

A Review into Traffic Signal Improvement at Pedestrian Signalised Crossings

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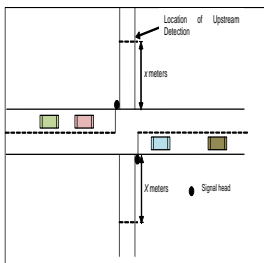
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Graphical abstract



Abstract

Signalised pedestrian crossings on busy urban street are used to facilitate the time-sharing of road space between vehicles and pedestrians so that pedestrians can cross the road safely. Puffin crossing is the most recent signalised crossings in UK. The operation of Puffin signal control is mainly based on traffic condition hence could impose longer waiting time on pedestrian. Therefore there is a need to review the operation of the signal control strategy of Puffin crossings to make it more pedestrian responsive without imposing significant delay to other road users. This requires the development of a conceptual model of new signal control strategy. Upstream Detection strategy has been identified as one of the potential alternatives that might enhance pedestrian amenity at signalised crossings. In the Upstream Detection strategy, detection is located at an upstream location of the crossing, so that the pedestrian demand can be registered earlier rather than waiting at the kerbside. Therefore, pedestrian does not need to arrive at the kerbside to activate the demand as in the normal operation of Puffin crossings. By doing so, pedestrian delay can be minimised. Therefore, this paper is intended to provide some insight into traffic signal improvement at pedestrian crossings, so that, it will be more pedestrian friendly without imposing significant interruption to vehicles. This paper seeks to explore the development of Upstream Detection strategy at Puffin crossings and its potential benefits. At this stage, Upstream Detection strategy has not yet been evaluated to explain specific findings of the strategy.

Keywords: Signalised crossings; upstream detection

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1.0 INTRODUCTION

In the years ahead there will be more and more traffic on the roads. Traffic congestion in urban roads and freeway networks leads to a less effective network infrastructure and consequently reduced throughput, which can be overcome via suitable control measures and strategies. As traffic congestion and air pollution became problems in many cities in the world, the impacts on the urban environment and pedestrians has grown enormous and government agencies of all levels are showing an increased interest in promoting walking as the best mode of travel for short journeys [1, 2]. Road widening and new roads cannot compensate for the growth. Hence, to permanently improve circulation, the entire infrastructure must be better utilised. Traffic management arose from the need to maximise the capacity and to minimise the delay of existing road networks.

A key facility for pedestrians on busy urban streets is the pedestrian crossing. This can take many forms, ranging from 'informal' facilities such as pedestrian 'refuges' in the middle of single carriageway roads through to 'formal' facilities involving street crossings controlled by traffic signals. With the increase in

the density of traffic signal installations in most towns and cities, this form of control becomes an integral component of pedestrian crossing opportunities. This gives rise to both problems and opportunities with respect to the pedestrians. Safe and comfortable facilities are two very essential elements in emboldening pedestrians to travel by foot rather than vehicles, which otherwise leads to the upsurge of traffic congestion.

In the UK, pedestrians are often not given the same priority as vehicle traffic at signalised intersections, as traffic signal control is usually designed to maximise vehicle capacity and/or minimise vehicle delay. Usually, the amenity of vehicles and their occupants are the primary objective in improving traffic system performance, while the needs of pedestrians may not be considered explicitly. For example, pedestrians are often only given an 'invitation to cross' (the 'green man') after traffic detection has confirmed that this can be done without delaying general traffic significantly— despite the waiting time this may cause for pedestrians. This often leads to an inequity in the facilities provided for these two groups of road users, with delays to pedestrians which often greatly exceeding delays to traffic at the same facility. This situation is rather contrary to the current

policies to encourage walking and will lead to reductions in pedestrian traffic.

Two key features of modern traffic signal control in the UK, such as MOVA and SCOOT are [3]:

- (i) the detection of vehicles upstream of the junction and
- (ii) real-time estimates of vehicle delay used for the optimisation of signal timings [3,4]

In these two traffic signal control, pedestrians are detected only at the junction itself, sometimes only through the activation of the pedestrian 'push button' and their presence are usually not considered in the optimisation process. It is this inequity which has prompted the need to re-examine the traffic control on the signalised crossings to give more benefits to road users especially pedestrians and drivers. This paper underlies specific intention which is to provide some insight into traffic signal improvement at pedestrian crossings, so that, it will be more pedestrian friendly without imposing significant interruption to vehicles. Therefore, this paper sets out to understand current facilities available in the UK for pedestrian crossings and to explore the development of new control strategy and its potential benefits.

The paper is structured in the following manner. The background literature related to the study is provided in the Section 2 and Section 3. The implications from the literature review help to determine the potential implementation of new signal control strategy described in Section 4. Finally, Section 5 summarises the conclusions and recommendations to this study.

■2.0 MOTORISED TRANSPORT VS NON-MOTORISED TRANSPORT

The transport policy of the 21st century has given greater emphasis on environmental considerations by promoting walking and the use of public transport [5, 6]. However, most cities around the world are more concerned with improving vehicular traffic conditions, thus rendering most road infrastructure designed to meet the requirements of motor vehicles. The policies to constrain the environmental impacts of motor vehicles have focused on traffic management, reducing vehicle travel times to allow smooth movement, more stringent emission legislations and greater investment in public transport schemes [7, 8]. Schemes often have a significant impact in reducing interrupted travel, shortening journey times and giving a greater convenience for car users. This attracts more road users to the car usage. However, the improvements for motor vehicles can have harmful consequences on the pedestrian traffic [9], particularly if they lead to more exposure and conflicts with traffic for pedestrians and to traffic generation.

The increase in car dependency gives a greater negative impact on the environment in the long term. Emissions and pollution produced by motorised transport come from dangerous or undesirable pollutants such as carbon dioxide, noise and vibrations. In creating an environment that is safe and pleasant for pedestrians involves both positive and negative measures. This could imply a need for designing pleasurable and enjoyable environment, or it may imply restraining traffic, that causes stop-and-go phenomenon to vehicles, making the traffic environment unpleasant.

The use of the car for short distance journeys is undesirable on environmental grounds (cold starts and the dominance of acceleration and deceleration operations). Therefore, for short trips, opt for walking is of particularly better travel mode and should be further encouraged over the use of motorised transport.

Henceforth, the most important factors influencing travellers' modal choice are travel time, travel distance and interaction with vehicular traffic [10]. Travel time and travel distance are linked with each other. Increases in both travel time and travel distance reduce the possibility of walking among road users. Land use policies could play a significant role in reducing the effect of travel distance in walking. The interaction between pedestrian and motorised traffic is focused around the activity of street crossings [11].

Since current transport policies are focusing more on the need to encourage the use of public transport, cycling and walking, better facilities to cater for all these road users are becoming more important. Realistically, public highways have to cater for all kinds of transport, and conflicts are bound to arise. So some compromise is inevitable between the conflicting priorities of different road-users. At a minimum, however, pedestrians should expect to receive equal consideration with other road-users in terms of provision for their needs and with regard to their safety on the roads. This is especially true of safety measures, simply because pedestrians are the most vulnerable of road users.

At signalised crossings pedestrians have received far less attention than other modes, particularly compared with motorised vehicles [12, 13]. Pedestrian travel is often treated as a road safety problem which is treated by ad hoc safety measures and is given less consideration than motorised modes. In reality, delays and conflicts with motor vehicles are also highly important for pedestrians and should be considered in any new pedestrian crossing facility.

■3.0 PEDESTRIAN SIGNALISED CROSSINGS

The main purpose of installing traffic signal control at junctions in or near urban areas is to increase safety and to enhance the capacity of junctions [14-16]. The installation of traffic signal control is a common control measure at junctions to control conflicting traffic streams and to provide sufficient pedestrian crossing facilities. Efficient signal phasing in traffic signal control contributes to the reduction of conflicts between different road users such as cyclists, pedestrians and vehicles where all road users are assisted by traffic signal control to move safely between the conflicting traffic. The properly designed traffic signal control, upon successful installation, could effectively minimise the delay on all traffic, consistent with safety.

In the UK, the most signalled mid-block crossings are Pelican type crossings, which are based on giving a priority to vehicles to minimise the vehicle delay, while the pedestrian phase is only activated based on demand [17]. Pelican crossings do not utilise any pedestrian detection technologies other than the 'push button' which is used to register pedestrian demand on the mid-block crossings.

The Pelican Crossing uses far-side pedestrian signal heads and a flashing amber/flashing green crossing period, of a fixed duration, which is demanded solely by a push button. The Pelican has a flashing amber display to the drivers during most of the clearance period, where drivers are allowed to proceed if the crossing is clear from pedestrians. A flashing green man begins at the end of signal demand cycle to warn pedestrians that they should not start crossing. A study by Walker *et al.* revealed that the flashing green man display can cause confusion to pedestrians, which is one of the reasons for the introduction of the Puffin crossing [18].

Puffin crossings are the form of signalised mid-block crossing now recommended in the UK [19]. One reason for this is that they provide a uniform approach at signal-controlled junctions and mid-block crossings, with the standard traffic signal

sequence—a steady red, amber and green signal to drivers—without flashing amber. By using a steady red signal to vehicular traffic instead of flashing amber at pelican crossings, it is expected that the Puffin gives more safety protection to pedestrians.

A Puffin is a new type of signal controlled facility that consists of pedestrian push button, signals and detectors [20]. The red man/green man indicator is positioned above the push button on the nearside signal pole to facilitate pedestrians with visual impairments and, the lack of a far side signal display encourages pedestrians to watch approaching traffic when crossing (or about to cross).

As the Puffin crossing is the most advanced signal controlled pedestrian crossing facility in the UK, and is becoming commonplace, it is appropriate to review the strategy in full, including its operational sequence and timings. This is set out below, in terms of mid-block crossing operation for clarity.

3.1 Puffin Crossings

At Puffin crossings, the pedestrian stage consists of a fixed green walking man (invitation to cross period), followed by a red standing man (variable clearance period) controlled by the pedestrian on-crossing detectors.

Pedestrian detector systems have been introduced in Puffin crossings to improve the operational efficiency of pedestrian crossings and as an alternative/improvement to the Pelican crossing. Pedestrian presence on the kerbside and on the crossing itself is sensed using appropriately sited Above Ground Detectors (AGDs) [19].

A pedestrian approaching a Puffin crossing will still need to register a demand to cross by pressing the push button. When the signals are ready to change from vehicle precedence to pedestrian precedence—according to the traffic state—then the kerbside detector checks whether its detection area is still occupied. If so, the signals will change; if not (i.e. the pedestrian has left the waiting area, perhaps already crossing the road in a gap), the signals will remain on vehicle green. When pedestrians have precedence, the vehicle red duration will depend on the length of time pedestrians are detected on the crossing itself. These innovations achieve a reduction in traffic delays and reduce conflicts between drivers and pedestrians [18, 21-22].

Footpath or kerbside pedestrian detectors detect and monitor pedestrians on the footpath. Kerbside detection is used as an initial detector to confirm the pedestrian presence on the kerb and has not crossed the road before the pedestrian phase initiates. Otherwise, the call for pedestrian phase will be cancelled [22]. It is to ensure that traffic is kept moving when there are no pedestrians waiting on the footpath before the pedestrian phase is initiated. This operation can reduce the number of ‘unnecessary’ pedestrian phases which can affect the traffic delay.

Another detection system on the Puffin crossing is on-crossing pedestrian detectors which are used to monitor pedestrians on the crossing. They are also based on Above Ground Detectors. The intent is to reduce traffic delay, by starting the vehicle green period as soon as pedestrians are clear of the crossing. They are also used to ensure pedestrian safety by extending the pedestrian clearance period when there is a need for a longer time to cross the road especially for slow walkers [18, 22]. Figure 1 shows the kerbside detection and on-crossing detection with their detection zones.

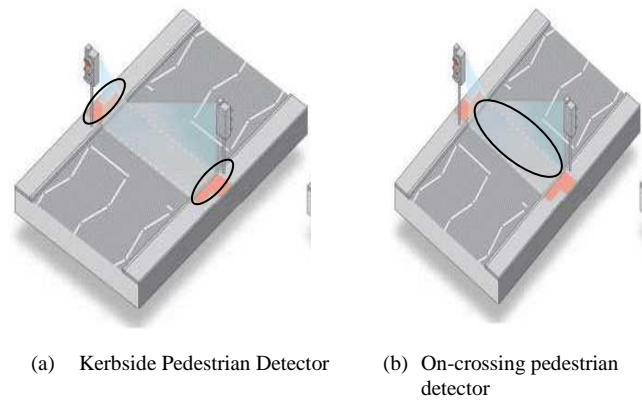


Figure 1 Kerbside and on-crossing pedestrian detector [21]

Compared to Pelican crossings, Puffin crossings can eliminate unnecessary pedestrian precedence periods and extend the crossing time for pedestrians to help them safely cross the road. However, the operational strategies for both Pelican and Puffin crossings are still 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.

The main concern with Puffin crossings is in spite of extending the pedestrian clearance time and to make a clear safety protection to road users, the Puffin operational strategy is still based largely on traffic conditions; so pedestrian precedence only occurs when traffic conditions are suitable: suitable gaps or low delay. This concern becomes the main focus of this study.

With these considerations, the Puffin crossing is the obvious choice to be the ‘base case’ for this study. It is the most advanced and flexible form of crossing currently operational in the UK and has the potential for further enhancements to its detection and control functions. The control system on the Puffin crossings is still based on vehicle delay where the vehicle arrival patterns or gaps are calculated to set up the signal timing for pedestrians. The control strategies should be improved to make them fairer for pedestrians and vehicles.

One method that is of considerable interest is the potential for upstream detection, with correspondingly improved control, to provide improved pedestrian crossing facilities and enhanced amenity. This new improvement strategy at Puffin crossing is described in the next section.

4.0 UPSTREAM PEDESTRIAN DETECTION AT PUFFIN CROSSINGS

The Puffin model in VISSIM microsimulation is developed further to test new strategy at Puffin crossing: Upstream Detection. The aim of the Upstream Detection scenario is to minimise the pedestrian delay time without major disbenefit to vehicular traffic. The principle of Upstream Detection is to provide an earlier activation of the pedestrian stage (pre-arrival detection).

At this stage, upstream pedestrian detection is assumed to occur through conventional push button(s) system, with the pedestrian demand registered some distance upstream of the crossing. Variations in pedestrian behaviour are considered within this new strategy such as walking speed and gap acceptance behaviour among pedestrians.

Figure 2 shows an illustration of Upstream Detection at the crossing.

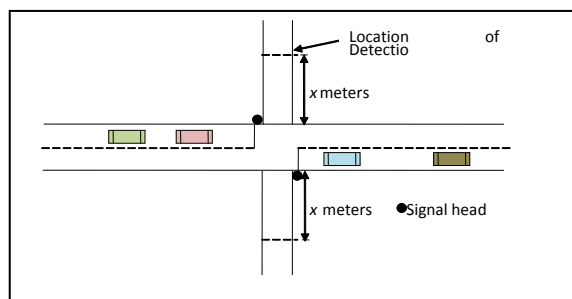


Figure 2 Upstream detection scenario

As shown in Figure 2, Upstream Detection is located at advanced of the crossings. Several pre-determine distances of the upstream detection are being set, and then the optimal distance for the upstream detection is evaluated using VISSIM microsimulation software.

The Upstream Detection strategy has the same operating system as the standard Puffin except it has an extra detection (push button) upstream of the crossing. With this method, pedestrians could register their demand earlier at the upstream location; therefore the pedestrian phase could be initiated earlier upon receiving the demand from the upstream detection. The principle of this new control strategy is same to the installation of vehicle detector at the upstream location of junction to provide earlier activation to signal control. Therefore, by doing so, it is expected to reduce the pedestrian waiting time at the kerbside without disturbing the vehicle flow.

In this new signal control strategy, when the Upstream Detection is activated by a pedestrian, the pedestrian demand is sent to the signal controller. Then, there are two traffic conditions checked before a pedestrian phase is given:

- a) Minimum green to vehicles
- b) Gap-out event or maximum green to vehicles

If the first requirement is satisfied (minimum green time has expired), the next requirement is to check for gap-out or max-out events. If either of these requirements is satisfied (i.e. there is a gap more than 4 seconds between vehicles or maximum green to vehicles has been reached) then the pedestrian stage can be given instantly to pedestrians. It is assumed if all these requirements are satisfied upon the activation of upstream detection, the interstage would happen in 4 seconds intergreen time. This principle is further illustrated in the following Figure 3.

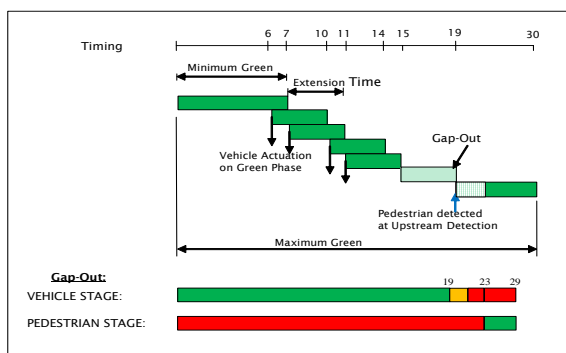


Figure 3 The principle of upstream detection

Figure 3 shows an example where detection could extend the vehicle green time up to its maximum of 15-seconds. At 19-seconds, Upstream Detection is activated by pedestrian. The first requirement is satisfied (more than minimum green time). Then the second requirement is checked (gap-out or max-out event). A gap-out event occurs at 19-seconds (there is a gap of 4 seconds or more since the last vehicle was detected), therefore the interstage happens upon the activation of Upstream Detection (rather than kerbside detection activation), and thus the pedestrian stage is initiated earlier at 23-seconds.

However, if the interstage does not occur in the first 4 seconds, pedestrian presence at kerbside is also checked. The principle is to cancel the demand if there is no pedestrian waiting on the kerbside.

The performance of the Upstream Detection strategy is then assessed based on efficiency (vehicle and pedestrian delay). VISSIM microsimulation is used as an evaluation tool in this study due to the dynamic behaviour of vehicles and pedestrians and the complex nature of vehicle-pedestrian interactions. It has been shown in previous studies that VISSIM has a good ability to model various pedestrian behaviours and the interaction between pedestrians and vehicles [8, 23].

5.0 CONCLUSIONS AND RECOMMENDATIONS

Generally, the use of signalised crossings on the road is primarily to maintain a peaceful and safe interaction between human and vehicle traffic, since it is impossible to maintain a complete segregation between these two road users. Therefore, this study seeks to identify the potential implementation of Upstream Detection strategy at signalised crossings for a better utilisation of signalised crossings to both vehicles and pedestrians. This is with a view at making a better traffic management at signalised crossings hence safer road environment for both vehicles and pedestrians.

Practically, in whatever situations, it is expected that there is a trade-off between pedestrian delay and vehicle delay at the signalised crossings. A reduction in pedestrian delay might cause an increase in vehicle delay. However, the utilisation of Upstream Detection at signalised crossings is expected to reduce the pedestrian delay without causing a significant increase in vehicle delay. This is done by allowing an earlier detection of pedestrian; therefore the signal control can have an earlier response to the pedestrian demand and at the same time does not impose interruption to vehicle traffic. The introduction of Upstream Detection at signalised crossings is expected not only to improve the safety of pedestrians on busy roads but improved the performance of the signalised crossings by allowing less interruption to both vehicle and pedestrian movement.

To gain better insight into this strategy, both Base Case Puffin crossing and Upstream Detection are subjected for further evaluations. Therefore, the possible benefits of this strategy can be assessed fully. Further analysis on this study can be used in the development of a traffic signal control strategy which takes into account both vehicles and pedestrians in the optimisation strategy. Various pedestrian behaviours including compliance to the traffic signal and gap-acceptance behaviour can be considered in the evaluations.

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