CHAPTER I

INTRODUCTION

1.1 Background

Traffic Congestion is a growing problem in many of the US cities over the past few decades. The 2002 Urban Mobility Study conducted by the Texas Transportation Institute states that in the year 2001, traffic congestion resulted in 5.7 billion gallons of wasted fuel and 3.5 billion hours of lost productivity costing the nation $ 69.5 billion. According to the report, a rush hour trip in 2001 takes thrice as long as a rush hour trip in 1982. In the same period, the annual hours of delay per person has increased by 19 hours. Apart from personal inconvenience, traffic congestion can hamper economic productivity in an area and increase the pollution caused due to vehicle emissions thus reducing the quality of life of the people.

According to Meyers (1997), congestion mitigation strategies can be broadly classified into three categories: Transportation System Management (TSM), Travel Demand Management (TDM) and Land Use Management. TSM techniques seek to improve the traffic flow through better management of existing facilities (Mobility 2020). Some of the TSM techniques adopted are reduction of delay of delay at intersections and freeways through better signalization procedures like coordination and traffic management measures to enhance the operation of roadways. The Travel Demand Management techniques focus on strategies to control the travel demand to reduce the peak hour travel time. Examples of TDM strategies are staggering the work hours, carpooling and encouraging the use of transit. Land Use Management strategies involve strategies like zoning and controlling land use which has a direct impact on the trip generation and demand distribution characteristics.

Another strategy which is increasingly becoming popular over the last decade involves the integrated use of sensors, computers, electronics and communication technology, collectively termed as Intelligent Transportation Systems(ITS) to reduce congestion and enhance mobility. The development and application of Intelligent Transportation Systems to solve transportation problems was established as a national priority by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.ITS have an important role to play in control of long term

initiatives to control recurring congestion and short term initiatives to control non recurring congestion (Paniati, 2003).

ITS can be directly used for operational purposes like Freeway Management Systems and Incident Management Systems or can be used in supporting and improving other measures like increasing the ridership of transit operations.

Advanced Traveler Information Systems (ATIS) constitute an important sub-system of ITS, which involve provision of real time information on traffic conditions or travel advisory information to users. ATIS can be broadly classified into pre-trip and en-route information systems. Pre-trip information systems provide information to users at the start of their journey through television, radio, internet etc. En-route information systems provide information to users during the course of their journey through Dynamic Message Signs (DMS) and In Vehicle Devices (IVD). Provision of information through various sources can play a significant role in improving system performance. These information sources have been generally studied and investigated in isolation. In contrast, the main focus of this study is to propose a new modeling framework that enables modeling a wide range of information provision sources, strategies and their interactions and study the network performance resulting under such strategies.

1.2 Motivation

One of the main factors influencing the effectiveness of ATIS is the information strategy adopted. The information strategy affects the diversion patterns of vehicles and thereby has a significant impact on the network performance. Unfavorable diversion patterns can result in deterioration of the system performance. This can lead to situations where the congestion is higher when information is provided than when it is not provided (Watling, 1993). Further, if the benefit in terms of trip time savings experienced by the users under information provision is small, then the compliance to information can drop significantly. Therefore, there is a need to study and develop information strategies which can significantly improve the system performance and enhance the users' travel experience.

In a traffic network, users can be classified into various classes depending on the information accessible or provided. If the number of users belonging to each user class or the information provided to each user class is assumed to be known beforehand, then the user classes are termed as pre-specified or fixed in this study. Current modeling efforts assume that these

information classes can be pre-specified or fixed (Peeta et. al., 1995). However, this assumption is restrictive and cannot be used to model a wide variety of information provision scenarios. For example, a user may be provided with predicted information at the start of his journey and may be provided with en-route information which may not be predicted information. In such situations the user belongs to different user classes at different points in his journey depending on his arrival time at those points. As the arrival time of a user at a particular point depends on the network characteristics like congestion level, incidents etc., the number of users belonging to each user class is dependent on the network dynamics and cannot be pre-specified. This context illustrates the need to develop a modeling framework in which the user classes need not be pre-specified and can vary dynamically. The development of such a modeling framework will enable the study of more realistic, richer and wider range of information strategies for ATIS. The thesis aims to develop such a framework which permits users to belong to different classes at different time-points during his/her journey.

One important application of the proposed framework in developing an information strategy for Dynamic Message Signs is also presented in this thesis. Many models of DMS information strategies employ idealized or restrictive assumptions due to computational or analysis tractability considerations. (Diaz et. al., 2000). For instance, it is assumed that DMS can supply information from the DMS location until each user's destination. This assumption is referred to hereafter as the DMS information with 'global and customizable scope'. This assumption is somewhat unrealistic since the DMS cannot provide information customized to each user's destination. Another common modeling assumption, regarding the DMS information strategies involves the provision of time-dependent (predicted) user-optimal information for routing. The use of this DMS strategy, in the context of incident, suggests one of two extreme possibilities. The user optimal information when solved under the incident scenario, implicitly but somewhat implausibly, assumes that users that leave/reach the DMS prior to the incident, will be guided on paths that reflect a future incident, even before it occurs. At the other extreme when the DMS user optimal information is based on the no- incident scenario, the presence of incident-induced dynamics cannot be captured adequately. An additional restriction in prevailing models pertains to the inadequate consideration of interactions and integration between multiple information sources. For example, pre-trip information sources can provide information at the network level whereas DMS can provide information from the location of the DMS to some

node downstream of the DMS location. In such a situation the interaction between the pre-trip information and the en-route DMS information can result in favorable network performance. The consequence of these restrictive assumptions is the possibility of seriously erroneous estimates of DMS effectiveness and system performance. Therefore, a key motivation of this study is to investigate the potential for relaxing these restrictive assumptions to enable more accurate and realistic models of DMS information strategies.

From an application standpoint, the development of the dynamic user class modeling framework and more realistic DMS information strategy is of interest in relation to the design, evaluation and operation of ATIS information and devices. The relaxation of the restrictive assumptions and development of richer and coordinated information frameworks also have important implications for network design problems like the DMS location problem. The system performance under the new information strategy can be studied under different DMS locations and hence optimal locations of DMS can be determined. Another research interest that has guided the development of the richer dynamic framework and DMS information strategy is the need to develop substantive insights into the performance and robustness of DMS under varying compliance rates, incident attributes (severity, duration, location etc.) and congestion attributes.

1.3 Objectives and Overview of Approach

This study seeks to address the motivations and issues presented in the previous section through the following objectives:

(i)   To propose a new framework where the users belong to various user classes depending on the network dynamics. To develop an algorithm to solve the above formulation.

(ii)   To propose and develop more realistic DMS information strategies based on the dynamic user class framework by explicitly accounting for key practical features of real-world DMS operations.

(iii)   Investigate the performance of the proposed DMS strategy under varying information, incident and congestion attribute levels.

Objective 1: The first objective intends to propose a new dynamic user class modeling framework. In the dynamic user class model, users can belong to different user classes depending

on the network dynamics. Users are classified into various classes based on the information accessible to them which, in turn, may depend on the dynamics. The dynamic user class model is formulated as a variational inequality and the equivalent minimization problem is provided. An algorithm based on the Frank Wolfe algorithm is provided to solve for the Dynamic User Class equilibrium. Through this objective, the assumption of static multiple user classes in traditional models is relaxed.

Objective 2: The dynamic user class framework proposed is used to develop a new information strategy for Dynamic Message Signs. Two sources of information are assumed to be present in the network – a pre- trip information source and an en-route information source. Both types of information sources are assumed to provide predicted information. To account for the local scope of DMS information, it is assumed that DMS provides information corresponding to a corridor that extends from the DMS location up to a point downstream on this corridor (referred to as DMS terminal node). This region of DMS influence is referred to as DMS activation zone. To be consistent with real-world incident scenarios, the proposed DMS information provides information corresponding to the no incident scenario for users that arrive at the DMS prior to the incident start time. In contrast, users that arrive later are provided with predicted information corresponding to the incident scenario. This property is termed as consistency. In addition, the pre-trip information and the en-route information are coordinated with each other. The above strategy is implemented in a simulation based framework using a dynamic network assignment tool (DYNASMART, Jayakrishnan et. al., 1994) as the traffic simulator. Computational experiments were conducted to compare the impact of the more realistic information strategies against current DMS models. The results reveal that restrictions in current DMS models can seriously overestimate or underestimate DMS performance in many cases.

Objective 3: Computational tests are conducted to study the impact of Prediction, Coordination and Consistency on network performance. In order to quantify the benefits of prediction, the performance of prevailing pre-trip and DMS strategy was compared against the performance of the two predicted strategies- Time Dependent User Equilibrium (TDUE) and the new proposed strategy. In the TDUE solution, users are routed along time dependent User

Equilibrium paths from their origins to destinations. To determine the impact of coordination, the system performance under the TDUE strategy was compared against the system performance under coordinated but not consistent strategy. In the coordinated but not consistent strategy, the information provided to all users, through DMS and pre-trip correspond to the incident scenario. Hence all users are assumed to have foreknowledge of incident. To determine the impact of consistency alone, the system performance under the TDUE strategy (neither consistent nor coordinated) was compared against the performance of the consistent but uncoordinated strategy. The performance of the new proposed strategy is compared to the prevailing strategy and the TDUE solution under several incident scenarios. The various incident scenarios are obtained by varying the following four attributes of the incident- location, start time, duration and incident severity. Two levels of compliance-low and high are tested in the above strategies.

1.4 Structure of the thesis

The remainder of the thesis is organized as follows. Chapter 2 provides a comprehensive review of the various frameworks used for modeling information strategies for ATIS, particularly DMS information. Chapter 2 then concentrates on the various information strategies developed for DMS and the limitations of some of them. In Chapter 3, a new Dynamic User Class framework is proposed and modeled as a variational inequality. An equivalent minimization problem is formulated and an algorithm is developed to solve this problem to obtain a Dynamic User Class Equilibrium (DUC). Some of the properties of the Dynamic User Class equilibrium like existence and uniqueness are also discussed. Chapter 4 presents the application of the Dynamic User Class modeling framework in developing a Predicted, Consistent and Coordinated strategy for Dynamic Message Signs. The system performance under the new information strategy for various incident scenarios is presented in this chapter. Finally the conclusions from this study are summarized and the directions for future research are proposed.