Considering Overtaking and Common Lines in the Bus Bunching Problem

停留所における追い越しと複数路線共通区間を考慮したバス・バンチング問題

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1. Introduction

Reliability is a significant challenge for bus transport service improvement and bus bunching is a typical consequence of unreliability and irregular arrivals of the bus services. Bus bunching is a well-known phenomenon where an initial delay to one service disturbs the whole schedule due to resulting differences in dwell times of subsequent buses at stops. Delay from upstream will prolong the dwell time at downstream stops and shorten the scheduled headway between this service and the next one along the corridor until they are bunched at one stop, leading to longer waiting times and frustration for passengers. The main contribution of this thesis is methodological in developing state equations that describe the bus trajectories considering specifically two factors so far not considered in previous work on bunching: overtaking and common-line effect.

2. Considering passenger choices and overtaking in the bus bunching problem

Firstly, this study deals with passenger behavior when there is more than one bus serving the stop at the same time and elaborates on the relation between overtaking and passenger choices. Possible queue switching actions of passengers are considered. A parameter γ is introduced to denote the percentage of passengers boarding the front bus when buses are bunched. $\gamma=1$ means all the passenger choose the front bus while $\gamma=0$ means they choose the back one. Cases whether overtaking is allowed or not are distinguished as they will also influence the passenger behavior. A bus propagation model is developed based on a set of discrete state equations is then implemented to obtain the departure times of the buses following the occurrence of an exogenous delay to one of the buses, noting that overtaking will not be generated if more users prefer the back bus.

3. Extension of proposed model with consideration of common lines

This study also considers the influence of a frequent but so far neglected characteristic of bus networks on bus bunching, that is the presence of common lines. We extend the bus propagation model implementing passenger choice behavior and overtaking to a corridor served by more than one line. Lines serving for the corridor are regarded as the common lines and the stops within this corridor are common-line stops at which passengers are divided into single-line user and common-line user. As is illustrated in Figure 1, passenger can be divided into 3 groups at the common-line (green) stop, some only consider to board the blue line, some others stick to the red one, and to still others, both blue and red line are attractive, they thus have a flexible choice set. Further, these common-line passengers are presumed to always join the shorter queue when two buses bunched at the stop. With this assumption, the probable dynamic queues during bunching is modelled and a bus propagation model is developed.

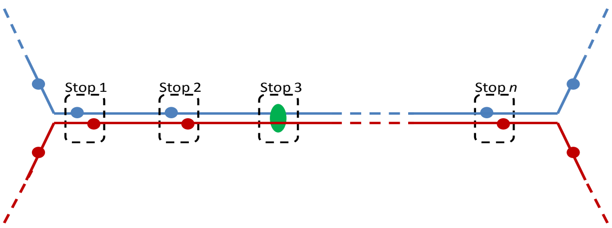
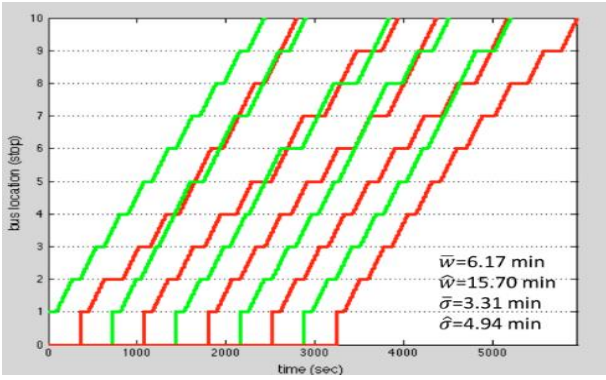


Figure 1. Illustration of two bus lines with some common-line stops

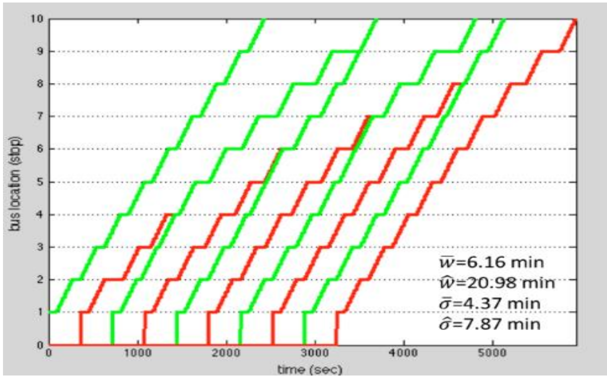
4. Case study

4.1 For the single-line model

A series of bus trajectories are generated by the bus propagation model under the extreme circumstance that no passenger (not listed) or all of them stick to the front bus. It is clearly to observe that once bunched some services are "lost" for the system in the case that all the passengers choose to board the front bus and overtaking is not allowed (Figure 2(b)). And if overtaking is allowed (Figure 2(a)), the service regularity is significantly improved by a 25% reduction (from 4.37min to 3.31min) of standard deviation of departure intervals Δ, which is more important to passengers than headway because they can still board the bus during the dwell time until departure.



(a) γ=1 with overtaking allowed

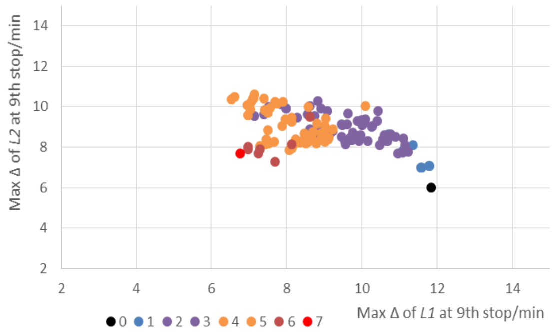


(b) γ=1 without overtaking
(overtaking not allowed)

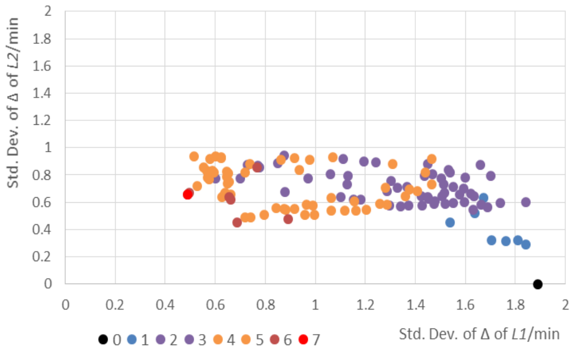
Figure 2. Bus trajectories when all passenger choose to board the front bus

4.2 For the common-line model

We assume a corridor served by 2 lines, sharing a common section among which 7 out of 10 stops having chances to be a common-line stop, thus there are 128 possible combinations for common-line stop configuration. Plotting some evaluation indices on the Figure 3, common line effect can contribute favorably to the bus system if overtaking is allowed, by reducing the delay of one line significantly at a slight cost of the other.



(a) Max headway at the end of common section



(b) Standard deviation of headways

Figure 3. Evaluation on the case with overtaking

5. Conclusions

A methodology is developed to consider two factor so far ignored but critical in the bus bunching problem: overtaking and common-line effect in this thesis.

For the single-line case, we demonstrate that overtaking can be considered a counter-measure to bunching if front-bus preference is high or the boarding-to-loading burden is heavy. And more generally, the case that passengers prefer to board the back bus tends to provide a better service.

For the common-line case, we observe that if overtaking at stops is not allowed or not possible, common lines can create significant knock-on effects on other lines. However, in general, and in particular if overtaking is possible, common lines tend to have a number of positive effects on waiting time reduction, service regularity maintenance, as well as a recovery from bunching at the end of common section.

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