongst children crossing on roads with no obstructive parking, but agrees that most occur on residential roads. In this case it is likely that the smaller sample sizes involved in the Christie study has had an effect on the findings.

4.2.5 Trip Purpose

Trip purpose can have an effect on collision risk and can vary between age groups; the literature has revealed that older children spend most of their time by the road, making journeys (to school, to shops etc) whilst younger children spend a large amount of time by the road, playing in the street (Christie, 1998). Time spent playing near roads is greater in British cities than in smaller towns or rural areas (MVA, 1999). Collision rates amongst children are high when they are playing unsupervised in the street (Sharples et al 1990 cited by Christie, 1995). Recent TRL research has shown that most fatal collisions involving child pedestrians occurred on 30mph roads and in light traffic conditions (Sentinella and Keigan, 2004). The literature reviewed has shown that the school journey is also associated with a high risk for children, as a high number of collisions amongst school age children occur on the journey to and from school (AA Foundation, 1994). In terms of the elderly pedestrians, shopping trips account for the majority of their outings (AA Foundation, 1995) and it is known from accident modelling that higher pedestrian collision risk is associated with shopping land-use (e.g. Summersgill and Layfield, 1997).

4.3 When do collisions occur?

4.3.1 Time

National statistics show that more pedestrian collisions occur during the winter months compared with spring and summer months (Department for Transport, 2004). Thinking about this in terms of exposure, less people are likely to walk longer distances in the winter months due to colder, wetter weather, therefore this appears to be an important contributory factor.

According to research by the AA Foundation, more collisions occur on a Saturday compared to weekdays, with fewest collisions occurring on Sundays (AA Foundation, 1994). This, however, contradicts data from Transport for London (2003) who found that 77% of pedestrian casualties occurred during the week, with a peak on Friday. This has also been found for child pedestrians, where most collisions occur during the week (Christie, 1998). It is likely that the results of the AA study are affected by the sample that was chosen (residents in Northampton), therefore the statistics for Greater London are more relevant here.

During the weekend, most collisions occur between midday and 7pm with another peak between 11pm, Saturday and 1am, Sunday (Department for Transport, 2004). National statistics show that more collisions occur between 3pm and 5pm (during the week) than at any other time of day (Department for Transport, 2004) and TRL research has also shown that most pedestrian collisions occur after school hours (Sentinella and Keigan, 2004). It is possible that earlier school closure times (and therefore earlier opening times) would mean that more pedestrians are walking at non-peak traffic times, therefore potentially avoiding conflicts with heavy traffic flows. Green (1980), in a study to examine the effects of darkness on collision rates, studied the number of collisions in the five working days before and after the Sundays in 1975, 1976 and 1977 when the clocks changed. Green (1980) found that in the evening period studied, the frequency of all injury collisions is about 50% higher and of fatal and serious collisions about 100% higher.

4.3.2 Weather and Lighting Conditions

Risk to pedestrians is greater when weather and lighting conditions are poor and injury severity is higher in these conditions. However less people are likely to go out in these circumstances therefore the statistics generally show fewer collisions under these conditions. The AA Foundation found that the weather can have an effect on collision risk to pedestrians as most collisions were reported in wet weather (AA Foundation, 1994) and the authors argue that weather has been shown to significantly contribute to the way older people cope with the road environment (AA Foundation, 1995).

Darkness may play a role in determining trends in pedestrian collisions, increasing the risk of having a collision by over four times than during daylight hours according to research by the AA Foundation (1994).

4.3.3 Travelling Alone

Travelling alone seems to have a significant effect on collision risk to pedestrians; research has shown that in many collisions, adult pedestrians were travelling unaccompanied (AA Foundation, 1994). This is not true for children, who are more likely to be travelling in groups according to research by Chinn (2004).

4.4 Demographic Influence on Pedestrian Collisions

4.4.1 Effects of Age & Gender

In 2003 there were 36,405 pedestrian collisions (involving injury) recorded on the roads of Great Britain. According to government statistics, 21,472 (approximately 60%) were male pedestrians and 14,905 were female pedestrians (approximately 40%)[1]. Research has also shown that men, and in particular, young males, are more likely to be involved in collisions as pedestrians than are women (e.g. Ghee et al, 1998).

In terms of age, 17,485 were adult pedestrians (aged between 16 and 59) which accounts for nearly half of all pedestrian collisions. Child pedestrians (aged under 16 years) account for approximately 35% of collisions (12,544) and older pedestrians (adults aged over 60) account for approximately 14% of pedestrian collisions (Department for Transport, 2004)[2]. This represents a higher collision rate amongst child pedestrians as there are fewer children in the lower age bracket compared with the number of adults in the adult age bracket (census data, 2001 shows that 20% of the population are under 16 years old). Other research has shown that young people aged 20-24 years are at a high risk as pedestrians (AA Foundation, 1994).

Statistics therefore show that young people are more at risk than any other age group; however older people are more likely to suffer greater injuries. Older people are also at risk of injury as a pedestrian, because although the collision rate amongst older pedestrians is lower (census data, 2001 shows that 20% of the population are over 60 years old), injuries to older people (over 65 years) tend to be more serious or fatal than injuries to other age groups (Department for Transport, 2004, AA Foundation, 1994 and TRL unpublished research undertaken as part of study by Wall, 2000). National statistics show that in 2003, only 0.5% of collisions to child pedestrians (those under 16 years) resulted in a fatality, whereas 21% of adults over 60 years old involved in a road collision were killed. Older females have also been shown to be at more risk than males of the same age (Department for Transport, 2004).

4.4.2 Effects of Social background

There is a link between the propensity for pedestrians to be involved in collisions and their social circumstances. In particular a link has been found between deprivation and the number of pedestrian casualties. The risk of having a collision as a pedestrian increases as social economic group (SEG) decreases. Evidence comes from a number of studies that have correlated various indicators of SEG with collision rates. Research has shown that:

- there are more pedestrian collisions in geographical areas with high unemployment rates compared with areas with lower unemployment rates (Graham et al, 2002);
- housing can be a common factor when examining the type of people that have collisions on or by the road. Casualty rates are much higher for people living in older houses (pre-1964) and houses built by local authorities and this has been explained by a lack of footpaths segregated from traffic in older areas with older housing (AA Foundation, 1994 and Christie, 1998).

[1] The figures for male and female accidents do not total 36,405 (total pedestrian accidents) due to 28 cases where gender was not reported in Road Accidents Great Britain 2004.
[2] Age was not recorded for 1330 cases.

Built-up areas are also a factor as they tend to have higher casualty rates for both adults and children (Graham et al, 2002);

- family circumstances can have an effect on the risk of child pedestrian collisions: children with unemployed parents, single parents and children living in crowded accommodation are all more likely to be involved in a collision (Christie, 1998). Christie (1995) reports that parents in lower SEG groups tend to take less responsibility for their children in traffic;
- household car ownership has an effect on casualty rates amongst children; children in households who have access to a car are less likely to be involved in a collision than those without (Christie, 1998);
- children in lower social economic groups are at a higher risk of being in a collision because they are more exposed to traffic, and in particular traffic which is less safe than those from higher socio-economic groups (Christie, 1995);
- pedestrians from lower social economic groups are more likely to cross the road at marked crossings, than higher groups (MVA, 1999).

There is little evidence or research to suggest that ethnicity plays a role in the typology of pedestrians who have collisions, however where ethnicity is linked with poverty and language barriers it is associated with more pedestrians collisions. In-depth studies (such as Lawson, 1991) indicate that Asian children have a high collision involvement as pedestrians, compared with children from other ethnic backgrounds. The data collected in this study (undertaken in Birmingham) showed that, per head of population, Asian child pedestrians (aged 0-9 years) were over represented in road collisions by a factor of two.

5 Review of Research on Pedestrian Attitude and Behaviour

The previous section examined the types of pedestrians who are involved in collisions, it did not, however, explore any behavioural factors involved in being a pedestrian; it explains who is involved in collisions, but not why they have collisions. It is known that more collisions involve males than females, and proportionally more younger people than older people. It is also known that risk is higher amongst pedestrians, and particularly children, belonging to lower social economic groups. There are higher collision rates on ‘A’ class, single carriageway roads with speeds of less than 40mph and away from designated pedestrian crossings. Crossing the road between parked cars is particularly risky, and adult pedestrians are more likely to have collisions whilst travelling on their own, whereas children are more likely to be in a group.

These variables do not help to explain why collisions might occur. In terms of interventions, these findings (in Section 4) provide limited information only. They can be useful to decide who interventions should be targeted at, but we need to identify variables that identify why collisions occur in order to get a better understanding of what can be done to reduce collisions. Pedestrian behaviour is regarded by many authors as being important for explaining why pedestrian collisions occur (e.g. TRL unpublished research undertaken as part of study by Wall, 2000). We therefore need to examine what behaviours are important in influencing pedestrian collisions and why these behaviours are carried out. Therefore, this section of the review describes the influence of behavioural and attitudinal variables on pedestrian safety.

Researchers studying the behaviour of pedestrians have used both video observation techniques and self-report data obtained via surveys and qualitative interviews or focus groups. The different research techniques have produced similar findings with respect to pedestrian road user behaviour.

On the basis of the available literature, pedestrian behaviour that can increase the risk of road traffic collisions can be classified as follows:

- Choice of crossing place;
- Non-compliance at designated crossings;
- Crossing speed;
- Failure to attend to traffic;
- Pedestrian alcohol consumption.

The following section describes these types of behaviours in turn.

5.1 Choice of Crossing Place

Choice of crossing place has a significant influence on pedestrian safety and therefore the section below describes the types of behaviours that influence choice of crossing place and discusses the reasons why pedestrians act as they do.

Pedestrians and drivers react differently in different situations; different behaviour can be found at crossings and away from crossings. For example, drivers are more likely to give way to pedestrians at formal crossings, whereas away from crossings, male pedestrians tend to speed up to avoid conflict with a vehicle, whereas female pedestrians slow down (Ghee et al, 1998).

Where pedestrians choose to cross can have a big impact on the risk associated with that crossing manoeuvre. The acts of risky behaviour involving choosing where to cross that have been found in the literature reviewed relate predominantly to pedestrians choosing to cross at or away from pedestrian crossings, but also include choosing to cross when obstructed by vehicles (e.g. between parked cars).

Signalised crossings are generally considered to be the safest place to cross (despite there being a relative high risk of pedestrian injury when pedestrians cross within 50 metres of a crossing) (TRL unpublished research undertaken as part of study by Wall, 2000). Risk in crossing the road is much higher away from crossings than at crossings (Transport for London, 2003, AA Foundation, 1994 and Ghee *et al*, 1998) and research also shows that crossing at signalised junctions is even safer (Older and Grayson, 1976, Hunt, 1995). More pedestrians in the UK choose to cross away from pedestrian crossings, according to American research which shows a much higher usage rate of designated crossings. This can be explained by the jaywalking laws in America which do not apply in the UK.

5.1.1 Effects of Traffic Volume

Crossing in light traffic is generally regarded by pedestrians as a safe action therefore they will not choose to cross at a designated crossing facility if they feel it is safe to cross where it is more convenient to them (Garder, 1989, Daff et al, 1991, Yagil, 2000). Pedestrians who said they always use signalised crossings gave safety and busy roads and traffic as reasons for doing so (Daff et al, 1991). American research has shown that commuters are more likely to risk crossing at non-designated crossing points than occasional users and did so because they perceived no risk in doing so, for example there was light traffic (Sisiopuki and Akin, 2003). It is also likely that they will be very familiar with their route and the traffic environment and will therefore feel more comfortable in taking risks.

5.1.2 Effects of Pedestrian Delay

Pedestrians will generally take the quickest route to their destination; therefore delay is linked closely with pedestrians' propensity to take risks. Pedestrians will generally try to shorten distances and reduce waiting times, often without adhering to the Highway Code and disregarding the risks involved. A need to hurry or a desire to keep moving is usually given as a main reason for disobeying pedestrian signals. These issues link with issues surrounding signalised crossings particularly in the signal timing and how long pedestrians must wait for a green man. Research has shown that pedestrians organise their crossing location and timing to minimise walking distance and delay (Daff et al, 1991, Sisiopiku and Akin, 2003).

A study conducted in Manchester showed that delay to pedestrians in UTC systems with long cycle times results in pedestrians being less likely to wait for the green man at signalised junctions (Preston, 1986). Route diversion is another influence on pedestrians' decisions to cross at a designated crossing place. In Daff's study only 27% of pedestrians using the crossing had diverted from their route (and most of these were female).

5.1.3 Effects of Demographic Variables

Choice of crossing place can be dependent on the type of pedestrian. Older pedestrians and females are more likely to choose to cross at signalised crossings (on green) than any other group (Daff et al, 1991, Preston, 1986, Garder, 1989). Studies have shown that young people (aged between 17 and 25 years) and especially young males, are more likely to cross the road at unmarked crossings and report more violations (disobeying the Highway Code), errors (e.g. in judgement when crossing the road) and lapses (e.g. in concentration) as pedestrians (Moyano, 2002, Daff et al, 1991). According to the research by Daff et al (1991), a high proportion of those pedestrians crossing away from the crossing were aged between 20 and 29 and pedestrians, who were over 60 years old, had a high proportion crossing the road at crossings (84%) compared with other age groups.

Research in Israel showed a difference in crossing behaviour amongst men and women, with men more likely to cross in unsafe places, away from crossings than women (Yagil, 2000). Although in this case, this finding could be culture specific, it is backed up by other studies (Preston, 1986, Daff, 1991, Diaz, 2002) and statistics in the UK which show that men are involved in more collisions than women (Ghee et al, 1998, AA Foundation, 1994).

Research (e.g. Elliott & Baughan, 2003) has shown that children, particularly teenagers, perform a number of potentially unsafe pedestrian behaviours. The frequencies with which those behaviours are performed tend to increase with age during childhood as children become more independent and capable road users. Children will often choose to cross behind a parked car or behind a bus even where there are other nearby places to cross. Over half of the adolescents surveyed in the study by Elliott and Baughan (2003) said they sometimes or often cross between parked cars and 43% said they sometimes or often cross behind a stationary vehicle such as a bus. AA Research (1994) also showed that there are a higher number of casualties in younger pedestrian age groups when they cross masked by parked cars on local distributor and residential roads.

No research from Great Britain was found on the effect of ethnic background on choice of crossing place, but a study conducted by Daff et al (1991) in Australia, found (through video observation and group discussions) that Greek and Asian pedestrians were also more likely to cross at a signalised crossing.

5.1.4 Effects of Pedestrian Physical Impairment

Pedestrians who are impaired in a particular way e.g. in a wheelchair, using crutches, carrying heavy bags etc. are likely to take longer to cross the road, feel more vulnerable, and therefore choose to cross at marked crossings. Little research has been found on this issue, however a study conducted by Daff et al (1991) in Australia found (through video observation and group discussions) that pedestrians carrying a heavy bag were more likely to cross at a signalised crossing.

5.1.5 Effects of Peer Pressure

Many studies, particularly those focussing on the crossing behaviour of children, found that reaction to peer pressure has a significant influence on a pedestrian's propensity to cross at a designated crossing (e.g. Yagil, 2000, Daff et al, 1991). School children are reported to be very influenced by peer group pressure which encourages them to disobey pedestrian signals. These children are aware of instructions given to them by parents, but parents are not as strong an influence as friends and peers and this influence by peers is greater the older the child gets (Daff et al, 1991, Martin, 1995). According to research in Virginia (Martin, 1995) significantly more *younger* students than older students indicated they would change their route if told to do so by their parents. This has an impact on how to influence children; parents may be the most useful channel for younger children whereas peers may be more influential on older children.

5.2 Pedestrian Non-Compliance at Designated Crossings

Studies (discussed below) have found that many pedestrian collisions occur due to negligent behaviour by pedestrians (whether intentional or not). Pedestrians tend to cross the road when it suits them, in terms of convenience and saving time rather than thinking of potential safety implications (e.g. Daff et al, 1991, Sisiopiku and Akin, 2003). In TRL unpublished research undertaken as part of study by Wall (2000) it was noted that pedestrians in the UK are more likely to ignore traffic signs and signals (such as the red man at signalised crossings) than are those in continental Europe. One possible reason for this is that there is no legal requirement in the UK to obey pedestrian signals, whereas in many other European countries (e.g. Germany, Sweden, Netherlands and Belgium) there is. The finding that compared with other European countries, pedestrians in the UK are more likely to ignore signals might also explain, in part, why the UK has a relatively poor safety record (in terms of pedestrian collisions) compared with some other European countries.

The acts of non-compliance that have been found in the literature reviewed (above) relate predominantly to pedestrians who cross against a red man, but also include crossing outside of pedestrian markings (studs) and jumping over pedestrian guard rail.

Crossing against a red man at a pelican crossing is seen as far easier to do by pedestrians than, for example, crossing on a dual carriageway or a residential road, despite it being associated with social disapproval (Evans and Norman, 1998). The research suggests that there is a link between crossing behaviours which are seen as easy to perform and having low perceived of risk. The authors suggest that pedestrians should be made more aware of the difficulties and risks associated with crossing the road in potentially dangerous situations which would increase pedestrian safety. American research shows that, despite jaywalking laws, American pedestrians are unlikely to wait for a green light before crossing (Sisiopiku and Akin, 2003).

It is known from current TRL research (Elliott and Baughan, 2003) that adolescents often fail to obey the traffic signals and/or fail to check that the road is clear. For example, nearly 25% of adolescents surveyed in this study, reported never or hardly ever checking to make sure the traffic had completely stopped before crossing at a pedestrian crossing, and 25% reported they fairly often or very often getting partway across the road and having to run the rest of the way. Knowledge of how to use crossings and encouragement to obey the signals is given as part of road safety education and by many parents. However, children may well copy ‘rule-breaking’ adults. Signal control strategies need to be readily understood by children.

In addition to failing to comply with the signals, pedestrians often cross outside the studs at signal controlled crossings (e.g. Wall, 2000). This is potentially unsafe as it is known that when pedestrians cross the road *near to* a crossing (within 50 metres), but not actually *on* the crossing, collision risk is increased by a factor of four (e.g. Older & Grayson, 1976, Grayson, 1987, Preston, 1989). Drivers anticipate the need to stop for pedestrians at crossings, but not necessarily elsewhere. Except in very low flow conditions, it is probable that pedestrians will only cross diagonally at a signalised junction rather than consecutive arms if there is an all-red phase for traffic. Pedestrians who are cautious or who take a long time to cross the road may be less likely to adopt this crossing behaviour than those who are not.

There is some evidence to suggest that installing guard rail at pedestrian crossings does not encourage all pedestrians to cross at the crossing. Pedestrians may get trapped outside guard railings and are forced to climb the railing to reach the footway (Gehl, 2004). A study at Southampton University (Zheng and Hall, 2003) concluded that there were safety benefits in installing guard rail at pedestrian crossings and junctions, however it also concluded that installing guard rail on links encouraged more risky behaviour such as jumping over the railing amongst those pedestrians determined to cross.

5.2.1 Effects of Traffic Volume and Speed

Research has shown that traffic volume also contributes significantly to pedestrian collision rates (Zegeer, 1985) and crossing behaviour. When traffic volumes are high, it increases the tendency for pedestrians to wait for the 'walk' sign or the green man (Garder, 1989, Daff et al, 1991, Yagil, 2000). Whether pedestrians wait for the green man often depends on whether there are gaps in the traffic (Preston, 1986).

5.2.2 Effects of Waiting Times

Studies have suggested that waiting time has an effect on pedestrian behaviour when attempting to cross a road. This is particularly important when pedestrians are waiting to cross at signalised crossings (e.g. Daff et al, 1991, Baass, 1989, Asaba and Saito, 1998). There is some evidence that the longer pedestrians have to wait at a crossing, the more likely they are to cross against the signal. One author, reviewing practice in Europe and North America, argued that if the waiting time is longer than 40 seconds, the number of pedestrians crossing against the signal increases significantly (Baass, 1999). However, different laws and cultures might mean this does not apply to the UK. In the 1960s it was widely thought that 30 seconds was the longest that pedestrians would wait at signalised crossings before attempting to cross against the red man. This is confirmed by recent, unpublished, TRL research into pedestrian behaviour that has involved conducting focus groups with both adult and child pedestrians. That research has shown that both adults and children report that 30 seconds is the maximum amount of time they are willing to wait a signalised crossing before they become impatient.

It is also the case that there may be more opportunities to cross during vehicle green time when there is a long cycle time, particularly where there is a UTC system with well-defined platoons of vehicles (Walker *et al*, 2005).

Video observations, reported in a study in Japan, showed that waiting time invoked a feeling of impatience amongst pedestrians which peaked at 40-45 seconds, although the questionnaire survey carried out amongst pedestrians in this study showed that a period of 21-28 seconds was reported as being the waiting time invoking a feeling of impatience (Asaba and Saito, 1998). This study also showed that when pedestrians became impatient they reported using the traffic to decide when to cross (looking for gaps in the traffic), crossed whenever they could, went to the front row of pedestrians waiting to cross or positively looked for a chance to jaywalk (which is illegal in Japan). This study suggests that traffic collisions involving pedestrians can be reduced by developing a control system that does not cause pedestrians to wait for an unduly long time.

5.2.3 Effects of Demographic Variables

Older pedestrians (typically defined as 65 years old and over) are more likely to comply with signals than are younger pedestrians (e.g. Daff *et al*, 1991). They are also known to take longer to cross the road and this may influence their decision to comply with signals. A number of studies have found that females are more likely to comply with signals than males (e.g. Yagil, 2000; Daff *et al*, 1991). *Young* men are three times more likely than average to cross on red and more likely than women (Daff et al, 1991, Preston, 1986, Garder, 1989).

TRL research has shown that almost 30% of adolescents (aged 11-16 years) reported often or very often crossing without waiting for the green man (Elliott and Baughan, 2003). Male children were more likely to cross without waiting for the green man than females, and crossing during the red man was found to increase with age during adolescence. This is perhaps unsurprising given that adolescence is the transition from childhood to adulthood where children become more independent from their parents and adopt more adult behaviour. Children are also more likely to run across the road than adults, whether or not they watch for traffic.

5.2.4 Effects of Pedestrian Impairment

A broad definition of impairment is taken here, covering any aspect that impairs manoeuvrability, increases crossing time, or affects perceptual/judgement skills that are necessary to cross a road safely. Pedestrians with mobility impairments take longer to cross a road than those with no mobility impairment (e.g. Reading *et al*, 1995, Austin and White, 1997) and therefore they may be more likely to comply with signals.

5.2.5 Effects of Peer Pressure/Group Dynamics

The mere presence of other people at a crossing/junction can represent a form of social pressure that can influence the way people behave. For example, when a number of people are waiting at a crossing and a few cross during the red man, other people may be likely to follow (Dannick, 1973). Yagil (2000) found that the presence of pedestrians was important in determining crossing behaviour because they stimulate conformity. In addition, Andrew (1996) found that the fewer pedestrians crossing at a junction, the greater the tendency for all age groups to check for traffic before crossing. In a study of adult pedestrian behaviour, Evans and Norman (1998) found that the scenario which included the presence of other people waiting at a crossing had an important role in determining whether pedestrians would cross against the ‘red man’ at a Pelican crossing. Adult pedestrians were less likely to cross if others were waiting.

5.2.6 Effects of Social Psychological Variables

Social psychological variables such as attitudes and intentions are known to be related to a number of social behaviours (see Ajzen, 1988, 1991; Godin & Kok, 1996). These variables have also been found to explain most of the behavioural differences between different demographic sub-groups (e.g. Elliott, 2004; Elliott, Armitage, & Baughan, 2003, 2004). Therefore, in the present context, social cognition variables have the potential to explain differences between the crossing behaviour of different age and gender groups, for example, at signalised crossings. In fact, Elliott (2004) showed that the effects of age and gender on crossing behaviour were fully mediated by social cognition variables (although Elliott's study was concerned specifically with adolescent road users and did not include adult pedestrians).

Two relevant studies were identified which explored the effects of attitudes and other social cognitions on *adult* pedestrian crossing behaviour. In one study by Yagil (2000), the health belief model (a social psychological theory of behaviour) was used to investigate non-compliance with pedestrian crossing signals. It was found that pedestrians were more likely to be non-compliant at signals:

- if they did not perceive danger/risk of a collision
- if they thought that there were few losses (e.g. ‘endangers lives’ and ‘annoys drivers’) and many gains (e.g. ‘saves time’, ‘prevents boredom’ and ‘prevents inconvenience’)
- if they did not have a strong sense of obligation to obey rules and procedures

In another study, Evans and Norman (1998) explored adult pedestrians’ attitudes towards crossing during the red man at a Pelican crossing using the theory of planned behaviour (another social psychological theory of behaviour) as a theoretical framework. Compared with pedestrians who did not intend to cross during the red man, those who did were more likely to have a positive attitude towards crossing during the red man, were more likely to believe that other people would approve of their crossing (subjective norm) and were more likely to perceive that their crossing during the red man would be an easy thing to do (perceived control). Also, the more pedestrians believed themselves to be careful road users, the more likely they were to intend to comply with the traffic signals. In this study it was found that the effects of age and sex on intentions were mediated by pedestrians’ attitudes, subjective norms and perceptions of control. For example, younger pedestrians had stronger intentions to cross during the red man than did older pedestrians because they had more positive attitudes towards crossing, perceived more social pressure to cross (subjective norm) and perceived that they had greater control over their performance of the behaviour (perceived control) than did older pedestrians.

The finding of the Evans and Norman (1998) study that social pressure is an important variable in determining pedestrians’ crossing decisions is of interest. Social pressure can mean a number of different things. It does not necessarily have to reflect the feeling that ‘other people would want me to behave in this way’ (as defined in the Evans and Norman study reviewed above). It could manifest itself in a more overt manner. For example, it was found in the recent TRL research into adolescent road user behaviour that children can verbally encourage one another to engage in ‘unsafe’ activities such as unsafe road crossing (Elliot and Baughan, 2003).

5.3 Crossing Speed

The time taken to cross the road depends on the road width and on walking speed. In the UK, signal settings are based on a walking speed of 1.2m/s (15th percentile crossing speed), considered to be a good compromise between operational efficiency and safety. This equates to 6 seconds to cross a standard two lane road. Extra time, or a central refuge and a separate stage, will be required on wider roads.

5.3.1 Effects of Demographic Variables

Pedestrians with a lower walking speed, whether because of age, infirmity or simply carrying a heavy object, may not have sufficient time to cross if they start at the end of the green period. Extra time might therefore be worth considering if the local population is elderly, as these users may have a speed less than 1m/s (e.g. Bennett *et al*, 2001, Baass, 1989, Wall, 2000). Other research suggests that pedestrians may cross more quickly at signal junctions than at mid-block crossings (Bennett *et al*, 2001) and older pedestrians in particular cross more slowly at Puffins than at Pelicans (Reading *et al*, 1995).

5.4 Failure to Attend to Traffic

Statistics for London in 2002 (Transport for London, 2003) show that the most common contributory factor in pedestrian casualties reported by the police was the pedestrian crossing the road heedless of traffic, although it should be noted that contributory factors can be subjective. TRL unpublished research undertaken as part of study reported in by Wall (2000) found that pedestrian error accounted for 75% of collisions involving pedestrians and that lack of observation was a significant factor. A study of collisions conducted in Australia documented reported pedestrian behaviour just before being involved in a collision and found that all related to the pedestrian being careless or making a mistake (child running across road, pedestrian not seeing vehicle, pedestrian standing in centre of the road etc) (McLean, 1978).

5.4.1 Effects of Demographic Variables

Failure to attend to traffic is one of the main causes of both adult and child pedestrian collisions. According to a study by Christie (1995, 1998) for the under 11's, attention absorbing activities, not related to the task of crossing the road, featured strongly just before the collision occurred e.g. playing, arguing/fighting etc.

Competing with traffic is a particular problem for elderly pedestrians, by their own admission and through video observations of their movements, in a study carried out by the AA Foundation in 1995. The second most common cause was grouped into occasions where the pedestrian found difficulty coping with the complexity or uncertainty of the crossing situation. According to the study, the main areas of concern for older pedestrians when on or by the road were the amount of traffic, competing with traffic to cross the road, traffic speeding in residential or shopping areas, the state of the pavements, and traffic collisions.

5.5 Pedestrian Alcohol Consumption

Despite alcohol having an obvious effect on pedestrian casualties, comparatively little research has been conducted on the issue, possibly because of difficulties involved in modifying legislation and behaviours of pedestrians. National data for Great Britain shows that the incidence of alcohol amongst fatally injured adult pedestrians is increasing: 46% of fatally injured pedestrians had BACs in excess of 9mg/100ml in 1997 compared with 39% a decade earlier (DETR, 1999).

There is evidence to suggest that alcohol has an effect on pedestrian collisions, though some of the research found on this subject dates back up to forty years with relatively few studies conducted in the last decade. In Scotland, 64% of pedestrian fatalities had been drinking and 30% in England and Wales (Heraty, 1986, quoting Older and Sims 1966) and in 1967 a third of all pedestrian fatalities had been drinking and 21% had exceeded the legal limit (Heraty, 1986, quoting Older and Sims, 1966). Despite the research being more than a decade ago, the problem is likely to have only got more widespread as the binge drinking culture in Britain has got worse in recent years (National Centre for Social Research, 2003). More recently, a study conducted in Oxford in 1988-89 (Everest et al, 1991) found that 27% of all injured pedestrians, admitted to the John Radcliffe Hospital in Oxford, had a BAC above 80mg/100ml (above the legal limit to drive). These pedestrians had the highest incidence of alcohol of any of the road user groups studied. Similar findings have been reported by The Scottish Office who also found that pedestrian casualties were significantly more likely to have consumed alcohol than any other of the casualty groups. Nearly a third (31%) of all pedestrian casualties had consumed alcohol prior to their collision compared to 5% of drivers and 9% of car passengers (The Scottish Office, 1998).

5.5.1 *Effects of Demographic Variables*

Further research, conducted in 1996 by the Department for Transport[3] as a repeat study to compare with previous results from a study in the 1970s (Clayton, 1977), found that one third of all fatally injured pedestrians (in a six year period in the West Midlands) had been drinking. A significantly higher proportion of males (40%) than females (12%) were found to have been drinking. Alcohol levels in males were also higher. This compares well with the original study conducted in 1977, where over a third of fatally injured male pedestrians were found to be above the legal limit for driving whereas no female pedestrians were found to be above the limit (Clayton, 1977). The research conducted for the Scottish Office (1998) also found that when drink is a factor in a pedestrian collision, male pedestrians are more likely to be involved than female pedestrians, with 87% of pedestrian casualties having consumed alcohol, being male.

In the DfT 1996 study, the highest incidence of pedestrians drinking alcohol was in the 30-54 year age group, where two thirds had been drinking. The Scottish Office found that pedestrians in the 40-49 age group showed an increased risk of being involved in a collision if alcohol was involved.

[3] Alcohol and Pedestrians (No. 20) web reference: http://www.dft.gov.uk/stellent/groups/dft_rdsafety/documents/page/dft_rdsafety_504585.hcsp

6 Evaluation of Measures

This section of the report examines interventions designed to improve pedestrian safety. In general, there are three main ways to improve safety by influencing road user behaviour:

(a) via education and publicity

(b) via enforcement of road traffic laws

(c) via traffic engineering.

Each of these methods can involve targeting interventions at pedestrians themselves (e.g. to encourage desirable pedestrian behaviour, from a road safety perspective). However, interventions targeted at drivers and riders of motor vehicles can also influence pedestrian safety. Interventions that are effective at reducing driving speeds, for example, would not only tend to reduce the total number of collisions and casualties, but also reduce collisions involving pedestrians, and their severity.

Given the main purpose of the present review was to examine the effectiveness of engineering interventions targeted at pedestrians, priority is given to these types of interventions in the following sections. However, because road safety education and the enforcement of road traffic laws are also important ways to improve road safety, these forms of intervention are briefly described (in section 6.1 and 6.2, respectively) before engineering solutions are discussed (in section 6.3). Attention is given to interventions aimed at motorists as well as interventions targeted at pedestrians themselves.

6.1 Traffic Education Measures

The first main way to influence road user behaviour, which is considered in this report, is via road safety education. Education is regarded as a "soft" approach to promoting desirable (from a road safety perspective) road use because, rather than placing external constraints on the individual (as is the case with enforcement and engineering interventions), it relies on *persuading* people to adopt appropriate behaviour. In terms of promoting desirable pedestrian behaviour, road safety education interventions can take a number of forms. Information and persuasive messages to promote safe road use can be given via:

- General publicity campaigns
- Television / Radio / Newspaper / Magazine adverts
- Posters
- Leaflets
- Formal classroom-based training
- Formal road-based training

Such interventions attempt to raise people's awareness of road safety. In particular, they attempt to promote desirable ("safe") behaviour by:

- Increasing road safety knowledge (e.g. knowledge of the rules and practices described in the Highway Code, and knowledge of what behaviour is considered to be safe and unsafe),
- Make road users aware of how unsafe their behaviour may be,
- Promoting desirable attitudes (e.g. positive attitudes towards safe road use),
- Providing / teaching people strategies to minimise the risk of being involved in a road traffic collision, and
- Increasing the awareness of the needs of other road users.

In terms of the groups that may be most and least influenced by road safety education interventions, younger (pre-adolescent) children are relatively easier to influence (especially when influenced by their parents) compared with older children. A review of trials (mostly in children) by Duperrex et al. (2005) found that pedestrian safety education can improve children's road safety knowledge and their observed road crossing behaviour, but may need to be repeated at regular intervals.

Heraty (1986) in her review of pedestrian safety research, found that the elderly are reluctant to accept advice, and education only seems to reach 20% of this age group. Unpublished TRL research has found that older age groups are also hard to target as a group.

> In practice, education measures are extremely difficult to evaluate in terms of their direct effect on reducing collisions and casualties. These difficulties stem from achieving adequate sample sizes, identifying appropriate control groups, lengthy timescales for measures to take effect, difficulty in separating other factors (e.g. changing road environment, engineering measures implemented etc) and the behaviours of people in the study which change simply as a result of being involved in the study (Sentinella, 2004).

Despite these difficulties, a study in America examining the effect of educational programmes in schools in four cities found that there was a statistically significant reduction in pedestrian collisions following the implementation of road safety education programs. An estimated saving of 40 collisions (during the two year study period) was calculated for the four cities, as a result of implementing the educational programs (Fortenberry and Brown, 1982).

Empirical evidence for the impact of road safety education on road user *behaviour* does exist. In the case of drivers, some studies have found that road safety education interventions can promote desirable attitudes and behaviours (e.g. Meadows & Stradling, 1999; Millar & Millar, 2000; Parker et al., 1996, 2002; Stead et al., 2002). Drink-driving behaviour serves as a particularly good case in point, where desirable attitudes and behaviour have been achieved through many years of remedial action. Although the improvements in drivers' attitudes and drink-driving behaviour may well have been a direct result of the introduction of the breathalyser enforcement tool, it is likely that at least some of the effects have been due to the accompanying publicity and education about drink-driving. As noted above, improvements in driver behaviour are likely to have a desirable impact on pedestrians because "better" driving behaviour should reduce vehicle-pedestrian conflicts. In addition, AA research conducted in 1995 concluded that in order to increase safety for pedestrians, safety programmes should be put in place to educate drivers (particularly young drivers) who are less likely to take pedestrians into consideration when driving.

Assessing the effectiveness of education interventions on adult pedestrian behaviour is more difficult than assessing the effectiveness of education interventions on driver behaviour. This is because there are very few education interventions aimed at adult pedestrians and even fewer evaluations of those interventions. Only one study has been identified that has evaluated road safety education interventions aimed at adult pedestrians and in this case the programme was aimed at elderly pedestrians and is a study conducted by Murray (1994) in Scotland. Elderly pedestrians in Scotland were targeted using various techniques including:

- a national bus back marketing campaign,
- a PVC coated shopping bag incorporating a reflective strip and the SRSC logo,
- a pension book holder with 'Take care on the Roads" message,
- a bookmarker with magnifier with "Take care on the Roads" message, and
- leaflets entitled "The Not So Young Pedestrian" which covered the subjects of eyesight, hearing and using pedestrian crossings.

Distribution of the materials varied between regions, for example, it was often combined with a talk on road safety to elderly members of clubs, or from road safety stands set up in town centres. In total 10,000 shopping bags and similar numbers of pension book holders and bookmarkers were handed out to elderly pedestrians throughout Scotland. Discussion groups took place in order to evaluate the effectiveness of the campaign and through these discussions elderly people reported that they did not mind being targeted by road safety campaigns, however they felt that there were other members in society who needed it more, especially the young road users, drivers and pedestrians. There was a general view that the majority of elderly people already did take care on the roads and that road safety campaigns merely served as a reminder to them. All members of the group who had received a shopping bag gave positive feedback and there was strong evidence to suggest they had been used frequently. The significance of the reflective strip was not appreciated by all, but many felt that it was an added safety benefit. The pension book holder and the bookmarker were favourably received and the safety message served as a useful reminder. There was a lot of confusion in respect of the contents of the leaflet and it was apparent that very few had actually received and read a copy of it. Overall there was a feeling that there were too many leaflets covering a wide range of subjects. Generally the groups felt that they were expected to read too much information in leaflets and when shown the campaign leaflet many thought the contents irrelevant. Overall however the campaign materials were received well by the elderly pedestrians. The message of the campaign served as a useful reminder, although there was a general attitude that they could not really be taught anything new. This study did not evaluate the impact the educational campaign had on road casualties.

Several education interventions aimed at children have been identified. The main ones evaluated in the UK have been:

- Children's Traffic Club: this intervention was aimed at pre-school children (aged between 3 and 5 years old) and involved a set of booklets issued every 6 months to parents and children which promoted road safety issues. The programme was found to increase knowledge and self-reported behaviour of the children and also had a positive effect on collisions. Since the programme has been introduced, there has been a decline in the number of people continuing with the programme and as it involved self-selection to take part, it was found that some social groups were not taking part (e.g. deprived groups) that are known to be more at risk of being involved in a road collision (Bryan-Brown and Harland, 1999).
- Kerbcraft: this intervention was designed to provide children in their first two years at infant school with pedestrian training. Three core skills are addressed: planning safe routes, crossing between parked cars and crossing at junctions. This scheme is running as part of the national pilot pedestrian training programme and is currently being re-evaluated in terms of its effectiveness. In the original evaluation, it was found to be effective in terms of observed behaviour and increased knowledge amongst pupils (Thomson and Whelan, 1997).
- JSRO (Junior Road Safety Officer scheme): this intervention was designed to increase knowledge, attitudes and awareness of primary school children in terms of road safety issues. Year 6 pupils are nominated to become a Junior Road Safety Officer and take responsibility for disseminating and promoting road safety issues in the school (via assemblies, organised activities etc). The scheme has been evaluated and has been effective in increasing the knowledge and awareness of the primary school pupils involved, but not their attitudes towards road safety (Sentinella, 2004, Appendix A).
- Making Choices: this intervention was aimed at children making the transition between primary and secondary school (Year 6 and 7) and involved issuing three booklets given to parents, children and teachers. It involved getting all three groups to think about an plan the pupils' new route to school and was found increase children's responsibility in relation to road safety issues, but not necessarily their knowledge (Platt et al, 2003).

In summary, research suggests that road user education can help to promote desirable attitudes and behaviours in child pedestrians, but no studies of the effect of education on adult pedestrians have been identified in this review. However, the previous sections of this review have shown that large numbers of both adults and children are involved in pedestrian road collisions, and both are known to carry out a number of potentially unsafe pedestrian behaviours. In line with Elliott (2004), perhaps road safety education campaigns to promote desirable pedestrian behaviour should be targeted globally at all road users, in addition to being targeted specifically at children.

6.2 Traffic Enforcement Measures

6.2.1 Driver Enforcement

Enforcement of road traffic laws is the second main way of controlling / changing road user behaviour to improve safety. With respect to the enforcement of road traffic laws designed for motorists, a recent literature review was conducted for TfL on how methods and levels of policing affect road casualty rates (Elliott & Broughton, 2005). The review included about 100 studies that had assessed the effects of enforcement on collisions, casualties and driving violations (e.g. speeding, drink-driving, red light running offences). Studies of physical policing methods were included in the review as were studies of automatic enforcement methods (e.g. speed cameras, red light cameras). The review concluded that, although its effects are limited in time and space (called “halo” effects), enforcement is effective at reducing collisions, casualties and driving violations. Although the review did not concentrate specifically on pedestrian collisions, it is likely that the effects of (driver) enforcement will tend to have a beneficial impact on pedestrian safety by reducing vehicle-pedestrian conflicts.

The most effective policing methods identified by Elliott and Broughton (2005) were stationary and highly visible policing (i.e. in marked police vehicles), although stationary enforcement in unmarked police vehicles was also found to be effective. In addition, automatic enforcement methods were also shown to be effective. More detailed information can be found in Elliott and Broughton (2005).

6.2.2 Pedestrian Enforcement

Great Britain, unlike other countries (America, Holland, Canada etc) have very few laws for pedestrians, therefore there is little need for enforcement aimed specifically at pedestrians. The UK has laws regarding not walking on motorways or slip roads and not loitering on pedestrian crossings, but has no laws, other than these specific instructions, to prevent pedestrians crossing the road. However the Highway Code does set out comprehensive guidelines about how pedestrians should behave whist walking on or near roads and British pedestrians do have precedence on zebra crossings or signal-controlled crossings when the signal to cross is illuminated. It is reasonable to assume that the presence of the police or police cameras might have a positive effect on pedestrian behaviour, particularly when crossing the road. In fact, Smeed in 1968 (quoted in Heraty 1986) found that the presence of police officers had a beneficial effect on both pedestrian and driver behaviour at automatic traffic signals in London. However, research in this field can be found mostly outside Britain where jaywalking laws are in place (where pedestrians are only permitted to cross the road at designated crossing points).

The UK has not adopted legislation that forbids jay-walking, and no research has been found on the impact these laws have on pedestrian casualty rates. However it is reasonable to assume that the existence of jay-walking legislation has a positive effect on reducing the number of pedestrians crossing the road away from designated crossing points and since this is where most collisions occur, it is reasonable to assume that this would also have a positive effect on reducing pedestrian casualties.

Various studies on levels of enforcement have been undertaken in countries where jaywalking is illegal. Traffic officers or police officers were asked to patrol in collision hot spots and issue pedestrian offenders (those who crossed the road after the pedestrian light had turned red, jay-walked, crossed against a traffic light or at a non pedestrian crossing) with an official notice warning that they had broken the law and could be charged. Where these studies have been carried out in America and South Africa (Heraty, 1986 quoting Winer, 1968, and ROBOT, 1995) there was an increase in the number of legal crossings (30% in America) and it was found to be a good way of educating the less educated sector of the community in South Africa.

6.3 Traffic Engineering Measures Targeted at Pedestrians

Traffic Engineering is the third main method for controlling/changing road user behaviour to improve safety. To improve pedestrian safety, engineering measures can be targeted at (a) pedestrians themselves or (b) drivers and riders of motor vehicles. Engineering interventions targeted at pedestrians are designed to improve their safety by directly affecting pedestrian behaviour (e.g. encourage compliance with pedestrian traffic signals or provide safe places to cross the road). This section of the report summarises the traffic engineering interventions identified in this review that have been used to reduce the risk to pedestrians. Those that are designed to influence pedestrian behaviour are described here and those designed to influence driver behaviour are considered separately in Section 6.4.

6.3.1 Interventions Used at Signalised Crossings

6.3.1.1 Pelican Crossing

Pelican crossings are often used on roads which have high traffic volumes, high traffic approach speeds or very high pedestrian flows. The Pelican crossing has a signal demand button mounted on the traffic signal pole that gives a message “WAIT” when pressed by a pedestrian. The red man signal on the far side of the crossing changes to a green man to indicate to the pedestrian that it is safe to cross the road and a red light is shown to traffic. The time allocated for the pedestrian crossing movement is dictated by DfT guidelines and is based upon the width of the road. The far side green man begins to flash at the end of the signal demand cycle, warning pedestrians that they should no longer attempt to start crossing.

Signalised crossings are generally thought to be safer places to cross than away from designated crossings; however unpublished research by TRL did find that when Pelican crossings were introduced at study sites, pedestrians were less cautious when crossing the road, more likely to cross without looking at traffic and looked less at the traffic whilst crossing.

6.3.1.2 Puffin Crossing

Puffin crossings were designed to reduce delays to vehicles and improve pedestrians’ sense of security while crossing the road. By detecting pedestrians on the crossing and varying the length of the vehicle red phase accordingly, they aim to give pedestrians (especially older or disabled pedestrians) a greater sense of protection compared with Pelican crossings. At a Puffin crossing, the red man / green man indicator is positioned above the push button on the upstream signal pole (rather than at the far side of road as on a Pelican). These nearside pedestrian signals at Puffins are intended to facilitate crossing for people with visual impairments and encourage pedestrians to watch approaching traffic and the pedestrian signal simultaneously.

If the lights change before a pedestrian completes his/her crossing, then either the pedestrian has to hurry out of the vehicle’s way, or the vehicle must wait until the pedestrian has completed his/her crossing. The use of on-crossing pedestrian detectors can solve this problem to a degree because they detect whether the crossing is still in use and hold traffic until crossing is complete. As a further refinement, pre-detection of pedestrians approaching the crossing can be used to change the signal (Rothengatter and Sherbourne, 1994). Kerbside detection of the continued presence or not of waiting pedestrians can be used to retain or cancel the pedestrian demand, avoiding the situation where the pedestrian presses the button, but then crosses during the red man, only for the pedestrian phase to then run unnecessarily, and thus minimising vehicle delay.

There are several technological options for pedestrian detection. Microwave is in widespread use for the on-crossing function. Infrared or pressure-sensitive mats have been tested for the kerbside detection and latterly, image based detectors have become available. Carsten *et al* (1998) considered that microwave detectors were superior as they can detect pedestrian movements by direction. One of the disadvantages of this type of crossing is that false cancellations (either as a result of faulty equipment or the pedestrian moving off the crossing) can occur, leading to longer waiting times and possibly greater non-compliance for pedestrians due to frustration. The detection of pedestrians at the kerbside is not entirely reliable. For this reason, Catchpole (2003) in Australia reported trials of both a Puffin and a 'partial' Puffin (with on-crossing detection only).

Reading *et al* (1995) found that the average time taken for pedestrians to cross the road at a Puffin was slightly longer than at a Pelican, particularly for older people (see Section 2.2.2), suggesting that crossing is less stressful at a Puffin, because the pedestrian is unaware of any change in the signal. With a Puffin, pedestrians are also more likely to be looking in the direction of the traffic before they commence crossing because of the location of the signal head.

Several authors concluded, from trials of signalised crossings / junctions in various European countries including the UK (Carsten *et al*, 1998) and in the US (Hughes *et al*, 2000), that there were fewer conflicts and fewer pedestrians crossing on red with pedestrian detectors. The improvements were obtained without any major effect on vehicle delay.

Using a simulation technique, Hunt and Chik (1996) reported that reductions in the proportions of pedestrians crossing during the red man at a Puffin could be obtained with a combination of reduced cycle time and better targeting of the times when pedestrian precedence periods occur. The reduced cycle time was partly a consequence of the automatic registration of pedestrian demand, but was mainly attributable to the relaxation of criteria for a change to pedestrian precedence. All four strategies increased the percentage of time which was effectively red to vehicles.

Crabtree (1997) compared pedestrian and vehicle delay at four different types of pedestrian crossing as follows:

- standard Pelican
- standard Puffin
- Puffin with standard MOVA
- Puffin with pedestrian-volume-sensitive MOVA

The only result that was statistically significant was that the Puffin with pedestrian-volume-sensitive MOVA used a shorter cycle time (and could therefore be considered more responsive to pedestrian demand than the other crossing types), but increased delay to vehicles. The difference in delay to pedestrians was negligible. The incidence of crossing during the red man was generally reduced.

Similar results were obtained in a before-and-after study by Reading *et al* (1995) that compared the performance of a Pelican crossing with that of a Puffin. The results of this study were unexpected, showing that with a Puffin crossing there was a slight increase in delay to vehicles, and a negligible reduction in delay to pedestrians. Pedestrian delay was found to be related mainly to the frequency of pedestrian stages. The authors note that the measured pedestrian delays were biased by faulty pedestrian detection and an observed reduction in the use of the push-button at the Puffin crossing. There was some evidence of lower levels of non-compliance at the Puffin, although there was no change in the level of crossing in anticipation of the green man.

More conclusive results on the relation between the 'pedestrian responsiveness' of Pelican crossings and the number of pedestrians crossing during the red man were found by Austin and Martin (1996). From trials at two sites in Brighton, they concluded that the removal of Pelicans from SCOOT control during the off-peak period significantly improved the responsiveness of the signals for pedestrians, resulting in a larger observed proportion of pedestrians waiting for the 'red to traffic' signal before starting to cross. The subsequent introduction of vehicle actuation and reduction of the vehicle-maximum-period increased the proportion of the cycle available to pedestrians and reduced the level of pedestrian non-compliance. The journey time for vehicles through the section of road with the two Pelicans did not show any relationship to the type of signal strategy. This is probably because linking of the signals was relatively unimportant at the sites in question.

6.3.1.3 Reduction of Waiting Time for Pedestrians

Signalised crossings that operate under long cycle times (e.g. under Urban Traffic Control) inevitably have longer waiting times for pedestrians, unless the pedestrian phase is repeated. The information found on the safety aspects of signal strategies is almost exclusively focussed on the effects on waiting times and delay for pedestrians, for example by reducing the cycle time or by double-cycling. It is assumed that longer waiting times increase the proportion of pedestrians crossing on red, which may increase collisions. Although this assumption sounds logical, very few of the studies provided collision-based data to support it. Longer waiting times were associated with larger numbers of pedestrians crossing on red in a number of studies, but little evidence has been found that this actually resulted in larger numbers of collisions involving pedestrians. In a limited study of collisions and flows at 12 Pelican crossings in Manchester, Preston (1989) showed that for males the risk of crossing on the green man was lower than that of crossing during other phases. For females, the risk was similar.

Hunt, Lyons and Parker (2000) state that ‘Although no clear relationship has been established between pedestrian delay and casualties, a more balanced and responsive approach to the allocation of time at Pelican/Puffin crossings has the potential to make a substantial contribution to a decrease in pedestrian casualties as well as improving pedestrian amenity’. They point out that because pedestrians are more likely to become impatient when a red man continues to be shown during periods of low vehicle flow, the reduction of unnecessary delay for pedestrians should encourage pedestrians to use crossings correctly and reduce risk taking.

A study of different types of crossings in Edinburgh, (Japs, 2000) concluded that at Pelican, Puffin and Toucan crossings, reducing the green time for vehicles can significantly reduce pedestrian delay. At signalised junctions, an exclusive pedestrian stage in addition to two traffic stages requires a substantially longer cycle time leading to longer waiting times for pedestrians. Japs showed that a better solution would be to adopt ‘walk-with-traffic’ operation in which pedestrians and traffic use the junction at the same time, but this tends to lead to pedestrians having to cross the road in several ‘hops’ and to more complicated signal phasing which has been shown to increase pedestrian collisions (Taylor *et al*, 1996). On the other hand, Hunt (1995) concluded from STATS19 data that crossings at signalised junctions are safer for pedestrians than mid-block Pelican crossings.

Various authors (Reading *et al*, 1995; Keegan and O’Mahoney, 2003; and Catchpole, 2003) found that shorter signal cycle times resulted in better compliance by pedestrians. It is highly plausible that a reason for poorer compliance with longer cycle times is that pedestrians become frustrated if they have to wait a long time and when they have to wait a long time to cross a road it increases the probability of acceptable gaps emerging in traffic. Keegan and O’Mahoney (2003) found a statistically significant reduction in non-compliance when comparing shorter cycle times with longer ones at the same junction. However, it should be noted that some authors have found no relationship between non-compliance and cycle time (e.g. Barker *et al*, 1991 in Australia; and Garder, 1989, in Sweden).

6.3.1.4 Clearance Phase

Austin and White (1997) studied the effects of different strategies at mid-block crossings to reduce the degree of pedestrian/vehicle conflict at the end of the pedestrian phase at different sites in the UK. The study compared a standard Pelican with a Pelican having a 2 second overlap period (where the invitation green-man period is followed by 2 seconds of flashing green man whilst red is still showing to traffic) and with a Puffin. Overall, the safety benefit for pedestrians of Puffin crossings was considered likely to be greater than that of an overlap period, because it can if necessary be longer than 2 seconds. However an overlap was considered to be a suitable alternative measure where funds do not permit the installation of a Puffin.

Asaba and Saito (1998, Japan) looked at increasing the length of the pedestrian clearance time (length of the flashing green man). When the flashing green man phase was increased, the number of pedestrians who completed their crossing during the all green/flashing green phase increased. When pedestrians became impatient they reported using the traffic more as a stimulus for crossing, crossed whenever they could, went to the front row of pedestrians waiting to cross or positively looked for a chance to jaywalk. The authors therefore concluded that there would be increased safety associated with giving green man and flashing green man signal timings in compliance with pedestrian behaviour patterns i.e. in accordance with their willingness to wait for the green man.

6.3.1.5 Pedestrian Phase at Signalised Junctions

Unpublished research by TRL examined the effect of introducing a pedestrian phase at signalised junctions and found that the proportion of pedestrians stopping at the kerb decreased, once the phase had been introduced. It was also found that more pedestrians crossed on green and that more people used the crossing facility rather than crossing near to it. There was a decrease in head movements, i.e. pedestrians were less likely to watch for traffic while crossing but this was offset by the improvement of pedestrians choosing when and where to cross. There were no statistics on casualties in this report.

6.3.1.6 Countdown Devices

The idea of a countdown device is to improve compliance by providing information about the remaining waiting time to pedestrians at junctions, by indicating the amount of time left in the pedestrian crossing phase.

Figure 2: Example of a countdown timer in Singapore

Source: http://www.lta.gov.sg/road/road_traffic_getacross.htm

Countdown timers have been installed and/or trialled in various countries including Singapore, France, Ireland, the Netherlands and the USA. They are often installed at signalised pedestrian crossings near schools and at busy junctions. According to the Metropolitan Transportation Committee in California[4] there are various advantages and disadvantages of using countdown timers, and they are presented in the table below:

[4] http://www.bayareatrafficsignals.org/toolbox/Tools/CDownSignals.html

Table 1: Advantages and Disadvantages of Countdown Timers

Advantages	Disadvantages
• Easily understood by all age groups • Increases the feeling of safety • Reduces the number of pedestrians *stranded* in the crosswalk when the light changes • Appropriately suited for wide crossing and areas where there are many senior citizens and people with walking disabilities • The great majority of installations are simple drop-in replacements	• Not accessible to pedestrians with impaired vision • Some suppliers start the countdown at the beginning of the pedestrian phase and others at the beginning of the pedestrian clearance interval; this may confuse some pedestrians • Drivers may use the countdown to get a head start before they have a green light • May create a possible legal conflict if a pedestrian starts during the pedestrian clearance interval but cannot finish crossing before the countdown timer reaches zero • May encourage pedestrians to begin crossing during the Flashing Don't Walk phase

They conclude that it is appropriately suited for wide crossings and areas where there are many senior citizens and people with walking disabilities; however a 3 second all-red phase should be added at the end of the countdown to discourage head starts by drivers.

A trial in France (see Druilhe, 1987) found that the supplementary information provided to pedestrians about how long they have to wait before being signalled to cross was beneficial in that it tended to make long waiting times a little more bearable. However, as noted by Baass (1989), this information might also lead to increased non-compliance when the indicated waiting times are 'too long'.

Countdown timer units have recently been installed at some junctions in Dublin. Keegan and O'Mahony (2003) reported a statistically significant reduction in the proportion of pedestrians crossing when the red man is showing, from 35% to 24%. They have been tested at only one location in the UK (in Glasgow), and no results are as yet available.

In the US, installations may instead count down the amount of time remaining to safely cross the junction, starting either at the beginning of the pedestrian phase or alternatively the clearance interval (Lalani, 2001). Allsbrook (1999) reported positive feedback from pedestrians using such a device in the USA: results found that 52% of pedestrians noticed the experimental countdown signal heads, 92% felt the experimental signals were clearer and 85% felt that the experimental displays were an improvement. Most frequent comments were that it was a good idea, like to see more, need more like it, increase time and needs to be brighter. However it may encourage pedestrians to across before the lights change, if they feel the time showing is too long to wait.

Countdown timers in the Netherlands have been found to be an effective way of providing positive reinforcement to non-motorised traffic: that the pedestrian timing button has been activated and the signal is operating properly. Among several devices is an indicator that surrounds the pedestrian push button (Exhibit 6). The yellow lights surrounding the push button darken sequentially (i.e., "count down") to let the pedestrians know their wait is ending.[5]

Figure 3: Example of a countdown timer in the Netherlands

Source: http://safety.transportation.org/htmlguides/sgn_int/app04.htm

Countdown timers can only work if the time to the start of the pedestrian phase can be predicted. This would not be possible in current UK isolated signal control systems (i.e. MOVA and VA), although it may be possible to modify MOVA to do this.

6.3.1.7 Pedestrian Priority at Signalised Crossings

This measure is designed to reverse conventional traffic priorities by giving pedestrians the default green and asking vehicles to wait at the stop line before being detected. It was trialled at two sites in Kingston Upon Hull for a three year period to the end of 1996 (Totton, 2001). Both sites have high pedestrian and vehicle flows (and a high bus flow). The scheme was successful in terms of reducing collisions: the total number of injuries dropped by 36% over the 3 years which includes a 67% drop in child collisions. There are no other sites in the Kingston upon Hull area with the same mixture of high pedestrian and vehicle flows (especially buses) that make this scheme suitable, although the team are reported to have said that they would use the measure again given similar site conditions.

6.3.1.8 Signal Strategies in Other Countries

Much of the thrust of strategies in countries where unlike the UK, a green man does not necessarily indicate an exclusive right of way, has been towards the investigation of exclusive pedestrian phases. Although the relationships were rather weak, possibly due to small numbers of sites with this type of phasing, Zegeer *et al* (1982 and 1985) in the US found that exclusive pedestrian phases were associated with fewer pedestrian collisions. A similar result was obtained by Abrams and Smith (1978), also in the US, and by Garder (1989) in Sweden, provided pedestrian compliance was high. These were the only studies found that directly relate signal strategies to numbers of pedestrian collisions. Abrams and Smith found that early or late release of pedestrians with respect to the turning traffic increased pedestrian and vehicle delay and early release had does not significantly improve pedestrian safety. Again in the US, Tian *et al* (2001) investigated various alternatives to determine when exclusive pedestrian phasing can improve operational efficiency. They found that:

- Split phasing with protected left turns eliminates conflicts between pedestrians and left-turning vehicles, but the provision of two pedestrian splits could significantly reduce the intersection capacity and normally requires use of longer cycle times in coordinated signal systems.

[5] Taken from the Strategic Highway Safety Plan, which is the output of a committee formed in the USA in 1997 to address critical highway safety problems across North America. http://safety.transportation.org/htmlguides/sgn_int/app04.htm

- Split phasing with permitted left turns provides more efficient traffic operations due to the accommodation of pedestrian crossing within a single pedestrian phase. However, the display of a green circle may not convey clear information to drivers and could condition them to make a left turn without yielding to opposing traffic at a permissive left-turn location.

By contrast, when considering the percentage of fatal collisions that involve pedestrians at junctions on major urban roads with and without signals, unpublished research by TRL found that UK percentages were higher than those elsewhere, but were similar at junctions with and without signals. It was concluded that there was no clear case that the overseas system is less safe for pedestrians than the UK system.

6.3.1.9 Right Turn on Red, RTOR (Left Turn On Red in countries that drive on the left))

Throughout America and many other countries, vehicles are permitted to turn right at red traffic lights at intersections, unless prohibited by a posted traffic sign. In the US, the policy of allowing drivers to turn right on red was introduced primarily to reduce fuel consumption following the energy crisis of 1973 (Retting et al, 2002). The following table details the countries which currently allow right turn on red:

Table 2: Countries that Permit Right Turn on Red

Country	Rule
USA	After stop on red, right turn and left turn from 1-way to 1-way road.
Virgin Islands	Left turn on red light after coming to a complete stop is permitted unless prohibited by signs.
Canada	After stop on red, right turn and left turn from 1-way to 1-way road.
Mexico	On red light, right turn with caution is permitted, as is left turn from a one-way road into a one-way road. A red light may be passed cautiously after stop from 23:00 to 05:00.
China	Right turn on red light is permitted if not interfering with other traffic.
Dominican Republic	Right turn on red light is permitted.
Republic of Korea	Right turn on red light after coming to a complete stop is permitted.
Myanmar	Right turn on red light is permitted.

Source: Justin (2005). Traffic Light Signals and Red Light Cameras

However, following the adoption of the policy, significant increases in motor vehicle, bicycle and pedestrian collisions were reported, with pedestrian collisions increasing from 1.47 to 2.28 per year at signalised intersections (Preusser et al, 1981 cited, in Retting et al, 2002). Preusser et al concluded that the reasons for this rise in collisions was that many drivers do not come to a complete stop before turning right on red (which is a traffic violation) and that pedestrians often feel they must give way to vehicles rather than the other way round.

There is other evidence to suggest that allowing vehicles to turn right on a red light has a negative effect on pedestrian safety. Most pedestrian collisions in Sweden occur when a turning vehicle hits a pedestrian crossing on green (Garder, 1989) and according to Sisiopiku and Akin (2002) approximately 50% of respondents in their survey complained that turning vehicles do not respect pedestrians who attempt to cross at signalised junctions during green and this was verified by field observations (right or left turning vehicles share the green phase with pedestrians). This situation was cited as a reason for pedestrians choosing to cross the road at locations other than signalised intersection crosswalks during green. Sisiopiku and Akin (2002) state that the conflict between turning traffic at intersections and pedestrians trying to cross is great and therefore encourages pedestrians to cross against the red light; they suggest that allowing pedestrians to begin crossing several seconds before the release of potentially conflicting vehicles (“leading pedestrian intervals”) would assist in reducing the number of conflicts in this situation. The effect of leading pedestrian intervals was researched by Van Houten et al (2000) and the authors found that when they were used, conflicts were almost non-existent and that drivers were more likely to give way to pedestrians.

Research in Canada has been conducted by Van Houten and colleagues into ways in which the potential conflicts of pedestrians and vehicles at signalised junctions can be mitigated. Van Houten et al (1999) evaluated the effect of alternative signal heads for pedestrians on conflicts between pedestrians and turning traffic. In situations where the green phase for pedestrians coincided with a green phase for turning traffic, pedestrians were warned by an additional signal head with animated eyes that scan from side to side at the start of the Walk sign. Observations showed that the number of pedestrians not looking for turning vehicles can be reduced by the new signal.

Despite the evidence given above, it has also been argued that the effect of RTOR on pedestrian safety is negligible. Hunt (1995) argues that where traffic flow is light to moderate and there is a speed limit of 20mph, the overseas practice of allowing pedestrian precedence to coincide with vehicle turning movements might be beneficial for pedestrians, provided appropriate changes were made in signing (flashing amber) and road markings. Research conducted by The National Highway Traffic Safety Administration in the USA, found that there are a relatively small number of deaths and injuries each year caused by right-turn-on-red collisions (US Department of Transportation, 1995). These represent a very small percentage of all collisions, deaths and injuries (approximately 0.2-%). The research analysed national collision statistics (via their Fatal Accident Reporting System) and looked in-depth at four States' crash data. This in-depth analysis showed that when a RTOR occurs, a pedestrian or cyclist is frequently involved and usually involve injury. Only 1% RTOR pedestrian and cyclist collisions resulted in fatal injury, however less than one percent (0.2%) of all fatal pedestrian and cyclist collisions result from a RTOR manoeuvre. This research concluded that as the number of collisions resulting from RTOR is so small, the impact on traffic safety is also small.

6.3.2 Interventions Aimed at Crossings in General

6.3.2.1 Zebra Crossing

Zebra crossings are formal crossings where the pedestrian is given legal priority over vehicles without the use of traffic signal controls. They are a relatively low cost option compared with signal-controlled crossings (e.g. Pelican crossings and Puffin crossings). A Zebra crossing is marked on the carriageway with alternate black and white stripes. Studs and `Give Way’ markings outline the crossing, and zig-zags replace centre and kerb side markings on either side of the crossing. These highlight the crossing and prohibit parking to ensure good visibility. Flashing yellow beacons are placed at each end of the crossing.

Ekman and Elvik, 1997 (cited in Sanca, 2002) do not believe that marked road crossings have a positive safety effect for pedestrians. They argue that collision risks can be higher at marked crossings with no other facilities (e.g. zebra crossing) as they give pedestrian a false sense of security because the road markings are not as visible to vehicles as they are to pedestrians.

6.3.2.2 Zebra/Pelican to Puffin Conversions

In recent years, many Zebra crossings have been replaced with Pelicans because it is thought to reduce the waiting time for pedestrians to cross the road and to have safety benefits for pedestrians. TRL research (Inwood and Grayson, 1979) comparing the safety effects of Zebra and Pelican crossings concluded that Pelicans do have a lower total collision rate than Zebras and that the difference is mainly due to the lower vehicle collision rates at Pelican crossings.

It is widely thought that there are added safety benefits to pedestrians in making these conversions, and it is the intention of the Department for Transport that Puffin crossings should be the standard pedestrian light controlled crossing in the UK. TRL research (Davies, 1992) showed that Puffin crossings operate in a flexible manner, allowing more time for slow pedestrians and giving greater share of total time when pedestrian flows are higher. The cancellation of unwanted pedestrian phases also gave a benefit to traffic. Research has been undertaken by TRL for Transport for London to investigate the safety benefits associated with Puffin crossings compared with Pelicans (Walker et al, 2005). The results were inconclusive due to insufficient conflict data recorded in the 12-hour time periods used in the study. It was also concluded that the detectors need to be operating correctly in order to gain maximum benefit from these crossings.

6.3.2.3 Stop Lines

Advanced stop lines (ASLs) are designed to hold traffic back further away from the crossing (compared to standard crossings). In the UK, advance stop lines are usually used to create a reservoir area in which cycles can wait in front of other traffic, but little research has been found that trials the advanced stop line in order to separate vehicles from pedestrians at crossings. However, Local Transport Note 1/04 suggests that, 'increasing the distance between the stop line and the crossing studs from 2m to 3m has been proven to improve safety and comfort for pedestrians by positioning waiting motor vehicles further from the crossing point'. Canadian research has shown that putting give way markings 10 metres in advance of the crossing reduced conflicts between pedestrians and vehicles (Van Houten et al, 2001) from 16.8% to 4.3%. Moving the markings to 15m did not show much more of an improvement, with conflicts falling to 3.3%. Although not all motorists stopped at or near the yield lines, many motorists stopped 9m or more before the crosswalk. Observers noticed that motorists tended to stop closer to the crosswalk when traffic was heavy and slow, and these times risk is greatly reduced to slower traffic speeds. Introducing in-roadway signs was associated with motorists yielding farther back from the cross walk.

UK research conducted by Wall (2000) found that at one location, moving stop lines back one metre reduced vehicles running red lights by 40%. A different study by Wall et al (2003) (quoted in Reid et al, 2004) also found that moving a driver's stop line back by 5 metres had no significant impact on junction capacity unless a traffic lane was removed in order to install it and recommended that the drivers’ compliance should be encouraged through the use of signs, road markings and education and/or enforcement.

A study for TfL examined the behaviour of road users at Advanced Stop Lines (ASLs) designed to allow priority to cyclists (Allen, Bygrave and Harper, 2005). The study found that all vehicles that encroached at control sites went into the pedestrian crossing, compared with 12% at ASL sites. This indicated that an ASL can provide a buffer zone that discourages vehicles from blocking the pedestrian crossing.

6.3.2.4 Raised Crossings

According to Sanca (2002), Jones and Farmer (1993) and Zegeer et al (2001), the effect of introducing raised zebra or signal-controlled crossings is a reduction in vehicle speed and an increase in vehicles giving way to pedestrians, both of which give a safety benefit to pedestrians and a significantly lower pedestrian collision rate. Pedestrian delay is also significantly decreased (by up to 25%) and the ramps were favourably received by 1 in 5 people surveyed (Jones and Farmer, 1993).

Sanca (2002) does, however, warn that this measure should not be introduced if sight distance is limited, if the street is steep or if the road is a bus route or emergency route. Special care should be paid to drainage.

Flat top road humps can also act as informal crossing points, particularly where they are distributed between humps that have been designed as crossings. This can work well in a High Street where drivers automatically give way to pedestrians whether the hump is a formal crossing point or not, however no research has been found on the effects of this.

Another idea that has been tested is the use of perceptual road humps at crossings. However, this type of measure tends to be ignored once drivers become accustomed to it.

6.3.2.5 Use of Intelligent Road Studs

An example of the use of intelligent road studs would be to highlight a crossing by flashing a warning to oncoming traffic that a pedestrian was crossing. The studs could be laid across the carriageway or down the centre of the road. This application is not currently legal in the UK and no evidence is available of how effective it is, or on the durability of the studs. If laid across the road, it will be important to ensure they do not create a hazard for powered two wheelers or cyclists.

6.3.2.6 Pedestrian Refuge Islands/Medians

Research has shown that painted medians (that were not raised) do not offer significant safety benefits to pedestrians compared with no median at all (Zegeer *et al*, 2001).

Refuges in the centre of the road can help pedestrians by providing a safe place to stop when crossing a road. The refuge means that pedestrians only have to deal with one way traffic and act as a brief resting point for the elderly or disabled. They are often installed on wide roads with high traffic volumes or speeds (Sanca, 2002).

Relatively few studies have been conducted on the safety effects of pedestrian refuges (Zegeer, 1991) however one study undertaken in London (Lalani, 1976) examined the effects of many roadway improvements, including pedestrian refuges. This study concluded that the provision of refuges decreased vehicle collisions, but surprisingly increased pedestrian collisions. Significant collision reductions were only obtained at sites where the purpose of the refuge was very clearly established, i.e. installed for safety reasons, reinforcement of the hatch markings etc.

6.3.2.7 Pedestrian Crossings with Narrowing

Road narrowing at a crossing can be achieved by widening the footway and therefore reducing the width to cross. It is a measure suitable for low volume streets. According to Sanca (2002) narrowing at a pedestrian crossing is an effective way to reduce traffic speeds and increase drivers' awareness of other road users.

6.3.2.8 Guard railing

Guard railings are put in place to prevent conflict between pedestrians and vehicles and reduce collisions with the idea that the railings will keep pedestrians on overcrowded footways from spilling into the road and channel people to cross the streets at few selected places (Gehl, 2004).

On the basis of the Older and Grayson (1976) study and similar research, guard railing was introduced at many crossings / junctions. According to some authors, there is little evidence to suggest that the provision of guard-railing is associated with reduced pedestrian collision risk (Taylor *et al*, 1996, Hall, 1986). It should be noted that in a ‘before and after’ study in London (Simmonds, 1983), there was a reduction in collisions when guard rails were installed, although this may be an artefact arising from selection bias.

A more recent study has been conducted by Southampton University (Zheng and Hall, 2003) where 37 sites across 5 London boroughs were studied to see how effective pedestrian guard railing is in reducing pedestrian collisions. The study found that across all sites, those with guard railing had lower average levels of pedestrian conflict, lower total collisions and statistically significant lower pedestrian collisions. However, the study did find different effects between site types, therefore there is some question as to whether the small sample sizes have had an effect. The study concluded that there were safety benefits in installing guard railing at pedestrian crossings and junctions, however installing guard rail at link sites encouraged more risky behaviour such as jumping over the railing amongst those pedestrians determined to cross. The study also concluded that guard railing at school sites and transport interchanges improved all aspects of safety (though this is based on a small sample size).

Further research on criteria for the use of guard rails is being undertaken for TfL by TRL.

6.3.2.9 Vehicle Activated Signs

These are automatic warning and detection systems designed to warn motorists of the presence of pedestrians and have been used in Sweden. Two infra-red or microwave detectors are modified to automatically detect pedestrians wishing to cross the road (it is not clear from the report where the signs should be sited). When the pedestrians are detected the signs light up their warning message consisting of warning triangle and/or text.

According to Sanca (2002) these signs improve drivers' speed and give way behaviour, and are well accepted by drivers. Pedestrians who use the crossings think it is easier and more convenient to cross.

6.3.2.10 Coloured Surfacing on Crossings

Various studies described below have examined the effectiveness of using coloured paving at pedestrian crossings and results generally conclude that there is a small safety benefit associated with using coloured surfaces at crossings. Coloured surfacing can be used in one of two ways: (a) where the colour of the road surface is changed to e.g. yellow on both approaches to the crossing (for vehicles) and (b) where the surface of the crossing is coloured e.g. red to distinguish it from the road.

One American study, by Sisiopiku and Akin (2003) which used video observations and questionnaire surveys, found that 41% of pedestrian respondents said that coloured paving was an engineering factor that would influence their decision to cross, though this was not as popular as other factors such as distance to desired destination, presence of a midblock crossing and presence of a pedestrian traffic light. However, other research has shown that the use of green coloured surfacing at pedestrian crossings near schools showed a slight increase in pedestrian usage and a slight increase in the proportion of those crossing within the marked area (Wall et al, 2000). Australian research (Corben et al, 2004) concluded by recommending that coloured surfaces be used on crosswalks in busy, complex pedestrian/traffic environments as they were found to have a positive effect on pedestrian safety (in terms of collision frequency and injury severity).

6.3.2.11 Wider Dashed Lane Markings

Increasing the width of the dashed lane markings at signal controlled junctions has been shown to reduce vehicles speeds and average speeds of approach to the crossings by approximately 1 to 3 mph (Wall et al, 2000). High vehicle speeds are associated with a greater risk for pedestrians therefore this measure should have a beneficial impact on pedestrian safety.

6.3.2.12 Lighting

Extra lighting can be used at crossings in order to mitigate against the high risk faced by pedestrians at night. Various studies have been undertaken which measure the effect that installing extra lighting has on pedestrian safety at crossings, and the results generally show a reduction in the amount of collisions occurring during night time hours. A study carried out in Australia (Pegrum, 1972) showed that a collision reduction of 18 collisions could be achieved at 63 sites over 4 years (89 collisions in the 2 years before the lighting was installed and 71 in the 2 years after). Other studies conducted in Israel and Philadephia have found similar results (Polus and Katz, 1978 and Freedman et al, 1975).

6.3.3 Other Interventions Aimed at Pedestrians

6.3.3.1 Footway Widening

Increasing the width of the footway is likely to have increased safety benefits to pedestrians (though no literature has been found to show this). Footways less than 1.2m wide can be inconvenient and sometimes unpleasant to use, and it is often necessary for pedestrians to step into the carriageway to pass each other, causing potential conflict with vehicles on the carriageway (LTN 1/04). Carriageway space to widen footways can often be released as a result of introducing traffic management schemes or parking restrictions and may be an appropriate measure where footways are unusually narrow or where pedestrian flow is high.

6.3.3.2 Pedestrian Zones

Town centres and other main shopping areas may require the exclusion of private traffic and public transport, in order to maintain safe and pleasant pedestrian priority areas. Vehicle restricted areas, which are often called pedestrian zones, are designed to provide a safer environment for pedestrians by closing an area off to all motorised vehicles, leaving the space open for uncontrolled pedestrian movement. Although no research has been found on the effectiveness of introducing pedestrian zones, in terms of increased safety benefits to pedestrians (both perceived and actual), it is thought that this may be an effective measure particularly in shopping areas.

6.3.3.3 Targeted Pedestrian Safety Zones

Research in two cities in America (Marvin et al, 1998) studied the effectiveness of defining safety zones specifically targeting the safety improvements for older pedestrians. Specific countermeasures, such as distributing education material, general publicity and media broadcasts, installation of pedestrian crossings, repairs to pavement, were introduced and targeted at specific zones (defined by the local authority).

Results showed that whilst overall pedestrian collisions increased during the study period, older adult collisions decreased by 13.7% (compared with 9.9% outside of the zone). The zonal approach to targeting safety initiatives was seen to be an efficient and cost effective way of deploying countermeasures over a small area.

A similar approach was used in the 'Gloucester Safer City' programme (Mackie and Wells, 2003). It was intended as a major road safety initiative to demonstrate to highway authorities that road collisions and casualties in urban areas can be substantially reduced if significant funds are made available and towns are treated using safety engineering in a strategic manner, but also with safety integrated into other town policies and activities. The safety improvements (collision and casualty reductions) were achieved through the implementation of traffic management measures, physical engineering measures, land use measures, enforcement, publicity, education and training. Over five years, net collision reductions (of all road collisions) of 16.7% were achieved (compared to what would have occurred had Gloucester's collisions increased at the rate of the control towns). Collision reductions were not split by mode, although all road user groups were said to have benefited from the project apart from cyclists.

6.3.3.4 Car Parking Management

Removing on-street parking can help to release road space for pedestrian and cycle facilities and can lead to improved safety (although the needs of disabled persons' parking card holders must be taken into account when restricting vehicular access). Controlling the capacity of available parking by introducing features to prevent verge side parking is a technique often employed in rural areas with high levels of tourism. However no research has been found on the effectiveness of removing on-street parking.

There are studies which have shown that the existence of parked cars on streets help to reduce vehicle speeds, and reduced speed is related to fewer pedestrian collisions. According to a TRL study for the Highways Agency (Chinn and Elliott, 2002) the addition of street parking, with vehicles parallel to the road, was found to reduce reported travelling speeds by 5 mile/h on average. Street parking with vehicles at right angles to the road was associated with a 7 mile/h reduction in average reported travelling speed.

Despite the speed reduction benefits of on-street parking, it has been shown in section 4.2 that more collisions occur when pedestrians are crossing between parked cars, therefore reducing the incidence of parked cars is likely to benefit pedestrians when attempting to cross the road.

6.3.3.5 Single/Double Summertime

The evidence that casualty rates, particularly fatal and serious injuries, are higher in darkness has led to several investigations of the potential road safety effects of adopting so called Single/Double Summer Time (SDST). SDST would involve setting clocks to one hour ahead of Greenwich Mean Time (GMT +1) from October to March and two hours ahead (GMT +2) from March to October. A study into the potential effects of adopting SDST (Broughton and Stone, 1998) found that the effects of darkness are greater for pedestrians than for vehicle occupants and greater for fatalities than non-fatalities. Overall, Broughton and Stone (1998) predicted that KSI casualty rates for the Great Britain for the period 1991-94 would have been 0.8% lower had SDST been in place.

6.4 Traffic Engineering Interventions Targeted at Reducing Vehicle Speeds

Interventions targeted at drivers of motor vehicles are also relevant to the present review because promoting safer driver behaviour (e.g. slower vehicle speeds) will tend to reduce the risk to pedestrians of a collision (Preston, 1995). Traffic calming techniques are a combination of mainly physical measures that reduce the negative effects of motor vehicle use and improve conditions for non-motorised street users (i.e. pedestrians). Mackie and Wells (2003) reported achieving large reductions of 85th percentile speeds of up to 12mph in Gloucester from use of interventions such as speed cameras, vehicle speed-activated speed limit reminder signs, 20mph school safety zones and area wide traffic calming.

Although traffic calming is designed to improve a number of driver and vehicle related behaviours (e.g. positioning on the road), their main purpose is to reduce vehicle speeds. By reducing speed, drivers should have more opportunity (time) to notice pedestrians and this will tend to reduce the risk of an incident occurring. In addition, the basic dynamics of an impact means that there will be less severe injuries sustained by pedestrians as vehicles travel at slower speeds.

Therefore, summarised below are the main traffic calming interventions that have been used to reduce motor vehicle speeds, and where possible evidence for their effectiveness in terms of collision and speed reductions is cited. Given the focus of this review is pedestrian safety in London, only those measures that are suitable for use in urban areas are reviewed.

6.4.1 20mph Zones

- Areas where vehicles are restricted to travelling at a speed no greater then 20mph, by physical measures.

20mph zones are considered to be effective in reducing vehicle speeds and therefore having a positive effect on pedestrian safety. Speeds can be reduced by about 9 mph and traffic flows reduced by 27% when 20 mph zones with traffic calming are implemented which can lead to a 60% reduction in overall collision frequency. Reductions in pedestrian and cyclist collisions of 63% and 29% respectively have been measured where 20 mph zones were introduced in the UK (LTN 1/04). Child pedestrian and child cyclist collisions were reduced by 70% and 48% respectively after the introduction of 20 mph zones (LTN 1/04).

The safety review of 20 mph zones in London by TRL (Barker and Webster, 2003) found that the frequency of injury collisions and severity of the casualties were substantially reduced following the introduction of 20mph zones (by an average of 45% for collisions and 57% in fatal and serious casualties respectively, where detailed information was available, taking into account background changes in collision frequency). As far as pedestrians were concerned, collisions with fatal and serious casualties were reduced by about 45%.

6.4.2 Speed Humps & Speed Cushions

- Speed Humps: Rounded raised pavement devices placed across roadways to slow and/or discourage traffic.

The standard round topped kerb to kerb road humps are an extremely effective means of keeping vehicle speeds low. The effect of road humps on vehicle speeds and collisions in the UK has been documented by studies by TRL (e.g. Webster, 1993, Webster and Layfield, 1998, Sayer et al, 1999), and updated to take account of improvements in vehicle design. Such research has shown that speed humps are effective at reducing mean vehicle speeds which ranged from 11mph to 16mph (100mm high flat-top and round-top humps). Installing 75mm high flat-top or round-top humps can reduce mean and 85th percentile speeds between humps by an average of 10mph.

- Speed Cushions: a form of road hump, occupying part of the traffic lane in which it is installed. Speed cushions are generally located in pairs, arranged transversely across the carriageway, but single cushions, "three abreast" versions, and double pair arrangements have also been used.

TRL carried out an assessment of 34 speed cushion schemes that have been installed by Local Highway Authorities (Layfield and Parry, 1998). The results of the study indicate that speed cushions are effective as a speed reducing measure, but not quite as effective as road humps. The overall mean and 85th percentile speeds at the cushions were 2mph to 7mph higher than those measured at the 75mm high road humps. They are more suitable than road humps on bus routes.

6.4.3 Chicanes/Pinch Points

- A build out of the kerb line to narrow the carriageway, usually on alternate sides of a two lane, single-carriageway road. May be combined with central islands and overrun areas.

TRL undertook an evaluation of chicanes and collected data on 49 chicane schemes from 134 Highway Authorities (Sayer and Parry, 1994). The average mean and 85th percentile speeds observed at the chicanes were 23mph and 28mph respectively. These each represent average speed reductions of 12mph, compared with speeds observed before the schemes were installed. After the schemes were installed, average reductions of 7-8mph were recorded in mean and 85th percentile speeds *between* chicanes.

6.4.4 Rumblewave Surfacing

- A rumble device developed as a quieter alternative to conventional rumble strips, considered suitable for residential areas. Rumblewave surfacing creates noise and vibration *within* vehicles passing over it, but does not increase noise levels significantly for those outside the vehicle.

Rumble devices are small raised areas across the carriageway with a vibratory, audible and visual effect. They act as alerting devices rather than causing discomfort and therefore speed reductions tend to be small relative to physical measures such as road humps. TRL undertook an assessment of rumblewave surfacing at seven sites (Watts and King, 2004) and found overall decreases in mean speed of between 0.2mph and 1.9mph.

6.4.5 Home Zones

- Residential streets in which the road space is shared between drivers of motor vehicles and other road users, with the wider needs of residents (including people who walk and cycle, the elderly and children) being accommodated. They are about promoting quality of life and neighbourliness.

The concept of shared road space, whereby roads are designed to cater for pedestrians and cyclists as well as motorists, originated in the Netherlands (e.g. the "woonerf") where large reductions in the number of collisions, particularly involving pedestrians and moped riders, have been reported following the implementation of such road environments (Alink, 1990).

Legally, no one type of road user has priority in a Home Zone, but, through design, the road may be configured to make it more favourable to pedestrians and cyclists, and less favourable to motorists. Traffic calming features, parking areas, trees and bushes, benches, play areas, and different types of road and pavement surfaces can be introduced to open up the street for social use and make clear to drivers the appropriate speed for the area. Home Zones can be built by re-designing existing streets – i.e. they can be 'retrofitted' – or they can be built within new housing development – i.e. they can be 'new-build'.

TRL research and monitoring of three Home Zones in Manchester (Tilly, Webster and Butress, 2005), Sittingbourne (Webster, Tilly and Buttress, 2005) and Leeds (Layfield, Chinn and Nicholls, 2003) demonstrated mean speed reductions of 4mph-8mph and 85th percentile speed reductions of 5mph-9mph. There were very few collisions occurring in the 'before' study and to date there has been only a short 'after' period, so that it is not possible to assess safety benefits from Home Zones, but the reductions in mean speed make this a likely outcome.

Research currently being undertaken for TfL into simplified streetscapes may in principle lead to a modest improvement in safety for pedestrians, but very little evidence has been identified as the main aim of such schemes seems to be to improve amenity.

6.4.6 Play Streets

- A residential street closed to all traffic during specific hours, to permit a supervised program of recreational activities to take place in the roadway. Originally employed in the United States.

Zegeer (1991) has written about a series of interview studies which were conducted at 20 sites in Philadelphia and New York in 1975. The play streets were found to be effective in eliminating traffic and parking and 96% of the residents believed that it reduced the number of children hit by cars. Zegeer (1991) also reports on a collision study carried out in Philadelphia, where there was a significant reduction in pedestrian collisions involving children in areas around the play streets, despite an increase in child pedestrian collisions, city-wide.

6.4.7 The Influence of Pedestrians

It is known that the presence of pedestrians influences drivers to reduce their travelling speeds e.g. The Scottish Executive study (SEDD, 1999). Psychologically, the presence of pedestrians may influence drivers to reduce their travelling speeds by increasing perceived danger or risk (e.g. being aware that a pedestrian may step out into the carriageway). It could also be argued that the complexity of the driving task increases when driving in areas with many pedestrians and, thus, drivers may be influenced to reduce their travelling speeds because of increases in cognitive load.

Clearly it is not possible to use pedestrians as permanent roadside features to reduce vehicle speeds, although it is possible to build roadside environments that have the potential to facilitate pedestrian activity (e.g. the use of shops or cafes, or the use of footpaths in rural areas). Given that pedestrians are not permanent roadside interventions, their influence on vehicle speeds is limited by a number of factors that influence their presence. Such factors might be time of day or weather conditions.

Transport for London (TfL) and other key stakeholders are keen to promote the principles and examples of good practice in ‘Towards a fine city for people’, a report prepared by Jan Gehl (2004) for TfL and the Central London Partnership. In particular, TfL aims to improve the quality of the street environment and the conditions experienced by pedestrians as well as public transport users, motorists and cyclists. Streetscape Guidance has therefore been developed and aims to influence all those involved in the design, construction and maintenance of London’s streetscape and to raise expectations of the standards that can be achieved.

The concept of streetscapes involves a move towards the ideas of shared space, improved amenity, pedestrian access, community development and improved road safety. Schemes involving removal of road markings, street furniture, traffic signs or signals in conjunction with other, sometimes significant, changes to layouts and appearance have been trialled in a number of countries, but their overall effect on pedestrian safety is not known.

6.4.8 Carriageway Narrowing

Studies that have researched road appearance and perceived safe travel speed, have found that carriageway narrowing can reduce mean estimated driving speeds by as much as 7 mph (e.g. Chinn and Elliott, 2002, Fildes et al, 1987, Kolsrud, 1985, Vey and Ferreri, 1968, Yagar and Van Aerde, 1983). The carriageway can be narrowed in a variety of ways including, build-outs, reducing the number of traffic lanes and widening the footway.

Lane width can be expected to influence driving speeds through a number of psychological mechanisms. The extra effort to negotiate a vehicle down a narrower carriageway compared with a wider carriageway could result in increased cognitive load for example. In addition, wider roads provide more time and space to deal with hazards. Depending on other treatments to the roadside space, narrowing of a carriageway could also result in increased flow in the visual periphery.

7 Application to London

7.1 Characteristics of pedestrian collisions in London [6]

In Greater London, there were 31,811 road traffic collisions in 2003, resulting in 38,430 casualties, with 5,164 involving fatal or serious injuries. Of these 38,430 casualties, 18.5% (7,127) involved injury to pedestrians, which is higher than the value of 13% for the whole of Great Britain (Transport for London, 2004).

Figures 4 and 5 below show how pedestrian casualty figures for both Great Britain and London have fallen since 1995. However despite the figures showing that the number of casualties is dropping each year, the absolute number of casualties remains high. Figure 6 shows that the casualties for Greater London are falling at a similar rate to those in Great Britain.

Figure 4: No. of Pedestrian Casualties in London 1995-2003

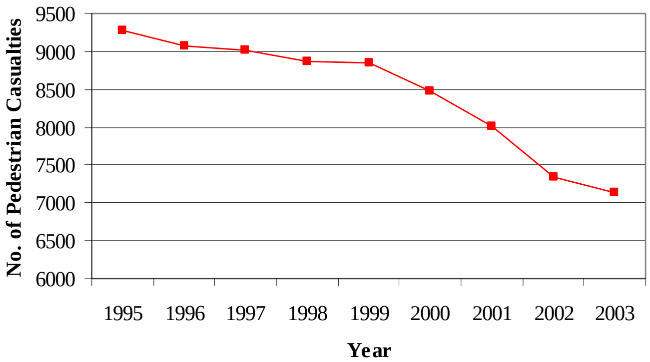


Figure 5: No. of Pedestrian Casualties in Great Britain and London 1995-2003

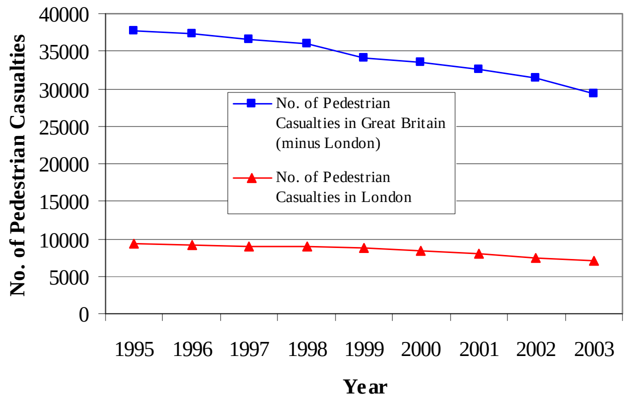
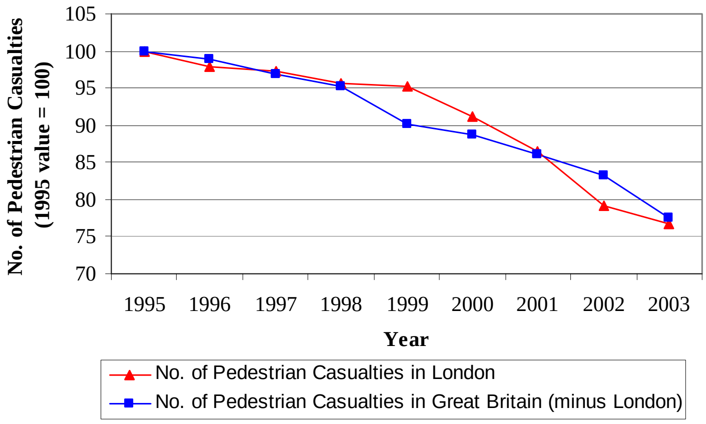


Figure 6: No. of Pedestrian Casualties in Great Britain and London (indexed at 1995)



[6] Statistics for London were provided by Transport for London and relate to collisions occurring in 2003; national figures have been sourced from Road Casualties Great Britain 2004

London and national casualty statistics are shown in Table 3 below. A detailed table of casualty/collision data, nationally and for London can be found in Appendix B.

Table 3: Casualty Figures: Nationally and London 2003

Measure	**National**		**London**	
	No.	**%**	**No.**	**%**
No. of road traffic collisions	**214,030**		**31,811**	
No. of casualties (total)	**290,607**		**38,430**	
No. fatally injured	6,617	2	272	1
No. seriously injured	44,252	15	4892	13
No. slightly injured	239,733	82	33,266	87
No. of pedestrian casualties	**36,405**	**13**	**7,127**	**19**
No. fatally injured	842	2	119	2
No. seriously injured	7,471	21	1,380	19
No. slightly injured	28,092	77	5,628	79

All data presented in the following subsections (7.1.1 to 7.1.6) are data from 2003.

7.1.1 Age and Gender

Table 4 shows that more males than females were injured as pedestrians, both nationally and in London (approximately 60% of male casualties for both). There are a high proportion of casualties amongst young people, both nationally and in London; however there are fewer casualties amongst children under 16 years in London, compared with the national figures. Further TfL data not in Table 4 shows that the highest proportion of pedestrian casualties occurs amongst 10-14 year olds. Although there are fewer casualties amongst pedestrians over 60 years (both in London and nationally), the severity of the injuries tends to be more serious.

Table 4: Casualty Figures by Age and Gender: Nationally and London 2003

Measure	National		London	
	No.	%	No.	%
No. of pedestrian casualties by gender	**36,377***		**7,127**	
Male	21,472	59	4,052	57
Female	14,905	41	3,075	43
No. of pedestrian casualties by age	**35,075***		**7,217***	
0-15	12,544	36	1,635	23
16-24	6,355	18	1,258	18
25-59	11,130	32	2,876	40
60+	5,046	14	939	13
Unknown	-	-	419	6
Severity of child pedestrian casualties (0-15)	**12,544**		**1,635**	
No. fatally injured	74	1	8	0
No. seriously injured	2,307	18	316	19
No. slightly injured	10,163	81	1,311	80
Severity of 60+ pedestrian casualties	**5,046**		**940**	
No. fatally injured	307	6	53	6
No. seriously injured	1,302	26	217	23
No. slightly injured	3,437	68	670	71

*** =** These figures do not equal the total number of casualties (36,405) as there were some that were not recorded by age or gender.

7.1.2 Location of Collisions

Most pedestrian collisions in London occurred on roads with a speed limit of 30mph, accounting for 97% of all pedestrian collisions (6717). The majority occurred on 'A' class roads (60%, 4106). Two-thirds of casualties occurred at junctions (4650).

Most pedestrian casualties occurred away from crossing facilities (57%, 3958), with 11% (765) at zebras, 9% (652) at mid-block signal-controlled crossings and 20% (1394) at signal-controlled junctions.

There are a high proportion of casualties in the centre of London and generally the number of casualties is greatly reduced towards the outskirts of London, although this is likely to be a consequence of the lower pedestrian flows in these outer areas.

7.1.3 Time of Collision

In London, a high proportion (27%, 1886) of pedestrian collisions occurred between 3pm and 6pm. There were a marginally higher proportion of pedestrian collisions on weekdays than weekends, with an average of 15.3% (1058) on weekdays and 11.7% (803) at weekends. In particular Friday had the highest proportion of collisions at 16.1% (1109). It should be noted that these figures take no account of exposure and it is likely that commuter traffic contributes to the increased number of collisions during the week rather than at the weekend.

7.1.4 Weather and Lighting Conditions

Most collisions in London (88%, 6091) in occurred in fine weather, but injury *severity* was higher in wet weather. 70% (4809) of pedestrian collisions occurred during daylight hours.

7.1.5 Tourists

Despite a large dip in foreign visitors in 2001 (after the incident of September 11th) the number of tourists visiting London is gradually increasing, with 11.7 million overseas visitors to London in 2003 (TfL 2004). Non-UK pedestrian casualties accounted for about 2% of the total. Their numbers peaked during the summer months with a maximum in July.

7.1.6 Vehicle type

On average in the UK, 73% of collisions with a pedestrian involved a car, 10% a powered two-wheeler, 8% a bus or coach, 7% a goods vehicle and 1% a pedal cycle.

7.2 Possible Measures for London

7.2.1 Education Programmes: Raising the profile of road safety

Educating children and young people on road safety has been shown to positively affect road user behaviour (see Section 6.1), and is therefore recommended as a way of targeting the relatively high number of casualties amongst children and young people nationally, and similarly in London.

Education relies on *persuading* people to adopt appropriate behaviour and attempts to raise children's awareness of road safety. As discussed in Section 6.1, it is recommended that education programmes for London focus on promoting desirable ("safe") behaviour by:

- Increasing road safety knowledge (e.g. knowledge of the rules and practices described in the Highway Code, and knowledge of what behaviour is considered to be safe and unsafe),
- Make road users aware of how unsafe their behaviour may be,
- Promoting positive attitudes towards safe road use,
- Providing / teaching people strategies to minimise the risk of being involved in a road traffic collision, and
- Increasing drivers' awareness of other road users.

These aims can be achieved by using some of the techniques (listed in Section 6.1) which are known to have positive effects on road user behaviour:

- Children's Traffic Club
- Kerbcraft
- Junior Road Safety Officer scheme (JRSO)
- Making Choices

Designing and implementing education programmes can be costly and are always difficult to measure in terms of casualty reductions. The potential benefits are great because they can encourage attitudinal change amongst young people and TfL have started a number of initiatives such as JRSO and Children's Traffic Club in London.

7.2.2 Zonal Approach

The use of targeted safety zones in cities has been shown to produce overall safety benefits in a study in America and in the Gloucester Safer City project (see Section 6.3.3.3) and is recommended as a possible approach in London. Whole or parts of London Boroughs could be targeted in terms of applying engineering countermeasures and awareness programmes. The American study found benefits from targeting older people. Reductions in casualties in Gloucester were not split by mode, but might be expected to reduce pedestrian casualties by 10% at the same time as reducing other casualties.

7.2.3 Play Streets

In order to address the high proportion of child pedestrian collisions, Play Streets could be introduced in residential areas (see Section 6.4.6 for more detail on Play Street schemes). The aim is to educate children in when and where it is safe to play in the road i.e. they learn that it is only safe to play in the road when the road is closed off specifically for that purpose and there is adult supervision. Areas targeted would need to be carefully chosen and a balance needs to be found between the number of vehicles using the street and the number of children wanting to play or take part in the scheme.

The Play Street scheme has been shown to be effective in reducing the number of child pedestrian collisions in the areas surrounding Play Streets, though it is thought the safety benefits are relatively small. There may be long term social benefits as children learn how to behave around roads and that under normal circumstances it is not safe to play in the road.

7.2.4 Measures to Implement at Crossings

7.2.4.1 Vehicle Activated Signs

Vehicle activated signs could be used in a number of ways, including detecting pedestrians waiting to cross at crossings and instructing vehicles to give way, or simply lighting up when vehicles are exceeding a suitable speed threshold to warn of the pedestrian crossing. These signs have been shown to reduce speeds and improve give way behaviour (see Section 6.3.2.7).

7.2.4.2 Coloured Surfacing on Crossings

Various studies have concluded that there are safety benefits associated with the use of coloured surfacing at crossings (see Section 6.3.2.8). It is recommended that this measure be used in London in order to alert drivers to the presence of crossings; this is thought to be particularly beneficial in London due to the high volume of vehicles, particularly in the inner parts of London. Careful consideration should be given as to where to implement this measure as it can be visually intrusive and may therefore not be suitable for historic areas. There is a need for a consistent approach to using coloured paving so that all road users are aware of its functionality.

This is a low cost, easy to implement measure, as it could be applied when re-surfacing work is being undertaken. The cost would be about £6,000 per crossing.

7.2.4.3 Re-location of Stop Lines

In order to create a safe space for pedestrians to cross, particularly in areas with high traffic volumes, it is recommended that stop lines could be used at pedestrian crossings and junctions. Advancing the stop lines can hold traffic back further away from the crossing and reduce the likelihood of drivers running red lights and/or edging onto the crossing before the lights have changed to green for vehicles (see Section 6.3.2.3). Van Houten *et al* (2001) found that pedestrian conflicts were reduced by 12.5% when stop lines were moved back by 10 metres, whereas the research by Wall (2000) suggested more modest distances would be sufficient.

As with coloured surfacing, this is a low cost, easy to implement, measure and could be applied when re-surfacing work is being undertaken. The approximate cost would be about £500 per junction approach.

Note that this measure is not the same as advanced stop lines for pedal cyclists, although where installed they would give a similar effect.

7.2.4.4 Raised Crossings

Raised crossings have been shown to produce a reduction in the speed of traffic and an increase in the proportion of vehicles giving way to pedestrians, both of which give a safety benefit to pedestrians.

This measure could be implemented on roads where road humps already exist or as road humps are being installed, therefore being a relatively low cost measure.

The approximate cost for a raised crossing is about £5,000. Approximate cost savings would be up to about 1 pedestrian collision per crossing every 2 years.

7.2.4.5 Road narrowing / central refuge at crossings

This measure would be expected to reduce collisions with pedestrians slightly by reducing the road width that pedestrians have to cross. The use of a central refuge is better than build outs on either side of the road as it avoids drivers competing over who can reach the gap first.

The approximate cost would be about £7,500.

7.2.4.6 Countdown Devices

The use of countdown timers could be considered at suitable pedestrian crossings. Research has concluded that pedestrians are difficult to influence and that they will often choose to cross on a red man due to impatience (see section 5.2.4). One way to address this may be to give pedestrians an indication of how much longer they have to wait before the green man, by using a countdown timer (see section 6.3.1.6). This can be displayed in numeric or pictorial form and is only applicable to crossings that are running on fixed signal timings. Some research has shown that pedestrians react positively to countdown devices and it is possible to reduce the number of pedestrians crossing on the red man by 11%, therefore potentially reducing conflicts by the same percentage. Countdown timers can only work if the time to the start of the pedestrian phase can be predicted. This would not be possible in current UK isolated signal control systems (i.e. MOVA and VA) and are most appropriate in a fixed time UTC system.

7.2.4.7 Zebra/Pelican to Puffin Crossing Conversions

In accordance with current government guidance, it is recommended that, where it is deemed appropriate, Zebra and Pelican crossings be converted to Puffin crossings, as there are benefits to pedestrians in terms of added time to cross the road. It is, however, important to ensure that all detectors are working correctly and regularly inspected and maintained (to avoid unnecessary delays to traffic). It is also important that clearance phase timing is set in line with current recommended guidelines.

The approximate cost of converting a Zebra to a Puffin is estimated to be about £10,000. The estimated saving in terms of reduced collisions would be about 1 pedestrian collision every 5 years.

7.2.4.8 Pedestrian Priority Crossings

Crossings where the default setting is to give priority to pedestrians are currently relatively few in number, however, good results have been found where they have been used. The location of these crossings is site specific, as they should only be implemented on roads with light vehicular traffic and high pedestrian flows. They may work particularly well outside schools at opening and closing times. However, the strategy outside these times would need careful evaluation; the signals may not be obeyed if there are no children about.

Safety benefits could potentially be high, with reductions of up to 36% for pedestrian collisions over a three year period and a 67% reduction in child pedestrian collisions a three year period.

In terms of changing the timings at a suitable crossing, costs would be fairly low. The main cost would be increased delay to traffic.

7.2.4.9 Improved Siting of Pedestrian Crossings

Research has shown that pedestrians are reluctant to deviate from their desired route and therefore tend to only use designated crossings if they coincide with their optimum route choice (see section 5.2). In order to ensure high levels of usage, it is important to consider pedestrian desire lines when introducing or planning new pedestrian crossings and observations should be undertaken in order to understand the directions in which pedestrians travel. It is of course not possible to cater for the routes of all pedestrians, however where there are obvious pedestrian routes, crossings should as far as possible be positioned accordingly.

Re-siting a pedestrian crossing is likely to have a similar cost to that for installation, £40,000 for a Puffin crossing, and is unlikely to be cost effective unless undertaken as part of major improvements to the road.

7.2.5 Pedestrianisation or semi-pedestrianisation

The introduction of pedestrianised areas is an ideal way of dramatically reducing pedestrian collisions on the roads concerned, as it removes the potential conflict with other road users. It is however, difficult to implement and there are usually good reasons for motorised vehicles having access to streets or roads. Pedestrianisation is often introduced in busy high streets or town centres with high pedestrian flows and so may be applicable to some parts or streets in London.

Research would first need to be conducted to see what the impact (e.g. on road safety) on other road users would be of making areas pedestrianised.

The cost of pedestrianisation depends on its extent and quality. Installation costs are likely to be high, as are delay costs to traffic. However, if the location had a history of pedestrian collisions, the predicted saving would be considerable and there are likely to be amenity benefits.

7.2.6 Measures to Implement at Signalised Junctions

Although most pedestrian collisions in London occur away from designated crossings, the second most common place for pedestrian collisions is at signalised junctions with a pedestrian phase (accounting for 20% of all pedestrian collisions). With this in mind, the following measures could be considered where possible:

- If the pedestrian phase was more responsive to pedestrians, delay to pedestrians would be reduced and compliance possibly increased

- Short cycle times should have a similar effect
- All-red periods potentially reduce conflicts between all road users and allow pedestrians to cross diagonally across the junction if desired
- Puffin style facilities should be adopted in order to give pedestrians longer to cross the road if necessary.

The cost of installing Puffin type facilities at a junction would be approximately £20,000. Changes to the signal settings involve only the time needed to assess what is required and to implement it, about £1,000 per site.

7.2.7 School Opening/Closing Times

Statistics show that 34% of pedestrian collisions in London occur between 3pm and 7pm, therefore measures could be targeted at reducing collisions at this time of day. For child pedestrian collisions specifically, 50% of collisions in London occur between 3pm and 7pm. One way of potentially reducing the number of conflicts at this time of day would be to change the opening and closing times of schools. Currently these times coincide with morning and afternoon peak traffic times and therefore there is a higher risk of conflict between pedestrians and vehicles. If schools were to open and close at an earlier time the potential conflicts might be reduced. The collisions might not necessarily occur at different times of day because this measure would potentially have a benefit similar to that indicated for adopting Single/Double Summertime – during the winter, children would travel home in daylight rather than darkness, reducing fatal and serious pedestrian casualties by 0.8% (Broughton and Stone, 1998).

There would be a number of costs associated with this type of approach including publicity and any costs associated with keeping schools open for longer periods, if required . Estimating these costs is beyond the scope of this study.

7.3 Speed Reducing Measures for London

7.3.1 20 mph Zones

It has already been shown that 97% of pedestrian collisions in London occur on roads with speed limits of 30mph. Converting 30mph roads to 20mph roads has been shown to have a positive effect on reducing pedestrian collisions (see Section 6.4.1) therefore it is recommended that this measure be more widely adopted throughout London. Physical measures, such as road humps, may be required to enforce the limit. The desire for implementing 20mph zones should also be balanced with the wants and needs of residents and consideration should be given to bus routes and emergency services. 20mph zones should be implemented in accordance with DfT guidance (LTN 1/04).

The study of 137 20mph zones in London (Barker and Webster, 2003) showed that not only was there a substantial reduction in the numbers and severity of collisions (see Section 6.4.1), but that there was no statistically significant evidence of accident migration to other roads in the vicinity of the zones. Speeds were also substantially reduced. However, the treated roads all had above average collision frequencies before the introduction of the zones, possibly indicating that the if regression to the mean was taken into account, the effect would lower than indicated.

Benefits of implementing 20mph schemes would depend on the extent of the problem before implementation, and on the length of the road to be included in the zone. The main costs would be for signs and speed-reducing measures. A conservative estimate would be a casualty reduction of 20%, although the figure could be higher. However, if traffic diverted to other routes, there might be an increase in collisions over the area as a whole. Careful thought would need to be given to diversion routes and the possible effect on safety and congestion, possibly using *Safe*NET software to predict changes in predicted collisions.

7.3.2 Enforcement

TRL research by Gorell and Sexton (2004) has shown that the estimated reduction in all collisions involving injury due to 77 speed cameras in London was 12.4%, and the reduction in fatal and serious injury collisions was 20.6%. In support of this, Mountain *et al* (2004) found that, for a sample of 62 speed cameras in the UK, the overall effect was a 25% reduction in all injury collisions within a distance of 250 metres from the speed cameras.

Currently speed cameras are not used in 20mph zones in the UK, however there is some evidence to suggest that safety benefits might be realised if they were to be installed. They may be particularly beneficial where self-enforcing measures, such as road humps, are not suitable (e.g. on a bus route).

The main benefit from speed cameras as far as pedestrians are concerned is the reduction in speed. Red light cameras potentially have a larger benefit in that they reduce red-running and therefore avoid conflict with pedestrians who may have started to cross early.

Each fixed camera costs about £27,000 to install, including signs. Savings in pedestrian collisions are expected to be about 12% (Gorell and Sexton, 2004) at 30mph TfL sites. Savings in pedestrian collisions might exceed this figure in 20mph zones because of the lower travelling speed.

7.3.3 Intelligent Speed Adaptation

Intelligent Speed Adaptation (ISA) is technology designed to influence drivers' speed by using roadside beacons, transmitters or tags to convey information to the car (Hoedmaeker, 1999). This could be used to advise the driver when they were reaching the speed limit through visual, auditory or haptic (in which the accelerator pedal becomes harder to press) means. It could also prevent the vehicle from travelling above the speed limit by automatic application of the brakes. This could be a voluntary system with an option to switch the device off, or could be mandatory. Further advances in technology have led to the development of system that could be spatially maintained, for example slower permitted speeds at sharp bends, or be time differentiated so only slow speeds were permitted outside schools at critical times or respond to weather or network conditions (Carsten and Fowkes, 2000a, Carsten and Fowkes, 2000b, Varhelyi and Makinen, 2001).

No research has been identified which studies the effect that this would have on pedestrian collisions, however the technology is designed to reduce vehicle speeds which is known to have a positive effect on reducing pedestrian collisions.

Many trials of ISA equipment have taken place in a number of European countries and the technology is applicable to London. However, a number of reasons suggest that ISA is unlikely to be universal plausible in the shorter, not least because of the high costs involved in retrofitting the entire vehicle fleet. In the long term however, vehicle manufacturers could be the most likely route to vehicles being fitted with the necessary equipment.

7.4 Conclusions

7.4.1 General

There are no simple universal solutions that would reduce pedestrian casualties in London, particularly because of the large numbers of pedestrians and the high traffic flows on London roads. However, a number of methods that might contribute towards reduced pedestrian collisions.

Enforcement measures such as safety cameras (and, in the longer term, in-car speed limiters) are best applied on strategic routes where physical traffic calming measures would reduce capacity.

Education is probably best targeted at a particular behaviour (e.g. speeding) or a particular group (e.g. school children or older people)

7.4.2 Enhancement of pedestrian crossings

Pedestrian crossings should be considered for enhancement in one or more of the following ways:

- Skid-resistant surfacing on the approaches to enable drivers to stop more easily
- Moving the stop line a few metres back at signalised crossings and junctions, to enable drivers of large vehicles to see pedestrians more easily
- Widening crossings so that pedestrians are less likely to walk off the crossing
- Reducing road width at pedestrian crossings so that pedestrians have a shorter distance to cross. (The use of build-outs makes pedestrians more visible)
- Flashing road studs to alert drivers to the presence of the crossing
- Re-locating the crossing to coincide with pedestrian desire lines to encourage pedestrians to use the crossing
- Raising crossings so that drivers have to slow down as they approach them
- Adding refuges so that pedestrians have fewer lanes to cross at a time
- Considering the need for guard railing to encourage pedestrians to use the crossing (although in some situations, it will be important to ensure that a situation in which pedestrians walk outside the guard rails does not occur)
- Increasing the responsiveness of signal-controlled crossings so that pedestrians may be more likely to wait for the green man
- Keeping cycle times short or having two pedestrian phases within the cycle so that again the responsiveness of the signals is improved
- Converting zebras and pelicans to Puffins can also be beneficial, either at an isolated hot spot or as a systematic policy over a period of years.

7.4.3 Measures at signalised junctions

Pedestrian collisions at signal-controlled junctions account for a surprisingly high proportion of the total. Suitable measures to adopt are signal strategies that shorten waiting times for pedestrians, the provision of pedestrian phases, and all-red periods. This may be achieved as in the list of possible enhancements to pedestrian crossings by using shorter cycle times or increasing the window of opportunity for the pedestrian phase. Clearly these proposals will tend to increase delay to vehicles and they will only be possible in suitable locations.

7.4.4 Measures suitable for use in residential areas

An area wide consideration of residential areas, to determine the route hierarchy and hence which streets should have traffic calming measures and 20mph speed limits and where home zones or play zones could best be implemented. On the latter, pedestrian crossings should be informal or zebra crossings depending on the flow. Simple measures such as road narrowings e.g. build-outs to allow pedestrians to cross safely, particularly if there are parked cars.

7.4.5 Measures suitable for use in shopping areas

Shopping streets are good candidates for pedestrianisation or semi-pedestrianisation. Where this is not possible, suitable crossings should be introduced at frequent intervals. These could be enhanced e.g. by the use of raised crossings or wide crossings with a central refuge. The use of pedestrian priority signals could also be considered.

7.4.6 Measures suitable for use outside schools

As far as possible, schools should be located in 20mph zones. Other possibilities are the use of intelligent road studs or vehicle-activated signals that work on 30mph most of the time but 20mph at school times, or pedestrian priority signals. The introduction of play zones may be appropriate.

7.4.7 Measures suitable for use in historic areas with high pedestrian and vehicle usage

In historic areas, it is important to maintain the aesthetic appearance. For example, the use of coloured surfacing should be avoided and high quality materials adopted.

Where there are large numbers of tourists, reminders on the road surface reminding foreign tourists in particular to look left / right, and wide crossings are appropriate. Timings should minimise delay to pedestrians as far as possible without increasing congestion. All red periods are easy to understand and decrease pedestrian delay.

7.4.8 Measures suitable for use on mixed priority routes

Reducing the amount of parking (e.g. by red routes) will allow drivers a clear view of pedestrians (although they may also encourage speeding), but generally zebra or Puffin crossings will be required. These should have short cycle times to minimise pedestrian delay. The use of countdown timers should also be considered. Speed cameras may be needed on the busier routes.

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Appendix A: Annotated Bibliography of Key Material

Reference **AA Foundation for Road Safety Research (1994).** ***Pedestrian Activity and Accident Risk.*** **University of London and Steer Davies Gleave. London.**

Aims To undertake surveys of pedestrian activity in selected urban areas; to establish relevant pedestrian casualty rates in reported traffic collisions; to establish a methodology for measurement of pedestrian exposure.

Method Household sample of residents of a selected town, with home interviews and household members keeping a written report of journeys made on foot during the survey period.

Results **GENERAL**

- In 1992, 1300 pedestrians killed and 12,800 seriously injured. Nearly 3000 over 65 and almost 5000 were under 15. 95% of pedestrians injured occurred in built up areas.

AGE & GENDER

- Those aged between 20-24 yrs are at a higher risk of injury when walking alongside traffic and crossing the road.
- Boys 5-15 yrs 1 ½ times more at risk than girls of the same age.
- Girls aged 10-15 yrs less safe than boys of the same age.
- During adulthood, females have lower casualty rates than males.
- Older females (over 64 yrs) are 2 ½ times more at risk of injury than males of the same age.
- 57% of injuries to older people (over 65 yrs) were fatal or serious, whereas for under 16 yrs its 29%.

HOUSING

- People living in housing built for private ownership, between 1918-1964, have a set of casualty rates which are half those for housing of the same age, built by the local authority and are amongst the lowest of all housing types.
- Casualty rates for residents of post-1964 housing types are lower than pre-1964. This is because post-1964 housing incorporates a greater number and length of footpaths segregated from traffic.

CROSSING THE ROAD

- 2/3 of all casualties were injured when crossing not using any pedestrian facility other than a dropped kerb.
- The use of light controlled pedestrian crossings halves the risk compared with crossing without this facility.
- Casualty rates per road crossed are lower at junctions than they are mid block (38% occur more than 20 metres from a junction).
- Higher number of casualties in younger groups when crossing and masked by parked cars on local distributor and residential roads.
- Half as many pedestrians are injured crossing from driver’s offside as from the nearside.

JOURNEY TYPES

- 1/3 of school age casualties occurred on the way to or from school.
  - 33% injured on main roads
  - 43% on local distributor roads
  - 24% on residential roads

OTHER

- The risk of injury in darkness is about 4 ½ times more than in daylight.
- About 1/3 of casualties occur in darkness (but only 8% of walking alongside traffic per

person).
- The risk tends to be higher when walking alongside traffic a distance of about 5km from home.
- Most injuries occur on Saturdays and fewest on Sundays.
    - Over 65s injured more on Tuesdays and Thursdays
    - 10-15 yrs injured least on Saturdays and Sundays
- Dip in casualty rates during the summer months, with a steep rise towards the end of the year.
- Over 70% of pedestrian casualties were on their own when they were injured.
- About 5/6 of casualties occur in fine weather and 2/3 on dry roads.
- Injuries to males were less likely to be reported than injuries to females.

Comments Study area was Northampton and sample size was 400 private households with approximately 1000 people of different ages (5 years old and over).

Reference **AA Foundation for Road Safety Research (1995).** ***Risk and safety on roads: the older pedestrian.*** **University of Newcastle upon Tyne, Rees Jeffreys Road Fund and Ross Silcock Partnership. London.**

Aims To gain a better understanding of the problems faced by the older pedestrian and to recommend ways of alleviating such problems.

Method Interview, questionnaire and observation of older people in terms of their activities as pedestrians. To devise and test experimental measures of older people's judgement of speed and distance.

Results **INTERVIEWS**

- The most popular cause of near misses stated by interviewees were instances where a driver or cyclist appeared to be at fault. The second most popular cause of near misses could be grouped into occasions where the pedestrian found difficulty coping with the complexity or uncertainty of the situation.
- Shopping comprised the majority of outings (2 out of every 3 trips)
- Factor analysis suggested two main areas of concern: (a) the amount of traffic; competing with traffic to cross the road (39% of men and 44% of women were anxious or concerned); traffic speeding in residential or shopping areas; the state of the pavements; and traffic collisions; and (b) provisions in health service; international events and conflicts; standards of education; changes in the environment due to pollution; and marginally the maintenance of a good transport system.
- Concentration skills, the weather, poor health, and walking discomfort or difficulty significantly contribute to the ways older people cope with the road environment.

OBSERVATIONAL DATA

- The safest way to cross was via traffic islands or a pedestrian crossing.
- Older people were disproportionately represented in potentially unsafe crossings and in areas of most concern.
- Older pedestrians were seen to take care and even extreme caution over crossing the first part of the road without considering the outcome for the second half of the road. Extreme cases resulted in older people being stranded mid-way across the road.

Conclusions

- Educational programs aimed at younger drivers who are less likely to take pedestrians into consideration when assessing the road.
- Educational programmes in road safety aimed at older pedestrians.
- Use of 20mph zones which also change driver attitudes.
- Use different surfaces to create the illusion of a narrower carriageway, landscape treatments to create a calmer environment, use of regularly spaced refuges.
- Use of countdown timers at pedestrian crossings would encourage older pedestrians to feel more certain about crossing and pedestrian crossings and would therefore be less likely to cross in unsafe places.
- More care should be given to understanding pedestrian routes when locating refuges or traffic islands so that people are not tempted to cross near but not using the refuge. Walking the shortest distance possible is often an important factor for older pedestrians who may have difficulty walking.

Comments 215 interviews were carried out in the study area which was Newcastle upon Tyne (respondents were aged 64 years and older).

Reference **Asaba, M and T Saito (1998).** ***A study on pedestrian signal phase indication system.*** **Road Transport Information and Control, 21-23 April 1998. Conference Publication No 454.**

Aims To analyse pedestrians' behavioural changes brought about when the pedestrian clearance time (the length of the flashing green man) is increased and impatience felt by pedestrians during the wait time. (Japan)

Method Observational video analysis on pedestrian movements at crossings and self-completion questionnaires for pedestrians.

Results

- When the flashing green man phase was increased, the number of pedestrians who gave up their attempts to cross sis not significantly change.
- When the flashing green man phase was increased, the number of pedestrians who began to cross did not significantly increase.
- When the flashing green man phase was increased, the number of pedestrians who completed their crossing during the all green/flashing green phase increased.
- When pedestrians became impatient they reported using the traffic more as a stimulus for crossing, crossed whenever they could, went to the front row of pedestrians waiting to cross or positively looked for a chance to jaywalk.
- A close relationship was found between the feeling of impatience and jaywalking.
- A major cause of jay walking, reported by pedestrians, was the non-existence of vehicles. Most pedestrians felt impatient when a red traffic light forced them to wait while no cars were passing.
- Video observations showed that waiting time invoking a feeling of impatience, peaked at 40-45 seconds. The questionnaire analysis indicated that a large number of pedestrians in the 15-19 year old age group began to feel impatient within 10 seconds, though overall a period of 21-28 seconds was reported as being the waiting time invoking a feeling of impatience).

Conclusions

- An increased degree of safety would be provided by giving green man and flashing green man signal timings in compliance with pedestrian behaviour patterns.
- Traffic collisions involving pedestrians can be reduced by adopting an ergonomic scale of a feeling of impatience and developing a control system that does not cause pedestrians to wait for an unduly long time.

Reference **Abrams C M and S A Smith (1978).** ***Pedestrian controls, bicycle facilities, driver research, and system safety.*** **Transportation Research Record 629. Virginia.**

Aims To study pedestrian phasing in terms of safety of pedestrians and delay to pedestrians and vehicles. Types included (a) combined pedestrian-vehicle interval, (b) early release of pedestrians with respect to vehicles, (c) late release of pedestrians with respect to vehicles, and (d) scramble timing.

Method Time-lapse video used to monitor delay and pedestrian compliance.

Results

1. Early release of pedestrians does not significantly improve pedestrian safety and always increases total delay at intersection.
2. Late release of pedestrians tends to increase overall delay at intersections- although better for case where vehicle queue consists of right-turning vehicles.
3. Compliance with late release of pedestrians in Sioux City 97%- although if implemented in new places probably much lower.
4. Scramble timing (exclusive pedestrian phase for whole intersection) always increases pedestrian delay. May be able to increase capacity in right-turning lanes, but still increases vehicle delay on through lanes. Can completely eliminate pedestrian - vehicular conflicts (if obeyed).
5. Combined pedestrian-vehicle interval almost always minimises overall pedestrian and vehicle delay.

Comments Not clear to what extent this applies to UK conditions.

Reference **Allsbrook L E (1999).** ***Pedestrian signal countdown device.*** **Enhancing Transportation Safety in the 21st Century ITE International Conference. Florida. Held: 28-31 March 1999. Washington DC, USA.**

Aims To evaluate pedestrian signal countdown devices. Discussion on communicating crossing messages to pedestrians and the confusion over different signals available.

Results Results found 52% noticed experimental countdown signal heads, 26% did not understand the meaning of conventional pedestrian displays, 92% felt experimental signals clearer, 85% felt experimental displays were an improvement. Most frequent comments were that it was a good idea, like to see more, need more like it, increase time and needs to be brighter = positive feedback.

Reference **Austin K and Martin B (1996).** ***Improving pedestrian priority in UTC systems*****. Traffic management and road safety; Proceedings of Seminar H held at the PTRC European Transport Forum, Brunel University, England, 2-6 September 1996.**

Aims — To determine whether decupling Pelicans from SCOOT control during the off-peak will reduce vehicle-pedestrian conflict.

Method — Measures evaluated by using video recordings to collect pedestrian, vehicle and signal data at two Pelican crossings controlled with SCOOT system in Brighton. Three trials were conducted:

1. fixed time operation and a vehicle maximum period of 30 seconds
2. with vehicle actuation and a vehicle maximum period of 30 seconds
3. with vehicle actuation and a vehicle maximum period of 20 seconds

Observations were taken off-peak over a 4 week period.

Results — **Crossing behaviour-** Proportion of pedestrians starting to cross during red phase decreased with all 3 trials. Greatest reduction was with trial 3.
Kerbside delay- More responsive signal strategy for pedestrians reduced collision risk associated with gap selection according to traffic flow. Less delay during trial conditions, especially for trial 3.
Behavioural effects- Improvement of pedestrian priority increases proportion of cycle time devoted to pedestrians allowing more to cross during green period. Substantial increase in pedestrians willing to wait until traffic stopped before starting to cross during trials 1 and 2. Fewer were prepared to wait until green during trial 3 than before.
Delay to traffic- The effect on traffic was slight, with average journey time through the section and the number of signal violations showing no relationship to the signal strategy adopted

Conclusions — The removal of Pelicans from SCOOT control during the off-peak significantly improved the responsiveness of the signals for pedestrians, leading to a greater proportion of pedestrians waiting until the red to traffic, before starting to cross. The subsequent introduction of vehicle actuation and reduction of the vehicle-maximum-period also reduced the level of pedestrian signal violations due to the increase in the proportion of the cycle time devoted to pedestrians.

Reference — **Austin K and White P (1997).** ***Reducing pedestrian and vehicle conflicts at Pelican crossings*. Traffic Engineering and Control. May 1997.**

Aims — Three strategies are compared to reduce the degree of pedestrian/vehicle conflict at the end of the pedestrian phase (flashing green figure for pedestrians and flashing amber for cars). Trial sites were selected with the following strategies:

- introduction of an overlap period (flashing green man, red to traffic)
- replacing the flashing green man with a black-out and all-red phases
- Puffin

Conclusions — In overall terms, the safety benefit from Puffin crossings is likely to be in excess of the other measures tested and is therefore considered to be the preferred choice

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Reference — **Baass K G (1989).** ***Review of European and North American Practice of Pedestrian Signal Timing.*** **RTAC Annual Conference Calgary, Alberta.**

Aims — Review of European and American pedestrian signal timing (Germany, France, Canada and the United States)

Results — **Waiting time**- In the 60s it was generally accepted that 30 seconds constitutes maximum limit for pedestrians to wait, but another recommendation (AT, 1985) shows a maximum of 60 seconds. The number of illegal crossings increases significantly if waiting time is longer than 40 seconds (US). Study in Germany (reported in Arbeitskreis Verkehr, 1987) showed that 38% pedestrians cross on red if waiting time 40-60 seconds and only 18% cross on red if shorter than

30 seconds. Druilhe *et al* (1987) indicated that supplementary information given to pedestrians is beneficial. Fegan (1978) found pedestrian signal cycle tends to be divided so minimum time allocated to Walk signal and remainder to Don't Walk phase to minimise pedestrian/vehicular conflicts- but pedestrians learn extra time is allowed and so this encourages wrong behaviour. Smith (1978) also found pedestrians tend to disregard clearance intervals that are longer than minimum required and cross anyway.
Walking speed- TCDH (1983) established that groups of pedestrians are slower than individuals and young, elderly and those with a disability significantly slower than average speed (1-1.4m/s in France/Canada).
Median / refuge islands- German study in 7 cities showed 65% of all pedestrian collisions at signalised intersections happened on crosswalks with median islands- but in Germany generally only provide enough time to cross to the island not all the way across (France generally allows time to cross in one go). Authors write that frequently observed pedestrians take risks in crossing illegally or cross away from crossing on islands with medians. NB German and French law at this time stipulated that pedestrians should only cross at signalised intersections.

Conclusions

Pedestrians will always try to shorten distances and reduce waiting times, often without adhering to the Highway Code and disregarding the risks involved. A need to hurry or a desire to keep moving was the prime motivation behind disobeying pedestrian signals. Key problems with the inefficiency of special pedestrian signal displays seem to be the timing and understanding of the message conveyed to drivers and pedestrians.

Reference

Carsten O M J, Sherbourne D J, and Rothengatter J A (1998). ***Intelligent traffic signals for pedestrians: evaluation of trials in three countries*****. Transportation Research Part C6 (1998) pp. 213-229.**

Aims

Trials of innovative pedestrian signalised crossings that were designed to be more responsive to pedestrian needs and thereby improve pedestrian safety and comfort. The strategy used microwave detectors, mounted on traffic signals to register the approach of pedestrians. The detection was applied to:

- replace the normal push-button
- provide earlier activation of the pedestrian stage
- provide an extension of the pedestrian stage for late arrivals
- provide longer pedestrian stages when there are large numbers of detections.

Method

Safety effects were measured by: conflict studies, percentage of pedestrians who violated the red light, especially the percentage violating red when vehicle traffic had green, and the number of encounters between pedestrians and vehicles

Results

While there were important differences in the impacts at the various sites, partly reflecting differences in implementation, there were general gains in safety and comfort for pedestrians. These improvements were obtained without major side effects on vehicle travel.

Reference

Catchpole J (2003). ***Win-win outcomes for pedestrians and drivers by optimising signal timings.*** **Road and Transport Research Vol 12 (3). pp74-82.**

Aims

The study was undertaken in Australia and demonstrates that compared with a fixed time for the pedestrian phase in every cycle, strategies that allow flexibility in the duration of the pedestrian phase can benefit both pedestrians and drivers. Optimising the length of the signal can also benefit pedestrians, with minimal disbenefit to drivers.

Method Video –recordings and on-site observations of different strategies:

- Pelican
- Puffin
- Partial Puffin
- Extended Walk display
- Reduction in cycle time

Results Both Pelican and Puffin crossings were found to reduce vehicle delay (although use of detectors to monitor the footway and cancel unwanted pedestrian phases was not a success – some pedestrians who wished to cross moved out of the detection zone).
The partial Puffin involved the detection of pedestrians on the crossing rather than those waiting to cross (i.e. disabling the call cancellation feature) and again reduced vehicle delay.
The extended Walk display was tested at a single site with low pedestrian flow. It involved showing the green man until all pedestrians had completed their crossing. Reducing the cycle time showed a significant reduction in the number of pedestrians crossing during the high risk part of the cycle (i.e. when there was a potential conflict with vehicles).

Reference **Christie, N (1998).** ***Accident involvement of child pedestrians: a holistic study of relative risk.*** **Centre for Transport Studies: University College of London.**

Aims To investigate why children from low socio-economic groups are over represented in pedestrian collisions.

Method Questionnaire based interview survey amongst a random sample of school children aged 5-16 years and a sample of children who, as a pedestrian, had been involved in a road collision. Interview parents or carers for each child interviewed.

Results

- 76% of collisions occurred on a weekday (slightly more than expected).
- Over 1/3 were alone at the time of the collision.
- Journeys (to school, shops or social) accounted for most road use by 11-16 year olds (74%), playing in the street was particularly high for 5-7 year olds (35%).
- For the under 11's, attention absorbing activities, not related to the task of crossing the road, featured strongly just before the collision occurred (playing, arguing/fighting, etc).
- Failure to attend traffic was most often mentioned as a causal factor in the collision, by parents and carers of children under 11; for older children, the speed of vehicles was thought to be the main cause (57%). These opinions were also shared by the children.
- There is a clear trend that child pedestrian collisions on arterial roads increase with age.
- Most collisions occurred on residential roads, where there was old housing stock and on roads with no obstructive parking.
- Children who lived in families where there were not working adults were significantly more likely to be involved in a collision (36%) than those with two working parents (34%) who were more likely to be involved in an collision compared with one working parent (31%).
- Children who were living in 'crowded' accommodation were more likely to be involved in a collision (88%).
- 62% of adults in the total sample scored a relatively poor responsibility score. Children whose adult carer scored poorly were more likely to be involved in a collision (72%).
- 77% of adult respondents said they had access to a car; children in these households were less likely to be involved in a collision (81%).

- Children who lived on roads with through traffic access were more likely to be involved in a collision compared to those who lived on a road closed to through traffic (80%).
- Children who lived on roads where the housing age was pre 1960s were more likely to be involved in a collision than those who lived on roads where the housing was newer.
- Children who lived on roads with no obstructive parking were more likely to be involved in a collision than those who lived on roads with obstructive parking (91%).

Conclusions	• Exposure was important in explaining collision involvement of child pedestrians (child not attending after school clubs, played more frequently in the street, lived in crowded accommodation, lack of parental accompaniment on school journeys and parents/carers not owning a car). • Parents/carers important in explaining collision involvement of child pedestrians (non-white carer, two working carers and no working carers). • Environmental variables proved to be some of the strongest indicators of predisposition towards collision group membership (older housing, absence of obstructive parking and living on a through-road).
Recommendations	• Design and implementation of safe play areas to encourage children away from the roads. • Set up after school clubs in areas of socio-economic disadvantage. • Any parking measures aimed at removing obstructive on street parking my need to be complemented by measures which reduce vehicle speed or afford greater protection to pedestrians (e.g. barriers between road and footway). • The principles of partial traffic/pedestrian segregation utilised in modern housing developments should be incorporated into older housing areas.

Reference	**Christie, N (1995).** ***Social, Economic and Environmental Factors in Child Pedestrian Accidents: A Research Review*****. TRL Limited: Crowthorne.**
Aims	Investigate why children from low socio-economic groups are over represented in pedestrian collisions.
Method	Review of all relevant literature.
Results	• Sharples et al 1990: Mortality rate (when looking at fatal collisions involving ahead injuries) is significantly related to social deprivation. • Sharples et al 1990: Many of the children were playing unsupervised. • In-depth studies (e.g. Lawson 1990) indicate that Asian children have a high collision involvement. • Sandels 1975: Children do not have an instantaneous appreciation of the total traffic environment, because they are reacting to other ‘more interesting’ stimuli to which they respond with the ‘whole of their personality’. • Sandels 1975: In an experiment, children had more difficulty in establishing the direction of the sound (an approaching car) than adults. • Zwahlen 1974: 33% of pedestrian collisions involve errors of distance perception. • Children in the lowest socio-economic group are over 4 times more likely to be killed as pedestrians than their counterparts in the highest socio-economic group. • Atypical family life seems to be a factor in child collision rates. • Sharples et al 1990: 53% of inquest reports on child fatalities indicated that the child was

playing unsupervised in the street.

- Social factors like family size and structure, over-crowding and maternal preoccupation have been linked to collision risk of child pedestrians in low socio-economic groups.
- Inner cities and areas of urban deprivation are linked to high collision risk for pedestrians.

Conclusions

1. Children from low socio-economic groups are more exposed to traffic as pedestrians than children from higher socio-economic groups.
2. The parents or carers of children in low socio-economic groups are less able to be responsible for their children in traffic and less informed about risk.
3. The traffic environments to which child pedestrians from low socio-economic groups are exposed are less safe than those to which children from higher socio-economic groups are exposed.

Reference **Clayton A B, Booth A C and P E McCarthy (1977).** ***A controlled study of the role of alcohol in fatal adult pedestrian accidents.*** **TRRL Supplementary Report 332.**

Aims To determine the BAC distribution of adult pedestrian fatalities in a large urban area, and by comparing it with the BAC distribution of a matched control sample of non-collision-involved pedestrians, establish the role of alcohol in the aetiology of such fatalities.

Method Data collection on all adult pedestrian fatalities which occurred in the West Midlands Metropolitan area during the period 1 January 1969 – 31 December 1975. Control data was collected from roadside interviewing of pedestrians (matched by gender) passing the collision site at the same time of day, day of week and time of year as the occurrence of the collision.

Results

- 1/3 of all fatally injured pedestrians had been drinking (22% were above the legal limit for drivers and 15% had BACs regarded as indicative of a regular, heavy, drinker. Figures for the control group were 21%, 6% and 1% respectively.
- Alcohol related collisions tended to occur mainly in the late evening and nearly half (47%) of the males in the collision group had been drinking (compared with 15% for females).
- For both males and females it appeared that the effects of alcohol on pedestrian fatal collision experience were not significant below BAC levels of 120mg/100ml. Above this level the risk increased rapidly.
- Apart from BAC, age appeared to be the most powerful determinant of collision liability; the risk of collision involvement increased with increasing age.
- Amongst males, impaired pedestrians (those with BACs greater than or equal to 120mg/100ml) were over-represented amongst the young and the middle aged, semi-skilled and unskilled manual workers and unmarried, divorced and separated persons and those who drink relatively often (at least 4 occasions per week).

Conclusions Alcohol has a major role in fatal pedestrian collisions: impaired pedestrians (those with BACs equal to or greater than 120mg/100ml) comprise 27% of male fatalities and 7% of female fatalities (of those who die within 12 hours of the collision).

Reference **Corben, B, Triggs, T J, Diamantopoulou, K and N Wilson (2004).** ***Coloured Surfacing of Pedestrian Cross-Walks at Traffic Signals.*** **Monash University Accident Research Centre.**

Aims To identify the overall utility and potential benefits of highlighted crosswalks in a busy shopping centre in Stonnington, Australia.

Method

- Estimate the number of potentially preventable pedestrian collisions whose severity could be reduced, assuming highlighted crosswalks would be effective in enhancing pedestrian safety.
- Discuss human factors considerations of highlighted crosswalks as they relate to pedestrians and vehicles.
- Present main findings of pedestrian surveys (300 pedestrians surveyed).
- Present main findings of observational study.

Results

- Found a potential reduction in pedestrian collisions between 29% and 100% across 10 sites.
- Nearly all respondents indicated that highlighted crosswalks can improve pedestrian safety.
- Respondents felt that it helped them to know where to cross and encouraged them to use crosswalks.
- Theoretical improvements in pedestrian safety was reflected in a number of statistically significant increases in the average time-to-collision between pedestrians and vehicles and in fewer pedestrians being exposed to short (i.e. potentially hazardous) times-to-collision.

Conclusion
The authors do recommend the use of highlighted crosswalks in busy, complex pedestrian/traffic environments.

Reference **Crabtree M R (1997).** ***A study of four styles of pedestrian crossing*****. Traffic Management and Road Safety. Proceedings of seminar K held at PTRC European Transport Forum, Brunel University, 1-5 September 1997. Volume P419 PTRC Education and Research Services Ltd 1997-09 p171-82.**

Aims
Assessment of four types of pedestrian crossing

- Standard Pelican
- Standard Puffin
- Puffin with standard MOVA
- Puffin with pedestrian-volume-sensitive MOVA

Method
Video recording of the different types of crossing.

Results
When considering the delay results for the Puffin crossings, there was just one statistically significant result; that was that the VSPD MOVA Puffin had longer delays for vehicles than the MOVA Puffin. There was a difference between the two control methods that manifested itself as a shorter cycle time, again statistically significant. Thus it can be concluded that the VSPD MOVA Puffin was more responsive to pedestrian demand than the MOVA Puffin. However, the difference in delay to pedestrians was too small to be measured. The remaining delay comparisons were largely inconclusive due to the lack of statistical significance.

Reference **Daff R, Cramphorn B, Wilson C J and Neylan J (1991).** ***Pedestrian behaviour near signalised crossings (Sydney)*****. Proceedings 16th ARRB Conference, part 4.**

Aims
To explore behaviour and perceptions of pedestrians crossing busy arterial roads in shopping strings in Sydney’s inner suburbs. To investigate decisions to use a nearby signalised pedestrian crossing or to cross elsewhere.

Method	Video, group discussion and roadside interviews.

Results

Pedestrians organised their crossing location and timing to minimise walking distance and delay. Waiting time and diversion distance are therefore seen as deterrents to use of pedestrian crossings.

Pedestrians observed were grouped into categories:

. A Diverted from route to cross at crossing with Walk signal
B Crossed at crossing with Walk signal on route
C Crossed away from crossing with Walk signal
D Diverted from route to cross at crossing, but went against Walk signal
E Crossed at crossing against Walk signal on route
F Crossed away from crossing against Walk signal

Age and gender variations: Those groups crossing away from the signalised crossing (C and F) had higher proportion in 20-29 age group (41% compared to 30% of total sample). Those crossing at the crossing on green (A and B) had higher proportion older pedestrians (84% of over 60s). Those crossing at signalised crossing on green walk sign (A and B) higher proportion of females (68%) than those crossing away from the crossing (C and F) (16%) - more likely to divert to a crossing than males.
Ethnicity: Greek and Asian respondents were more likely to cross at crossing, especially with green walk signal, than the Australian/Anglo Saxon respondents. Could be due to cultural factors or desire to be law-abiding in a new country.
Familiarity: No difference in **c**rossing behaviour between those familiar with the area and those who were not.
Carrying a bag: Those who were carrying something more likely to cross at the crossing (92% compared to 66%). Maybe related to perceived speed with which able to cross.
Diverting to crossing: Only 27% of those using crossing actually diverted from their route to use them- more women than men.
Perceived reasons for using crossing: People who claimed always to cross at crossing with green walk signal motivated by safety considerations and belief that road is busy and traffic dangerous. Those who claimed to sometimes or never use green walk signal concentrated on convenience and avoidance of delay - strength of influence determines when opportunity taken to cross road. Many pedestrians who crossed away from the crossing claimed the traffic had already stopped.
Group discussions:
Adults- Ability to pick gaps between traffic even if area regarded as dangerous for pedestrians - aided by other crossings breaking up traffic.
Short green walk time another reason given for taking opportunity to cross road when gap presents itself rather than at the crossing.
Although crossings perceived as reducing risk for everyone, particularly associated with elderly, people with a handicap, and children.
Convenience a key factor in decision to cross at crossing- use if on route and not have to divert, but just cross straight otherwise.
School children - Peer group pressure encourages them to disobey pedestrian signals. Aware of instructions from parents but not very strong influence if feel they themselves don't follow rules. Convenience and time factors considered. Running mentioned a lot as the best way to cross a busy road- feel the traffic will stop for them also.
Video observations: Crossings themselves most popular point to cross - determined as 20m band of road space centred on crossing with 3m within the painted lines. Pedestrians didn't cross in band from 10-20m in each direction from centre crossing due to cars queued up there or so close to crossing decided to cross on it. Traffic volume important in determining whether crossing used. At crossing, most walked with green walk signal- varied from 54% to 84% at various sites. 'Shadow effect' with pedestrians crossing other than at crossing when on pedestrian phase- though other opportunities taken as well. Stopped traffic seemed to signal to all pedestrians the opportunity to cross regardless of their location. High proportion crossed on red flashing Don't Walk signal to time in cycle, most likely because pedestrians saw it as last chance to cross for a while- as cars still stopped. About 28% of those who commenced to cross on the Don't Walk or flashing Don't Walk signal ran for at least a few steps, compared to only

4% of those who crossed on green walk signal.

Conclusions	Model of diagonal crossing behaviour proposed for pedestrians whose destination is diagonally across the crossing and walking against oncoming traffic (can scan traffic for gaps without turning head) and had clear view of oncoming traffic free from parked cars. The pedestrian walks along kerb watching for gap in traffic, crossed when one appeared. Even if no gaps before reach signalised crossing, if on Don't Walk then pedestrian ignored crossing if destination still ahead. Decision to use crossing therefore seems to depend on flow of traffic and convenience.
Other	Techniques for videoing behaviour at signals include setting up a video camera in an elevated position pointed towards crossing. Usually just above awning height. At one location, about 8 stories high. Pedestrians have not normally been aware of camera so have not altered behaviour.

Reference	**Evans D and P Norman (2003).** ***Predicting adolescent pedestrians' road-crossing intentions: an application and extension of the Theory of Planned Behaviour.*** **Health Education Research, 18 (3), pp267-277.**
Aims	Application of Theory of Planned Behaviour (TPB) to the prediction of adolescent pedestrians' road crossing decisions.
Method	Self-completed questionnaires which involved a scenario of a potentially dangerous road crossing behaviour; included measures of attitude, subjective norm, perceived behavioural control, self-identity and intention.
Results	Respondents held slightly negative intention to the cross the road as depicted in the scenario, a negative attitude towards the behaviour in the scenario and felt the behaviour would attract social disapproval. Behavioural control and self-identity emerged as the strongest correlates of intention. Those adolescents who intended to cross the road in a potentially hazardous manner were more likely to justify their behaviour, believe that others would approve of the behaviour and perceive the behaviour as easy to perform.

Reference	**Elliott M A (2004).** ***The attitudes and behaviour of adolescent road users: an application of the theory of planned behaviour.*** **TRL Report 601: Crowthorne.**
Aims	To use the theory of planned behaviour (TPB) to investigate adolescents' (aged 11-16 years) attitudes towards four specific examples of road using behaviour which were identified as being important in terms of road safety.
Method	Four questionnaires were designed (one for each of the target behaviours) and pupils from six secondary schools completed the questionnaires.
Results	The study showed that adolescents' intentions (to use cycle helmets, to use nearby crossings to cross the road, to cross the road between parked cars and to challenge traffic) were strong predictors of their behaviour. Their attitudes to perform these behaviours were powerful predictors of intention, more so than demographic and exposure variables.

Reference	**Evans D and Norman P (1998).** ***Understanding pedestrians' road crossing decisions: an application of the theory of planned behaviour*****. Health Education Research, 13 (4), pp418-**

489.

Aims Application of Theory of Planned Behaviour (TPB) to the prediction of pedestrians’ road crossing intentions.

Method Self-completed questionnaires (210) which included scenarios of 3 potentially dangerous road crossing behaviours, measures of attitude, subjective norm, perceived behavioural control, self-identity and intention.

Results Found negative attitudes towards crossing a dual carriageway and a residential road, but a positive attitude towards crossing against the red man at Pelican crossing, stronger intention to perform this behaviour than other road crossing behaviours, perceived as easier to perform (although it would attract social disapproval= subjective norm). Social psychological variables considered were able to explain 52 of the variance in intentions to cross against the red man (49% TPB variables plus 3% self-identity variables). In terms of self-identity, people who view themselves as ‘safe pedestrians’ are more conscious of dangers involved in road crossing behaviours, and so less inclined to take potential risks.

Conclusions Perceived behavioural control component of TPB found to be the strongest predictor of pedestrians’ intentions, suggesting that perceptions of control have an important role to play in road safety behaviour. When behaviour is seen to be easy to perform, the person is more likely to engage in a potentially hazardous road safety behaviour; the findings suggest a link between crossing behaviours which are seen as easy to perform and low perceptions of risk.
Increase safety by making pedestrians more aware of the difficulties and risks associated with crossing road in potentially dangerous situations.

Other Questionnaire study, not encompassing complex decision-making processes involved in actually crossing the road.

Reference **Fortenberry J C and D B Brown (1982).** ***Problem identification and evaluation of a pedestrian safety program.*** **Accident Analysis and Prevention Vol. 14 (4). Pp315-322.**

Aims To evaluate the success of four educational programs implemented in schools, in relation to the number of child pedestrian collisions.

Method Educational programmes were implemented in the first and second grade of four cities aiming at 6-7 year age group. The objectives were to teach the children how to behave safely when on or near a road. An analysis of monthly collision data was employed in order to judge the success of each of the programs.

Results The study found that there was a statistically significant reduction in pedestrian collisions following the implementation of the safety programs (tests proved it was reasonable to assume that these reductions were a result of the programs). An estimated saving of 40 collisions was calculated for the 4 cities, as a result of implementing the educational programs.

Reference **Garder P (1989). Pedestrian safety at traffic signals: a study carried out with the help of a traffic conflicts technique. Accident Analysis and Prevention. Vol 20, No. 5, pp435-444.**

Aims To examine risk to pedestrians at intersections.

Methods Traffic conflicts technique and interviews with 450 pedestrians in Sweden.

Results Most pedestrian collisions in Sweden occur when a turning vehicle hits a pedestrian crossing on green (not relevant to UK) or a pedestrian crossing on red is hit by a vehicle. A separate phase for pedestrians was found to reduce collisions satisfactorily, provided that only a low percentage cross on red, but delay to pedestrians and vehicles increased.
A model was developed for the percentage of pedestrians arriving on red who cross on red, with independent variables road width, town size, presence of a refuge, pedestrian crossing flow, the number of cars per red-hour of the pedestrian signal, the number of cars per green-hour of the pedestrian signal, seconds of red time for pedestrians per cycle, whether fixed time or VA and whether the use of a push button is necessary. Traffic volume and town size had the most effect, with fewer pedestrians crossing on red with high volumes of traffic but more in larger towns. Pedestrians were more likely to cross on red if the road was narrow or if there is a refuge. Waiting time for green appeared to have little effect.
From the interview surveys, young men are 3 x more likely than average to cross on red. Men are more likely to cross on red than women. People in a hurry, especially men, are more likely to cross on red. Familiarity with the junction did not appear to have an effect. Pedestrians fell into two groups: those who almost never cross on red and those who frequently do so. The latter reported that shorter waiting times and/or more supervision by the police would be likely to increase their compliance.

Reference **Ghee C E, Knox D J, Selby T A, Silcock D T, Walker R T and D W Packer (1998).** ***Pedestrian behaviour and exposure to risk.*** **Ross Silcock Limited.**

Aims To measure pedestrian exposure to risk at various locations across the whole road network.

Method Video record the chosen locations and to extract data from the tapes describing the numbers of crossing movements and the observed interactions between pedestrians and vehicles.

Results

- This study backs up the general finding that risk in crossing the road is much higher away from crossings (150 rated events per thousand crossings in zones with no crossings compared with 30 or less rated events per thousand crossing on refuges, pelicans or other light controlled junctions).
- More males were found to be involved in coded events relative to the number of crossings (of all 1069 events 66% involved male pedestrians).
- Young males and older females appeared to be involved in more than expected coded events (particularly away from formal crossings).
- At pelicans there were more coded events for those crossing during the flashing green pedestrian phase, than those starting to cross during the steady green phase.
- In terms of avoidance action (pedestrians avoiding a collision), at formal crossings, vehicles tended to give way rather than pedestrians slowing down, and away from crossings male pedestrians tend to speed up or not to change speed whereas female pedestrians slow down; also pedestrians are more likely to change direction to resolve an encounter away from crossings.
- The absence of crossing facilities affects older women.
- Male pedestrians are more likely to confront or compete with vehicles, forcing an opening or take advantage of small gaps that appear in the traffic.

Conclusions

The study recommends:

- The use of crossing facilities as there was a substantially higher risk involved in crossing away from formal facilities.
- The use of refuges rather than no crossing facilities at all.
- Severe traffic calming in shopping streets (to benefit elderly females in particular).
- Re-evaluation of pelican and puffin pedestrian waiting times, so as not to encourage pedestrians to cross outside the steady green because the wait time is too long.
- Introduce hazard perception training into driving test.
- Review road traffic law and consider making it illegal for pedestrians to cross on a red man.
- A general reduction of speeds on all urban streets to protect pedestrians.

Comments

For practical reasons the research concentrated on busier urban sites which tended to be on main roads in the town centre or on arterial routes. Children under 16 years were excluded from this survey.

Reference

Graham D, Glaister, S and R Anderson (2002). ***Child Pedestrian Casualties in England: The effect of Area Deprivation.*** **Centre for Transport Studies. London.**

http://www.cts.cv.ic.ac.uk/documents/publications/iccts00268.pdf

Aims

Analysis of child pedestrian casualties in England, focusing on the influence of socio-economic deprivation. Testing the hypothesis that the level of socio-economic wellbeing influences child collision rates.

Method

Area-based approach, developing a model that attempts to explain spatial variation in collision numbers.

Results

- STATS 19 data: 40,665 pedestrian casualties in 2000. 16,184 were child pedestrians, 24,481 were adult pedestrians.
- There does appear to be a real deprivation effect that influences the number of pedestrian casualties. This is present for both children and adults, but more so for children.
- As the number of jobs proximate to wards increases, the number of child and adult pedestrian collisions tends to decrease.
- As the extent of built development becomes greater, the average number of pedestrian collisions increases.
- An increase in population density by 10% accounts for a 6.1% decrease in number of adult collisions.
- Adults are more likely to be knocked down in large employment centres.
- Both adults and children are more likely to be knocked down where residential populations are high and where more people are active as drivers.
- Built up areas have higher casualty rates for both adults and children

Conclusions

The results show a statistically significant positive and strong association between measures of area deprivation and the incidence of child casualties. Using the index of multiple deprivation score, the effect of deprivation on children is twice that on adults in terms of pedestrian collisions. This study has proved that the deprivation effect is over and above influences arising from local environmental characteristics.

Reference **Heraty M (1986). *Review of pedestrian safety research.* TRL Contractor Report CR 20.**

Aims Review of previous research into all aspects of pedestrian safety.

Results Traffic management and environmental design:

- In 1970s many zebra crossings converted to Pelicans, but study by Rayner (1975) of 38 sites in Greater London showed no clear safety benefit.
- Common complaint about Pelicans that insufficient time to cross, particularly women, and younger adults (Todd and Walker, 1980).
- DOE (1973) threshold of 30 seconds for pedestrians to wait at Pelicans before take greater risks to cross.

Pedestrian behaviour:

- Grayson (1975) found that while children perform each stage of road crossing as well as adults, they are less competent at putting the stages together. Differences with age and gender, but no clear behavioural explanation.
- Elderly pedestrians are more cautious and younger adults the most adept at crossing roads with minimum delay and apparent effort (Wilson and Grayson 1980).
- Grayson (1979) highlights that head movements may not necessarily mean seeing and seeing may not necessarily mean perceiving.
- Pedestrians do not seem to realise how ‘invisible’ they are after dark (Lynam, 1983).
- Circumstantial evidence that consumption of alcohol puts pedestrians at risk. In Scotland, 64% of pedestrian fatalities had been drinking and 30% in England and Wales (Older and Sims 1966). Codling and Samson (1974) also found a third of all pedestrian fatalities had been drinking and 21% had exceeded the legal limit according to 1967 for driving.

Road safety publicity:

- Elderly reluctant to accept advice, and education only seems to reach 20% of this age group (Sheppard and Valentine, 1980).

Legislation and enforcement:

- In Britain pedestrians have precedence on zebra crossings or signal-controlled crossings when signal to cross is illuminated. Pedestrians must not proceed when asked to stop by police officer controlling traffic or walk on motorways. No law other than these specific instructions to prevent pedestrians crossing the road. Research in this field mostly outside Britain.
- Smeed (1968) Presence of police officers had beneficial effect on pedestrian and driver behaviour at automatic traffic signals in London.
- In USA, study of elderly pedestrians (Wiener 1968) 30% increase in legal crossings where police gave written or verbal advice/warning to ‘jaywalkers’. Afterwards, those areas where education only received, legal crossings returned to same level, whereas enforcement areas still 10% higher legal crossings. In short term therefore, police enforcement more effective than education.

Comments Signalised junctions not included.

Reference **Houten R van, Retting R A, Houten J van, Farmer C M, and Malenfant L (1999). *Use of Animation in LED Pedestrian Signals to Improve Pedestrian Safety*. ITE Journal February 1999.**

Aims To determine the effects of a strategy to remind crossing pedestrians to look for turning vehicles at signalised crossings (NB: both turning vehicle and pedestrian are shown green). Strategy consists of LED pedestrian signal head with animated eyes that scan from side to side at the start of the Walk indication.

Method	Observation
Results	Number of pedestrians NOT looking for turning vehicles was reduced by the new signal.
Conclusions	Results are not very convincing if numbers of conflicts are compared.

Reference	**Hughes R, Huang H, Zegeer C, and Cynecki M (2000).** ***Automated Detection of Pedestrians in Conjunction with Standard Pedestrian Push Buttons at Signalized Intersections*****. Transportation Research Record 1705, pp 32-39. Transportation Research Board, Washington DC.**
Aims	Evaluation of whether automated pedestrian detectors used in conjunction with standard pedestrian push buttons, would result in fewer overall pedestrian-vehicle conflicts and fewer inappropriate crossings (i.e. pedestrians crossing on Don't Walk signal).
Method	Before-and-after video at intersections in Los Angeles (infrared and microwave), Arizona (microwave) and New York (microwave). At the Los Angeles site, additional detector had ability to extend clearance interval for slower pedestrians.
Results	81% decrease in pedestrians crossing during steady Don't Walk signal and number of conflicts. Overall 24% increase in pedestrians beginning to cross during Walk signal. Conflicts with pedestrians during first half of crossing reduced by 89%, and 42% in second half. Significant reduction in vehicle-pedestrian conflicts, and reduction in pedestrians beginning to cross during Don't Walk signal, therefore significant operational and safety benefits, but still some non-compliance. Improvements in detector accuracy are required to reduce the number of false actuations and missed calls. The detectors were considered to work best at mid-block intersections. Further research is needed to relate the reduction in inappropriate crossings and conflicts to a reduction in collisions and in vehicle and pedestrian delay.
Conclusions	Based on only three sites.

Reference	**Hunt J G (1994).** ***The operation and safety of pedestrian crossings in the United Kingdom*****. Proceedings of the 17th ARRB Conference, part 5. 15-19 August 1994.**
Aims	Paper reviews operation of pedestrian crossing facilities in the UK.
Method	Simulation.
Results	Current operating practice is biased towards optimising vehicle delay. Pelicans with fixed time control have the vehicle precedence period selected to ensure vehicle capacity of the crossing is not exceeded under peak flow conditions; thus at most times of the day, there will be spare capacity available. VA signals are much more responsive than fixed time, but need an operating strategy linked to pedestrian demand. In UTC systems, Pelicans on long links could operate independently. At signalised junctions, the use of a central refuge is suggested, so that pedestrians can cross the exit stream whilst it is held on red and the entry stream during suitable gaps.

Reference **Hunt J G (1995).** ***Pedestrian signals at junctions – a review of practice and effectiveness.*** **Proceedings of Seminar G held at the 23rd PTRC European Transport Forum, University of Warwick, September 11-15 1995, p285-96. PTRC Education and Research Services Ltd.**

Aims Paper reviews operation of pedestrian signals at junctions in the UK compared with other countries.

Results No significant safety benefit from an all-red phase, unless introduced as an collision remedial measure. Similarly, a parallel pedestrian phase had no significant effect on collisions.
Assuming that exposure at Pelican crossings is not significantly different from that at signalised junctions, analyses of STATS19 data seem to suggest that it is safer for pedestrians to cross at signal controlled junctions than at Pelican crossings
It is suggested that where traffic flow is light to moderate and there is a speed limit of 20mph, the overseas practice of allowing pedestrian precedence to coincide with vehicle turning movements might be beneficial for pedestrians, provided appropriate changes were made in signing (flashing amber) and marking.
An alternative would be to increase the number of arms with pedestrian stages, leading to more complex signal phasing.
Other alternatives involve reconsidering the relative weights given to the needs of vehicle occupants and pedestrians.

Reference **Hunt J G & A A Chik (1996).** ***Mid-block signalled pedestrian crossings – Alternative operating strategies*****. Road Traffic Monitoring and Control, 23-25 April 1996. Conference Publication No. 422. IEE, 1996.**

Aims Article describes a simulation study into the performance of alternative signalling strategies of mid-block pedestrian crossings, which give a higher priority to pedestrians.

Method Four alternative Puffin strategies were simulated.

Results All four strategies reduced the percentage of pedestrians who cross the road during the red man. This was achieved by a combination of reduced cycle time and better targeting of the times when pedestrian precedence periods occur. The reduced cycle time was partly a consequence of the automatic registration of pedestrian demand, but was mainly attributable to the relaxation of criteria for a change to pedestrian precedence. All four strategies increased the percentage of time which was effectively red to vehicles.

Reference **Hunt J, Lyons G and M Parker (2000).** ***Evaluating alternative operating strategies at Pelican crossings*****. Traffic Engineering and Control, November 2000.**

Aims Consider strategies which improve response to pedestrian needs at mid-block signalled pedestrian crossings such as the Pelican and Puffin which are operated in areas where speed limits of 30mph or lower are in operation.

Method Microscopic simulation model PEDXSIM used to evaluate alternative operating strategies:
Based on a hybrid model to identify ‘acceptable’ gaps in vehicle flow using detectors
A More complex strategy with extended pedestrian precedence periods
B A simple modification of existing strategies
C Model estimates mean cycle time, % pedestrians crossing during red man, mean delays for vehicles and pedestrians.

Results	The simulation demonstrated that it is possible, using currently available technology, to provide an operating strategy which is more responsive to pedestrian requirements. The alternative strategies reduce the percentage of pedestrians who cross during the red man, except for periods when the signals are changing to the green man aspect or when vehicle precedence is held for prescribed minimum period following a change of signal aspect. Model assumes all pedestrians press button on arrival at Pelican - less likely to if vehicle flow is low. Percentage of pedestrians crossing during the red man decreased with increase in vehicle flow, from a maximum of 40% at lowest vehicle flow. Compared with fixed time operation, vehicle actuated signals benefit pedestrians by responding more rapidly to pedestrian demand when there are gaps in vehicle flow. At vehicle-actuated Pelicans, pedestrians continue to identify, and cross during gaps in vehicle flow, suggesting that current vehicle detection system and control strategies are not well matched with pedestrian perceptions of suitable crossing opportunities.
Conclusions	Alternative strategies can be effective in reducing percentage pedestrians crossing during red man period.

Reference	**Hunt J (1998).** ***A comparison of pedestrian safety in Great Britain when crossing the road at signal controlled crossings at midblock and at junctions.*** **VTI Conference 13A (5).**
Aims	To review the difference in safety when crossing at signal controlled crossings, midblock and junctions.
Results	This comparison of pedestrian casualty frequency at Pelican crossings and at signal controlled junctions confirms previous evidence that the risk to a pedestrian crossing the road is typically substantially lower at the arm of a signal controlled junction than at a Pelican crossing (despite most junctions in Great Britain not have a pedestrian signal). Although the reasons for this are not known, it is evident that pedestrians often disobey the signal indications and vehicles may travel at quite high speeds (speeds are generally lower at signal controlled junctions due to turning movements).
Conclusions	Pedestrians are safest in a low vehicle speed environment and when the crossing task has no ambiguities; this is more likely to occur at a signal controlled junction with simple staging and phasing arrangements, with or without a full pedestrian stage.

Reference	**Keegan O and M O'Mahony (2003).** ***Modifying pedestrian behaviour.*** **Transportation Research Part A (37), 889-901.**
Aims	To evaluate the impact of countdown timers on pedestrian behaviour, particularly on numbers of pedestrians crossing during the red man. The timer counts down how much time is left until the green man shows.
Method	Attitude questionnaire of 150 pedestrians who waited for the green man and 150 who did not. Video survey of behaviour with and without countdown timer.
Results	The video survey showed that there was a statistically significant reduction in the proportion of pedestrians who started to cross while the red man was showing, from 35% to 24%. It also showed a significant reduction in the numbers of pedestrians starting to cross while the red man was showing when the cycle time is shorter, whether or not a countdown timer was present.

Reference	**Lange J (2000).** ***Bicycle and pedestrian facilities at small roundabouts in built-up areas.*** **2nd International Symposium on Highway Geometric Design. Germany: 14-17 June 2000.**
Aims	To investigate the influence of zebra crossings and traffic islands on the traffic safety for pedestrians and the quality of traffic flow for both pedestrians and vehicles in Germany.
Method	Collision analysis at 46 roundabouts, behavioural observations of cyclists and pedestrians at 16 roundabouts, roadside interviews of pedestrians at 4 roundabouts. Pedestrian facilities at the roundabouts included traffic islands, zebra crossings and no traffic control applications.
Results	Results showed that small roundabouts are a safe solution for pedestrians. Only 7 collisions occurred in 172 collision years. Pedestrians reported few conflicts with other users, 70% felt safe whilst using the roundabout, felt delay was acceptable and 80% preferred the roundabout compared with a signal controlled junction. Acceptance of right of way of pedestrians at zebras was high, regardless of the traffic volume.
Conclusions	Zebra crossings should be employed at all approaches and traffic islands should be employed at approaches with higher traffic volume. The unrestricted visibility of pedestrians for vehicles and vice versa is of great importance. Small roundabouts are a safe solution for pedestrians regardless of traffic volumes.
Reference	**Martin, L (1995).** ***Knowledge and perceptions of young pedestrians.*** **BioTechnology, Virginia.**
Aims	To develop guidelines for the protection of young pedestrians (ages 5-14 years) walking to and from school.
Method	Survey of primary and secondary school pupils to provide basic facts with respect to the students' stated school walking-trip behaviour and knowledge that relates to school-trip safety.
Results	The survey found a progression in the level of understanding of children regarding traffic rules; as children got older they better understood safe places to cross, not crossing on a red man etc. The survey responses to questions on route choice and route change indicate an increasing independence from parents and increasing influence of peer group pressure.
Conclusions	Significantly more younger students than older students indicated they would change their route if told to do so by their parents. This has an impact on how to influence children; parents may be the most useful channel for younger children whereas peers may be more influential on older children.

Reference	**Marvin M et al (1998).** ***Field test of a pedestrian safety zone program for older pedestrians.*** **42nd Annual Proceedings of the Association for the Advancement of Automotive Medicine. Pare Number 440, pp 321-334.**

Aims To develop and apply procedures for defining pedestrian safety zones for the older (65+) adult and to develop, implement and evaluate a countermeasure program in the defined zones (in the US).

Method Two cities were chosen (Phoenix and Chicago) and zones were identified in each. Specific countermeasures were then applied in the zones and monitored for any improvements in pedestrian collision rates. City traffic safety representatives designed their own countermeasure programs. Measures included: educational material distributed to residents via flyers and leaflets through doors, television and radio public service announcements, bus cards and notices in the newspaper, police presentations to the elderly, signal information signs erected near pedestrian crossings, repairs to pavement, traffic signal timing errors were corrected and crosswalks were repainted and repaired.

Results Results showed that while overall pedestrian crashes in the city increased over the study period, older adult crashes decreased by 13.7%. This decrease was greatest in the zones set up by this study (a decrease of 46.3% compared with 9.9% outside the zones). Significant decreases were particularly seen at intersections (which was where the countermeasures were concentrated e.g. project flyers addressed intersection issues, use of pedestrian signal information signs, increase in the available sight distance and corrections in signal timings).

Project flyers distributed as door hangers were reported to be the primary source of education information received by the respondents in the Phoenix survey of residents.

(Countermeasures in Chicago were not implemented due to personnel cuts).

Conclusions There was a clear ‘efficiency factor’ in being able to deploy countermeasures in a small area in both cities and reach a relatively large number of the target population. Based on the Phoenix crash results, the zoning process worked and was cost effective.

Reference McLean, A J (1978). ***In-depth study of pedestrian accidents.*** **University of Adelaide.**

Aims To review the characteristics of pedestrians, drivers and road and traffic flows, with emphasis on the possibilities for prevention.

Method Collision analysis of 304 collisions occurring over a 12 month period in Adelaide. Road collisions to which an ambulance was called were examined and collision reports were reviewed which were written by an engineer, a psychologist and a medical officer.

Results <u>Characteristics of the Pedestrians:</u>

- 40% female, 60% male
- 40% aged 19 years or under, 20% 60 years and over
- 6 pedestrians (14%) had consumed alcohol before the collision. 5 of these pedestrians had consumed enough to have an adverse effect on their ability to cross the road. Most common reason given for collision by these pedestrians was a misjudgement of distance of car (they thought they had enough time to cross the road).

<u>Pedestrian Actions:</u>

- 29% Child ran across road
- 20% Pedestrian did not see vehicle
- 11% Pedestrian stood in centre of road

- 11% Pedestrian crossed through banked-up traffic
- 9% Pedestrian crossed from behind parked vehicle
- 20% Other actions.

Road and Traffic Factors

- The lowest average annual daily traffic flow was 8,100 vehicles and the highest was 40,000 vehicles.
- Almost all of the pedestrian collisions occurred on arterial or sub-arterial roads.

Conclusions

Many of the pedestrians were involved in a collision because they were careless or made a mistake. Almost all of the child pedestrians ran into the road, the elderly very often did not see the vehicle approaching and other pedestrians chose to stand in the road or cross through banked up traffic. Alcohol was an important factor in some of the collisions.

All but one of the collisions occurred on busy roads, therefore measures to increase the rate of flow of traffic are detrimental to the safety of pedestrians. Wider use of raised median strips could reduce the frequency of pedestrian collisions by about one-fifth on roads which are currently undivided. Pedestrian actuated traffic signals have the potential to reduce midblock pedestrian collisions by one-seventh.

Reference **Moyano Diaz E (2002).** ***Theory of planned behaviour and pedestrians' intentions to violate traffic regulations.*** **Transportation Research Part F (5), pp169-175.**

Aims To apply the theory of planned behaviour in order to investigate pedestrians' intentions to violate traffic regulations.

Method A questionnaire survey was undertaken addressing pedestrian and traffic behaviour and was administered to 146 participants from the city of Santiago (Chile).

Results

- Young people have a more positive attitude towards illegal road crossing than adults do.
- Young people report that they commit more violations, errors and lapses as pedestrians.
- Men report more violations than women, but do not differ in errors or lapses.

Conclusions The results from this study support the notion that pedestrian behaviour significantly contributes to their collision involvement (e.g. reported behaviour such as using the entry door rather than exit door to get off a bus, crossing the street in unprotected crossing zones, crossing between stationary vehicles etc). Pedestrians' intentions are determined by attitude rather than by subjective norms, which may be attributed to lack of social or legal enforcement of pedestrian behaviour. The author suggests that the pedestrian is not the victim of aggressive and unscrupulous drivers, but are responsible for their own actions.

Reference **MVA Limited (1999).** ***Comparative Study of European Child Pedestrian Exposure and Accidents.*** **MVA Limited. Woking.**

Aims To understand the differences in exposure and collision rates of 5 to 15 year olds within similar road environments and assess the implications for policy by identifying the factors that may explain higher collision rates in Great Britain.

Method One-day travel diaries collected via face-to-face interviews with children in 3 different countries: Great Britain, France and the Netherlands. 1000 children surveyed.

Results

Exposure & Risk

- The frequency with which collisions happen is equal to the risk of a collision happening in any particular circumstances, multiplied by the amount of exposure of people to those circumstances.

  Number of Collisions= Exposure x Risk

- Exposure is measured by the time children spend walking in different road environments, and the number of times they cross a road in each environment.
- The risk associated with any defined road environment can be estimated by dividing the number of collisions which occur in each category of road environment by the total amount of exposure to that environment.
- Some of the differences in collision rates could be explained by differences in exposure. Need to look at both behaviour and road design.

Survey Results

- Number of roads crossed increases by age.

- In Britain, females seem to spend more time near the road than males (opposite occurs in Netherlands and France).
- However, estimated risk (as calculated above) is greater to males in all countries.
- Time spent playing near roads is greater in British cities than in smaller towns or rural areas.
- Children in Britain spend more time on main roads than in the other countries.
- Main roads in Britain do not seem to be inherently less safe than those in other countries, but local distributor and residential roads might carry an intrinsically higher risk.
- There is a greater exposure of British children to higher traffic volumes than in the Netherlands, which explains about a 5^{th} of the difference in overall collision rates.
- Children in Britain spend a larger proportion of their exposure in speed limits more than the standard urban limit, and on roads where the traffic is judged to be ‘faster’ than normal (than the other 2 countries).
- Estimated collision risks increase with road width for different types of road; children in Britain (and France) cross wider roads more frequently than those in the Netherlands.
- It’s likely that special measures to reduce speed in the Netherlands play a substantial role in reducing collision rates.
- Children in Britain are much more likely to cross the road between crossings, though marked crossings are associated with a higher risk than unmarked crossings.
- Lower socio-economic groups in Britain are more likely to use marked crossings than the higher groups.
- Footpaths are narrower in Britain than in the Netherlands.
- Greater risk in Britain associated with houses close to the road and with apartment blocks.
- Shops in Britain are associated with a high risk compared with France and the Netherlands.
- Children in Britain are more likely to be accompanied by other children.

Conclusions

- Half of the difference in overall collision rate between Britain and the other countries can be explained by Britain's children being more exposed to busier roads. This could be addressed by traffic safety schemes (separating traffic from pedestrians) and education and training. Other things that are recommended are traffic calming and lower speed limits, the design of local distributor and residential roads to provide a more forgiving road environment (so that mistakes by child pedestrians are less likely to result in collisions) and crossings at junctions.

Reference **Older S and G Grayson (1976).** ***An international comparison of pedestrian risk in four cities.*** **TRRL, Department of the Environment.**

Aims

To determine how pedestrian risk compares in different countries where there are different provisions of facilities, different regulations and enforcement, and possible differences in behaviour and social attitudes.

Method

Information on pedestrian and vehicle flows and pedestrian casualties collected from busy streets in Vienna, Copenhagen, London and Tel Aviv. Data analysed to compare levels of pedestrian risk.

Results

Risk levels between the cities similar. Consistent pattern in distribution of risk over different sections of road found. Relative risk is lowest at signal controlled intersections (with and without pedestrian signals). Areas of high relative risk were those within 50m of crossing facilities. Signalised crossings provide overall benefit in reduced risk, especially with pedestrian signals (when risks at crossing and within 50m are combined).
Pedestrian use of crossings differed in the cities (Vienna 39%, Copenhagen 73%, London 62%, Tel Aviv 71%), although differences in provision. With percentage of pedestrians on crossings based on provision, Vienna still had lowest usage. Signalised crossings used more than non-signalised crossings.

Conclusions	Low risk on crossings and high risk on adjacent sections of road common in all four cities. Ranked crossings, safest first: 1. crossings with pedestrian signals at signalised intersections 2. crossings without pedestrian signals at signalised intersections 3. crossings with pedestrian signals at non-signalised intersections 4. crossings without pedestrian signals away from intersections.
Other	Different ways of classifying data in the different cities, but still overall quite similar findings. Regulations differ: Austria must cross on crossing if one within 25m, Denmark and Israel must use crossing if nearby, UK no obligation.

Reference	**Preston B (1986).** ***The behaviour and safety of pedestrians at Pelican crossings in Greater Manchester.*** **TEC pp596–599.**
Aims	To assess the risk of crossing at the Pelican compared to within 50m and of crossing on the green man compared with other phases when vehicles have priority.
Method	On site visits to 12 Pelican crossings related to police collision data.
Results	Whether people cross at the Pelican depends on the amount of traffic. Females are more likely than males and older more likely than younger to use the Pelican. Whether people wait for the green man depends on gaps in the traffic. Same gender / age split. Risk of crossing within 50m about 4 x risk on crossing. For males, risk of crossing on green man less than other phases. For females, risk similar (reason for the latter is not known).
Comments	Limited number of sites all in 1 city. NB delay at pelicans with not much pedestrian flow and VA can be as little as 3 seconds (add in up to 20 seconds if green man has just finished.) Delay in UTC systems can be much longer as green to vehicles can exceed 60 seconds.

Reference	**Preston B (1995).** ***Cost effective ways to make walking safer for children and adolescents.*** **Injury Prevention (1) pp187-190.**
Aims	To evaluate cost effective ways to make walking safer for children and adolescents.
Method	Review of literature.
Results	• Most pedestrian collisions occur in built-up areas and the very young are most likely to be injured on minor roads, very near home and especially in inner-city areas. • Children are killed when crossing the road (going to the shops, visiting friends), on the journey to or from school or whilst playing in the street. • The reduction in traffic speeds is most important in the short term (whilst long term objectives are to reduce the number of trips made by car). • Traffic calming measures are shown to be a success in many countries and usually involve reducing the traffic speed to 20mph. This would help to reduce the number of casualties to

children, however much lower speeds are needed in residential areas.

- Many countries recognise that children need to play outdoors which means streets need to be safe for children to play. This attitude should be adopted more greatly in Britain and particularly in inner-city areas, residential street should be freed from fast traffic. The use of Woonerven (used in the Netherlands) where physical measures are used to reduce traffic speed to 5mph are recommended. Re-visit ‘play-streets’ which were introduced in Salford in the 1930s where the number of children injured was reduced by nearly half.
- Introduce more Home Zones where traffic integrates with pedestrian movements.
- Many of the casualties incurred on the school journey, occur near the schools. School crossing patrols should be used not just at school entrances but also at busy roads near to the school where many children cross.
- Pelican crossings near schools should be wide enough to allow all waiting children to cross during the steady green man phase.
- Buses are mentioned in many collision reports; where children travel to and from school by a school bus, the bus should pull up by the school so that pupils can board or alight without having to cross the road.

Reference **Reading I A D, Dickinson K W, and Barker D J (1995).** ***The Puffin pedestrian crossing: pedestrian-behavioural study*****. Traffic Engineering & Control, 472-478.**

Aims: Effect of conversion of Pelican to Puffin crossing in Edinburgh studied in terms of pedestrian behaviour.

Method: Video-recording of Pelican crossing for 3 days, Puffin for 1 day.

Results: Vehicle delay longer at Puffin crossing than at Pelican - 5 seconds per stopped vehicle on average. Pedestrians took 0.3 seconds longer to cross on average at Puffin than at Pelican.
A longer cycle time was found to be associated with more non-compliance (pedestrians start to cross before amber-to-traffic signal commences). Possible reasons include frustration. Longer cycle times also increase probability of gaps in traffic when pedestrians could cross.
Other studies (e.g. Garder, 1989) did not find that average delay to pedestrians or cycle time explains non-compliance.
More anticipatory crossing with Puffin but fewer crossing on red man – differences not statistically significant.
Differences in delay experienced by pedestrians were negligibly small. The delay was mainly related to the frequency of pedestrian stages rather than to the detailed operation of the crossing in terms of signal aspects.
Cancellation of pedestrian demand when pedestrian is no longer waiting at Puffin crossing, but can get false cancellation resulting in delay to pedestrians. 8% of valid requests were undetected.

Conclusions: Longer occupation and crossing times indicate that Puffin is less stressful for pedestrians. Increased delay to vehicles with Puffin (5 seconds per vehicle).

Comments: Small sample size used. Measured pedestrian delays were biased by faulty pedestrian detection and reduction in the use of the push-button.

Reference **ROBOT (1995).** ***An East Rand bid for urban pedestrian safety.*** **ROBOT (March/April**

1995, pps 30-31).

Aims — Discusses the law enforcement efforts aimed at pedestrians in East Rand, South Africa where they implemented a programme called 'Project Walk Safe'.

Method — Enforcing pedestrian law was thought to be virtually impossible due to pedestrians providing false information and the lack of identity documentation. Pedestrians had to be prevented from crossing the road after the pedestrian light had turned red and jay-walking, crossing against a traffic light or at a non pedestrian crossing.

Springs town council and the Traffic Section and Department of Public Relations joined forces to implement an initiative which involved patrolling pedestrian trouble spots. Pedestrians breaking the law were immediately approached by a traffic officer and presented with an official notice. The notice served as an information bulletin warning and informing pedestrian of the real dangers they face by breaking the law. It also reminded pedestrians that pedestrian offences are criminal offences which can lead to prosecution.

Results — The new approach appears to be effective in getting the message across, especially to the less educated sector of the community who were observed paying more attention to the notice than more 'sophisticated' pedestrians who barely glanced at the notice before disposing of it.

Reference — **Rothengatter J A and D J Sherborne (1994).** ***Responsive signal settings for pedestrians in urban areas.*** **Telematics for transport. Towards an intelligent transport system. Proceedings of the first World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway systems, November 30 - 3 December 1994, Paris. Volume 2 ERTICO, Brussels, Belgium.**

Aims — Evaluation of pedestrian safety and mobility as well as interactions between pedestrians and vehicles where signal settings are amended by pre-arrival microwave detection of pedestrians

Method — Before-and-after video observations of trials carried out in Greece, Portugal, and England (Leeds). Leeds had 3 pedestrian crossings on one road, which were part of a UTC system. Detectors worked by acting as a pre-arrival button and by extending the green. Measurements taken of waiting time at kerb (pedestrian movement efficiency), conflicts and encounters between vehicles and pedestrians, pedestrian gap acceptance, pedestrian red light violations (pedestrian safety indicators), vehicle queue lengths and vehicle journey times (traffic movement efficiency).

Results — Some evidence that in certain circumstances vehicle movements, or reflections of movements, could trigger off detection. No detrimental effect on working of system, but need to ensure that detectors only pick up pedestrian movements. Need to collect information before installation on existing pedestrian routes so that the detectors can be installed in the appropriate positions.

Conclusions — Feasible to use pre-arrival detection of pedestrians to alter signal timings. Changes in pedestrian behaviour can result from minor changes to infrastructure - needs further research.

Reference — **Sanca, M (2002).** ***Application of design for safer urban roads and junctions: selected countermeasures.*** **Linkoping University, Sweden.**

Aims — To review design approaches used in Nordic countries with a focus on the safety of vulnerable road users and discuss the general way in which they might be applied.

Results

Marked Crossings

Although there is a general belief that marked road crossings have a positive safety effect, the author provides evidence to counter this argument (Ekman, 1996, Elvik, 1997). They suggest that collision risks can be higher at marked crossings with no other facilities. These marked crossings give pedestrians a false feeling of safety. Crosswalk markings are not as visible to vehicles as they are to pedestrians.

Raised Crossings

Increased safety is reached if different texture or colour is used and/or warning strips at the edge are drawn. The effect is speed reduction of traffic and increased yielding to pedestrians by vehicles (e.g. Cambridge, USA where motorists yielding to pedestrians increased from 10% to 55% after the installation of a raised crosswalk). Another advantage is better accessibility for wheelchair users who do not have to overcome a step elevation.

This measure should not be used if sight distance is limited, if the street is steep, or if the road is an emergency or bus route. Special care should be paid to drainage.

Pedestrian Crossings with Narrowing

An effective way to reduce traffic speeds and increase drivers' attentions to other road users. Narrowing can be achieved by widening the pavements: bringing both curbs in. This treatment is appropriate for low volume streets.

Pedestrian Refuge Islands

These are raised islands placed in the centre of the street to help protect crossing pedestrians from vehicles. The islands mean that pedestrians only have to deal with one way traffic and provide resting points for the elderly or disabled. Refuge are most beneficial on wide, two-way streets and intersections with high traffic volumes, high traffic speeds and large pedestrian volume or wide streets where the elderly, people with disabilities and children pedestrians regularly cross.

Combined Countermeasure

The use of speed cushions and narrowing of the carriageway. The carriageway was narrowed to 3.2m and the speed cushion was placed 5m in front of the crossing. Emphasis was placed on self-explanatory design and attractiveness of the measure. The crossings were equipped with lampposts to increase the visibility of the location. Results showed that speed decreased from 49-60kmh to 26-34kmh and the give way behaviour was significantly improved (only 20% of vehicles gave way to pedestrians before introduction, but 67% by a year later). Car-pedestrian collisions decreased by 41% (car-car collisions decreased by 60% and car-bicycle decreased by 31%).

Variable Warning Signs

These are automatic warning and detection systems designed to warn motorists of the presence of pedestrians. Two infra-red or microwave detectors are modified to detect automatically pedestrians wishing to cross the road. When the pedestrians are detected the signs light up their warning message consisting of warning triangle and/or text.

These signs improve drivers' speed and give way behaviour, and are well accepted by drivers. Pedestrians who use the crossings think it is easier and more convenient to cross.

Reference **Sisiopiku V P and D Akin (2003).** ***Pedestrian behaviours at and perceptions towards various pedestrian facilities: an examination based on observation and survey data.*** **Transportation Research Part F (6), p249-274.**

Aims To analyse user behaviours, perceptions and preferences toward various pedestrian facilities, including signalised and unsignalised intersection crosswalks, unsignalised midblock crosswalks, physical barriers and crosswalk furniture.

Method Questionnaire survey of users and video observation of user behaviour.

Results

- 59% of the sample chose to cross at designated locations (signalised, unsignalised and midblock crosswalks).
- Only 10% were willing to wait for a green man when there were acceptable gaps in the traffic in which they could cross on red.
- A difference was found in attitude between regular and occasional users of designated crossing points. Only 18% of occasional users admit to cross frequently at non-designated crossing points (compared with 34% of daily users). Commuters are more likely to risk crossing at non-designated crossing points and therefore more intensive effort should be made in order to discourage this behaviour.
- When asked why they chose to cross at non-designated crossing points, convenience is the number one priority sited by users (42%), while time-savings were also of major importance (27%). 30% chose to cross at non-designated crossing points because they perceived no risk in doing so (due to light traffic).
- When asked what engineering factors affected their choice of whether to cross or not, 90% indicated that distance to their desired destination was a major factor. This indicated that's crossings should be placed as close as possible to major pedestrian paths. 83% said that the presence of a midblock crosswalk affected their decision to cross and 74%, the presence of a pedestrian traffic light. Shelters and coloured paving were not as popular (34% and 41% respectively).
- Approximately 50% of respondents complained that turning vehicles do not respect pedestrians that attempt to cross at signalised junctions during green. This was verified by field observations (right or left turning vehicles share the green phase with pedestrians). This situation was sited as a reason for pedestrians choosing to cross the road at locations other than signalised intersection crosswalks during green.
- Only 35% of users replied that a pedestrian sign displaying the message "Cross only when traffic clears" made a difference in their decision to cross.

Conclusions Results support the notion that properly designed and placed pedestrian facilities encourage users to cross at a certain location and midblocks were found to be the most influential pedestrian facility (a finding also supported by actual movement data analysis). Signalised intersections with crosswalks help channel pedestrian traffic, however prove to be unable to persuade pedestrians to comply with signal indication (particularly under low traffic demand conditions). The most important factor affecting pedestrian's in their decision to cross is the distance of the crosswalk to their desired destination. The conflict between turning traffic at intersections and pedestrians trying to cross is great and therefore encourages pedestrians to cross against the red light. It is suggested that leading pedestrian intervals would assist in reducing the number of conflicts here.

Comments Study carried out in Michigan, US.

Reference **Tian Z Z, Urbanik T, Engelbrecht R and K Balke (2001).** ***Pedestrian timing alternatives and impact on coordinated signal systems under split-phasing operations.*** **Transportation Research Record 1748.**

Aims To investigate alternatives for providing pedestrian timings under split-phasing operations in the US.

Results
- Split phasing with protected left turns eliminates conflicts between pedestrians and left-turning vehicles, but the provision of two pedestrian splits could significantly reduce the intersection capacity and normally requires use of longer cycle times in coordinated signal systems.
- Split phasing with permitted left turns provides more efficient traffic operations due to the accommodation of pedestrian crossing within a single pedestrian phase. However, the display of a green circle may not convey clear information to drivers and could condition them to make a left turn without yielding to opposing traffic at a permissive left-turn location.
- The protected/permitted left-turn phasing scheme provides an intermediate solution between the protected and permitted left-turn phasing schemes.
- Two-stage pedestrian crossing can also minimise pedestrian crossing impact compared with a single-stage crossing.
- A model is proposed that can be used to determine when use of an exclusive pedestrian phase under split-phasing operations can be more efficient. Use of exclusive pedestrian-phasing scheme favoured with high pedestrian volumes, wide crossings, and relatively low traffic demand.

Reference **Todd, J. E. and A Walker (1980). *People as Pedestrians*. HMSO: London.**

Aims Investigation of the patterns of pedestrian behaviour and the incidence and type of pedestrian collisions (particularly comparing the elderly and other adults).

Method Firstly, home interviews were undertaken, collecting information on journeys made on a particular day. Secondly, the collection of detailed road information using interviewers as observers (using information provided by interviewees they walked all journeys that had been undertaken).

Results
- Younger adults (18-59 yrs) experienced greater pedestrian exposure than older people.
- Women experienced greater exposure than men, but men owned more cars than women.
- Single people had the greatest overall pedestrian activity level.
- General impression that men take more risks and are less cautious than women (they think they walk faster, walk diagonally to cross the road, and complain that you have to wait to cross at pelicans).
- Speculation about older people and their ability to deal with current traffic flows (due to changes in the last 60 years).
- People did not realise the importance of being able to hear when crossing the road (might explain high casualty rates amongst the elderly).

Conclusions The study found that differences in pedestrian exposure do not generally explain the differences in casualty rates between the young and the old, and men and women. The study suggests that men show a degree of impatience and therefore perhaps a greater likelihood of taking additional risks which could lead to a pedestrian collision.

Reference **Totton, B (2001). *"A question of priorities"*. Surveyor 8 February 2001 (pps 16-17).**

Aims To review a pedestrian scheme implemented in Kingston Upon Hull that gives priority to pedestrians and signalised crossings.

Method
Two crossing sites with a total of 14 sustained injuries occurring over both sites in a 3-year period to end of 1996. The sites both have high pedestrian and vehicle flows (high bus flow). The council decided to reverse conventional traffic priorities by giving pedestrians the default green and asking vehicles to wait at the stop line before being detected. The prime method of control is vehicle activated, with a 24 hour vehicle green time phase of between 7 and 12 seconds depending on demand.

Results
The scheme has been successful in terms of reducing collisions: total number of injuries has dropped by 36% over the following 3years (after installation) and that includes a 67% drop in child collisions. There has been an increase in cycle collisions (from 0 to 2) however this could be because of an increase in cycle traffic.

The work on the signals cost around £23,000 and the first year's return rate, based on injury collision costs, was 536%.

Reference
Van Houten, R, Malenfant, J E and D McCusker (2001). ***Advance Yield Markings: Reducing motor vehicle-pedestrian conflicts at multilane crosswalks with uncontrolled approach.*** **Transportation Research Record 1773, Paper No. 01-2247.**

Aims
To investigate the effectiveness of advance yield (give-way) markings and a symbol sign prompting motorists to yield to pedestrians at the markings.

Method
Field observations of vehicle-pedestrian interactions at three multilane crosswalks in Canada. Advanced give way markings were placed at either 10m or 15 m in advance of the crossing. Signs were also used by the side of the road to prompt motorists to give way to pedestrians and each of the sites were equipped with pedestrian-activated flashing yellow beacons to alert motorists that pedestrians were crossing.

Results
With no advance markings (but with the other equipment) 16.8% of the total events recorded were considered to be conflicts. Introducing advance yield markings at 10m decreased conflicts to 4.3%. Moving the markings to 15m did not show much more of an improvement, with conflicts falling to 3.3%.

Although not all motorists stopped at or near the yield lines, many motorists stopped 9m or more before the crosswalk. Observers noticed that motorists tended to stop closer to the crosswalk when traffic was heavy and slow, and these times risk is greatly reduced to slower traffic speeds. Introducing in-roadway signs was associated with motorists yielding farther back from the cross walk.

Conclusions
Introducing advance yield markings had a beneficial effect on the number of vehicle-pedestrian conflicts.

Reference
Van Houten, R, Retting, R A, Farmer, C M and J V Van Houten (2000). ***Field evaluation of a leading pedestrian interval signal phase at three urban intersections.*** **Transportation Research Record 1734, Paper No. 00-3271.**

Aims
To examine the influence of a 3-s leading pedestrian interval-LPI- (which permits pedestrian traffic to begin crossing several seconds before the release of potentially conflicting motor

vehicles) on pedestrian behaviour and conflicts with turning vehicles.

Method Field observations were undertaken at three signalised intersections and events and conflicts were recorded at each site. The crossing each had automatically configured Walk/Don't Walk signs installed. Before and after studies were conducted (with and without the LPI).

Results
- After introduction of the LPI, conflicts were almost non-existent.
- The likelihood of pedestrians giving up their right of way to turning vehicles during the LPI condition was significantly lower. The LPI condition made it easier for pedestrians to cross the street by allowing them to begin crossing before turning vehicles were allowed to enter the intersection.
- Once pedestrians were in the crosswalk, drivers were more likely to give way, as pedestrians were more visible.

Reference **Wall G T (2000).** ***Road markings to improve pedestrian safety at crossings.*** **Traffic Engineering and Control.**

Aims Assessment of the benefits and disadvantages of various measures installed to improve pedestrian safety and amenity at junction in terms of how pedestrians behave.

Method Before-and-after video study of three signal-controlled junctions using video surveys (Woking, Camberley and Wokingham).

Woking: stop lines moved back one metre, additional guard railing installed to prevent pedestrians crossing in the increased gap, on-crossing detectors (PUFFIN-type) installed

Camberley: stop lines moved back one to one and a half metres, wider than normal dashed lane markings installed.

Wokingham: stop lines moved back 3 metres, wider than normal dashed lane markings installed, pedestrian crossing coloured green (in order to encourage pedestrians, especially school children, to use the crossing rather than crossing diagonally to minimise walking distance).

Results **All sites:** Moving the stop lines back increased the distance between waiting vehicles and the crossing, improving visibility of crossing especially for HGV drivers

Woking-. People who pressed the button waited longer before crossing than those who did not (because they arrive first before button is pressed!). Found that people tend to believe that if pressed the button and then move onto the refuge it automatically registers that they wish to cross from the refuge to the other pavement (falsely). Large differences in the size of gap accepted by different pedestrians. No significant difference between crossing speed of those crossing with and without conflicting traffic.

Camberley- Installation of wider, dashed lane-lines reduced average speeds of approach and speeding vehicles. People who pressed the button waited longer before crossing than those who did not (because they arrive first before button is pressed!). Differences noted in proportion pressing button travelling in different directions. Proportion of people complying with the signals varied from 7%- 42% at different locations (7% figure due to pedestrians given a long time to cross without needing to press button). Younger pedestrians crossed faster than older pedestrians. Most looked before they crossed (86%-98%), but only 36%-47% looked during crossing - no variation with age. Most pedestrians who had to wait before crossing crossed within the designated area (64% compared to 34% who did not have to wait). Most of those crossing outside the designated area travelling away from central island towards pavement and crossed diagonally (at risk from turning vehicles).

Wokingham- Moving the vehicle stop lines back also reduced vehicles running red light by 40%. Installation of wider, dashed lane-lines reduced average speeds of approach and speeding vehicles. Increase in proportion using crossing within marked area (from 29% to

35%), but may also have had a ‘traffic calming’ effect on approaching vehicles.

Conclusions Scope for using low-cost engineering measures to improve pedestrian safety at signal-controlled junctions. The installation of wider, dashed-lines was associated with a reduction in average speeds in both Camberley and Wokingham.
The introduction of a green coloured surface at the pedestrian crossing near a school encouraged slightly more pedestrians to use the crossing (but not as much of an increase as was expected).
Behavioural patterns could be used to improve amenity of pedestrian crossings, such as the effect of positioning push-button units for pedestrian signals on frequency of use.

Comments Technique used for videoing behaviour used six cameras at strategic positions near junction to record vehicle and pedestrian behaviour and corresponding signal phases.

Reference **Yagil D (2000).** ***Beliefs, motives and situational factors related to pedestrians’ self reported behaviour at signal-controlled crossings.*** **Transportation Research Part F 3 (Israel).**

Aims Explored relationship of road crossing with *health belief model* (Becker 1974, incorporating cues to action, perceived threat, and barriers), *instrumental motives* (gains and losses- external) and normative motives (personal values- internal), and *situational variables*.

Method Questions relating to measurements asked for level of agreement with statements administered to 203 students at two Israeli higher education institutions (age range 18-37, average 24):
Health Belief model- collision risk likelihood, perceived seriousness, benefits and barriers.
Normative motives- sense of obligation to obey laws, belief in the law. **Instrumental motives**- perceived danger of crossing on Don’t Walk on 10-point scale, perceived likelihood encounter with police. **Situational factors**- how presence of factors would affect behaviour

Results 1. *Health belief model, normative and instrumental motives*: Women are significantly more likely than men to perceive themselves as more susceptible to a collision, believe that their social life will be affected by an injury (perceived seriousness), and that crossing against a Don’t Walk will annoy drivers (perceived barriers). A significant gender difference was found with frequency of unsafe crossing, which was much higher among men.
2. In terms of *normative and instrumental m*otives, men are more likely than women to believe that walking signals are designated for children and elderly (normative), and evaluate that they are less likely to be approached by a police officer (instrumental) - they therefore differ in their respect for the law. Overall, normative motivation- obligation to the law- had the largest contribution to prediction of crossing rather than health belief model and instrumental motives. Unsafe crossing for men was predicted by normative motives and perceived benefits, and for women perceived benefits and perceived danger of crossing were more important.
3. Situational factors: Traffic volume contributes <u>significantly</u> to crossing behaviour (high volume increases tendency to wait for Walk sign). Darkness also increases the tendency to wait. Bad mood decreases safe behaviour and good mood increases it. Presence of children and other pedestrians who don’t cross increase tendency to wait for Walk sign- stimulating conformity. Men are affected more by traffic volume and physical conditions (darkness, weather, and duration of a Don’t Walk sign); women are affected more by presence of others and by beliefs about behaviour of others (social environment).

Conclusions Findings suggested that pedestrians’ motives for safety rule compliance are different from drivers’ motives - with drivers instrumental and normative are similarly important. Crossing on Don’t Walk is perceived as less dangerous than traffic violations and pedestrians have a sense of control over consequences (collision and apprehension) greater for pedestrians. Deviant pedestrians also more visible than deviant drivers (more anonymous) therefore social norms enhance compliance with law greater than for drivers. When pedestrians <u>don’t</u> cross on Don’t

Walk (i.e. they comply with rules) likely to attribute this to personal values rather than gain/loss evaluations.

Comments Study based on self-reported data, small sample of all young adults, reliability of the questionnaire used (as claimed by the researchers).

Reference **Zegeer C V, Opiela K S and Cynecki M J (1985).** ***Pedestrian signalisation alternatives. Final Report.*** **US Department of Transport. Federal Highway Administration.**

Zegeer C V, Opiela K S, and Cynecki M J (1982). ***Effect of Pedestrian Signals and Signal Timing on Pedestrian Accidents*****. Transportation Research Record 847. TRB, Washington DC.**

Aims To determine the operational and safety effects of various pedestrian signalisation alternatives.

Method Analysis of pedestrian collisions, traffic and pedestrian volumes, geometrics, and signal data for 1,297 signalised intersections in 15 US cities to determine the safety effects of pedestrian signals and signal timing.

Results

- The presence of standard-timed pedestrian (Walk / Don't Walk) signals was found to have no significant effect on pedestrian collisions.
- The presence of an exclusive pedestrian stage (scramble timing) was associated with significantly lower pedestrian collision risk compared to concurrent-timed or no signals, when controlled for other important data variables. This was not the case for intersections that had pedestrian volumes less than 1200/day, possibly due to the limited sample of exclusive-timed signal locations within that volume category.
- Alternatives recommended for high pedestrian hazard intersections include the Walk With Care signal, a Yield To Pedestrians When Turning regulatory sign, a Pedestrian Watch For Turning Vehicles warning sign, and pedestrian signal explanation sign (word and symbolic). A three-phase pedestrian signal using Don't Start to indicate clearance interval was recommended for additional testing, and little or no benefit was found from the flashing Walk or the steady Don't Walk. Allowing pedestrians to yield to traffic and cross against the pedestrian signal was found to be undesirable based on safety considerations.
- The presence of exclusive-timed, protected pedestrian intervals was associated with significantly lower pedestrian collision experience compared to concurrent-timed or no signals, when controlled for other important data variables. This finding was not found for intersections that had pedestrian volumes less than 1200/day, possibly due to the limited sample of exclusive-timed signal locations within that volume category.
- Use of concurrent-timed pedestrian signals had no significant effect on pedestrian collisions.
- The number of pedestrian collisions involving turning vehicles was significantly higher for concurrent-timed signals than with no pedestrian signals - pedestrians are often less cautious if they have a Walk signal. This finding was not conclusive and was based on a small sample of collisions.

Pedestrian volume was the single most important explanatory variable for pedestrian collisions with traffic volume the second most important.

Conclusions Not clear to what extent this applies to UK conditions.

Reference **Zegeer C V, Stewart JR, Huang H and P Lagerwey (2001).** ***Safety effects of marked versus unmarked crosswalks at uncontrolled locations.*** **Transportation Research Record 1773, Paper No. 01-0505.**

Aims	To evaluate marked crosswalks at uncontrolled location and offer guidelines for their use.
Method	The study involved an analysis of 5 years of pedestrian crashes at 1,000 marked crosswalks and 1,000 matched unmarked comparison sites.

Results

- Analyses showed that several factors, in addition to crosswalk markings were associated with pedestrian crashes: higher pedestrian volumes, higher traffic ADT and a greater number of lanes.
- The presence of a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multi-lane sites (for both marked and unmarked crosswalks). Medians that were painted, but not raised, did not offer significant safety benefits to pedestrians compared with no median at all.
- Factors which were found to have no effect were: area type (residential etc), location type (junction, midblock etc), speed limit, traffic operation (one-way, two-way), condition of crosswalk marking and crosswalk marking pattern.
- On two-lane roads there was no significant differences in pedestrian crashes for marked versus unmarked crosswalks (based on a sample of 914 crossing sites).
- On multilane roads with ADTs of less than 12,000 there were also no differences in marked or unmarked crosswalks.
- On multilane roads with no raised medians and ADTs greater than 12,000, sites with marked crosswalks had a higher pedestrian crash rate than unmarked crosswalks. The crash rate increased as the ADT rate increased.

Conclusions

- Pedestrian crashes are relatively rare at uncontrolled pedestrian crossings, however the certainty of injury to the pedestrian and severe or fatal injury is high.
- Marked crosswalks alone (i.e. without traffic calming treatments or other crossing improvements) are not recommended at uncontrolled crossing locations on multilane roads (i.e. 4 or more lanes) where traffic volumes exceed 12,000 vehicles per day or where speed limits are higher than 40mph.
- In some situations (e.g. low-speed, two-lane streets in downtown areas) installing a marked crosswalk may help consolidate multiple crossing points.
- The authors recommend using other pedestrian facilities to improve pedestrian safety including: raised medians or crossing islands, traffic signals with pedestrian signals, curb extensions, traffic calming measures, raised crossings, adequate night time lighting, use of pedestrian warning signs, advance stop lines.

Appendix B: Comparative Collisions / Casualties, Nationally and for London

MEASURE	NATIONAL	NATIONAL	LONDON	LONDON
	No.	%	No.	%
No. of road traffic collisions	**214,030**		**31,811**	
No. of casualties (total)	**290,607**		**38,430**	
No. fatally injured	6617	2%	272	1%
No. seriously injured	44,252	15%	4892	13%
No. slightly injured	239,733	82%	33,266	87%
No. of Pedestrian casualties	**36,405**	**13%**	**7127**	**19%**
No. fatally injured	842	2%	119	2%
No. seriously injured	7471	21%	1380	19%
No. slightly injured	28,092	77%	5628	79%
No. of Cyclist casualties	**17,033**	**6%**	**3056**	**8%**
No. fatally injured	119	1%	19	1%
No. seriously injured	2350	14%	421	14%
No. slightly injured	14,564	86%	2616	86%
No. of PTW casualties	**23,532**	**8%**	**6469**	**17%**
No. fatally injured	698	3%	63	1%
No. seriously injured	6585	28%	1089	17%
No. slightly injured	16,178	69%	5317	82%
No. of pedestrian casualties by gender	**36,377**		**7127**	
Male	21472	59%	4052	57%
Female	14905	41%	3075	43%
No. of pedestrian casualties by age	**35,075**		**7127**	
0-15	12544	36%	1635	23%
16-24	6355	18%	1258	18%
25-59	11130	32%	2876	40%
60+	5046	14%	939	13%
Unknown			419	6%
Severity of child pedestrian casualties (0-15)	**12,544**		**1635**	
No. fatally injured	74	1%	8	0%
No. seriously injured	2307	18%	316	19%
No. slightly injured	10,163	81%	1311	80%
Severity of 60+ pedestrian casualties	**5046**		**940**	
No. fatally injured	307	6%	53	6%
No. seriously injured	1302	26%	217	23%
No. slightly injured	3437	68%	670	71%
Gender of 60+ pedestrian casualties	(Killed/seriously injured)		(All injuries)	
Male	730	45%	483	51%
Female	879	55%	457	49%
No. of pedestrian collisions by road class	**36405**		**6898**	
Motorways	82	0%	1	0%
A Roads (non-built up roads)	34981	96%	4106	60%
Other (B, C and unclassified)	1342	4%	2791	40%
No. of pedestrian collisions by day of week	**36405**		**6898**	
Monday-Thursday	21329	59%	4182	61%
Friday	6212	17%	1109	16%
Saturday	5209	14%	939	14%
Sunday	3655	10%	668	10%
No. of pedestrian collisions by time of day	**36401**		**6898**	
0000-0659	2418	7%	461	7%
0700-0959	4436	12%	938	14%
1000-1459	9508	26%	1830	27%
1500-1859	13314	37%	2348	34%
1900-2359	6725	18%	1321	19%