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Queue clearance rate method for estimating passenger car equivalents at signalized intersections

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HIGHLIGHTS

- Different methods of passenger car equivalent estimation at signalized intersections were compared.
- Simulation using VISSIM was employed for comparison.
- Most techniques relied upon the accurate measurement of saturation flow.
- Queue clearance rate method was found to be a good alternative.

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ABSTRACT

This study explored the use of queue clearance rate method for estimating passenger car equivalent (PCE) at signalized intersections. PCE was estimated based on the assumption that the rate at which a queue of vehicles clears the intersection is a function of its composition. Results of this method were compared with the results estimated by some popular techniques. A four-legged intersection was simulated in VISSIM software and different techniques were used to convert the traffic mix into a uniform one. Parameters of VISSIM were modified to closely reflect the traffic behaviour under heterogeneous traffic conditions. All approaches of the intersection were loaded to saturated conditions and accuracy of estimated PCEs were established by comparing converted flow (PCE/h) with the capacity of an all-car traffic stream. Method based on saturation flow delivered the best result, but its use was limited to traffic composed only of two types of vehicles. Results of regression and optimization techniques were almost similar and the converted flow was close to the capacity of all-car stream. However, accuracy of these methods strongly relied on the correct measurement of saturation flow. Queue clearance rate method did not require value of saturation flow and yielded good estimates of PCE throughout the simulation runs. The maximum difference between the converted flow and capacity estimated with all car situations was found to be less than 10% in all cases considered in this study.

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1. Introduction

In most of the countries across the world, road traffic is composed of multiple types of vehicles that differ in their physical and dynamic characteristics. They often share the same road space and render the analysis of such facilities quite tediously. One of the foremost steps in analyzing traffic flow on these facilities is to convert the heterogeneous traffic stream into an equivalent traffic stream constituted by a single vehicle type. Although some researchers have introduced heterogeneous traffic in terms of equivalent number of motorcycles (Cao and Sano, 2012), the common practice is to convert it into equivalent number of passenger cars by using multiplicative factors known as passenger car equivalents (PCE). PCE for a particular type of vehicle should be a representative of its performance as well as physical dimensions that influence the flow of entire traffic stream.

PCE was first introduced in the 1965 edition of Highway Capacity Manual (HCM) to account for the effect of trucks and buses on the traffic stream (TRB, 1965). PCE factor was developed on the basis of relative speed reduction and defined it as the number of passenger cars to be displaced from a traffic stream by a truck or bus under the prevailing roadway and traffic conditions. The latest edition of HCM (TRB, 2010) defined PCE as the number of passenger cars which will result in the same operational condition as a single heavy vehicle of a particular type under specified roadway, traffic and control conditions. Researchers have investigated the use of different parameters to ascertain the variation in operational conditions that result from the addition of a vehicle type into a traffic stream composed only of cars. Some of the popular techniques for PCE estimation at signalized intersections include headway ratio method (Greenshields et al., 1947; Lam, 1994; Molina, 1987; Saha et al., 2009), saturation flow ratio method (Demarchi and Setti, 2003; TRB, 2010), delay method (Benekohal and Zhao, 2000; Rahman et al., 2003) and regression method (Arasan and Jagadeesh, 1995; Branston and Van Zuylen, 1978; Kimber, 1985). Optimization technique (Radhakrishnan and Mathew, 2011) is an alternative approach for PCE estimation which is based on minimizing the deviation in flow rate of a queue from saturation flow.

Some of the above listed methods are suitable when there are only a few types of vehicles in the traffic stream. Measuring headway under non-lane based traffic conditions in developing countries is quite cumbersome. Although regression approach and optimization techniques could be useful under heterogeneous traffic conditions, the accurate measurement of saturation flow is a prerequisite for either of these methods which becomes difficult when the traffic stream is composed of multiple types of vehicles. The present study investigates the application of queue clearance rate (QCR) method in estimating PCE at signalized intersection. QCR method is based on the actual interaction that occurs among the vehicles in a queue while clearing the conflict area of the intersection. The present study further compares the results from this method with the results from popular techniques at an intersection created in VISSIM.

2. Popular methods of PCE estimation at signalized intersections

Several methods are in vague for estimation of PCE at signal controlled intersections. A few of them are discussed here. These methods have been subsequently used to derive the PCE factors for different types of vehicles and compare the results with QCR method's results.

2.1. *Headway ratio method*

This is one of the earliest approaches for determining PCE at intersections and was commonly used owing to its simplicity. PCE of a vehicle type is defined as the ratio of average time headway of subject vehicle to that of a passenger car. However, headway of a vehicle type (especially heavy vehicles) varies with respect to its position in the queue and hence PCE may be over-estimated on the basis of its position within a queue (Hurdle et al., 1981).

2.2. *Saturation flow ratio method*

HCM advocates the multiplication of a heavy vehicle adjustment factor (f_{HV}) with base saturation flow to calculate the saturation flow of an approach. This adjustment factor can be related to PCE of heavy vehicles as given in Eq. (1).

$$f_{HV} = \frac{1}{1 + P_{HV}(\mathrm{PCE} - 1)} \tag{1}$$

In the saturation flow ratio (SFR) method, adjustment factor for heavy vehicles is calculated by taking the ratio of base saturation flow to the saturation flow of mixed traffic stream. Using this adjustment factor and knowing the proportion of heavy vehicles (P_{HV}) in the traffic stream, PCE can be found from Eq. (1).

2.3. *Delay method*

This method estimates PCE on the basis of additional delay encountered by a mixed traffic stream with respect to a stream composed entirely of passenger cars. This method also requires the proportion of subject vehicle in PCE estimation, but application of this method is limited to streams composed of two types of vehicles.

2.4. *Regression technique*

Regression technique (RT) is well suited for traffic streams composed of multiple vehicle types. Number of vehicles of each type constituting the queue is counted and regressed with base saturation flow which could occur during the period of analysis. The form of regression model is given in Eq. (2).

$$Q_b t = n_{car} + \sum_{j=1}^{k} n_j \cdot \mathrm{PCE}_j \tag{2}$$

where Q_b is the base saturation flow in PCE per unit time, t is the duration of counting, n_{car} and n_j are the respective number of cars and vehicle type j crossing the stop line during the time period t.