Available online at www.sciencedirect.com
ScienceDirect
Procedia Social and Behavioral Sciences 16 (2011) 419–429
Procedia
Social and Behavioral Sciences

6th International Symposium on Highway Capacity and Quality of Service
Stockholm, Sweden June 28 – July 1, 2011

A Comparison of Freeway Work Zone Capacity Prediction Models

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Abstract

To keep the freeway networks in a good condition, road works such as maintenance and reconstruction are carried out regularly. The resulting work zones including the related traffic management measures, give different traffic capacities of the infrastructures, which determines the travel time for road users. A work zone capacity prediction model therefore is highly needed to evaluate mobility. Considering the work zone capacity as a function of work zone configurations, different prediction models have been developed in the past. The conventional models assume a linear relationship between the capacity of a work zone and its configuration variables. Recent artificial intelligence models are more flexible in constructing nonlinear relationships, but the accuracy of the models is not suffiently tested. This research gives a comparison study of the existing models. Firstly, a selection of the critical work zone configuration variables is shortly discussed. Then three currently used prediction models are introduced, namely the model in the Highway Capacity Manual (2000), two multi-linear regression models, and a fuzzy logic based artificial neural network model. These models are tested for Dutch cases. Results show that comparing to the widely-applied linear regression models, the neuro-fuzzy model has the highest average accuracy and the prediction error can be reduced as large as 20%. The neuro-fuzzy model is recommended to serve in practice, as the choice of work zone configuration and the corresponding traffic measures can be made based on the capacity calculation.

Keywords: work zone capacity; work zone configuration; capacity prediction; traffic management

1. Introduction

In order to keep the freeway network in a good state, regular road works such as maintenance and extension are necessary.

These road works create physical changes on freeway and result capacity reduction. If the capacity can be predicted, a systematic planning of traffic management can be executed for maintaining certain capacity. In practice, predicting capacity is not easy. Firstly, a number of variables, e.g. the composition of vehicles, road geometric design, and traffic measures, affect the capacity [1]. Those variables should be thoroughly considered, especially for

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doi:10.1016/j.sbspro.2011.04.463

work zones since more infrastructural variables can influence the capacity. Secondly, the relationship between the capacity and work zone variables should be established by a mathematical model that has a great flexibility in constructing the relationship, as well as a good accuracy in prediction. The current work zone capacity prediction models do not sufficiently meet these demands. Previous studies and guidelines take limited number of variables into account respectively [2] [3] [4]. In most studies, the relationship between the variables and the capacity is assumed to be linear [4] [5]. Furthermore, the recent non-linear models are not sufficiently proved to have better prediction accuracy, although there were a few comparison studies [6] [7]. Therefore this research aims to compare the existing prediction models for freeway work zone capacity, in term of the assumptions, the construction and the accuracy of the models. Note that since the behavioral-based models require a large amount of data for model calibration for all possible work zone configurations, which is out of the available data source for this research, the focus of this study is only on data-driven models.

Section 2 gives a literature summary of the existing freeway work zone capacity prediction models. While section 3 gives a brief discussion on input variable selection. In Section 4, three prediction models are calibrated and a cross-validation method is designed to test the accuracy of the models. In Section 5, the test results for a Dutch case are presented. Section 6 will draw conclusions based on the discussion and the test results in Section 5.

2. Literature review

Two types of models are generally distinguished for capacity prediction, namely the data-driven models in which the capacity is related to the infrastructural and external variables, such as linear regression models, and the behavioral based model in which the capacity is the result of driving behavior in response to various conditions, such as the car-following models. The classic data driven model is the linear regression model. The Highway Capacity Manual (2000) gives a linear prediction model, considering the capacity in relation to the following four variables: intensity of the work activities, proximity to ramps, number of available lanes, and percentage of heavy vehicles. While Al-Kaisy et al. [4] and Kim et al. [5] also proposed linear models and added the following variables into their linear models: location of the closed lane, driver population, work zone gradient, lateral distance, work duration, weather condition, and work time. Recent studies focus on applying artificial intelligence (AI) models. Karim et al. [6] proposed a radial basis neural network model with eleven variables while Jiang and Adeli [7] proposed a neuro-fuzzy logic model considering seventeen variables, six of which were added to [6]: work zone location, work zone duration, weather condition, work day, work time, and work zone length. Compared to linear regression models, the AI models are more flexible in constructing the relationship between the variables and the capacity. Both Karim [6] and Adeli [7] showed that the AI models have better accuracy than the linear regression models. Although the results are promising, they are not sufficiently convincing. This is because in most researches the available data were split into construction data and test data, and the split was fixed. There could be different results by different choices of data. The other type of model is the behavioral-based model however not the focus of this research. Studies on applying behavioral-based models for work zone conditions can be found in [8] [9] [10].

3. Variable selection

The considered variables in the abovementioned models are summarized. Based on another study by the authors [11], the following eighteen variables should be considered and the corresponding definitions of the variables are given below: Composition of heavy vehicles: the percentage of heavy vehicles to the whole traffic population. Driver population: it distinguishes travel purposes (e.g. commuters and visitors) or the aggressiveness of drivers by age differences. Lane width: the total/average width of the available lanes/lane. Lateral distance: the distance from the edge of a lane to the work zone or to the physical separations (e.g. barrier). Number of available/ closed lanes: the number of lanes. Distance to ramps: the distance between a work zone and ramps in its vicinity. Month factor: different months. Presence of traffic signs: warning signs for infrastructure change, speed limit regulation, route information and etc. Presence of signal control: a control strategy that is used for demand management, especially at the areas that have reduction of available lanes. Road gradient: the geometric gradient of the lanes/temporary infrastructure. Road curve radius: the geometric radius of the lanes/temporary infrastructure. Sight deprivation: the absence or presence of sight proof, which is to prevent drivers from being distracted by work activities. Separation measures: to separate freeway from work zones. “Open” separation measures and the “closed” separation measures