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Signal Design Of A Busy Intersection Using Modelling Technique

Visalakshi. R (761525304)

PG Student, Prist University, Thanjavur

Abstract

In the last decade increasing congestion problems on urban streets combined with environmental concerns and reduced funds for adding road capacity have evoked an interest in promoting Public Transport (PT) all over Western Europe. There have also been shifts in focus from building metros to high quality surface transport, e.g. Bus Rapid Transit (BRT) and/or tram lines that share intersections with other road traffic. One of the most important factors that is known to influence modal choice is the travel time ratio between car and PT travel. It is also known that delay at signalised intersections constitutes a large part of PT journey time in urban areas. One way to reduce delay and improve service regularity for PT at a relatively low cost to other traffic is to introduce PT priority at traffic signals (Bång 1987; Al-Mudhaffar & Bang 2006; Zlatkovic, Martin & Stevanovic 2009). Traffic signals are traditionally designed to minimise the delay per vehicle.

The overall aim of this thesis is to enhance the knowledge regarding effective strategies for conditional priority of public transport in traffic signals; i.e. how to give better benefits to public transport while minimising negative effects to other traffic. Subaims, included in the licentiate part of the work, in order to review the criteria for and fundamentals of public transport priority in traffic signals (PTSP) and analyse the impacts of different PTSP priority functions/strategies in a coordinated signal system based on simulation trials.

Introduction

In the last decade increasing congestion problems on urban streets combined with environmental concerns and reduced funds for adding road capacity have evoked an interest in promoting Public Transport (PT) all over Western Europe. There have also been shifts in focus from building metros to high quality surface transport, e.g. Bus Rapid Transit (BRT) and/or tram lines that share intersections with other road traffic. One of the most important factors that is known to influence modal choice is the travel time ratio between car and PT travel. It is also known that delay at signalised intersections constitutes a large part of PT journey time in urban areas. One way to reduce delay and improve service regularity for PT at a relatively low cost to other traffic is to introduce PT priority at traffic signals (Bång 1987; Al-Mudhaffar & Bang 2006; Zlatkovic, Martin & Stevanovic 2009). Traffic signals are traditionally designed to minimise the delay per vehicle. However vehicles carry a very different number of passengers; a bus typically has 10 – 20 times the number of passengers compared to an average car and a tram contains even more (Bång 1987). In order to minimise the delay per person, PT vehicles need to be treated differently from cars at traffic signals, i.e. the PT vehicles need to be prioritised in order to minimise the delay per

person. PT priority is not trivial to implement in conventional coordinated traffic signal systems, as "green waves" are often disrupted, and lengthy minimum times for pedestrian crossings restrict the possible signal changes. It may also be necessary to make green time compensations on other approaches once a PT vehicle has passed, which may have further negative impacts on the performance of the coordinated system (Wahlstedt 2013a). Public transport traffic signal priority (PTSP) can be passive or active. In passive PTSP signal timings are set to favour PT in general. Active PTSP triggers priority measures when there is a PT vehicle present, thus requiring selective detection of PT vehicles. Active PTSP can be unconditional or conditional. Unconditional priority will always favour the PT vehicles without considering negative impacts for other road users, while conditional priority in one way or another tries to restrict the impacts on other traffic. The criteria for conditional PTSP can be based on the impacts on other traffic and/or on the PT vehicles. Examples of criteria for conditional PTSP based on PT vehicles are: only give priority to certain lines; not giving priority to early buses/only giving priority to late buses. Criteria
based on the on-time status of PT vehicles can improve PT regularity and service reliability (Furth & Muller 2000).

Objective

The overall aim of this thesis is to enhance the knowledge regarding effective strategies for conditional priority of public transport in traffic signals; i.e. how to give better benefits to public transport while minimising negative effects to other traffic. Sub-aims, included in the licentiate part of the work, in order to achieve this are:
1. Review of criteria for and fundamentals of public transport priority in traffic signals (PTSP)

2. Analysis of the impacts of different PTSP priority functions/strategies in a coordinated signal system based on simulation trials

3. Study of the possibilities to use conditional signal priority to avoid bus bunching.

Methodology

The conflicts arising from movements of traffic in different directions is solved by time sharing of the principle. The advantages of traffic signal include an orderly movement of traffic, an increased capacity of the intersection and require only simple geometric design. However the disadvantages of the signalized intersection are it affects larger stopped delays, and the design requires complex considerations. Although the overall delay may be lesser than a rotary for a high volume, a user is more concerned about the stopped delay.

Criteria for Signal Control

There can be many goals or criteria to optimise the design and settings of traffic signals. The most common are maximum capacity, minimum average delay or cost also including the impact of stops and emissions. Local regulations and traffic safety concerns also need to be considered, and can limit the possible design and potential to achieve other goals. In the Swedish LHOVRA control strategy (Al Mudhaffar 2006) traffic safety is of great importance and is allowed to increase minimum delay and number of stops if necessary. However the goals and criteria for optimal control are seldom clearly stated and local tradition and best practice is often applied when making the design. Traditional control strategies also often use heuristic methods to achieve the aimed goals, making it hard to balance between the different criteria.

Co-ordinated Signal control

With coordinated controlled signals, the green periods and cycle time are set considering adjacent signals, coordinating the

offsets for the start of green periods to facilitate passage through the system in the main directions. With some exceptions, this implies a common cycle time for all coordinated signals. With conventional control strategies, the common cycle time means that the signals need to be mainly FT controlled, but some local traffic adaptation within the fixed cycle time is possible. This can include setting signal groups to green on demand only, green extensions or other functions as long as their overall influence is not too large.

Methods for Bus Priority

The configuration and timing of signalised intersections as well as physical design of streets are often optimised to minimise average delay for all motor vehicles. However, since buses and trams normally carry much higher number of passengers this will not minimise the delay per person. Public Transport Vehicles therefore need to be handled differently in order to minimise the overall delay per person. The bus lines sometimes use other streets than the main routes prioritised in the street network, and have a different speed profile due to bus stops compared to the design speed of signal coordination made for cars. Therefore buses and trams need to be specially prioritised in urban traffic to minimise the delay per person. There can also be political reasons to "over compensate" buses and trams in order to promote travel by public transport instead of by car to reduce pollution and congestion. The City of Stockholm has adopted the "Urban Mobility Strategy" stating that the more surface efficient modes of mobility, such as public transport, cycling and walking should be prioritised over cars in central Stockholm (Firth 2012).

Results and Discussions

The case studies in this thesis supports the conclusions, found in literature, that PTSP can considerably reduce the travel time for buses, at the expense of slightly increased travel time for other traffic. Principally PTSP reallocates green time to the bus approach from other approaches by green extension or red truncation, and one could therefore imagine that other traffic following the bus route would also benefit. In some cases this is true, but the reallocated green time is not necessarily useful for traffic other than the prioritised bus. If the signal is green, but no vehicle is present there is no use for this extra green time. The changes in green times made by the PTSP strategy to prioritise buses do not only redistribute green time between the approaches, they redistribute green time over cycles as well. If the green time for the cross street is determined by the minimum time for pedestrians to cross, it cannot be shortened but only moved forwards in the cycle. This will affect the bus approach in the next cycle by delaying the green period, and deteriorating the green wave progression. This will mostly affect vehicles travelling in the opposite direction to the prioritised bus. Green time compensations to avoid cross street queue accumulation will have similar effects, and therefore need to be carefully timed.

This shows one conceptual error in most implementations of PTSP in coordinated systems with conventional control strategies; the PTSP changes of green times are made one intersection at a time without explicitly making any changes of green times in adjacent intersections to maintain green wave progressions. However, a PTSP strategy applied within conventional control strategies that could make green time changes in several intersections would be complex though, while it would be one of the strengths of self-optimising control strategies.

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