JURNAL KEJURUTERAAN AWAM (JOURNAL OF CIVIL ENGINEERING) Vol. 12, No. 1, 2000

Midblock Signalled Pedestrian Crossing - Alternative Controller Algorithms

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ABSTRACT

Observation at midblock signalled pedestrian crossings in Malaysia showed that violation of the red signal aspect by both the motorists and pedestrians is close to 70 %. Motorists may travel on the red signal aspect when there is no pedestrian on the crossing. Pedestrians are also observed to cross in vehicle gaps at the crossings during the right of way to vehicles. Such behaviour is dangerous especially at a system where the traffic movements rely on the signal aspects shown to them. Four alternative algorithms were designed in order to enhance the operation and safety of users at the midblock signalled pedestrian crossings in Malaysia. The objectives are to increase pedestrian safety and drivers compliance with the signal. The developed strategies required detectors to register the vehicle and pedestrian demands. Algorithms were designed to compute the appropriate time to start and terminate the vehicle and pedestrian precedence. The applied computation aimed to limit vehicle delay and to ensure that vehicle saturation flow does not exceed 85 % of the road capacity. Apart from the vehicle demands, the developed strategies also attempt to emphasis on the requirement and limits of pedestrian behaviour. Four measures of performance are compared and evaluated. These measures are the percentage of vehicles crossing on the red man, pedestrian mean delay, mean cycle times and vehicle mean delay. The measures of performance of all algorithms are evaluated using a fully calibrated and validated simulation program. All of the new strategies increase the pedestrian compliance and balance. This indicates that the present system does not respond satisfactorily to the gaps in vehicle flow and may contribute to the users disrespect of the system.

INTRODUCTION

As part of their journey, most pedestrians need to cross the road. The need to retain adequate road capacity limits the provision of pedestrian facilities at signallised junctions. In an urban network, the imperative for traffic management was to move vehicles with minimum delay. Other road users requirement, including pedestrians were usually satisfied on the basis that there was minimal disruption to vehicle flow. In Malaysia, overhead footbridges are normally constructed across busy roads to assist crossing pedestrians. However, these elevated footbridges are expensive and their height may cause difficulties to the young, elderly, pedestrians with pram and heavy shoppers. Thus, midblock signalled pedestrian crossings, which is a level crossing that segregate the times of vehicles and pedestrians interaction offer better alternatives on many of the urban roads. These types of crossing are operated on the basis that vehicle precedence period was maintained at a level to satisfy the highest vehicle flow. It is not practical to accommodate the increasing car population in town and cities. In Malaysia, the local authorities have long been trying to upgrade the services of public transportation system. The air-conditioned stage buses, light rail transit and commuter trains have been introduced. The publics are now being encouraged to reduce the use of private vehicles for short journeys, many of which could be made on foot. In these circumstances, it is appropriate to consider changes to the present operating strategies for midblock signal pedestrian crossings with the objective of improving pedestrian amenities and compliance. In this paper, the main concern is with the present fixed time midblock signal pedestrian crossing system operating in Malaysia.

CURRENT OPERATION OF MIDBLOCK SIGNALLED PEDESTRIAN CROSSING IN MALAYSIA

Fixed time operation system in Malaysia differs from that of the United Kingdom [1]. The midblock signalled pedestrian crossing strategy based on the United Kingdom practice is intended to minimise the lost time to vehicles by introducing the flashing green man to pedestrians and flashing amber to drivers. During this period, the priority is given to the pedestrian on the carriageway to complete the crossing. Studies [2, 3, and 4] showed that many drivers intend to move when the pedestrians are still on the carriageway. Arriving pedestrians are also observed to join the pedestrians, which already on the crossing even though the flashing green man has already started. To avoid this, the recent United Kingdom strategy [3] uses carriageway detectors to determine the duration of right of way for crossing pedestrians. This abolished the flashing green man/flashing amber aspect.

The Malaysian system assumes the pedestrians as a stream of conflicting traffic, where a fixed period is provided to invite them to cross. A period of flashing green man is provided, but not the flashing amber to the motorists. This is probably due to the low degree of respect by motorists to pedestrians and also the large composition of motorcycles in the traffic stream. Essentially, all of these systems are designed to provide pedestrians with a crossing period that is protected by the red light shown to the vehicles. Figure 1 highlights the differences between the systems.

However, the strategy adopted in Malaysia may cause irritation and dismay to motorists and pedestrians. On many circumstances, drivers are shown the red signal aspect even though there was no pedestrian on the crossing. This may increase the motorists disregard to the system. This happened after pedestrians activated the push button, crossed during the red man period. Pedestrians may also seek to reduce their delay by crossing in gaps in traffic flow. Pedestrians and motorist behavioural studies are carried out at several midblock signalled pedestrian crossings in Malaysia. Figure 2 shows the percentage of pedestrians starting to cross the road during the red man period. Figure 3 highlights the degree of motorist disregard to the present system. It can seen that, for both pedestrians and motorists, the degree of violation is higher at lower to moderate flows. Based on the data, it may be inferred that the present system are either not responding to gaps which pedestrians perceive as safe crossing opportunities or, are not responding to traffic flow sufficiently.

The United Kingdom fixed time system

Driver action	stop unless unsafe	stop			give way if necessary – pedestrian priority		proceeds
Driver signal aspect	**Amber**	**Red**			**Flashing amber**		**Green**
Typical signal timing	3 s	1 s	4-7 s	2 s	6 s	2 s	20-60 s
Pedestrian signal aspect	**Red man**		**Steady Green man**		**Flashing Green man**		**Red man**
Pedestrian aspect	waits		cross with care		do not start to cross		waits

Malaysian fixed time system

Driver action	stop unless unsafe	stop				proceeds
Driver signal aspect	**Amber**	**Red**				**Green**
Typical signal timing	3 s	1 s	5 s	2 s	1s	40 s
Pedestrian signal aspect	**Red man**		**Steady Green man**	**Flashing Green man**	**Red man**	
Pedestrian aspect	waits		cross with care	do not start to cross	waits	

Figure 1 Comparison of the midblock signalled pedestrian crossing operational cycle.

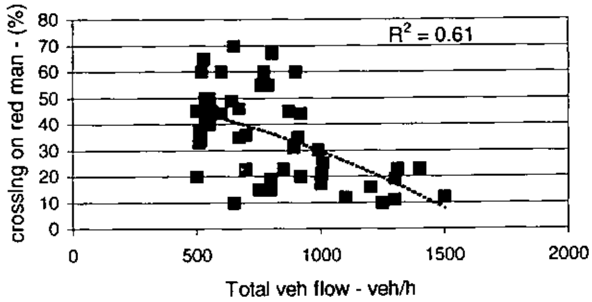

Figure 2 Site data for pedestrians violation of red signal aspect.

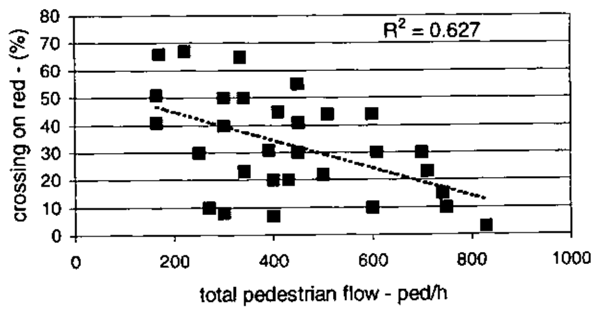

Figure 3 Site data for motorist violation of red signal aspect.

ALTERNATIVE CONTROLLER ALGORITHM

Alternative algorithm is designed with the objective of reducing the percentage of pedestrians who cross the road while the red man is displayed during the periods of low to moderate vehicle flow. The present system is without detection equipment. In order for a system to be sensitive to changes in vehicles and pedestrians flows, a detection equipment should be provided.

The present vehicle detection system is designed primarily to avoid initiating an amber period when there are vehicles within the 40 m from the crossing. The 40 m section upstream of a traffic signal junction is often referred as dilemma zone for the approaching drivers at high speed. This is because the difficulties for the drivers to stop their vehicles if amber is shown to them when they are within 40 m from the stop line. In speed restricted areas, such as the 50 km/h speed zones, few vehicles actually stop within the first 2 seconds of an amber. Some drivers just outside the 40 m zone at the time a change to pedestrian precedence is initiated, and with a clear road ahead, will often accelerate to pass through the crossing location during the last second of an amber or at the start of the red signal.

The above inadequacies support the case to vary the operation of existing vehicle detection system. The basic principle for a new algorithm should ideally has a detection equipment which monitor vehicle movements upstream of the present location. A change to pedestrian precedence would be granted if, for example, the combined sequence of vehicle arrivals offered a crossing opportunity during the next 3 seconds which was acceptable to at least 50 % of the pedestrians. A simple count by the controller in the designated section provides a possible measure of vehicle arrival sequences, which offer crossing opportunities. Based on the crossing index [4], crossing opportunities would be available when as many as nine vehicles were in the 150 m section upstream of the crossing.

The remaining of this paper describes the design and measures of performance of four alternative algorithms. The measures of performance were calculated by a simulation program [4]. The measures of performance presented are based on the comparison of the mean cycle time, percentage of pedestrians crossing during the red man, pedestrian mean delay, and vehicle mean delay. The evaluations are based on a midblock signal controlled pedestrian crossing located on an 8 m wide single carriageway road with vehicles moving at an average speed of 50 km/h. The total pedestrian demand at the crossing is simulated at 500 ped/h. Three levels of vehicle flow (600 veh/h, 800 veh/h and 1800 veh/h), divided equally between the two directions of flow were considered. The vehicle inter-arrival times were based on the displaced negative exponential distribution function. The signal timings are based on those shown in Figure 1. The United Kingdom's vehicle actuated system with f_{max} = 60 and the Malaysian current system provide the basis for comparison.

The four alternative algorithms considered here are summarised below. In all cases, a demand for a pedestrian precedence period is registered automatically when a pedestrian arrives at the crossing [3].

Algorithm 1

The vehicle detectors are assumed to be located at 25 m and 150 m from the crossing location with vehicle speed recorded at the outer detector. Signal controller will calculate the number of vehicles within the section and a weighted sum (W), which takes into account the distance of the vehicle from the crossing. Vehicles closer to the crossing are highly weighted, as they would have higher delay if a change to pedestrian precedence were initiated at the current instant.

A standard Malaysian cycle is used but with a change to pedestrian precedence, on demand, if five or less vehicles in the section and the weight is below a specified level. In this test, the minimum weighted sum is taken as 800. The objective is to provide a more responsive system but to avoid high vehicle delay.

Algorithm 2

Similar to algorithm 1, but slightly bias towards pedestrians with the requirement to satisfy the vehicle weight criteria is replaced with automatic change to pedestrian precedence if a pedestrian waiting time exceeds 20 seconds.

Algorithm 3

Maximum pedestrian waiting period is set at 20 seconds. Detectors are located at 25 m and 40 m. Vehicle extension time between the two loop is set at 1.5 seconds. This means that, when a vehicle passed a detector, the current green period to vehicles is extended another 1.5 seconds.

Algorithm 4

Similar to algorithm 3, but without the detectors. If there is a pedestrian demand, the system will terminate the vehicle precedence period when the vehicle flows on both sides of the road falls below the 85 % of the saturation level.

RESULTS OF SIMULATIONS

The results of comparison for all of the measures of performance are shown in Figures 4, 5, 6 and 7. The results show that all of the alternative controller algorithms satisfy the objective of reducing the percentage of pedestrians whom cross during the red man period. This is achieved by a combination of a reduced cycle time and better targeting the times for pedestrian precedence periods to occur. The reduced cycle time, at low vehicle flow in particular, is partly due to the automatic registration of pedestrian demand and relaxation criteria for a change to pedestrian precedence. The simulation results on the measure of performance to test the existing and alternative algorithms are summarised in the following paragraphs.

Results of simulation of existing operation

The existing operation provides long cycle time at low to moderate pedestrian and vehicle flows. At all levels of vehicle flow, the Malaysian midblock provides higher cycle time and the percentage of pedestrian crossing during the red man period than the United Kingdom system. The results for the existing crossings suggest the benefits of automatic pedestrian demand detectors to register pedestrian presence. Signal imposed delay to pedestrian for the Malaysian crossing is about 45% of the mean cycle time. The higher percentage of pedestrian crossing during the red man period suggests that vehicle precedence are often retained during periods when there are gaps acceptable to pedestrians in vehicle flow.

Results of simulation of alternative algorithms

The alternative strategies reduced the percentage of pedestrians crossing during the red man period for both higher and lower pedestrian flow. All the alternative strategies increase the percentage of time, which is effectively red to vehicles. This is not shown directly in Figures 4, 5, 6, and 7 but, can be inferred from the cycle times. The consequence is an increase in vehicle mean delay. For low to medium vehicle flows, the mean vehicle delay may double the delay at the present system. However, the signal imposed mean delays to pedestrians and vehicles are more balance with the alternative algorithm. At 1800 veh/h flow, the vehicle mean delay for algorithm 1, 2 and 3 is actually lower than the current system. This is an indication that the alternative strategies respond satisfactorily for the specified pedestrian and vehicle flows. Algorithm 2 provides the best overall results for a wider range of vehicle and pedestrian flow.

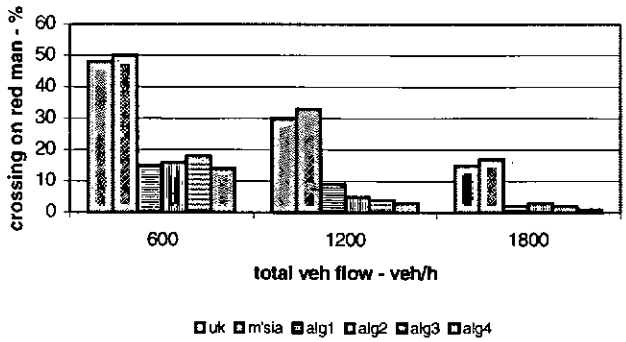

Figure 4 Comparison of the percentage pedestrian violation of the signal aspect.

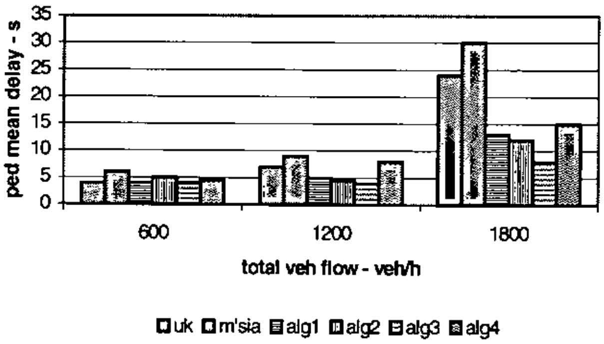

Figure 5 Comparison of the mean delay to pedestrians.

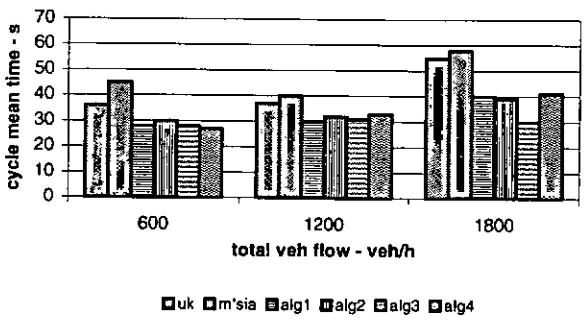

Figure 6 Comparison of the mean cycle time.

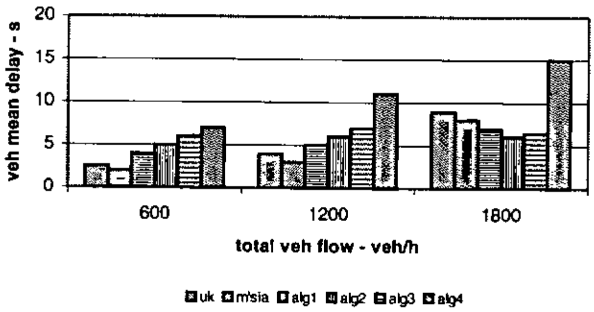

Figure 7 Comparison of the vehicle mean delay.

CONCLUSIONS

The results presented shows that at low to moderate vehicle and pedestrian flows, all alternative algorithms reduced the mean cycle time and increased the effective red period to vehicles. This substantially will reduce pedestrian violation to the signal aspect. This effect would be expected to increase the vehicle mean delay. However, some of the measures of performance are against expectation. The signal imposed mean delays using the alternative algorithm for vehicles and pedestrians are more balanced. This shows that cycle time is terminated during the period of low vehicle delays. Based on the performance of the new strategies, there is little justification for continuing with the existing system that unnecessarily retains vehicle precedence during period of low to medium vehicle flow. However, since the results are based on simulations, assumptions made in defining pedestrians and vehicles behaviour may influence the output. To verify the results, further studies are suggested to validate the algorithms.

REFERENCES

[1] Department of Environment, *Pelican pedestrian crossings, Circular Roads.*

[2] Davies, H. E. H., *The Puffin Pedestrian Crossing: Experience with the First Experimental Sites*, Research Report 364, TRL Crowthorne, 1992.

[3] Reading, I. A. D., Dickenson, K. W. and Barker, D. J., *The Puffin Pedestrian Crossing: Pedestrian Behavioural Study*, Traffic Engineering and Control, Vol. 35, 1995.

[4] Chik, A.A., The Operation of Midblock Signalled Pedestrian Crossings, *Ph.D Thesis*, University of Wales College of Cardiff, Wales, U.K., 1996.