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## Robust Calibration of Macroscopic Traffic Simulation Models using Stochastic Collocation

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### Abstract

The predictions of a well-calibrated traffic simulation model are much more valid if made for various conditions. Variation in traffic can arise due to many factors such as time of day, work zones, weather, etc. Calibration of traffic simulation models for traffic conditions requires larger datasets to capture the stochasticity in traffic conditions. In this study we use datasets spanning large time periods to incorporate variability in traffic flow, speed for various time periods. However, large data poses a challenge in terms of computational effort. With the increase in number of stochastic factors, the numerical methods suffer from the curse of dimensionality. In this study, we propose a novel methodology to address the computational complexity due to the need for the calibration of simulation models under highly stochastic traffic conditions. This methodology is based on sparse grid stochastic collocation, which, treats each stochastic factor as a different dimension and uses a limited number of points where simulation and calibration are performed. A computationally efficient interpolant is constructed to generate the full distribution of the simulated flow output. We use real-world examples to calibrate for different times of day and conditions and show that this methodology is much more efficient than the traditional Monte Carlo-type sampling. We validate the model using a hold out dataset and also show the drawback of using limited data for the calibration of a macroscopic simulation model. We also discuss the drawbacks of using a single calibrated model for all the data.

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## 1. Introduction

Traffic simulation models are mathematical abstractions of the transportation system in which output is derived from a particular set of mathematical equations and relationships given a specific input data. The input data consists of two main groups of data sets: physical input data  $I_s$  (e.g., volume counts, capacity and physical features of roadway sections) and driver specific parameters  $C_s$  (i.e., adjustable components of driver behavior such as free flow speed, reaction time, mean headway, etc.). Output from a simulation model can be expressed as shown in equation (1). The process of calibration entails adjusting the calibration parameters ( $C_s$ ) so that the error between the output from simulation and field observations is minimized.

$$O_{obs} : f(I_s, C_s) \rightarrow O_{sim} | I_s, C_s + \varepsilon$$

$f(I_s, C_s)$  = functional specification of the internal models in a simulation system

$O_{sim}$  = simulation output data given the input data and calibrated parameters, (1)

$\varepsilon$  = margin of error between simulation output and observed field data, and,

$O_{obs}$  = observed field data.

Traditionally traffic simulation models are used to study scenarios for a certain time period of a so called “typical day”. However, as shown in Ozbay et al. (2014), the determination of a typical day is not a trivial task or a typical day may not even exist in reality. In fact, the typical day scenario might not also be the best scenario to test the effectiveness of operational strategies. Moreover, there is an increasing trend for using well-calibrated simulation models as predictive tools for real-time traffic control (Vasudevan and Wunderlich (2013), Yelchuru et al. (2013), USDOT ICM, Olyai (2011), Dion et al. (2009)). Clearly, these simulation models have to work under a combination of conditions that will considerably deviate from the typical day scenario.

Thus, calibration parameters estimated using limited sample data are not always representative of all possible conditions of the simulated system and might thus result in inaccurate predictions. In other words, models that are not adequately calibrated cannot accurately capture time-varying conditions of traffic. Traditional sources of traffic data used in the calibration of traffic models are either limited by the availability of the data that only cover typical conditions or may not be reliable enough. However, with the advent of new information technologies, unprecedented wealth of calibration data is on the fingertips of users by means of connected vehicles, smart phones, GPS-equipped devices, RFID readers among others. This, in turn, has led to massive amount of passively collected location and event data for various time periods. These data provide an opportunity to validate and calibrate traffic simulation models for a variety of spatio-temporal conditions.

Variability can be incorporated within *inputs* (demands)  $I_s$  and *calibration parameter set* (supply)  $C_s$  during different periods of the day, weather conditions, driver population composition, highway geometry, etc. There were previous studies that captured traffic variability (Li et al. (2009), Ngoduy (2011), Zhong and Sumalee (2008), Jabbari, Liu (2012), Lee and Ozbay (2009)) to name a few. However, the increase in the number of factors affecting stochasticity increases the dimensionality of the calibration process. This in turn results in increased computational effort required in calibrating traffic simulation models for different conditions such as variability within weekday/weekend, and seasonal variability, and special situations including adverse weather, work zones, etc.

In this study, we propose a novel calibration methodology to address the computational complexity due to the need for the calibration of simulation models under highly stochastic traffic conditions. We show the utility of larger datasets to capture variability in traffic flow and speed for various time periods.

## 2. Literature Review and Motivation

Typically, accurate modeling traffic flow requires three types of data: model inputs, model parameters and observed outputs. Model inputs involve the demand-side data for which the traffic simulation is performed. Model parameters involve different types of supply-side parameters used in the traffic simulation depending on the level of complexity in modeling. The output data observed in real-world is required to compare model outputs and evaluate the accuracy of the models.

There are myriad of studies that deal with the calibration of traffic simulation models using various types of input and output data. Due to space constraint, we show a selected sample of them in Table 1.

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