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High-Occupancy Toll Lanes Can Improve Driving for Everyone if Dynamically Priced

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Issue

High occupancy vehicle (HOV) lanes allow carpool vehicles to bypass congestion and save travel time. However, HOV lanes are often underutilized, leading to a waste of road capacity or the loss of travel time advantage over general purpose lanes. To address this issue, high-occupancy toll (HOT) lanes have gained popularity. HOT lanes, when properly priced, preserve the advantage of HOV lanes, while allowing single-occupant vehicles to pay for access, making use of spare HOT lane capacity.

Real-time, dynamic pricing plays a crucial role in balancing the travel needs of carpoolers and single-occupant vehicles while maintaining the travel advantage of HOT lanes. In turn pricing schemes must: 1) account for the price sensitivity of single-occupancy vehicle drivers, 2) predict the spare capacity of HOT lanes, and 3) consider the operating conditions (i.e., level of congestion) of general purpose lanes. However, current pricing schemes are often too simple, usually based on the vehicle volume or speed on HOT lanes, without considering traffic conditions on general purpose lanes.

To inform better pricing and utilization of HOT lanes, our research team analyzed traffic data from both HOT and general purpose lanes to identify patterns in how toll rates impact traffic flow—sometimes referred to as the "flow-tolling pattern." We then used these insights to build a specialized machine learning model (a Long Short-Term Memory, or LSTM model) that captures the complex connections between toll prices and vehicle speeds. We tested our model using the I-580 express lane dataset.

Key Research Findings

Dynamic tolling leads to a more even distribution of lane usage and a higher proportion of HOT lane usage. Figures 1 and 2 display average speed heatmaps before (left) and after (right) implementing the proposed tolling strategies for the HOT lane and its neighboring general purpose lanes over one month. The results indicate a significant reduction in severe congestion zones (yellow to red areas). This suggests that the proposed tolling approach not only encourages a more even distribution of vehicles across all lanes, but also influences a driver's lane choices, prompting more of them to pay to use HOT lanes and thus reducing congestion in general purpose lanes.

Using HOT lanes results in a slightly greater reduction in vehicle hours traveled and person Hours Traveled as compared to use of a GP lane. Table 1 quantifies the system performance of VHT and PHT in general purpose and HOT lanes for solo drivers and carpoolers. Overall, the VHT and PHT reduction in the HOT lane is slightly higher than in the GP lane (6% versus 5%). Solo drivers traveling on the HOT lane also benefit more compared to carpoolers.

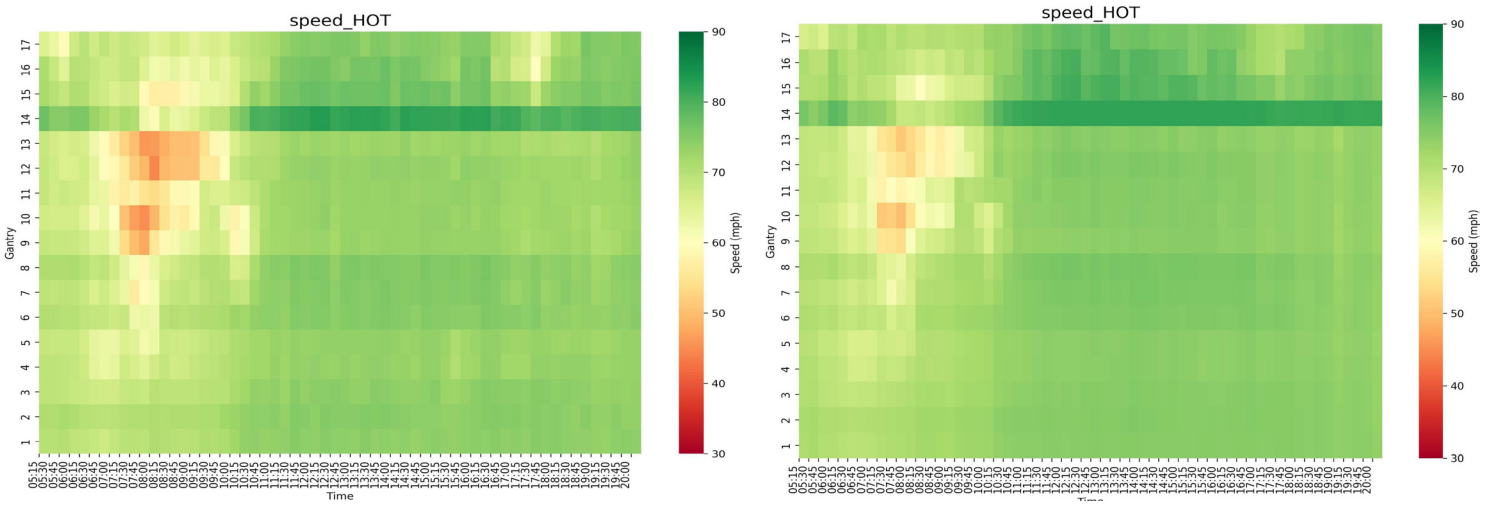

Figure 1. Average speed over one month in the HOT lane before (left) and after (right) implementing the proposed tolling strategy

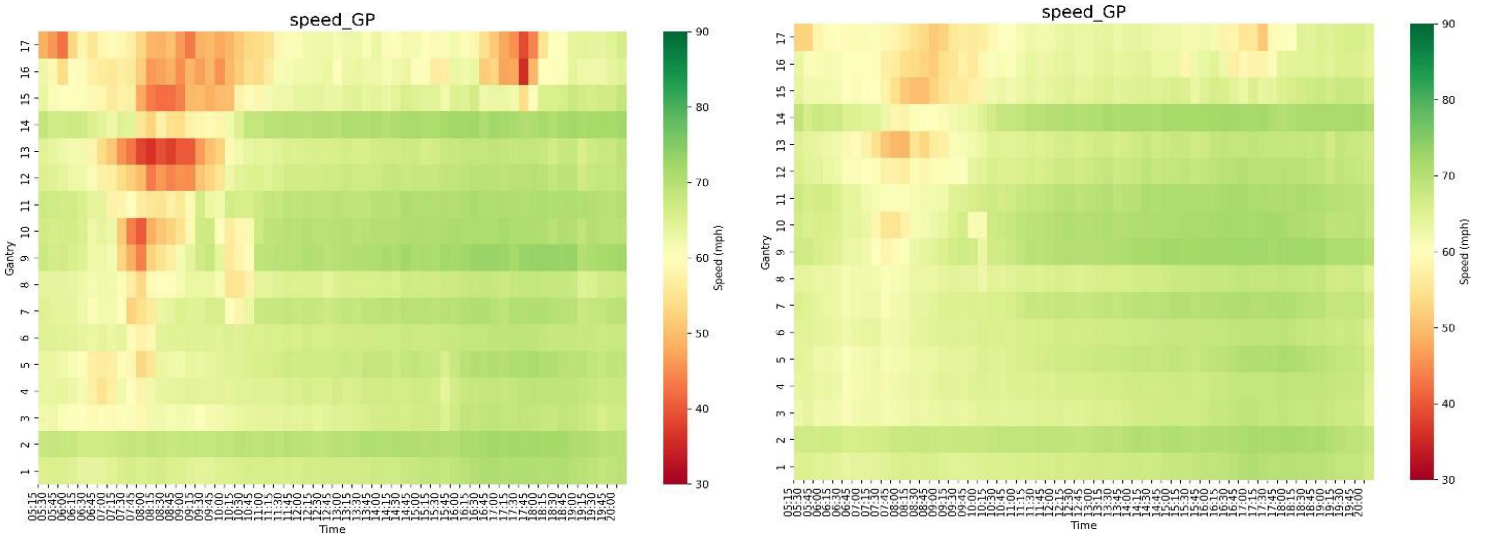

Figure 2. Average speed over one month in the general purpose lane before (left) and after (right) implementing the proposed tolling strategy

Table 1. System performance regarding the number of vehicle hours and people hours in HOT lanes and general purpose lanes before and after implementation of the proposed tolling strategy.

	Number of Vehicles Hours		Number of People Hours		
	HOT Lane	General Purpose Lane	Total for HOT lane	For solo driver vehicles in HOT lane	For carpool vehicles in HOT lane
Before Tolling After Tolling Improvement	177,794.82 166,550.65 6.32%	372,720.79 352,196.73 5.51%	200,251.82 187,855.69 6.19%	161,598.69 151,194.15 6.44%	38,653.13 36,661.53 5.15%

Conclusion

The findings of this study demonstrate that 1) HOT lanes can benefit every traveler when properly priced, and 2) AI models trained on quality data can be a viable approach to come up with dynamic tolling prices that bring this benefit to all road users. Looking ahead, more studies are needed to evaluate the transferability of the trained AI tolling model and how to improve its robustness in the presence of missing data.

More Information

This policy brief is drawn from the report "A data-driven approach to manage HOT lanes in California" prepared by Hang Gao, Di Chen, Yanlin Qi, and Michael Zhang of the University of California. The report can be found here: https://www.ucits.org/research-project/2023-06/. For more information about findings presented in this brief, please contact Michael Zhang at hmzhang@ucdavis.edu.

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