

The effect of traffic signal strategies on the safety of pedestrians

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The effect of traffic signal strategies on the safety of pedestrians

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Executive summary

Background

Research into traffic signals during the 1970s and early 1980s was largely concerned with increasing capacity and minimising delay to vehicles. The emphasis then shifted towards safety and particularly to that of vulnerable road users including pedestrians and cyclists. More recently, delay to pedestrians has become an issue, both in its own right and in its possible effect on safety, if it leads to pedestrians taking greater risks. Knowledge about how traffic control strategies (and the way in which they are applied) affect accident patterns is limited.

TRL was commissioned by the Department for Transport (DfT) to consider the effect of signal control strategies on casualties, particularly for pedestrians. The research is intended to provide input into the decisions faced by practitioners in optimising the split between safety and delay.

In the UK there are four signal control strategies currently in use: MOVA and VA for isolated junctions (i.e. junctions with traffic patterns that are not influenced by other nearby signals) and SCOOT and fixed time (usually TRANSYT) for networks of closely spaced junctions.

Methodology

A literature review was conducted to determine what research had been undertaken to date. Some instances of poor pedestrian behaviour were discussed by focus groups in order to gain insight into the underlying reasons. Following a reconnaissance survey, a total of 16 signal-controlled junctions and 6 mid-block crossings with different forms of signal control were selected as case studies. Details of the junction or crossing layout and signal timings were recorded. A four hour video survey was undertaken at each site and flow counts and extensive behavioural analysis undertaken. Alternative strategies were then tested and any changes in pedestrian behaviour evaluated. TRANSYT modelling was undertaken to investigate the trade-off between vehicle and pedestrian delay.

Literature review

The main findings from literature review were as follows:

- Most of the research relating to pedestrian behaviour at signal-controlled crossings is for mid-block crossings rather than junctions and does not consider the effect of signal strategies.
- Pedestrians crossing the road act according to their own convenience. If a gap in the traffic presents itself they will cross. They will tend to follow their desire lines in preference to diverting to a formal crossing.
- Pedestrians are at increased risk where there are more complex staging arrangements.
- Risk to non-compliant pedestrians is increased if the pedestrian phase ends just as a platoon of vehicles is approaching, which is likely to be the case in a UTC system.
- Pedestrians are more likely to comply with a signal if they are older, female, their mobility is impaired (by a physical disability or because they are carrying something heavy or accompanying a young child or pushing a pram etc), the traffic is heavy, other pedestrians are waiting or they have been waiting less than 30 seconds
- There is greater scope for reducing delay to pedestrians at mid-block crossings than at signalised junctions where at least 2 separate stages are required for traffic, meaning that longer cycle times are required. 'Walk with traffic' operation can be used in some cases to reduce delay (mainly to vehicles), but tends to lead to pedestrians having to cross the road in several 'hops' and can increase risk.
- The time taken to cross the road depends on the road width and on walking speed. In the UK, clearance periods are based on a walking speed of 1.2m/s (i.e. the speed exceeded by 85% of pedestrians crossing the road), considered to be a good compromise between operational efficiency and safety. 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-man period. On-crossing pedestrian detection is one method of alleviating this problem but the clearance period should be set to take account of relevant factors such as a large elderly population in the local area,.

- Uncoupling mid-block crossings from SCOOT control in off-peak periods was found in one study to improve pedestrian compliance with no significant increase in delay to vehicles. However, this result is likely to depend on the extent to which linking of the adjacent signals is important at the site in question during the off-peak.

Focus groups

Four focus groups were held, two with adults and two with adolescents aged 14 or 15 (boys and girls separately). They were shown video clips of risky behaviour which they were asked to assess and to state how likely they would be to perform this type of behaviour. In general, most participants said they would perform the behaviours if there were advantages in terms of reduced waiting time or a shorter distance to walk, provided they believed they could cross safely. They were more likely to do so if they were in a hurry, or if others were doing the same thing, and less likely to do so if they had young children with them or were encumbered by heavy shopping.

The participants considered that all-red phases at junctions are a good idea, but they had some important provisos, namely that if one signal-controlled junction had an all-red phase, then all signal-controlled junctions in the area should have all-red phases in order to minimise confusion. In addition, all-red phases are less worthwhile if their presence substantially increases the cycle time and thus leads to longer waiting times for pedestrians.

Although participants were not familiar with countdown timers, the idea of a countdown display giving the number of seconds remaining until the green man appears was popular with adults and adolescents alike, However, they felt that if the timer indicated too long a wait, pedestrians would be more likely to cross the road without waiting for the green man.

Participants also suggested more education in schools, including showing typical examples of poor behaviour, and legislation to enforce pedestrian compliance would be desirable.

Case study analysis

For the purposes of the case study analysis, pedestrians were classified in terms of their behaviour as Non-delayed, Compliers (who arrive when the red man is showing and wait for the green man), Late Starters (who fail to finish crossing before the signal changes to red), Non-compliant pedestrians (arrive on red and cross entirely against the red man) and Anticipators (who start to cross just before the green man). Not surprisingly, compliers had the longest mean waiting time. A majority of pedestrians were non-compliers, crossing during gaps in the traffic.

The results broadly confirmed the findings from the literature survey: men on average crossed slightly faster than women and younger people crossed more quickly than older ones. Pedestrians who were impeded in some way crossed more slowly than those who were not and were more likely to comply with the traffic signals.

A high proportion of accidents at the case study sites were found to have occurred late at night or in the early hours of the morning.

Potential strategies to improve safety

The obvious way to try to increase compliance and thereby potentially improve safety is to increase responsiveness by switching to the green man as soon as possible after the demand is made, or by reducing the cycle time, or by increasing the proportion of the cycle that can be used by pedestrians. This was trialled at two different Puffin crossings, in one case by a change to pre-timed maximum under VA and in the other by increasing the window of opportunity for the pedestrians phase within the cycle under fixed time. In both these cases, there was a reduction in mean waiting time for pedestrians overall. However, although pedestrian delay was reduced, there was no change in the level of compliance.

A trial of Compact MOVA for pedestrians at a junction gave encouraging results, reducing delay and considerably increasing compliance.

Compliance might be improved by the type of countdown device that tells pedestrians how long they have to wait for a green man, particularly if the waiting time is short. This type of timer is not likely to be suitable in traffic/pedestrian responsive signal control strategies. With responsive systems such as MOVA and VA, for example, it is not possible to provide more than a second or so advance notice of when the signals are about to change. However, these systems may be the safer option because they are more responsive to pedestrians.

Non-exclusive pedestrian phases may reduce waiting time for pedestrians before they start to cross, but the total time taken to cross may increase if pedestrians have to wait in the centre of the road. A 'staggered crossing' arrangement increases the crossing distance.

TRANSYT modelling

TRANSYT modelling was undertaken to look at the balance of delay between vehicles and pedestrians. This suggested that the dominant factor affecting pedestrian delay is cycle time. This finding is expected since the capacity of the crossing for pedestrians is rarely an issue (unlike the capacity for vehicles which if insufficient will lead to queuing and, therefore, much higher delay). Overall, the results suggest that there may be more scope for reducing delay to pedestrians if account is taken of them in the model, and some attempt made to weight their delay. In practice, this could be worth bearing in mind, but much will depend on the number of pedestrians and the scope for introducing pedestrian-friendly timings.

Conclusions

Pedestrians will cross the road during gaps in the traffic whatever the signal strategy adopted. Although reducing their delay should reduce the need for this, it will not necessarily increase compliance, which is mainly influenced by the level of flow. The lack of compliance does not necessarily imply a lack of safety. Most adults will be capable of judging correctly whether or not it is safe to cross. Children and older people will have more difficulty in making this judgement, but the latter are also more likely to comply with the signals.

A high proportion of the pedestrian accidents at the case study sites occurred late at night or in the early hours of the morning, suggesting that the pedestrians involved may have been drinking. There may therefore be merit in considering different signal strategies late at night. Alternatives include decoupling from UTC, running night-time plans with a much shorter cycle time, and 'rest on red'. As ever, options should be considered on their merits for any given set of circumstances.

Pedestrians tend to follow their desire lines regardless of the crossing location and this should be taken into account when signal-controlled crossings are installed.

Cycle time rather than the signal strategy employed has the dominant effect on pedestrian delay for those pedestrians who comply with the signals. Signal settings are generally optimised for vehicles. The scope for reducing the cycle time in congested conditions is limited, but should be routinely undertaken when traffic signals are installed or timings updated.

It was not possible to determine a link between the different signal strategies and pedestrian safety. Giving more green time and increasing responsiveness can improve pedestrian compliance to a degree. However, this will be at the expense of vehicle delay and it is not practical at busier junctions, except during the less busy periods of the day.

It is recommended that the use of /Compact MOVA for pedestrians be trialled at more sites to see if the benefits indicated in this report apply more widely.

Guidance to Local Highway Authorities

One of the key objectives of this research project was to provide advice to Local Highway Authorities regarding the application of signal control strategies. Given that the results from the work have not indicated any strong relationship between signal control strategy and safety, any guidance will necessarily be based as much on common sense and experience as on specific safety issues. Seeking to increase pedestrian compliance with the signals is desirable for pedestrian safety and this is likely to be achieved mainly by reducing pedestrian waiting times.

It is of particular importance to take into account local factors, such as a large elderly population, presence of a school or community centre, presence of shops when determining signal timings. This may become more important in the future in view of demographic changes leading to an increase in the proportion of older people in the general population.

Both the Department for Transport and the Highways Agency have issued much detailed advice about pedestrian crossings. Taking the results of this project into consideration has not resulted in the need to change any of this advice. However, advice in relation to signal control strategies is less detailed and both the findings of this project and discussions with stake-holders now provide additional advice.. Essentially, the aim of advice is to help pedestrians get a better level-of-service than they otherwise might.

Abstract

This project for the Department for Transport investigated the effect of signal strategies on the safety of pedestrians at signal-controlled junctions and midblock crossings. The methodology included a literature review, focus groups, video analysis of pedestrian behaviour at 22 case study sites, including both junctions and mid-block crossings, analysis of accident data and trials of different signal strategies. Although there is no direct evidence that improving compliance reduces casualties, it seems an obvious way forward. The strategies tested were therefore aimed at increasing the responsiveness of the signals to pedestrian demands and included comparing the use of vehicle actuation (VA) with and without pre-timed maximum and trialling MOVA for pedestrians.

1. Introduction

1.1 Background

Research into traffic signals during the 1970s and early 1980s was largely concerned with increasing capacity and minimising delay to vehicles. The emphasis then shifted towards safety and particularly to that of vulnerable road users including pedestrians and cyclists. More recently, delay to pedestrians has become an issue, both in its own right and in its possible effect on safety, if it leads to pedestrians taking greater risks. Knowledge about how traffic control strategies (and the way in which they are applied) affect accident patterns is limited.

TRL was commissioned by the Department for Transport (DfT) to consider the effect of signal control strategies on casualties, particularly for vulnerable road users. The research was aimed at providing important input into the decisions faced by practitioners in optimising the split between safety and delay.

The study investigated links between the operation of the various traffic control strategies and casualty rates and patterns, and the ways in which casualty rates for vulnerable users are related to the level of provision for these groups within the strategies. In addition, the study aimed to explore whether changes in casualty rates / patterns can be linked to the introduction of a variety of new schemes and control philosophies and to devise and test potential responses to these problems. The results provide advice to Local Highway Authorities on how to minimise the impact of schemes on casualty rates.

A decision was taken early in the project that the bulk of the work would be directed towards pedestrians as this is the group that can be most influenced by changes in signal timings.

1.2 Signal control strategies at junctions

In the UK there are four signal control strategies currently in use, as follows:

For isolated junctions (i.e. junctions with traffic patterns that are not influenced by other nearby signals)

- MOVA
- D-system Vehicle Actuation (normally abbreviated to VA) with and without Speed Assessment

For signal-controlled networks (where there are at least two junctions close enough to each other for one to influence the arrival patterns at the other)

- SCOOT
- Fixed time (usually optimised by the use of the off-line program TRANSYT)

These signal control strategies represent the top level of the operation of signal-controlled junctions. They effectively govern when the signals change from favouring one or more traffic streams to favouring other traffic streams. They vary in their intelligence but are all primarily designed to minimise traffic delays.

A signal-controlled junction has to have a specific collection of signal phases to cater for different traffic and pedestrian streams and the phase-to-phase intergreens have to be specified. These phases and intergreen times are dictated by the design and geometry of the junction (to standard TRR2210, formerly called TR0141). Hence each junction is ‘configured’ to operate in a predefined way in terms of how phases relate to one another. Some safety aspects of signals can be improved by, for example, adopting certain staging arrangements, but this may be at the expense of efficiency. For example, right turns, especially off the major road, can be more risky when the right-turners have to give way to oncoming traffic. It is safer to separately signal such right-turns but this may require additional signal stages (and additional road space). The result is that each stage potentially caters for less traffic (e.g. right turners only instead of rights, lefts and straights) which reduces capacity.

1.3 Signal control strategies at mid-block crossings

All of the control methods in Section 1.2 can also be used at mid-block crossings. These are generally Pelican (pedestrian light controlled) crossings, and may have a fixed green period or be pedestrian-activated. They include an audible signal to assist people with vision impairments and tactile cones for those with both vision and hearing impairment.

More recently, the Puffin (Pedestrian User Friendly Intelligent) crossing was developed (Davies, 1992), which performs in a similar way to the Pelican, but was designed:

- To detect waiting pedestrians so that unwanted pedestrian phases can be omitted
- To detect crossing pedestrians to enable extra time to be allocated to the pedestrian phase if needed

‘Toucan’ crossings allow pedestrians and cyclists to share a crossing, whilst ‘Pegasus’ crossings include equestrians as well as cyclists and pedestrians. Both Toucan and Pegasus crossings operate in the same way as Pelicans or Puffins.

When mid-block crossings are incorporated within UTC systems (i.e. SCOOT or fixed-time) the green-man period is given a ‘window’ in which it can appear if needed. The window, which is a time period within the cycle-time for the nearby signal-controlled junctions, appears at a point in the cycle, and is of a given length, intended to benefit motorised traffic. There are some actions that can be taken to improve the provision for pedestrians, though. It is common to allow the window to appear twice within the master cycle, especially when the cycle time is long. SCOOT has the ability to offer slightly better provision than fixed time since it will keep the cycle time as low as possible, and will also tend to allow double-cycling more frequently than fixed time would. Another possibility is to allow the pedestrian signal at a mid-block crossing to respond to gaps in the traffic in real-time. This strategy would increase risk, however, as in co-ordinated signal control systems the biggest gap often appears just in front of the biggest platoon of traffic.

1.4 Pedestrian safety at signal-controlled crossings

National accident statistics show that each year about 9000 pedestrians are killed or seriously injured (2000 of them children). About half of these are injured at signal-controlled junctions. Overall about 20% of accidents at these junctions involve one or more pedestrians. In urban areas this percentage is much higher and pedestrians are the largest accident group of vulnerable road users.

The Government’s report ‘Tomorrow’s Roads – Safer for Everyone’, which presents national accident reduction targets for the year 2010, emphasises the importance of addressing the safety of vulnerable road users. In order to increase pedestrian safety, there is a trend towards increased provision of pedestrian phases at junctions and more mid-block crossings.

For signal-controlled crossings to be used safely, pedestrians need to understand how to use them (e.g. to know when a junction arm needs to be treated as two separate crossings), to continue to pay attention to the traffic (i.e. not be over-reliant on the traffic signal and to be wary of traffic running the red light) and to obey the signals (which may not happen if there is a delay and the road is clear).

Many signal-controlled junctions do not provide a specific pedestrian stage and, even when they do it is known (Hall, 1986, and Taylor *et al*, 1996) that more complex pedestrian staging arrangements are associated with increased pedestrian accidents, although the reasons for this are not clear. These junctions are frequently designed so that pedestrian and traffic movements can co-exist as opposed to providing stages that are ‘all red’ to traffic. This is often beneficial for traffic, but may mean that pedestrians have to cross the junction in two, three or even more separate ‘hops’. It is possible to co-ordinate the pedestrian phases to allow good progression across an approach, but generally this will only be successful in one direction, and for people walking at a suitable speed, and overall junction performance for traffic is still likely to be compromised. Where there is a separate ‘all red’ stage during which all vehicles are stopped, pedestrians on all arms of the junction can cross simultaneously. They can also cross diagonally, thereby taking the shortest path through the junction. In terms of delay, being able to cross diagonally makes no difference to pedestrians crossing a single arm, but it can help pedestrians who wish to cross more than one arm of the junction. The effects of these strategies on safety have not been fully explored, but clearly they have different impacts on the capacity of the junction.

Mid-block crossings present similar safety issues to junctions and they, too, sometimes require pedestrians to cross a road in two sections, with a ‘staggered’ arrangement in the middle. The differences in the way they are controlled tend to be subtle. Under vehicle actuation, some use a ‘pre-timed maximum’ which effectively allows the pedestrian stage to run as soon as a demand for it appears, once the traffic green has exceeded the maximum (as opposed to the more common situation when the maximum timer starts only when a demand for the pedestrian phase is made). This feature is good for pedestrian convenience, but could result in more red-running as the change in signal aspect does not necessarily coincide with a gap in the traffic.

1.4.1 Adults

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. Earlier studies have observed similar pedestrian behaviour (Dannick, 1973).

1.4.2 Children

It is known from 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. 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.

1.4.3 Older pedestrians and those with a disability

Choice of signal control strategy will also affect the safety of older pedestrians and those with a disability. Both these categories of pedestrians may take longer to cross and Puffins are particularly appropriate since they minimise traffic delay whilst giving pedestrians sufficient time to clear the crossing. Though no evidence was traced in the review, for sensory impaired people as for children, simpler control strategies (i.e. those requiring fewer decisions by pedestrians) are likely to be safer.

1.5 Cyclist provision at signal-controlled junctions

Cyclists are also vulnerable at signal-controlled crossings, particularly junctions. However, the safety of cyclists at crossings is likely to be more affected by having to share the road space with vehicles than by the signal control strategy itself. For example, right turning vehicles searching for a gap in the opposing traffic at a 4-arm junction may fail to see on-coming two-wheelers. Pedal cyclists going ahead may be in conflict with left turning vehicles, whilst right turning

cyclists have to change lane, leading to a high involvement rate in left turning and approaching accidents at signals. Attempts to counter this include the use of advanced stop lines for cyclists.

The needs of cyclists on shared use routes can be accommodated by Toucan crossings and here it is important that the signal control strategy used encourages safe behaviour.

1.6 Use of Speed Assessment/Speed Discrimination Equipment

Government advice about the use of traffic signals on high speed junctions has recently been revised by DfT and is described in Traffic Advisory Leaflet TAL 02/03. Advice is given as the use of speed assessment or speed discrimination equipment (SA/SDE) at signal-controlled junctions.

Essentially, SA/SDE is required at signal-controlled junctions or mid-block pedestrian crossings if the 85th percentile approach speed exceeds 35mph. (MOVA can also be used in place of SA/SDE in such circumstances). The principle of the SA/SDE strategy is to avoid presenting an amber signal to a driver when his/her choice between stopping sharply and continuing, risking crossing the stop line during red, is awkward. SA/SDE achieves this by measuring vehicle speeds and extending the green to avoid catching drivers in this 'dilemma zone'. Green extensions continue where necessary up to a pre-set maximum. If the maximum is reached the signals change, and, at junctions, the inter-green is extended by two seconds (Unfortunately, the manufacturers misread the signal-controller specifications and the intergreen extension occurs on both gap-changes and max-changes with all but the newest equipment.) At mid-block crossings on high speed roads, the all-red period is normally set to three seconds whether or not the traffic green ends on a maximum.

Since the SA/SDE strategy is employed in addition to D-system VA, the propensity for the green to be extended to maximum is increased. In fact it becomes quite difficult for the signals to change in response to a gap in the traffic. Pedestrians wanting to cross, especially at mid-block crossings, often have to wait for maximums to elapse before being serviced. The more able-bodied will often find it possible to cross before the signals change.

In order to avoid unacceptable performance, it is necessary to keep the equipment used in good working order (Traffic Advisory Leaflet TAL 02/03). For SA/SDE equipment, the detectors need to be working, and set to the correct (medium) sensitivity if vehicle speeds are to be measured accurately. Also, all other detectors need to be fully functional if signal operation is to respond as intended. If any detectors are faulty, the traffic greens will always continue until the pre-set maximum: this is far from desirable as pedestrians may have to wait unnecessarily, and may be tempted to cross in gaps at a time when they might otherwise have had the protection of a red-to-traffic.

2. Outline methodology

2.1 Methodology

There were a number of different stages to this project as detailed below:

- Literature review.
- Focus groups.
- Accident analysis.
- Case studies at selected junctions and mid block crossings.
- Test potential strategies.
- Use of TRANSYT.

2.2 Literature review

A literature review was undertaken to analyse existing knowledge and research on this subject. The results of the review are summarised in Section 3.

2.3 Focus groups

Focus group research was conducted to explore:

- The kinds of pedestrian and cyclist behaviour that are considered to be safe and unsafe at signal-controlled junctions and crossings
- The factors that influence safe and unsafe behaviour

Opinions were sought on two signal strategies (countdown devices and an all-red phase to traffic) and on how signal-controlled crossings can be made safer. Details are given in Section 4.

2.4 Accident analysis

A high level accident analysis was undertaken using STATS19 to determine overall accident patterns at signal-controlled crossings (see Section 5).

2.5 Case studies

2.5.1 Initial STATS19 approach

The initial approach to identification of suitable sites for the case studies was to try to identify signal-controlled crossings with high numbers of pedestrian casualties. Data was extracted from the STATS19 database for the period 1999-2002 using the filters ATS (automatic traffic signal), pedestrian crossing and junction control. These accidents were collected within 100m squares. Not all accidents at an individual traffic signal have identical grid references but they tend to cluster close together. It was thought that the identification of clusters within the squares would identify individual sites with a high proportion of accidents involving vulnerable road users. In the event, this procedure did not prove to be useful because it was not possible to locate individual crossings where several junctions were closely spaced.

2.5.2 Site selection

Following the difficulties in identifying individual sites from STATS19, it was decided to use personal contacts. Five Local Highway Authorities (London, Manchester, Brighton, Bristol and Surrey) were approached concerning the case studies and asked for suitable sites where there was a history of accidents involving pedestrians and/or busy pedestrian sites.

The contacts were each sent a questionnaire to gather information about sites with moderate to high pedestrian flows, or where signal control strategies had been, or were planned to be, modified to address capacity or safety issues. Information was requested on signal control strategies and, if available, on flows of all road users.

A total of 49 sites were selected, all in urban/suburban areas. Project staff undertook a reconnaissance survey of the sites to confirm their suitability and to identify the required camera positions for the video surveys. The sites proposed in Surrey were rejected because of low pedestrian flows.

A significant risk of this type of study is attempting to cover too many parameters, because of the difficulty in interpreting the results. It was agreed at an early stage of the project that rural locations, Toucan crossings and dual carriageways would be excluded from the study and that the focus would be on pedestrians rather than cyclists, motorcyclists or equestrians.

The case studies were selected as having as wide a range of relevant characteristics as possible. Mid-block crossings as well as junctions were included for a number of reasons. In particular, they offer a simpler environment to investigate the problems under study, which was expected to give a greater potential for understanding the issues and developing transferable solutions.

It was important to include sites with different levels of traffic flow/congestion because of the issue of trade-off between safety and capacity. For example, the safety improvements that are likely to be achievable at high levels of congestion, without affecting traffic throughput unacceptably, are likely to be smaller than those at lower levels of congestion. This issue was covered by videoing each site during both a peak and an off-peak period.

Sites with a range of cycle times and complexity were included. Pedestrians are likely to become frustrated where there are long cycle times e.g. within a UTC system, or at complex junctions where the crossing involves several 'hops', with associated separate waiting periods for the pedestrian.

Selection criteria were:

- Locations to include 3- and 4-arm junctions and mid-block
- Moderate to high pedestrian flow, range of vehicle flows
- At least one example of each signal control system (TRANSYT, SCOOT, MOVA, VA)
- Different types of pedestrian provision (e.g. all-red phase, whether crossing is staggered)
- A range of junction geometry (3 or 4-arm, size and complexity)
- All sites to be on single carriageway roads, with speed limit not greater than 40mph

In order to ensure the results are generally applicable, the following additional criteria were applied:

- Not all sites with a particular form of signal control to be in one Local Highway Authority
- Sites to have a good geographical spread

2.6 Data collection

A detailed data collection exercise was undertaken at each site, including accident data, vehicle and pedestrian counts, geometric, signal and behavioural data.

2.6.1 Accident data

Accident data for the selected sites were obtained from STATS19 and casualty patterns analysed in detail.

2.6.2 Flow counts

In the event, none of the Local Highway Authorities were able to provide counts of either vehicles or pedestrians. Consequently, four hour counts in 15 minute periods were taken from the video surveys at each of the selected sites. The counts of vehicles and pedestrians were undertaken for each arm at each site, within 20m of the crossing. The vehicle counts were classified and coded separately by turning movement and the pedestrian counts by direction.

The possibility of using software to automatically count vehicle and pedestrian movements was considered. It would be relatively straightforward, at least in principle, to count vehicles which move into an area defined on screen. However, pedestrians are much more difficult to track since they are infinitely flexible in terms of route choice and can easily change direction when partway across the road; in addition pedestrians may be too close together to distinguish as individuals. Thus both vehicle and pedestrian counts were undertaken manually.

2.6.3 Geometric and signal data

For each site, the following was established:

- Geometric layout from plan
 - Number of arms
 - Number of lanes on approach and at stop line
 - Lane usage and movements
- Signal configuration from Local Highway Authorities or by direct observation

Strategy(s) in use
Cycle time
Pedestrian facilities
Phasing and staging

In addition, the number of signal cycles for each 30 minutes of the observation period was counted, along with the start and end of each red and green period for vehicles.

2.6.4 Pedestrian behaviour

Pedestrian crossing behaviour at signal-controlled crossings was observed using video cameras (positioned discretely at the roadside). Both a peak and an off-peak period were included, with a total of 4 hours of video recording at each site. The inclusion of a peak period was important as the balance of traffic and consequently signal control strategies vary by time of day.

Initial video material captured by the cameras was used to develop a coding framework i.e. to categorise the various types of crossing behaviour that are carried out by pedestrians.

The following observations were made for a sample of 100 pedestrians on each junction arm or mid-block crossing for a sample of pedestrians at the crossing or junction arm, or within approximately 20m of the stop line:

- Crossing location e.g. between studs if present, outside of studs/stop line, diagonally across junction etc
- Proportion that are under 16, over 60, accompanied/unaccompanied child, encumbered by shopping, using a walking stick etc
- Size of group (defined as those crossing/starting to cross at the same time)
- Pedestrian delay
- Head movements before / during crossing
- Crossing time
- Whether pedestrians run or walk
- Signal aspect when start to cross
- Signal aspect when crossing complete

In addition, examples of risky behaviour or behaviour in violation of traffic law or the Highway Code e.g. vehicle movements during red or amber, pedestrians who step into the road and turn back, pedestrians jumping over guard rails, running across the road, cyclist veering onto the pavement, riding across the crossing as a pedestrian, jumping a red light etc were recorded. Further details are given in Section 6.

2.6.5 Conflict analysis

The possibility of using conflict studies to assess the sites was considered. A traffic 'conflict' is generally defined as 'an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged'. The approach is appropriate for considering site-specific accident risk. However, even though they will be much more frequent than accidents, there are likely to be few near-misses at most sites. Given the number of sites and the detailed observations at each site, it was not possible to analyse more than a short period. The four hour periods observed were not long enough to provide sufficient examples for a conflict study. An alternative approach would have been to undertake video recordings over a much longer period of several days, and to severely restrict the range of data collected. However, this might have limited the types of risky behaviour observed. It was also recognised that conflict analysis involving pedestrians is considerably more complicated than that involving vehicles only. For these reasons, conflict analysis was not used in this study.

2.7 Test potential strategies

The literature review and observations of case studies led to several ideas for possible ways of increasing pedestrian compliance. Four different ideas were tested, one at a case study site where there was significant potential for improving compliance and where the Local Highway Authority was willing to co-operate, and the others at two new sites. An after video survey was undertaken at all three sites, and before video survey at the two additional sites.

A thorough evaluation of the 'after' situations at the three sites was undertaken in the same manner as the case studies. Video records were collected and analysed as described in Section 6, for comparison with the 'before' data.

It was not possible during the timescale of the project to evaluate changes in accident rates and therefore an assessment was made of changes in behaviour following the change in strategy that would indicate lower risk, for example, fewer people crossing during a red-man period.

2.8 Use of TRANSYT

TRANSYT was used to undertake limited sensitivity testing of the relationship between capacity and pedestrian delay at two sites, the second of which was a case study site. This approach enabled an examination of the expected level of change in capacity for suitable changes in signal strategies that may influence safety at different levels of congestion. This was a cost-effective way of estimating the likely impact on capacity, for a range of conditions. Details are given in Section 7.

3. Literature review

3.1 Safety aspects of signal strategies

3.1.1 TRL generalised linear modelling

Two major studies on accidents by TRL used generalised linear modelling to develop accident-flow-geometry relationships at 3-arm (Taylor *et al*, 1996) and 4-arm (Hall, 1986) signal-controlled junctions. The analysis involved developing relationships between separate accident groups (for example, 'right turn from major', 'pedestrian with exiting vehicle') and the flow, geometry and signal control features that influence them.

The main findings on pedestrian accidents relating to signal strategies or provision of safety measures for pedestrians were as follows.

In both studies, even when pedestrian and vehicle flows were taken into account:

- The presence of pedestrian crossing facilities (red/green man signals) at the junction was associated with increased pedestrian accidents
- There was evidence that the more complex signalling arrangements were associated with increased pedestrian accidents; in particular, the situation where there was a pedestrian stage at the junction but not a red/green-man signal on every arm

In the study of 4-arm signals, again with pedestrian and vehicle flows taken into account

- Higher vehicle inflow per second of green per lane was associated with reduced pedestrian accidents rate
- More stages at the junction were associated with fewer pedestrian accidents with vehicles turning left or right on exit
- Signals in UTC systems were associated with increased pedestrian accidents with vehicles exiting straight ahead

In the study of 3-arm signals, with pedestrian and vehicle flows taken into account:

- Pedestrian accidents on the major road other than those with entering or exiting vehicles were reduced with increasing maximum number of cycles per hour (equivalent to a shorter cycle time)
- There were more pedestrian accidents with entering vehicles on the major left (with the site viewed as a T) at sites with early cut-off, late release or separate arrow heads
- Pedestrian accidents with entering vehicles on the major right were greater at sites with more entry lanes
- There was no evidence that the provision of guard railing reduced pedestrian accidents

3.1.2 TRL study of pedestrians at signal-controlled junctions

The study by TRL on behalf of DfT (Wall, 2000) involved literature reviews including data collected in the studies summarised in Section 3.1.1, an investigation of UK fatal and serious pedestrian accidents at traffic signals and a before-and-after video investigation of various sites.

Police records were traced relating to 31 fatal and 68 serious accidents which occurred between 1986 and 1995. The main accident causes were as follows:

- Lack of compliance with the signals by the pedestrian
- Crossing close to the facility but not on it
- Failure to look before / during crossing / running across the road
- Crossing through stationary traffic
- Vehicle manoeuvres

Few accidents involved speeding cars or cars jumping the red. About half the accidents did not appear to be associated with any aspect of signal strategy.

The review suggested that, based on a small number of sites in London, adding a full pedestrian phase reduced accidents, but implementing a parallel pedestrian phase did not. The characteristics of junctions with high numbers of pedestrian accidents were identified as concealed or misleading vehicle movements and unsaturated flow. These characteristics were considered to arise where there is:

- Asynchronous signalling (i.e. turning and straight ahead movements operate independently for all or part of the signal stage)
- Situations where right turning movements must give way to oncoming traffic
- Vehicles queueing over a pedestrian crossing

The two main factors affecting pedestrian compliance that relate to signal strategy were:

- Long waiting times
- Confusing signals

3.2 Behaviour of pedestrians at signalised crossings

3.2.1 Introduction

This section of the report deals with pedestrian behaviour at signalised crossings. Reasons for compliance or non-compliance with pedestrian signals and the demographic characteristics of people who comply with signals are covered along with other types of crossing behaviour. Unpublished results from the DfT study in 3.1.2 noted that both motorist and pedestrian attitudes and behaviour are important factors in the poor UK pedestrian accident record, with pedestrians in the UK more likely to ignore traffic signs and signals (such as the red man at signalised crossings) than those in continental Europe.

Most research studies investigating the crossing behaviour of pedestrians have focused on behaviour at mid-block crossings (e.g. Pelicans and Puffins) with only a limited number on behaviour at signal-controlled junctions. Researchers have used either video observation techniques or self-report data obtained via surveys and qualitative interviews or focus groups. These different research techniques have produced similar findings with respect to pedestrian road crossing behaviour. The findings of these studies are summarised below.

3.2.2 Crossing speed of pedestrians

The time taken to cross the road depends on the road width and on walking speed. In the UK, the pedestrian clearance period is based on a 15th percentile walking speed of 1.2m/s (i.e. the speed exceeded by 85% of pedestrians crossing the road), considered to be a good compromise between operational efficiency and safety. This equates to 6 seconds to cross a 7.3m road. Extra time, or a central refuge and a separate stage, will be required on wider roads. 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. Older people 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-controlled junctions than at mid-block crossings (Bennett *et al*, 2001), and that older pedestrians in particular cross more slowly at Puffins than at Pelicans (Reading *et al*, 1995).

Local Highway Authorities should therefore take into account local factors, such as a large elderly population, presence of a school or community centre or shops when determining signal timings. This may become more important in the future in view of demographic changes leading to an increase in the proportion of older people in the general population.

3.2.3 Non-compliance with pedestrian signals

A potentially useful categorisation of pedestrian crossing behaviour at signalised crossings was provided by Reading, Dickinson and Barker (1995). In their study, pedestrians were classified as one of the following:

1. **Compliant pedestrians:** who start to cross the road during pedestrian green-man
2. **Anticipatory pedestrians:** who start to cross in anticipation of the green man when they see the leaving amber (to traffic) signal (strictly speaking these are non-compliant pedestrians given that they leave the kerbside before the green to pedestrian signal)
3. **Non-compliant pedestrians:** who cross during the red man, before the leaving amber-to-traffic signal commences

Reading *et al* undertook a before-and-after study at a site in Edinburgh where a Pelican crossing was converted to a Puffin crossing. They found that between 17% and 49% of pedestrians using it as a Pelican were non-compliant or anticipatory crossers compared with 39% when it was a Puffin crossing. These non-compliance levels were lower than at the UK sites studied as part of the DfT study (see Section 3.1.2). At a site in Wokingham (in Berkshire) with a cycle time of 120 seconds in the am peak, the percentage of pedestrians observed to cross during the red man ranged from 42% to 92% and an additional 16% to 46% of people crossed just before the green man was displayed (i.e. anticipators) - the staging arrangement at the Wokingham site encourages this behaviour). At a site in Camberley (in Surrey) only 7% to 42% of pedestrians crossed while the green man was showing. Generally, non-compliance rates are likely to be higher where there are suitable gaps in the traffic flow for pedestrians to cross and the waiting time is long, if there is a central refuge, or if the road is narrow.

Overseas non-compliance rates are generally much lower than in the UK. For example, Tracz and Tarko (1993) reported a mean value of 17% for pedestrian non-compliance in Poland, and Barker, Wong and Yue (1991) a mean value of 19% for pedestrians violating the continuous Don't Walk display in Australia. This difference may be cultural in part but is more likely to be due to differences in the law and its level of enforcement or the definition of non-compliance. Because of this, it is difficult to compare overseas strategies with those in the UK.

A number of factors found to influence pedestrian compliance with signals are described below – age and sex, impairment (in its broadest sense), waiting times, traffic volume and speed, weather, social psychological variables such as attitudes and perceived risk) and familiarity with the crossing.

3.2.4 Age and sex

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 (Section 3.2.2) 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. Andrew, 1991; Yagil, 2000; Daff *et al*, 1991). These age and sex differences mirror those found across a number of behavioural domains, including car driving, where males and younger people are known to behave in a more unsafe way than are females and older people. Reasons for age and sex differences are likely to reflect differences in a number of psychological variables, including level of perceived risk, propensity to obey traffic rules and attitudes to safety (discussed below).

The health and age of the pedestrian can affect the outcome of an accident. In the DfT project (see Section 3.1.2) in a study of 31 fatalities, only four were under 65 and/or in good health, whereas the proportion of older people was similar to the proportion of younger people for serious accidents. Older people were less likely to look before and/or during crossing and were also at greater risk of fatality because of existing poor health and greater frailty.

When considering age groups of pedestrians, it is important to take account of children and adolescents. TRL research has shown that a reasonably large proportion of adolescents (aged 11-16 years) report 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.

3.2.5 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.

Alcohol and drug use may influence ‘inappropriate’ pedestrian behaviour at signal-controlled crossings. Alcohol impairment of either driver/rider or pedestrian is recognised as a contributory factor to accidents (Broughton *et al*, 1998) and it is known that a high proportion of pedestrian casualties are recorded as having been drinking. For example, the DfT study (Section 3.1.2) found that the pedestrian had been drinking in 10 of the 35 serious pedestrian accidents at signal-controlled junctions studied (in which the pedestrian was in the 16 to 65 age group. Heraty (1986) reported several studies in which almost one-third of adult pedestrian fatalities had been drinking. The DfT study in Section 3.1.2 reported a finding that 27% of injured pedestrians admitted to hospital after a road accident had blood alcohol levels above the legal limit for drivers. Similarly, Broughton and Buckle (2008) found that ‘pedestrian impaired by alcohol’ was a contributory factor in 29% of pedestrian fatalities occurring between 6pm and 6am at weekends.

Pedestrians with a mobility impairment 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.

Age may be regarded as a form of impairment in that reduced mobility and a number of other health issues are associated with ageing. As mentioned above, older pedestrians are more likely to comply with signals than are younger people.

Daff *et al* (1991) found that those pedestrians carrying a bag (e.g. shopping) were more likely to use crossings. However, Daff and colleagues did not report any effect of carrying a bag on

compliance with pedestrian traffic signals or on any other type of behaviour at signalised junctions. They did, however, speculate that carrying a bag may be related to the speed at which pedestrians perceive they are able to cross a road. One could speculate further that this perceived impairment may increase compliance with pedestrian traffic signals and other 'safe' rules/procedures that should be followed when crossing a road. A similar effect would arise from carrying anything heavy or cumbersome which impairs movement.

It is likely that many pedestrians with a physical or sensory impairment comply with 'safe' crossing procedures because they are aware of their impairment and as a result take more care when crossing roads.

3.2.6 Waiting times

A literature review by Baass (1989) showed that the longer pedestrians have to wait at a crossing, the more likely it is that they will cross while the red man is showing. This is supported by TRL research (Wall, 2000) which suggests that pedestrians are normally prepared to wait up to 30 seconds for the green man – those waiting over 40 seconds are increasingly tempted to cross during the red man (and are more likely to have an opportunity to do so). Baass also found that pedestrians will always try to minimise the distance they have to walk and reduce waiting times, often without adhering to the Highway Code and disregarding the risks involved; being in a hurry or the desire to keep moving are key motivators behind people disobeying pedestrian signals.

Waiting times are related to cycle times at signal-controlled junctions and mid-block crossings in a UTC system and can therefore be directly influenced by signal strategies.

3.2.7 Traffic volume and speed

Traffic volume is one of the most important variables associated with whether people wait for the green man at signal-controlled crossings (e.g. Daff *et al*, 1991; Yagil, 2000, Barker *et al*, 1991). The higher the volume of traffic, the more likely people are to wait, probably because of the reduced number of gaps; in other words, people have less opportunity to cross during the red man. Speed of traffic is also likely to be a factor in pedestrian crossing decisions at signal-controlled crossings. People are more likely to wait for the green man due to the perceived risk of fast moving traffic.

Research has shown that some people are willing to accept gaps as short as 2 to 3 seconds, whereas others will reject gaps of 6 seconds or over. Those accepting short gaps may have a greater propensity to take risks, may be in a hurry or may have poor perceptual skills for judging safe gaps in traffic. They are more likely to be young and male. Generally older pedestrians, pedestrians with disabilities or pedestrians carrying baggage (e.g. shopping) will take longer to cross the road and are therefore less likely to accept gaps in traffic.

3.2.8 Weather/lighting conditions

'Physical' factors other than traffic volume and speed can influence pedestrians' crossing behaviour (Andrew, 1991). If people are aware that they are less visible, poor lighting conditions or bad weather may result in greater adherence to safe rules and practices of crossing a road (e.g. waiting for the green man or generally taking more care when crossing). Ideally, lighting needs to make pedestrians more conspicuous in addition to helping them find their way. However, bright lighting on a crossing may increase the danger of crossing close to the crossing but beyond the bright lighting.

Alternatively, it could be conjectured that bad weather may make 'unsafe' crossing more likely. For example, the desire to get out of the rain as quickly as possible may influence people to take more risks when crossing a road, so they can get to their destination or seek shelter faster. The use of an umbrella may make it difficult for pedestrians to see approaching vehicles.

3.2.9 Social psychological variables

Social cognitive variables such as attitudes and perceived risk are known to be related to a number of social behaviours and they have the ability to explain behavioural differences between different demographic sub-groups. In the present context, social cognitive variables have the ability to explain, at least in part, differences between the crossing behaviour of different age and gender groups, for example, at signalised crossings.

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 an accident
- 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 TRL research by Elliott and Baughan (2003) into adolescent road user behaviour that young people can verbally encourage one another to engage in 'unsafe' activities such as unsafe road crossing.

The mere presence of other people at a signal-controlled crossing can also 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 other pedestrians was important in determining crossing behaviour because they stimulate conformity. In addition, Andrew (1991) found that the fewer pedestrians there were crossing at a junction, the greater the tendency for all age groups to check for traffic before crossing.

3.2.10 Familiarity with crossing

Familiarity with a particular signal-controlled crossing or junction may influence behaviour. For example on a regular journey, people will often know the sequence of traffic signals and how long they will have to wait. They may also know how much time they need to cross and whether people usually cross during the red man. This familiarity is likely to have a powerful effect on behaviour, but does not appear to have been the subject of research.

A change in the type of control may lead to more cautious behaviour by pedestrians. For example, in a study at one site, Reading *et al* (1995) found that non-compliance with the pedestrian signals was reduced when a Pelican was converted to a Puffin (when controlling for cycle times and vehicular traffic). The researchers speculated that this reduction in non-compliance may reflect lower pedestrian risk-taking at the Puffin crossing (due to the fact that pedestrians are given priority over traffic at this type of crossing). However, they also suggested that the results could be explained by the greater attentiveness of pedestrians at an unfamiliar type of crossing.

Pedestrian compliance at Puffins may improve further as other types of crossings are phased out and also due to the increased publicity and improved detector reliability. To this end, the Department for Transport has developed a Toolkit to assist Local Highway Authorities, including a leaflet, posters, the Puffin Good Practice Guide and two DVDs, one for adults and one for children aged 9 to 10 (DfT, 2006).

3.2.11 Crossing outside the studs

In addition to failing to comply with the signals, pedestrians often cross outside the studs bounding the crossing area 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, accident 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 exclusive pedestrian phase (all-red to 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. Adolescents and young adults may be more likely to cross in this way. However, no research was found on this topic.

In the US, junctions with ‘scramble’ timing (i.e. an exclusive pedestrian phase) sometimes have explicit signs showing that diagonal crossing is permissible (Lalani, 2001).

3.3 Interventions or strategies to improve pedestrian compliance

3.3.1 Reduction of waiting time for pedestrians

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 will have a negative impact on safety. Although this assumption sounds logical, the studies traced mostly considered compliance rather than accidents. Longer waiting times were associated with larger numbers of pedestrians crossing on red in a number of studies, but no direct evidence has been found that this actually resulted in larger numbers of accidents involving pedestrians. In a limited study based on accidents and flow counts at 12 Pelican crossings in Manchester, Preston (1989) showed that for males the risk of crossing was lowest when the green man was showing. For females, the risk was similar whether or not the green man was showing.

Hunt, Lyons and Parker (2000) postulated 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 pointed 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.

In a study of different types of crossings in Edinburgh, Japs (2000) concluded that at mid-block signal-controlled crossings, reducing the green time for vehicles can significantly reduce pedestrian delay. At signal-controlled 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. However, this strategy 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 the risk of pedestrian accidents (Taylor *et al*, 1996). On the other hand, Hunt (1995) concluded from STATS19 data that signal-controlled junctions are safer for pedestrians than mid-block Pelican crossings.

Various authors (Reading *et al*, 1995; Keegan and O’Mahony, 2003; and Catchpole, 2003) found that shorter signal cycle times resulted in better compliance by pedestrians. Possible reasons for poorer compliance with longer cycle times include pedestrians becoming frustrated if they have to wait a long time and an increase in the probability of acceptable gaps emerging in traffic for pedestrians to cross. Keegan and O’Mahony (2003) found a statistically significant reduction in non-compliance when comparing shorter cycle times with longer ones at the same junction. By contrast, some authors found no relationship between non-compliance and cycle time (e.g. Barker *et al*, 1991 in Australia; and Garder, 1989, in Sweden). It is likely that shorter cycle times correspond to off-peak periods and longer cycle times to peak periods, and this may give rise to differences in both driver and pedestrian behaviour. When traffic volumes are low, many pedestrians will not bother to wait for the green man.

3.3.2 Signals with pedestrian detectors

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. 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. As a further refinement, pre-detection of pedestrians approaching the crossing can be used to change the signal (Rottengatter and Sherbourne, 1994).

There are and have been several technology 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 can occur (either as a result of faulty equipment or the pedestrian moving off the crossing), 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).

Puffin crossings utilise both kerbside and on-crossing detectors and are now common in the UK. The Department for Transport is continuing to facilitate, through various research projects, improvements to current / emerging detection systems to improve performance and reliability. To date, the results have been encouraging. Further development in the Puffin control strategy has resulted in a control algorithm which ensures that a pedestrian is not missed in the wait area or whilst crossing, even if the detectors go faulty or intermittent.

Reading *et al* (1995) found that the mean time taken for pedestrians to cross the road at a Puffin was slightly longer than at a Pelican, particularly for older people (see Section 3.2.2), 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 signal-controlled 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 at sites 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 numbers 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.

Crabtree (1997) compared 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 sites with the Puffin pedestrian-volume-sensitive MOVA used a shorter cycle time (and could therefore be considered to be 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 pedestrians crossing during the red man was generally reduced.

More recently, Henderson et al (2005) compared MOVA, Compact MOVA and VA at a number of sites, including a busy Puffin in Bracknell. Although pedestrian delay was not measured directly, various proxies indicated that pedestrian delay was very substantially reduced by both versions of MOVA and particularly so with Compact MOVA. This was in comparison with standard VA; pre-timed maximum VA is becoming more widely used and this will give pedestrians better service than standard VA. However, the authors concluded that at a site with heavy pedestrian demand, Compact MOVA (and probably Standard MOVA) will still maintain significant advantage if the pre-timed VA maximum is set at the normal 18 to 20 seconds. Simulation showed pedestrian delay at a Puffin crossing reduced by between 23 and 30% depending on the assessment period, with small reductions in vehicle delay compared to VA. While the Puffin on-street trial indicated pedestrian delay reductions of the order of 21 to 46% with small increases in vehicle delay compared to VA, at the simulated junctions, vehicle delay was reduced by between 0 and 10% depending on the junction and assessment period.

A before-and-after study by Reading *et al* (1995) compared the performance of a Pelican crossing converted to 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, probably because linking of the signals was relatively unimportant at the sites in question.

3.3.3 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 accidents. This was the only study found

that directly relates signal strategies to numbers of pedestrian accidents. 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. Abrams and Smith found that early and late release of pedestrians with respect to the turning traffic increased pedestrian and vehicle delay and early release had little effect on safety. Again in the US, Tian *et al* (2001) investigated various alternatives to determine when exclusive pedestrian phasing can improve operational efficiency.

By contrast, when considering the percentage of fatal accidents that involve pedestrians at junctions on major urban roads with and without signals, the DfT study (Section 3.1.2) 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.

An American study by Houten *et al* (1999) evaluated the effects of alternative signal heads on conflicts between pedestrians and turning traffic. In situations where the green phase for pedestrians conflicted 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 this type of signal.

3.3.4 Clearance period

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. The safety benefit for pedestrians from Puffin crossings was considered likely to be greater than that of an overlap period, because clearance periods are more flexible and can if necessary offer extensions that are longer than 2 seconds.

It should be noted that this study was undertaken in 1997 and Puffin crossings are now routinely installed, particularly as they are considered to offer other distinct advantages over Pelican crossings. There is no flashing sequence and therefore a straight across Puffin can be installed even on a wider road where a staggered arrangement would be warranted, resulting in reduced delay for pedestrians.

3.3.5 Countdown devices

Countdown devices have been installed and/or trialled in many countries including Singapore (Figure 1), France, Ireland, the Netherlands (Figure 2) and the USA. The idea of a countdown device is to improve pedestrian compliance at signal-controlled crossings by indicating either the amount of time left in the pedestrian clearance period, or the length of time before the next green man. Neither type provides assistance to people with a visual impairment.



Figure 1: Example of a countdown timer in Singapore

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

Countdown to start of pedestrian green

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 increasing compliance. 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 of this type are installed at crossings 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%. To date, they have been tested at only one location in the UK (in Glasgow) and no results are as yet available.

Countdown timers have been found to be an effective way of providing positive reinforcement to non-motorised traffic in the Netherlands, indicating 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. The yellow lights surrounding the push button darken sequentially (i.e. "count down") to let the pedestrians know their wait is ending (Figure 2). This type of timer reduces the responsiveness of signals to pedestrian demand and to gaps in the traffic flow.



Figure 2: Example of a countdown timer in the Netherlands

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

Countdown of time to end of pedestrian clearance period

In the US, installations generally count down the amount of time remaining to safely cross the junction, starting at the beginning of either the pedestrian phase or more commonly the beginning of the clearance period (e.g. Lalani, 2001, Markowitz *et al*, 2006, Reddy *et al*, 2008). Various authors (e.g. Allsbrook, 1999 and Markovitz *et al*, 2006) reported positive feedback from pedestrians using such a device. They are particularly useful where multiple lanes have to be crossed, a common occurrence in US cities. They also assist pedestrians who require extra time to cross the road, for example due to a disability, and increase perceived safety for pedestrians. One possible disadvantage is that pedestrians may use the information to start to cross during the clearance period, believing that they can complete their crossing during the time indicated.

3.3.6 Pedestrian priority at signal-controlled crossings

This measure is designed to reverse conventional traffic priorities by making the signals revert to pedestrian green in the absence of any demand and by registering vehicle demand only once they have reached the stop line. 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 reducing injury accidents by 36% over the 3 years which includes a 67% drop in child collisions, but took no account of regression to the mean effects that can result at sites with a high accident rate before treatment (Hauer, 1997). 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.

3.3.7 Guard railing

In a ‘before and after’ study in London (Simmonds, 1983), there was a reduction in accidents when guard rails were installed. This may have been in part an artefact arising from selection bias, as the sites where guard rails were installed were selected on the basis of their high accident record rather than at random. These sites can be expected to have lower accident rates even without an intervention due to regression to the mean.

On the basis of this study, guard railing was introduced at many crossings / junctions. However, there was no evidence from the accident research outlined in Section 3.1.1 that the provision of guard railing reduced pedestrian accident rates. Recent research for DfT and Transport for London was directed at deriving criteria for the use of guard railing rather than its effect on safety; the results appear to have been inconclusive (Zheng and Hall, 2003; DfT, 2009).

3.3.8 Other features

The DfT study mentioned in Section 3.1.2 (Wall, 2000) noted that the presence of dropped kerbs and the provision of tactile paving make the presence of a crossing more obvious. The authors recommended moving the stop line further back from the crossing in order to allow drivers of large vehicles a clearer view of pedestrians.

Other recommendations from this study are:

- Anti-skid surfacing
- Median strips on high speed roads
- Elimination of parking near pedestrian facilities
- Red light cameras
- Removal of blackout period between showing of green man and red man (the use of nearside signals at Puffin-style crossings avoids the need for this)
- Puffin-style crossings with kerbside and on-crossing detectors and pedestrian signal shown at the nearside
- Audible signal for pedestrians (already used wherever possible)

3.4 Summary of review

The main findings from the literature review are as follows:

- Most of the research relating to pedestrian behaviour is for mid-block crossings and does not consider the effect of signal strategies.
- Pedestrians crossing the road act according to their own convenience. If a gap in the traffic presents itself, they will cross.
- Pedestrians are at increased risk where there are more complex staging arrangements.
- Risk to non-compliant pedestrians is increased if the pedestrian phase ends just as a platoon of vehicles is approaching, which is likely to be the case in a UTC system.
- Pedestrians are more likely to comply with a signal if:
 - They are older
 - They are female
 - Their mobility is impaired by a physical disability or because they are carrying something heavy or accompanying a young child or pushing a pram etc
 - The traffic is heavy
 - Other pedestrians are waiting

They have been waiting less than 30 seconds

- There is greater scope for reducing delay to pedestrians at mid-block crossings than at signal-controlled junctions where at least two separate stages are required for traffic, meaning that longer cycle times are required. ‘Walk with traffic’ operation can be used in some cases to reduce delay (mainly to vehicles), but tends to lead to pedestrians having to cross the road in several ‘hops’ and has the potential to increase risk.
- The time taken to cross the road depends on the road width and on walking speed. In the UK, the clearance period is based on a 15th percentile walking speed of 1.2m/s (i.e. the speed exceeded by 85% of pedestrians crossing the road), considered to be a good compromise between operational efficiency and safety. This speed equates to 6 seconds to cross a 7.3m road. 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-man period. On-crossing pedestrian detection is one method of alleviating this problem but the regular clearance period should be extended if necessary to take account of relevant factors such as a large elderly population in the local area,
-
- Decoupling mid-block crossings from SCOOT control in off-peak periods was found in one study to improve pedestrian compliance with no significant increase in delay to vehicles. However, this result is likely to depend on the extent to which linking of the adjacent signals is important at the site in question.

4. Focus groups

4.1 Aims

Focus group research was conducted to explore:

- The kinds of pedestrian and cyclist behaviour that are considered to be safe and unsafe at signal-controlled junctions and crossings,
- The factors that influence safe and unsafe behaviour, and
- Opinions about two signal strategies (countdown devices and an all-red phase to traffic) and how signal-controlled crossings can be made safer.

4.2 Method

Four focus groups were conducted, two with adults and two with adolescents aged 14-15 years old. In each focus group with adults, there were eight participants (four male and four female). These participants were sampled from a database held by TRL, which includes over 1,000 drivers residing in the South East of England. Although the database comprises drivers, all drivers are pedestrians at least some of the time and therefore the people on the TRL database were deemed to be suitable participants for the present research. In addition, the TRL database was sampled to ensure that some of the participants were cyclists. Adolescents who participated in the focus groups were sampled from a local school. One of the focus groups with adolescents consisted of six females and the other of eight males.

In each focus group, the session was divided into four parts.

4.2.1 Part 1 - Introduction

A general introduction to the project was given. Participants were told the purpose of the project was to find out how people (pedestrians and cyclists) behave at signal-controlled junctions and mid-block crossings and why, and that it is part of a government research project designed to explore signal control strategies and behaviour at signal-controlled junctions in order to improve road safety. Participants were told what the focus group would involve and that their comments

would be treated confidentially. They were also given a brief description of the different types of crossing.

4.2.2 Part 2 – Video clips of risky behaviour

Participants were shown 18 video clips of various examples of potentially unsafe behaviour at signal-controlled junctions and crossings. The video clips were selected from the observation footage taken from the case studies. Participants were asked to rate how safe or risky they thought each behaviour was, and how often they perform that sort of behaviour themselves. The 18 examples of potentially unsafe behaviour that were shown to participants were as follows:

- Pedestrian diverts off the crossing to take short cut avoiding guard rail
- Pedestrian stands in road waiting for turning traffic
- Cyclist rides across crossing (not dismounting)
- Pedestrian walks across road into path of turning car
- Pedestrian crosses on red in small gap in traffic
- Pedestrians divert off crossing and walk along off-side of guard rail
- Pedestrian does not use crossing and walks along central reserve
- Pedestrian does not use crossing and walks between moving traffic
- Pedestrian crosses without looking and is nearly hit by turning car
- Pedestrians wait in middle of road while crossing at busy junction
- Older woman crosses slowly at junction and is nearly hit by turning car
- Skateboarder rides across crossing at signal-controlled junction
- Man not paying attention while crossing at signal-controlled junction is nearly hit by turning car
- Pedestrians wait in middle of road while crossing at signal-controlled cross roads
- Pedestrians cross away from mid-block crossing and in between parked cars
- Adolescents cross on red man at junction with staggered crossing and in between slow moving vehicles
- Man with child in arms crosses in front of bus
- Cyclist riding on road goes through red light

4.2.3 Part 3 – Examples of safe and unsafe behaviour

Participants were asked to mention examples of safe and unsafe pedestrian and cyclist behaviour at signal-controlled junctions and mid-block crossings. They were then asked to discuss the kinds of people who carry out those behaviours, the reasons for doing those behaviours and the circumstances in which they are carried out.

4.2.4 Part 4 – Discussion

Participants were asked to discuss the advantages and disadvantages of the following signal strategies at crossings:

- All-red phase to traffic on all arms of a junction (i.e. pedestrians who wish to cross more than one arm can cross diagonally).
- Countdown devices that provide information on remaining waiting time before green man comes on (or on remaining time to cross).

- Participants were also asked to discuss how signal-controlled crossings can be made safer and what other ways there are to promote safer behaviour at these sites.

4.3 Sample characteristics

As described above, each of the adult focus groups consisted of eight participants, meaning that 16 adult participants were included in the focus groups in total (8 male; 8 female). Table 1 summarises the age distribution of respondents in the focus groups. The mean age was 42 years old (range 18 to 76).

Table 1: Age distribution of respondents in the adult focus groups

Age Band	No. of Participants
18-20 years old	5
21-50 years old	5
60 years old and over	6

Ten of the participants were cyclists, 6 of whom reported riding a bicycle at least once a month. The rest rode a bicycle once a year or less often. All but one participant reported going out as a pedestrian at least once a week (the one exception reported going out as a pedestrian on a monthly basis).

Altogether, 14 participants were included in the focus groups with adolescents aged 14-15 years old. One group consisted of 6 females and the other of 8 males. All adolescents reported that they go out as a pedestrian on a daily basis. All adolescents were cyclists (5 rode less often than once a year, 1 reported riding once a year, and 5 reported riding on a monthly basis, 2 on a weekly basis and 1 on a daily basis).

4.4 Ratings of video clips

The following results are based on a small sample of people, which is appropriate for qualitative research, but less so for conducting quantitative analysis. Therefore the results presented in this section should be treated as indicative only.

Table 2 shows participants' mean ratings of each behaviour shown in the video clips (for adults and adolescents separately). Mean ratings of how safe or risky each behaviour was rated are shown (a higher mean score indicates that the behaviour was rated as being more risky) as are the mean ratings for how often participants reported carrying out the behaviours themselves (a higher mean score indicates a greater reported frequency of performing the behaviour). It can be seen that adolescents generally rated the behaviours as less risky than did the adults and that they generally reported carrying out those behaviours more often.

The behaviours that participants reported performing most frequently (relative to the other behaviours) were:

- Pedestrians cross away from mid-block crossing and in between parked cars
- Pedestrians wait in middle of road while crossing at a busy junction
- Pedestrians cross on red in small gap in traffic
- Pedestrians do not use crossing and walk between moving traffic

In addition, adolescents reported cycling across crossings without dismounting as another behaviour that they performed more frequently than the others.

For adults and adolescents, respectively, these behaviours were rated as being among the least risky to perform, suggesting that the more risky the behaviours were rated, the less often they tended to be reported. This general trend can also be seen to an extent in Table 2 which shows data categorised into whether the respondent felt the behaviour was "risky", "neither risky nor safe" or "safe", and cross tabulated by how often respondents reported carrying out those

behaviours (“very often or often”, “occasionally or rarely”, or “never”). However, while more risky behaviours tended to be reported as less often carried out, a number of responses appeared to show that adolescents were more likely to report actually doing behaviour that they rated as being risky than were adults.

Table 2: Participants' mean ratings of behaviour for adults and adolescents

	Description of video clip	Adult Rating (N=16)		Adolescent Rating (N=14)	
		How safe/risky is the behaviour? ^a	How often do you do this behaviour yourself? ^b	How safe/risky is the behaviour? ^a	How often do you do this behaviour yourself? ^b
1	Pedestrian diverts off the crossing to take short cut avoiding guard rail	3.93	2.33	3.07	3.00
2	Pedestrian stands in road waiting for turning traffic	4.33	1.87	4.07	2.07
3	Cyclist rides across crossing (not dismounting)	3.40 (3.10) ^c	1.87 (2.30) ^c	2.14	3.07
4	Pedestrian walks across road into path of turning car	4.25	2.13	4.21	2.71
5	Pedestrian crosses on red in small gap in traffic	4.00	2.63	3.79	2.86
6	Pedestrians divert off crossing and walk along off-side of guard rail	4.50	1.81	4.43	1.86
7	Pedestrian does not use crossing and walks along central reservation	4.38	1.31	3.36	2.57
8	Pedestrian does not use pedestrian crossing and walks between moving traffic	4.19	2.50	4.29	2.93
9	Pedestrian crossed at junction without looking and is nearly hit by turning car	4.81	1.27	4.86	1.79
10	Pedestrians wait in middle of road while crossing at busy junction	4.19	2.67	3.79	2.86
11	Older woman crosses slowly at junction and is nearly hit by turning car	4.81	1.43	5.00	1.64
12	Skateboarder rides across crossing at junction	3.94	1.27	3.29	1.50
13	Man not paying attention while crossing at junction is nearly hit by turning car	4.56	1.29	4.14	2.07
14	Pedestrians waiting in middle of road while crossing at junction	3.38	2.67	3.07	3.21
15	Pedestrians cross away from mid-block crossing and in between parked cars	3.44	2.93	3.14	3.43
16	Children cross on red man at junction with staggered crossing and in between slow moving vehicles	3.94	2.33	3.79	2.57
17	Man with child in arm crosses in front of bus	4.94	1.00	5.00	1.07
18	Cyclist riding on road goes through red light	4.13 (1.70) ^c	1.44 (1.70) ^c	3.36	1.64

^a = Coded: 1 = Very Safe, 2 = Safe, 3 = Neither Safe nor Risky, 4 = Risky, 5 = Very Risky^b = Coded: 1 = Never, 2 = Rarely, 3 = Occasionally, 4 = Often, 5 = Always^c = cyclists ratings only (non-cyclists excluded) (N=11) – all adolescents in the focus groups were cyclists

4.5 Discussion of behaviour at signals

The following behaviours at signal-controlled junctions and crossings were mentioned by the participants in the adult focus groups as being unsafe:

- Not looking when crossing.
- Assuming the road is going to be clear of traffic.
- Following the crowd and not paying attention to traffic or the signals.
- Crossing with no clear view (e.g. away from crossing in between parked cars).
- Being distracted (e.g. wearing headphones, talking with others, using mobile phones).
- Not using designated crossing points.
- Jumping barriers.
- Crossing against the pedestrian signals (i.e. on flashing green man or on the red man).
- Cyclists going through red lights when riding on the road or mounting the pavement to “get around” the red light to traffic.
- Cyclists not dismounting when crossing at pedestrian signal.
- Skateboarding across the road.
- Standing in the middle of the road waiting to cross.
- Walking in the road.
- Diverting off the crossing.
- Walking diagonally across the road.

In the focus groups with adolescents, many of the same behaviours were mentioned but adolescents placed more emphasis on distraction when crossing. In addition to mentioning the distracting effects of talking with friends, listening to music and using mobile phones, male adolescents mentioned the distracting effects of playing with new acquisitions on shopping trips.

In each focus group, “safe” behaviour at signal-controlled junctions and mid-block crossings was thought to be behaviour that is consistent with the Highway Code, and the opposite of the above mentioned behaviours (e.g. paying attention to traffic, using the designated crossing points and not jumping guard rails).

It should be noted that the participants felt that while some of the above behaviours might be unsafe in some circumstances, in other circumstances they would be safe (most notably crossing against the pedestrian signals would be safe in the absence of traffic). This is discussed in more detail in the following sections.

The factors believed to influence safe and unsafe behaviour at signal-controlled junctions and crossings were as follows.

4.5.1 Demographics

The participants in the adult focus groups felt that younger and less experienced people were likely to take more risks than were older and more experienced people. In particular they felt that adolescents tend not to appreciate the dangers and have more difficulty judging risk (e.g. the conditions under which certain behaviours are acceptable). When not accompanied by an adult and when in groups, participants felt that adolescents tended to “mess around” and take risks with traffic, sometimes deliberately. In addition, participants felt that older people and non-drivers tend to make poor decisions about when to cross.

The focus group adolescents largely supported the views of the adults. The adolescents felt that young adults and teenagers are more likely to cross unsafely and are less likely to pay attention than older people.

They stated that people get more cautious as they get older but boys also stated that some elderly people may also pay little attention to the traffic. Female adolescents did not believe there to be a difference between the sexes in terms of their pedestrian and cyclist behaviour, but the male adolescents felt that males are more likely to cross unsafely than are females due to their “ego”.

4.5.2 Time of day

Both adult and adolescents participants felt that people are more likely to take risks and carry out unsafe behaviour during the day rather than at night because there are more risky situations during the day, when traffic is busy. However, adults generally felt that non-compliance with (pedestrian) traffic signals was greatest at night because people can cross the road safely without paying attention to the pedestrian signals when the roads are quiet. Adolescents felt that it was in the morning when people in general, and in particular themselves, were least likely to pay attention to the traffic because they are “less awake”. Adolescents also mentioned that, at night, people (adults and teenagers) are more likely to be “drunk” and that those people may cross unsafely.

4.5.3 Weather conditions

There were mixed views, in the adult focus groups, about the influence of weather conditions on pedestrian and cyclist behaviour at signal-controlled junctions and crossings. On the one hand, participants thought that bad weather conditions (e.g. rain, snow, ice) might promote safer behaviour because there might be poor visibility and people might fall over when crossing. On the other hand, they also felt that people might be more likely to take risks (e.g. rush across the road and not adhere to pedestrian signals) because people want to minimise their exposure to the poor weather conditions. By contrast, adolescents only mentioned that poor weather conditions (rain) would cause people to accept smaller gaps in traffic when crossing and make people less likely to use crossings, or to wait at crossings.

4.5.4 Traffic conditions and junction type

Road and traffic conditions were perhaps the most important factors in determining whether participants felt many of the behaviours mentioned above were truly unsafe. Generally, the more complex the junction, the busier the traffic conditions, and the faster the traffic is moving, the more the behaviours mentioned above were regarded as being unsafe. In particular, non-compliance with pedestrian signals (including crossing half way across the road and waiting for a gap to cross the second half), not using designated crossing points, diverting off the crossing, and walking along the side of the road were regarded as being more unsafe in busier environments. That said, participants observed that even when traffic is stationary or slow moving, people should still use the designated crossings and abide by the signals because traffic might start moving again.

Adults and adolescents both felt that some behaviours were unsafe regardless of how busy the traffic conditions were. For example, not paying attention to traffic (and all the associated behaviours such as being distracted) was considered unsafe even in quiet traffic conditions. However, not using designated crossings and disobeying the “green man” signal were thought to be safe behaviours when the road is clear or when there are large gaps in traffic.

In more complex, busier and faster traffic environments, participants felt that unsafe behaviours are less likely to be performed, because of the increased risks involved. However, participants also mentioned that many people (including themselves) do take risks. In particular, the adolescents felt that on faster roads it is more difficult to judge the amount of time there is to cross (e.g. potential difficulty judging the speed of traffic) and therefore they are more likely to use crossings and wait for the signals. They also felt that they take extra care at junctions.

Adults mentioned that, at 4 arm signal-controlled junctions without an all-red period, “dangerous” behaviour, such as “crossing diagonally across the junction” and “cutting off corners”, is often observed, and this behaviour is particularly unsafe because traffic can be approaching from many directions. Adolescents pointed out that the traffic lights take longer to change at junctions than at mid-block crossings, and that this makes people less likely to wait (see section 4.5.5 below).

Adults also felt that in very busy conditions (i.e. when there a lot of people using the crossing), crossings with a pedestrian refuge or central reserve can become very congested, which can be unsafe (e.g. people having to “spill over” into the road) and can lead to people taking risks when crossing (e.g. getting frustrated and crossing elsewhere, or not complying with the pedestrian signals).

The adult participants stated that guard rails are good because they force people to take the safe route when they are approaching or leaving a crossing. However, it was stated that there are always some people who jump over them. Adults tended to believe that if guard rails at crossings are long, it can encourage some people to jump over them or to walk in the road around them so they can get to their destination more quickly. There was a consensus among the adolescents in the focus groups that they would jump over guard railings, rather than use crossings, to get across the road quicker. Some adolescents also stated that it is quicker to get across a road by jumping over the railings that separate the opposing traffic lanes, even when they are walking past the crossing.

In the child focus groups, the differences between urban and rural areas were discussed. The adolescents felt that they are more likely to take care in busier urban environments rather than quieter rural ones. However, they also recognised the importance of being safe and using crossings in, for example, rural villages, where they felt vehicles might be travelling fast and their view might be obstructed by bends and hedges.

4.5.5 Waiting times

Adults and adolescents felt that having to wait a long time for the “green man” was the main reason for not complying with pedestrian signals. Having to wait a long time, it was believed, caused frustration and thus lower levels of compliance. Participants mentioned that people can wait a long time to cross at 4 arm signal-controlled junctions because they may have to wait at more than one arm. In particular, adolescents felt that the longer the waiting time, the more likely they would be to “take a risk” with crossing.

On average, adults felt that 20-30 seconds is an acceptable waiting time. However, an acceptable amount of time to wait was believed to be dependent on the situation. If it is a busy time of day (e.g. rush hour) or if it is a large junction, participants thought that it was acceptable to wait longer. That said, participants felt that if there was no traffic, if there were large safe gaps in the traffic, or if they were in a rush, they would tend to cross without waiting for the green man, regardless of how long there is to wait.

Adolescents felt that 10-15 seconds was an acceptable waiting time and 30 seconds maximum. Similar to the adults, they also felt that if there are gaps in the traffic then there is “no point in waiting”. Some adolescents stated that they are not prepared to wait for any amount of time and that they simply try to cross the road without waiting for the signals. Some adolescents felt that if the signals changed in their favour then this would be an advantage, but that they would not wait to cross if the signals did not change provided they felt that they could get across without being hit by a car.

4.5.6 Attitudes and skills

Being late or in a rush and being impatient were regarded by both adults and adolescents as an important determinant of whether people take risks or do not comply with pedestrian signals. Adults felt that, when in a rush, “getting to your appointment on time”, for example, is important and “you are more likely to disobey pedestrian signals” and cross between moving vehicles. Adolescents cited “being late for school” as a reason for taking “short-cuts” (e.g. crossing diagonally, not using designated crossings, not waiting for traffic signals to change). Adolescents recognised that their own personal safety was important. However, when they are late for school (i.e. when they are in the actual situation), they seemed to feel that getting to school quickly is more important than “obeying the rules”.

“Laziness” was also mentioned by adults as a reason for not using designated crossing points. If people are walking past the crossing on their way to where they are going, then it was felt that the crossing should be used. However, adult participants felt that there is no point in going back on yourself to use a designated crossing if you are not going to pass it on the way to where you are going. An exception to this general “rule” was that if the road is very busy, going out of the way to walk to the crossing may save time (i.e. because it is easier to cross at the crossing).

Adolescents also felt that “it would be stupid” to go out of your way to get to a crossing, unless the road is very busy. Even under those circumstances, some adolescents said that they would not walk out of their

way to get to a crossing. Instead they would “take a risk” and try to cross where they could because it is quicker.

As mentioned above, in section 4.5.1, participants in the adult focus groups believed that adolescents tend to take deliberate risks with traffic. Possible reasons that were mentioned included social pressure in the form of “showing off” or “trying to impress their friends”. These factors were also mentioned by some of the adolescents in the focus groups. Some of the boys in particular mentioned it was likely that they would deliberately not use crossings due to perceived peer pressure and in the girls’ focus group, participants mentioned that some adolescents show off by playing stupid games with traffic (e.g. purposely forcing cars to slow down when crossing, or pressing the button for the green man but not wanting to cross).

Another type of social pressure involves “following the crowd” (e.g. not paying attention yourself and following other people who cross at signal-controlled crossings without waiting for the green man). This was mentioned by both adult and child participants as one reason why people often cross unsafely (e.g. not paying attention to traffic or disobeying pedestrian signals). Although “showing-off” was regarded by adults as a reason for unsafe pedestrian behaviour by adolescents, “following the crowd” was regarded as a reason for unsafe behaviour in both adolescents and adults. Adolescents also mentioned following the crowd as a reason for not paying attention to traffic or traffic signals when crossing and mentioned that both adolescents and adults do this. They also specifically mentioned “safety in numbers” as a reason for unsafe behaviour such as not looking when crossing and not paying attention to traffic signals – e.g. they felt safe doing this because drivers will easily notice larger groups of people.

A factor that influences how some people behave at signal-controlled junctions or mid-block crossings that was mentioned in one of the adult focus groups related to “a sense of responsibility”. This person stated that when she was with her children she behaved different than when alone (e.g. she would be more likely to use crossings and wait for the signals). A similar factor was also mentioned by many of the adolescents in the focus groups. They felt that they carried out “safe” behaviour more often when out with younger siblings than when alone or with their friends because they felt responsible for their well-being. However, some adolescents also felt that some adults may be less safe when with their children; if their children are misbehaving (i.e. it would be a distraction).

4.5.7 Familiarity with surroundings

Both adults and adolescents felt that familiarity with crossings/junctions was important in influencing their behaviour. Adult participants believed that if people are familiar with the situation, they are in a better position to make “correct” decisions about what the traffic is likely to do and what behaviour they should adopt (e.g. when it is safe to cross). Adolescents also believed that, on familiar roads, they know what the traffic conditions are like and how other drivers are likely to behave. They stated that they know on which roads to pay more attention and on which roads to pay less attention.

Adults also stated that knowing the crossing well can sometimes lead to unsafe behaviour. They considered that if people know the crossing well, they tend to get a feel for the time lags between the red and green signal phases, and if people know the time until the next green man is going to be long, it means that they are likely to start to cross the road when the signals have just turned against them.

Both adults and adolescents believed that they would be less likely to take chances in unfamiliar situations and recognised that it is more important to pay attention.

4.5.8 Mobility

All participants felt that whether behaviour at signal-controlled crossings is unsafe depends on mobility issues. For example, non-compliance with pedestrian signals (e.g. crossing on the red man or crossing on the flashing green man) was felt to be unsafe when performed by older/less mobile people and by people pushing a child in a buggy or pram, or when carrying heavy shopping. Under those conditions, it was felt that it is less easy to cross quickly and it was believed that people are more likely to comply with the “rules”.

4.6 Opinions about signal strategies

4.6.1 *An all-red phase at a junction*

All participants mentioned that the main advantage of this signal strategy is that people can cross diagonally across the junction in a safe manner. In particular, adolescents mentioned that this strategy is good because:

- it is less confusing
- those who pay less attention to the traffic will be safe (because traffic will be stopped on all arms)
- it will take less time to cross the road

However, a major disbenefit that was mentioned (by both adults and adolescents) was that it considerably reduces capacity for traffic. Adults felt that, for this reason, pedestrian waiting times would have to be longer.

Both adults and adolescents mentioned that this strategy needs to be used at all junctions in a town in order to be safe. If it was used only at some junctions, unsafe and inappropriate behaviour might increase when people encountered a junction that did not have an all-red phase (e.g. people might think that crossing diagonally at a signal-controlled junction is safe and acceptable in all circumstances).

4.6.2 *Countdown devices*

When participants were asked to discuss the advantages and disadvantages of using countdown devices that provide information on remaining waiting time before the green man comes on, it was generally felt that it would be a good idea. Adult participants felt that it would have a calming effect and would increase compliance with the pedestrian signals. Similarly, adolescents felt that countdown timers would be a good idea because they would know how long there is to wait before the green man. However, both adults and adolescents felt that if the countdown device displayed a long waiting time (e.g. 2 minutes) people would ignore it and try to find other opportunities to cross the road, especially if they were in a rush. As with the pedestrian signals currently used, participants in each of the groups agreed that if the road was empty of traffic or if there were large safe gaps in traffic in which to cross, there would still be a lot of non-compliance.

A countdown device that provides information on the remaining time people have to cross the road was regarded as a bad idea. All participants felt that it would increase the likelihood of people crossing at the very last moment (e.g. with only one or two seconds remaining), especially if people were aware that there would be a long time to wait until the next “pedestrian green”. Participants also felt that it would “panic” people who are less mobile and cause people to rush across the road. In the focus group with male adolescents it was felt that the signal might cause people to rush towards the crossings and run across the road if there were only a few seconds left before the lights change – they felt that they would not want to wait for another cycle.

4.6.3 *Other ways to promote safer behaviour at signal-controlled crossings*

Other ways to promote safer behaviour at signal-controlled junctions and crossings were mentioned by participants. They were as follows (note that not all may be practical or appropriate – these are simply what were mentioned by participants):

- Adults mentioned raising the height of guard rails to make it more difficult for people to jump over them.
- Both adults and adolescents mentioned greater use of subways/tunnels and bridges on certain roads, but some adolescents felt that they would not use them because it will be quicker to cross the road “normally”.
- Adults mentioned the need for more road safety education in schools, and more general education/publicity interventions aimed at both adults and children. Female adolescents also felt

that this would be a good idea but male adolescents felt that it would not be effective – some stated that it would not influence their behaviour.

- Adults suggested that showing people examples of “typical, everyday, unsafe” behaviour, in addition to the consequences of fatal accidents – the kind of behaviour examples show in the video clips (see section 4.2.2) would have a beneficial effect.
- Adults mentioned more stringent legislation and enforcement of pedestrian behaviour (e.g. jay-walking laws).
- Adolescents mentioned the use of lollipop men/women outside schools
- Adolescents suggested the use of barriers across the road to stop cars jumping red lights.

5. Accidents at signal-controlled crossings

5.1 STATS19 analysis of all signal-controlled crossings

An analysis of the STATS19 national road accident database was undertaken. The accidents considered were all those that involved pedestrians crossing on or within 50m of a pedestrian crossing.

The findings showed that in the five year period 2000-2004 there were a total of 19,703 pedestrian casualties at signal-controlled mid-block crossings and 16,507 pedestrian casualties at signal-controlled junctions (36,210 in total). A traffic signal survey carried out in 2000 by the Traffic Control Users Group (TCUG, 2000) indicated that nationally there were in the region of 12,300 signal-controlled junctions, of which 59.9% had pedestrian facilities, and 13,800 pedestrian crossings. These figures have to be treated with caution as they are based on a return rate of 42% from the Local Highway Authorities that the survey was sent to. However, they suggest that on average there are 0.29 pedestrian casualties per year at a signal-controlled mid-block crossing and 0.27 at a signal-controlled junction.

Table 3 shows that for the five year period 2000-2004 the proportion of Fatal and Serious pedestrian casualties is broadly similar at junctions and mid-block crossings.

Table 3: Pedestrian casualties from 2000 to 2004 by severity

	Fatal	Serious	Slight	Total	% Fatal and serious
Mid-block	411	4285	15007	19703	23.8%
Junction	286	3346	12875	16507	22.0%

Table 4 shows the location of the pedestrian casualties by age group. Over one half (58%) of the pedestrian casualties in all age groups occurred on the crossing itself or within the zigzags, the remainder occurred beyond the zigzags but within 50m of the crossing. Both older and younger pedestrians appear to be over-represented.

Table 4: Pedestrian casualties for 2000 to 2004 at mid-block crossings by pedestrian location and age group

Age group	On Crossing		Within Zigzags approach		Within Zigzags exit		Within 50m of crossing		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
<16	2733	35.1%	207	36.3%	184	40.2%	2033	32.1%	5157	34.0%
16-60	3853	49.5%	291	51.1%	227	49.6%	3378	53.3%	7749	51.1%
>60	1199	15.4%	72	12.6%	47	10.3%	930	14.7%	2248	14.8%
Total	7785	100.0%	570	100.0%	458	100.0%	6341	100.0%	15154	100.0%
	51.4%		3.8%		3.0%		41.8%		100.0%	

1 Table excludes those casualties with age not known

Table 5 gives the same information for signal-controlled junctions. A higher proportion of casualties are within 50m but not using crossings at junctions (49.4%) than at mid-block crossings (41.8%).

Table 5: Pedestrian casualties for 2000 to 2004 at signal-controlled junctions by location and age group

Age group	On crossing		Within zigzags approach		Within zigzags exit		Within 50m of crossing		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
<16	1422	24.3%	21	25.6%	17	28.8%	1350	23.1%	2810	23.7%
16-60	3478	59.5%	53	64.6%	33	55.9%	3836	65.5%	7400	62.5%
>60	945	16.2%	8	9.8%	9	15.3%	669	11.4%	1631	13.8%
Total	5845	100.0%	82	100.0%	59	100.0%	5855	100.0%	11841	100.0%
	49.4%		0.7%		0.5%		49.4%		100.0%	

1 Table excludes those casualties with age not known

Vehicle manoeuvres (Table 6) were surprisingly diverse at mid-block crossings; 75.7% of crashes involved vehicles going ahead, 2.5% involved vehicles turning left or waiting to turn left and 4.0% involved vehicles turning right or waiting to turn right. Turning vehicles were presumably those turning at priority junctions. The figures were similar at junctions, 69.8% of crashes involved vehicles going ahead, 7.7% involved vehicles turning right or waiting to turn right and 5.6% involved vehicles turning left or waiting to turn left.

Table 6: Pedestrian casualties for 2000 to 2004 by manoeuvre of the vehicle involved

Vehicle manoeuvre	Number		%	
	Mid-block	Junction	Mid-block	Junction
Reversing	607	407	3.1%	2.5%
Parked	77	73	0.4%	0.4%
Waiting to go ahead but held up	205	175	1.0%	1.1%
Stopping	404	326	2.1%	2.0%
Starting	556	624	2.8%	3.8%
U turn	41	35	0.2%	0.2%
Turning left	470	895	2.4%	5.4%
Waiting to turn left	21	27	0.1%	0.2%
Turning right	759	1228	3.9%	7.5%
Waiting to turn right	27	25	0.1%	0.2%
Changing lane to left	40	50	0.2%	0.3%
Changing lane to right	59	42	0.3%	0.3%
Overtaking moving vehicle on offside	137	81	0.7%	0.5%
Overtaking stationary vehicle on offside	732	500	3.7%	3.0%
Overtaking on nearside	182	152	0.9%	0.9%
Going ahead left hand bend	243	164	1.2%	1.0%
Going ahead right hand bend	225	180	1.1%	1.1%
Going ahead other	14888	11498	75.7%	69.8%
All manoeuvres	19673	16482	100.0%	100.0%

Table 7 shows that 34.2% of pedestrian casualties at junctions and 30.9% at mid-block crossings happened at night. The reasons for this are likely to include poor conspicuity of pedestrians, higher vehicle speeds and a higher proportion of pedestrians who have been drinking.

Table 7: Pedestrian casualties for 2000 to 2004 by light condition

Lighting	Number		%	
	Mid block	Junction	Mid block	Junction
Daylight	13616	10864	69.1%	65.8%
Darkness	6087	5643	30.9%	34.2%
Total	19703	16507	100.0%	100.0%

Table 8 shows that cars were involved with 72.9% of pedestrian casualties at junctions and 79.4% at mid-block crossings. Minibuses/buses/coaches were involved in 11.1% of pedestrian casualties at junctions and 8.1% at mid-block crossings. Motorcycles were involved with 7.7% of pedestrian casualties at junctions and 5.1% at mid-block crossings.

Table 8: Pedestrian casualties by type of vehicle involved for 2000 to 2004

Vehicle type	Number		% of total	
	Mid block	Junction	Mid block	Junction
Bicycle	122	145	0.6%	0.9%
Motorcycle	1007	1264	5.1%	7.7%
Car or taxi	15637	12035	79.4%	72.9%
Minibus/ Bus/ Coach	1602	1833	8.1%	11.1%
Goods vehicle	1121	1091	5.7%	6.6%
Other	196	133	1.0%	0.8%
Unknown	18	6	0.1%	0.0%
Total	19703	16507	100.0%	100.0%

5.2 Further investigation of 3-arm signal data

The data from the 3-arm traffic signals project (Taylor *et al*, 1996) was briefly re-visited as part of the current project. The idea was to search for interactions between variables that were too complex to appear in the generalised linear modelling, but which could be seen by eye. The most fruitful way of doing this appeared to be on an individual site basis or possibly for subgroups of sites, for example those operating under SCOOT or having more than two stages.

As a first step, the accident data, including plain language descriptions, for the sites with the most pedestrian accidents were examined individually. The main finding was that accidents could arise where pedestrians have to deviate from their desire line. For example, one site had an island segregating traffic turning left from the major right and ahead traffic (viewing the junction as a T). In order to cross the major right arm, a pedestrian had first to cross to the island which necessitated a considerable detour. There were a number of accidents involving a pedestrian crossing this arm but not at the crossing, suggesting that the layout should be redesigned to take account of pedestrian desire lines. This investigation did not appear to be productive and therefore no further work was undertaken.

6. Case studies

6.1 Description of chosen sites

A total of 22 sites were selected, four in London, seven in Manchester, six in Brighton and five in Bristol. Sites comprised six mid-block crossings, twelve 4-arm junctions, three 3-arm junctions and one 2-arm junction with associated Puffin.

Additional data was obtained as part of the testing of alternative strategies. This involved adding one further 4-arm junction (for which one arm was analysed), changes at a case-study Puffin and three sets of results at an additional Puffin site in London. The data from these sites has been added to the tables that follow.

Table 9 summarises the site details, whilst Table 10 gives the number of sites by type and location and Table 11 the form of signal control by location.

Table 9: Summary of site details

Location	Site type	Characteristics	Control Type	Accidents involving pedestrians (2000 – 2004)
BRIGHTON				
London Rd/ Cheapside/ St Peter's Place/ York Place	4-arm	Staggered crossroads, 1 slip road with island	SCOOT	3
Montpelier Rd/ Western Rd	4-arm	All-red pedestrian phase	VA	1
North Street/ Ship Street	3-arm	All-red pedestrian phase	SCOOT	6
Oxford Street/ London Road	3-arm	All-red pedestrian phase on demand	SCOOT	1
Queens Road/ North Road	4-arm	All-red pedestrian phase	TRANSYT	1
London Road/ Baker Street	Pelican		VA	0
BRISTOL				
Lodge Causeway/ Forest Rd/ Berkeley Rd	4-arm	All-red pedestrian phase	VA	2
Queens Rd/ Park St	3-arm	2 central islands	SCOOT	6
Queens Rd/ University Rd/ Triangle Square	2-arm & pelican		SCOOT	3
Park Street/ Unity Street	Pelican	Central island	VA	0
Whiteladies/ Cotham Hill	Pelican	Central island	SCOOT	0
LONDON				
High Street Penge/ Green Lane/ Croydon Road	4-arm	1 slip lane with island, all-red pedestrian phase	VA	6
Beckenham Road/ Royston Road/ Kent House Road	4-arm	3 central islands, all-red pedestrian phase	VA	0
Chislehurst High Street	Pelican		VA	0
Bromley High St/ Ethelbert/ Elmfield	4-arm		VA	3
MANCHESTER				
Parrs Wood Lane/ Kingsway (Didsbury)	4-arm	2 slip lanes with islands, 2 central islands, 1 arm with no pedestrian facilities	FT UTC	4
Mount Street/ Peter Street	4-arm		FT	4
Princess Street	Puffin		FT	2
Deansgate/ Peter Street/ Quay Street	4-arm		FT UTC	10
Eccles Old Road	Puffin		SCOOT	0
Moston Lane/ Factory Lane Rochdale	4-arm		FT UTC	1
Wilshaw Lane/ Newmarket Rd, Tameside	4-arm		MOVA	1
ADDITIONAL SITES				
Farnham	4-arm	Cross roads with minor one-way exit and minor arm with island separating lefts and right. Ped facility across major to island on minor	MOVA	N/A
Beckenham	Puffin		VA	N/A

Table 10: Number of sites by type and location

Location	3-arm	4-arm	Pelican	Puffin	Other ¹	Total
Brighton	2	3	1			6
London	1	2	1			4
Manchester	5		2	2		7
Bristol	1	1	2		1	5
Initial total	9	6	6		1	22
Additional		1		4		6

¹ 2-arm & Pelican

Table 11: Form of control by location

Location	FT or FT/VA	FT UTC	SCOOT	TRANSYT	MOVA	VA
Brighton			3	1		2
London						4
Manchester	2	3	1		1	
Bristol			2			3
Initial total	2	3	6	1	1	9
Additional					1	1

FT is fixed time; VA is vehicle actuated

6.2 Accident record at the case study sites

Table 9 includes the number of accidents involving a pedestrian at each of the selected sites in the five year period 2000 to 2004. The accident record at those sites with 4 or more accidents in five years was investigated in more detail. Accident data were not obtained for the additional sites.

6.2.1 North Street/ Ship Street

There were 6 accidents in the 5 year period, 5 of which involved PSVs. Five of the accidents were classed as slight but the sixth was serious. Three of the accidents occurred at night when the street lights were lit. The survey period did not include the times when the majority of the accidents occurred and therefore it is not possible to evaluate if there is a common cause of the accidents.

During the survey period it was observed that, on occasions, congestion occurs and traffic backs up across the crossings. Pedestrians were observed cross between the stationary vehicles. Although this behaviour does not appear to be contributing to the accidents at this location, safety is potentially compromised.

6.2.2 Queens Road/ Park Street

There were again 6 accidents in the 5 year period, of which 5 occurred in the dark when the street lights were lit. Two of the accidents were serious and the rest were slight. One of the slight accidents resulted in injuries to two pedestrians.

As the accidents were mainly outside the survey period, it was not possible to identify a common theme.

6.2.3 Parrs Wood Lane/ Kingsway (Didsbury)

There were a total of 4 accidents at this junction during the five year period. One of the accidents was serious and the rest were slight. One of the slight accidents resulted in injuries to two pedestrians. The accidents occurred on three separate arms of the junction and there does not appear to be a common factor.

6.2.4 Mount Street/ Peter Street

There were a total of 4 accidents at this junction during the 5 year period, all of which were slight. Two of the accidents occurred in daylight and two at night. All of the accidents involved cars; however there do not appear to be any common factors.

6.2.5 Deansgate/ Peter Street/ Quay Street

This was the junction with the worst accident record with 10 occurring during the 5 year period. Two of the accidents were serious with one of these also resulting in slight injuries to a second pedestrian. Seven out of the ten accidents occurred in the dark when the streetlights were on, six of them occurring between midnight and 3:05 am.

The accidents were spread around the junction and there appears to be no common factor, other than the time. The majority of the accidents again occurred outside the survey period. However analysis of the video survey did indicate that pedestrians at the junction tend to cross one arm when traffic is flowing on the opposing arms i.e. they will cross Peter Street against the red man when traffic is flowing on Deansgate, waiting in the middle of the road as necessary. Conflicts can arise when vehicles waiting to turn right are presented with a gap and turn into the side road when pedestrians are still crossing. The accident record does not appear to show this as a particular problem but safety is potentially compromised.

6.2.6 High Street Penge/ Green Lane/ Croydon Road

During the five year period, there were 6 accidents at this junction, all classed as slight. The majority of these accidents involved traffic travelling straight ahead on High Street North hitting pedestrians crossing from the driver's nearside.

6.2.7 Summary

The most common theme is the high proportion of accidents that occur in the dark. Given the urban location of the junctions this is not unexpected, but it does suggest that consideration should be given to special night time strategies to cater for pedestrian behaviour at these times.

Analysis of the video surveys did highlight a significant problem associated with right turning vehicles being released after being held up by straight ahead traffic and pedestrians crossing the side road. Often these vehicles can be travelling from behind pedestrians who are already committed to crossing the road and the pedestrians can be unaware of their presence. This situation was most clearly demonstrated at the Deansgate/ Peter Street/ Quay Street junction. At this particular site, there was insufficient space to install a refuge, but pedestrians commonly waited in the middle of the road for turning traffic.

6.3 Video analysis

6.3.1 Types of pedestrian behaviour

Pedestrian crossing behaviour was categorised in a similar way to that followed by Reading, Dickinson and Barker (1995):

- **Anticipatory pedestrians:** arrive on red, start to cross before the green man appears, finish on green man (red to traffic) (strictly speaking these are non-compliant pedestrians given that they leave the kerbside before the green to pedestrian signal)
- **Compliant pedestrians:** arrive on red and wait for green before starting to cross the road
- **Non-compliant pedestrians:** arrive on red and cross entirely against the red man
- **Non-delayed pedestrians:** arrive on green, start on green and complete crossing on green
- **Late Starters:** arrive on green or flashing green, start to cross on green or flashing green, but do not complete the crossing before the pedestrian signal turns red

The following sections investigate these behaviours and the factors that influence them.

6.3.2 Mean waiting times for pedestrian

The delay to pedestrians once they arrive at a junction depends on the signal control strategy in use and the current stage in the signal cycle. Table 12 below show the numbers of pedestrians in each category and the mean delay they experienced before crossing. There is considerable variation from arm to arm in the mean waiting time for both compliant and anticipatory pedestrians. Standard deviations are also high. This variability is only to be expected as cycle times are variable and pedestrians arrive at random times during the cycle. On average, compliers had to wait four times as long as non-compliers and twice as long as anticipators.

Table 12: Mean waiting time in seconds for pedestrians arriving on the red man by behaviour

Arm	Anticipators			Compliers			Non-compliers		
	Count	Mean	St Dev	Count	Mean	St Dev	Count	Mean	St Dev
Brighton Cheapside									
Cheapside	14	4.7	5.0	10	15.2	20.1	54	10.0	11.5
London Road	6	5.2	5.6	14	11.7	12.0	36	6.3	7.2
St Peters Place	12	11.6	10.0	7	15.7	15.9	40	1.6	1.5
York Place AB	3	8.0	10.6	20	12.9	8.1	9	3.7	7.1
York Place BC	4	2.5	2.1	7	17.1	29.2	40	2.6	4.5
Brighton Baker Street Pelican									
Baker St	15	7.1	6.6	52	11.9	8.5	17	6.5	4.9
Brighton Montpelier St / West St									
Mont (North)	19	16.8	14.2	12	16.9	11.8	35	8.6	11.9
Mont (South)	12	4.8	5.7	2	1.5	0.7	54	1.7	1.4
West St (East)	10	9.3	16.4	14	15.7	18.7	48	7.2	8.2
West St (west)	4	12.5	18.4	25	22.3	21.0	54	6.1	7.5
Brighton North St / Ship St									
North St (East)	15	18.4	12.6	20	17.0	15.8	31	11.4	10.0
North St (West)	14	16.5	10.2	29	23.7	24.1	25	10.3	11.8
Ship Street	5	4.4	5.9	6	2.2	0.8	56	3.3	3.2
Brighton London Rd / Oxford St									
London Rd (N)	1	29.0	-	44	18.2	13.8	33	3.2	2.4
London Rd (S)	2	7.5	4.9	59	29.9	22.5	21	8.0	9.9
Oxford Street	1	5.0	-	4	39.8	43.8	87	3.4	3.4
Brighton North Rd / Queen's Rd									
North Road	6	11.3	12.0	33	24.5	19.1	44	9.6	11.3
Queens (North)	2	9.0	11.3	40	23.4	16.9	7	3.0	2.1
Queens (South)	7	24.3	13.7	40	31.5	20.9	28	9.8	10.3
Bristol Lodge Causeway									
Berkeley	4	16.0	17.1	50	25.3	19.6	13	6.6	12.4
Forest Road	5	12.2	3.8	49	29.6	19.9	17	6.1	9.6
Lodge (East)				60	31.8	18.9	25	12.7	11.7
Lodge (West)	1	22.0	-	51	36.8	19.9	10	13.1	18.8
Bristol Park Street Pelican									
Park St Pelican	18	8.11	8.6	15	8.9	6.5	53	3.1	6.9
Bristol Park Street / Queen's Road									
Park St	19	6.6	9.3	8	11.0	7.8	57	4.8	7.3
Queens Rd	8	3.5	4.4	17	12.9	8.3	65	4.6	6.4
Bristol Queens / Uni									
B Square	3	17.0	8.7	30	13.0	7.0	9	5.3	7.1
East	4	9.8	8.9	29	34.6	13.6	43	13.4	13.6
Bristol Queens / Uni Pelican									
Queens/Uni Pel	7	19.1	16.6	46	22.6	16.5	38	12.8	14.8
Bristol Whiteladies Pelican									
Whiteladies	23	10.0	10.7	21	18.3	12.7	25	12.6	15.9
Farnham Farnborough Rd									
Farnborough (N) B	3	28.3	15.5	34	19.0	18.2	33	8.6	10.6
Farnborough (N) A	6	9.8	5.2	51	13.9	10.0	11	7.9	12.6
London Beckenham Junction									
Beckenham	7	17.7	15.3	21	24.1	15.9	61	7.4	11.5
High Street	8	5.5	5.5	13	15.2	18.9	50	10.1	14.3

Arm	Anticipators			Compliers			Non-compliers		
	Count	Mean	St Dev	Count	Mean	St Dev	Count	Mean	St Dev
Kent House	15	6.6	15.7	9	22.9	18.2	61	4.9	11.1
Royston	6	1.8	2.8	2	19.0	7.1	86	1.1	4.2
London Beckenham Puffin									
Beck Puffin 1	16	9.7	8.4	39	16.9	9.3	27	9.1	10.8
Beck Puffin 2	12	5.8	6.4	39	21.7	15.4	21	8.2	11.7
Beck Puffin 3	8	6.9	8.2	43	14.5	10.3	21	2.5	4.9
London Bromley High									
Elmfield	21	9.7	13.9	2	3.0	2.8	54	3.9	5.9
Ethelbert	8	8.1	11.7	8	8.9	11.5	71	3.1	7.0
High Street	14	4.7	6.7	7	5.1	4.7	46	1.9	3.2
London Chislehurst Pelican									
Chislehurst A	27	5.9	4.9	36	11.4	7.6	30	4.7	5.8
London Penge High Street									
Croydon Rd	3	15.3	26.6	23	21.7	15.9	61	7.0	9.8
Green Lane	5	10.0	18.7	23	31.7	20.8	63	7.1	9.8
High St (N)	10	10.0	8.7	17	27.1	16.5	57	3.8	5.6
High St (S)	14	14.9	15.6	10	22.8	25.3	64	3.5	7.6
High St (S) Filter	4	8.75	11.4	1	33.0	-	87	1.9	5.6
Manchester Deansgate									
Deansgate (N)	23	26.96	18.38	26	17.19	16.53	37	8.0	14.1
Deansgate (S)	19	11.05	15.93	15	25.33	15.28	38	3.3	6.3
Quay Street	4	2.50	1.29	17	22.24	20.47	61	8.0	10.6
St Peter's Street	5	1.2	0.5	11	22.7	18.0	65	3.2	5.8
Manchester Didsbury									
AB	2	13.5	0.71				88	4.4	7.1
BC	14	15.5	15.6	34	21.7	19.5	16	8.3	11.5
CD	8	0.6	0.74	1	12.0	-	49	1.8	3.4
EF	10	29.7	28.9	12	31.7	18.4	59	6.7	9.1
FG	8	29.4	19.7	22	38.8	17.5	45	10.1	13.3
GH				1	9.0	-	54	1.0	0.7
GJ	6	17.8	6.3	20	26.0	10.0	61	6.9	9.3
Manchester Eccles Old Road Puffin									
Eccles Old Road	7	13.9	9.28	21	17.76	18.0	55	3.5	5.8
Manchester Princess Puffin									
Princess Puffin B	6	22.7	24.1	15	24.1	21.4	64	10.5	11.7
Princess Puffin A	11	14.5	20.4	14	13.4	12.2	63	5.5	8.4
Manchester Wilshaw Lane									
Newmarket	2	0.0	0.0	9	46.9	29.5	45	14.5	30.7
Oldham Rd (N)	10	29.5	14.7	19	38.6	29.3	33	7.6	11.4
Oldham Rd (S)	7	18.7	10.2	11	34.4	11.0	26	8.9	12.3
Wilshaw Lane				22	46.1	28.2	70	11.2	18.2
Total	590	11.7	13.8	1510	22.4	18.8	2931	6.0	10.3

From the information gathered from the literature review and the focus groups, it is likely that a high percentage of the anticipators are either familiar with the crossing or that they notice drivers slowing down as the amber to vehicles shows.

In terms of signal strategies, it is the non-compliant and to a lesser extent the anticipators and late starters that are of interest. There are two main groups of non-compliant pedestrians: those who cross as soon as a suitable gap appears in the traffic and those who cross after waiting for some time and losing patience. Figure 3 below shows the percentage of non-compliant pedestrians against the time they waited before they started to cross. This graph is a combination of data from all of the sites in the study. Around 70% of non-compliant pedestrians crossed within 5 seconds of arrival rather than waiting. This behaviour is not necessarily unsafe, but is dependent on the pedestrian accepting a safe gap in the traffic and therefore some pedestrians could be at increased risk.

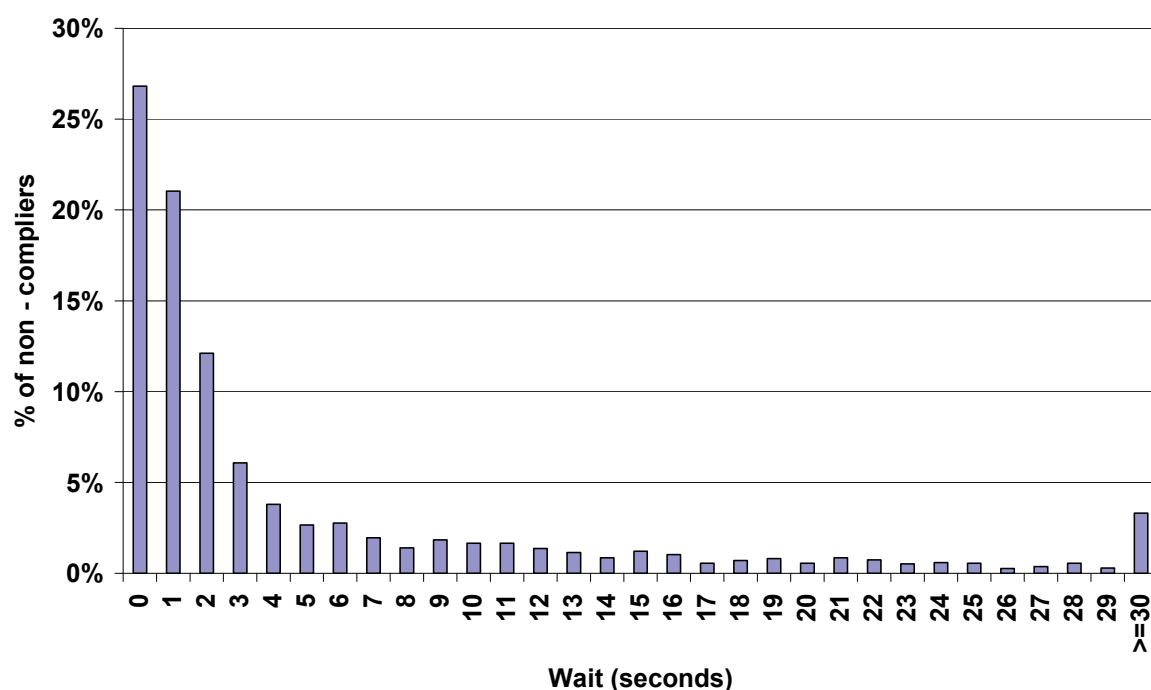


Figure 3: Proportion of non-compliers as a function of wait time

Table 13 and Figure 4 below show the percentage of pedestrians crossing on the red man. There is no clear relationship between the volume of traffic on the arm of a junction and the percentage of pedestrians who cross on red, although there is a slight tendency for the percentage crossing on red to reduce as flow increases. Therefore it is likely that factors other than flow are also involved in the decision to cross. Overall, 71% of pedestrians who arrived on the red man crossed without waiting for the green man signal.

Table 13: Percentage of pedestrians arriving on red who start to cross on red

Town	Site	Arm	Start on green	Start on red	Total arriving on red	Traffic volume	% crossing on red
Brighton	Cheapside	Cheapside	10	68	78	1924	87%
		London Road	14	40	54	2741	74%
		St Peters Place	7	51	58	1494	88%
		York Place AB	20	12	32	2865	38%
		York Place BC	7	44	51	2865	86%
	London/Baker	London/Baker Pel	52	32	84	2819	38%
	Montpelier	Montpelier (North)	12	54	66	2106	82%
		Montpelier(South)	2	66	68	849	97%
		West St (East)	14	57	71	2969	80%
		West St (west)	25	58	83	3136	70%
	North/Ship	North St (East)	20	46	66	3166	70%
		North St (West)	29	38	67	3035	57%
		Ship Street	6	60	66	673	91%
	Oxford/London	London Rd (North)	44	33	77	902	43%
		London Rd (South)	59	23	82	2123	28%
		Oxford Street	4	88	92	281	96%
	Queens/North	North Road	33	50	83	3880	60%
		Queens (North)	40	9	49	4627	18%
		Queens (South)	40	32	72	2105	44%
Bristol	Lodge	Berkeley	50	17	67	2646	25%
		Forest Road	49	21	70	2291	30%
		Lodge (East)	60	25	85	3524	29%
		Lodge (West)	51	11	62	3633	18%
	Park Street	Park Street Pelican	15	70	85	4661	82%
	Queens/Park	Park St	8	76	84	4014	90%
		Queens Rd	17	73	90	4488	81%
	Queens/Uni	B Square	30	10	40	1347	25%
		East	29	46	75	4337	61%
	Queens/Uni Pel	Queens/Uni Pel	50	40	90	4187	44%
	Whiteladies	Whiteladies	21	48	69	6232	70%
Farnham	Farnborough Road (N) Before	Farnborough Road (N)	34	36	70	8303	50%
	Farnborough Road (N) - After	Farnborough Road (N)	51	18	69	N/A	26%

Table 13 continued: Percentage of pedestrians arriving on red who start to cross on red

Town	Site	Arm	Start on green	Start on red	Total arriving on red	Traffic volume	% crossing on red
London	Beckenham junction	Beckenham Rd	21	67	88	6407	76%
		High Street	13	57	70	4875	81%
		Kent House	9	76	85	2843	89%
		Royston	2	92	94	697	98%
	Beckenham Puffin	Strategy 1	39	42	81	4750	52%
		Strategy 2	39	33	72	4393	46%
		Strategy 3	43	29	72	4592	40%
	Bromley High	Elmfield	2	72	74	1327	97%
		Ethelbert	8	76	84	334	90%
		High Street	7	60	67	1637	90%
	Chislehurst	Chislehurst	36	57	93	3909	61%
	Penge High	Croydon Rd	23	64	87	3510	74%
		Green Lane	24	68	92	2740	74%
		High St (N)	17	67	84	4054	80%
		High St (S)	10	78	88	3606	89%
		High St (S) Filter	1	91	92		99%
Manchester	Didsbury	AB		90	90	4192	100%
		BC	33	27	60	5490	45%
		CD	1	57	58	310	98%
		EF	12	69	81	5874	85%
		FG	22	51	73	6730	70%
		GH	2	80	82	5197	98%
		GJ	20	66	86	135	77%
	Eccles Old Road	Eccles Old Road	21	62	83	4216	75%
	Princess Street B	Princess Puffin B	15	69	84	2137	82%
	Princess Street A	Princess Puffin A	14	74	88	1445	84%
	Wilshaw Lane	Newmarket	9	47	56	87	84%
		Oldham Rd (N)	19	43	62	117	69%
		Oldham Rd (S)	11	33	44	85	75%
		Wilshaw Lane	22	72	94	159	77%
	Total		1511	3511	2	5028	70%

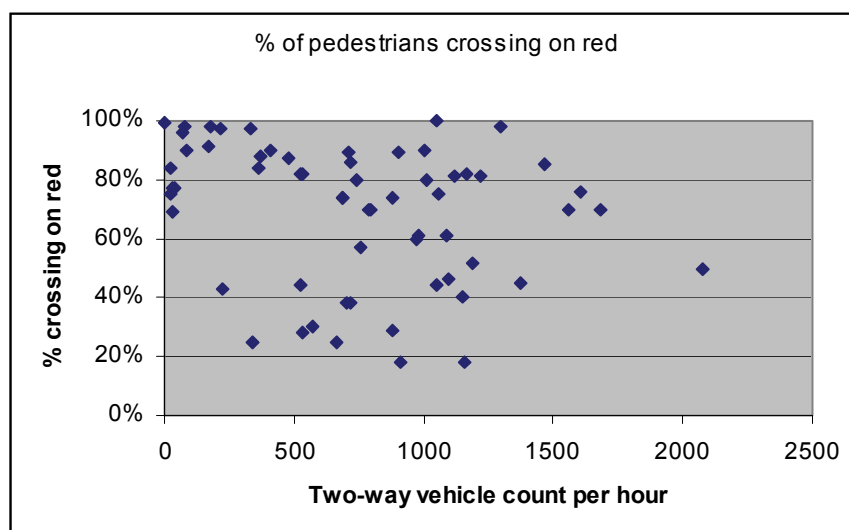


Figure 4: Percentage of pedestrians at mid-block crossings and junctions with pedestrian facilities that start to cross on red as a function of traffic counts

Figure 5 shows the mean waiting time for pedestrians as a function of vehicle flow for compliant and non-compliant pedestrians. For compliers, the mean delay is broadly independent of vehicle flow, whilst for non-compliers, the mean delay increases from near zero at low flow to a limit of about 10 seconds at a flow of about 1000 vehicles per hour. The time advantage gained by crossing on red can be substantial.

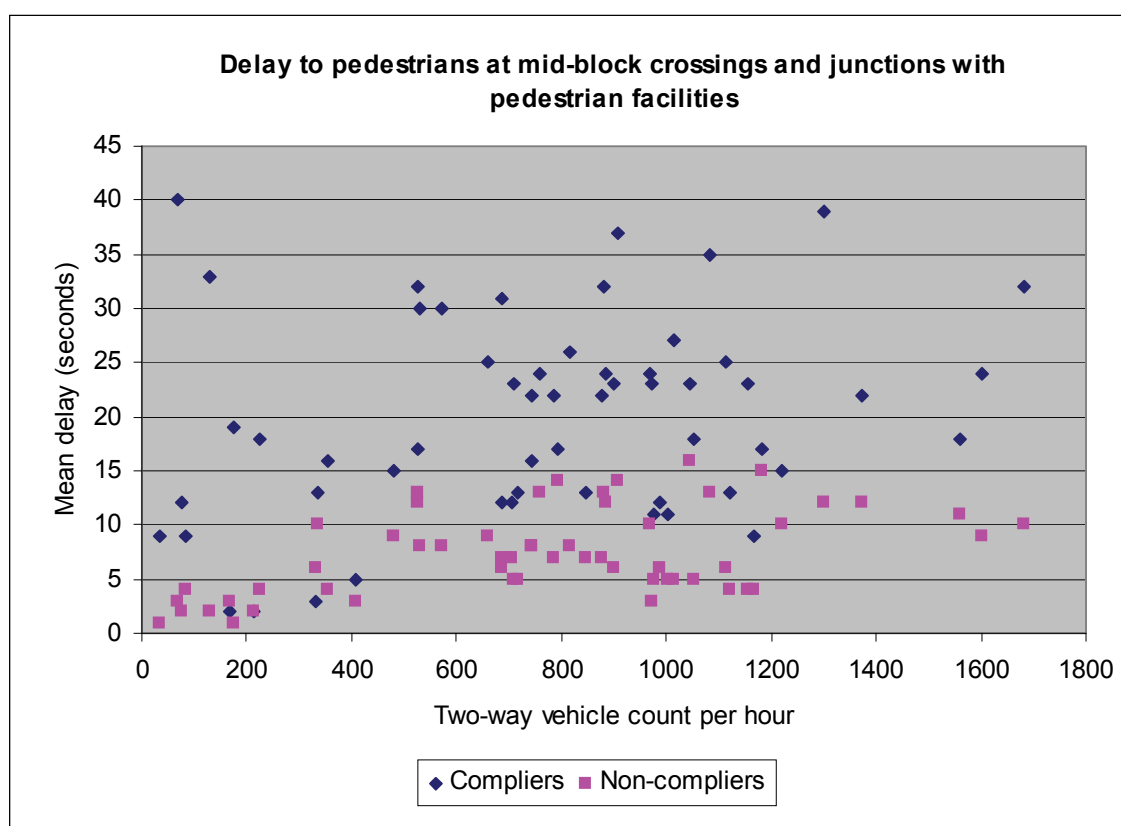


Figure 5: Delay to pedestrians as a function of traffic counts at mid-block crossings and junctions with pedestrian facilities

6.3.3 Crossing time

An important issue that should be taken into consideration in the provision for pedestrians at traffic signals is the length of time that should be allowed for pedestrians to cross the road. Mean crossing times for all sites combined according to behaviour type, gender, age, and with or without an obvious impediment in Tables 14 and 15 below.

The non-delayed had the fastest mean crossing time, as they could cross without needing to stop and assess the traffic. Somewhat surprisingly, the late starters were the slowest.

Table 14: Mean crossing time in seconds by pedestrian behaviour (all sites combined)

Description	Count	Mean	St Dev
Anticipator	590	7.1	2.1
Complier	1509	8.1	2.8
Late starter	425	8.3	3.6
Non-complier	2882	7.6	4.8
Non-delayed	862	6.1	4.3

Table 15 shows that people who were impeded in some way were slightly slower than those who were not. Older people also had slower mean crossing times.

Table 15: Mean crossing time in seconds by pedestrian type (all sites combined)¹

	Anticipator	Complier	Late Starter	Non-Complier	Non-delayed	All
Men	6.9	7.5	8.0	7.4	5.5	7.3
Women	7.2	8.0	8.4	8.4	7.6	7.7
Impeded	7.6	9.1	9.0	8.0	6.4	8.3
Non-impeded	6.9	7.8	8.0	7.4	5.9	7.4
Age 16-60	7.1	7.6	8.1	7.4	5.8	7.5
Age >60	7.0	8.9	9.5	8.3	6.7	8.3
All	7.1	8.1	8.3	7.6	6.1	7.5

1. The numbers of pedestrians under 16 crossing unaccompanied was too small to be statistically reliable and there were a number of sites with no such pedestrians

6.3.4 Percentage of pedestrians who looking before and/or during crossing

A significant influence on the safety of pedestrians is the extent to which they look to check if traffic is approaching. Table 16 shows the percentage of pedestrians who did not appear to look, by sex, behaviour type and whether or not they were impeded.

Table 16: Percentage of pedestrians not looking before and/or during crossing

%	Female		Male		Mix		All			All	
	Not impeded	Impeded	Not impeded	Impeded	Not impeded	Impeded	F	M	Mix	Not-impeded	Impeded
Anticipator	27	15	17	33	21	20	23	21	21	21	23
Complier	38	33	33	23	33	22	37	31	30	35	28
Late Starter	24	47	18	38	43	42	32	23	43	23	43
Non-Complier	17	24	13	17	11	14	19	14	12	14	19
Non-delayed	60	50	45	35	66	31	58	43	57	53	41
No ped facilities	14	14	13	8	2	8	14	12	4	12	10

From the table it can be seen that the groups of pedestrians least likely to look are the late starters and the non-delayed. Impeded pedestrians are more likely to look before/during crossing than unimpeded

pedestrians if they are late starters, but less likely to look if they find the green man showing when they arrive at the crossing.

6.3.5 Percentage crossing between the studs

Table 17 shows the percentage of pedestrians crossing between the studs at each site. The overall figure is 68%, but there is considerable site-to-site variation. Sites with poor compliance are likely to be located away from where most pedestrians wish to cross. Where pedestrians cross next to the crossing, but not on it, there may be scope for widening the crossing. Only two sites showed more than a handful of people crossing the junction diagonally.

Table 17: Percentage crossing within the studs

	Site	At crossing	Partial use of crossing	Next to crossing	Diagonally across crossing	Diagonally across junction	Mix	Total	% fully using crossing
Brighton	Cheapside	344	134	16	4			498	69%
	London/Baker	79	20		1			100	79%
	Montpelier	291	84	22	3			400	73%
	North/Ship	260	38	1	1			300	87%
	Oxford/London	232	61	6				299	78%
Bristol	Queens/North	225	41	9				275	82%
	Lodge	266	44	28		27	10	375	71%
	Park Street	20	55	15	9		1	100	20%
	Queens/Park	94	94	7	7			202	47%
	Queens/Uni	113	27	13	1		51	205	55%
	Queens/Uni Pel	85	8				7	100	85%
	Whiteladies	31	49	15	5			100	31%
Farnham	Farnborough Road before	84	79	101	5			269	31%
	Farnborough Road After	31	35	3	1			70	44%
London	Beckenham	323	44	7	1	2		377	86%
	Beckenham P1	28	53	15	4			100	28%
	Beckenham P2	21	53	18	8			100	21%
	Beckenham P3	26	52	14	8			100	26%
	Bromley High	262	24	9	1	1	2	299	88%
	Chislehurst B	87	9	3			1	100	87%
	Chislehurst A	93	3	4				100	93%
	Penge High St	207	204	77	10			498	42%
Manchester	Deansgate	263	71	29	5	20	10	398	66%
	Didsbury	567	121	57	3		4	752	75%
	Eccles Road	35	19	30				84	42%
	Mount / Peter	341	24	10		3	22	400	85%
	Princess Street B	49	11	30	1		9	100	49%
	Princess Street A	36	29	33	2			100	36%
	Rochdale	413	26	23				462	89%
	Wilshaw Lane	115	75	69	1			260	44%
	Total	4972	1481	631	69	53	117	7323	68%

7. Potential strategies to increase compliance

7.1 Possible strategies

7.1.1 Non-exclusive pedestrian phases

Non-exclusive pedestrian phases reduce delay to vehicles compared with an-all red phase and may be the only viable strategy at large junctions. Whilst they may reduce initial delay to pedestrians waiting to cross, pedestrians will then have to wait in the centre of the road, and may have to walk an additional short distance if the crossing is staggered, which may increase overall their combined waiting and crossing

time. This strategy was tested using TRANSYT to estimate both vehicle and pedestrian delays (see Section 8).

7.1.2 Increased responsiveness to pedestrians

Responsiveness to pedestrians can be increased in various ways:

- Switching to the green man as soon as possible after the demand is made (pre-timed maximum)
- Reducing cycle time (see Section 7.1.3)
- Increasing the proportion of cycle time for pedestrians (see Section 7.1.3)

Increasing responsiveness might be expected to increase compliance and potentially safety.

7.1.3 Increase proportion of cycle time for pedestrians/ reduce cycle time

Frequently, mid-block crossings in UTC systems are permitted to run the pedestrian phase only at one point in the cycle in order to coordinate vehicular traffic travelling through the crossing. If the road is busy, pedestrians would have to wait on average a little less than half the cycle time unless there are suitable gaps in the traffic. Increasing the ‘window of opportunity’ for the pedestrian phase to run improves responsiveness for pedestrians. Where a pedestrian makes a demand for the pedestrian phase during the window of opportunity, the phase runs almost instantly. Delay can also be reduced by reducing the cycle time. Both of these methods can have adverse effects on delay to vehicles and a careful evaluation of each junction (for example using TRANSYT to model both vehicle and pedestrian flow) is required.

7.1.4 Puffin or Puffin-style crossings

The proportion of late starters might be reduced by Puffin or Puffin-style crossings, which extend the all-red period if a pedestrian is still using the crossing.

7.1.5 Countdown devices showing time remaining until the green man

Countdown devices showing pedestrians how long they will have to wait for the green man might be expected to increase compliance. However, they might have the opposite effect if the time shown was longer than a few seconds. This type of countdown timers can only work if the time to the start of the pedestrian phase can be predicted and are therefore not suitable when using traffic/pedestrian responsive signal control strategies. With responsive systems such as MOVA and VA, for example, it is not possible to provide more than a second or so advance notice of when the signals are about to change.

7.1.6 Use of different strategies during quieter periods

Section 5 showed that around one-third of pedestrian accidents occur at night and this was also true for the case study sites in Section 6. It is known (Section 3.2.5) that alcohol is likely to be involved in a high proportion of them. However, many urban areas retain UTC operation (whether fixed time or SCOOT) throughout day and night. Such operation is rather unresponsive to pedestrian demands leading perhaps to pedestrians crossing with the signals green to traffic, especially at night when vehicle flow is low. The likelihood of misjudgement is perhaps at its greatest then, and vehicle speeds may also be higher.

It seems likely that maximising the responsiveness of the signals could increase compliance and, therefore, safety. At the very least a night-time plan (for fixed time UTC) with a very short cycle time could help, or perhaps better still switching to VA. Resting on red in such circumstances may help if it encourages vehicles to slow down on approaches to signals. This would not necessarily be suitable in all cases – if a vehicle claims priority at a time when a pedestrian has just decided it is safe to cross (because the signals are red to traffic) this may be hazardous. Resting on red for stand-alone crossings is not recommended for this reason.

At some locations, UTC is already switched off for one reason or another at certain times of the day. However, whatever the reason is, it is not normally to benefit pedestrians. There may be locations where

selective decoupling (whether it is at a standalone crossing or a junction) could be used to the benefit of pedestrians. Decoupling of pedestrian crossings may be a full-time option for some standalone crossings. However, this may not be ideal if the crossing then tends to present red to a large approaching platoon of vehicles. Many pedestrians will cross without waiting for the green man if traffic is light.

7.2 Test sites

7.2.1 Princess Street Puffin

The signals in and around the centre of Manchester operate under a fixed time regime controlled from the Manchester UTC. The timings have been largely derived by hand. There are two basic timing plans; the off-peak plan which uses a sixty second cycle time and a peak-time plan that uses an eighty second cycle time.

The Puffin crossing that was the subject of this trial was originally permitted to run the pedestrian phase only at one point in the cycle. In theory this means that pedestrians would have to wait on average a little less than half the cycle time (in practice there was plenty of opportunity for pedestrians to cross in gaps with the signals green to traffic). The reason for having just one opportunity for the pedestrian phase to run was to coordinate vehicular traffic travelling through the Puffin crossing. The timing was designed to coincide with a gap in the traffic.

For this trial, Manchester UTC kindly agreed to change the timings so as to give a ‘window of opportunity’ for the pedestrian phase to run. The window was made to be half the signal cycle time. Hence, where a pedestrian made a demand for the pedestrian phase during the window of opportunity, the phase would run almost instantly. If the demand was made outside the window, the pedestrian phase would run at the start of the next window, which would mean the delay would be, at worst, no more than half the cycle time. Thus pedestrian delay was expected to be significantly less than before.

Table 18 shows that the mean waiting time for pedestrians who complied with the signals reduced from 24 to 13 seconds. However the percentage of pedestrians arriving on red who complied with the signals changed very little. This suggests that pedestrians will benefit greatly in congested conditions, but less so when the road is less busy, as pedestrians will continue to ignore the signals when the road is clear.

Table 18: Mean delay before and after change in signal strategy at Princess St Puffin by pedestrian behaviour (seconds)

	Anticipator			Complier			Non-complier		
	Count	Mean	St dev	Count	Mean	St dev	Count	Mean	St dev
Before	6	22.7	24.1	15	24.1	21.4	55	3.5	5.8
After	11	14.5	20.4	14	13.4	12.2	64	10.5	11.7

7.2.2 Beckenham Puffin

Three trials were undertaken at a Puffin site in Beckenham running under VA. It was known that Puffins in London run conservative timings, i.e. long all-red periods at the end of the green man period. Three different surveys were undertaken:

1. Initial configuration (long all-red extension periods)
2. With the currently recommended time for periods 5 to 8 of the Puffin sequence (see TR2210)
3. With pre-timed maximum VA

The results are displayed in Table 19. The main result is the reduction in delay for compliers with pre-timed maximum.

Table 19: Mean delay at Beckenham Puffin (seconds)

	Anticipator			Complier			Non-complier		
Survey	Count	Mean	St. Dev.	Count	Mean	St. Dev.	Count	Mean	St. Dev.
1	16	9.7	8.4	39	16.0	9.3	27	9.1	10.8
2	12	5.8	6.4	39	21.7	15.4	21	8.2	11.7
3	8	6.9	8.2	43	14.5	10.3	21	2.5	4.9

A very high proportion of late starters was observed at this site (Table 20). The reasons for this are not known, but may be due to the lack of a suitable familiarisation period with the reduced all-red extension period.

Table 20: Mean delay for late starters under the three different signal strategies at the Beckenham Puffin (seconds)

Survey	Count	Mean	St. Dev.
1	18	0.06	0.24
2	28	0.14	0.52
3	27	0.22	0.70

7.2.3 Alma Lane / Farnborough Road junction

The junction in question (J757 Alma Lane / Farnborough Road in Farnham) is running under MOVA control. At the time of the trial in November 2005, TRL had developed a 'Beta' version of MOVA M6 which was loaded into the MOVA equipment on site. This version of MOVA included pedestrian priority facilities. The experiment was conducted to contrast pedestrian behaviour with and without these pedestrian facilities being implemented.

The pedestrian priority facility works as follows: when a pedestrian demand is lodged, the length of the following signal cycle will be reduced to cater for the pedestrians and to get back to where it was in the cycle. In unsaturated conditions or where saturation has not existed for long (and may, therefore, be transitory) alternative stage maximums will be used. These alternative values are set by the user. For this experiment, 12 seconds was used for all stages.

In over-saturated conditions, an alternative strategy is used. In this case the user specifies the percentage of the normal recent greens to use as a maximum. This is designed to cater for congested conditions in a user defined way. In this experiment the percentage was set at 90% to avoid introducing traffic problems in the peak periods - it was not considered to be important for the purposes of this trial to consider the peak periods.

Because of the low number of pedestrians, analysis was undertaken for only one arm of this junction. The videoing was undertaken for an eight hour period in the middle of the day (from 9am to 5pm). There were two reasons for the change in the analysis compared with that at other sites. Firstly, the survey period was later in the year when there were fewer hours of daylight. Secondly, there were fewer pedestrian movements to analyse than at most of the other sites. The first two pedestrians in every 15 minute period for the whole day, were studied, concentrating on those pedestrians that cross from the Wellington Avenue side of Farnborough Road to the triangular island and vice-versa (i.e. those using the pedestrian facility with the red/green man, see Figure 6).

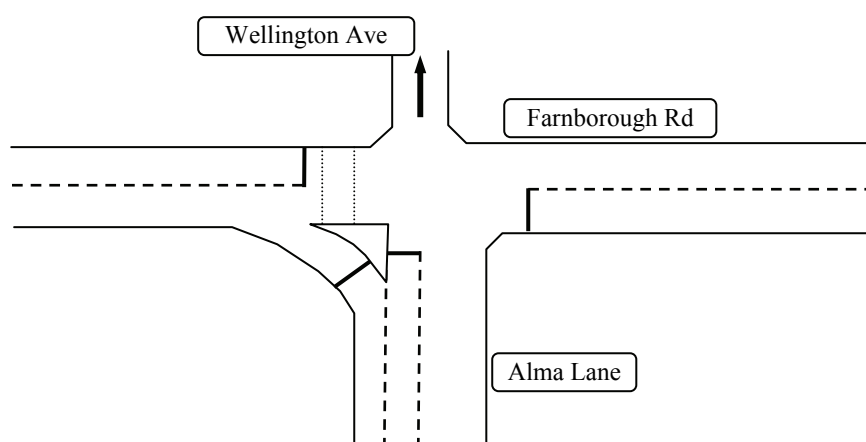


Figure 6: J757 Alma Lane / Farnborough Road schematic

Table 21 shows the numbers of pedestrians arriving on red who were included in the analysis and their mean delay by pedestrian type. With Pedestrian MOVA, the numbers of non-compliers was reduced by a factor of 3 and the mean delay for compliers reduced by 5 seconds.

Table 21: Mean waiting time for anticipators, compliers and non-compliers before and after the change to Pedestrian MOVA (seconds)

	Anticipator			Complier			Non-complier		
	Count	Mean	St. Dev.	Count	Mean	St. Dev.	Count	Mean	St. Dev.
Before	3	28.3	15.50	34	19.0	18.2	33	8.6	10.6
After	6	9.8	5.19	51	13.9	10.0	11	7.9	12.6

This is a remarkably positive result for the pedestrian priority facilities in MOVA. Pedestrian delay for compliers, which was not particularly long in the first place, has been noticeably reduced (27%) with compliance dramatically improved (82% versus 51%). The result bodes well for future use of the facility and there appears to be a good early indication from this that safety could be improved at a number of junctions where currently service to pedestrians is poor.

8. Modelling pedestrians in TRANSYT

TRANSYT is a software package marketed by TRL which is normally used to assess the performance of a network of mainly signal-controlled junctions. Networks are modelled with a series of links and nodes that model the traffic and the junction signal control respectively. Links can be used to model the movement of almost anything around a signal-controlled junction, including pedestrians, and TRANSYT then optimises the signal timings.

8.1 Optimising traffic signals for pedestrians and the effect on other road users

Traffic signals at junctions are usually optimised to minimise delay to vehicular traffic with very little being done to aid other road users, especially pedestrians. Exceptions to this do exist, but usually take the form of capping cycle time rather than any attempts to react to pedestrian demand or to optimise their progression in any real time sense. Some MOVA junctions exist where pedestrians are given priority, but not many. Future developments to MOVA will allow engineers to programme a chosen level of priority and developments to SCOOT are being made to help incorporate Puffin crossings.

The question is whether optimising for pedestrians is possible and the whether the extra delay caused to vehicular traffic, especially in fixed-time networks, or VA actuation at busy times is acceptable or not.

8.2 Example 1

Figure 7 shows a schematic TRANSYT link diagram of an isolated signal-controlled junction with pedestrian phases across the main road entries and exits, on both sides of the junction. It is based on a real junction where the pedestrians have to cross the main road in two separate phases in both cases, the two crossings being separated by an island in the centre of the road.

Pedestrians have been modelled simplistically in this case. Effectively it has been assumed that all pedestrians obey the green man and do not cross in gaps. Modelling pedestrians in this way maximises the sensitivity of the junction to the pedestrians needs and highlights the benefits and disbenefits to them of changes to the signal timings.

8.2.1 Walk with traffic

Figures 8 to 10 shows the results from three runs through TRANSYT of this junction at two arbitrarily chosen flow levels, based on real flows observed at the junction, over a range of cycle times. Note that pedestrian flow has been modelled with separate links for each direction and the progression across the junction is included. A third run with the high flows was undertaken with the pedestrian links set to a high delay penalty in order to further optimise pedestrian progression across the road.

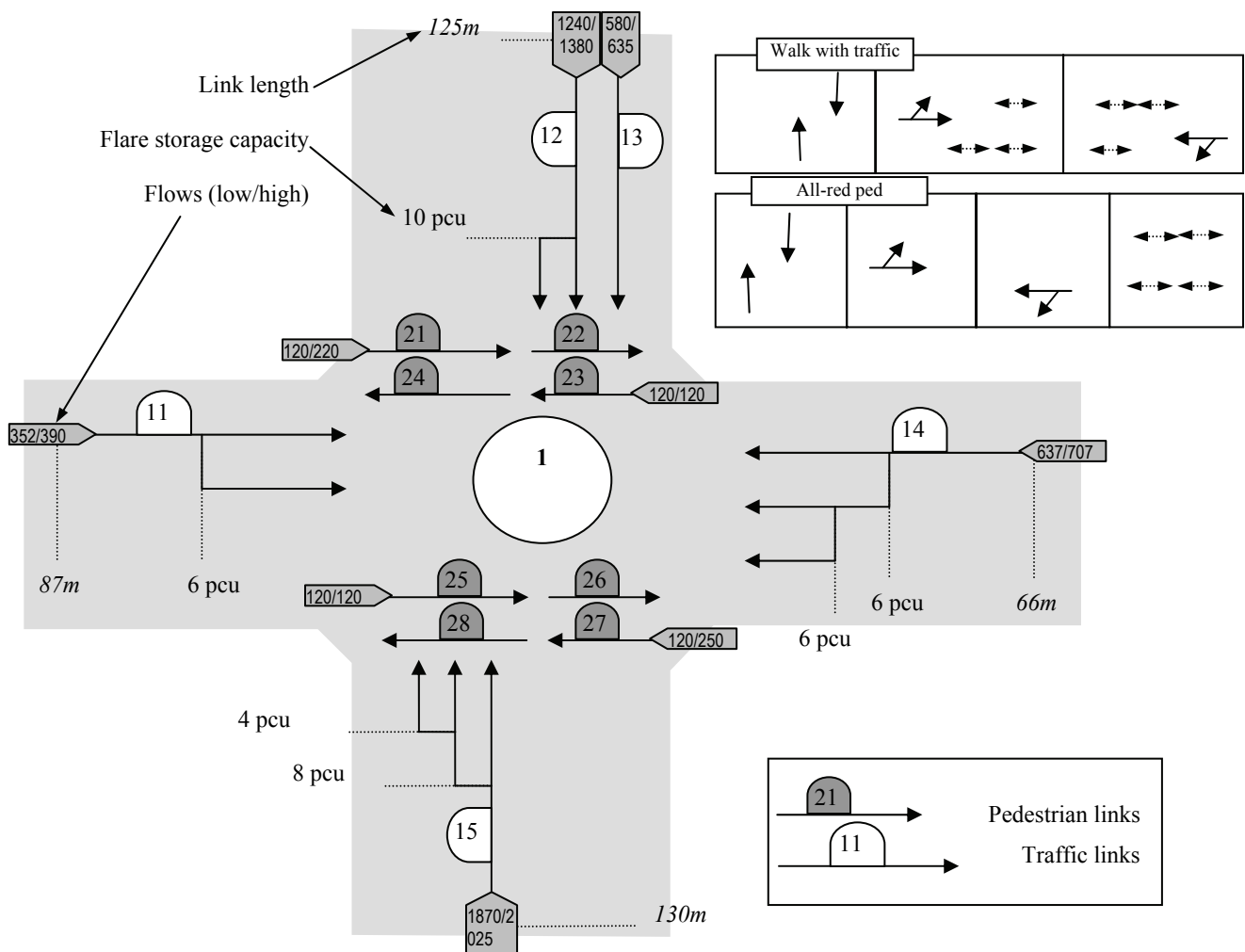


Figure 7: Link diagram

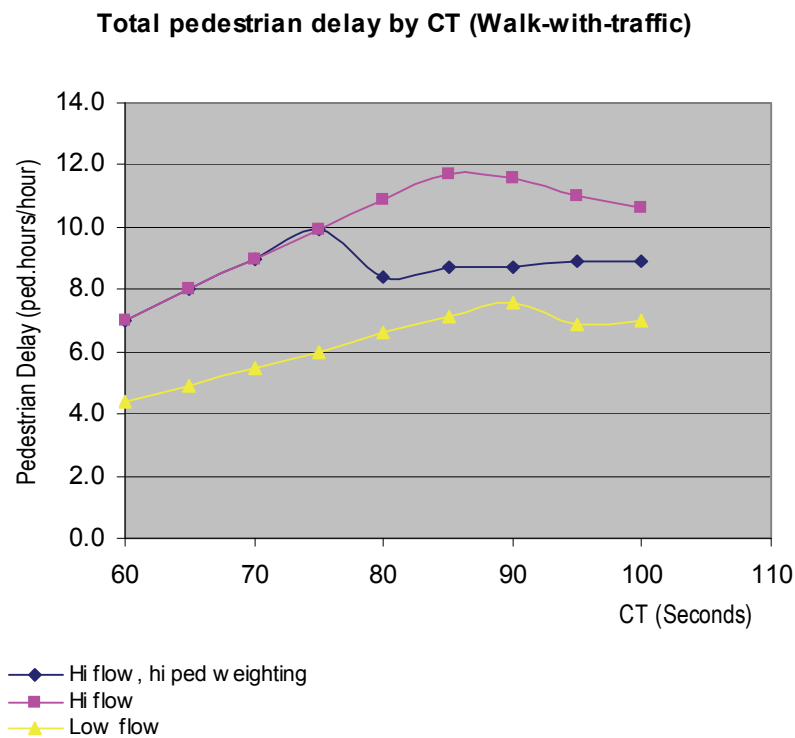


Figure 8: Total pedestrian delay as a function of cycle time (walk with traffic)

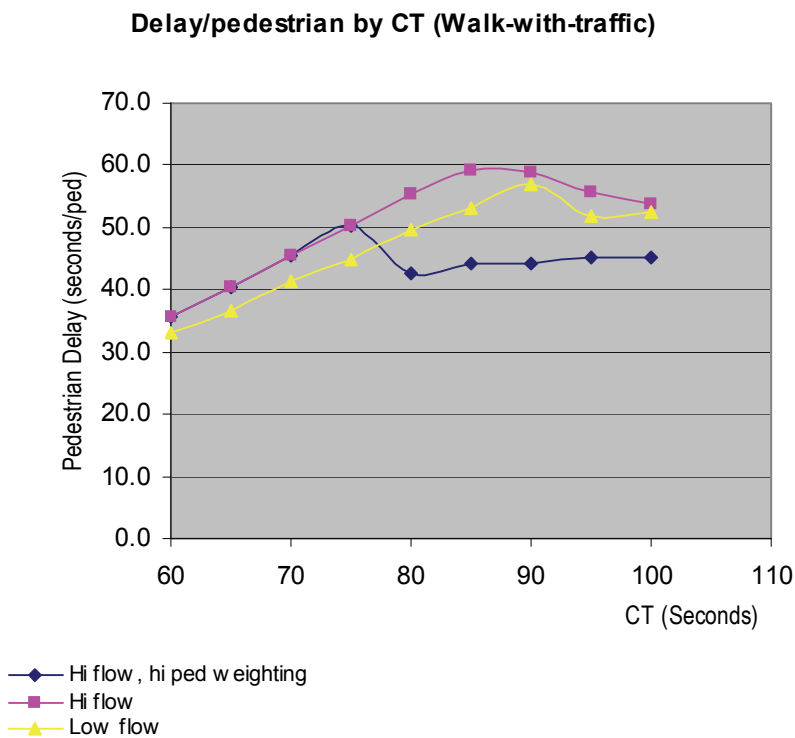


Figure 9: Delay per pedestrian as a function of cycle time (walk with traffic)

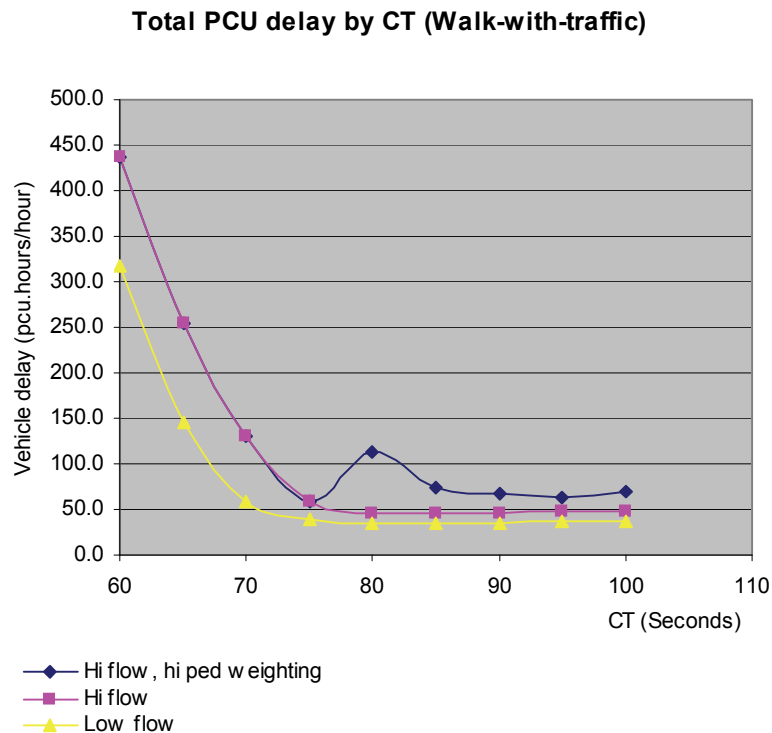


Figure 10: Total passenger car unit delay as a function of cycle time (walk with traffic)

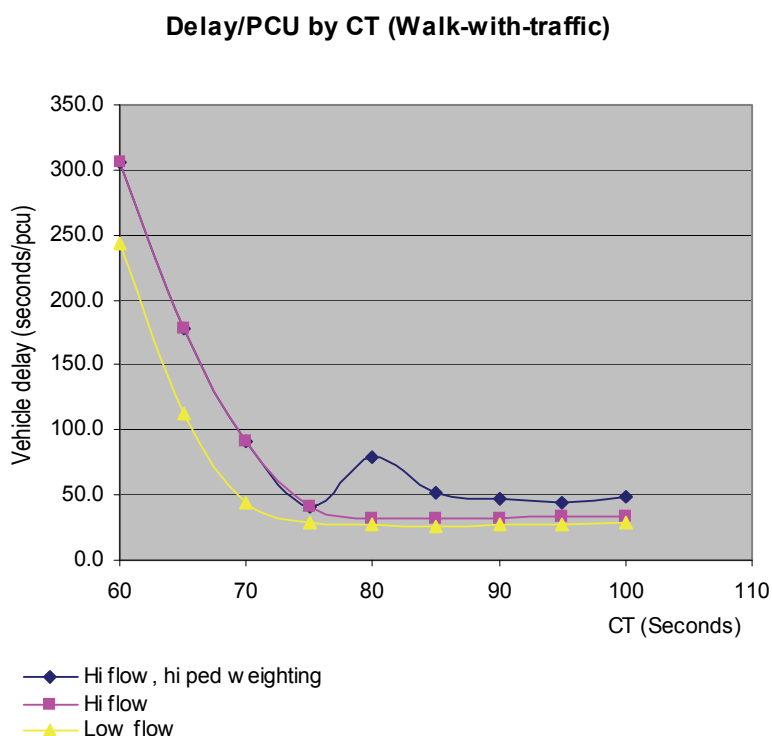


Figure 11: Delay per passenger car unit as a function of cycle time (walk with traffic)

It can be seen that cycle time has a considerable effect on pedestrian delay (Figures 8 and 9). This characteristic is predictable since it is the number of opportunities per unit time that has the most noticeable effect on pedestrian delay as opposed to the length of the opportunity when it does appear. The reason for this is because, with a very high saturation flow, waiting pedestrians will all start to cross easily

within even a short green. There is also some effect of progression at this junction: at the lower cycle times it is possible to obtain good progression across the road in one direction only. At higher cycle times, there are likely to be more opportunities to help progression in both directions. Those pedestrians that do badly in progression terms at lower cycles will benefit from better progression at higher cycle times. Those that do well at the lower cycle times may be worse off with the higher cycle times (even if progression remains good, they will still have to wait longer for an opportunity to cross because of the increased cycle time.)

Delay to vehicular traffic follows a predictable pattern for the relatively simple isolated junction studied here. There is an optimum cycle time, above which there is little variation in delay, but with much higher delays at low cycle times. The delay to vehicles in the runs where pedestrian delay was highly weighted was identical up to somewhere between 75 and 80 seconds, where the delay penalty starts to have an effect. At about 80 seconds, pedestrians benefit noticeably, but with a significant increase in delay to vehicles. After that, vehicular delay improves, whilst the overall pedestrian delay remains improved over the equivalent standard high-flow runs. Vehicle delay remains higher with weighting, but not necessarily unacceptably so at the higher cycle times.

This exercise showed that it may well be possible to provide better progression overall for pedestrians (where they have to cross the main road in two 'hops') and the disadvantage to vehicles may be considered acceptable. However, this is just one example. In other cases, reducing pedestrian delay may not be achievable without significantly disadvantaging vehicles, especially if the traffic flow levels and the junction layout are such that high cycle times are required. The complexity of the problem grows even further when the junction is within a network of coordinated signal control.

8.2.2 All-red pedestrian stage

At many junctions it is impossible to service pedestrian needs without including an all-red (to traffic) pedestrian stage. This has been tried at the above junction by altering TRANSYT to model an all-red period. The period in this case is quite lengthy because the road is four lanes wide and pedestrians would need a relatively long time to cross. The junction has been modelled in this way to make direct comparison with the walk-with-traffic version above valid. The flows and the pedestrian weighting are unchanged.

Pedestrian delay (Figures 12 and 13) grows with cycle time which simply reflects the higher proportion of red to pedestrians, leading to greater number of pedestrians waiting for longer. The delay is similar in magnitude to that experienced under the walk-with-traffic scenario; the small reduction with the all-red pedestrian phase scenario is due to the fact that virtually all pedestrians cross in one go and do not have to stop in the central reserve.

The delay to traffic is increased compared with the walk-with-traffic example because of the greater proportion of time that is red to traffic (Figures 14 and 15). The delay per pedestrian is slightly better, except for the high flow scenario. In truth the model is sensitive to parameters such as platoon dispersion, speed and saturation flow. However, ultimately the model reflects the fact that pedestrians who start to cross late on in the green man period may have to wait in the middle of the crossing. In the higher flow scenario, extra delay is incurred because there are more pedestrians waiting in the middle.

For the run with increased pedestrian weighting, the benefits to pedestrians were achieved by lengthening the pedestrian green period. The reduced delay is the result of allowing a slightly greater number of pedestrians to make their crossing without having to stop, and reducing the waiting time for those who do have to stop.

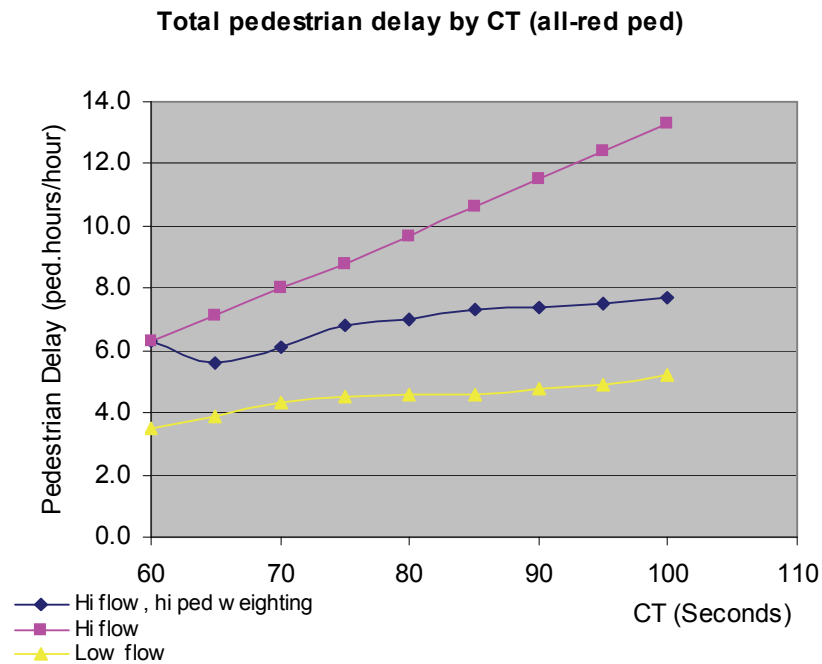


Figure 12: Total pedestrian delay as a function of cycle time (all-red period)

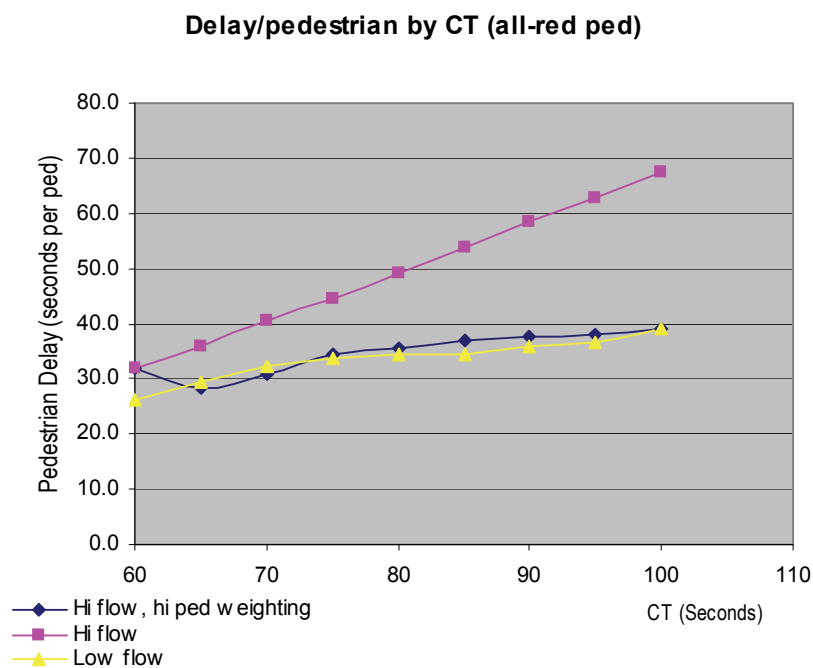


Figure 13: Delay per pedestrian as a function of cycle time (all-red period)

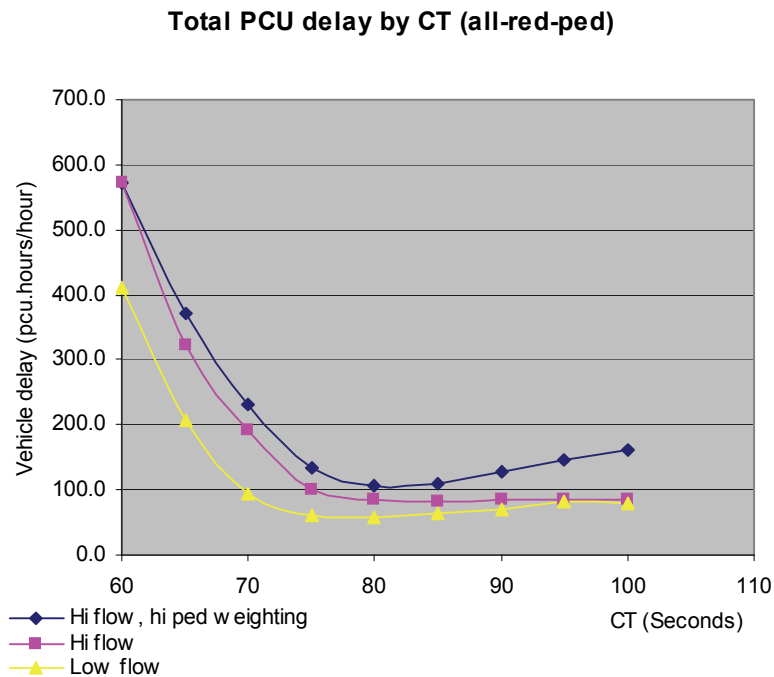


Figure 14: Total delay as a function of cycle time (all-red period)

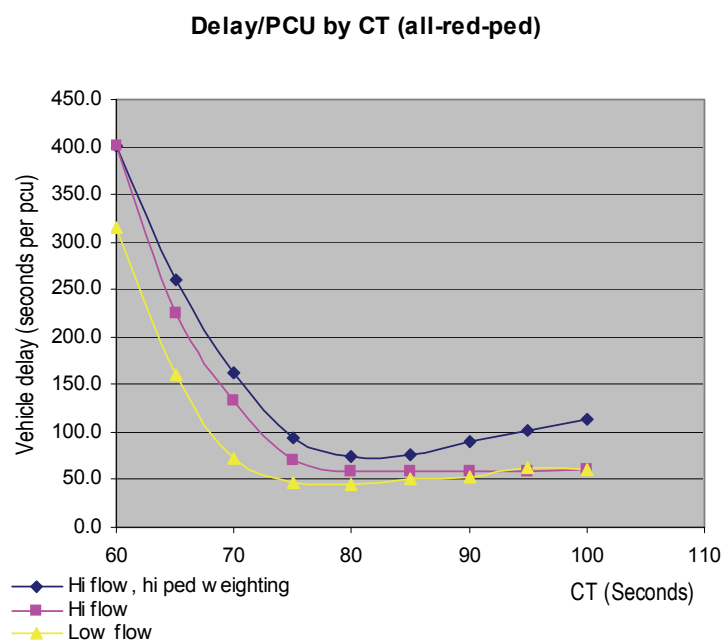


Figure 15: Delay per passenger car unit as a function of cycle time (all-red period)

8.2.3 Conclusions from Example 1

From these trial runs, it can be seen that the most dominant effect on pedestrian delay is that of cycle time. This is as expected since there is rarely an issue with the capacity of the pedestrian crossing (unlike vehicles where insufficient capacity will lead to queuing and, therefore, much higher delay). However, the example was chosen because of the progression issues that pedestrians face when crossing a road which

has a dividing island. At short cycle times, progression in one direction is usually possible, but the other direction then suffers. At higher cycle times, it would appear that it may be possible to provide more equitable progression, and possibly achieve better overall pedestrian delay figures as a result, with acceptable increase in delay to vehicles.

With the all-red pedestrian stage modelled in the second example, progression was not an issue because pedestrians cross the whole approach within one cycle. Longer cycle times lead to the inevitable increase in pedestrian delay in the absence of pedestrian weighting. Weighting pedestrians leads to longer pedestrian crossing times, which reduces pedestrian delay by giving more opportunity to cross without delay, and a shorter delay for those who have to wait. However, there is little point in lengthening cycle times and then giving proportionally less green to traffic. It increases vehicle delay without benefiting pedestrians.

Overall, the results suggest that there may be scope for reducing delay for pedestrians if account is taken of them in the model, and their delay weighted. In practice, this could be worth bearing in mind, but much will depend on the number of pedestrians and the scope for introducing pedestrian-friendly timings.

8.3 Example 2

One of the junctions that was analysed as a case study in the project was in Didsbury, Manchester. The junction is large as can be seen from the site layout diagram (Figure 16). Three of the arms have signal-controlled pedestrian facilities, with one arm having unsignalled pedestrian facilities (i.e. studs and tactile paving etc, but no pedestrian signal aspects). Pedestrians crossing the junction exits on the main (north-south running) road have separate pedestrian phases (i.e. the crossing has to be completed in two 'hops'), with the exit to the north running as a separately controlled stream. The eastern arm requires pedestrians to cross the whole arm in one 'hop'. Both main road approaches have short left-turn lanes cutting off the corners for that movement. These have created islands between the main road, the side road and the left-turn lane. All the pedestrian phases are of the 'walk with traffic' type and run only if requested by the pedestrian demand units. The junction would not be suitable for an all-red pedestrian stage as it is physically too large and the crossing times would require a stage of substantial and unacceptable length.

Pedestrian activity around the junction is relatively modest, but more than enough to require the facilities present. The junction itself is busy during peak periods and during the evening peak it runs a fixed cycle time of 112 seconds. Pedestrians wishing to cross the main road, especially if they want to go from corner to corner, face significant delays if they cross only on a green-man display. However, like most signal-controlled junctions, there are opportunities to cross in gaps in the traffic, against the red man, especially for able-bodied people who make up the majority of pedestrians using the junction.

To investigate the delay to pedestrians, the junction has been modelled in TRANSYT (Figure 17). All pedestrian movements have been modelled, with one corner-to-corner movement (from B to D) separately modelled to assess the impact specifically for that movement. Each of the pedestrian links has been modelled as a 'bottleneck' and as a give-way. This allows parameters to be separately specified for crossing in gaps and during the green man period. The parameters have been chosen so as to simulate the relative difficulty in crossing in gaps, and the relative ease in crossing with a green man. The parameters have been applied somewhat arbitrarily as there is little data to suggest a more accurate modelling method. However, TRANSYT's cyclic flow profile graphs have been inspected to make sure behaviour is not too unrealistic.

Table 22 gives results for the signal cycle, 112 seconds which is currently used on-street at the site for the PM peak. The existing timings at the junction are fixed UTC and are optimised as part of a network of signal-controlled junctions. When optimised as an isolated junction, the timings would not necessarily be the same, but in this case the results are close. The fact that the optimised result appears slightly worse in the table is due to rounding effects within TRANSYT - the actual performance index being slightly better.

The effect of varying the cycle time was predictable. Pedestrians benefit from lower cycle times and the lower the better. Vehicles also benefited very slightly down to about 90 seconds cycle time. However, for the real junction the cycle time would have been optimised from a network point-of-view, not for this junction in isolation.

Table 22: Delay results

Signal timings used	Delay (ped-hrs/hr and pcu-hrs/hr)		
	All peds	B - D peds	Vehicles
Taken from existing timings on site	3.4	1.0	51.0
Optimised over whole junction (including peds)	3.4	1.2	51.2
Optimised for all pedestrians (ignoring traffic)	2.1	1.3	51.4
Optimised for pedestrian movement B – D	3.2	0.9	51.2

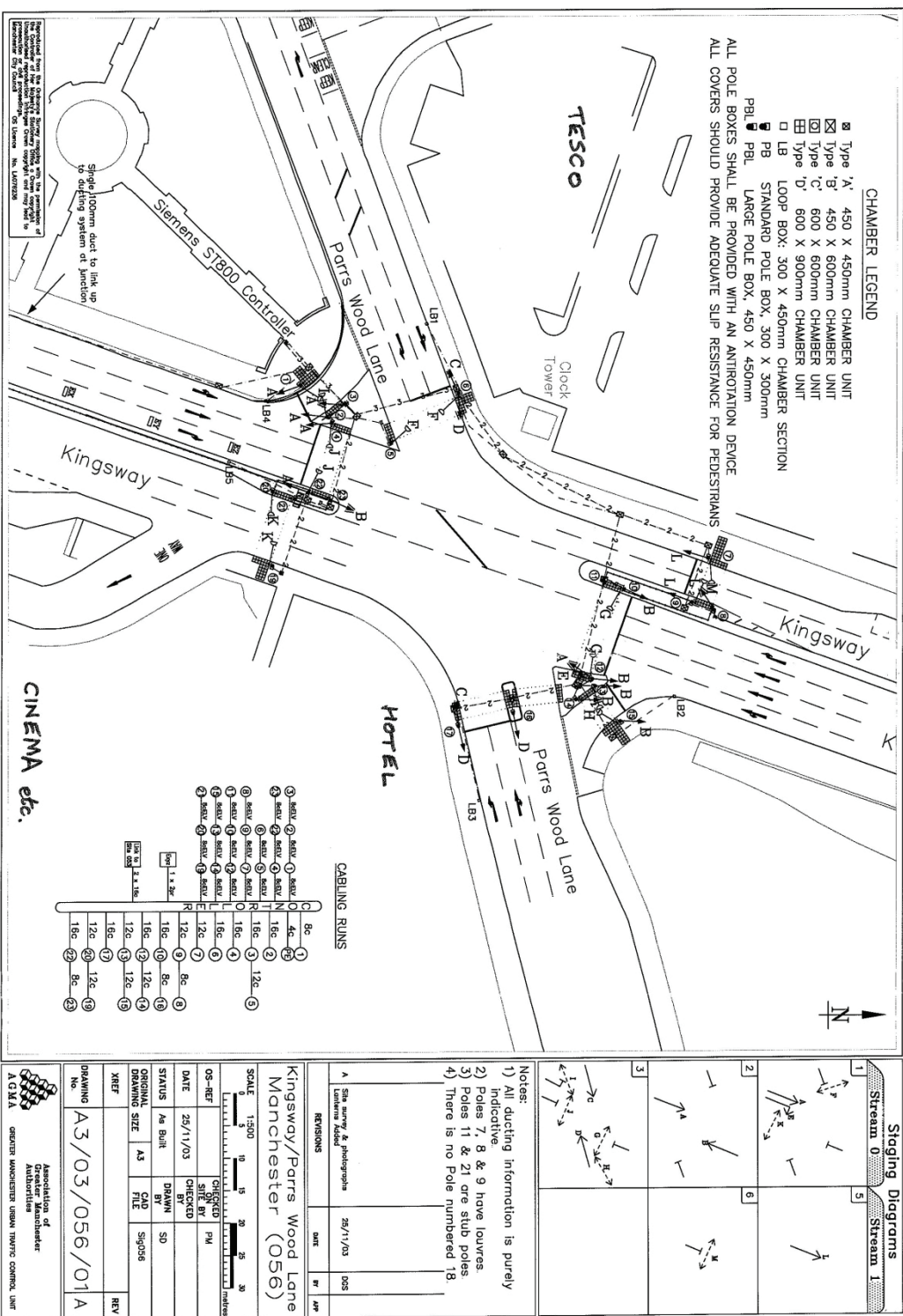


Figure 16 Layout plan for Didsbury

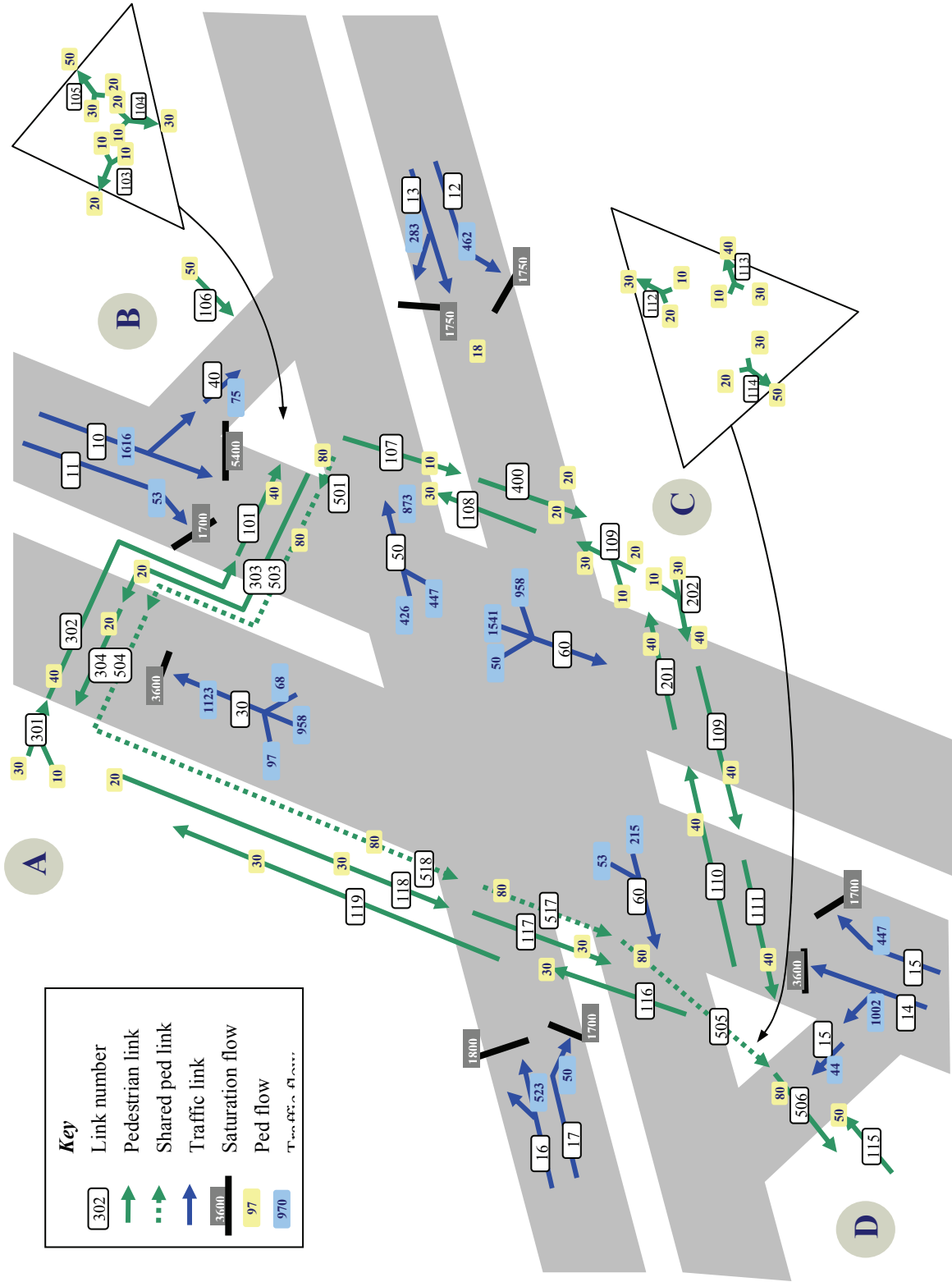


Figure 17: TRANSYT link diagram for Didsbury

Figures 18 to 20 show the delay per vehicle and the delay per pedestrian.

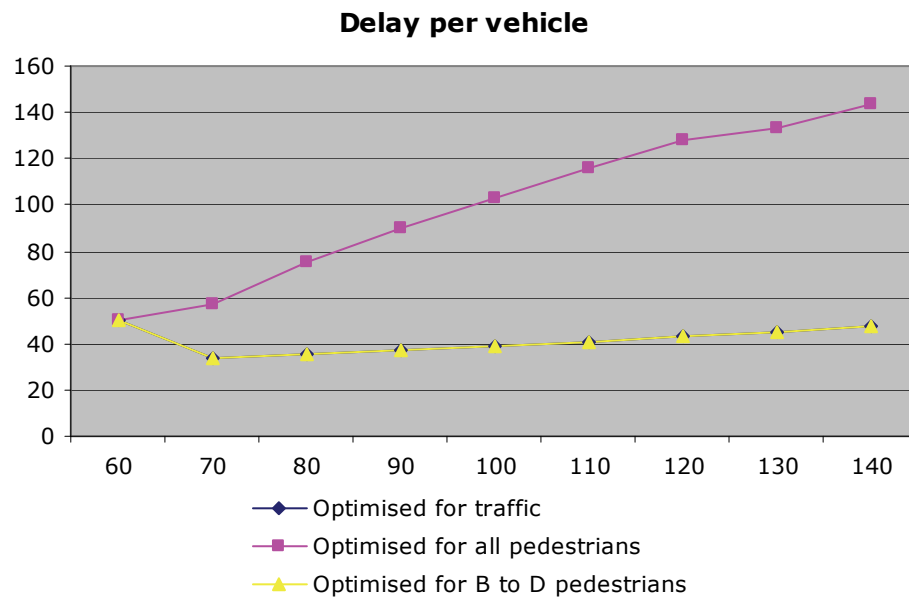


Figure 18: Delay per vehicle

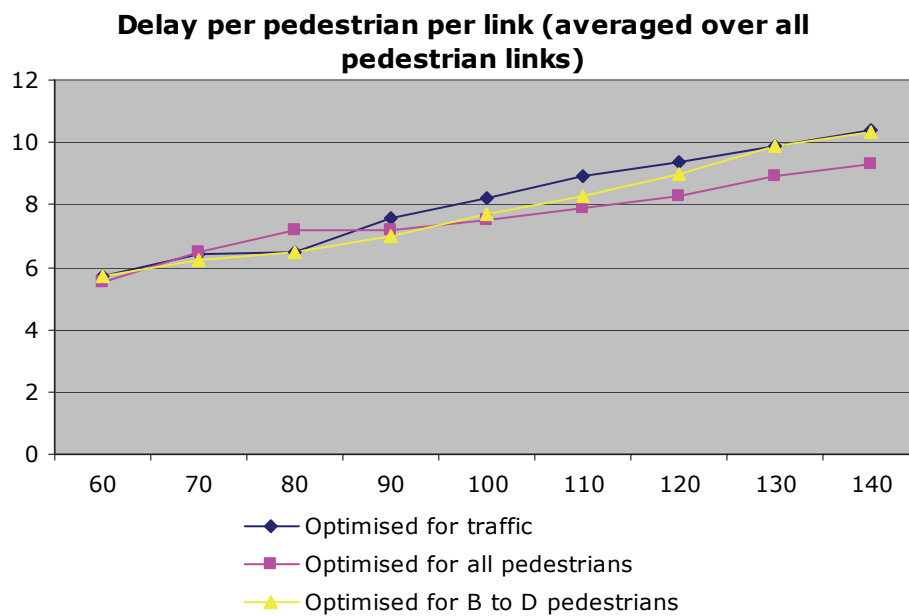


Figure 19: Delay per pedestrian per link

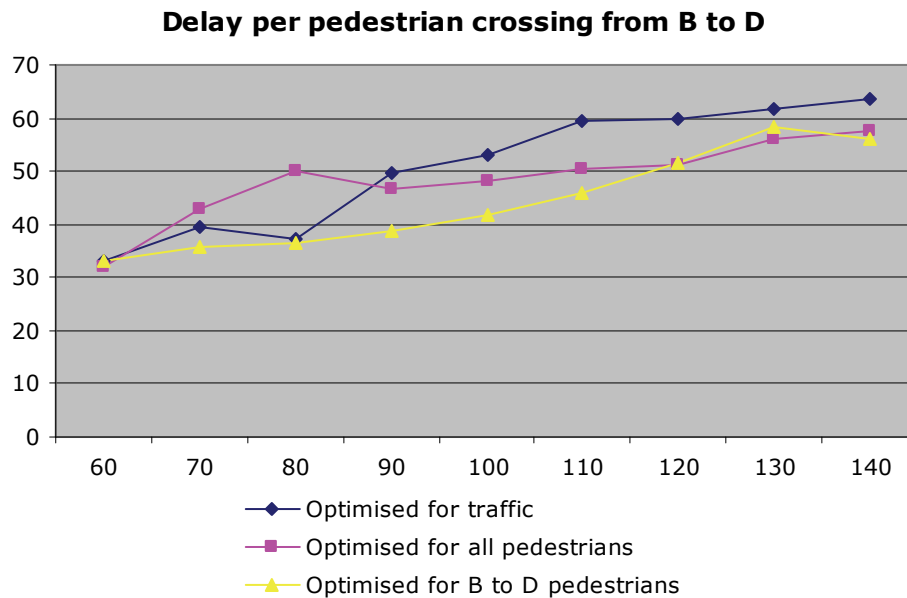


Figure 20: Delay per pedestrian crossing from B to D

8.3.1 Conclusions from Example 2

Once again, pedestrian delay is mostly affected by the cycle time rather than opportunities to progress. Whether it is worth modelling pedestrians may well depend on the nature of the junction being considered. Modelling pedestrians does require rather a lot of extra links in the Didsbury case (27 ignoring the corner-to-corner modelling). For most links, both a bottleneck and a give-way specification will be required (to allow crossing in gaps in the traffic against a red man to be modelled). Didsbury is particularly complex, however, and other situations should mostly be easier to model. At what point the extra effort to specify a model becomes worthwhile is difficult to suggest: sites with high pedestrian flows, particularly if there are dominant movements that may benefit from better progression, may be worth modelling.

There may also be scope for using TRANSYT to decide whether pedestrian facilities are required or not. By modelling particularly what is likely to happen on the junction exits, it is possible to see if there are sufficient opportunities to cross in gaps or not in the absence of pedestrian facilities. A comparison can then be made with the same situation with pedestrian aspects introduced.

For the most part though, pedestrians are likely to gain most in terms of delay when junctions operate at a low cycle time, and this is irrespective of whether the facilities provided are walk-with-traffic or through the use of an all-red pedestrian stage.

8.4 Use of TRANSYT to model pedestrians

As has been indicated above the facilities in TRANSYT permit the modelling of pedestrians. However, there are questions as to how best to model pedestrians. The simplest method of modelling pedestrians is to pretend that they all obey the signals. This has its uses as it maximises the sensitivity of the model to changes in signal control. However, it is not particularly realistic to expect all pedestrians to obey the signals all of the time (unless traffic is so bad that crossing in gaps is impossible). Crossing in gaps can be modelled in TRANSYT and has been attempted in the Didsbury example above. However, the give-way parameters have been estimated with the resulting flow profiles checked merely to confirm that they look reasonable. No attempt has been made to validate the parameters against real observed behaviour. Such validation could potentially be very resource intensive and the benefits of doing so may be small. Without validation the delay results cannot be guaranteed to be reliable, although including a priority model for pedestrians is likely to be more representative of real life than not including one.

Whether modelling pedestrians is productive is something that needs to be considered on its merits in each case. Specifying the additional links requires extra work and the link diagrams become quite complex.

The results also need to be inspected. The extra work would be worthwhile only if pedestrians benefited to a noticeable degree.

9. Advice to Local Highway Authorities

9.1 General advice to improve level-of-service to pedestrians

One of the key objectives of this research project was to provide advice to Local Highway Authorities regarding the application of signal control strategies. Given that the results from the work have not indicated any strong relationship between signal control strategy and safety, guidance is necessarily based as much on common sense and experience as on specific safety issues. However, there is the implication that seeking to increase pedestrian compliance with the signals is desirable. Increasing compliance is likely to be achieved mainly by reducing pedestrian waiting times.

The Department for Transport and the Highways Agency have issued a number of advice notes that describe how to design, commission and maintain pedestrian crossing facilities as follows:

- TAL 5/05, which covers pedestrian facilities at signal-controlled junctions;
- Local Transport Note (LTN) 2/95 covering stand-alone pedestrian crossings (some of which also applies to junction);
- TD 50/04 ‘The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts’;
- Puffin Good Practice Guide (DfT, 2006)
- TAL 2/03 which covers signal-control at junctions on high-speed roads.

The list is not exhaustive and each of the publications refers to other relevant documents.

The advice provided in these documents is highly detailed and is essential reading for anyone designing pedestrian facilities. Taking the results of this project into consideration has not resulted in a need to change any of the advice already given. However, advice in relation to traffic signal control strategies is less detailed in the documents and both the findings of this project and discussions with stake-holders mean that additional advice as set out below is available. Essentially, the aim of the advice is to help pedestrians get a better level-of-service than they otherwise might. The advice below assumes that full pedestrian facilities are present at the junction.

In designing traffic signal schemes, authorities should consider the following:

For junctions

- Consider use of the most responsive signal control strategy available especially if traffic levels are high. The best strategies are likely to be SCOOT for urban networks, MOVA for high speed sites and Compact MOVA for low speed sites.
- Where the control strategy is fixed time (either CLF or UTC) minimise pedestrian waiting times as much as possible by using cycle times that are no longer than necessary.
- Where the control strategy is VA, set the maximums so as to avoid unnecessarily long cycle times.
- Consider the use of Puffin facilities (i.e. call-cancel pedestrian demand and on-crossing extensions, both via the use of suitable detectors) particularly if the junction caters for pedestrians with an all-red (to traffic) stage. The resulting extra efficiency can help in reducing the cycle time necessary which in turn will help pedestrians.
- Where ‘walk-with-traffic’ facilities are considered most appropriate, consider the cross-junction movements that pedestrians are likely to make. Minimise the number of ‘hops’ a pedestrian needs to complete a popular movement (e.g. a corner-to-corner movement) as far as possible. Also note that it is still desirable to minimise the cycle time especially as some movements may potentially require two, three or even more cycles to complete for fully compliant pedestrians.

- Equipment, especially detectors, must be well maintained in order to retain the desired system responsiveness.
- Where using Puffin type facilities, the current guidance must be adhered to.
- Consider night-time operation and whether a different strategy is appropriate, or (in the case of UTC) whether cycle times can be substantially reduced (e.g. where fixed time UTC is in use, produce a night time plan instead of using an off-peak daytime plan). Consider the use of rest-on-red for certain situations.

For stand-alone or mid-block pedestrian crossings (Pelican, Puffin, Toucan and Pegasus crossings)

- It is essential that current guidance is used in setting up Puffin, Toucan and Pegasus crossings.
- It is essential that detection equipment is maintained to a high standard.
- At sites in urban areas, especially at busy crossings, consider using Compact MOVA for best response to pedestrian demands. Alternatively, at less busy sites, consider the use of pre-timed maximum VA.
- At sites in urban areas use one second all-red immediately prior to the green man aspect appearing (unless there are clearly observed reasons for doing otherwise).
- At high speed sites, consider (Standard) MOVA in place of SA/SDE as it will give pedestrians much better service (SA/SDE may encourage pedestrians to take risks by making them wait too long at the same time as not changing when there is a reasonable opportunity to cross).
- In UTC systems, consider the option of not linking with nearby junctions, or making the 'window-of-opportunity' much longer, or appear at least twice in the master cycle. If decoupling is not sensible during the day, still consider decoupling at night or at other quiet times.

9.2 Rest on all-red

Resting on all-red may be an option that improves service levels and safety to pedestrians in a small number of cases. Many junctions return to all-red in the absence of any demands as this means that, at quiet times, the next vehicle or pedestrian will be serviced immediately upon being detected (or nearly so). The fact that the signals were on all-red immediately prior to the change can help moderate the speed of approaching vehicles which may improve safety both generally and for pedestrians.

Resting on all-red has also been put forward as an idea for standalone crossings, again mainly as a means of moderating speeds on the approach.

However there is a potential problem, particularly in respect of stand-alone crossings: if a pedestrian presses the demand button, s/he may well be used to the signals responding by changing to the pedestrian phase immediately; they will in many cases anyway see that the traffic phase is red at that point. They could well start to cross at this time in anticipation of the pedestrian phase running almost immediately, or at least seeing that vehicles will stop due to the red signal.

If a vehicle arrived, putting in a demand just before the pedestrian, the signals will change to the traffic phase rather than the pedestrian phase (and this could arise if the vehicle detectors were faulty and had switched to permanent demand). That first vehicle may well be almost at standstill at that point and not present a threat to the pedestrian. Unfortunately, other vehicles on the approach may well be in a position to pass through the junction/crossing without slowing down, thus presenting a real threat to pedestrians.

At junctions it may not be too much of a problem as pedestrians will have to be more cautious in this more complex environment, probably assessing the traffic situation and/or waiting for the green man. Nevertheless, it may still be an issue and the safety of allowing rest-on-red needs to be considered from the pedestrian's point-of-view.

At stand-alone crossings, it is difficult to see how rest-on-red can be made foolproof for pedestrians, given that they do not have to obey the red/green man and can take their cue as to whether they can cross or not from the signals to vehicular traffic. This questions any safety case and, on top of that, the delay benefits are negligible to pedestrians.

10. Summary and conclusions

10.1 Literature survey

The main findings are as follows:

- Most research relating to pedestrian behaviour is for mid-block crossings and does not consider the effect of signal strategies.
- Pedestrians crossing the road act according to their own convenience. If a gap in the traffic presents itself, they will cross. They will tend to follow their desire lines in preference to diverting to a formal crossing.
- Pedestrians are at increased risk where there are more complex staging arrangements.
- Risk to non-compliant pedestrians is increased if the pedestrian phase ends just as a platoon of vehicles is approaching, which is likely to be the case in a UTC system.
- Pedestrians are more likely to comply with a signal if:
 - They are older
 - They are female
 - Their mobility is impaired by a physical disability or because they are carrying something heavy or accompanying a young child or pushing a pram etc
 - The traffic is heavy
 - Other pedestrians are waiting
 - They have been waiting less than 30 seconds
- There is greater scope for reducing delay to pedestrians at mid-block crossings than at signal-controlled junctions where at least two separate stages are required for traffic, meaning that longer cycle times are required. ‘Walk with traffic’ operation can be used in some cases to reduce delay (mainly to vehicles), but tends to lead to pedestrians having to cross the road in several ‘hops’ and has the potential to increase risk.
- The time taken to cross the road depends on the road width and on walking speed. In the UK, the clearance period is based on an 85th percentile walking speed of 1.2m/s (i.e. the speed exceeded by 85% of pedestrians crossing the road), considered to be a good compromise between operational efficiency and safety. 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-man period. On-crossing pedestrian detection is one method of alleviating this problem but the regular clearance period should be extended if necessary to take account of relevant factors such as a large elderly population in the local area.
- Decoupling mid-block crossings from SCOOT control in off-peak periods was found in one study to improve pedestrian compliance with no significant increase in delay to vehicles. However, this result is likely to depend on the extent to which linking of the adjacent signals is important at the site in question. It would not, for example, be desirable to decouple a standalone crossing if the pedestrian phase then tended to run just as a large platoon of vehicles was about to arrive.
- Timers that count down to the start of the green man period may improve compliance, but are not suitable for use with responsive. Timers that give the time remaining to cross do not suffer from this drawback but may not work well at Puffin style facilities and seem less likely to improve compliance. They are of most use on wider roads that are crossed in a single “hop”.

10.2 Focus groups

Most participants in the focus groups said they would perform risky behaviours similar to those shown to them on video-clips if there were advantages in terms of reduced waiting time or a shorter distance to walk, provided they believed they could cross safely. They were more likely to perform risky behaviours if they were in a hurry, or if others were doing the same thing, and less likely to do so if they had young children with them or were encumbered by heavy shopping.

The participants considered that all-red phases at junctions are a good idea, but they had some important provisos, namely that if one signal-controlled junction had an all-red phase, then all signal-controlled junctions in the area should have all-red phases in order to minimise confusion. In addition, all-red phases are less worthwhile if their presence substantially increases the cycle time and thus leads to longer waiting times for pedestrians.

Although participants were not familiar with countdown timers, the idea of a countdown display giving the number of seconds remaining until the green man appears was popular with adults and adolescents alike. However, they felt that if the timer indicated too long a wait, pedestrians would be more likely to cross the road without waiting for the green man.

Participants also suggested more education in schools, including showing typical examples of poor behaviour, and legislation to enforce pedestrian compliance.

10.3 Case study analysis

For the purposes of the case study analysis, pedestrians were classified in terms of their behaviour as Non-delayed, Compliers (who arrive when the red man is showing and wait for the green man), Late Starters (who fail to finish crossing before the signal changes to red) and Anticipators (who start to cross just before the green man). Not surprisingly, compliers had the longest delay time. A majority of pedestrians were non-compliers, crossing during gaps in the traffic.

The results broadly confirmed the findings from the literature survey: men on average crossed slightly faster than women and younger people crossed more quickly than older ones. Pedestrians who were impeded in some way crossed more slowly than those who were not and were more likely to comply with the traffic signals.

A high proportion of accidents at the case study sites were found to have occurred late at night or in the early hours of the morning.

10.4 Potential strategies to improve safety

The obvious way to try to increase compliance and thereby potentially improve safety is to increase responsiveness by switching to the green man as soon as possible after the demand is made, or by reducing the cycle time, or by increasing the proportion of the cycle that can be used by pedestrians. This was trialled at two different Puffin crossings, in one case by a change to pre-timed maximum under VA and in the other by increasing the window of opportunity for the pedestrians phase within the cycle under fixed time. In both these cases, there was a reduction in mean waiting time for pedestrians overall. However, although pedestrian delay was reduced, there was no change in the level of compliance.

Compliance might be improved by the type of countdown device that told pedestrians how long they have to wait for a green man, particularly if the waiting time is short. It might encourage children to adopt the 'correct' crossing behaviour. However, it is unlikely to change the behaviour of those pedestrians who are starting to cross within the amber-to-vehicles period. This type of timer is not likely to be suitable in traffic/pedestrian responsive signal control strategies. Responsive systems such as MOVA and VA, for example, it is not possible to provide more than a second or so advance notice of when the signals are about to change. Such systems, in being more responsive to pedestrians, may be the safer option however.

Having non-exclusive pedestrian phases may reduce waiting time for pedestrians before they start to cross, but the total time taken to cross may increase if pedestrians have to wait in the centre of the road. A staggered crossing arrangement can increase the crossing distance.

A trial of Compact MOVA for pedestrians at a junction gave encouraging results, reducing delay and considerably increasing compliance.

10.5 TRANSYT modelling

TRANSYT modelling was undertaken to look at the balance of delay between vehicles and pedestrians. This suggested that the dominant factor affecting pedestrian delay is that of cycle time. This finding is as expected since there is rarely an issue with the capacity of the pedestrian crossing (unlike vehicles where insufficient capacity will lead to queuing and, therefore, much higher delay). Overall, the results suggest that there may be more scope for reducing delay to pedestrians if account is taken of them in the model, and some attempt made to weight them. In practice this could be worth bearing in mind, but much will depend on the number of pedestrians and the scope for introducing pedestrian-friendly timings.

10.6 Conclusions

Pedestrians will cross the road during gaps in the traffic whatever the signal strategy adopted. Although reducing their delay should reduce the need for this, it will not necessarily increase compliance, which is mainly influenced by the level of flow. The lack of compliance does not necessarily imply a lack of safety. Most adults will be capable of judging correctly whether or not it is safe to cross. Children and older people will have more difficulty in making this judgement, but the latter are also more likely to comply with the signals.

A high proportion of the pedestrian accidents at the (urban) case study sites occurred late at night or in the early hours of the morning, suggesting that the pedestrians involved may have been drinking. There may therefore be merit in considering different signal strategies late at night. Alternatives include decoupling from UTC, running night-time plans having a much shorter cycle time, and 'rest on red'. As ever, options should be considered on their merits for any given set of circumstances.

Pedestrians tend to follow their desire lines regardless of the crossing location and this should be taken into account when signal-controlled crossings are installed.

Cycle time rather than the signal strategy employed has the dominant effect on pedestrian delay for those pedestrians who comply with the signals. Signal settings are generally optimised for vehicles. The scope for reducing the cycle time in congested conditions is limited, but should be routinely undertaken when traffic signals are installed or timings updated.

It was not possible to determine a link between the different signal strategies and pedestrian safety. Although giving more green time and increasing responsiveness can improve pedestrian compliance to a degree. However, this will be at the expense of vehicle delay and it is not practical at the busier junctions, except during the less busy periods of the day.

The use of Compact MOVA for pedestrians should be trialled at more sites to see if the benefits indicated here apply more widely.

10.7 Guidance to Local Highway Authorities

One of the key objectives of this research project was to provide advice to Local Highway Authorities regarding the application of signal control strategies. Given that the results from the work have not indicated any strong relationship between signal control strategy and safety, any guidance will necessarily be based as much on common sense and experience as on specific safety issues. However, there is the implication that seeking to increase pedestrian compliance with the signals is desirable. Increasing compliance is likely to be achieved mainly by reducing pedestrian waiting times.

One note in particular is the importance of taking into account local factors, such as a large elderly population, presence of a school or community centre, presence of shops when determining signal timings. This may become more important in the future in view of demographic changes leading to an increase in the proportion of older people in the general population.

Both the Department for Transport and the Highways Agency have issued much detailed advice about pedestrian crossings. Taking the results of this project into consideration has not resulted in any need to change any of this advice. However, advice in relation to traffic signal control strategies is not given in much detail in the current advice and both the findings of this project and discussions with stake-holders means that additional advice can now be offered. Essentially, the aim of advice is to help pedestrians get a better level-of-service than they otherwise might.

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The effect of traffic signal strategies on the safety of pedestrians



TRL was commissioned by the Department for Transport (DfT) to consider the effect of signal control strategies on casualties, particularly for pedestrians and to provide input into the decisions faced by practitioners in optimising the split between safety and delay.

A literature review was undertaken to determine what research had been undertaken to date. Some instances of poor pedestrian behaviour were discussed by focus groups in order to gain insight into the underlying reasons. A total of 16 signal-controlled junctions and 6 mid-block crossings with different forms of signal control were selected as case studies. Details of the junction or crossing layout and signal timings were recorded. A four hour video survey was undertaken at each site and flow counts and extensive behavioural analysis undertaken. Alternative strategies were then tested and any changes in pedestrian behaviour evaluated. TRANSYT modelling was undertaken to investigate the trade-off between vehicle and pedestrian delay.

One of the key objectives of the project was to provide advice to Local Highway Authorities regarding the application of signal control strategies. Given that the results from the work did not indicate any strong relationship between signal control strategy and safety, guidance will necessarily be based as much on common sense and experience as on specific safety issues. However, there is an implication that seeking to increase pedestrian compliance with the signals is desirable. Increasing compliance is likely to be achieved mainly by reducing pedestrian waiting times.

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