CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The growth in urban traffic congestion has been recognized as a serious problem in all large metropolitan areas in the country, with significant effect on the economy, travel behavior, land use and a cause of discomfort for millions of motorists. Although traffic congestion is not a new problem in urban areas, it has been extended to suburban areas sooner than expected. Schrank and Lomax (1997) estimated that the annual cost of congestion in 50 urban areas in 1994 exceeded $53 billion. They also estimated that 90 percent of total congestion costs in major urban areas are attributed to travel delay, with the other 10 percent attributed to fuel cost.

The decline in urban mobility resulting from traffic congestion has become a major concern to the transportation and business community and to the public in general. Various detection systems have been installed in urban areas as a means of monitoring traffic congestion in order to assist drivers in making better travel decisions. In addition, the prediction of future traffic conditions has become a critical component for many Intelligent Transportation System (ITS) applications such as Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). Among the many issues that require attention in congestion management is the need for analytical procedures as well as traffic simulation procedures to study the effect of congestion and, furthermore, to be utilized in evaluating alternative congestion-mitigating strategies. A key issue in utilizing these procedures is an understanding of the assumptions and limitations of these procedures in order that they are utilized within their domain of application.

Several methods have been used for measuring congestion (based on travel time and delay studies). Although numerous theories and mathematical methods, despite the importance of

these methods, have been developed to alleviate traffic congestion, there is no unified congestion measure for use by public agencies. None of existing methods provide consistent and accurate results. To obtain such results, one would need not just better methods but better information about traffic patterns. Moreover, current methods neither produce comparable results for various systems with similar congestion conditions nor are they appropriate for evaluating the effect of Intelligent Transportation System (ITS) applications such as traffic management systems. There is a need for a new congestion measure that accounts for variations in traffic pattern resulting from the implementation of traffic management systems.

Several Measures of Effectiveness (MOEs) have been used to quantify congestion, including travel time, delay, number of vehicle stops, queue lengths, and acceleration noise. Furthermore, several analytical and simulation approaches have been developed to quantify the different MOEs. The focus of this dissertation is on the estimation of delay, queue size, and number of vehicle stops using analytical and simulation approaches.

1.2 PROBLEM DEFINITION

Microscopic simulation models are commonly used to evaluate alternative traffic-improvement projects prior to their field implementation. A key factor in the use of simulation tools is their validity or their consistency with standard traffic flow theory. Unfortunately, the analytical solution to traffic flow problems is typically limited in scope and, furthermore, requires simplifying assumptions in order to ensure that it can be solved analytically. Consequently, an analysis of the simplifying assumptions associated with the analytical procedures together with their impacts on the accuracy of their solutions need to be quantified. Furthermore, there is a need to ensure the validity of existing simulation approaches for conditions where analytical solutions are feasible.

1.3 RESEARCH OBJECTIVES

It has long been appreciated that significant benefits in the management of urban signalized networks could be obtained by allowing traffic signals to be responsive to variations in traffic demands. With respect to that objective, the methods of delay measurement for urban networks have proven their ability to reduce the stops and delay incurred by vehicles or vehicle passengers. However, while these methods have demonstrated benefits, their implementation has also resulted in the identification of a number of remaining limitations. These current methods notably reveal that they are still not capable of accurate delay measurement at signalized networks.

Given the lack of guidance in the current methods, the primary objectives of the research are to review the methods currently available for estimating the delay, queue size, and number of stops incurred by motorists at signalized intersections, to identify the main limitations of these methods, and to identify their domain of application. More specifically, the goal of the dissertation is to compare the delay, queue, and stop estimates obtained using a microscopic car-following approach against state-of-the-practice analytical models that are derived from deterministic queuing and shock wave analysis theory.

The main objectives of this research effort can be summarized as follows:
a. To quantify the consistency and assumptions of the different state-of-practice analytical delay models. The models will be analyzed for a single **under-saturated** and **over-saturated** approach at a fixed-time signalized intersection assuming **uniform** and **random homogeneous** vehicle population arrivals. In addition, **maximum queue length** and **number of stop estimates** will also be analyzed.
b. To examine the ability of the **INTEGRATION microscopic traffic simulation model** to produce delay measurements based on car-following behavior at signalized intersections that are consistent and valid with standard traffic flow theory. Specifically, the intent is to ensure that the performance measures, such as total delay, stopped delay, number of stops and

number of vehicles in queue, produced according to the INTEGRATION microscopic traffic simulation model are consistent with standard traffic flow theories.

c. Having established the validity of the delay estimates produced by the INTEGRATION microscopic traffic simulation model, the dissertation will attempt to quantify the impact of **non-homogeneous** (heterogeneous) traffic flow conditions on delay estimates. Specifically, the research will investigate the delay associated with a **mixed flow of buses and passenger cars** at an isolated signalized intersection. An analysis of non-homogeneous flow is currently beyond the scope of state-of-the-art analytical approaches.

1.4 RESEARCH CONTRIBUTIONS

The dissertation illustrates the consistencies and inconsistencies of different delay, stop and queue length computation techniques. It is anticipated that the knowledge provided in this dissertation will have many practical and methodological implications in traffic engineering and will provide valuable information to traffic analysts and policy makers.

The research effort provides three main contributions. First, it systematically compares the different state-of-the-art analytical queuing and shock wave models. The main outcome of this comparison is that it identifies the assumptions, limitations, and domain of application of the different analytical approaches. Second, the dissertation demonstrates the validity of estimating delay based on car-following behavior without the need for an explicit delay formula. Third, the research effort establishes the potential of a validated simulation software to evaluate conditions that are beyond the scope of analytical formulations.

1.5 RESEARCH APPROACH AND LAYOUT

The dissertation initially provides an overview of the different analytical approaches that are utilized in North America to compute delay at fixed-time signalized intersections. In addition, Chapter 2 describes the INTEGRATION model which is a widely used simulation tool because

model provides an opportunity to evaluate conditions that are beyond the scope of analytical approaches

Chapter 3 describes the proposed research methodology prior to comparing the delay estimates at an isolated fixed-time signalized intersection in Chapter 4. Chapter 5 extends the research that was presented in Chapter 4 by focusing on the estimations of delay at over-saturated fix-time signalized intersections.

While significant research has been conducted on the computation of delay at under-saturated fixed-time signalized intersections, less research has addressed on over-saturated signalized intersection and even less research has addressed the issue of queue length and vehicle stop estimations. Chapter 6 compares, develops and analyzes alternative analytical and simulation procedures for computing these parameters.

A major limitation of analytical approaches is the assumption that traffic flow is homogeneous. Chapter 7 investigates and compares alternative approaches for estimating delay at a fixed-time signalized approach for heterogeneous traffic arrivals. Finally, the conclusions of dissertation are presented in Chapter 8.