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Transfer and updating of Logit models of gap-acceptance and their operational implications

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ABSTRACT

This paper deals with the problem of model transferability in the specific case of Logit models of gap-acceptance behavior. Transfer Scaling, Bayesian Updating and Combined Transfer Estimation are adopted as transfer methods, and the effectiveness of model transfer is evaluated, on the basis of experimental data collected at two priority intersections, using several indicators proposed in the travel demand modeling literature. The main conclusions are that the accuracy of the transferred models is generally similar to that of the locally estimated ones, and that the method known as *Combined Transfer Estimation* performs best among the tested approaches. These results are not significantly affected by the size of the sample of observations used for model transfer. Moreover, the potential impacts of the differences between transferred and locally estimated models on capacity estimates appear to be negligible for practical purposes.

1. Introduction

Gap-acceptance behavior at unsignalized intersections has been extensively studied in the field of traffic theory and engineering using various methods. Among several approaches that have been adopted for modeling this type of behavior, Logit models appear to be especially suitable as they allow to analyze the effect of several factors on gap acceptance. In this paper, we study in particular the issue of *transferability* of such models across different intersections and with data collected in different years, which means that we are considering both a *spatial* and a *temporal* transfer. The problem of model transferability has been studied mostly with reference to travel demand models (for example, mode choice models), although recently transferability analyses dealing with driving behavior models have appeared in the literature. The possible use of transferred models, however, appears to be of practical importance in many other areas of transport modeling, as it may imply significant reductions in data collection efforts; in particular, the research described in this paper represents, to our knowledge, the first study of transferability of gap-acceptance models for priority intersections in urban road networks. Our transferability analysis is based on experimental observations collected at two stop-controlled intersections, and is conducted by specifying and estimating Logit models on one intersection (called *estimation context*) and then transferring the estimated models to the other intersection (called *application context*). First, we consider the effectiveness of the full model transfer (*direct transfer*), which does not involve any updating of model parameters. Then, we evaluate model transfer with updating of parameters, and we carry out an analysis of the performance of different transferred models, characterized by varying size of the sample dataset used for updating. Alternative methods of model transfer are compared, and several indicators for the evaluation of model transferability are considered. In consideration of the existing literature on the characteristics of the available transfer procedures, their technical description is presented in short form, focusing instead on the consequences of the use of such procedures in terms of intersection operational analysis.

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The primary objective of the present work is to evaluate, with specific reference to gap-acceptance Logit models, the possibility of performing a successful transfer of such models from an original context to a different context using the parameters of the original model and a "small" sample of gap-acceptance observations in the application context. In order to show the practical relevance of this analysis, the impact of model transfer on the estimated capacity of a stop-controlled maneuver is examined. Therefore, the significance of the contribution of our study is mainly related to the fact that it deals with the application of a widely used and simple to estimate model, such as Logit, to a problem which is of fundamental importance in traffic engineering analysis, simulation and design. Nevertheless, it should be emphasized that the work described in this paper, being limited to a specific type of model, may be considered as the starting point for a more general research effort regarding the transferability of other kinds of gap-acceptance modeling approaches.

The paper is organized as follows. In Section 2 a brief introduction to Logit models of gap-acceptance behavior is provided. Section 3 discusses the issue of model transferability in general, with respect to both transfer methods and measures for evaluating transfer effectiveness. Section 4 describes the case studies used in the application and the experimental data collected to support the analysis. The estimation of the original Logit models is presented in Section 5. Section 6 describes the application context sampling strategy and justifies the choice of the model transfer methods. In Section 7 the effectiveness of model transfer performed by alternative methods is evaluated using the measures presented in Section 3. Section 8 deals with the impact of model transfer on the estimation of capacity. Concluding remarks are presented in Section 9.

2. Logit models of gap-acceptance behavior

The gap-acceptance problem considered in this paper refers to the situation in which a driver, starting from the secondary approach of a priority intersection, wants to perform a crossing or merging maneuver into a primary road. Essentially, this requires the choice between two mutually exclusive alternative actions: to accept or reject a gap (or lag[1]) of a given time size in the primary traffic stream. Evidently, such a choice is the result of a decision process affected both by driver characteristics (for example, driving experience, sex and age; see Wennel and Cooper, 1981; Teply et al., 1997a,b) and characteristics of the gap/lag and of the choice situation (for example, gap/lag size, waiting time and speed of vehicles on the primary road, see Adebisi and Sama, 1989; Polus et al., 1996; Pollatschek et al., 2002). Thus, as shown by several previous studies, gap-acceptance behavior varies among drivers and, for the same driver, over time (Daganzo, 1981). Gap-acceptance behavior is also an important element in the context of lane-changing models (Toledo, 2007; Choudhury and Ben-Akiva, 2008).

Probabilistic discrete choice models are considered to be appropriate and relatively simple to calibrate for modeling the choice behavior under examination. Hamed et al. (1997), for example, used a binary Probit model to compute gap acceptance probabilities for left-turn maneuvers at unsignalized T-intersections. Several applications of the Logit model to the representation of gap-acceptance behavior can be found in the literature; see, for example, Cassidy et al., 1995; Teply et al., 1997a,b; Maze, 1981.

3. Model transferability

In general terms model transferability (spatial and/or temporal) refers to situations in which a model specified and estimated in a given original (estimation) context is subsequently transferred and applied to another (application) context. The main reasons for performing this operation are:

– to reduce the efforts in model development (using the same structure of the model previously identified);
– to reduce or eliminate the need for a large data collection in the application context.

Model transferability has been studied in the past with reference to trip generation models (Agyemang-Duah and Hall, 1997), mode choice models (Atherton and Ben-Akiva, 1976; Koppelman and Wilmot, 1982; Koppelman et al., 1985; Badoe and Miller, 1995), four-step models (Karasmaa, 2007), path generation techniques and route choice models (Bekhor and Prato, 2009), and gap-acceptance models for freeway merging situations (Choudhury et al., 2010). These authors studied the effectiveness of both full model transfer (direct transfer) and updating the original model using a small dataset for the application context.

3.1. Model transferability/updating methods

The simplest way to transfer an original model to another context is to use directly the model without updating the transferred coefficients (*direct transfer*); this implies the assumption that the choice behavior in the application context is exactly the same as in the estimation context. In a study of transferability of trip generation models, Agyemang-Duah and Hall (1997) report that satisfactory results may be obtained by direct transfer, based on a comparison of predicted shares in the application context with the observed choices in the same context.

[1] A lag is defined as the portion of a gap between vehicles on the major road, measured from the instant in which the vehicle on the controlled approach arrives at the stop-line until the arrival of the first vehicle on the main road.