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THE CONTROL SYSTEMS AT SIGNAL CONTROLLED JUNCTIONS FOR BUS PRIORITY

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Introduction

One of the main aims of all larger cities is to ensure effective transportation of persons which can be ensured by two existing options. The first option is based on the development of roads network. This option doesn't appear to be the best solution in terms of ecological impacts in the area of built roads and also the high costs of their building. The second option is to ensure the transportation of persons by increasing the efficiency of use of existing roads, because the well-functioning management system improves the flow of traffic, reduces road accidents, and improves the comfort of transport.

The way which is possible to ensure the increase the efficiency of use of existing roads in the cities is the building a system of public transport priority. Because public transport is able to satisfy the transport requirements of a much larger number of passengers and acts more favourably than private transport on urban areas. Priority of public transport by light signalling means a possibility of a preferred option and an extension of the green signal for a vehicle, which come to a junction. It is desirable so that the vehicle can cross signal controlled junction as far as possible without stopping or at least with minimum delay.

A variety of traffic signal control systems and associated strategies are operational in different cities around the world. These may be conveniently grouped into the two categories-isolated systems and co-ordinated systems.

Isolated Systems

Signal controlled junctions that are located and operated independently are known as isolated junctions. This form of control is selected when traffic arrivals at the junction are largely unaffected by any neighbouring traffic signals. These signals, which may still be linked to a Traffic Control Centre (e.g. for fault monitoring), are more common in suburban areas where traffic signal density is lower or in smaller towns. An isolated system can be controlled by fixed time or vehicle actuated.

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With fixed time control, signal timings ('plans') are calculated off-line, and implemented using the traffic controller at the site. These plans use historic, based on measured traffic data to generate optimum plans that usually vary by time of day and day of week.

Vehicle actuated (VA) systems rely on traffic detectors on junction approaches to detect vehicles, to allocate green times to different traffic movements according the traffic detected. With its traffic responsive capability, VA is the very common form of control for isolated junctions. In this system, a vehicle approaching a red, or amber, signal registers a demand for a green. This demand is stored in the controller, which serves allowed stages in cyclic order omitting any stages for which no demand has been received. Once a green signal is displayed, the duration may be extended by vehicles detected moving towards the signal. If vehicles continue to extend the green period and a demand exists for another stage, the green signal will be terminated on expiry of a preset maximum period. On expiry of the last extension and with no more vehicles detected, the controller will answer a demand for another stage.

The VA system can give priority to buses detected on the approach by extending the current green period or by recalling the priority stage for the buses early. A 'priority recall' may be implemented by curtailing the non-priority stages to their minimum values. Non-priority stage curtailed to give priority may be compensated by increasing its normal maximum value by the compensation period. An inhibit facility can also be provided which prevents bus priority actions in consecutive signal cycles. This ensures that compensation can be given to non-priority stages.

MOVA

MOVA (Microprocessor Optimised Vehicle Actuation) is an advanced VA controller developed in the UK . MOVA analyses lane-by-lane detector data and controls the signal timings to optimise delay and stops or capacity (if any approach becomes oversaturated). Bus priority can be implemented within MOVA using Selective Vehicle Detectors (SVDs) to distinguish buses from most other vehicles. The system gives priority to the buses detected on the approach by extending the current green period or by demanding the priority stage for the buses. The priority stage demand may be implemented by truncating the non-priority stages to their minimum values (stage truncations) or by skipping all those stages en-route to the priority stage (stage skipping).

Co-ordinated Systems

When signal controlled junctions are more closely spaced, and traffic interactions occur, coordinated control is often implemented. Operations at a junction are then influenced by operations at one or more neighbouring junctions, with all junctions then co-ordinated using an Urban Traffic Control (UTC) system. UTC systems are implemented in most medium and large towns and cities around the world, particularly in central areas where junction density is highest. One of co-ordinated UTC systems is traffic responsive.

Traffic responsive UTC

Traffic responsive systems rely on traffic detectors on junction approaches to provide data that is used to calculate optimum signal settings in real time. The improved traffic performance that has been demonstrated with traffic responsive control has led to the development of a number of systems, such as SCOOT, SCATS and UTOPIA. Nevertheless, full traffic responsive control carries a significant implementation and maintenance cost, so has not become widespread in all cities.

SCOOT

SCOOT (Split Cycle Offset Optimisation Technique) is an adaptive Urban Traffic Control (UTC) system that responds automatically to fluctuations in traffic flow obtained from the on-street detectors. This is carried out by continuously adapting three key traffic control parameters - the amount of green for each approach (Split), the time between adjacent signals (Offset) and the time allowed for all approaches to a signalled intersection (Cycle time). The adaptation is aimed at minimising wasted green time at intersections and reducing stops and delays by synchronising adjacent sets of signals. The changes in signal timings are made such that they are small enough to avoid major disruptions in traffic flow, but are frequent enough to allow rapid response to changing traffic conditions.

Bus priority can be provided in SCOOT by extending the current stage for a bus to allow it clear the junction, or shortening intervening stages to return more quickly to the bus stage. The amount of priority given to buses can be restricted depending on the saturation of the junction as modelled by SCOOT and the target degrees of saturation for extensions and recalls. These are the degrees of saturation to which the non-priority stages can be run in the case of a priority extension or recall respectively. Normally, the amount of priority is decided by the SCOOT optimiser at the UTC centre and communicated to the local traffic controller. However, in the case of priority extensions, there is a facility to decide it locally within the limit set by the central control. In recent developments, SCOOT also has facility to give different levels of priority to buses based on their performance against the predefined criteria. For example, no priority for buses running on time, moderate priority for late buses, high priority for very late buses. The recent version of SCOOT also has facility give priority by skipping non-bus stages.

SCATS

SCATS (Sydney Coordinated Adaptive Traffic System) is an urban traffic control (UTC) system originally developed for application in Sydney and other Australian cities. SCATS primarily manages the dynamic (on-line, real-time) timing of signal phases at traffic signals, meaning that it tries to find the best phasing (i.e. cycle times, phase splits and offsets) for the current traffic situation (for individual intersections as well as for the whole network). This is based on the automatic plan selection from a library in response to the data derived from loop detectors or other road traffic sensors.

Public Vehicle priority in SCATS caters for both buses and trams. SCATS has a facility to provide three levels of priority:

- High –In the high priority mode the hurry call facility is used. i.e. the phase needed by the tram is called immediately, skipping other phases if necessary,
- Medium – Flexible window – Phases can be shortened to allow the bus/tram phase to be brought in early. The bus/tram phase can occur at more than one place in the cycle.
- Low –takes its turn

Trams would normally be given high priority, the aim of which is to get the tram through without it stopping. Buses would normally expect to receive a medium level of priority.

MOTION

MOTION (method for the Optimization of Traffic Signals Online-Controlled Networks) has two components, MOTION central and MOTION local. The central function creates plans that can then be adjusted by the local element, where suitable detectors are installed. Buses can be given priority in the offset optimisation in MOTION central by limiting the range of options for optimising stage sequence, split and offset for private vehicles to those that provide a green time window for public transport vehicles at their expected arrival times.

MOTION provides the following means of PT-prioritisation:

- at the network level: coordination of traffic lights can be forced to take into account predominantly the routes of important and frequently used PT-lines, offsets may be determined by using average travel times of PT along the respective links,
- at the intersection level: automatic generation of new signal timings by the network-optimization can be forced to treat splits and stage sequences in a PT oriented way. The degree of local PT-prioritization can dynamically be set to a more or less restrictive mode- according to an assessment of the current traffic situation by the network-model.

UTOPIA/SPOT

UTOPIA (Urban Traffic Optimisation by Integrated Automation)/SPOT (System for Priority and Optimisation of Traffic) is a hierarchical-decentralised traffic signal control strategy developed by Mizar Automazione in Italy. It is now used in several cities in Italy and also in the Netherlands, USA, Norway, Finland and Denmark. UTOPIA/SPOT aims to minimise the total time lost by private vehicles during their trips, subject to the constraint that public vehicles to be prioritised shall not be stopped at signalised intersections. This is carried out by optimising a cost function depending upon various elements including: vehicle delays and stops, delays to public transport; and deviation from the reference plan and previous signal settings. The optimisation is carried out at two levels: local and network. At the local level, the controller determines the signal settings by optimising a cost function adapted to the current intersection traffic situation.

Optimisation is done on a ‘time horizon’ for the next 120 seconds and is repeated every three seconds. At the network level, optimisation is based on the cost function taking account of the state of neighbouring intersections to build dynamic signal co-ordination.

In UTOPIA/SPOT, bus priority is provided by shifting the ‘green window’ to match the estimated arrival time of a bus at the stop line. This method uses bus location information from well upstream of the junction and the signal timing is gradually adapted to match the relevant green stage occurrence to the predicted arrival time of the bus. This method has the potential advantage of a less abrupt impact on signal timings but its efficiency is more dependent on accurate journey time forecasting. Information on all vehicles is provided to the

SPOT controllers by inductive loop vehicle detectors located just downstream of the previous junction.

Bus Priority

This part shows that bus priority at signal controlled junction is implemented widely around the world, in small towns as well as big metropolitan cities. Table 1 shows the population in individual cities, number of signal junctions providing bus priority, as well as number of buses equipped for bus priority. The information is from 2009.

City	Countries	Population	No. of signal junctions providing bus priority	No. of buses equipped for bus priority
Aalborg	Denmark	197 426	51	249
Cardiff	UK	346 100	46	191
Genoa	Italy	608 493	84 500	500
Glasgow	UK	598 830	241 500	500
London	UK	8 113 885	3200 8000	8000
Prague	Czech republic	1 258 106	65	352
Stuttgart	Germany	591 127	34	-
Toulouse	France	427 000	160	-

Table 1 Examples of cities and bus priority at signal controlled junction

As you can see in table 2, in most of the cities (priority request communication), the priority request is communicated directly from each bus to the traffic signals (decentralised method) although there are a number of cities which have adopted a centralised architecture. The next column gives examples of the variety of traffic control systems used in different cities providing bus priority at traffic signals. Within Europe, SCOOT is widespread in the UK and UTOPIA/SPOT is used in a number of countries, particularly Italy and Sweden. Many other European countries use their nationality preferred traffic control systems, with functionality added for bus priority. The last column shows the detection technologies. GPS detection is used for bus priority purposes in most cities, particularly in European countries.

Beacon based detection is still popular in some cities. An earlier study found that approximately two-thirds of US cities use optical beacon detection.

City	Priority request communication	Traffic signal control systems with bus priority facility	Detection technologies
Aalborg	Centralised	GPS supplemented by Odometer	GPS
Cardiff	DeCentralised	SCOOT UTC	GPS
Genoa	DeCentralised	SIGMA UTC	GPS
Glasgow	Centralised	SCOOT UTC	GPS
London	DeCentralised	SCOOT UTC, VA	GPS supplemented by Odometer and map matching
Prague	DeCentralised	MOTION	Beacon
Stockholm		UTOPIA/SPOT UTC	GPS
Stuttgart	Decentralised		Beacon and GPS
Sydney		SCATS	GPS
Toulouse	Centralised	CAPITOUL UTC	GPS supplemented by Odometer

Table 2 Priority request communication and detection technologies

Benefits of bus priority for several cities are shown in table 3. This shows some variation in the criteria used to report benefits and also some degree of variability in the levels of benefit reported between different cities. It should be noted that these benefits are often affected by the policy adopted rather than the capability of the system. For example, for 56 SCOOT in London, the policy is to provide bus priority with minimal impact on other traffic. Given the high levels of bus flow and congestion in London, this means that priority has had to be constrained.

City	Delay savings	Travel time
Aalborg	5.8 sec/bus/jun	4% reduction in average
Cardiff		3-4% reduction
Genoa		7-10% reduction
Glasgow		Reduced
London	9 sec/bus/jun at isolated and 3-5 sec/bus/jun at SCOOT junctions	
Prague		2% reduction
Stockholm		10% savings
Sydney		up to 21% reduction
Toulouse		5-24% decrease

Table 3 Priority benefits

Conclusion

Providing of public transport priority requires constant monitoring of transport development on individual junctions and consequently changes in the organization of traffic on them. Ensure effective management of signal controlled junctions to achieve significant time savings not only for public transport vehicles but also for other road users. Favorable method for the management of urban areas as well as for the management of public transport which using of the traffic detector response to the current traffic situation and on the basis of its evaluation adjust signal plans, length of the green signal, and to assign signal "free" for public transport vehicle for individual directions of junctions etc.. In this way, although it is necessary to consider the higher costs associated with the construction and maintenance of the system, but the control in this way ensures free flow of traffic at the intersection.

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