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Influence of lane and vehicle subclass on free-flow speeds for urban roads in heterogeneous traffic

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Abstract

Free-flow speed (FFS) is the speed of vehicles under low volume conditions, when the drivers tend to drive at their desired speed without being affected by control delay. Estimation of FFS is important in several applications. FFS varies extensively across various road facilities as they are influenced by driver behaviour, vehicle characteristics, road factors, landuse, geometric features, control factors, etc.

The estimation of FFS in homogeneous traffic is comparatively simpler as the speed variation across vehicles is limited. However, in heterogeneous traffic conditions existing in countries such as India, the FFS distribution varies across vehicle classes. The studies conducted by the authors explored the FFS distribution of various vehicle classes such as two-wheelers, three-wheelers, cars, buses, etc. However, detailed analysis revealed that the variation in FFS can be better explained by further classification of vehicles into subclasses. The study also found that the vehicle's lane position is a factor affecting FFS.

The study was conducted on four- and six-lane divided roads in Chennai, India. A total of 24 study sections were chosen for data collection. Speed data were collected during early morning hours to ensure free-flow conditions. The vehicle movements were recorded using video cameras. The details regarding site factors such as carriageway width, link length, landuse, presence of kerb and type of area were collected manually. The speed and lane data were extracted and tabulated from the video recordings. The authors studied the speeds of about 17,800 vehicles (36% two-wheelers, 8% three-wheelers, 8% buses, 33% cars, 10% light commercial vehicles and 5% trucks). The vehicles were classified into 14 subclasses and speeds were analysed. The study also evaluated the effect of lane position on FFS of different classes of vehicles. It was found that vehicles on kerb lanes experienced lower speeds than those on inner lanes. Furthermore, FFS models for four- and six-lane divided roads were developed using multiple linear regression. Significant difference in speeds was observed within and across subclasses of vehicles. The models also evaluated the effects of various road factors such as carriageway width, link length, adjacent landuse type and presence of kerb on FFS. Models such as these can find applications in planning and operational analysis of urban road facilities.

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1. Introduction

Free-flow speed (FFS) is the average speed of vehicles on a given facility, measured under low volume conditions, when the drivers tend to drive at their desired speed and not constrained by control delay (Transportation Research Board, 2010). Vehicle-to-vehicle interaction is negligible during low volumes of traffic, which facilitates better manoeuvrability compared to congested conditions. FFS is an important parameter which finds several applications in planning and operational analysis of urban and rural roads. The general procedure to estimate FFS is to collect vehicle speeds from field during very low volume hours. However, this consumes significant amount of capital, human resource and time for studies on large road networks. Hence, it is essential to develop models to predict FFS. Importantly, the models must be capable of capturing variations in FFS due to local factors.

Most of the available FFS models are developed for homogeneous traffic conditions, where passenger cars constitute the dominant vehicle class. However, the traffic scenario in countries like India is heterogeneous in nature, due to the presence of multiple vehicle classes having widely varying physical and dynamic characteristics. In addition, it is observed that subclasses within many of such vehicle classes show divergent characteristics. The FFS variations across vehicle groups could be a significant factor affecting overall FFS in heterogeneous traffic, if vehicle composition varies considerably. Also, urban road facilities in India have diverse road characteristics.

The present study attempted to capture the effect of vehicle subclasses and lane position while developing FFS prediction models for four- and six-lane urban roads in Chennai, India. Authors have also examined the various road factors and landuse characteristics that may influence FFS on urban roads in India.

2. Literature Review

Past FFS studies have examined the effect of various factors influencing FFS. The important influencing factors include roadway characteristics and geometry, vehicle factors, driver characteristics, control conditions and environmental factors. The prevalent combination of the above factors decides the FFS on any road facility. Past studies show that variations in FFS are mainly due to the above factors. Hence, for any FFS model, understanding the influence of the relevant factors is crucial in developing FFS models.

Studies on factors influencing FFS can be broadly classified as those pertaining to homogeneous traffic and those related to heterogeneous traffic. One of the earliest studies on FFS in homogeneous traffic was conducted by Yagar and Van Aerde (1983), where the researchers developed regression models for FFS on rural highways in Ontario, Canada with speed limit, lane width, vertical gradient and access from other roads as independent factors. The study confirmed that the effect of various geometric factors on FFS greatly depends on the conformity in design standards. Similar studies on roadway factors and geometry were conducted by Figueroa and Tarko (2005); Himes and Donnell (2010); De Luca et al. (2012).

Dixon et al. (1999) evaluated the effect of raising speed limits on FFS on rural multi-lane highways in Georgia and found that FFS and speed limits are positively correlated. Deardoff et al. (2011) have also confirmed the existence of strong correlation between FFS and posted speed limits in rural multi-lane highways of South Dakota in the United States. A recent study by Moses and Mtoi (2013) developed FFS models for urban arterials in Florida (U.S.) and proved that the road features such as kerb (curb) and median have greater influence on FFS along with speed limits.

Another important set of influencing factors is related to weather conditions. Kyte et al. (2000) found out that inclement weather conditions such as precipitation, poor visibility, wind, etc. cause significant reduction in FFS. Similar studies have been reported by Hablas (2007); Shi et al. (2012).

FFS studies in heterogeneous traffic are comparatively lesser. However, a few studies have been identified which are relevant to the present research work. The earliest of the studies was reported by Kadiyali et al. (1983), where the authors investigated the FFS distributions of vehicles on rural highways in India. However, one of the most comprehensive research works on FFS factors in heterogeneous traffic came from Bang (1995). The author evaluated the influence of various parameters such as side friction, carriageway width, shoulders and kerbs (curbs), adjacent landuse, etc. on FFS as part of developing Indonesian Highway Capacity Manual. In a similar study on rural highways in India, Madhu et al. (2011) studied the effect of number of lanes and road roughness on FFS of different vehicle classes.