Mitigating Initialization Bias in Transportation Modeling Applications

Wonho Suh*

Department of Transportation and Logistics Engineering, Hanyang University, Ansan, Korea.

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Abstract

Traffic simulation model is a useful tool to evaluate real world transportation solutions in a risk free environment. Traffic simulation model requires some form of initialization before their outputs can be considered meaningful. Models are typically initialized in a particular, often "empty" state and therefore must be "warmed-up" for an unknown amount of simulation time before reaching a "quasi-steady-state" representative of the systems' performance. The portion of the output series influenced by the arbitrary initialization is referred to as the initial transient and is a widely recognized problem in other areas, but less emphasized in the transportation application. After reviewing methods of accounting for the initial transient bias, this paper selects and evaluates three techniques; two popular methods from the general simulation field, Welch's and MSER method, and one from the current state of the practice in the transportation application, Volume Balancing. VISSIM models were created to compare the selected methods. After presenting the results of each method, advantages and criticisms of each are discussed as well as issues that arose during the implementation. It is hoped that this paper informs the current practice in transportation application as to how to account for the initial transient in order to continue facilitating meaningful and reliable results.

Keywords: traffic simulation, initialization bias, Simulation analysis

1. Introduction

Traffic simulation modeling has become an increasingly vital instrument for the transportation analysis. Traffic simulation modeling provides the flexibility to manipulate conditions that could influence network operations in a risk-free environment, allowing for complex network analysis, testing assumptions and possible outcomes to determine their potential for implementation [1]. There are a numerous means to employ traffic simulation modeling to aid in the analysis and decision making process. Thus, it is extremely important that the simulation output is both meaningful and reliable. One area often overlooked in transportation is guidelines to govern the initialization of traffic simulation models [2].

The simulation start-up problem is of significant interest and has been widely studied in simulation related fields [3]. When a model is initialized in a condition uncharacteristic of steady-state of the real-world condition it is attempting to represent bias may be introduced in the simulation's output. The bias can in turn lead to inaccurate results and possibly faulty conclusions [3].

There are two categories of methods for mitigating the initialization bias problem. The most common approach is truncation, or discarding the initial data influenced by the starting conditions. The second approach is intelligent initialization, or starting the model in a state with a high probability of being equilibrium/steady state. However, it is not always convenient or even practical to start the simulation in steady state [2].

More importantly, determining equilibrium a priori in a traffic simulation model can be difficult and arbitrary. For example, determining a priori how many vehicles to queue at each signal, where to place all the vehicles on a link, and what initial speed may be nearly impossible in many instances.

The need to eliminate initialization bias, also known as the start-up problem, is a widely-recognized challenge with simulation analy-

* Corresponding author. Email: iamwonho@gmail.com

sis [3]. This occurs because non-terminating simulations do not have predefined run lengths or initial conditions. The simulation processes must be initialized arbitrarily, which creates bias in steady-state parameter estimates. Although methods of removing initialization bias exist, there is currently no largely accepted method that performs suitably in all applications. Additionally, there is an overall negligence of the initial transient problem in practice [2].

The purpose of this paper is to examine and evaluate the effectiveness of several techniques used for eliminating initialization bias from transportation applications.

2. Method

Methods used to mitigate initialization bias attempt to inform the treatment of data affected by the initial transient for discrete, stochastic simulation models. And as a result these methods seek to provide more accurate, meaningful and reliable results for simulation output. The methods can be grouped into the following categories as described by Robinson [4]: graphical, heuristic, statistical, initialization bias testing, and hybrid methods.

2.1. Graphical Methods

The most common methods to identify the initial transient are graphical procedures [4]. Graphical procedures consist of a visual inspection of the output time series to determine the extent of the initial transient. A major advantage of the graphical method is its simplicity and the reliance on few assumptions. A disadvantage is that these methods are typically highly subjective and the truncation points could vary based on the analyst’s judgment. Fishman’s and Welch’s method are two are examples of graphical methods.

2.2. Heuristic Methods

Heuristic methods provide definitive rules or formulas to determine the length of the warm-up period [4]. The advantages of these methods are lack of user specific subjectivity, ease of implementation, and only a few assumptions are generally needed. Marginal Standard Error Rule (MSER), Conway’s Rule, Crossing of the Means Rule, and Replicated Batch Means are categorized as Heuristic methods.

2.3. Statistical Methods

Statistical methods rely on statistical principles to determine the warm-up period [4]. Disadvantages tend to include the complexity of these procedures, constraining assumptions, and increased computing time. Randomization Test, Welch’s Regression-Based Method, N-Skart, and Automated Simulation Analysis Procedure (ASAP) fall into this category.

2.4. Initialization Bias Testing

The goal of initialization bias testing is to determine if bias is present in the data due to the initial transient. The majority of these methods build upon the work of Schruben [4]. The estimates of the mean and variance are used to compute a test statistic which is compared to an appropriate F distribution [5]. Hypothesis testing is performed with the null hypothesis that no initialization bias exists. These procedures can also be used in union with previously described methods to determine if initialization bias has been successfully removed.

2.5. Hybrid Methods

Hybrid methods are typically a combination of two methods, usually initialization bias testing method and either a graphical or heuristic method. These methods are typically complex and can require large amounts of data [4].

3. Results and Discussion

Hoad et al. performed a comprehensive review on the existing methods of estimating the length of the warm-up period and found 42 methods for detecting the extent of the warm-up period [6]. These methods were evaluated and graded based on the following criteria: accuracy and robustness of method, simplicity of the method, ease of potential automation, generality, number of parameters required, and computation time [7]. The list was then narrowed down to six methods for further evaluation. Graphical methods were excluded due to their need for human intervention and their subsequent inability to be automated. Of the six methods, MSER substantially outperformed the rest while the other methods either severely underestimated the truncation point or required an extremely large number of computational resources.

As the research team looks to inform transportation analysts as to how to mitigate initialization bias, the team investigated detailed analyses of three available truncation methods. The methods selected were Welch's Method, due its simplicity and use in practice, MSER, for its effectiveness in identifying the truncation point and use in industry, and the volume method that is currently being use in a couple of traffic applications.

It was found that Welch's Method and MSER method provide comparable results for the truncation points for when the simulation model has reached steady-state. The results from implementing these procedures indicate that 1) Welch's Method would be easy to implement in practice and 2) MSER method, which selects the truncation point by selecting the point that minimizes the width of the confidence interval about the truncated sample mean, provides consistent results with possibility to be fully automated.

For the MSER method the truncation point can be determined based on each replicate run, while Welch's approach gives a single truncation point that is determined from and can be applied to all replications. The MSER method has the potential to be a robust and useful tool since it can be included in large automated replication process without human interpretation.

4. Conclusions

The goal of this research is to explore different methods of mitigating initialization bias for transportation applications. The initialization bias problem has often been neglected in practice and when unaccounted for it can yield inaccurate, unreliable and less meaningful results.

Throughout the process of implementing initialization bias minimization procedures, several issues arose. Overall, it is also important to have the analyst involved in the decision so that the decision can be made according to the objective of the study and the application model.

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