ENHANCED OPERATING STRATEGIES TO IMPROVE PEDESTRIAN AMENITY AND SAFETY AT MIDBLOCK SIGNALLED PEDESTRIAN CROSSINGS

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1. INTRODUCTION

In recent years there has been a major change, some would say a U turn, in UK Government policy on the use of the private car. Transport policy during the period of the Thatcher Government of the 1980s emphasised the role of the private car as a symbol of personal freedom. Traffic management in urban areas focused on the requirement to move cars through the urban road network with minimum delay. The development and widespread use of Urban Traffic Control systems such as TRANSYT and SCOOT further emphasised the perceived requirement to minimise vehicle journey times. In many instances the requirements of vulnerable road users such as pedestrians were given a relatively lower priority with the result that particularly in UTC areas pedestrian level of service was low at signalled crossings both at midblock and at junctions.

During the 1990s there has been a growing awareness of the need to redress the balance, with traffic engineers and transport planners giving greater weight to the needs of pedestrians. At the same time Government has gradually recognised the impossibility of providing sufficient road space to satisfy increasing demand by road vehicles. This, coupled with concerns about the environmental effects of road traffic, has led to the pursuance of policies that seek to reduce dependence on the car and encourage the use of other modes of transport. For local journeys walking is seen as a suitable alternative mode of transport. The development of policies to encourage walking is likely to accelerate following the change of Government in May this year.

One of the ways in which walking can be encouraged is to improve the level of service offered to pedestrians when they need to cross the road. The United Kingdom has more than 11000 Pelican crossings (County Surveyors’ Society, 1994) installed between junctions to provide pedestrians with signal protected periods in which to cross streams of traffic between junctions. Midblock provision of signalled pedestrian crossings is much greater in the United Kingdom than in most other countries. A new type of signalled pedestrian crossing, the Puffin (Pedestrian User Friendly Intelligent), Davies (1992), is being evaluated at both signal controlled junctions and at midblock. The Puffin crossing eliminates unnecessary pedestrian precedence periods and extends crossing time for pedestrians. However the basic strategy and timings during periods of vehicle precedence are similar to those employed at Pelican crossings.

This paper considers possible strategies to improve pedestrian amenity and potentially
reduce pedestrian casualties at midblock signalled pedestrian crossings such as the Pelican and Puffin. Ongoing research to develop appropriate strategies is also described.

2. BACKGROUND

Before considering changes to operating strategies it is useful to review briefly the development of midblock signalled pedestrian crossings in the United Kingdom. Pedestrian phases associated with traffic signals have been in existence since the 1930s but were employed infrequently between junctions until the 1960s. In the 1960s there was a determined effort to develop midblock signalled pedestrian crossings which retained some of the flexibility of the Zebra crossing. A major objective, which has continued to the present time and which has been given a higher priority in the United Kingdom than elsewhere, was to avoid holding vehicles on a red signal at times when pedestrians have cleared the crossing. Panda crossings, which had surface road markings and a complex sequence of signal aspects including no display during periods of vehicle precedence, were installed at 45 locations in 1962 but received widespread criticism. A new experimental crossing, the X-Way, which had a simpler set of signal aspects and with a white cross displayed to indicate vehicle priority was installed in 1967. The white cross was confusing for drivers and was replaced by the normal green light with the improved crossing forming the basis for the introduction of Pelican crossings in 1968. The benefits of the Pelican crossing were described by the Department of the Environment (1968) as '.... the new type of crossing will be able to assist traffic flow at the right sort of site..' (authors' italics).

Initially all Pelicans were fixed time but, in revised criteria (Department of the Environment, 1968) vehicle actuated Pelicans were recommended for use at all sites where the 85 percentile speed exceeds 35 mph. The specification (Department of the Environment 1975) for vehicle detection at Pelicans at that time recommended loops at 79m from the stop line with speed discrimination equipment also installed at higher speed sites. A new standard (Department of Transport, 1979) detailed new requirements for vehicle actuated operation of Pelicans while retaining the option, for roads subject to a speed limit of 30 mph, to operate Pelicans on a fixed time basis. On roads with a 30 mph limit vehicle actuation was to be either based on a single loop at 39m from the stop line with a 4s extension, or a multi loop configuration such as System D. The maximum vehicle precedence period for both fixed time and vehicle actuated operation was set at 40s. This was extended to 60s by a further revision (Department of Transport, 1987). Microwave vehicle detection was included in recommended strategies for vehicle detection on roads with a speed limit of 30 mph.

Over the period of more than 20 years since Pelicans were first introduced the sequence and timing of signal aspects have been adjusted in response to comments received. The basis of operation has, however, remained substantially unchanged and complaints have continued. The Puffin, which was developed in the late 1980s, uses pedestrian detectors at both kerbside and on the crossing with the objective of improving efficiency and reliability. Trials at two junctions were sufficiently promising to encourage the installation of midblock Puffin crossings at 50 sites on trunk roads. Results from these sites which include town centre locations are not yet available but Reading et al. (1995) reported that the performance of kerbside pedestrian detectors is
not fully satisfactory and that alternative methods, including low cost image processing, of detecting pedestrians at kerbside are under active consideration. Midblock Puffin crossings are designed to cancel unnecessary pedestrian precedence periods and to provide more effective control of the pedestrian precedence and clearance periods. It is too early to assess whether Puffin crossings have been successful in achieving these objectives.

The operational strategies for both Puffin and Pelican crossings (Department of Transport, 1995) are based on default priority for vehicles with pedestrian right of way available, on demand, at times and with frequencies that are consistent with minimising delay to vehicle occupants. Pedestrian precedence periods are typically in the range 6-16s and are intended to provide sufficient time for a pedestrian who steps on to the carriageway during the green man to reach the footpath on the farside of the road. At Fixed Time Pelican crossings the vehicle precedence period terminates, subject to the expiry of a preset minimum in the range 20-60s, on pedestrian demand. At Vehicle Actuated crossings the vehicle precedence period terminates on pedestrian demand subject to a preset minimum in the range 6-15s and either a gap in vehicle flow or the expiry of a preset maximum time of up to 60s. The preset vehicle precedence periods for both Fixed Time and Vehicle Actuated crossings are usually determined to ensure that the crossing operates well within the vehicle capacity. At the substantial numbers of remaining Fixed Time Pelicans this procedure inevitably result in unnecessary pedestrian delay outside of peak periods.

3. ALTERNATIVE OPERATING STRATEGIES

3.1 Scope

Current UK Government policy is to discourage car use and encourage pedestrians in built up areas. In this context it is now possible to consider operating strategies for signalled midblock pedestrian crossings which discriminate positively in favour of the pedestrian. In evaluating alternative strategies it is, however, appropriate to consider the impact on vehicle occupants and to ensure that there is no safety disbenefit to either car occupants, pedestrians or any other road users. It is unlikely that a single strategy will be appropriate for all roads in all circumstances and a range of strategies, including those currently used, will need to be available. There are a number of issues, including the following, which should be considered in developing alternative strategies.

- Vehicle drivers are legally required to obey a red signal; in the United Kingdom pedestrians are not legally required to obey a red man signal.

- If the vehicle capacity of the crossing is exceeded, vehicle delay will be excessive. Long queues of vehicles may also lead to an increase in emissions which would be detrimental to pedestrians. Saturation flow at Pelican crossings is typically 1400 veh/h/ lane. (Hunt and Griffiths, 1991). Design peak hour flow for a 7.3m wide two way single carriageway road is in the range 850-1000 veh/h/ lane for less than 15% HGV (Department of Transport, 1985).

- The saturation flow of pedestrians is substantially higher than for vehicles so that at
most locations the pedestrian capacity of the crossing will not be exceeded even if pedestrian precedence periods are short and infrequent.

- Pedestrian tolerance of waiting time is much lower than that of vehicle occupants; an upper limit of 30s is typical for pedestrians.

- Typically, vehicle flow varies with time of day with much lower vehicle precedence periods acceptable, in terms of vehicle capacity, at off-peak times.

- Intelligent traffic systems and associated technology are developing rapidly and allow the implementation of more sophisticated control strategies than has been possible in the past.

The extent of the current move towards higher levels of service for pedestrians and lower levels of service for car occupants in urban areas is unclear. If the objective is to actively discourage car use in urban areas then strategies which impose substantially higher delay on vehicle occupants at midblock signalled pedestrian crossings in order to reduce delay to pedestrians may be considered acceptable. Indeed further to the realisation that new roads (or increased capacity) generate traffic, the DOT and London Transport are currently funding a study to determine what happens when capacity is reduced (Local Transport Today, 1997). If the hypothesis that traffic will be depressed is proven then pedestrian crossing strategies that can contribute to capacity reduction may be viewed favourably.

### 3.2 Positive discrimination in favour of pedestrians

One possible strategy at locations, where pedestrian activity is high and vehicle occupants are to be given a low priority, would be based on reversing the current default priority to vehicles by giving pedestrians precedence by default. An outline of a, seemingly radical, strategy of this type would be developed on the basis that, in the absence of sufficient vehicle demand, the signals would display red for vehicles and green man for pedestrians. A change to vehicle precedence would follow vehicle demand and the earlier of:

- the expiry of a preset maximum waiting time for vehicles, or
- the identification of a suitable gap in pedestrian presence on the crossing.

Once established the vehicle precedence period would continue until the earlier of:

- the time at which the vehicle discharge rate fell below a predefined level, or
- the time at which a preset pedestrian maximum waiting time expired.

The detailed design of the operating cycle would need careful consideration to ensure safe operation. The potential benefit to pedestrians of a strategy of this type is clear as is the potential disbenefit to vehicle occupants who may find themselves held by a red signal at times when pedestrian occupation of the crossing is minimal. This could be regarded as the opposite of the current cycle in which pedestrians are held by a red man at times when vehicle flow is minimal. In assessing the level of impatience likely to be experienced by vehicle drivers, the differing legal requirements for vehicle driver and pedestrian compliance with signal indications needs to be taken into account. The implementation of a strategy of this type would need the approval of the general public. This approval is only likely to be forthcoming in the context of an accepted
National Policy of positive discrimination in favour of pedestrians.

3.3 A balanced approach

It should be possible to achieve a substantial improvement in pedestrian level of service at signalled midblock crossings without substantially increasing vehicle delay. At most crossings vehicle precedence is retained during periods when vehicle flow is sufficiently low for pedestrians to identify gaps in vehicle arrivals in which they can cross the road. Current operating strategies impose substantially higher delays on pedestrians who obey the signal indications. The United Kingdom differs from most other countries in not requiring, by law, that pedestrians obey signal indications.

There is a strong incentive for pedestrians to seek to reduce their delay by crossing in gaps in traffic flow when the red man is showing. Griffiths et al (1984) found little difference between the performance of Fixed Time and Vehicle Actuated Pelicans measured by the percentage of pedestrians who start to cross the road during the red man. This is surprising since it would be expected that Vehicle Actuated Signals would respond to gaps in vehicle flow and hence provide a green man at appropriate times. It may be inferred that at Pelican crossings vehicle detection systems, most of which have changed little since the 1980s, are either not responding to gaps which pedestrians perceive as safe crossing opportunities or are not responding sufficiently rapidly.

Pedestrians become particularly impatient when a red man continues to be shown during periods of low vehicle flow. The reduction of unnecessary delay for pedestrians who obey the signal indications would encourage more pedestrians to use the facility correctly and reduce pedestrian annoyance and risk taking. 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. The potential improvement in pedestrian amenity can be demonstrated using simulation as described by Chik(1996).

Figure 1 compares measures of performance for standard Vehicle Actuated Pelicans, with fmax set at 30 s and 60 s respectively, and a Pelican operating under an alternative strategy as described below. The measures of performance are taken from simulation results for a two way single carriageway operating as 2 lanes. There are complex interactions between behavioural characteristics which can confuse the basic comparison. For this reason the simulation results are based on a model in which it is assumed that all pedestrians register their demand on arrival at the crossing. All Pelicans have basic timings as below:

minimum vehicle green 7s; amber 3s; all red 1s/3s; green man 5s; flashing green man 8s; red man/flashing amber 1s

The standard Vehicle Actuated Pelican has System D vehicle detection, with detectors located at 39m, 25m, 12m from the stopline; for the alternative strategy detectors are located at 25m and 150m from the stopline with vehicle speed measured at the outer detector.
In simple terms System D will not allow a gap change if there are one or more approaching vehicles within the detection zone of about 80m centred on the crossing. The alternative strategy allows a pedestrian precedence period to start provided there are 5 or less vehicles within the detection zones of 25 to 150m upstream either side of the crossing, and that a change of signal aspect will not result in vehicle delay exceeding a predetermined threshold. The criteria employed were established by trial and error. Cumulative weighted vehicle position within the detection zone was used as a measure for vehicle potential delay, the threshold was established by trial and error. The use of a combined criteria of a threshold for weighted position and the limit on the number of vehicles within the detection zone also serves as a proxy definition of occasions when pedestrians are likely to cross during the red man period.

The results are shown for vehicle flow in the range 200 - 1000 veh/h/lane, and three levels of pedestrian flow; 200 ped/h, 500 ped/h and 2000 ped/h. For the standard Vehicle Actuated Pelican the variation, in measures of performance, with vehicle and pedestrian flow are as expected. The key features of the differences in performance of the alternative strategy are:

- lower cycle times, indicating a more responsive system, particularly at low to medium vehicle flow

- a small increase in vehicle effective red time, implicitly indicating a transfer of benefit to pedestrians

- a substantial reduction in the percentage of pedestrians crossing during the red man

- a reduction in pedestrian mean delay at medium to high vehicle flow; the absence of a reduction at low flow is a consequence of red man crossing by pedestrians using the standard Vehicle Actuated Pelican

- a complex effect, varying with vehicle and pedestrian flow, on vehicle mean delay; overall, any increase in vehicle delay is small

These results are based on a simulation model and are influenced by algorithms modelling the behaviour of pedestrians and vehicle drivers. They are however very encouraging and led to the initiation of a research programme to develop strategies suitable for implementation in practice.

4. CURRENT RESEARCH TO DEVELOP A MORE RESPONSIVE STRATEGY

4.1 Objectives

The aim of the current work is to investigate the feasibility of components of strategies to improve pedestrian amenity and reduce pedestrian casualties at midblock signalled pedestrian crossings. The proposed alternative strategies are based on the concept that it is possible to identify, in advance, a sequence of vehicle arrivals at a midblock signalled pedestrian crossing which the average pedestrian would perceive as a
crossing opportunity. The notion of the average pedestrian is considered on the basis that to discriminate using information such as age and gender would be inappropriate given the capabilities of pedestrian detection technologies. Continuous monitoring and interpretation of detector data in real time is required to provide a responsive system of this type. The enhanced strategies will minimise disbenefit, which may otherwise be associated with a system which is more responsive to pedestrian demand, to vehicle occupants by making more effective use of periods of low vehicle flow. The enhanced strategies depend on the ability to identify periods of low vehicle flow as perceived by pedestrians, and to determine projected potential vehicle delay associated with the identified periods. The specific objectives to satisfy the aim are to:

- develop a neural network technique to identify vehicle arrival patterns which represent a gap crossing opportunity for the average pedestrian

- develop a neural network technique to predict projected potential vehicle delay associated with the identified vehicle arrival pattern assuming a change to pedestrian precedence at the signalled pedestrian crossing

- use microscopic simulation to demonstrate, for a typical midblock signalled crossing, the benefits of employing an enhanced operating strategy based on the above

### 4.2 Methodology

Established models (Tanner, 1951) of pedestrian road crossing delay are based on strategies in which pedestrians respond to symmetrical nearside and farside gaps. Hunt and Griffiths (1991) have used an alternative approach to assemble a series of matrices representing observed pedestrian road crossing decisions for sequences of vehicle arrival times at a random roadside location. The matrices show the probability of pedestrian acceptance of tabulated time gaps, which define the arrival sequence of nearside and farside vehicles and were constructed from analysis of more than 13000 pedestrian manoeuvres. The matrices may be used, for example in microscopic simulation, to determine the probabilities of pedestrian acceptance of crossing opportunities represented by the time gap to the next nearside vehicle arrival, and the time gaps to the arrivals of pairs of successive farside vehicles between which a pedestrian might elect to cross. This process would not be suitable for online application on street. A number such crossing opportunities typically present themselves to a pedestrian at a given point in time and would all need to be considered to determine whether the pedestrian elects to step onto the carriageway. Further nearside vehicle arrivals may provide additional explanatory variables associated with a gap acceptance decision. Additional variables considerably augment the number of matrices that would be required for a decision to be made. Pursuance of this approach is consequently likely to place excessive computer processing demands on existing signal controller equipment. Artificial neural networks (ANNs) provide a tool for developing an appropriate on line system that can interpret a greater number of possible explanatory variables in an efficient way with a potential enhancement in performance.

ANNs have become an increasingly popular analytical technique in recent years with a
wide range of applications in transport (Dougherty, 1995). An ANN model is essentially a transfer function relating one or more inputs to one or more outputs. Such a model is developed using a training process in which the model is presented with large numbers of input examples and corresponding desired output responses. Based on errors in the model's predicted output response the model's internal configuration is automatically adjusted such that the errors in response are reduced. ANN modelling techniques are notable in their ability to handle large amounts of data and to derive underlying relationships in the data. The limitation of such techniques is that underlying relationships in the data are implicitly held in the model's architecture (a configuration of interconnected processing elements analogous to the construct of the human brain) and cannot be explicitly defined.

Initial work has concerned the application of ANNs to associate upstream detector output with pedestrian crossing opportunities. ANN models have been developed that can match or exceed the accuracy of gap acceptance decision modelling using the probability matrices described above. The use of a series of consecutive vehicle arrivals as model inputs has also produced results comparable with the processed data used in the matrices to consider crossing opportunities. Work is continuing to determine the most appropriate neural network paradigm and architecture to model pedestrian road crossing decisions. The efficiency of this process has been improved by the availability of the model development package Predict which can automatically address the issues necessary to build usable data-based models. These issues include data selection and transformation, and network architecture optimisation.

The adequacy and size of the basic data set is a major consideration in determining the success of the ANN model. Ideally the ANN would be based on data defining pedestrian gap acceptance behaviour at midblock signalled pedestrian crossings but the collection of these data requires substantial resources. In order to minimise costs for the feasibility study the development work is based on the existing data set for random crossing locations. These data are of a similar form to those for midblock signalled crossings and the successful development of an ANN model for the random crossing data would clearly demonstrate the viability of the technique.

A database defining projected vehicle arrivals and the associated vehicle delay following a change of aspect to pedestrian precedence is not currently available. These data will be generated using a microscopic simulation model of a Pelican crossing. Microscopic simulation provides a low cost alternative, for a representative range of site types, to on street collection of data. A similar approach to that described above will be used to train and test an ANN, based on the assembled database, to forecast the vehicle delay at a Pelican crossing, if vehicle green was terminated, corresponding to a pattern of vehicles on each of the approaches.

Microscopic simulation will be used to develop and evaluate the enhanced operating strategies incorporating the prototype neural networks. The NeuralWare model development packages both convert a trained ANN into flashcode (the source code of a function representing the trained ANN) which can be integrated with the simulation program. The benefits of the enhanced strategies will be evaluated using pedestrian compliance with signal aspects, pedestrian delay and vehicle delay as measures of performance. The model will also be used to consider detector location and
configurations which could be used on street to provide data for the intelligent control strategy.

5. CONCLUDING REMARKS

There is little justification for continuing with control strategies which retain vehicle precedence and delay pedestrians during periods of low vehicle flow at midblock signalled pedestrian crossings. Car drivers may be reluctant to accept a strategy which transfers default right of way to pedestrians but prepared to tolerate a strategy which makes more effective use of available time. Simulation results have demonstrated the potential benefits of implementing Pelican crossing control strategies which are more responsive to pedestrian demand in periods of low to moderate vehicle flow (Hunt and Lyons, 1992). It is possible to demonstrate similar benefits when comparable strategies are employed at Puffin Crossings (Hunt and Chik, 1996). The alternative strategies are likely to be even more beneficial in areas operating UTC. Individual Pelican or Puffin Crossings could operate independently with the local control ensuring that there is no major impediment to the passage of platoons through the crossing and providing pedestrian precedence at other times.

Application in practice of more sophisticated strategies of this type will require changes in the vehicle detection systems currently employed and associated efficient methods of interpreting detector data in real time. Research is currently underway to develop appropriate strategies which can be implemented on street using the newer technologies which are developing rapidly. The results of this research which will be available within 12 months should lead to on street trials and more widespread implementation.

6. REFERENCES


Department of the Environment (1975). Siting of inductive loops for vehicle detecting equipments at permanent road traffic signal installations, Specification MCE 0108B.


Figure 1 Measures of performance for an alternative operating strategy at a Pelican crossing
total ped flow = 2000 ped/h

Figure 1(cont) Measures of performance for an alternative operating strategy at a Pelican crossing
total ped flow = 200 ped/h

Figure 1  Measures of performance for an alternative operating strategy at a Pelican crossing
total ped flow = 2000 ped/h

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**Figure 1 (cont) Measures of performance for an alternative operating strategy at a Pelican crossing**