BUS PRIORITY AND QUEUE RELOCATION CAPABILITIES OF PRE-SIGNALS: AN ANALYTICAL EVALUATION

S.S.P. Kumara* and N.B. Hounsell

Transportation Research Group, School of Civil Engineering & the Environment, University of Southampton, Highfield, Southampton SO17 1BJ, United Kingdom
*Corresponding author. Tel.: +44-23 8059 3713; Fax: +44-23 8059 3152.
Email address: spks@soton.ac.uk

Abstract: Pre-signal sites consist of sophisticated traffic control techniques and traffic interactions. Bus priority and queue relocation are two such techniques. An analytical technique based on control delay is proposed to evaluate bus priority and queue relocation capabilities at pre-signal sites. Results from two case studies indicated that pre-signals are capable of providing a strong priority to buses at congested road sections via bus priority and queue relocation techniques. *Copyright © 2006 IFAC*

Keywords: delay analysis, priority, queues, traffic control.

1. INTRODUCTION

The importance of bus transit systems has led to a range of priority measures being adopted, including special priority facilities at traffic signals and segregated facilities along arterials. However there is an important necessity to combine segregated facilities with priority measures at intersections to further enhance transit timing. This is because bus lanes are often implemented on a small section of the route and stops short of a junction or a bottleneck section allowing general traffic to utilize full carriageway width ahead. One of the interesting facilities under the combined segregated and signal priority systems is the pre-signal, which can be defined as the traffic signals at or near the end of a with flow bus lane to provide buses with priority access to the downstream road section.

A bus pre-signal can be used to create two basic arrangements namely the bus advance area and the virtual bus lane. Bus advance area, as shown in Fig. 1 is the area created by the pre-signal in advance of a traffic signal junction for buses to take weaving manoeuvres. On the other hand a virtual bus lane (Fig. 2) is the area created by the pre-signal to relocate queues off congested and/or bottleneck sections to allow buses to bypass the queue and rejoin the main traffic stream. There are two basic priority facilities a pre-signal can offer. They are queue relocation and bus priority. Queue relocation is used to hold general traffic at the pre-signal stop line for a pre-specified duration once a predefined saturation level is reached in the road section between the pre-signal and the main signal. In other words queue relocation limits green duration to general traffic at the pre-signal to ensure that it does not leave wasted green at the downstream junction. On the other hand a bus can be given a priority access to the bus advance area or the virtual bus lane once a bus is detected in the vehicle actuated systems or during the predefined portion of pre-signal red phase in fixed time systems.

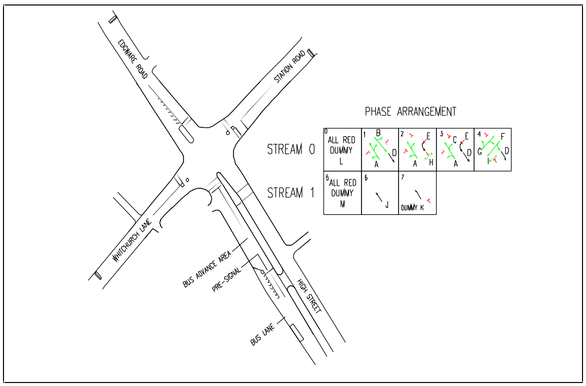

Fig. 1. Bus advance area at Edgware Road pre-signal site in London

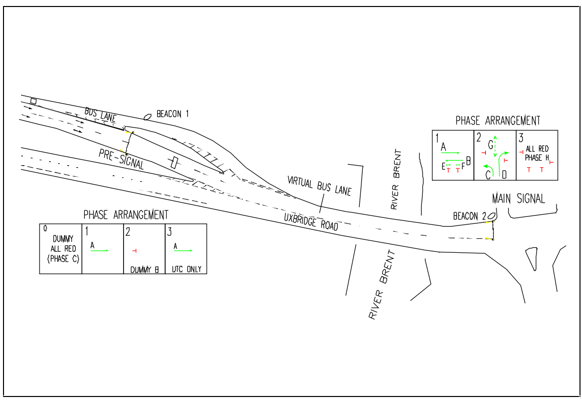

Fig. 2. Virtual bus lane at Hanwell Bridge pre-signal site in London

The main advantages of pre-signalling are savings in delay by getting the bus into the neighbourhood of the junction if queues are long and slow moving, additional benefits from the bus passing the junction in early part of the green, and allowing right turning buses an easy manoeuvre across normal traffic lanes. Further pre-signalling may offer both bus and general traffic a congestion free movement along the downstream road section.

The main aim of this paper is to evaluate bus priority and queue relocation capabilities of pre-signals through analytical modelling. The paper is organized as follows. Design and evaluation techniques are established in the following section, while section three is used to describe selected pre-signal sites. Results form analytical modelling for the selected sites are then explained. Finally a brief summary concludes the paper.

2. DESIGN& EVALUATION TECHNIQUES

TfL (2004) recommended using analytical methods for design and evaluation of pre-signals where possible. However there is limited literature on these methods. Wu and Hounsell (1998) proposed an analytical methodology for the design and evaluation of pre-signals in the pre-implementation stages. However, inability to model advanced controller settings, and inability to take into account residual queues were major drawbacks in this methodology. Therefore this paper proposes an analytically sound methodology for the design and evaluation of pre-signals.

2.1 Signal Timing Design

The green time required at the pre-signal stop line for non-priority traffic to maintain capacity can be estimated by equalling capacities between two sets of signals when signal timings of the main signal (for pre-signal approach) are known, is given by,

$$g_p = \sum_{i=1}^{n} (g_i s_i)_m / s_p \text{, (1)}$$

Subject to,

$$g_p < C \text{, i.e. } \sum_{i=1}^{n} (g_i s_i)_m / C < s_p \text{, and (2)}$$

$$t_o \geq t_p \text{ (3)}$$

where, $g_{i,m}$ and g_p are effective green times (sec) at the main signal stop line for phase i and effective green time (sec) required at the pre-signal for non-priority traffic respectively, while $s_{i,m}$ and s_p are saturation flow (veh/hr) at main signal stop line for phase i and total approach saturation flow (veh/hr) at pre-signal stop line respectively, and n is the total number of phases for the main signal approach. C is the common cycle time (sec) for both signals, while t_p is the passage time (sec) of the front queue between two signals, and t_o is the offset between two signals.

This is the optimum signal time for a pre-signal under queue relocation. If the actual green time is less than the optimum, there is less number of vehicles being released, hence wasted green at the main signal. Obviously the actual timing can not be higher than the optimum for queue relocation to happen. This value can also be treated as the optimum signal timing for a pre-signal for bus priority close to saturation. However it may be necessary to modify this value for bus priority for under saturated conditions. That is, this value is subjected to vary based on delay minimization and offset optimization adjustments. In these circumstances,

$$(g_p)_{\max} = \sum_{i=1}^{n} (g_i s_i)_m / s_p \text{ and (4)}$$

$$(g_p)_{\min} = \textit{main signal green duration} \text{, (5)}$$

The optimum green time should be greater than or equal to $(g_p)_{\min}$, but lower than $(g_p)_{\max}$. For the minimum green time, the optimum offset that offers maximum priority to buses can be obtained when $t_o = t_p$. This means that main signal green starts t_o sec later than pre-signal and pre-signal green terminated t_o sec earlier than main signal. This helps to maintain a favourable platoon between two signals and a vehicle free bus advance area on which buses can take weaving manoeuvres and position where appropriate.

2.2 Operational Assessment

The 'control delay', which includes movements at slower speeds and stops on intersection approaches as vehicles move up in their queue position or slow down upstream of an intersection can be used to evaluate pre-signals. According to highway capacity manual (HCM) (TRB, 2000), the average control delay (D) per vehicle for a given lane group is given by,

$$D = d_1(PF) + d_2 + d_3 \text{(6)}$$

where, d_1 is the uniform control delay, PF is the uniform delay progression adjustment factor, d_2 is the incremental delay to account for the effect of random arrivals and oversaturation queues, and d_3 is the initial queue delay. Readers can refer to HCM for more details. It is observed (Benekohal and El-Zohairy, 2001) that for low and moderate degrees of saturation, the average delay mainly comes from the uniform delay term. The contribution of d_2 and d_3 is more pronounced under higher degrees of saturation. The PF factors take into account the quality of signal coordination and have a considerable range, thus indicate the importance of arrival patterns on uniform