A BI-LEVEL APPROACH FOR CALIBRATING A TRAFFIC SIMULATION MODEL OF GREATER CAIRO REGION

By

Hossameldin Ibrahim Said Mohammed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Civil Engineering - Public Works

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Title of Thesis:

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Key Words:
Traffic Simulation Calibration; Mesoscopic Traffic Simulation.

Summary:
Traffic simulation has proved to be a vital tool for planning and operating transportation systems. This research developed and calibrated a mesoscopic traffic simulation model for the exceptionally large traffic network of Greater Cairo Region (GCR). Open source traffic simulation software "DynusT" was used as a modeling platform. A wide range of field data was consolidated from previous related studies. The calibration procedure involved two levels: theoretical-based, and simulation based calibration. A sensitivity analysis on estimated parameters values was conducted to verify the appropriateness of chosen values. Limited discrepancy was observed between simulation-based link traffic volumes and actual ones in most observed links, with a normalized root mean square error (NRMSE) of 10.6 %.

Acknowledgments

Dedication

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Nomenclature

GCR: Greater Cairo Region
MGM: Modified Greenshield's Model
GA: Genetic Algorithm
SQP: Sequential Quadratic Programming

Abstract

Traffic simulation has proved to be a vital tool for planning and operating transportation systems. Traffic simulation models need to be calibrated by adjusting model parameters to ensure the model's ability to reproduce local traffic conditions and serve as a reliable test-bed for evaluating modification scenarios. This research developed and calibrated a mesoscopic traffic simulation model for the exceptionally large traffic network of Greater Cairo Region (GCR). The scope of the study is limited to calibrating traffic stream parameters, while a typical user equilibrium traffic assignment model was adopted. Open source traffic simulation software "DynusT" was used as a modeling platform. A wide range of field data was consolidated from previous related studies. The calibration procedure involved two levels: theoretical-based, and simulation based calibration. In the theoretical-based calibration stage, traffic stream parameters of the modified Greenshield's traffic flow model was estimated using non-linear regression approach. On the other hand, the simulation-based calibration involved the estimation of the Anisotropic Mesoscopic Model parameter using a genetic algorithm optimization approach. A sensitivity analysis on estimated parameters values was conducted to verify the appropriateness of chosen values. Testing results revealed the potential of the adopted calibration approach and the credibility of estimated traffic stream parameters values. Limited discrepancy was observed between simulation-based link traffic volumes and actual ones in most observed links, with a normalized root mean square error (NRMSE) of 10.6 %.

Chapter 1 : Introduction

1.1. Background

Traffic Simulation provides a cost-effective, reliable, and robust solution for analyzing increasingly complex real-world transportation problems, such as congestion and traffic safety, that sometimes cannot be solved by conventional traffic analysis means. Traffic simulation models can be divided into 3 main types according to the level of detail they offer. Microscopic traffic simulation models uses a detailed vehicle-based models to describe traffic conditions. On the other hand, macroscopic traffic simulation models implements high level aggregated traffic stream models to explain the behavior of traffic flows.

Mesocopic traffic simulation models represents a middle ground between the two conventional approaches. The use of mesoscopic traffic simulation models avoid the long processing times and labor intensive simulation model development processes with a reasonable level of detail, and hence, is appropriate for large scale traffic networks modeling. To ensure the credibility of traffic simulation platforms, simulation models need to be calibrated by adjusting model parameters to ensure the model's ability to reproduce local traffic conditions and serve as a reliable test-bed for evaluating modification scenarios.

1.2. Problem Statement and Motivation

Egypt, as many other developing countries, suffers from a strained transportation system that fails to keeps pace with the increase in transportation demand. The significant increase in population and car ownership, coupled with an exhausted transportation infrastructure, hinders the country's struggle for an improved economic welfare. Greater Cairo Traffic Network is the largest and most complicated traffic network in the country, with more than 30,000 km of roadways and more than 3.5 million registered vehicle. With the absence of a calibrated network-wide traffic simulation model of Greater Cairo Region (GCR), real consequences of planning/operational modification strategies are difficult to be realized. As such, the need for a fully calibrated traffic simulation platform for GCR is crucial to serve as a creditable decision support tool for future traffic-related decisions.

1.3. Research Aim and Objectives

This research aims to develop and calibrate a mesoscopic traffic simulation model for the exceptionally large traffic network of GCR, using DynusT open source traffic simulation software. The model will serve as a testbed for network wide evaluation of planning/operational modification decisions.

Detailed objectives are:

1) Consolidation of a wide range of field data from previous related studies.

2) Developing a replica of GCR roadway network within the simulation enviroment
3) Conducting a theoretical-based calibration to estimate traffic stream parameters of the modified Greenshield's traffic flow model.
4) Conducting a simulation-based calibration to estimate the value of the Anisotropic Mesoscopic Traffic Simulation (AMTS) model parameter using a genetic algorithm optimization approach.
5) Conducting a sensitivity analysis on estimated parameters values to verify the appropriateness of chosen values by measuring the discrepancies between model and field data.

1.4. Thesis Organization

The thesis is organized as follows:

Chapter 1 includes an introduction to the research, presenting a background about traffic simulation and stating research the objectives and motivation. Chapter 2 provides a literature review of previous studies related to traffic flow theory, traffic simulation, and traffic simulation models calibration techniques.

Chapter 3 presents the research methodology. This chapter summarizes the main steps that have been conducted in the development/calibration of the simulation model starting from the data consolidation to simulation model development, and the description of the bi-level calibration procedure.

Chapter 4 presents the procedure used for acquiring and consolidating data from various previous studies and the preparation of each dataset for the use in the calibration procedure. Chapter 5 includes a detailed procedure creating a replica of GCR roadway network and getting the traffic simulation model up and running.

Chapter 6 firstly, provides a detailed description of the theoretical-based calibration procedure and estimated parameters values. Secondly, it provides a detailed description of the simulation-based calibration procedure, genetic algorithm optimization, and estimated parameter value. Finally, the results of the conducted sensitivity analysis are presented.

Chapter 7 summarizes the research and presents the conclusion, recommendations, and future work.

Chapter 2 : Literature Review

2.1. Introduction

Many studies have been conducted in Greater Cairo Region (GCR) to model the characteristics and behavior of traffic flow. Traffic can be modeled using analytical or simulation approaches. Traffic simulation is an efficient way for modeling traffic networks for measuring network performance for both planning and operation purposes. Traffic simulation can model complex traffic characteristic having the advantage of ease of implementation, flexibility and scalability. In other words, traffic simulation models can reasonably represent traffic conditions in large network sizes for different analysis purposes. Traffic simulation models needs to be calibrated to generate robust results. Traffic simulation models are generally divided into macroscopic, microscopic, and mesoscopic traffic simulation models according to the level of detail they offer in modeling the traffic network. This chapter offers a review of previous studies conducted for modeling traffic flow characteristics in GCR, traffic simulation approaches, and traffic simulation calibration procedures.

2.2. Macroscopic Traffic Stream Models

Traffic stream models aim to describe the relationship between traffic stream parameters that includes flow, speed, and density. The general relationship between the three traffic flow parameters can be described as:

$$q = k \cdot u \tag{2.1}$$

Where,

q: traffic flow rate (veh/hr/lane)

k: traffic density (veh/km/lane)

u: speed (km/hr)

Many models have been developed trying to identify a data-driven relationship between two of the three parameters, to fully describe traffic flow at a given section. Every model attempts to fit the field data by a mathematical formula that represents actual traffic conditions. Greenshields, Channing, & Miller (1935) developed the first model to describe the relationship between the speed and density as a linear relationship (Boxill & Yu, 2000). Many models have been developed since then. Greenberg (1959) developed another model that assumed a logarithmic relation between speed and density (Boxill & Yu, 2000). The model has a downside that the model becomes unrealistic when the density value approaches zero. To overcome the limitation of Greenberg's model, Underwood (1961) developed an exponential relationship between speed and density. The Underwood's model has the drawback that it gives unrealistic values of density when the speed approaches zero.

2.3. Local Greater Cairo Region Traffic Stream Models

Many attempts for modeling traffic stream characteristics in Egypt has been conducted since early 1990s. El-adawi (1993) developed two exponential models to describe the relationship between traffic stream parameters. The models were based on