Efficient use of traffic simulators can optimize design and operations of urban transportation networks

PROBLEM
City traffic operations planners and managers use traffic simulators known as stochastic microscopic simulators to inform the design and operations of the urban road network. These detailed simulators embed models that describe how individuals make decisions about departure time, mode and route choice, lane changes and response to real-time traffic information. And they provide a detailed description of traffic dynamics and the interactions between vehicle performance, traveler behavior and the underlying transportation infrastructure. But the computational evaluation of a network design or traffic operation strategy on a microscopic simulator can require days or even weeks. Hence, use of these simulators is mainly limited to analysis of very small areas or of a few transportation alternatives chosen beforehand. At the regional level, less detailed deterministic macroscopic traffic models, which are computationally less costly than micromodels, are typically used to evaluate transportation strategies, but these lack a detailed representation of transport demand and supply.

APPROACH
MIT Professor Carolina Osorio and Professor Michel Bierlaire of the École Polytechnique Fédérale de Lausanne designed an optimization framework that bridges the high-definition results of a microscopic simulation model with the computational efficiency of a macroscopic analytical model. They addressed a traffic signal control problem that aims to reduce the average trip travel time. Their approach uses the macromodel to provide a global approximation of the trip travel time function; they then use the micromodel to improve the accuracy of that high-level macroscopic approximation. Osorio and Bierlaire applied their framework to the problem of optimizing traffic signals in the city center of Lausanne, Switzerland. The area contains 48 roads and 15 intersections, nine of which have traffic signals. The signals run in either 90- or 100-second cycles that control the flow of 30 roads. Between 3,000 and 4,000 vehicles move through this area of the city during the period studied, 5-6 p.m., the peak of the evening commute.

FINDINGS
For the case study of the Lausanne city center, the new method identified signal plans that lead to a 34 percent reduction in average trip travel time, compared with an existing signal plan. A primary challenge for transportation management agencies is identifying a transportation strategy that will improve network-wide performance. The optimization framework designed by Osorio and Bierlaire does this, even within a tight computational budget, and it outperforms traditional simulation-based optimization methods. The framework is robust to initial points, meaning the agency doesn’t need to have a good initial guess of what a successful strategy might be prior to using the models.

IMPACT
This simulation-based optimization method enables the use of detailed stochastic traffic simulators to go beyond a what-if analysis of guessing how to change input variables in a network to get the desired outcome. It identifies transportation strategies with improved performance in just a few simulations. This enables transportation planners and operators to address a variety of transport optimization problems in a practical manner, accounting in detail for the interaction among the performance of individual vehicles, the behavior of individual drivers and the road network infrastructure, and their impact at an urban scale. This framework is being used to design on-demand mobility systems such as car-sharing systems and to design traffic operations that improve the reliability and robustness of transportation systems.

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A paper on this work by Carolina Osorio and Michel Bierlaire has been accepted for publication in an upcoming issue of *Operations Research*. Osorio has since proposed a similar framework for large-scale problems and applied it to the entire city of Lausanne (603 roads, 231 intersection) to optimize traffic signals at 20 significant intersections.