Vehicle holding and conditional priority strategies in public transit operations

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This presentation focuses on the improvement of speed and regularity of intermediate capacity transit systems, a key factor in establishing a viable alternative to private car in medium sized towns and in complementing high capacity rapid transit in larger urban areas. The strategies aiming at improving transit performance are tested within the framework of an operation model, where relevant phenomena are duly represented. The impact of such phenomena on waiting times is measured by headway variance.

A review of operation models and other transit related issues at various planning levels can be found in the survey paper by Desaulniers and Hickman (2007). Transit line operation models have been studied with the aim to apply control methods in presence of service irregularity. With reference to normal service conditions, Desaulniers and Hickman report that the most important control methods are vehicle holding and transit signal priority.

Vehicle holding is the process of intentionally delaying a vehicle at a stop/station after passengers have alighted and boarded. Eberlein et al. (2001), using headway data collected by an automated system, formulated the optimal holding problem utilizing a deterministic transit operation model, within a rolling horizon approach. Hickman (2001) formulated, within an analytic stochastic operation model framework, the optimal holding at a control stop as a convex quadratic program. Sun and Hickman (2008) formulated the control problem of holding vehicles at a given subset of stations on the route, in the context of a deterministic model of transit operations.

Conditional transit priority strategies at traffic lights, that is, to allow only selected vehicles to get priority, can increase transit speed while keeping operation regular. A comprehensive review of signal priority methods (unconditional, conditional and adaptive), is performed by Shalaby *et al*. (2006). In the same paper a number of design and operation issues, such as the prediction of transit travel time, are addressed. Furth and Muller (2000), focusing on the schedule adherence, tested a conditional priority strategy at the busiest intersection along a mixed traffic bus route and compared the results with an absolute priority strategy (where all vehicles, and not only those behind schedule, get priority) formulating also additional considerations regarding the impact to the general traffic. Furth and Muller (2007) investigated the effect of “timepoints” (schedule based holding) on bus transit, utilizing a method to transform the lack of punctuality into time loss including the introduction of a “potential time”, accounting for anticipated travelling in order to rely on arriving on time with a given probability. Altun and Furth (2009) studied a combined schedule based conditional priority and holding with different schedule tightness.

In the present case, the operation model for a one-way transit line is defined by recursive relationships corresponding to the line operation within a certain time horizon. The adopted modeling approach (see for example Bellei and Gkoumas, 2009) involves Monte Carlo simulation implemented by repeatedly drawing the outcome of the main random phenomena, such as the arrival of passengers at stops, the alighting from transit vehicles and the running time between stops. These are given as input to the operation model, to obtain a random drawing of the whole operation pattern. The boundary conditions for the first and last vehicle, and from (to) the first (last) stop are set accordingly. The model, implemented in Visual Basic, takes into account the passengers arriving during the dwell time and the vehicle capacity constrain. The traffic lights are represented within the operational model by assuming that there is a one-to-one correspondence among stops, traffic lights and intersections, being each stop and traffic light located immediately upstream the intersection. The same fixed cycle and green are defined at each traffic light, the offsets are all zero and lost times are neglected. A graphical output of a single iteration outcome (21 vehicles over 30 stops) can be seen in figure 1. In order to achieve statistical consistency, in each simulation cycle an elevated number of iterations is performed.

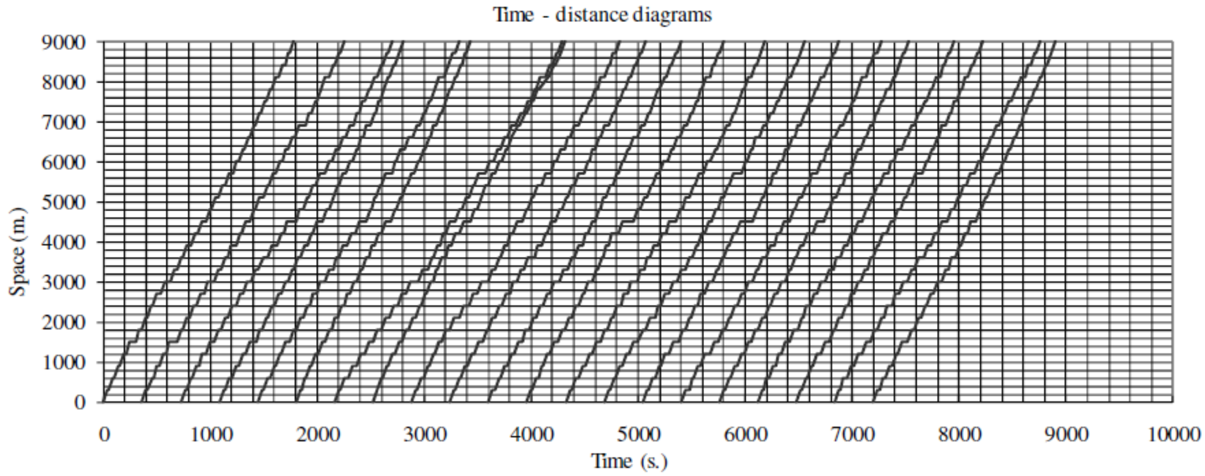

Figure 1: Graphical representation of the model outcome (time-distance diagram)

The control strategies implemented (either singularly or jointly) and compared include:

- a conditional priority strategy at all stops, defined by the maximum green extension;
- a vehicle holding strategy (at single or multiple stops); in the specific case the aim is to restore a threshold value of the headway, planned in two different ways: either considering only the position of the preceding vehicles (threshold based holding), or taking into account the position of the following vehicles by means of a prevision model (information based holding).

A multiclass priority strategy (combination of conditional priority and holding) has also been defined and implemented, with different priority levels, ranging from *extra priority* for vehicles with a long preceding headway, to *negative priority* (holding) for vehicles with a short preceding headway. This latter strategy has been also implemented focusing on the adherence to schedule.

The performance indicators implemented to evaluate the control strategies are passenger travel time (TT), passenger waiting time (WT) and delay caused by the traffic lights to the road traffic flow (TD). Subsequently, total passenger time (PT) is defined as the sum of TT and WT, and total system time (ST) as the sum of PT and TD. To take into account punctuality (when considering a schedule based control, where the control decision is based on the adherence to the schedule), the component of potential time, as defined in Furth and Muller (2007), is accounted for as well.

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