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RESEARCH PROBLEM

Continuous transportation demand growth in recent years has led to many traffic issues in urban areas. Among the most challenging ones are traffic congestion and the associated vehicular emissions. Efficient design of traffic signal control systems can be a promising approach to address these problems. A thorough review of the literature suggests that although there are some developed modal emission estimation models, there is no real-time signal timing optimization algorithm to minimize emissions or a combination of emission and person delay that have been estimated based on these models. The initial objective was to develop a real-time signal control system that simultaneously minimizes person delay and emissions for both cars and buses in bi-modal transportation networks. However, after the initial literature review, it made more sense to start by developing a real-time signal control strategy to minimize emissions at an isolated intersection before combining the two objectives. Therefore, this research project first developed a real-time signal control system to minimize total car and bus emissions at an isolated intersection that operates in undersaturated traffic conditions while research efforts to combine the two objectives are still in progress. The developed signal control optimization can assist transportation agencies in utilizing traffic signals to minimize emissions in critically polluted areas.

METHODOLOGY

This research project developed an emission-based real-time signal control system whose mathematical model and emission estimation model formulations are based on previous research. Christofa et al. (2011; 2013) developed a person-based signal control system that provides priority to transit vehicles by accounting for their higher passenger occupancy. The proposed system focuses on minimization of total emissions from both autos and transit vehicles. In particular, equations that can be used to estimate vehicle delays and time spent per driving mode have been developed. To be able to calculate vehicle operating times, cruising speed and acceleration/deceleration rates are assumed to be constant. Another assumption is that auto and transit vehicles travel in the same lanes. In addition, we have assumed that the vehicle arrival rates are deterministic and that the capacity for each approach at the intersection is fixed and known. It should also be noted that the signal cycle length, phase sequence, and yellow times are constant in this signal control strategy and only phases' splits are optimized for every cycle. Additionally, we assume certain upper and lower bounds for the green times of each phase, which guarantee that no phase is skipped and minimum green times for each lane group.

Vehicle emissions vary significantly during different operating modes. Therefore, in order to estimate emissions, time spent on different modes is predicted using an incorporation of the model developed by Shabihkhani and Gonzales (2013) and another model developed by Christofa et al. (2013). Then, this information is used along with modal emission rates to estimate total emission levels. The emission rates are calculated based on the Vehicle Specific Power (VSP) mode, which is an indicator of engine power demand. Emission estimation approaches that use VSP, categorize vehicle operating modes are categorized into several VSP bins that are defined based on vehicle speed and acceleration rates and provide emission rates for each VSP bin. In particular, gasoline autos and diesel buses were assumed.

In addition to the analytical model, simulation models of two isolated intersections of Katechaki and Mesogion Avenues, in Athens, Greece, and San Pablo and University Avenues in Berkeley, CA were developed in the microsimulation software AIMSUN and were used for the evaluation of the real-time signal control system.

The proposed real-time emission-based signal timing optimization strategy is tested both through deterministic and stochastic arrival tests at an isolated intersection. Deterministic arrival tests have been performed under the assumption of perfect information on all inputs while stochastic arrival tests are performed with the use of a microsimulation software where perfect information is not available in real-time and estimates of input values need to be used instead.

RESULTS

The results of the evaluation of the proposed system using data from both real-world intersections in indicate that the proposed system can reduce both total emissions and person delay compared to a vehicle-

based optimization scenario (Figure 1). Additionally, transit person delay in the proposed scenario is considerably reduced, which can potentially result in improved transit ridership. The evaluation results also show that it can reduce total emissions when compared to the person-based optimization system. A sensitivity analysis with respect to intersection flow ratio shows that the developed system is more effective in reducing total emissions and person delay for lower intersection flow ratios. As the flow ratio increases, the vehicle-based and emission-based signal optimization systems converge since the higher auto demand at nearly saturated conditions outweighs the weight given to transit vehicles due to their higher emission potential. In addition, the stochastic arrival tests performed indicate that the loss in accuracy of auto and transit vehicle arrivals occurring in a more realistic environment deteriorates the performance of the emission- and person-based optimization methods especially for traffic conditions close to saturation.

Tests performed at the intersection in Berkeley, CA indicate that the higher the auto demand and the fewer the number of phases the lower the flexibility of the emission-based signal control system in reducing emissions.

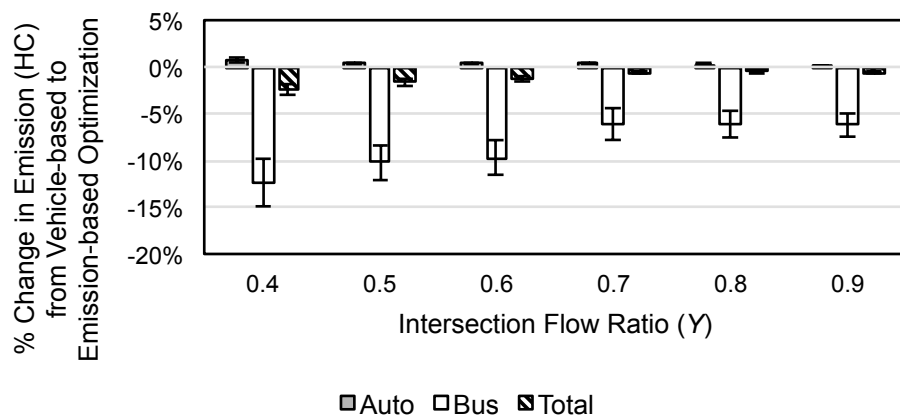


FIGURE 1 Percent change in HC emissions from vehicle-based to HC emission-based optimization (deterministic arrival tests)

CONCLUSIONS

Overall, this research project has shown that both the proposed emission-based and the person-based optimization that had been previously developed can be used to provide priority to transit vehicles and reduce overall emissions at intersections compared to commonly used vehicle-based optimization methods. This study also verified that person-based optimization is still the preferred method for improving person mobility while emission-based optimization should be used when the primary focus is on improving air quality at intersections. Note that the results are sensitive to the specific emission rates that are utilized and are expected to differ with different types of vehicles and will depend on the mix of those.

The outputs of this research project consist of one journal publication, one refereed conference publications, four presentations, and a Masters thesis. We are currently working on extending this real-time signal control system to optimize a linear combination of total emissions and person delay under the assumption of elastic demand in order to be able to identify the optimal weighting factors for emissions and person delay in the objective function.