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NEW STRATEGIES FOR TRAFFIC SIGNAL CONTROL OF PEDESTRIAN CROSSINGS: THE ADVANTAGES OF PEDESTRIAN REAL TIME AUTOMATIC DETECTION

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Abstract

A presentation is made of the results of a research study in which pedestrian-actuated traffic signal solutions were implemented to test their effectiveness in enhancing the safety and comfort of pedestrians in crossing facilities with little inconvenience to motorised traffic.
Three pilot real life traffic control schemes have been implemented where a number of different pedestrian friendly traffic control strategies have been tested and proved viable e.g. automatic triggering of pedestrian demand before they actually reach the crossing points, extension of pedestrian green time to serve late comers or advancement and extension of it when pedestrian demand reaches a certain threshold.

INTRODUCTION

Pedestrians' Safety and Mobility

In urban areas the pedestrian movements have a significant role, with approximately 60% of all the trips with a length of less then 1.5 Km being made using the pedestrian mode. According to Brög and Erl (1994) data obtained at a number of German cities has revealed that, on average, a person makes 2.9 trips per day of which 78% are made on foot and for each hour spent on trips, 23 minutes are spent as pedestrians.

On the other hand, pedestrians represent a significant part of the victims of road accidents with the EU having approximately 9000 dead pedestrians per year. According to the CEMT (1994) data from 23 European countries shows that approximately 23% of all the dead and 13% of all the victims of road accidents in those countries are pedestrians.

The Pedestrian-Vehicle Conflict

In spite of this situation in many cases when there is a conflict of interests between the motorised traffic and the pedestrian one, the selected solution is the one that restricts the least the needs of the motorised traffic.

For example at signalised crossings, which are the subject of the current text, the safety and comfort of pedestrians poses many difficulties for local highway engineers in scheme design due to the lack of methods by which optimisation techniques can be used to maximise global efficiency.

From the point of view of pedestrians, they would like to have immediate priority over vehicular traffic, when they reach the crossing point, and ample time to cross in safety. These objectives can also be swayed by the age of the pedestrians with the young, particularly schoolchildren, tending to be impatient and not willing to wait for a significant time. The elderly however tend to be more appreciative of being allowed a longer safe crossing time.

The VRU-TOO Project

The work which is being described and that was mostly carried out under the VRU-TOO project (see VRU-TOO, 1995) was targeted specifically at the application of ATT for the reduction of risk and the improvement of comfort for vulnerable road users, in special pedestrians.

Since these problems cannot be solved by segregation of pedestrians and vehicles, because such total segregation is impractical in most sites of European cities, the VRU-TOO project has opted for the development of new and intelligent traffic signal systems which enable an adequate separation in time of the two systems. Such signals can detect the pedestrians' approach and movement through the crossings and, in real time, take that information into consideration to optimise their functioning.

The VRU-TOO project has identified a number of signal strategies which can be applied not only at isolated signalised crossings (e.g. pelicans) but also at crossings which are integrated in isolated signalised crossings and even at crossings which are located in areas under the control of area wide UTC systems.

The testing of the strategies was carried out in three field trials implemented in three countries (Greece, Portugal and the United Kingdom). These three trial sites enabled the study of different types of layout and of traffic signal control with two of them involving crossings at isolated signalised junctions and the other involving three crossings which are located in an area controlled by an UTC system.

THE WORK STRUCTURE

General Objectives

The introduction of microwave detectors enables an increase of the junction micro regulation by allowing an improved and in real time knowledge about pedestrian behaviour and allowing it to be taken into consideration the intelligent use of new traffic signal control strategies.

Basically the project main objective was the development of new traffic control solutions capable of improving the safety and comfort of pedestrians while at the same time not affecting significantly the motorised traffic movement efficiency and having a reasonably low implementation cost.

The assessment indicators selected to quantify the results of the three trials in terms of the selected objectives were the same and are presented in Table 1 below.

Table 1 – Project Objectives and Assessment Indicators

OBJECTIVE	INDICATOR
Increase Pedestrian Comfort	Waiting Time at Kerb % of pedestrians arriving during green phase
Increase Pedestrian Safety	Conflicts between vehicles and pedestrians Pedestrians' and vehicles' red light violations
No Increase in Traffic Delays	Vehicular queue lengths Journey times
Small Increase in Implementation Costs	Ratio of 'new' over 'standard' costs

Based on these indicators a number of specific objectives, which will be presented later on, were selected for each of the trials.

The New Traffic Signal Control Strategies

One of the potentially significant problems with current practice is that, in many solutions, in order to be allocated any formal priority at a crossing the pedestrians are required to press a push-button. Due to a generally poor understanding of the functioning logic of these devices which is partially induced by the fact that the effect of the pedestrians' actions is normally not immediate and can sometimes be quite delayed and by the fact that it is not uncommon to have systems not working properly, these are not considered by pedestrians to be very friendly solutions.

Another weak aspect of the state-of-the-art practice is that, contrary to what happens in relation to vehicles, the timings given to pedestrians are fixed, both in frequency and length, and cannot be altered in a real time situation to respond to fluctuations in the number of pedestrians wishing to use the crossing point.

A number of new regulation strategies can be applied to fulfil the previously presented objectives which, as is easily understood, are partially incompatible:

- To change the priority given to pedestrians (basically in terms of percentage of green time allocated in the cycle) in accordance to the relative importance of pedestrian and car movements.
- To increase the time period during which pedestrian demand can be called within a cycle. Basically this can be done using automatic remote detection techniques which might or might not have to be confirmed by push-button inputs.
- To increase the "safe" crossing periods when either a slow moving or a "late comer" pedestrian is detected crossing the junction in the latest moments of the normal green period.
- To increase the length of the crossing periods or anticipating the pedestrian phase when a large number of pedestrians is detected trying to cross a junction.
- To annul the need for pedestrians to positively express their desire to cross by pressing the push-buttons, thus overcoming the problem resulting from the generally poor understanding pedestrians have of push-buttons.
- To reduce or eliminate unused pedestrian green periods occurring because the initially detected demand no longer exists.

The selection and combination of some or all of the above described possible solutions has to be made on a case by case base because of the very different layout and functioning characteristics of each crossing.

The Evaluation Framework

The evaluation of the three trials was carried out in a way as similar as possible so that the individual results could be compared. Thus all the data collection was carried out on a before and after basis with every effort made to ensure that all the non-relevant conditions remained the same during the before and after period. Further a period of at least three weeks was allowed after implementation of the solutions, but before data collection, to allow the traffic and pedestrian conditions to settle down.

The main data fields that were collected during the three trials so as to evaluate whether the specific objectives of the trials had been achieved are the following:

- The number of pedestrians who crossed the road at all crossing points and the corresponding signal setting. These were counted for at least a total of twenty-four hours covering both peak and off-peak weekday periods. The pedestrians' actions were recorded together with the signal settings at the salient times during their movements. This recording was carried out by video wherever possible and the settings of the signals were transmitted directly to the input channel in the recorder using a specially made piece of equipment involving sensors on the signal lights. The signal settings over an extended period were also recorded allowing the quantification of a reference to be made regarding the proportion of time allocated respectively to pedestrians and to the main road traffic.
- The number of vehicles that passed the different crossing facilities at the different settings of the signals.
- A vehicle registration plate check was carried out at both ends of the length under consideration in Leeds to check the time taken to travel along the length. This work was done for 10 minutes intervals in each hour covering the full working day with at least four records collected. In Porto, the same type of data was collected using the moving observer method.
- Queue lengths for the various streams of motorised traffic passing through the pedestrian facilities were obtained from video.
- A manual record of the number of vehicles that violated the red lights was made throughout different periods of the trials.
- Finally, in order to assess changes in safety, a comprehensive conflict study was carried out on the different sites by properly qualified conflict analysis personnel using the Swedish Conflict Technique (see Hyden, 1987). A minimum of twenty-four hours of observation was taken.

THE EQUIPMENT

Available Technology

As referred before, at least in theory, the quality of traffic signals will be better if in real time one can adapt their functioning to the real existing demand not only by vehicles but also by pedestrians.

In what concerns the pedestrians, it is important that the detection equipment to be used is capable of detecting their presence and approach to the facilities as well as counting them. It is also important to refer that it is essential that they can do it in any kind of environment particularly under severe wéather conditions. The problem of installation costs can also be an important one.

There are a number of detectors commercially available based on infrared or micro-wave technologies and others based on pressure detection technology and usually called maths detectors (Sherborne, 1992 and Pires da Costa et al, 1996).

Some effort has also been made recently in the development of pedestrian detection systems based on automatic video image analysis (see Reading and Dickinson, 1995). Although the results have been promising this type of system is still in a development stage.

The Selected Equipment

The potential to detect and count approaching pedestrians, its simplicity to install and its relatively low cost has determined the selection of micro-wave detector systems. A Microsense microwave detector, adjusted by the manufacturers in terms of speed threshold was selected.

Due to the potential problems of false detections and false non-detections which was identified during the selection period it was decided to carry out a number of preliminary analyses of this question.

From the point of view of installation, no special technical problems were encountered neither when the detectors were connected to the GK 4000 traffic counter nor when they were connected to the Siemens M32/MQ signal controller in Elefsina-GR, to the SFIM Traffic Transport – type Castor Europe 8000 series controller in Porto-PT, or to the UTC System in Leeds-UK.

THE ELEFSINA-GR FIELD TRIAL

Location and Layout

The site is a signalised junction with standard pedestrian facilities (i.e. push-button calling the pedestrian phase). This junction is on the main road which runs directly through the city of Elefsina, across which there is an established pedestrian route for workers and shoppers.

It is important to notice that prior to this project this junction was unsignalised and that the signals were put in place approximately three months before the implementation of the new pedestrian friendly traffic control system. During those three months the functioning of the junction was allowed to settle down with only small adjustments being made to the signal timings using local best practice (see Tillis et al, 1995).

Specific Objectives

In the case of the Elefsina trial the overall objectives referred to above were translated into the following specific objectives:

- Significant increase of pedestrian comfort while using the facility namely reflected in a significant reduction in pedestrian delay;
- Significant reduction in the number of serious conflicts between main road traffic and pedestrians;
- No significant increase in the vehicular journey times or the average queue lengths.

Strategies for Elefsina's Traffic Signal Settings

At this location different strategies were implemented on each of the major road crossing facilities:

- On the western side of the junction the detectors were used to detect approaching pedestrians and automatically initiate the activation of the pedestrian phase. This procedure enabled an advancing of the response to the pedestrian demand by up to 4 seconds.
- On the eastern side of the junction the detectors were directed at the crossing facility enabling the provision of a green extention for pedestrians which would make the completion of the crossing easier for them.

The complete logic behind the new traffic signal settings is presented in Figure 1 (for a more detailed analysis see also Tillis et al, 1995).

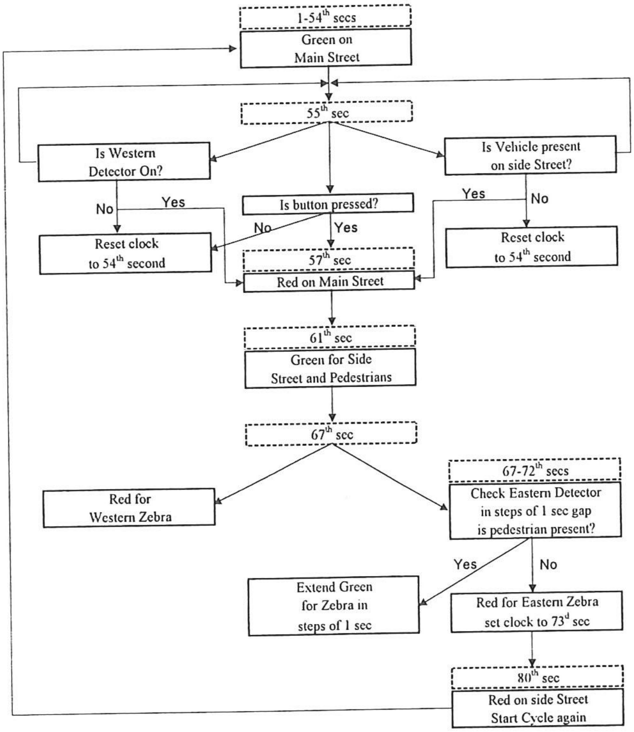

Figure 1 – Elefsina's Traffic Signal Settings (Source: Tillis et al - 1995)

Results

The implementation of these strategies has, according to the before and after evaluation, resulted in the following results:

- There has been an increase, from 5 to 9 percent, in the proportion of pedestrians who arrived at the crossing during the pedestrian green signal;
- There has been a small reduction in the overall pedestrian delay, from a mean of 18.5 to 17 seconds. This has been most marked in the proportion of pedestrians who waited for more than 30 seconds, where there has been a decrease from 28 to 18 percent;
- There has been a slight reduction in the number of vehicles who violated the red light on the main road from 7 to 5 vehicles per hour;
- There has been a 22% overall reduction in the number of serious conflicts with a 51% reduction being observed on the western crossing and a 10% increase on the eastern crossing;
- There was no increase in the length of the vehicle queues (a slight reduction was observed, but it was not statistically significant).

As an overall conclusion it seems worth referring that the trial has been completely successfully and that the results have shown some benefits to pedestrians from the implementation of the new solution. It should however be noticed that the impacts have been comparatively small but this is not unexpected due to the limited size of the changes introduced in the traffic signal settings.

It is also worth noticing that the extra installation costs associated with the new control system (including direct construction costs) were approximately 10% of the installation costs associated to the standard solution.

THE PORTO-PT FIELD TRIAL

Location and Layout

The junction where the Porto trial took place is located on a major arterial road running out west from the city centre towards the coast. The site is basically a signalised crossroads on a dual carriageway with the added complication that there is a tram line running down the middle of the road, and a tram stop in the middle of the pedestrian crossing (see Pires da Costa et al, 1995).

The junction and particularly its pedestrian crossing facility across the main road is situated adjacent to the pedestrian and motorised traffic entrance of a large school (which is attended by 6 to 17 year-olds).

Before the implementation of the new, pedestrian friendly, traffic regulations, the junction was working as a semi-actuated signalised one with vehicle detectors placed on the more important of the minor road entrances (the North one).

There are heavy traffic flows along the main road for nearly all day and this is exacerbated at those times of the day when school children are entering or leaving the school.

Specific Objectives

In the case of Porto the overall objectives were translated into the following specific objectives:

- Reduction of at least 10% in the number of children crossing the major road against a red light and a significant reduction in pedestrian delay;
- Significant reduction in the number of serious conflicts between main road traffic and pedestrians;
- No significant increase in the number of vehicles going trough red lights;
- No significant increase in the vehicular journey times or the average queue lengths.

Strategies for Porto's Traffic Signal Settings

From the different possible combination of traffic control strategies specifically aimed at the pedestrians which were presented before, three were selected to be used:

- To increase the pedestrian share of green (by anticipating the pedestrian green stage) when a certain threshold of demand was reached in order to obtain a more balanced weighting of the importance of the modes and, specially important, to deal with the very high pedestrian demand peaks occurring during the school entrance and exit periods. The threshold of demand was defined in terms of pedestrian occupancy rates and, after a field evaluation, where consideration was given not only to the flows involved but also to the average ratio of non-crossing pedestrians being detected, the value of 30% was selected.
- To use extended green periods to allow the safe crossing by late comers. These pedestrians were identified by pointing the detectors to the approaches of the crossings in the middle of the dual carriageway and taking them into consideration when they occurred during the later stages of the pedestrian green periods. The fact that there were trams running in the middle of the carriageway was not a problem, because the logic of the program meant that pedestrian detections were only to be registered in periods during which there were no trams crossing the detection area.
- To reduce the pedestrian green periods when no crossing movement was observed in the early stages of the pedestrian green periods so that wasted green time was kept to a minimum. These situations were identified by pointing the detectors at the initial areas of the crossing facilities. This was the solution found to overcome the fact that the detectors could only detect moving pedestrians which meant that only in those early stages the lack of detections could be considered synonymous of absence of pedestrians willing to cross.

The complete logic behind the new signal settings is presented in Figure 2 (for a more detailed analysis see also Pires da Costa et al, 1995).

Results

The implementation of these strategies has, according to the before and after evaluation, resulted in the following results:

- There was no significant change in the number of pedestrian red light violations by adults or children, although there were variations in the effects on different sides of the dual carriageway.
- There was a reduction in the number of pedestrians and a non-significant reduction in the number of children who waited longer than 20 seconds.
- There was a slight overall reduction of 2% in the number of serious conflicts but this was not statistically significant.
- There has been no increase in the observed traffic queue lengths and also no significant increase in the length of the stated vehicular journey times.

The interpretation of these results is slightly complicated by the fact that, although there was no overall change in the number of pedestrians crossing the road, there was a 6% reduction in the total traffic flows across the main road pedestrian crossings, between the before and after collection phases, probably due to some temporary road works which were being carried out on another section of the main radial route.

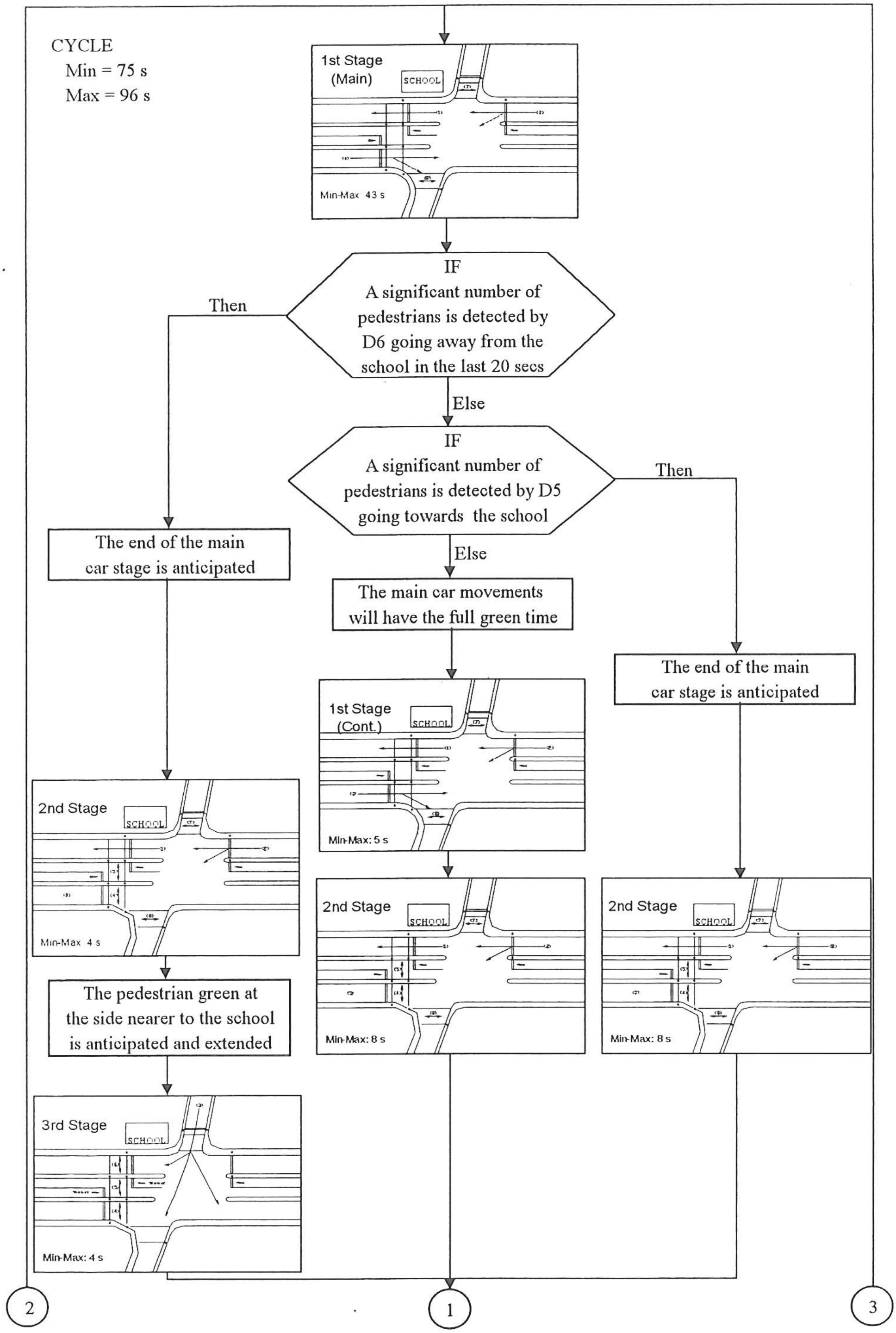

Figure 2 – Porto's Traffic Signal Settings

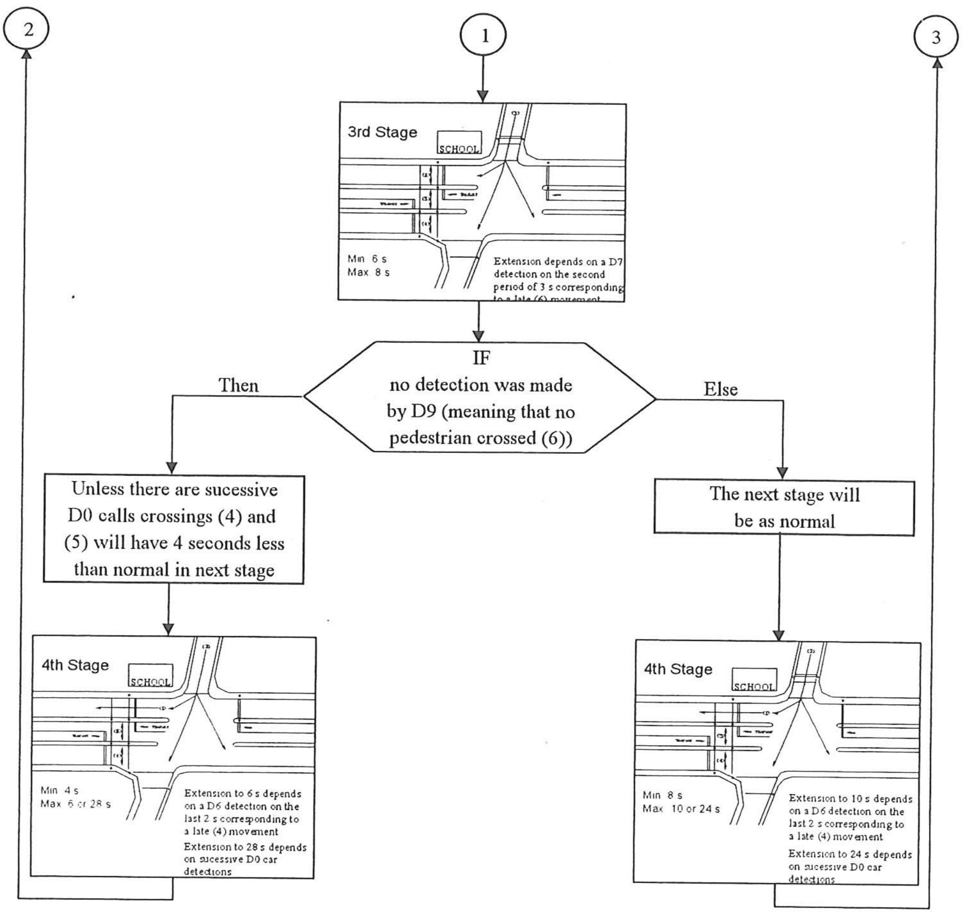

Figure 2 (continuation) – Porto's Traffic Signal Settings (Source: Pires da Costa et al -1995)

In spite of this problem the trial showed that it was feasible to use pedestrian detectors in such a situation and that their use could be integrated within existing signal installations. The results have also indicated an overall but small improvement, which was consistent with the small scale of the signal timing changes which could be introduced in view of the significant existing vehicle congestion problems. It may also highlight the additional problems occurring in formal facilities in situations where the majority of pedestrians are schoolchildren.

It is also worth noticing that the extra installation costs associated with the new control system (with no direct construction costs involved) were approximately 20% of the installation costs associated to the standard solution.

THE LEEDS-UK FIELD TRIAL

Location and Layout

The Leeds trial was performed in three pedestrian crossing facilities located along the recently constructed one way City Centre Loop. This is a one way arterial inner ring around Leeds City centre, which is being built so as to keep private through vehicles out of the city centre.

Prior to the introduction of the new, pedestrian friendly, traffic control strategies, the section of the City Centre Loop containing the three study locations was controlled by an UTC system operating on a series of fixed time plans.

The layout of all three pedestrian crossings involved in the Leeds trial was similar with a signalised pedestrian facility crossing a one way, three lanes, road (for a more detailed description see Sherborne and Hodgson, 1995).

Specific Objectives

In the case of Leeds the overall objectives were translated into the following specific objectives:

- Reduction in the number of pedestrians who cross the road against a red light;
- Reduction in the number of pedestrians who wait for longer than 20 seconds;
- Reduction in the number of serious conflicts between main road traffic and pedestrians;
- No increase in the number of vehicles going through red lights;
- No significant increase in the total time for vehicles to travel through the length of the main road nor in the average queue lengths.

Strategies for Leeds' Traffic Signal Settings

The introduction of the microwave detectors in the new, pedestrian friendly, configuration allowed real time information on the desire by pedestrians to cross, to be used by the individual signal controllers.

However, due to the fact that all three crossings worked on fixed time plans and were co-ordinated within the UTC programme, there would be a constraint about the way in which in an intelligent real-time manner the signals could be adapted to provide enhanced conditions for pedestrians. For example, the sequence of the signals when providing conflict-free pedestrian crossing opportunities across the City Centre Loop were limited, this meant that the numbers of green periods for pedestrians within a cycle could not be increased.

In spite of this there was still flexibility in the system to use the information from the signal detectors in a real-time manner so as to amend the proportion of green time allocated to the pedestrians, when there was a demand for it. It was decided to do it in two different situations:

- The detection of a pedestrian approaching the crossing point would, automatically, trigger off the demand for a pedestrian green phase within the signal cycle; The fact that the pedestrian demand is automatically identified not only eliminates the need for the use of push-buttons but also means that there is more chance for the pedestrian to catch the "window of opportunity" within the signal cycle and to get the green man phase;
- The detection of a pedestrian approaching the crossing point whilst the green-man phase is already present, allows the pedestrian phase to be extended to serve that pedestrian.

Results

The implementation of these strategies has, according to the before and after evaluation, resulted in the following results:

- There has been a reduction in the number of pedestrians who crossed the road whilst the signals were green for vehicles.
- There was a slight reduction in the number of pedestrians who waited for more than 20 seconds.
- There was a 17% reduction in the number of serious conflicts at the major crossing point along the length (site 4), but this was not statistically significant. At the other two crossing points the original level of conflicts was much lower making any results more difficult to evaluate. Even so at one of them there was a significant reduction from 4 to 1, and at the other there was no change from the initial 10 conflicts. The overall reduction in conflicts was 18%, significant at the 0.10 level.
- There was no increase in the number of vehicle red light violations.
- There was no increase in any of the queue lengths but the survey has shown some increase in total journey times.

The overall results of this trial showed that it was possible to incorporate such intelligent pedestrian facilities into a City Centre traffic management scheme and obtain benefits for pedestrians without undue problems for vehicles.

It is also worth noticing that the extra installation costs associated with the new control system (with no direct construction costs involved) were approximately 6% of the installation costs associated to the standard solution.

GLOBAL RESULTS AND CONCLUSIONS

The first aspect worth referring to concerns the applicability of the selected technology both in terms of quality of results produced and in terms of flexibility of application:

- In what concerns the quality of results produced, the microwave technology has shown its capabilities to detect approaching pedestrians in real life environments. However, it should also be noticed that these detection capabilities are not perfect and that, under unusual circumstances, false detection and false non-detection situations could occur which only partially could be overcome by careful positioning and setting of the detection equipment. The main observed problems involved difficulties in detecting small children and false detections caused by vehicles (especially heavy ones) moving nearby. Also the counting capabilities of the system, although reasonable, have shown some difficulties in dealing with groups of people. In one of the trials it was decided to use 'occupancy' as a demand surrogate measure.
- In terms of flexibility of use and reliability the technology has proved to be very good with no significant problem occurring neither in terms of connecting difficulties with any of the controllers used nor in terms of malfunctions during the all period of the project.
- Also in terms of costs the system seems quite attractive with the extra equipment costs for the new installations being estimated at less (in some cases much less) than 20% of the costs of a standard solution. Notice that the sites' basic construction costs (building of roads, etc) are not being considered but the construction costs directly associated with the equipment installation, if existent, are. If all the costs were considered the extra cost would be less than 1%.

In what concerns the capabilities shown by the new traffic control system to give answer to the overall objectives defined by the project, namely in what concerns the improvement of pedestrians' comfort and safety without significantly affecting the motorised traffic flow conditions, the results from the three trials have shown that:

- In all three locations there was an overall reduction in the number of serious conflicts between pedestrians and vehicles. There were however considerable variations between the sites and even between different carriageways on the same site.
- There was a reduction in the average length of time pedestrians had to wait at the kerb edge. There was also an overall increase in the number of pedestrians who arrived at their crossing point to a green signal.
- There was no significant increase in vehicle queue length at the individual sites although there was a slight increase in overall journey time over the length in Leeds-UK.

Generally thus, the system has proved capable of producing small but consistent improvements in terms of quality of service offered to the pedestrians without undue restrictions being forced into the motorised traffic. However, the variability of results obtained even within the same site suggests that some extra effort might be worth to do the validation of these results in other locations and in the production of guidelines in relation to different levels of layout adequacy and in relation to strategy selection rules.

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