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Public Transport Priority Strategies: Progress and Prospects

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Abstract

In the years to come, public transport will be called to play a significant role towards achieving the sustainable transport system objective set for the future in Europe and beyond. To this end, the quality, accessibility and reliability of its operations should be improved. In this context, the favorable treatment of public transport means within the road network may have, among others, a significant contribution. Such treatment can be derived as a result of an appropriate design of the road network facilities and/or the employed signal control at the network junctions. To this end, several approaches have been proposed, and it is the aim of this paper to review them, focusing mainly on those attempting to provide priority via appropriate adjustment, in real time, of the junction's signal control.

KEYWORDS

Public transport systems; public transport priority; priority strategies

1. INTRODUCTION

The road transport network, used for the mobility of people and goods, consists of the road network and any existing bicycle and pedestrian paths or spaces, the pedestrians, the public and private transport means and the terminals. The continuous increase of the urban population and of the mobility needs of people and goods, as well as of the use of the private vehicle, in combination with the fact that the road transport system had not been designed considering such a significant increase, have resulted in substantial traffic and environmental problems. City centers, especially, suffer most from congestion, poor air quality and noise exposure. To confront the significant challenges and set the roadmap towards a sustainable transport system by 2050, the European Union (EU) has released a White Paper on Transportation (EC, 2011), according to which three main goals have been set, which can be summarized as "use less energy, use cleaner energy and better exploit infrastructure".

Public transport (PT) can play a significant role in the achievement of the aforementioned goals via increased ridership, which may be enabled by improving the quality, accessibility and reliability of its operations. In this context, the favorable treatment of PT means within the road network, which is called *Public Transport Priority* (*PTP*), may have, among others, a significant contribution. PTP can be derived as a result of an appropriate design of the road network facilities and/or the employed signal control at the network junctions. To this end, several approaches have been proposed, and it is the aim of this paper to review them, focusing mainly on those attempting to provide priority via appropriate adjustment, in real time, of the junction's signal control. Applications of PTP systems worldwide are also presented and discussed in an effort to identify the current trends and future perspectives in the respective field. The paper is based on the outcome of an extensive literature review, which is reported in more detail in Diakaki et al (2013).

2. PUBLIC TRANSPORT PRIORITY MEASURES

The PT means include buses, Light Rail Transit (LRT), trams and trains, and the measures, which may be used to improve their performance, fall into two general categories, the *facility-design-based* and the *signal-control-based* measures. The facility-design-based measures are used in the case of PT means that do not necessarily move on fixed paths, and may include exclusive lanes of several configurations (e.g. with-flow, contra-flow, reversible, etc.), as well as other infrastructure arrangements such as high occupancy vehicle (HOV) lanes, intermittent bus lanes (IBLs), bus gates and rising bollards, queue jumper and bus bypass lanes, etc.; while signal-control-based measures rely on the junction signal control and range from appropriate provisions in fixed-time signal settings to real-time signal priority locally or network-wide, so as to favor the movements of PT means.

As far as the signal-control-based measures are concerned, the level of provided priority may vary for different types of served PT means. Highway-rail crossings are typically assigned the highest priority that provides the most aggressive manipulation of the signal controller (Nelson and Bullock, 2000), while emergency vehicles, such as fire trucks, are assigned a slightly lower priority to allow a signal from a highway-rail grade crossing to override the emergency vehicle request. Buses, trams and LRTs are generally assigned an even lower priority, which is often only granted if specific conditions are satisfied; mainly when the PT vehicle is behind its schedule (Nelson and Bullock, 2000).

3. SIGNAL-CONTROL BASED PUBLIC TRANSPORT PRIORITY

Within urban networks, the prime means of traffic control are the traffic lights installed at appropriate network junctions, and there are several methods employed to modify their normal operation in order to provide priority to PT vehicles. The main methods for this modification are (see Figure 1 for examples):

- *Green extension*: This method refers to the extension of green time to serve a PT vehicle approaching the junction towards the end of the green time. It is commonly used where the detection is relatively close to the priority junction and is subject to constraints like maximum extension time, minimum green-time for the other stages, etc.
- *Stage recall*: This method refers to the recall of a stage, if its signal is on red at the estimated arrival time of the PT vehicle. It may involve the (green) truncation of more than one stage, subject to minimum green-time constraints. As green extension, stage recall is also commonly used where the detection is relatively close to the priority junction.
- *Stage skipping*: The previously mentioned methods do not affect the normal stage sequence. An alternative and stronger form of priority is to omit one or more stages from the normal stage sequence so as to allow for the service of a priority request as soon as possible.
- *Stage reordering*: An even stronger form of priority is to modify the normal sequence, i.e. to activate a stage, which is later in the order, before others to serve a received priority request.
- *Special stage*: According to this method, a special stage is allocated to the movements of PT vehicles and is introduced into the normal sequence at the first available opportunity in order to serve a received priority request. This might mean that other stages may have to be truncated to their minimum green times (as in stage recall) or even totally skipped (as in stage skipping).

The aforementioned methods may be either considered explicitly or they may result as a solution of related optimization problems. In general, the strategies employed to modify the normal signal control of junctions in order to provide priority to PT means are classified as *fixed-time* and *real-time* strategies.

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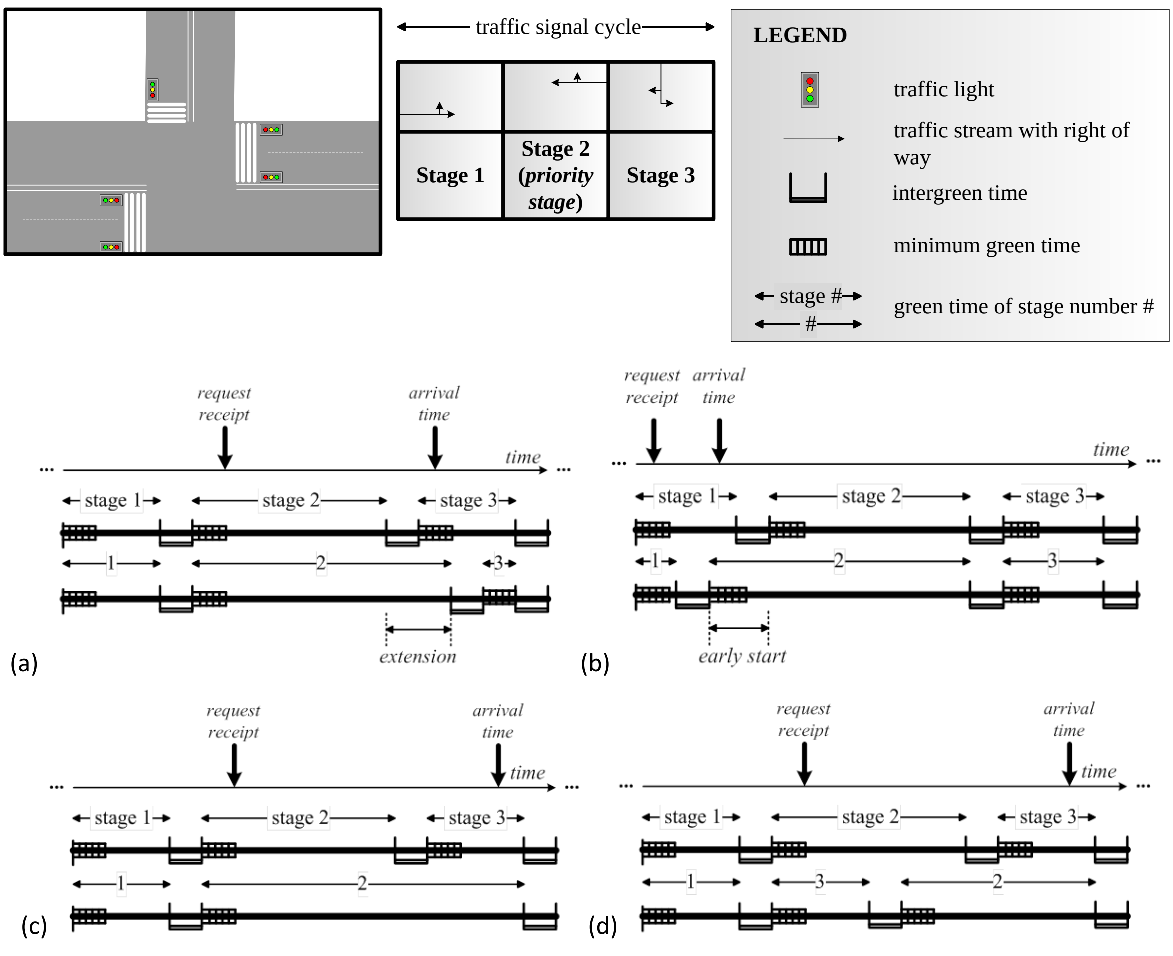
Fixed-time strategies are in fact fixed-time signal plans especially developed to favor the movements of PT vehicles by considering factors such as longer green times for stages serving PT vehicles, reducing the cycle length to reduce delay, providing stage sequences designed to more frequently serve the stages that have high demand of PT vehicles, etc.. The most known example in this class of strategies is the TRANSYT PTP tool, while more recently, Genetic Algorithms (GAs) coupled with micro-simulation tools have been employed to solve appropriately developed optimization problems and provide the necessary fixed-time plans.

The real-time strategies attempt to overcome the flexibility disadvantages of fixed settings via closed-loop operation. To this end, they require the ability to detect in real-time PT vehicles approaching signalized junctions via, as a minimum, Selective Vehicle Detectors (SVDs), such as bus detection loops and transponders on buses. The sophistication and resulting performance though of these strategies may be improved in case of availability of more advanced systems such as Automatic Vehicle Location (AVL) and Global Positioning Systems (GPS), which provide in real-time more detailed PT-vehicle related data. Real-time strategies may be further classified as *rule-based* versus *optimization-based*, depending on whether their control decisions are based on a set of identified conditions or on the optimization of an appropriately defined performance index.

Figure 1 Examples of priority methods: (a) green extension; (b) stage recall; (c) stage skipping; (d) stage reordering



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Rule-based strategies are triggered by the receipt of particular priority calls and respond to them according to their underlying rules, by directly modifying the implemented signal control; this modification may be more or less aggressive depending on the prescribed priority level. Known examples include the PTP modules that complement known signal control strategies such as SCOOT, SCATS, BALANCE, MOVA, TRAFCOD and TUC, as well as strategies such as PRIBUSS, BCC-RAPID and SPRUCE that have been developed specifically for PTP purposes.

A difficulty with the rule-based strategies is that they are not able to respond adequately when multiple requests arrive simultaneously or in short time intervals, calling for contradictory signal control modifications. This limitation may be overcome by the employment of optimization-based strategies. The optimization-based strategies attempt to provide priority based on the optimization of some performance criterion; primarily delay (passenger delay, vehicle delay, weighted vehicle delay or combination). They use actual observed (both private and public) vehicle arrivals as inputs to traffic models that either evaluate several alternative timing plans to select the most favorable option, or optimize the actual timing in terms of stage durations and stage sequences. Common optimization techniques that are employed in this respect include linear, mixed-integer and dynamic programming; heuristic approaches have also been proposed aiming at reducing the computational effort that is usually very high due to the typical utilization of binary decision variables representing the green-red switching of the traffic lights. Known examples of optimization-based strategies include PRODYN, RHODES/BUSBAND and CAPRI, UTOPIA/SPOT, MOTION, DARVIN, etc.

Beyond the above classification, PTP strategies may also be distinguished according to criteria, which address other characteristics and lead to the following classifications:

- *Local* vs. *network-wide* strategies: The local strategies operate at individual junctions, independently of all other junctions, in the aim of accelerating the PT vehicle passage at those junctions; while the network-wide strategies attempt to improve the progression of PT vehicles within a network.
- *Reactive* vs. *proactive* strategies: The reactive strategies are typically local, i.e. applied at each junction separately of the others, and react to received PT presence messages from approaching links to enable an accelerated passage, without involvement of model predictions other than the estimated time of arrival of the PT vehicle at the specific junction. The proactive strategies, on the other hand, attempt to proactively respond to priority requests. They receive a request of service well in advance, perhaps when the PT vehicle is one or more signals upstream, thus having more time to plan for the arriving vehicle, to accommodate multiple requests for service, and to co-ordinate the vehicles' transfer point of operation.
- *Unconditional* vs. *conditional* strategies: The unconditional strategies provide priority regardless of the status of the PT vehicle, i.e. regardless of whether the vehicle really needs to be treated in a special way at its approach to a signal-controlled junction (e.g. the vehicle may be in advance of its schedule, thus it does not need any priority treatment), while in conditional strategies, the decisions are usually made based on the schedule or headway adherence of the arriving vehicle. This assumes that the signal control system knows the operating status of the arriving vehicle, which in turn implies that the application of conditional strategies requires additional real-time information regarding the operating status of a detected PT vehicle.

4. APPLICATIONS OF PUBLIC TRANSPORT PRIORITY SYSTEMS

Although a few efforts towards PTP have been reported as early as in the 1970s, the most serious efforts did not start until the late 1980s; since then, with ever increasing interest. Nowadays, many cities around the world include within their UTC systems special priority features; at the same time they increasingly also

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adopt facility-design-based measures in an effort to improve their PT operations, thus encouraging modal shift and promoting the use of PT means.

The reported PTP applications in European cities, as well as in cities in the rest of the world, concern strategies of different architectures (centralized or decentralized) employing different detection and communication devices and systems. Despite their differences, however, the vast majority of reported strategies are based on a local, reactive, conditional, rule-based logic, which favors the movements of PT vehicles at a higher or lower degree, depending upon the adopted priority levels as well as the availability of other facility-design-based measures.

The European philosophy to PTP has been rather aggressive, with provision of higher priority levels and less concern for the potential negative impacts to the rest of the traffic. The bus seems to be the most common PT mean with the length of the bus networks ranging from a few to thousands of kilometers; cities of similar size have considerably different bus network lengths, depending on the presence of other PT means in the city (Kaparias et al, 2010). LRT and tram systems are also very common in European cities (Kaparias et al, 2010).

To improve the performance and efficiency of PT, many European cities employ PT priority measures, mainly of a facility-design-based nature; exclusive bus lanes in specific. Known PTP strategies that are used or have been tested in European cities include:

- SCOOT, MOVA, SPRUCE, SPRINT and TUC in UK;
- UTOPIA/SPOT in Italy, Romania, UK and Sweden;
- PRIBUSS in Sweden;
- PRODYN in France and Belgium;
- BALANCE in Germany and Poland.

Beyond the above, several other rule-based strategies have been locally developed and applied in Austria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, Romania, Sweden and Switzerland. The case of Zurich in Switzerland where a full PT-oriented philosophy and approach has been developed and adopted since 1970 is perhaps the most noticeable from all reported PTP cases. This philosophy, which resulted in a full bus-tram priority via all available means, produced mobility and traffic conditions that enabled a significant modal shift towards PT; it has been reported that approximately 42% of trips in Zurich are made by PT means (Gardner et al, 2009).

Similarly to Europe, several PTP strategies have been reported in other cities in the rest of the world such as:

- SCATS in Australia and Canada;
- RAPID in Australia;
- SCOOT in Brazil and Chile.

In USA and Canada, several other PTP strategies of a rule-based nature have been developed by local or state traffic/highway departments, with the level of deployment varying considerably from location to location, and ranging from equipping a few junctions and a limited number of buses, to equipping entire corridors and to system-wide deployment. PTP applications have also been reported in Japan.

5. CONCLUSIONS

As discussed in the previous sections, several different signal-control based strategies have been developed and applied worldwide. The relevant literature offers a few examples of fixed-time priority strategies, and

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numerous examples of real-time priority strategies, mainly of a rule-based nature. A similar tendency is also observed in the practical applications of PTP systems, where the vast majority of adopted strategies are real-time, rule-based.

Rule-based strategies are triggered by the receipt of particular priority calls and respond to them according to their underlying rules, by directly modifying the implemented signal control. However, they are not able to respond adequately when multiple requests arrive, simultaneously or in short time intervals, calling for contradictory signal control modifications. This limitation may be overcome by the employment of optimization strategies at the expense, however, of the required computational effort that is usually much higher than that of the rule-based approaches.

For the above reasons, the development of more efficient rule-based strategies still remains a prime subject of research and development, which calls for novel solutions that will evidently improve the public transport operations and promote their use

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