CHAPTER 1
INTRODUCTION

The Clean Air Act Amendments of 1990 (CAA Amendments) and the Transportation Equity Act for the 21st Century (TEA21) both contain provisions that encourage the use of transportation control measures (TCMs) to help reduce motor vehicle emissions. The primary goal of these provisions is to assist states and regions in complying with the National Ambient Air Quality Standards (NAAQS). The most widely implemented class of TCMs in the United States, in attainment areas and non-attainment alike, is traffic management strategies designed to improve traffic flow. In 1992, 36 percent of the Congestion Mitigation and Air Quality (CMAQ) program funds were obligated to traffic flow improvement projects, second only to transit related projects (FHWA, 1994). Freeway ramp metering is one traffic flow improvement strategy that is gaining popularity in many urban areas throughout the United States.

A rapid increase in vehicle-miles of travel and congestion levels, coupled with limitations on construction of additional lanes to handle increased traffic demand, has increased the importance of ramp metering as a freeway traffic control. Ramp metering is one of the most cost-effective ways to alleviate freeway traffic congestion (Meyer, 1997). Ramp metering controls the flow of traffic onto a freeway and breaks up vehicle platoons (natural fluctuations in entering traffic streams) that impair optimal freeway flows. The balanced entry of vehicles reduces the potential for freeway traffic flow breakdown and thereby significantly reduces overall system delay. Inducing small delays on the onramps can significantly reduce mainline travel time. A system-wide strategy optimizes freeway flow control by controlling entry at numerous ramps to stabilize the flow approaching critical network locations.

In conjunction with installation of the Atlanta Advanced Transportation Management System (ATMS), the Georgia Department of Transportation (GDOT) installed meters on five ramps along the northbound corridor of Interstate 75 in metropolitan Atlanta. The existing ramps were retrofitted with variable interval meters to control flow of traffic onto the freeway mainline. The ramp meters are only located on the northbound direction for five consecutive interchanges, Northside Drive, Howell Mill Road, Moores Mill Road, West Paces Ferry Road, and Mount Paran Road. Each interchange offers a unique geometry that has the potential to affect the vehicle activity of the merging traffic, and impact the response of the vehicles operating along the corridor.

The CAA Amendments and TEA21 encourage the use of traffic flow improvements, such as ramp metering, as a means to improve air quality, because these strategies mitigate traffic congestion. However, emissions from motor vehicles are not in direct proportion to traffic congestion and vehicle delay. Emission rates are a function of delay measures, such as average speed, but also of the modal operation of the vehicle associated with speed/acceleration profile. Thus, it should not be surprising that the current version of the USEPA model (MOBILE5b) does not produce accurate emissions estimates under certain applications (Gertler et al., 1997; Pierson et al., 1990; NRC, 1991). The MOBILE5b mode utilizes speed correction factors to adjust emissions, to account for average speeds that differ from the average speed of the USEPA new vehicle certification testing cycle. However, the FTP drive cycle does not adequately represent
the range of driving conditions encountered under most typical driving scenarios. To date, modeling techniques have not been capable of the emissions effects that result from driving conditions that differ significantly from laboratory test conditions. Thus, the models are unable to accurately analyze the air quality impacts of many traffic management strategies, including ramp meters. Modal modeling approaches that take into account the physical operating mode (speed/acceleration conditions) of vehicles are necessary to evaluate the impacts of ramp metering systems.

One research study indicated that the USEPA MOBILE5b model would predict reduced emissions levels resulting from ramp metering systems (Sierra Research, 1997). However, other research has indicated that the MOBILE series of models are inaccurate and tend to under-predict emissions levels under many real world scenarios. Additional research has indicated that when vehicle operating mode is considered, emissions rates for vehicles operating on freeway onramps would possibly increase when ramp meters were in place (Sullivan, 1993). Recent studies also indicate that a disproportionate amount of emissions occur under limited levels of modal activity, such as load induced enrichment, i.e. low air/fuel ratios (LeBlanc, et al., 1994). That is, a large amount of vehicle emissions, particularly carbon monoxide and hydrocarbons, result from small amount of vehicle activity such as might occur under hard acceleration conditions at an onramp. Studies show that roadway grade (an acceleration against gravity) can increase emissions more than tenfold, and that one sharp acceleration may cause as much pollution as the remaining portion of a trip (Cicero-Fernandez and Long, 1995; Kelly et al., 1993). Indeed, vehicle acceleration to freeway speed after stopping at a ramp meter would be a likely scenario for high power demand and enrichment conditions. What is not known, is the extent to which onramp emissions are elevated and what the modal activity and related emissions impact would be for vehicles operating on the freeway mainline. Also, the effect of ramp design factors (i.e. geometric design, grade, acceleration distance) and what mainline flow conditions influence the most significant changes in emissions rates are unknown. The research conducted in this study involved collection of detailed onroad operating mode data for a set of ramp meters and the application of traditional average speed and modal emission rates to analyze these potential emissions tradeoffs.

Over the past several years, the Georgia Institute of Technology has been developing a modal emissions model that associates vehicle emissions with certain types of engine and vehicle modal operation (i.e. cruise, acceleration, deceleration, idle, and power demand) rather than average speed. The Mobile Emissions Assessment System of Urban and Regional Evaluation (MEASURE) modeling framework incorporates MOBILE5 emissions rate relationships as well as an Aggregate Modal Model (Guensler, et al., 1997; Fomunung, et al., 1999). The aggregate modal model is a statistically based model that predicts emissions for various vehicle technology groups as a function of vehicle operating mode distributions. Because the aggregate modal model is sensitive to changes in vehicle operating characteristics expected with the implementation of ramp metering systems, it served as one basis for evaluating the emissions impacts of the Atlanta ramp metering systems.

Given the importance of vehicle operating mode on emissions, it is important to assess how the introduction of ramp meters changes the operations of vehicles on ramps as well as along the mainline freeway segments. The research team collected light-duty vehicle activity data from the onramps and mainline freeway facility along the existing metered system. Video equipment,
traffic counters, laser rangefinders, and floating cars equipped with distance measuring instruments were all employed to collect activity and speed/acceleration profiles on the freeway and metered ramps. Resource limitations prevented the collection of local roadway operating mode data. The team collected approximately four hours of data during each of 18 field studies (over a two-month period). Researchers then analyzed the modal operation (speed/acceleration profiles) of the light-duty vehicles along the corridor, and estimated the emissions for the metered ramp and mainline system.

The basic goal of the project was to measure the activity and operating modes of light-duty vehicles on Atlanta’s five-ramp metered facility and to analyze system impacts on congestion and motor vehicle emissions. Emissions for measured field activity data were estimated using both the MEASURE Aggregate Modal Model and the Environmental Protection Agency's MOBILE5b emission rate modeling functions. A significant portion of this research included the assessment of how varying mainline congestion levels and flow conditions influenced onramp emission rates. The results of the congestion and air quality analyses were used to identify the design parameters that significantly impact the emissions from the metered system. To achieve the goals of the project, researchers:

- Undertook a basic literature review on impacts of ramp metering on traffic activity and the capabilities of various equipment packages and modeling tools employed
- Developed field deployment methods designed to capture and store comprehensive vehicle activity and operating mode profile data for the existing Atlanta ramp metered facility.
- Collected 18 days of comprehensive, afternoon peak period, vehicle activity data, under metered and non-metered conditions
- Employed MOBILE5b and MEASURE Aggregate Modal Model emissions functions to predict emissions from measured speed/acceleration profiles for merging vehicles, weaving sections, and mainline traffic flow
- Developed the CORSIM base scenario for use in predicting changes in both traffic flow and speed/acceleration profiles for the existing Atlanta ramp-metered facility
- Used the field data to calibrate the CORSIM base scenario for the metered corridor so that the model accurately predicts segment traffic volumes and delays
- Modified the CORSIM model to output vehicle speed/acceleration profiles
- Coupled the CORSIM outputs with MEASURE Aggregate Modal Model emission rates to quantify the potential impact of the Atlanta ramp meter operations on system efficiency and vehicle emissions under observed conditions and high travel demand conditions (when ramp metering provides the greatest congestion benefits)
- Performed field emissions validation tests (remote sensing and vertical emissions flux studies) to compare the results of MOBILE5b and MEASURE Aggregate Modal Model application and to evaluate the observed emissions effects of ramp metering
- Identified the geometric design and ramp timing plan parameters that significantly impact the emissions from the metered system so that the results could be used to develop guidelines for optimizing the air quality benefits of metered systems.
The report organization follows the implementation plan for the project. Chapter 2 provides a discussion of the background of this research including a review of air pollution issues, motor vehicle emissions, and air quality and emissions rate modeling. Chapter 3 presents the general research approach. This includes a discussion of the research hypothesis and objectives, in addition to the proposed experimental design. Chapter 4 provides details of the research procedures; focusing on the data collection process and field deployment, site descriptions, and data analysis methods. The findings from the field assessment of vehicle activity and predicted from the observed activity are presented in Chapter 5. Chapter 6 then summarizes the simulation modeling results (activity and predicted emissions) for the freeway corridor under observed, high flow, and lane closure conditions. In Chapter 7, the Georgia Tech Air Quality Laboratory presents the findings from concurrent remote sensing and vertical emissions flux validation studies. Finally, Chapter 8 includes the research conclusions and final recommendations.