Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Automatic Signal Retiming for Large-Scale Networks with Vehicle Trajectory Data

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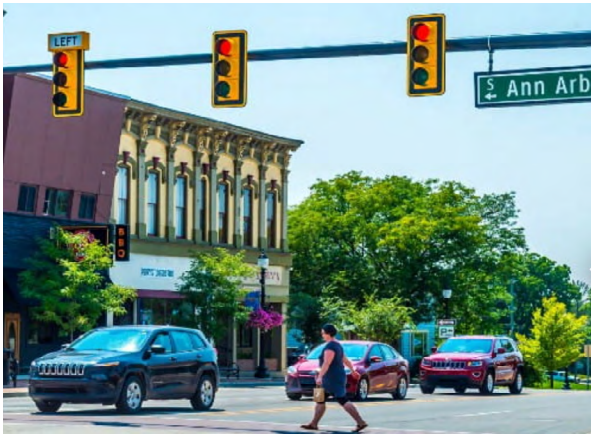
Optimizing traffic signal retiming with connected vehicle data

Retiming traffic signals is a relatively low-cost way to reduce congestion, but updating large numbers of signals using traditional methods takes significant time and resources. This research explored whether vehicle GPS data could make the retiming process faster, easier and less expensive, allowing the Michigan Department of Transportation (MDOT) to retime signals more frequently as traffic volumes and patterns change.

PROBLEM



Well-timed traffic signals keep traffic flowing smoothly and safely through Michigan intersections, reducing congestion and the environmental impacts of idling vehicles.

Traffic patterns are constantly changing due to population growth, new development, construction and shifts in daily commuting habits. To keep up with these changes, traffic signals need to be retimed periodically so that green time is allocated appropriately to each direction of travel. Outdated signal timing can increase delays, contribute to unsafe driving behavior and worsen environmental impacts from unnecessary starting and stopping. Delays at signals also carry substantial economic costs. The U.S. experiences an estimated $22.9 billion in congestion costs at traffic signals annually.

Traditionally, retiming relies on short-term traffic counts collected by using cameras or by manually building and validating a model. These processes are labor-intensive, require driver behavior assumptions and can miss real-world variability. In general, signal retiming is done on a fixed five- to 10-year cycle or after major changes to an intersection.

MDOT controls more than 3,000 signalized intersections, and due to personnel and budget constraints, many signals aren't updated as frequently as the agency would prefer.

(continued)

"This research is a great example of leveraging new data and technology to produce a better product, which furthers MDOT's safety and mobility goals."

William (Billy) Seeger, P.E.
Project Manager

The University of Michigan developed a traffic signal optimization system that uses GPS data from connected vehicles as its only input. While this approach could provide a scalable, economical way to update signal timing, connected vehicles represent only 5 to 10 percent of traffic. MDOT needed to confirm that this model could produce reliable signal timing recommendations despite a limited share of vehicles.

RESEARCH

MDOT partnered with the University of Michigan to evaluate whether a traffic signal optimization system based on anonymized GPS data from connected vehicles could work in real-world conditions. Although this data represents a small share of the vehicles on the road, it provides detailed information about where vehicles travel, how fast they move and where they stop.

The system uses these trajectories to estimate traffic demand and predict congestion under different timing scenarios. For example, when a vehicle stops at a signal, the data can help estimate the length of the queue ahead of it. By compiling many observations over time, the system can reliably estimate traffic patterns and generate optimized timing plans.

Researchers tested the system at seven coordinated intersections along a 2.5-mile segment of US-24 (Telegraph Road) in Pontiac, allowing the team to directly compare the GPS-based timing plans with those produced during a recent traditional signal retiming project along the same corridor.

RESULTS

Field implementation showed that vehicle trajectory-based signal optimization can perform as well as – and in some cases better than – traditional retiming methods. Along the Telegraph Road corridor, the GPS-based system reduced overall vehicle delays by about 17 percent and reduced the number of stops by about 20 percent. The traditional retiming project reduced delays and stops by roughly 14 percent and 15 percent, respectively.

Equally important as the performance results was how the system generated its recommendations. Both approaches use algorithms to analyze traffic conditions and produce time-space diagrams showing how vehicles move through a corridor. In this study, the GPS-based method tended to produce more intuitive timing plans. For example, drivers might wait briefly at the first signal but then travel through a sequence of green lights. In contrast, traditional optimization sometimes produced timing plans that resulted in less predictable stopping patterns along the route.

The GPS-based approach also offered unexpected benefits. Because it reflects real-world driving behavior across a corridor, the data helped identify signal coordination issues, detector malfunctions and opportunities to improve coordination with nearby signals outside of MDOT's jurisdiction.

Cost emerged as another advantage. Because the trajectory-based approach largely eliminates the need for field data collection, the estimated cost per intersection was approximately 35 percent lower than a traditional retiming study. Once the system is set up, timing plans can be updated more frequently and at a lower cost.

IMPLEMENTATION

MDOT views the GPS-based approach as a complement to, rather than a replacement of, traditional timing methods. The new system is well suited for retiming existing signals but is not designed to evaluate major geometric changes such as adding or reconfiguring lanes.

Further testing of the method under more complex conditions and signal types is needed before broader deployment. If future research confirms its reliability across a wide range of settings, this approach could help modernize signal timing practices and allow MDOT to make better use of limited resources.

Research Administration

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The final report is available online at
MDOTjboss.state.mi.us/TSSD/tssdResearchAdminDetails.htm?keyword=SPR-1761.

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