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New England
University Transportation Center

Year 24 Final Report

Grant Number: DTRT12-G-UTC01

Project Title:

A Person-based comparison of Transit Preferential Treatments on Signalized Arterial Corridors

Project Number:	Project End Date:	Submission Date:
UMAR24-15	08/31/15	01/01/16

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RESEARCH PROBLEM

Transit preferential treatments (TPTs) are promising strategies for reducing delays for transit vehicles and improving person mobility, leading to more sustainable and economically competitive multimodal transportation systems. However, the exact impact of such strategies, individually or combined, on the person carrying capacity and person delay of signalized arterial corridors are yet to be determined. This project focused on the development of analytical models to explicitly assess the impact of TPTs on the person carrying capacity and person delay of signalized intersections that are part of a larger signalized arterial (i.e., autos arrive in platoons). In addition, domains of application that dedicated bus lanes (DBL) and pre-signals with or without green extension and red truncation, should be used to minimize total person delay for a generic isolated intersection and undersaturated conditions were also determined. These models allow for a comprehensive comparison of various TPTs without the need for time-consuming simulations.

METHODOLOGY

Analytical models that estimates vehicle delays and discharge flows for both autos and buses and consequently person delay and person discharge flow using average passenger occupancy values of autos and buses was developed. All models were based on the assumption that kinematic wave theory holds, and therefore, delays can be calculated as functions of the arrival time of the platoon at the intersection, the number of vehicles in the residual queue, and the signal settings. Additional assumptions are that vehicles travel in platoons and that auto arrivals arrive at intersections at capacity and are served at capacity. For simplicity, it has also been assumed that there is no platoon dispersion. The proposed analytical models are capable of handling oversaturated conditions as well as undersaturated conditions since it accounts for residual queues in each signal cycle. The TPTs that were tested included both changes in the facility design, such as DBLs and queue jumper lanes (QJL), and in the signal control design, such as transit signal priority (TSP) strategies, in particular green extension.

In addition to the analytical model, a simulation model of the four-intersection signalized arterial segment of San Pablo Avenue in Berkeley, CA was developed in the microsimulation software AIMSUN and was used for the evaluation of the different TPTs tested. Several models were created to represent DBLs addition and substitution, and queue jumper lane addition. An external code was also developed and added to the simulation model through the Advanced Programming Interface to allow for implementation of external control and provision of Transit Signal Priority (TSP), in particular, green extension, with the same characteristics as the ones used for the analytical model.

Models were developed with (Farid et al., 2015) and without bus stops (Farid et al., 2014) in order to investigate the impact of bus stops on auto and bus operations and more specifically on the person delay and discharge flow when the aforementioned TPTs are implemented. These TPTs were evaluated through both analytical and simulation tests using data from a four-intersection segment of San Pablo Avenue in Berkeley, CA.

Finally, in collaboration with Dr. S. Ilgin Guler of Penn State University we utilized queuing theory to identify domains of application that DBLs and pre-signals with or without green extension and red truncation, should be used to minimize total person delay for a generic isolated intersection and undersaturated conditions for a variety of green ratios, ratios of bus to auto passenger occupancies, and auto demands for the main approach and cross street.

RESULTS

Both the analytical model and the simulation tests indicate that the space TPTs have the potential to produce substantial benefits for bus users and that DBL substitution imposes long delays to auto users since it reduces the capacity of the intersection for autos. Therefore, DBL substitution is not suitable for high volume approaches, but it may be justified for high frequency transit lines. QJLs can be as effective as DBLs in reducing bus delays when they are long enough to ensure that buses do not have to wait in car queues when traffic volumes are high (Figure 1). As a result, they can be implemented instead of DBLs, which are more expensive and require more scarce space. This may be especially appealing for crowded urban streets. Implementation of green extension leads to favorable results for total person delay and bus person delay while autos on the priority approach also benefit. However, green extension is more beneficial in reducing total and transit person delay when traffic volumes on the subject approach are high and/or offsets of the adjacent signals are such that a big part of platooned and transit vehicles arrive during red at the intersection of interest. A comparison of the analytical with the microsimulation test results indicates that the proposed analytical model can be used to quantitatively assess space and time TPTs.

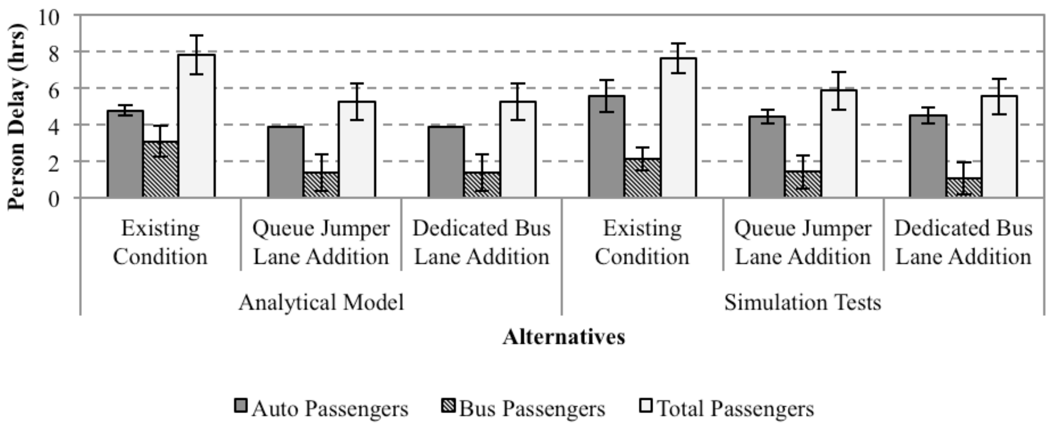

FIGURE 1 Analytical model and simulation test person delay for San Pablo Avenue northbound direction at the intersection with Cedar Street under the presence of bus stops. (Farid et al., 2015)

Regarding the results of the isolated intersection models, when pre-signal is combined with Transit Signal Priority (TSP), it performs identical to a dedicated bus lane in terms of bus delay. The evaluation at a single intersection also showed that the higher the ratio of bus to auto passenger occupancy the higher the need for pre-signals with TSP, while the higher the auto demand on the priority approach, the lower the need for pre-signals with TSP. Finally, the higher the green ratio of the priority approach, the more likely it is that the mixed lanes with TSP will be minimizing the total person delay at the intersection.

CONCLUSIONS

The analytical models developed as part of this research project are expected to be useful for testing different TPTs and guiding decisions on determining the best treatments or combinations of treatments that improve person mobility and the reliability of transit service without compromising the performance of autos too much. The outputs of this research project consist of two journal publications (one in press and one to be submitted), two refereed conference publications, eleven presentations, and a forthcoming PhD dissertation.