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Speed variation during peak and off-peak hours on urban arterials in Shanghai

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ABSTRACT

Increased speed variation on urban arterials is associated with reductions in both operational performance and safety. Traffic flow, mean speed, traffic control parameters and geometric design features are known to affect speed variation. An exploratory study of the relationships among these variables could provide a foundation for improving the operational and safety performance of urban arterials, however, such a study has been hampered by problems in measuring speeds. The measurement of speed has traditionally been accomplished using spot speed collection methods such as radar, laser and loop detectors. These methods can cover only limited locations, and consequently are not able to capture speed distributions along an entire network, or even throughout any single road segment. In Shanghai, it is possible to acquire the speed distribution of any roadway segment, over any period of interest, by capturing data from Shanghai's 50,000+ taxis equipped with Global Positional Systems (GPS). These data, hereafter called Floating Car Data, were used to calculate mean speed and speed variation on 234 road segments from eight urban arterials in downtown Shanghai. Hierarchical models with random variables were developed to account for spatial correlations among segments within each arterial and heterogeneities among arterials. Considering that traffic demand changes throughout the day, AM peak, Noon off-peak, and PM peak hours were studied separately. Results showed that increases in number of lanes and number of access points, the presence of bus stops and increases in mean speed were all associated with increased speed variation, and that increases in traffic volume and traffic signal green times were associated with reduced speed variation. These findings can be used by engineers to minimize speed differences during the road network planning stage and continuing through the traffic management phase.

1. Introduction

Mean speed has been traditionally used as a measure of traffic operational performance, and while it reflects overall time consumed during a trip, it does not provide sufficient information to evaluate the conditions leading to changes in

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operational performance. Speed variation reflects speed differences among vehicles and speed changes of any single vehicle, and can provide key additional information on operational conditions.

Excessive speed variation can undermine the stability of traffic flow (Verhoef et al., 1999). They found that speed differences were one of the most important reasons for congestion, especially outside peak hours. The situation where high speed vehicles change lanes to pass low speed vehicles often slows vehicles on adjacent lanes, and is one example of how speed differences can lead to congestion.

Increased speed variation can also affect safety (Solomon, 1964; Cirillo, 1968). These researchers found that crash counts were the lowest for vehicles traveling near the mean speed, and increased as drivers moved away from the mean speed. Greater speed variation has also been shown to lead to greater headway differences, and consequent serious injuries (Aarts and Schagen, 2005; Wang et al., 2015).

Previous research has shown that traffic flow, mean speed, traffic control parameters and geometric design features may influence speed variation (Figueroa and Tarko, 2005; Dinh and Kubota, 2012). However, relationships observed among these variables have differed in these studies. One reason may be that they all acquired speed data at specific locations, rather than throughout the roadway segments under study. Such spot speed collection methods are not adequate for acquiring distributions of speeds along roadway segments because the speeds of vehicles can change at any location along a segment. Global Positioning Systems (GPS) can provide a location and time stamp for every equipped vehicle, and this allows speed data acquisition to reach a new stage where speeds can be obtained at any point or throughout the segment. This speed data acquisition method is hereafter called the Floating Car Data (FCD) method. Shanghai has a 50,000+ vehicle taxi fleet equipped with GPS, and capturing data from this fleet makes it possible to adopt the FCD method to measure speeds wherever desired throughout its 10,000 km+ road network.

The current study used the FCD method by recording sequentially the location of each taxi in the sample approximately every ten seconds along the selected road segments. This position and time data was then used to calculate mean speeds and speed variations along the selected segments. Locations along road segments where taxis were recorded had an equal probability of being selected, and this ensured full coverage of the segment. The FCD method also allowed any individual vehicle to be tracked, enabling examination of speed differences among vehicles and speed changes of any single vehicle throughout the sampled segments.

The objective of this study was to identify factors associated with speed variation that may later be used to develop guidelines for improving operational performance. Based on 234 road segments from 8 urban arterials, traffic flow, mean speed, traffic control parameters and geometric design features were acquired to estimate their role as potential influencing variables. Mean speed and speed variation were calculated using FCD. Bayesian hierarchical models with random variables were developed to account for spatial correlations among segments within each arterial and to accommodate heterogeneities among different arterials. Considering that operational conditions vary over the day, AM peak, Noon off-peak, and PM peak hours were examined separately.

2. Literature review

2.1. Spot and FCD speed collection methods

Researchers have mainly adopted two collection methods to measure speeds, spot methods and the Floating Car Data (FCD) method. Spot methods commonly use loops, radar or laser to collect speeds at specific points along a roadway segment, while the FCD method uses GPS equipped vehicles to acquire speeds along complete roadway segments. Poe et al. (1998) used loop detectors to collect speeds and compared speed characteristics at different cross-sections. They found the speed at the middle point of a road segment was the highest. This finding shows that the selection of measuring points determines the speeds acquired and that such speeds may not be representative of speeds over the entire segment. Another shortcoming of spot methods is their inability to capture speed changes of single vehicles along road segments. In contrast, by recording locations and times of each floating car, the FCD method is better for acquiring mean speed and speed variation data along a full segment. Readers can refer to Xie et al. (2013) and Wang et al. (2015) for more details.

2.2. Selection of a modeling approach

Modeling approaches depend on the data distributions and structures, the scales of measurement, and the purpose and design of the study. When response variables are continuous and normally distributed, simple linear models are most suitable. Within this category of models, Multiple Linear Regression (MLR) models are frequently used. Wang et al. (2014) used MLR models and found associations between geometric design features and mean speed on urban arterials. However, these simple linear models fail to accommodate dependent data structures often seen in these kinds of studies. Hierarchical models offer one approach to handling the lack of independence problem by separating samples into different levels and assigning each level a random effect term to account for correlations among samples. For example, an arterial-level random effect term that represents a common unknown variable for all segments within an arterial can correct for spatial correlations among segments. Using a two-level hierarchical model, Park and Frank (2006) found increases in the radius of curves were associated with decreases in speed variability. Hierarchical models are also well suited to accommodating data that falls on