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Automated intersection delay estimation using the input–output principle and turning movement data ☆

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ABSTRACT

Vehicle delay is one of the most important performance measures of effectiveness (PMOE) in intersection traffic operations. It allows traffic engineers to evaluate the performance of a traffic system component or the effectiveness of the system-wide control strategy. It is often utilized for real-time applications such as adaptive signal control, congestion management, and dynamic traffic assignment. However, obtaining intersection performance data in real time such as intersection control delay can be very time consuming and labor intensive. This paper develops and tests a reliable method called the Automated Vehicle Delay Estimation Technique (AVDET), which automatically estimates delay at a signalized intersection using detector data and signal timing information from the existing traffic signal controller. Results from the delay estimation algorithm were compared with those from simulation, followed by statistical tests under varying traffic operation conditions. The findings showed that AVDET was able to provide effective results under different traffic and signal control scenarios. Future work of field implementation for the proposed algorithms is recommended to investigate the model reliability and effectiveness in real-time traffic conditions.

1. Introduction

Vehicle delay is considered as one of the most important performance measures of effectiveness (PMOE) in intersection traffic operations because it allows traffic engineers to evaluate the overall performance of a traffic system. Currently, vehicle delay is used as a principal performance measure to determine intersection level of service (LOS), estimate average speed, and calculate fuel consumption and emissions. Therefore, it is essential to develop a reliable method to accurately measure delay in real time.

According to the Transportation Research Board's *Highway Capacity Manual* (HCM2010), control delay is defined as the additional travel time experienced by a vehicle affected by intersection control (Highway Capacity Manual, 2010). As shown in Fig. 1, control delay can be separated into different parts such as deceleration delay, stop delay, acceleration delay, approach delay and intersection delay. The definitions for these terms are provided as follows:

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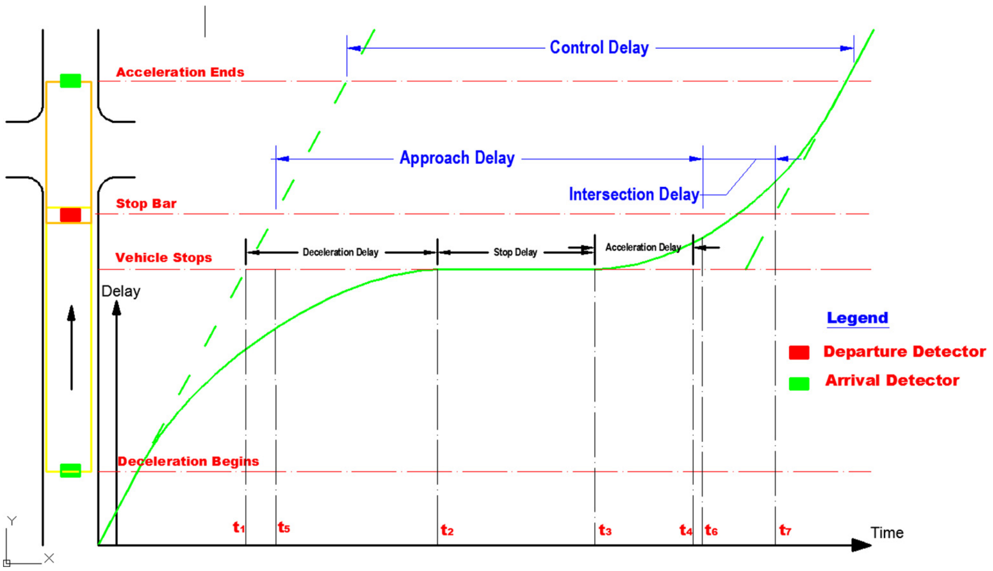

Fig. 1. Delays at signalized intersection.

- *Control delay* is the total delay experienced by a vehicle due to intersection control.
- *Approach delay* is the delay experienced by a vehicle before entering the intersection.
- *Intersection delay* is the additional travel time experienced by a vehicle after it enters the intersection and before it reaches free-flow speed.
- *Deceleration delay* is defined as the delay experienced by a vehicle when it is reducing its speed.
- *Stop delay* is the waiting time for a vehicle when its speed is zero (practically, we consider a vehicle as stopped when its speed is less than 5 mph) (William Walker, 1955).
- *Acceleration delay* is defined as additional travel time experienced by a vehicle during the acceleration period.

Thus, control delay may be obtained as:

$$\text{control delay} = \text{deceleration delay} + \text{stop delay} + \text{acceleration delay} \tag{1}$$

To simplify,

$$\text{control delay} = \text{approach delay} + \text{intersection delay} \tag{2}$$

Delay can be estimated through field measurement, simulation, analytical derivation, or by using a combination of these methods. Of these, simulation and analytical estimation models are the most convenient and are more commonly used, since field experiments are costly and time-consuming to conduct. From a technical perspective, it is also very challenging to obtain field measurements of approach delay, which consists of delay experienced by vehicles decelerating towards a queue or red light, delays experienced by vehicles stopped at the intersection or in a queue, and delays experienced by departing vehicles as they accelerate through the intersection and depart.

Although the simulation method is more convenient, less expensive and more flexible, the biggest challenge is to ensure that the simulation platform is built to represent the field environment in a realistic manner and that the simulation model is fully calibrated to replicate the individual behavior as well as the interactions of the vehicles at the intersection such that the artificial process is not biased. Likewise, the application of analytical models to this type of engineering problem is often limited in effectiveness due to assumptions and constraints on the initial boundary conditions or oversimplifications to find feasible and meaningful mathematical solutions.

In this study, we present a new approach to estimating vehicle delay at a signalized intersection. This method makes use of the input–output principle as well as vehicle origin–destination (O–D) information obtained from the Automatic Turning Movement Identification System (ATMIS) (Xu and Yi, 2013). Using this framework, approach delays can be estimated by analyzing real-time data obtained from the arrival and departure detectors located at the areas upstream and downstream from an intersection. Also, intersection delay is calculated by measuring the time spent within the intersection by comparing the time it takes a vehicle to pass between the paired detectors defining the origin and destination of each turning movement. Laboratory simulation using the proposed method demonstrates that it is feasible, effective, and reliable in dealing with different traffic conditions (low, medium, high, and saturated), oversaturated conditions which may cause street gridlock have not considered in this study. This paper presents the fundamentals of the proposed model, its modeling details and implementation.

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