Transportation Research Procedia
Volume 15, 2016, Pages 378–388
ISEHP 2016. International Symposium on Enhancing Highway Performance

A Model for Estimating Free-Flow Speed on Brazilian Expressways

Gustavo Riente de Andrade[1], Cira Souza Pitombo[1], André Luiz Cunha[1] and José Reynaldo Setti[1]
[1] University of São Paulo, São Carlos School of Engineering, São Carlos, SP, Brazil.
guriente@usp.br, cira@sc.usp.br, acunha@sc.usp.br, jrasetti@usp.br

Abstract

Free flow speed (*FFS*) is defined in the HCM as the "average speed of vehicles on a given segment, measured under low-volume conditions, when drivers are free to travel at their desired speed and are not constrained by the presence of other vehicles or downstream traffic control devices". *FFS* is a very important parameter for the estimation of LOS and capacity for uninterrupted highways facilities. Ideally, *FFS* is determined using field measurements, but the HCM 2010 provides models for its estimation, when field data is not available. Such models must be recalibrated for local conditions when the HCM 2010 is adapted for use in countries outside North America.

In this paper, Multivariate Analysis (MVA) techniques are used to investigate which infrastructure characteristics are related to *FFS* on Brazilian expressway facility segments, in order to provide a framework for the development of models to replace those used in HCM 2010 to estimate *FFS*.

This study used a database with a large number of speed-flow observations obtained at 36 sites on Brazilian expressways (freeways and divided multilane highways), along with information on seven variables describing segment characteristics such as: expressway type; roadside environment; number of lanes; rise and fall; bendiness; access point density; and posted speed limit for passenger cars.

Principal Component Analysis (PCA) was used to select the variables to be included in the proposed model. The results of the PCA indicated that three components are responsible for most of the variance on observed *FFS*: (1) posted speed; (2) the combined effects of road class, number of lanes and density of access points; and (3) the interaction of geometric design and roadside environment. Stepwise linear regression was used to fit a *FFS* model from these three components. This model was mathematically manipulated to provide a *FFS* that is structurally similar to the one used by HCM 2010 but in fact accounts for the interactions among variables. The proposed model can replace the HCM 2010 model and does not require the user to choose an initial value for the base *FFS*.

Keywords: Free flow speed, HCM, freeways, multilane highways, multivariate analysis

 Selection and peer-review under responsibility of the Scientific Programme Committee of ISEHP 2016

doi:10.1016/j.trpro.2016.06.032

1 Introduction

The HCM procedure for estimating level of service for freeways or multilane highways segments requires selecting a speed-flow curve among a set of given curves. Level of service is a function of density, defined as the ratio between flow rate and average travel speed. The selection of the appropriate speed-flow curve requires the estimation of the *free flow speed* (*FFS*) for each segment.

The HCM 2010 defines *FFS* as “the prevailing speed on freeways at flow rates between 0 and 1,000 pc/h/ln” (TRB, 2010, p. 9-8). Under such flow rates, average speeds are nearly constant and the choice of speed by drivers is affected mainly by factors related to the drivers themselves, to the highway characteristics and to posted speed limit enforcement, with little or no influence of other vehicles in the stream.

Ideally, *FFS* is the mean speed of passenger cars measured at a representative location, under low flow rates; there are, however, many instances under which it is not possible or practical to conduct speed studies. For these cases, the HCM provides models to estimate *FFS*, based on the physical characteristics of the segment. Such models must undergo recalibration to local conditions when the HCM is adapted for use in countries other than the USA. The research reported in this paper focused on the investigation of the factors that affect *FFS* on expressways in the state of São Paulo, in Brazil, and on the development of a model for the estimation of *FFS* for such highways.

This paper is structured as follows: initially, an overview of models for the estimation of free-flow speed is presented; the next section presents the procedure used to choose the variables to be included in the model. The fourth part discusses how the model was obtained and present the derivation of the final user “format”. The fifth section discusses the quality of the estimates obtained using the proposed model and the last section comprises concluding remarks.

2 Models for the Estimation of *FFS*

A search of the literature has highlighted two main approaches to the estimation of FFS. The first one is the adopted by the Highway Capacity Manual (TRB, 2010); the second one is the one used by the Highway Development & Management model (HDM-4). These two approaches are briefly described in the next paragraphs. This section concludes presenting an overview of conclusions from several recent studies on the estimation of *FFS*.

2.1 The HCM 2010 Models

The HCM 2010 (TRB, 2010) provides models for basic freeway segments (Chapter 11) and for multilane highways (Chapter 14). These models have the same general structure:

$$FFS = InVal - f_1 - f_2 - ... - f_n \quad , \tag{1}$$

that is, *FFS* is calculated by subtracting a series of adjustment factors f_i from *InVal*, a base value. The HCM 2010 considers that the highway characteristics that influence *FFS* are: lane width; lateral clearance, median type and density of access points.

For freeway basic segments, the base value is 75.4 mi/h (121.3 km/h) and three adjustment factors are used. These adjustment factors account for: (a) lane width; (b) right-side lateral clearance, which depends on the distance to obstruction and the number of lanes; and (c) total ramp density, the number of ramps located within 3 miles, upstream and downstream for the midpoint of the segment under study, divided by 6 miles (TRB, 2010, p. 11-11). Median type is not considered because lanes on opposing directions on a freeway are physically separated.

The multilane highways chapter only provides general guidelines for choosing the base value, leaving the choice for the user. The provided guidelines suggest using design speed, if available, or the posted speed limits plus 5 mi/h (for speed limits ≥ 50 mi/h) or 7 mi/h (for speed limits < 50 mi/h). Four