

Title: Integrated Surrogate Metrics for Capacity, Progression, and Operational Risk at Urban Signalized Intersections using ATSPM Data

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ABSTRACT

Signalized intersections play a pivotal role in urban transportation systems, significantly influencing mobility, safety, and operational efficiency. Traditionally, intersection performance has been assessed using separate metrics that individually address capacity utilization, progression quality, and safety. Capacity metrics such as the volume-to-capacity (v/c) ratio and control delay provide insights into operational levels. In contrast, progression quality is typically gauged through coordination plans facilitating "green waves," reducing stops and delays. Safety evaluations often rely on violation counts or historical crash data. However, this compartmentalized assessment method fails to capture the complex interplay between these performance aspects, thereby limiting holistic improvement strategies. The advent of Automated Traffic Signal Performance Measures (ATSPM) systems has introduced the collection of high-resolution, granular event data, creating opportunities to refine intersection performance evaluations significantly. Despite this advancement, existing analytical frameworks predominantly offer isolated metrics or visual diagnostics without integrated, actionable indices.

Addressing these critical gaps, this research proposes two novel, integrated performance metrics derived from high-resolution ATSPM data. First, the Cycle Efficiency and Progression Score (CEPS) is introduced as a comprehensive measure that incorporates volume-to-capacity ratios, arrival-on-green timing, and platoon coherence into one unified score, offering a detailed assessment of both capacity utilization and signal progression. Second, the Red-Light Violation Risk Index (RLVRI) is developed to quantify intersection safety risk. This index uniquely combines the frequency and severity of late-yellow and red-light violations with severity-weighted adjustments normalized by traffic volumes, enabling consistent and objective comparisons across diverse intersection environments. The research also entails the validation and calibration of the RLVRI using historical collision data, with a particular focus on right-angle crash occurrences. This validation ensures that the proposed index reliably predicts safety risks, providing actionable insights for targeted interventions.

Together, CEPS and RLVRI represent significant advancements toward integrated, multidimensional intersection performance assessment, enabling traffic engineers to effectively optimize both operational efficiency and intersection safety through data-driven, comprehensive evaluation.