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16. Abstract

Major planned disruptions, such as those caused by highway reconstruction, impose major costs on system users. The consideration of user responses is important in planning reconstruction activities and developing control strategies. A methodology is developed to capture the day-to-day responses of commuters to control actions, including supply-side measures (such as ramp control) and demand-side measures (such as information dissemination strategies). The methodology integrates a user-decisions component with a traffic simulation model for freeway corridor systems. Extensive surveys of actual commuter behavior in the North Central Expressway Corridor in Dallas were conducted to characterize the day-to-day dynamics of commuter decisions and to calibrate the user-decision models. The resulting data provide unique information that is of value to a wide array of travel demand measures and traffic operations measures, including IVHS.

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Driver Responses to Traffic Disturbances and Control Strategies
Research Project 3-18-89/1-1216

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
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THE UNIVERSITY OF TEXAS AT AUSTIN

November 1992

IMPLEMENTATION STATEMENT

The findings of this study can be used by two primary groups. Traffic system operations at the state and district level can use the procedures developed to design and analyze such control measures as ramp controls and IVHS traffic management schemes. Transportation planners concerned with travel demand management and systems planning will find a wealth of useful information regarding the travel behavior of commuters in the Dallas North Central corridor area, with applicability to other metropolitan areas in Texas. The procedures have particular applicability to planning major reconstruction activities and similar disruptive events.

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, a specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

NOT INTENDED FOR CONSTRUCTION,
BIDDING, OR PERMIT PURPOSES

Hani S. Mahmassani, P.E. (Texas No. 57545)
Study Supervisor

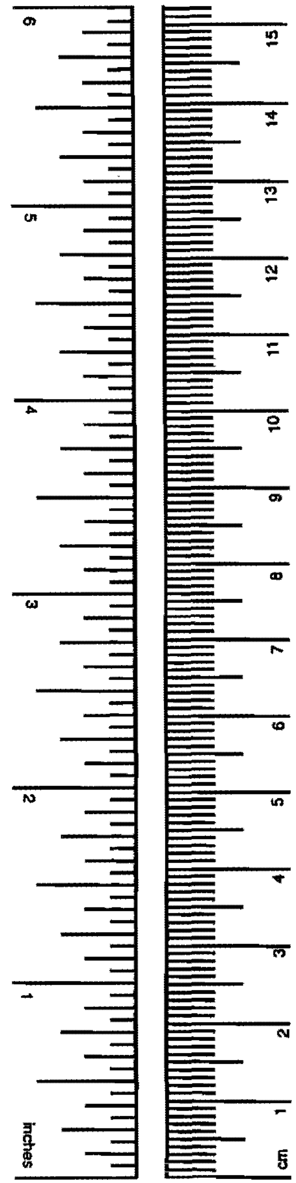
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.0765	meters cubed	m^3

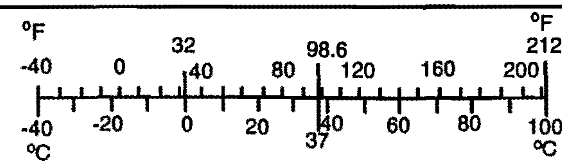
NOTE: Volumes greater than 1,000 L shall be shown in m^3.

Symbol	When You Know	Multiply by	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.20	square yards	yd^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1,000 kg)	1.103	short tons	T
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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SUMMARY

This report presents the principal findings of Project 1216, "Dynamic Framework for the Analysis of User Responses to Traffic System Disruptions and Control Actions," as well as the methods developed as part of the study. The major product of the study is a modeling framework capable of analyzing the day-to-day dynamics of a traffic corridor system in response to the introduction of major control actions or disruptions in the supply (e.g., lane closures caused by reconstruction activities). The modeling framework described in this report differs from existing methods in that it explicitly considers the decisions made by users (primarily commuters during peak periods) in response to changes in the system and experienced traffic conditions. Two types of responses are considered in the model: changes of departure time and changes of route through the network. Processes by which users "learn" and adjust their behavior over time are explicitly represented. The model is implemented in connection with the Multi-Route Macro Particle Simulation Model (MRMPSM) of freeway corridors with parallel facilities. It allows the simulation of traffic conditions as they evolve over several days after the introduction of a disruption and/or control actions.

The report also describes the procedure followed to obtain observations of actual commuter decisions in the Dallas area along the I-75 North Central Expressway Corridor in connection with the observational component of the study. A novel survey diary approach, initially developed and tested in Austin, was adapted and used to observe actual commuter behavior. The results of the survey are described in detail in a companion report (1216-1, "Daily Variability of Commuter Decisions: Dallas Survey Results"); a summary is given in the present report.

The data also served to calibrate the principal behavioral response models used in the modeling framework. The resulting framework was then demonstrated through application to the analysis and design of two types of control strategies: freeway entry ramp control, and information dissemination strategies. The model was used to investigate the sensitivity of the system to different values of the parameters of the ramp metering strategies considered, and to determine parameter values for efficient system operation. The provision of information to commuters on suggested departure times can greatly reduce system congestion and help mitigate the effect of planned disruptions.

CHAPTER 1. STUDY OBJECTIVES AND ACHIEVEMENTS

INTRODUCTION

The problem of traffic congestion continues to be a topical issue not only because of the escalating travel delays encountered but also because of heightened public concern over air quality attainment and energy efficiency considerations associated with congested facilities. It is estimated that in 1987 traffic congestion accounted for over 1.2 billion vehicle-hours of delay, 1.3 billion gallons of wasted fuel, and over $9 billion in user costs in the United States alone. These figures are predicted to grow to nearly 6.9 billion vehicle-hours of delay, 7.3 billion gallons of wasted fuel and over $50 billion in user costs by 2005 (Ref 1). A primary cause of the increase in congestion is the continuing increase in the number of vehicles on the road. The global motor vehicle population has increased rapidly in the last 30 years and is now about 540 million (including cars, buses, trucks, and commercial vehicles)(Ref 2). Demographic changes have further added to the problem. Between 1960 and 1990, the suburban population of the United States has increased 126.4 percent (Ref 3). Recent studies have shown that 68-91 percent of all newly constructed office space is in the suburbs. Suburb-to-suburb commuting has increased rapidly since 1960, accounting for about 57 percent of the total increase in commutes from 1960 to 1980. Workers commuting from suburb to suburb now outnumber those commuting from suburb to central city by the ratio of two to one. These commutes are difficult to serve in a cost-effective manner by conventional public transit. In 1980, private vehicles accounted for 85.9 percent of all work trips, compared to 69.5 percent in 1960 (Ref 4).

Traditionally, methods for relieving congestion have focused on expanding or otherwise improving the physical facilities. However, land, which is a key resource in such projects, is becoming extremely scarce, especially in congested urban areas. This, together with the high costs typically associated with the expansion, improvement, and maintenance of the facilities, has made these methods less attractive, if at all feasible. The Federal Highway Administration estimated that it would cost close to $6 billion a year to just maintain the 1983 safety and operational service levels (Ref 1).

Over the past fifteen years, methods to relieve congestion have shifted emphasis to the demand side, focusing on innovative techniques to reduce or otherwise modify the demand in order to increase the efficiency of the network. Examples of these types of strategies include demand reduction through telecommuting, peak spreading through flexible work hours and congestion pricing, and delay reduction through information technologies. Lindley (Ref 1) illustrated the effectiveness of demand-side strategies relative to supply-side strategies using a simple analysis. He evaluated three supply side measures: road widening; implementing surveillance and control systems; and low-cost modifications to increase capacity (e.g., using the shoulder as a travel lane). Based on 1984 figures on urban freeway congestion, he estimated that the congestion problem imposes approximately $9.2 billion per year in user costs. The most effective of the three improvement alternatives analyzed—low cost geometric improvements—would eliminate only about half the problem ($4.7 billion). Implementation of a combination of improvements would eliminate about 70 percent of the problem, but would require an initial capital investment of over $10 billion (which was more than the annual level of capital outlay in 1989). On the other hand, if one could implement a demand-side strategy that could effectively "remove" one of every five single-occupant vehicles (by forming a carpool or using transit), then total 1984 urban freeway travel could be reduced by 17 percent. Recurrent congested travel would be reduced by 55 percent, recurring delay by 67 percent, and incident delay by 63 percent. The total annual cost of urban freeway congestion would be reduced from $9.2 billion to $3.3 billion (i.e., 64 percent , as compared with 70 percent from the combination of all three supply-side strategies). Calculating the cost of reducing demand by this extent was difficult and therefore not addressed in the study. However, it is evident that demand-side methods hold good potential as part of an integrated strategy to solve urban network congestion problems.

The emerging demand-side methods have placed significant new requirements on our ability to understand and predict travel behavior. Also affected is the information available to characterize and model the various aspects of travel behavior. For instance, strategies like telecommuting and peak spreading through flexible work hours require knowledge of aspects of travel behavior that have not been addressed to a sufficient extent previously. Similarly, information strategies for better system operation require a deeper understanding of tripmaker behavior. However, this essential body of knowledge and information on travel behavior is lacking.

Central to the successful development and implementation of demand management strategies is the consideration of the users responses over time, which requires the characterization of current choices as well as an understanding of the underlying behavioral decision processes. The dynamics of how users adjust to major changes in the traffic system must also be incorporated in the analysis and development of traffic control and operations strategies. Failure to do so could result in changes in traffic patterns that were not anticipated at the time the strategies were developed, and might therefore lead to less effective or perhaps even counterproductive strategies.

Congestion associated with the work commute during the AM and PM peak periods remains a subject of primary concern in the major urban areas. It is well recognized that the problem arises because too many people want to use the same facilities at the same time. The situation is exacerbated when capacity is significantly reduced, such as when construction activities are taking place on high-demand facilities. The choices of route and departure time are the two most immediate options available to regular tripmakers to deal with unfavorable trip characteristics on a day-to-day basis. Changes of mode of travel involve a more elaborate decision-making process and are usually made over a longer timeframe. While regular users might eventually learn to live with the congestion through successive adjustments of their decisions and experience with the facility, the adjustment process could be very inefficient and might require a considerably long period. Part of the reason is that users are making decisions individually (non-cooperatively), with little or no information on what other users are doing and what the resulting traffic conditions are. In current practice, in the limited instances where potential changes in travel patterns have been considered, engineers and planners have relied on the conventional tools used in transportation planning (i.e., those used in the four-step planning process). However, these tools are intended for long-term planning studies, and assume future steady-state conditions. As such, they do not address the daily adjustments in the users' trip-making patterns.

A study of users' route and departure time switching behavior and associated decision-making processes will have direct relevance to the traffic dynamics existing during at least the initial stages of a long-term disruption, e.g., reconstruction activity on the facility. Given the scale and duration of the disruption resulting from reconstruction, planning for these activities is essential. Previous work has addressed some of the traffic flow aspects of the problem, such as models of queue formation and dissipation caused by work zones on freeways. However, these models neither address the time shifts and mute diversions resulting from users' decisions, nor ways to influence these decisions in a manner that reduces the overall negative impact of the disruption. It is, however, well recognized that users can and will adjust their trip making in situations of major disruption, particularly if they persist over a long period of time, resulting in potentially significant changes in traffic patterns in the affected system. Furthermore, these changes provide a powerful mechanism for accommodating and mitigating the impacts of these disruptions by reducing and spreading the demand geographically (as well as over time), thus underscoring the importance of a systematic and effective tool to analyze users' dynamic responses. However, essential information is lacking in this area, namely, how users respond to changes in service quality, such as those induced by reconstruction activities. Consequently, the motivation for this study was the need for effective tools for the development and systematic analysis of corridor and network-level traffic management and control strategies.

STUDY OBJECTIVES

This study was initiated to address the deficiencies discussed above. The overall objectives of the study were to develop and test a systematic procedure for capturing changes in trip decisions. The procedure is to be used to develop effective control strategies and management techniques for traffic facilities. This is expected to provide an essential component in the development of guidelines for corridor management planning for normal operating conditions as well as during disruptions caused by long-term reconstruction activities.

Specifically, the objectives addressed by the study were:

(a) to develop a methodology to capture the day-to-day responses of drivers; and
(b) to develop an analytical capability to anticipate drivers' daily responses to disruptions and control actions, and integrate this capability in an effective corridor and network level management tool.

STUDY ACHIEVEMENTS

The methodological approach devised to address the first objective included an extensive survey of daily commuter tripmaking decisions. The survey included an activity diary for participants to report information about their trips to and from work (e.g., link-by-link descriptions of route, stop details, etc.) on a daily basis, for a period of 10 work days. This is a significant period, considering the extent of detailed information required for each trip. Realizing the extent of the commitment required from the participants for a survey of this nature, we decided to proceed in two stages. The second stage addressed the implementation of the detailed survey diary. The first stage consisted of a one-time, single-page questionnaire that provided a screening tool to identify participants willing to provide the kind of detailed information required in the second stage. A good response rate for the number of commuters willing to participate in the second stage made it possible to conduct another long diary survey about a year later. This survey, which was beyond the original scope of the study, included a certain number of participants who had participated in the previous survey. The intent of this second survey wave was to provide insights into longer-term adjustments in travel characteristics.

Under the second objective, a framework was developed to study the interaction of user decision making and the traffic performance. This consisted of a vehicle simulation component and a vehicle generation component. The vehicle simulation component describes the movement of traffic along a facility based on well-established properties of traffic flow. Incorporated within the simulation component are capabilities to represent real-time control and information technologies. The core of the vehicle generation component is a behavioral module to capture the users' trip-related decision making. Several plausible behavioral models have been incorporated within this module.

An extensive analysis of the survey responses was conducted after the data from the diaries were coded and recorded. Because of the richness of the data contained in the surveys, a separate companion report (Ref 5) has been dedicated to the analysis of the survey results, providing important characteristics of travel behavior in the Dallas commuting context, as well as models of the decision-making process of commuters. These data were also used to calibrate some of the behavioral models incorporated in the modeling framework.

In addition to the analysis of the survey results and their inclusion in the modeling framework, the latter was used extensively to support the development and analysis of control strategies that explicitly consider user responses. The effort included defining appropriate performance measures to characterize the day-to-day dynamic performance of the system, and developing and exploring various entrance control and information strategies. The details of this work are described in a separate report (Ref 6).

The remaining portion of the report is organized as follows. The second chapter describes the modeling framework developed to study day-to-day traffic dynamics in response to user decision making. The third chapter discusses the details of the design and implementation of the observational component of the study, conducted to capture the day-to-day responses of users. A summary analysis of some results is also provided. As mentioned earlier, the complete analysis is the subject of a companion report (Ref 5). The next chapter provides an illustration of the overall modeling framework and a demonstration of the possible benefits of implementing control strategies that consider user behavior and responses. Concluding comments are presented in the final chapter.

CHAPTER 2. THE MODELING FRAMEWORK

INTRODUCTION

The modeling framework used to capture the interaction between tripmakers' daily decisions and system performance, or Day-to-day Dynamic Traffic Simulation Model (DDTSM), consists of two principal components. The first component, the Multi-Route Macro-Particle Simulation Model (MRMPSM), is a fixed-time traffic simulation model that uses established traffic flow relations to describe the movement and the interaction of vehicles along one or more highways in a corridor. Unlike most macroscopic simulation programs (e.g., the MACK or FREFLO family), the traffic flow in the highway is not modeled as a compressible fluid, but, rather, is viewed as a collection of vehicle groups or bunches, termed macro-particles. The model keeps track of the physical positions of those particles using a pre-specified speed-density relationship that can be calibrated for the particular system under consideration. The macro-particle approach avoids the significant computational cost of representing the detailed maneuvers of individual vehicles, which are not essential to the present research. In addition, it avoids approximating traffic as a continuous fluid and the resulting inaccuracies (such as the occurrence of non-physical speeds).

The second component, the vehicle generation component, processes the daily decisions of users into route and sector-specific discretized time-dependent demand patterns. At the core of this component is a behavioral module consisting of the user decision-making rules. At the end of the simulation period, control is transferred to this module, where individual decisions are made for the next trip based on their current as well as previous experiences in the system.

Two types of data are required as input to the DDTSM: supply-side data and demand-side data. Supply-side data refer to the key physical and operational features of the highway facilities, such as the number of routes, the total corridor length, the number of analysis sectors in the corridor, the number of discrete sections or segments that each highway facility is subdivided into, the number of lanes, the location of detectors, as well as the allowable free-flow speed in each section. The parameters of the speed-density model and entrance control strategies, as well as various simulation control parameters (described later in this section), are also included in this category. The demand-side data include origin-destination demand patterns, as well as the characteristics of users that comprise the demand, e.g., age, gender, work start times, preferred arrival times at work, etc. This type of information is mostly used in the decision-making component of the behavioral module.

The day-to-day simulation of traffic with the consideration of user switching behavior is the distinguishing feature of the DDTSM. This experience and "learning" through repeated tripmaking should be captured in some manner, since it is expected to influence the user's decisions for the next trip. In DDTSM, this information is stored as user attributes and is updated every time a trip is made. The number of attributes required increases with the complexity of the behavioral model. In the present version, 30 attributes have been defined for each macro-particle. Keeping track of the identity of individual macro-particles and their attributes through the simulations of daily tripmaking is essential. Details of the two components are provided later in this chapter. The conceptual framework of the DDTSM is shown in Figure 2.1.

THE MULTI-ROUTE MACRO-PARTICLE SIMULATION MODEL (MRMPSM)

The MRMPSM consists of two components:

(1) the ramp highway interface; and
(2) the highway traffic simulator.

The Ramp Highway Interface

Every departing vehicle is assumed to start directly at the corresponding entry ramp onto the highway facility. Therefore access time from a specific residence to the ramp is not explicitly considered in these analyses, which is equivalent to implicitly assuming that it is a constant term and would thus merely shift a user's departure time by a fixed amount. Vehicles cannot all enter the facility simultaneously, owing to physical and operational capacity constraints (including possible traffic control devices). Since the microscopic details of merging maneuvers are beyond the level of detail of the model, a simple deterministic queuing approximation is employed to handle this phenomenon.

Denoting the service rate by s, the queue length at time t by D(t), and the fixed simulation time step by Δt, a user wishing to depart in the interval $[t, t + \Delta t]$ is considered to incur a wait time only if $D(t) > s\,\Delta t$. Note that the value of the service rate s is not necessarily a constant and may be dictated by the outcome of a ramp metering strategy.

Vehicles leaving the queue are subsequently grouped in macro-particles for moving on the highway proper. When using a fixed macro-particle size, a minor problem arises when the number of entering vehicles does not form an integer number of complete macro-particles, thus delaying some vehicles until a sufficient number are present to complete that last group. Since a typical macro-particle size is between 3 and 12 vehicles, the resulting delay is often negligible and not in excess of Δt (typically of the order of a fraction of a minute), except possibly at extremely low usage levels (when congestion is not of concern anyway).

Highway Traffic Simulator

The highway traffic movement simulator is the core of the MRMPSM. This part of the program executes a set of procedures at every simulation interval, the length of which is user controlled and possibly different from that of the vehicle generation component. These procedures are described here and contrasted with other available models.

Most of the commonly used macroscopic simulation models, though developed for their own particular purpose, share the following set of assumptions:

(a) time is discretized into small, equal intervals;
(b) the highway facility is divided into sections;
(c) traffic demand and system performance are effectively constant over a given time interval; and
(d) traffic flow is viewed as a compressible fluid where the details of individual vehicle movement are inconsequential.

Three basic equations are then used to govern the flow of traffic in the facility: a conservation equation, a speed-concentration relation, and the identity of flow to the product of speed and concentration. The conservation of vehicles can be stated as

$$k_i^{t+1} = k_i^t + \left[\Delta t / \left(l_i \Delta X_i\right)\right] \left[l_{i-1}\, q_i^{t+1} - l_i\, q_{i+1}^{t+1} + \left(N_i^{t+1} / \Delta t\right)\right] \qquad [1]$$

where:

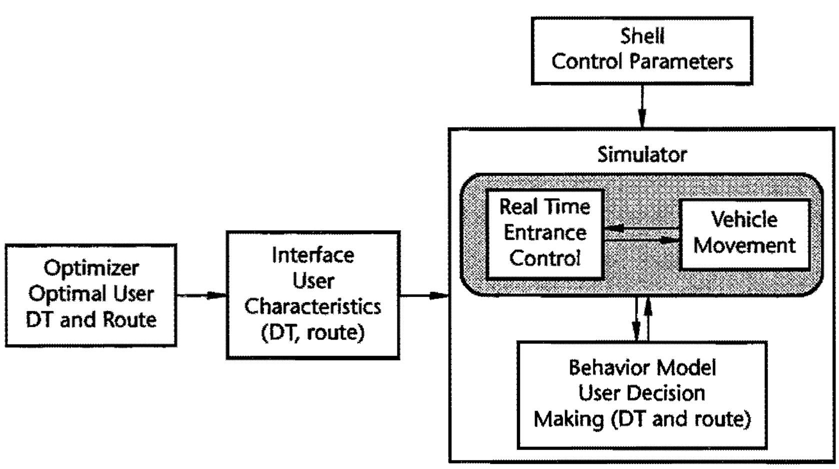


Figure 2.1 Modeling framework

k_i^t = concentration in section i during the t-th time step, in vehicles per lane-mile;
q_i^t = flow into section i during the t-th time step;
N_i^t = number of vehicles generated in section i minus those exiting section i during the t-th time step;
l_i = number of lanes of section i;
ΔX_i = length of section i; and
Δt = simulation time step.

The second equation is the speed-concentration relationship, which varies between the various models, and the third equation simply states that

$$q_1^{t+1} = k_1^t v_1^t \quad [2]$$

In the MRMPSM, both conservation and speed-concentration equations are used. However, the flow relation is not used. Instead, vehicles in the flow are viewed as groups of physical entities, termed macro-particles, and move in accordance with the local speed field, specified by a speed-concentration relationship. Thus, the concentration of each section can be updated at every time step by tracing the actual physical positions of the particles. The logic of the macro-particle approach adapted in this model follows that of the "magneto hydrodynamic particle code" developed for the simulation of plasmas (Ref 7).

The conservation equation used in the MRMPSM then has the following form:

$$k_i^{t+1} = k_i^t + (1/l_i \, \Delta X_i)\left(M_i^{e,t+1} - M_i^{o,t+1} + N_i^{t+1}\right) \quad [3]$$

where $M_i^{e,t+1}$ and $M_i^{o,t+1}$ denote the vehicles that enter section i from the preceding section, respectively, in a given time step Δt.

In the MRMPSM, the concentration in each section is updated, using Equation 3, at the beginning of every time step, and is assumed to remain constant over the interval [t, t+Δt]. The corresponding mean speed prevailing during this interval can then be obtained from the speed-concentration relation. The functional form adopted in most of the simulations is

$$v_i^t = (v_f - v_o)\left(1 - k_i^t / k_o\right)^{\alpha} + v_o \quad [4]$$

where:

v_i^t = mean speed in section i during the t-th time step;
v_f, v_o = mean free speed and minimum speeds on the facility, respectively;
k_o = jam concentration; and
α = a parameter.

The speed-concentration relation could be modeled using different or more elaborate formulations.

Macro-particles are moved at the prevailing section mean speed, yielding the respective distances traveled during a particular time step and the resulting positions at the end of the interval. Section concentrations are subsequently updated, as described earlier, for the next time interval. In addition to its computational efficiency, tracing the macro-particles obviates the need for monitoring the traffic flow with a macroscopic flow equation. The use of such a flow equation to control the flow from one finite section to another can transport material in unrealistically short times over long distances, thereby resulting in non-physical high transport speeds. Figure 2.2 displays the logical framework of the MRMPSM.

Real-Time Monitoring and Entrance Control

Incorporated within the simulation component is a module for the simulation of real-time traffic monitoring and entrance control. The traffic monitoring is performed through the placement of detectors along the facility and on the on- and off-ramps. Detectors on the facility can either measure occupancy or indicate presence, while those on the on- and off-ramps can only indicate presence. The data from the monitoring system are cumulated over a period of time, called the ramp metering interval. At the end of this interval the data are transferred to another module responsible for the computation of new ramp rates for the next interval. The new ramp rates, which are constant during a specific ramp metering interval, dictate the maximum number of vehicles that are allowed to enter the highway within a certain period.

The user is provided the flexibility to incorporate rules required for the computation of the ramp metering rates in the entrance control module. The latter is designed to serve as an independent block, for easy modification or replacement if necessary. Currently, it contains three types of traffic responsive strategies. The first strategy, proposed by Papageorgiou and called Alinea (Ref 8), computes ramp rates in an attempt to drive the traffic density to a nominal state, predetermined by the user. The second strategy, which is the most commonly used, changes the ramp rates as a user-specified function of the traffic density alone. The third strategy assigns ramp rates in an attempt to modify the rate of change of traffic density according to some user-specified function of traffic density. While the first two strategies use only information on the traffic densities from the detectors on the facility alone, the third uses information from detectors on the on- and off-ramps as well. Considerable research has been conducted to explore these strategies. Details are found elsewhere (Ref 6).

Perturbation Modeling

MRMPSM is also capable of modeling the features necessary for applications to reconstruction activities through its ability to represent supply-side perturbations, consisting of reductions in capacity in certain highway segments over particular time periods. Such perturbations are modeled by changing the physical and operational characteristics of the corresponding section over a given period. This is accomplished by simply changing the number of lanes, which in turn translates into a reduced jam concentration (and therefore capacity) for the section.

Perturbations can be treated either as deterministic or random events. Random perturbations would be used to model accidents that effectively block one or more lanes over a given duration. On the other hand, deterministic perturbations are appropriate for scheduled lane closures for highway maintenance and reconstruction. The simulation program can handle generic lane-blocking perturbations, exogenously specified in terms of the exact time, location, duration and magnitude of the perturbation. The input for the perturbation modeling includes the facility, sector, starting time and ending time of the disruption. Details of the dynamics of traffic flow at the onset of such lane blockages are not explicitly addressed in this model. A more complete observational basis is necessary to develop models of the details of these complex phenomena, which could subsequently be incorporated in the present simulation framework.

An important objective of this research is to study the effect of information dissemination strategies. Two types of information are possible: normative and descriptive. Normative information is intended to prescribe a course of action in an attempt to satisfy some system-wide objectives. Descriptive information, on the other hand, simply provides information on system conditions that existed at some prior time or that may be predicted to exist in the future. In a day-to-day scenario, the type of descriptive information disseminated will typically include the travel times on the various

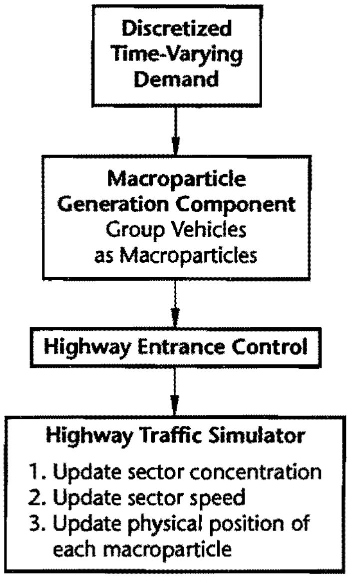


Figure 2.2 Framework for multi-route macroparticle simulator

routes for previous days for several possible departure times. A typical problem that arises in this respect is that the travel times for departure times on previous trips can ordinarily only be obtained from the simulation if there was an actual departure at that time. Obtaining travel times for all possible departure times may be necessary, for instance, to compute "utilities" as required in the "utility maximization" behavioral approach discussed later. This problem was overcome by introducing what are called "pilot" vehicles or passive probes. The characteristic of the pilot vehicle is that, while it follows the exact same rules of movement as other vehicles in the system, its introduction into the traffic stream does not in any way affect the concentration, speed, and, therefore, the flow of traffic on the route. Thus the "regular" vehicles are not impeded by the presence of the probes. Travel times for any departure time could be obtained by generating a probe vehicle at that time.

VEHICLE GENERATION COMPONENT

The key demand-side input to the traffic simulation is the time-dependent vehicle departure patterns from each of the residential or origin sectors considered in the analysis. The user provides the departure pattern for each route for the first day. At the end of the day the departure pattern for the next day is endogenously generated, using individual decision rules to determine users' (macroparticle) route and departure time choices, in response to the service levels experienced on the current day, as determined by the traffic simulation.

A user-decisions framework is a key element in this component. The rules used for the readjustment process constitute an important area of the overall research effort. Possible behavioral rules include those based on the widely used "utility maximization" concept and process rules reflecting so-called boundedly rational or "satisficing" behavior. Following is a discussion of some key issues in behavior and decision making. Since the frameworks for both of the above rules are incorporated in the DDTSM, they are discussed in more detail later in this chapter.

The Decision Process

Decision making usually involves some means of perceiving or evaluating the available alternatives. Many studies of decision making have been conducted in the area of marketing research and relate to the behavior of consumers in the purchase of different types of products. Probably the most significant difference between decision making in the marketing and traffic environments involves the concept and social implication of conspicuous consumption. Veblen (Ref 9), an economist, argued that much of human consumption is motivated by the desire to impress others through the extravagant consumption of luxury goods. Economists, however, normally assume that consumers derive satisfaction from intrinsic, and generally objective, properties of the goods they consume, rather than from such social and highly subjective factors as conspicuous consumption. Despite the differences, however, an understanding of some important concepts used in the study of consumer behavior in the marketing context may prove valuable in the study of commuter behavior. The following summarizes some of these concepts.

The Economic Rational Person. The economic analysis of demand assumes that the consumer derives satisfaction from the consumption of goods, a satisfaction measured in theoretical units of utility. Economic theory postulates rationality on the part of the consumer, which implies that the consumer will try to achieve the maximum utility, or satisfaction, possible given his or her resource limitations (budget, time, etc.). More precisely, rational behavior is equivalent to the following statements (Ref 10):

(1) for all possible pairs of alternatives A and B the consumer knows whether he/she prefers A to B or B to A, or whether he/she is indifferent to them;
(2) only one of the three possibilities is true for the pair of alternatives; and
(3) if the consumer prefers A to B and B to C, he/she will prefer A to C (transitivity).

Information Processing Approach. The dominant approach to the study of consumer behavior is generally known as the information processing approach or theory. This perspective generally assumes that the consumer is a problem solver who formulates buying problems in terms of a choice among competing alternatives and actively acquires and uses information in an attempt to solve the buying problem in a satisfactory manner.

Enviromental Complexity. By viewing buyer behavior in terms of choice alternatives, information processing researchers have had to consider the nature of those alternatives. This has naturally led to an explicit recognition of the great complexity of the environment in which buying decisions are made. In this vein, Herbert Simon (Ref 11) advanced the following hypothesis:

> A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself (Simon, *Sciences of the Artificial*, 25).

Although many consumer behavior researchers might take exception to the first part of Simon's hypothesis, agreement is virtually unanimous that much of the behavior of consumers can be at least partially understood in terms of their attempt to cope with an environment that is extraordinarily, and sometimes overwhelmingly, complex.

Limited Cognitive Capabilities. Along with the recognition of the complexity of the environment is a growing recognition that the consumer's ability to process information has rather severe limits. That is, at any specific point in time, people appear to be able to deal actively with only a few pieces of information. Most important, this limitation on consumers' information processing or cognitive capabilities is inherent and independent of any unwillingness to actively acquire and process information. From this perspective, behaviors that may not seem rational become more understandable. Why, for example, do some consumers use price to indicate product quality for certain products when an objective analysis might show little relationship between price and quality for at least some of the products? The answer lies in the fact that a consumer who cannot objectively evaluate a certain product is likely to fall back on some rule of thumb, such as "you get what you pay for," which allows decisions among the alternatives to be made with relative confidence and ease.

Bounded Rationality. Recognizing the limitations of human information processing abilities in coping with a complex decision environment, Simon proposed the concept of bounded rationality to explain the actual behavior of decision makers. Simon's concept of bounded rationality recognizes that, faced with a complex environment and limited resources (e.g., time, money, cognitive capabilities), consumers attempt to formulate and resolve buying problems in ways that are satisfactory, even if they are not "optimal." The notion of bounded rationality is usually operationalized in the form of the satisficing rule, widely accepted as a behaviorally-realistic alternative to the utility maximization rule of economic rationality.

States of Decision Making. In marketing research it is generally hypothesized that when a buyer recognizes the need to purchase a specific product, he or she will be in one of three decision-making states: routinized response behavior, limited problem solving, or extensive problem solving (Ref 10).

In routinized response behavior, the decision maker is sufficiently knowledgeable of his/her alternatives and their characteristics to where he/she can select an acceptable alternative without any extraordinary effort. In limited problem solving, although he/she may be aware of all the alternatives, the information regarding their characteristics is inadequate. Further information is therefore required to make a satisfactory decision. Extensive problem solving corresponds to a decision situation where a totally new or unique product is involved. In this state, the buyer has difficulty evaluating the new product because there is no established product class concept (a product class is a group of brands all judged by the same choice criteria and with the same weight given to each criterion) into which it can be placed. Thus, the buyer is unable to start the learning process by ascribing to the new brand the general properties of all brands in an already understood product class. While the first two states seem plausible in the commuter decision-making context, the extensive problem solving state seems unlikely over prolonged periods of time.

Commuter Decision Framework in DDTSM

As stated earlier, the principal choice dimensions available to auto users, in the urban commuting context, in the short run (i.e., from one day to the next) for their work-related trips are those of departure time and of the route to take to their destination. The models adopted for the two alternative approaches, namely utility maximization and bounded rationality, or "satisficing behavior," are based on previously conducted research and experiments in the dynamics of commuter behavior. The utility maximization approach is based on random utility theory under the assumption that each individual will evaluate available alternatives and select the one which is perceived to be the best (i.e., with the highest associated utility, where utility is treated as a random variable). Applications of random utility theory in choice modeling and transportation demand analysis are described in several references (Refs 12, 13). In the application to departure time choice, commuters can be assumed to evaluate discrete "time slices" as choice alternatives. The application to route choice is somewhat more straightforward, owing to the discrete nature of the alternatives.

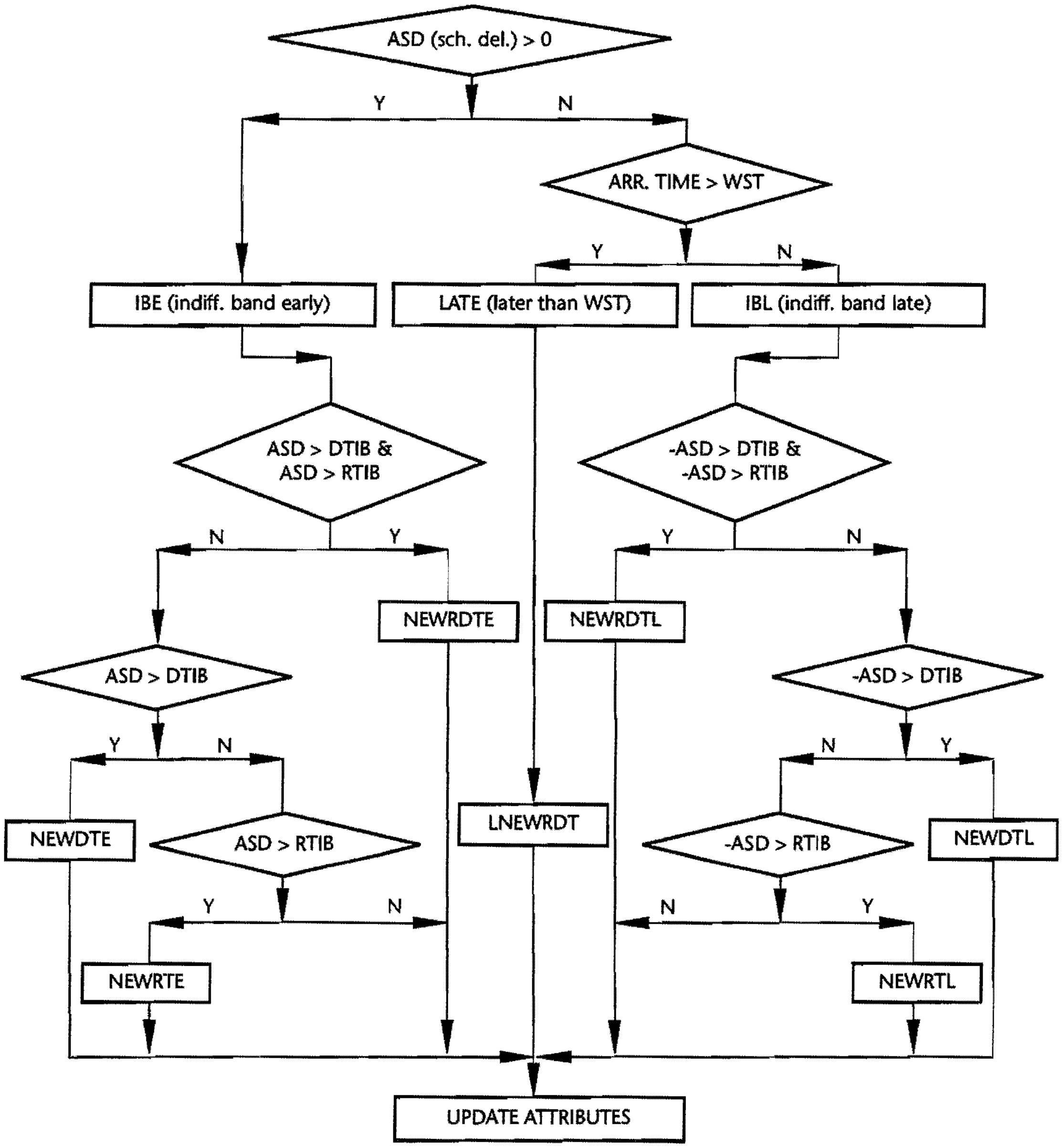
In the bounded rationality framework, commuter behavior is viewed as a boundedly rational search for an acceptable outcome, in this case an arrival time at the destination. Each commuter i is assumed to have a preferred arrival time PAT_i at which he/she would like to arrive in the absence of traffic congestion, given the official work start time. A particular arrival time AT_i^t on day t, is evaluated relative to the preferred arrival time by a measure called the schedule delay, defined as $SD_i^t = PAT_i - AT_i^t$. The basic operational mechanism proposed for the acceptability of a given decision is that if the resulting schedule delay is within some tolerable interval or "indifference band," then the trip maker maintains the same route and departure time on the next day. Previous studies show that commuters tend to change their departure times more frequently than their route, thereby suggesting two different "indifference bands": one for departure time switching and the other for route. Further, individuals may be willing to tolerate arriving earlier than their preferred arrival time more than arriving later. The indifference bands may therefore be different for late versus early arrivals.

Preliminary attempts to quantify the various indifference bands have shown strong evidence of the following:

(1) the indifference bands may be distinct for each individual;
(2) for each individual, the length of the indifference bands appears to change with time;
(3) the indifference band for the route appears to be larger than that for the departure time, in general; and
(4) for each individual, the indifference bands for the route and departure time seem to be correlated to each other.

The flowchart (Figure 2.3) summarizes the commuter decision-making process under the bounded rationality approach.

Three categories of vehicles can be defined in DDTSM in terms of the decision-making approach and information-processing strategy followed by the driver. The first category consists of drivers that use the "learning rules" as defined in the bounded rationality approach discussed previously. The second category of drivers adopt the utility maximization approach in conjunction with the descriptive information provided on travel times in prior trips. The third category of drivers relies on some normative type of information specified to them prior to the trip. This information is usually obtained so as to achieve some transportation systemwide objectives. Currently, the normative information is obtained in DDTSM through an interface with an optimization module that maximizes the sum of individual utilities, defined as a function of the individual's travel time and schedule delay. Details of the optimization can be found elsewhere (Ref 6).



IBE(L)	- indifference band early (later than PAT)
LATE	- later than work start time
NEWDTE(L)	- new departure time early (later than PAT)
NEWRTE(L)	- new route early (later than PAT)
NEWRDTE(L)	- new route and departure time early (later than PAT)
LNEWRDT	- new route and departure time when later than WST

ASD	- schedule delay = (PAT - actual arrival time)
WST	- work start time
DTIB	- departure time indifference band
RTIB	- route indifference band
PAT	- preferred arrival time

Figure 2.3 User decision-making process model flowchart

CHAPTER 3. METHODOLOGY TO CAPTURE THE DAY-TO-DAY DYNAMICS OF TRAVEL BEHAVIOR

BACKGROUND

The dynamics of commuter decisions in congested corridors have been the subject of laboratory-like experiments conducted previously at The University of Texas at Austin (Refs 14, 15, 16, 17, 18, 19). These interactive experiments involved actual commuters supplying departure time and route choices in a simulated traffic system. While these experiments provided good insights into the underlying behavioral processes, they did not necessarily replicate the commuters' actual settings. Simplifications were introduced in order to retain a sufficient degree of experimental control and to avoid overly complex response tasks. For example, trip chaining was not considered in these experiments, even though it is significant in the commuting context, as noted by Hanson (Ref 20) and Oster (Ref 21).

Prior to this study, only a limited observational basis was available on the dynamics of trip-makers' decisions in actual settings, as these affect their responses to new policies. Virtually no systematic information was available on the daily fluctuations of user decisions and of the resulting flows. Four principal travel choice dimensions are key determinants of those phenomena: trip chaining, trip timing, path choice, and modal choice (including carpooling), with the latter probably taking place over a longer timeframe than the first three. In addition, interactions among these dimensions need to be considered, preferably in the context of the pattern of activities in which commuters are engaged.

Traditional approaches to planning data acquisition, primarily in the form of cross-sectional home or phone interview surveys documenting a single day of travel, provide only limited information and cannot address the daily variations in the travel behavior processes. Longitudinal data are required for this purpose, at a level of detail normally unavailable in travel surveys, especially with regard to trip timing and path selection decisions. Pas (Ref 22) and Pas and Koppelman (Ref 23) have illustrated the importance of daily variation of travel choices, and advocated the use of multi-day surveys on both substantive and statistical grounds.

The data required to study commuter decision processes in actual commuting are of a rather detailed nature, requiring specific information on time of departure and arrival, intermediate stops, and detailed link-by-link descriptions of the paths followed. Such data are not usually available in conventional travel surveys. For this reason, a survey approach was developed to obtain information for the study of commuter behavior dynamics. It consists primarily of an activity diary, limited to the commuting trips, from home to work and returning to home. The following sections describe the survey approach developed and document its implementation.

THE STUDY AREA

The following criteria were set for the selection of a study area for the survey:

(1) the majority of the work trips should terminate in a zone within the study area; and
(2) the area should contain distinct major facilities that anchor the principal commuting routes (e.g., freeways or major arterials) that are parallel and terminate in the above zone.

These conditions were expected to limit somewhat the set of user decision-making options, thereby simplifying the task of studying user behavior, with little loss of generality.

The selected study area is located in Dallas, north of the CBD, west of the North Central Expressway (HWY 75) and east of the Dallas Tollway (Figure 3.1). In this area, the majority of the work-related trips terminate in the CBD. Several parallel facilities pass through or terminate in the CBD (the Dallas Tollway, Preston Road, Hillcrest Road, Coit Road, Greenville Avenue, Skillman Road, Abrahms Road and the North Central Expressway [HWY 75]).

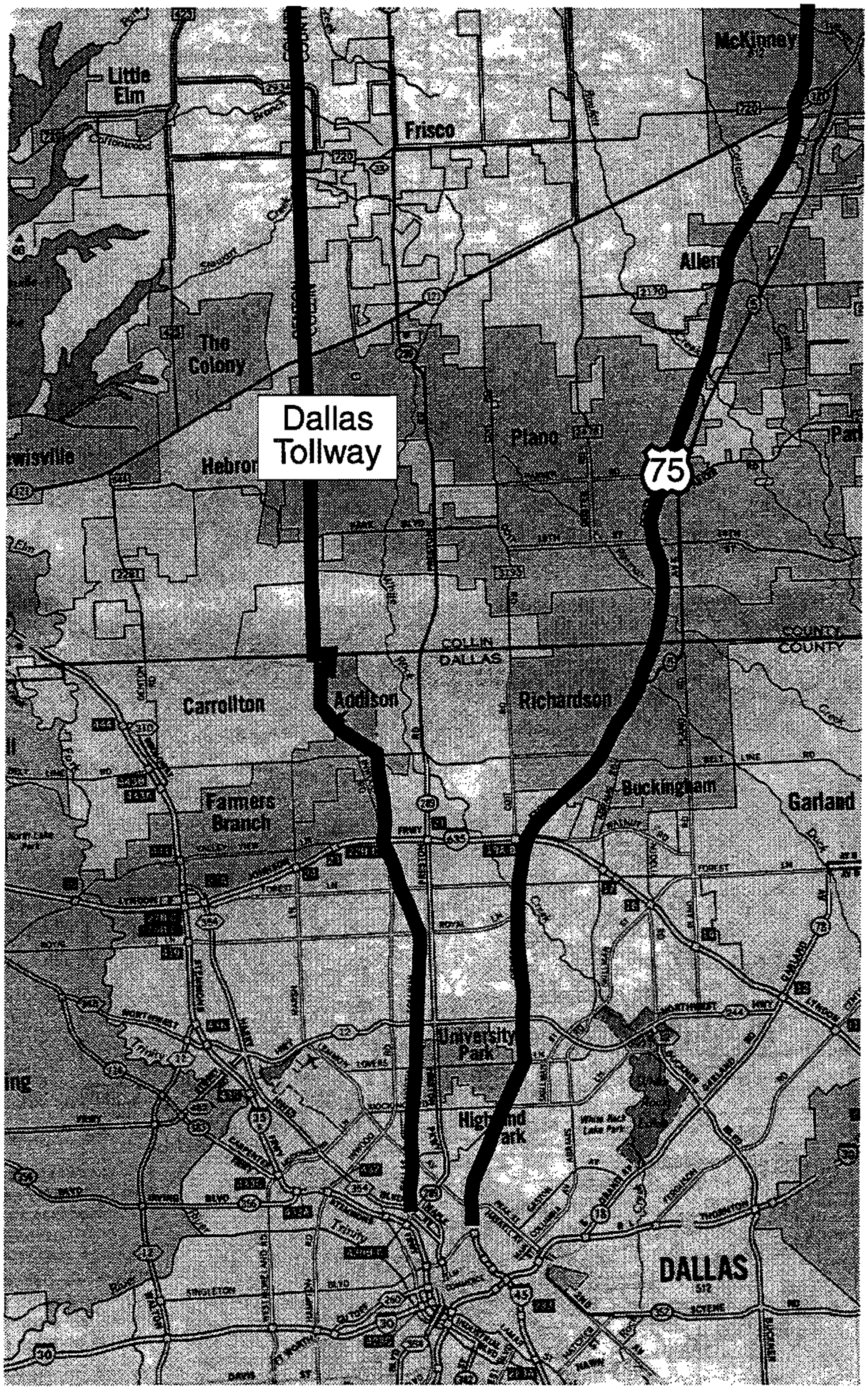


Figure 3.1 Survey location

In addition, major reconstruction was scheduled along the North Central Expressway (HWY 75) around the time of the survey. It was hoped that the survey would therefore also provide data on the adjustment behavior of commuters during a long-term disruption. Details of the construction on HWY 75 are provided in Appendix A.

SURVEY DESIGN

The survey methodology was comprised of two stages. The main objectives of the survey, i.e., the dynamics of commuting trip decisions and related aspects of travel behavior, were addressed in the second stage using a detailed activity diary. Since participation in this survey required meaningful commitment on the part of the respondents, another short (one-sheet, two-sided) questionnaire, which constituted the first stage of the survey, was designed to serve as a screening mechanism for prospective participants for the second stage. The first stage also provided a general characterization of commuting decisions in the study area. Details of the two stages are discussed below.

The First Stage

A two-sided, single-sheet questionnaire was designed for this stage of the survey. The questionnaire was mailed to 13,000 households in the study area. Each household received two survey forms, one for each commuter in two-worker households. A sample questionnaire is included in Appendix B. The questions were designed to achieve the following three objectives:

(1) acquire data on trip-related factors that are relatively constant over extended periods (e.g., commuter characteristics);
(2) obtain information on commuter attitudes and other potentially important factors that contribute to the decision-making process; and
(3) provide a mechanism to screen for prospective candidates for the second stage.

The questions can be split into three categories that respectively addressed:

(1) characteristics of the commuting situation;
(2) behavioral characteristics of the commuter; and
(3) socioeconomic and other variables potentially related to trip-making behavior.

Information on the workplace address, mode used to travel to work, type of work, and length of commuting time directly fall in the first category (questions 1, 4, 5, and 8). Apart from being used as input in statistical analysis and the study of behavior, they also served the purpose of screening and sampling candidates for the second stage. For instance, commuters with very short travel times were not considered particularly relevant to the objectives of the survey and were therefore screened out.

The second category, i.e., behavioral characteristics of the commuter, can be further subdivided into four sub-categories that addressed the respondents':

(1) decision state;
(2) decision mediators;
(3) information acquisition; and
(4) evoked set of alternatives.

In light of the discussion in the preceding chapter on decision making in the marketing arena, understanding the state of decision making—whether it be routinized behavior, limited problem solving, or extensive problem solving—is important. Although the data from the second stage survey would be a more definitive source for this type of information, indications of the state can be inferred from responses to several questions. The information on the duration of stay at the current home and duration of work at the current work location (questions 2 and 3) reflects possibly on the experience in commuting on specific routes from home to work and vice versa. Furthermore, it is expected that the longer the experience with the specific system, the less extensive will be the decision process (i.e., a routinized or very limited problem-solving state).

An important commuter attribute obtained in the first stage survey is the preferred arrival time (PAT) at work (question 6). Previous studies have indicated the significance of this factor in day-to-day trip-related decision making. The PAT appears to provide a good indicator of a commuter's risk attitudes (a larger PAT tends to reflect greater aversion towards the risk of late arrival at work), and possibly of the commuter's perception of the risk in his/her particular commuting situation. In designing the questionnaire, it was realized that the question eliciting one's PAT would be subject to different interpretations. For example, commuters may have had an initial PAT that was unattainable in their current situation because of congestion or parking problems. This may have shifted their preference as they have reconciled to another attainable and satisfactory PAT. This "equilibrium" value of the PAT may be reported by commuters as a response to a non-specific question about the PAT.

Two versions of the question were finally included in the survey questionnaire. About half the households were asked to provide their PAT with no conditions specified (case 1), while the other half were asked to provide it under the assumption of no congestion and no parking difficulties (case 2). Analysis of the distribution of the PAT obtained from both versions provides interesting insights into the possible adjustment of the PAT, and guidance on how to elicit such information in future surveys.

The information obtained from responses to the question on how important it is for the commuter to avoid being late (question 7) reflects three factors: the policy at the workplace; the perception of the policy by the commuter; and the personal characteristics (attitude) of the commuter towards arriving late.

Responses to questions on whether commuters "normally" modify their time of departure and route (questions 9 and 10) to and from work provide clues on the decision state. It is likely that commuters who adjust their times and routes are more actively engaged in the decision-making process than others.

Decision mediators are rules that the commuter uses in order to select a satisfactory alternative from his/her set of evoked alternatives. These rules will depend on the subjective evaluation of the various factors that characterize the system and the alternatives involved. For example, commuters may select to travel on a freeway instead of a major arterial because they feel negatively towards traffic lights on their travel route. Clues to these subjective rules may be obtained from information on the importance commuters attribute to the various factors that characterize the alternative, like the existence of construction activity, familiarity with the route, driving time, reliability of the driving time, environment, safety, frequent traffic lights, and congested conditions (question 12).

Information acquisition and processing are usually associated with any decision-making process. Information can be acquired actively or passively. In active acquisition, the commuter makes a conscious and deliberate attempt to obtain information to assist in the decision process; no such deliberate attempt is made during passive acquisition. In the commuter trip-making environment, information on traffic conditions can either be obtained actively or passively. Response to the question on whether the commuter normally obtains information on traffic conditions prior to a trip (question 13) is a direct indication of active acquisition. Similar is the response to the question on awareness and use of the sources of information related to the reconstruction activity on the North Central Expressway (question 18). Response to the question on whether the commuter listens to traffic reports on the radio during his/her usual drive, however, may reflect either passive or active acquisition of information (question 14). A commuter listening to the radio for the purpose of entertainment may be "forced" to hear the traffic reports broadcast at regular intervals. While not explicitly sought, some aspects of the broadcast may indeed capture his/her attention, and subsequently play some role in his/her future evaluation of the system. It is also possible that this question might be interpreted as inquiring if the commuter listened to the radio for the specific purpose of obtaining traffic reports. In this case the response would reflect active acquisition. The process of information acquisition is also closely related to the decision maker's state. Passive acquisition of information is likely to indicate a routinized type of decision making, while active acquisition is likely to indicate some extent of problem solving. Responses to the question on whether the commuter owns a cellular phone (question 15) would serve the purpose of evaluating the potential for information acquisition.

The commuter's evoked set of alternatives for the pertinent choice dimensions include feasible departure times, routes and modes to and from work. Previous studies have indicated that although a large number of feasible alternatives may exist, the choice is only made from a "few" convenient and satisfactory alternatives, in line with the concept of limited cognitive capabilities and bounded rationality. Responses to the question on the frequency of use of various major roads in the study area (question 16) reflect familiarity with the specific routes, which in turn will indicate if the routes are plausible options for consideration in the evoked set. Responses to questions on the commuter's impression of transit as a viable alternative to commute to work, and its availability and frequency of services to his/her neighborhood (question 19 and 20) will have direct bearing on the inclusion of the transit mode in the evoked set of alternatives.

The third category of information includes socioeconomic and other variables expected to relate in some manner to trip-making behavior. Job title (question 21) is likely to reflect both situational constraints and the associated attitude of the commuter towards arriving late to work. An office assistant is typically required to be at work at a given time, whereas the owner of a company has more flexibility in setting his/her own schedule. The information on whether the commuter rents or owns his home (question 22) is expected to reflect financial and social status, though only weakly so. Recent studies have shown that the social group status has more bearing than age on behavior. The behavior of married people of different ages was found to be more similar to each other than was the behavior of single individuals of the same age. Since directly inquiring about the commuter's marital status was considered inappropriate, the information on the number of children in the household was considered an appropriate proxy indicator of the marital status (question 23). In fact, it is highly likely that the presence of children influences trip-making behavior to a greater extent than the marital status per se. Information on the type of car owned, the commuter's age and gender (questions 24, 25, and 26) were also expected to bear in some way on the behavior.

A pilot survey was conducted at The University of Texas at Austin to test if the framing of the questions was appropriate to achieve the correct interpretation. About 25 employees were randomly selected from the University and requested to respond to the questionnaire. Some Dallas site-specific questions were modified to reflect appropriate conditions in Austin. Two modifications were made as a result of this pilot survey: in question 16, the statement "not necessarily to commute to work" was included in parenthesis for clarity; and in question 17 the word "normally" was included to remove ambiguity.

Sampling Strategy for the First Stage

The survey covered an area comprising nine postal zip codes and encompassing the major part of the North Central Expressway and its alternative routes. The population in each of the nine zones was obtained for the year 1988 from "CACI's 1988 source book of demographics and buying power for every zip code in the U.S.A." The data indicated there was a total population of 261,676 in the study area. We decided to send questionnaires to a total of 13,000 households uniformly from the entire area. The sample size from each zone was selected such that the ratio to the total sample size was equal to the ratio of the population in the zone to the total population in the entire survey area. A sampling rate was then computed for each zone based on the number of available address labels in the database. Table 3.1 shows the results of the sampling for the first stage.

A total of 2,521 useful responses were received in the first stage. In response to the question on further participation, 1,249 indicated "yes," 804 indicated "possibly," and 468 indicated "no."

Screening for the Second Stage

The primary screening criterion for the second-stage survey was based on the response to the question, in the first-stage survey, on whether the respondent was willing to provide additional information on his/her commuting habits. As mentioned earlier, the "possibly" option was provided in order to retain potentially agreeable commuters who were not yet willing to commit without more information. Only commuters responding with a "yes" or "possibly" were considered past this first screening step. From this set of respondents, those whose characteristics are not within the scope of the survey (e.g., retired, very short travel time, frequent out-of-state travel, work at home, no fixed work location, walk or bike to work) were removed in a second screening step. The questionnaires were mailed during the first and second weeks of April 1990.

The Second Stage

The second stage of the survey addressed the key objective of obtaining data on the day-to-day dynamics of the behavior of commuters. For this

Table 3.1 Sample size computation details for the first stage

Zip Code	Population	Available Labels (households)	Sample Size (households)	Adjusted Sample Size (households)
75023	38,158	13,709	1,896	1,900
75024	433	357	22	50
75075	48,941	11,896	2,431	2,400
75252	2,182	865	108	150
75248	40,781	14,669	2,026	2,000
75080	46,623	14,399	2,316	2,300
75240	37,750	16,142	1,875	1,900
75230	28,800	12,578	1,431	1,400
75225	18,008	9,453	895	900
Total	261,676	94,068	13,000	13,000

stage, two types of diaries, a long and a short version, were designed to record the day-to-day behavior of a smaller sample of commuters over a two-week period. The length of the trip diary stage (10 working days) was determined to be sufficient for examining short-term dynamic behavior but not so long as to jeopardize the respondents' goodwill. The booklet was designed to be easy for the commuter to handle while in the car. Each day had separate pre-dated pages for the morning and evening commutes. Also included in the booklets were detailed instructions and a sample of a completed day's entries. Appendix C contains a sample of the long and short versions of the diary.

The second-stage survey differed from the first stage in that the amount of interpretation and recollection was reduced while the level of detail was significantly increased. Prior to their departure to work, commuters were asked to note down their mode of travel, their departure time, target time to arrive at work, and work start time for the day. The difference between the target arrival time and the departure time provides the commuter's a priori estimate of his/her travel time for the trip. The intent was therefore to obtain information on the commuter travel-time prediction process and the significance of arrival time constraints (e.g., tolerance to lateness). However, it was also realized that this question might be interpreted differently by different commuters. For example, commuters may consider the target time as the time at which they were required to arrive at their workplace rather than as a consequence of some sort of travel-time prediction process.

Details of the route taken and stops made for each trip were also required for each trip. The principal difference between the long and the short versions of the diary lies in the level of detail of the information required on the route and stops. In the longer version, commuters were asked to list their route on a link-by-link basis, thereby revealing even "minor" deviations, if they existed. In the shorter version, only the major street or facility was required. Similarly, while commuters were asked to write down the details of every intermediate stop in the longer version (the arrival and departure times, and the purpose of the stop), only the number of stops were required in the shorter version.

If reconstruction activities, traffic jams, or accidents were observed during a particular trip, the commuter was asked to note down the street along which this occurred. Two questions were directed towards the acquisition of information on traffic conditions prior to and during the trip. From the responses to these, valuable information on the extent of pre-trip planning, states of commuter decision making (e.g., routinized, extensive problem solving, etc.), and the potential for information-based strategies (e.g., ATIS/ATMS) can be extracted.

Questions pertaining to the trip from work were similar to those for the trip to work. At the end of the survey, commuters were asked to respond to six final questions on the last page of the diary. The first three questions were related to parking and included the type of parking, cost of parking, and time to travel from the parking lot to the workplace. These were intended to provide information on the influence of parking-related factors on trip-maker behavior and decision process. The final three questions were related to information acquisition and measured the propensity to acquire and use information if provided, and the potential of various information sources.

As mentioned earlier, because this stage required extensive record keeping on the part of the participants, the maximum duration for the participation of a given commuter was limited to two weeks (10 working days). In order to obtain information on commuter patterns in the area over a longer period during the initiation of the freeway reconstruction activity, the survey was administered in two subwaves of ten working days each. The first subwave extended from the 11th to the 22nd of June, 1990. The second subwave extended from the 18th to the 29th of June, 1990. A second wave was conducted about a year later, from the 29th of April to the 10th of May, 1991, in an attempt to capture any long-term effects of the reconstruction activity on commuter patterns. Participants in the second wave included a combination of new respondents and participants who had taken part in the previous wave. To improve the return rate of these diaries, telephone calls were made to a considerable number of prospective participants to encourage them to participate in this stage.

Sample Design for the Second Stage

A total of 2,521 "good" responses to the first stage were obtained. In the survey, 1,249 indicated "yes," 804 indicated "possibly," and 468 indicated "no" to the question on the willingness to participate in the second stage. Of the 2053 willing candidates, those with commuting characteristics that were undesirable for the purpose of the survey were eliminated. This resulted in a total of 1,973 eligible participants.

The second stage was administered in two waves. A portion of the available sample was kept aside for use in the second wave. The first wave was further split and administered in two subwaves. The satisfactory response rate from the first stage provided a sufficient pool for each of the waves. Of the sample available for the first wave, two separate lists were made of all the candidates who responded with a "yes" and a "possibly." Each of these were further subdivided into four distinct lists based on the response to the question on the type of work, i.e., "regular" "scheduled shift," "flexible shift" or "other." An approximately equal number of addresses were sampled randomly from each of the eight lists for the two subwaves. Adjustments were made to the list to ensure that two eligible candidates from the same household were always grouped together to participate in the same subwave of the survey.

The sample for each subwave was separated into two groups. One group received the short form of the diary and the other the long version. Almost all participants who received the long form of the diary were selected from the subgroup of candidates that indicated "yes" to the participation question. This was based on the hypothesis that commuters who respond with a "yes" rather than "possibly" are likely to be more strongly committed to their participation, and could therefore be expected to make the effort to fill out the longer version of the diary. The remaining portion of the sample (including a few remaining "yes" and all the "possibly" responses) were sent the shorter version. Again, two eligible members of the same household always received the same version of the diary regardless of their response to the participation question. For example, if one of the two participants of the household was selected to receive the longer version, the other would automatically be included in the list and was sent a long version even if he/she responded with "possibly" to the participation question.

A second wave of a similar nature was administered about a year later. The sample for this wave consisted of 150 candidates who had participated in the previous wave, along with 350 new candidates. The "old" candidates were selected randomly from the subgroup that filled out the long version of the diaries in subwaves 1 and 2. The 350 new candidates were randomly selected, mostly from the sample of 456 that was kept aside specifically for this wave. Unlike those in the first wave, all participants received the long version of the diary in the second wave. A total of 54 "old" participants and 74 "new" participants responded to this wave of the survey. Figure 3.2 and Tables 3.1, 3.2, and 3.3 show the sampling plan and sample details for the second stage.

Information from the returned diaries were coded into a database for analysis. The routes were coded using a detailed node-by-node approach by means of the Dallas area network (obtained from the North Central Texas Council of Governments).

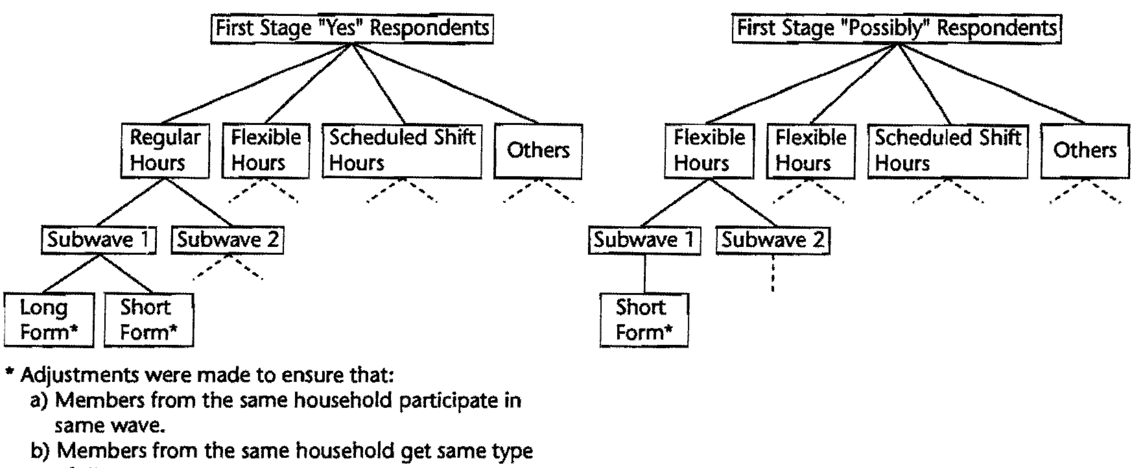


Figure 3.2 Sampling plan for second stage

Table 3.2 Sample details for the second stage, wave 1

Response to Participation Question	Type of Work Hour	Sub-Wave 1	Sub-Wave 2	Sub-Wave 1	Sub-Wave 2
Yes	Regular	65	59	262	294
Yes	Scheduled Shift	5	2	11	4
Yes	Flexible	16	16	75	78
Yes	Other	3	3	9	7
Possibly	Regular	206	207	20	7
Possibly	Scheduled Shift	13	8	1	1
Possibly	Flexible	58	63	5	2
Possibly	Other	9	4	2	2

Table 3.3 Returned diaries, wave 1

Response to Participation Question	Type of Work Hour	Sub-Wave 1	Sub-Wave 2	Sub-Wave 1	Sub-Wave 2
Yes	Regular	24	28	79	91
Yes	Scheduled Shift	2	1	1	0
Yes	Flexible	3	4	20	19
Yes	Other	0	0	3	1
Possibly	Regular	59	76	3	2
Possibly	Scheduled Shift	2	2	0	0
Possibly	Flexible	11	16	2	0
Possibly	Other	2	1	0	0

CHAPTER 4. SURVEY RESULTS

INTRODUCTION

The survey generated a considerable amount of data on commuters' travel behavior and patterns. A separate companion to this report has been prepared to address these results (Ref 5). This chapter is intended as a summary of highlights of the more extensive results in the above-mentioned report. The scope of this chapter is limited to the characterization of the daily variability of commuter decisions. Specific mathematical models and decision-process rules are discussed in the next chapter.

FIRST-STAGE SURVEY: GENERAL RESULTS

Summary statistics for the first-stage survey results are presented in Table 4.1. The vast majority of respondents (94 percent) used their own vehicles to commute. All other options including the use of carpool, transit, and park and ride accounted for less than 7 percent. While this may indicate the current state of "attractiveness" of these options, it also shows latent potential for strategies that encourage the use of these options to improve the efficiency of traffic flow. The majority of respondents (71 percent) had regular work hours. Of those commuters with regular work hours, the majority had work start times between 7:45 and 8:15 AM, and work end times between 4:45 and 5:15 PM. The relatively low percentage of workers with flexible work hours suggests the still untapped potential of peak spreading as a traffic relief strategy.

The preferred arrival time (PAT) represents a safety margin to protect against lateness at work and allows some time for preparation at the onset of the working day. It was found to be an important determinant of the dynamics of commuter behavior in previous experiments (Ref 14). As noted in the previous section, two versions of this question were used, with the wording in the second case specifically indicating that the PAT was intended in the absence of congestion and/or parking problems. The average was 16 minutes for the reported PAT with no conditions stated (case 1) and 15 minutes for the PAT in the absence of congestion and/or parking difficulties (case 2). The stated PAT's under the two definitions follow the distributions shown in Figure 6, which reveals that around 50 percent prefer to arrive at their workplace within 10 minutes before the official work start time in both cases. It can be noted that the distribution of PAT for case 2 is "tighter" than that for case 1, as indicated by the respective standard deviations (16 minutes for case 1, and 13 minutes for case 2). A chi-squared test indicates that the two distributions are significantly different at any reasonable confidence level. This is probably due to the higher percentage of commuters with a PAT of zero in case 1.

Over one-third of the respondents indicated that they had unlimited lateness tolerance, whereas more than 50 percent indicated there was no lateness tolerance at their workplace. The remainder (7.3 percent) reported various lateness tolerance intervals, with 10, 15, and 30 minutes being the most common. The average reported travel time to work was 25 minutes and the return commute averaged 27 minutes. The distributions are shown in Figure 4.1. A chi-squared test reveals that the two distributions are significantly different.

More commuters adjust their departure time for the morning commute than for the evening commute, but there is only a 1-percent difference in reported route switching between the home-to-work and return commutes. A considerably larger percentage switches route than departure time in the evening commute, while a somewhat larger percentage of commuters report adjusting departure time rather than route in the home-to-work commute. The results suggest that different considerations govern commuter switching behavior in the morning and evening commutes. Similar general insights were obtained in an earlier survey conducted in Austin (Ref 24). Almost half of the respondents indicated no arrivals after their intended time of arrival at work. Only 8 percent reported "more than 5 times."

Table 4.1 ***Summary statistics for first-stage survey results (all values are percentages of the respondents to the particular question unless otherwise specified)***

Mode of Travel for Commuter (2518):				
	Car (alone)	93.6		
	Car Pool	2.4		
	Transit	1.0		
	Park and Ride	1.3		
	Other	1.7		
Type of Work Hour (2518):				
	Regular Work Hours	70.5		
	Scheduled Shift Work	2.9		
	Flexible Work Hours	20.0		
	Other	6.6		
Preferred Arrival Time at Workplace:				
Case 1:	No Conditions Specified (1178)	16 minutes		
Case 2:	In the Absence of Congestion or Parking Problem (1192)	15 minutes		
Tolerance of Late Arrival at Workplace (2429):				
	Unlimited	38.2		
	Given Time	7.3		
	None	54.5		
Average Daily Travel Time:				
	From Home to Work (2485)	25 minutes		
	From Work to Home (2346)	27 minutes		
Commuter Adjusting Departure Time:				
	From Home to Work (2489)	52.9		
	From Work to Home (2461)	31.4		
Commuter Modifying Route:				
	From Home to Work (2487)	47.1		
	From Work to Home (2467)	46.1		
Arrival after Intended Time:				
	More than Five Times	8.3		
	Between 1 and 5 Times	42.3		
	None	49.4		
Information:				
	Radio Traffic Reports (2494)	70		
	Before Leaving from Home (2499)	34		
	Before Leaving from Work (2468)	12		
	Own Cellular Phones (2503)	10.5		
Information Sources on HWY 75 reconstruction:				
		Used	Not Used	Unaware
Video Tapes (2359)		1	20	79
Periodic Brochures (2349)		4	22	74
Information Phone Number (2353)		13	61	26
Transit:				
		Yes	No	Not Enough Information
Satisfied with availability and frequency (2488)		24.5	24.9	50.6
		Yes	No	Do Not Know
Convenient alternative to current mode (2412)		14.2	63.3	22.5
Age (2504)				
	Under 18	0.6		
	18-29	14.9		
	30-44	46.5		
	45-60	31.3		
	Over 60	6.7		
Gender (2505)				
	Male	63.3		
	Female	36.7		
Commuter Willing to Help Further (2514)				
	Yes	49.6		
	No	18.6		
	Possibly	31.8		

* Total sample size is 2,521. Value in parenthesis is the number of responses for each question.

Seventy percent reported listening to traffic reports on the radio during their usual commutes. However, only 10 percent indicated having cellular car phones. Thirty-four percent reported obtaining information on traffic conditions before leaving home for work and 12 percent reported obtaining information on traffic conditions before leaving work for home. With respect to the specific sources of information related to the construction on the North Central Expressway (Hwy. 75), the following responses were obtained. Only 1 percent reported that they had used video tapes on traffic aspects associated with the construction; 20 percent indicated that they were aware of these tapes but did not use them, and the remaining 79 percent were not aware of the existence of the video tapes. Similarly, 4 percent of the sample indicated they had read brochures on the construction, 22 percent indicated they were aware but had not used them and the remaining 74 percent were unaware of such brochures. Thirteen percent of the sample indicated they used construction information phone numbers that were available, 61 percent indicated they were aware but did not use, and 26 percent were unaware of such numbers.

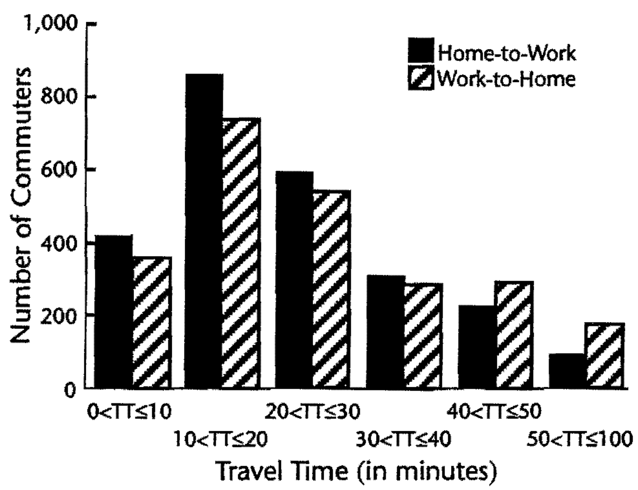


Figure 4.1 ***Frequency distributions of reported travel times for the home-to-work and work-to-home commutes***

With regard to the question on transit service to their respective neighborhood, 50 percent of the respondents indicated that they did not have sufficient information to decide if they were satisfied with the availability and frequency of transit service to their neighborhood. The remaining responses were equally distributed between those who did and did not consider its availability and frequency satisfactory. Furthermore, 63 percent of the respondents did not consider transit as a convenient alternative to their current mode of travel to work, and only 14 percent considered it as a convenient alternative. The remaining 23 percent of the respondents indicated they "did not know." It can be noted that many respondents apparently rejected transit as a convenient alternative to work without having sufficient information about its availability and frequency.

As indicated at the bottom of Table 4.1, almost half the respondents in this stage were aged between 30 and 44 (46.5 percent), 31.3 percent were between 45 and 60, 14.9 percent were between 18 and 29, and the remaining 7.3 percent accounted for ages below 18 or above 60.

Figure 4.2 displays statistics on the importance of various factors in the selection of a route. The presence of congestion and the driving time were the two most important characteristics considered by a majority of the respondents (77 percent and 70 percent, respectively) in the selection of a travel route. Among the factors considered least important were the "environmental aesthetics" and "familiarity of route" (10 percent and 30 percent, respectively). About 60 percent of the respondents considered "construction activity" and the "reliability of travel time" important, and about 50 percent considered the existence of signals and "safety" as important factors.

Figure 4.3 displays the statistics on the usage levels of the four main highway facilities along the corridor, namely HWY 75, Coit Road, the Dallas Tollway, and Preston Road. Preston Road seems to exhibit lower usage levels, possibly because the high frequency of traffic signals lights along that road.

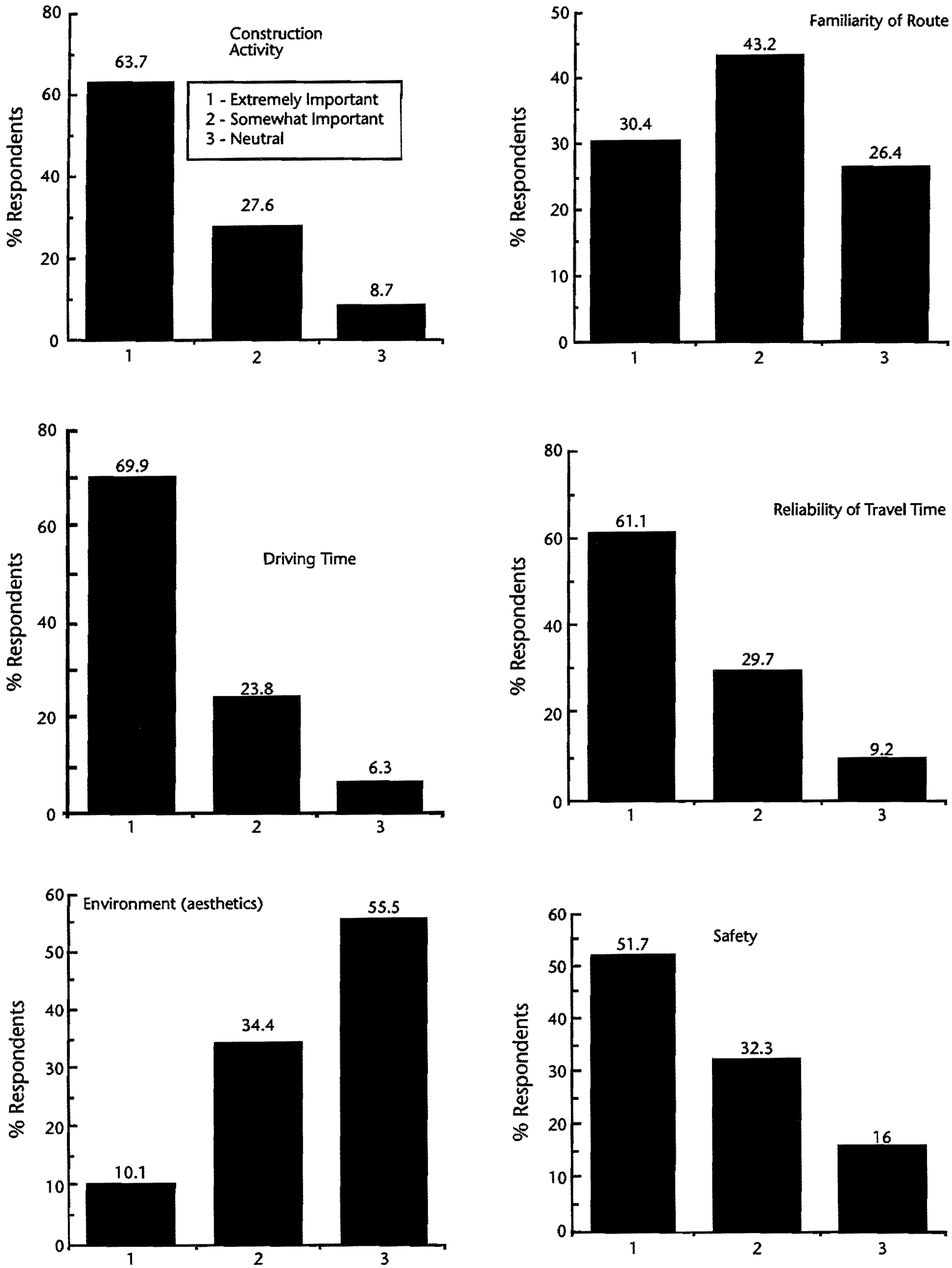


Figure 4.2 Importance of factors in the selection of a route

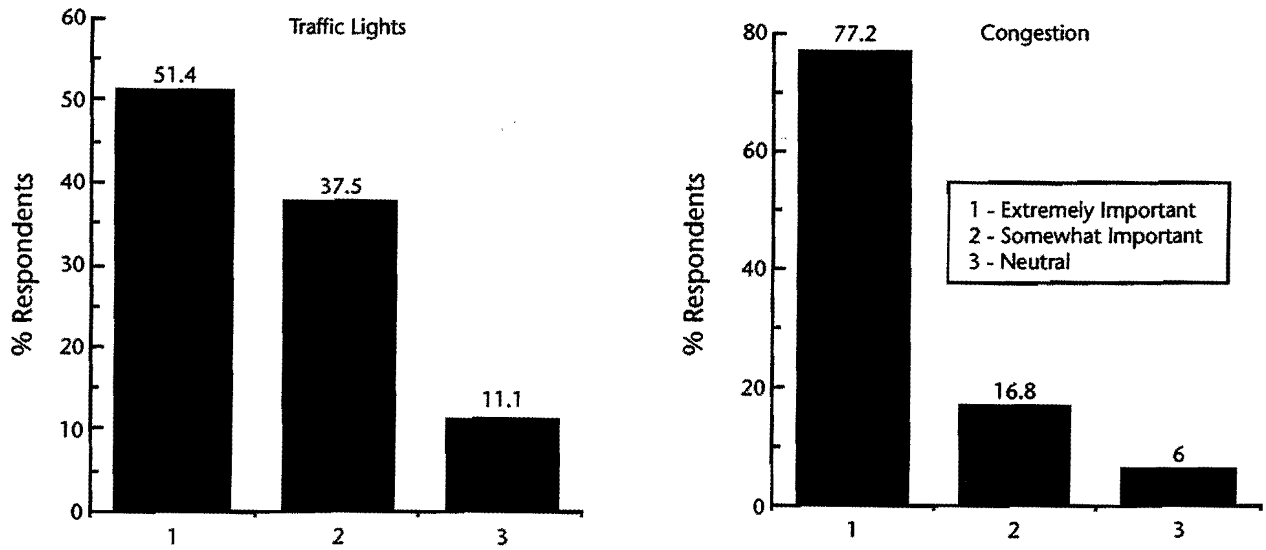


Figure 4.2 Importance of factors in the selection of a route (continued)

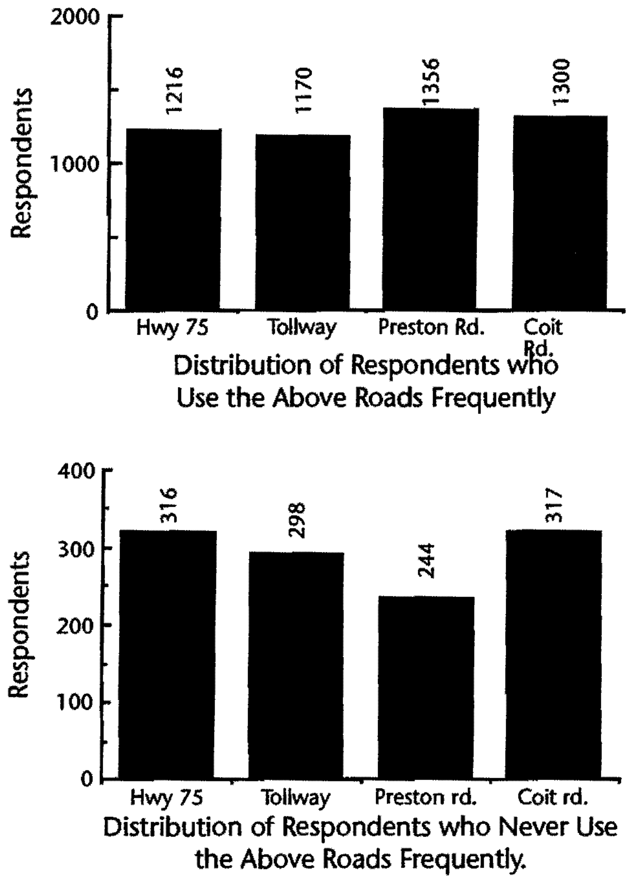


Figure 4.3 Level of usage of major routes

In the first-stage survey, commuters were asked about departure time and route switching in general terms only, in connection with "usual" behavior. No specific timeframes were specified, and no attempt was made to obtain recalled information about recent switches. As such, the responses may be more reflective of the users' perceptions of their own attitudes towards switching rather than actual behavior. The second-stage diaries, however, provide detailed and reliable information on actual departure times, routes, and intermediate stops in connection with the AM and PM commutes. The next section highlights some of the results of the second stage.

SECOND-STAGE SURVEY: GENERAL RESULTS

The second stage of the survey consisted of two waves. The first wave was administered in two subwaves. The first subwave extended from the 11th to the 22nd of June, 1990, while the second subwave extended from the 18th to the 29th of June, 1990. The second wave was administered about a year later and extended from the 29th of April to the 10th of May, 1991. The following sections deal only with the results of the first wave. Furthermore, only the long version of the diary is addressed here, as it is sufficient to provide a general characterization of the day-to-day dynamics of commuter decisions. Results from the second wave are analyzed in the above-mentioned companion report. The long diary contained detailed morning and evening trip information for a period of two weeks (ten work days), including actual trip departure and arrival times, link-by-link route descriptions, and information on the location, purpose, and timing of stops in multipurpose chains. Commuters were asked to provide official work start times. A total of 198 respondents from subwaves 1 and 2 completed the diary. Possible differences between subwaves 1 and

2 are not examined here, and the results hereafter are given for the entire sample of respondents from both subwaves. The subsequent analysis is limited to those trips that begin and end with the usual home and work locations (for each commuter), resulting in 1,724 and 1,639 usable morning and evening trips, respectively.

Table 4.2 summarizes the general characteristics of the diary respondents. The average travel time to and from work for the commuters on days with no intervening stops are 24.6 and 26.5 minutes, respectively (compare with 25 and 27 minutes, respectively, reported in the first stage!). The majority of commuters are male, regular hour workers, and own their place of residence. The majority of participants are between the ages of thirty and sixty. About 52 percent of the commuters reported tolerance to lateness at the workplace in excess of 5 minutes. The average preferred arrival time before work start for this sample is 15 minutes. Overall, comparisons of the distributions of the variables in Table 4.1 and Table 4.2 indicate that the diary participants are representative of the first-stage respondents. In particular, the travel time to and from work, preferred arrival time, gender, and age characteristics are very similar. The second-stage survey, particularly the long version diary, has provided a heretofore unique opportunity to observe the day-to-day variation of three key aspects of the commute: trip chaining, departure time, and route choice. The following sections address these three aspects in turn.

Trip-Chaining Aspects

Trip chaining, in the context under consideration, refers to the temporal and spatial linkage of individual stops during commutes. The available diary information for each stop includes the purpose, location, arrival time, and departure time. Stop locations were coded to the nearest node of the Dallas network. The frequency, purpose, and variability of stops made during morning and evening commutes were explored.

Table 4.3 shows the number of AM and PM stops made. Only 75.1 percent of all morning and 63.9 percent of all evening commutes contain no stops at all, indicating that trip chaining is an essential feature of urban commuting. As expected, commuters stop more often during evening commutes, possibly because of less stringent time constraints after work and because of the availability of more stopping opportunities (more stores open, etc.). A chi-squared test led to the rejection of the hypothesis that the distributions of the number of AM stops and PM stops are similar.

Table 4.3 Number of AM and PM stops made during the survey period (percentages shown in parentheses)

Number of Stops	0	1	2	≥3	Total
AM	1,294	360	63	7	1,724
	(75.06)	(20.88)	(3.65)	(0.41)	(100)
PM	1,050	419	127	42	1,638
	(64.10)	(25.58)	(7.75)	(2.56)	(100)

For each commuter, the total number of stops made was calculated. Only 21.2 percent of commuters never stopped on the way home during their recorded trips, while 33.8 percent of commuters did not make any stops on the way to work. On the other hand, 11.6 percent of the evening commuters and 5 percent of the morning commuters made more than 10 total stops over the 10-day survey period.

The types of activities pursued at stops during commutes are of direct interest in any trip-linkage analysis. Twenty-two original stop purposes

Table 4.2 Characteristics of the 198 diary respondents

Average Actual Travel Time to Work (no intervening stops)			24.6 min
Average Actual Travel Time to Home (no intervening stops)			26.5 min
Commuters with:			
	Regular Work Hours	82.3%	
	Flexible Work Hours	14.6%	
	Shift/other Work Hours	3.1%	
Male/Female		66.8/33.3(%)	
Percentage with Lateness Tolerance (>5 min) at work			51.6
Average Preferred Arrival Time before Work Start			15.3 min
Age:			
	18-29	15.6%	
	30-44	47.9%	
	45-60	31.3%	
	over 60	5.2%	
Commuters Who Rent			21.3%

were coded and subsequently combined into five major categories for analysis. The frequency distributions of activity types of stops made by commuters are shown in Table 4.4. While the "serve passenger" and "personal business" activities account for 64.2 percent of all AM stops, they account for only 44.5 percent of PM stops. The main difference between AM and PM is that shopping accounts for almost one-fifth of all stops made during the evening commute. Overall, personal business is the predominant activity pursued at stops during the commuting day, accounting for one-third of all AM and PM stops. The differences between the distributions of stops by purpose for the AM and PM commutes are statistically significant.

The set of all stops was separated into "routine" and "non-routine" stops. A stop was classified as routine if made (for a given commuter):

(1) at the same location; and

(2) with a frequency of at least three per five commuting trips (the location had to be visited at least three times to be considered) (Ref 25).

This definition is based on the location and not on the purpose of the stops, though most stops at a given location will have the same purpose.

Table 4.5 gives a breakdown of the activities pursued at routine and non-routine stops for morning and evening commutes. By this definition, AM stops are more likely to be routine than are PM stops. As expected, these activities differ between the two types of stops. The serve passenger activity tends to be routinely pursued on both AM and PM commutes. Personal business, food/social/recreational, shopping, and "other" stops are predominantly non-routine. Chi-squared tests for independence lead to a clear rejection of the null hypothesis that the stop-activity frequency distributions are similar for the two stop types, for both the AM and PM commute.

Table 4.4 Activity types of stops made during morning and evening commutes

Activity Type	AM Frequency	%	PM Frequency	%
Serve Passenger	132	27.4	100	12.9
Personal Business	177	36.8	246	31.6
Food/Social/Recreational	77	16.0	127	16.3
Shopping	16	3.3	146	18.8
Other	79	16.4	159	20.4
Totals	481	100.0	778	100.0

Table 4.5 Activities completed at routine and non-routine stops on the trip to work

Activity Type	Routine Stops Frequency	%	Non-routine Stops Frequency	%
Serve Passenger	67*	67.0	65	17.1
	(38)**	(48.1)	(62)	(8.9)
Personal	19	19.0	158	41.5
Business	(8)	(10.1)	(238)	(34.0)
Food/Social/	6	6.0	70	18.4
Recreational	(6)	(7.6)	(121)	(17.3)
Shopping	0	0.0	17	4.4
	(0)	(0.0)	(146)	(20.9)
Other	8	8.0	71	18.6
	(27)	(34.2)	(132)	(18.9)
Totals	100	100.0	381	100.0
	(79)	(100.0)	(699)	(100.0)

*AM
**(PM)

Departure Time Analysis

This section addresses the daily variation of commuter departure-time decisions over the survey period. The departure-time decision plays a critical role in the effectiveness of demand management strategies aimed at peak reduction and peak spreading.

Previous work defined a departure-time switch in a dynamically evolving context as a day-to-day change of a certain magnitude (Ref 26). Mannering (Ref 27) described a time change as a deviation from a "normal" departure time with the "intent of avoiding traffic congestion and/or decreasing travel time." Following Mahmassani, Hatcher and Caplice (Ref 28), two ways of capturing departure time switching behavior are discussed here:

(1) switching from a commuter's median departure time (median switching); and
(2) switching from a user's previous day's departure time (day-to-day switching).

The former is intended to capture deviations from a usual daily routine. The median is used instead of the mean to avoid the undue influence of outliers in a commuter diary. By the day-to-day definition, the current day is considered a switch from the previous day if the absolute difference between the respective departure times exceeds (or meets) some minimum threshold.

Results of the departure-time switching analysis are presented in Table 4.6. Departure time switching thresholds of 3, 5, and 10 minutes are considered: deviations (absolute value) greater than or equal to the thresholds are considered "switches." Departure-time switching that is directly induced by a different work start or end time is controlled for by limiting the analysis to commuter trips with the same (mode) work start or end time (for median switching, definition 3), or trips in which the work start or end time is within five minutes of the previous work start or end (for day-to-day switching, definition 4).

Commuters obviously engage in a substantial amount of departure-time switching, for both morning and evening commutes. Departure-time switching for evening commutes is more frequent than that for morning trips, under all definitions and thresholds. Even at the 10-minute level from the median departure time, 31 percent of AM trips and 48.5 percent of PM trips are switches (controlling for work start and end times). As expected, the day-to-day definition results in a higher percentage of switches than does the median definition. The 3-minute threshold tends to confound what may be considered "noise" with actual intended changes in departure time.

Unlike the controlled experiments of Mahmassani and colleagues (Refs 14-19), where the commuting system was dynamically evolving and not at equilibrium, the aggregate rate of switching in the diaries remains about the same over the 10-day period, although daily oscillations around the average rate are detectable, as shown in Figures 4.4 and 4.5. These figures depict the aggregate switch rates for AM and PM commutes, respectively, for the first 10 days of the survey only (June 11 to June 22). Trips completed between June 25 and June 29 (from the second subwave of diaries) are not included because of the small sample size. One of the useful contributions of this analysis is that it captures actual decisions of commuters in an uncontrolled environment, yielding a characterization of the "natural" variability of these decisions in a real system.

Table 4.6 Results of departure time switching analysis
(WSC = work start controlled, WEC = work end controlled)

Percent of AM Trips that are Departure Time Switches

	Switch Threshold (minutes)			
Definition	3	5	10	Number of Trips
1. Median	69.7	58.6	38.8	1,720
2. Median (WSC)	61.7	50.2	31.0	1,275
3. Day-to-day	78.7	69.5	49.1	1,520
4. Day-to-day (WSC)	75.7	65.4	42.5	1,235

Percent of PM Trips that are Departure Time Switches

	Switch Threshold (minutes)			
Definition	3	5	10	Number of Trips
1. Median	75.8	68.4	55.2	1,633
2. Median (WEC)	70.1	62.3	48.5	1,112
3. Day-to-day	86.6	81.7	70.0	1,434
4. Day-to-day (WEC)	82.7	76.4	62.3	1,047

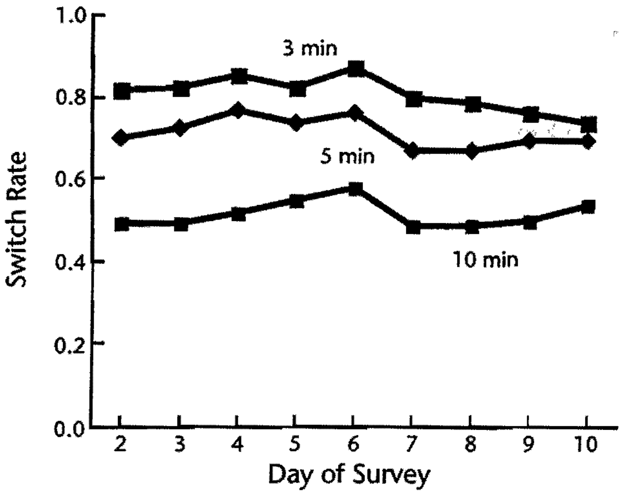


Figure 4.4 ***Daily AM departure time switch rate exhibited by commuters: day-to-day definition (uncontrolled work end). Day 1 is June 11***

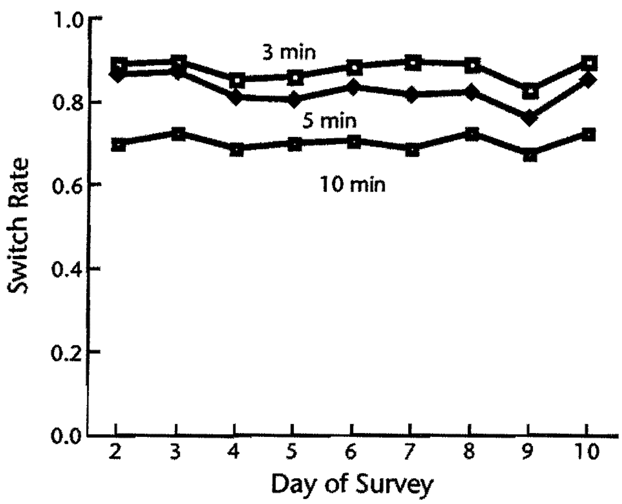


Figure 4.5 ***Daily PM departure time switch rate exhibited by commuters: day-to-day definition (uncontrolled work end). Day 1 is June 11***

The values in Table 4.6 do not highlight differences across individuals, especially since different commuters reported different numbers of trips during the survey period. Switching ratios were obtained by dividing the number of switches by the number of possible switches, for each individual, for each departure time switching definition (a ratio of 1.0 indicates a switch on every possible day). Figures 4.6 and 4.7 depict the differences between departure time switching definitions by showing the cumulative relâtive frequency distributions (across commuters) of the departure-time switching ratios for the different definitions (for controlled work start/end times). For example, the percentage of workers never switching departure time for AM commutes is 30 percent according to the 10-minute median definition, 22 percent by the 10-minute day-to-day definition, 13 percent by the 5-minute median definition, or 8 percent by the 5-minute day-to-day definition. These discrepancies underscore the importance of definitional issues with regard to departure time switching. According to the conservative 10-minute median definition, only 12 percent of commuters never switched departure times in the evening, and 49 percent had a switch ratio of 0.5 or higher. Only 9 percent of workers never switched departure times by the 10-minute day-to-day definition, 5 percent by the 5-minute median definition, or 3 percent by the 5-minute day-to-day definition. The emerging picture of PM commuting habits clearly suggests high variability of the daily departure time from work.

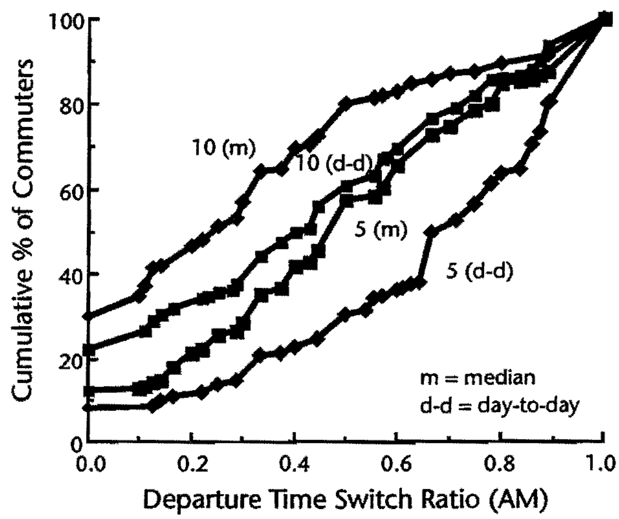


Figure 4.6 ***Cumulative distributions of departure time switch ratios for WSC case, by definition, AM commutes. Sample sizes are 176 for median and 170 for day-to-day (commuters included if had three or more switching opportunities)***

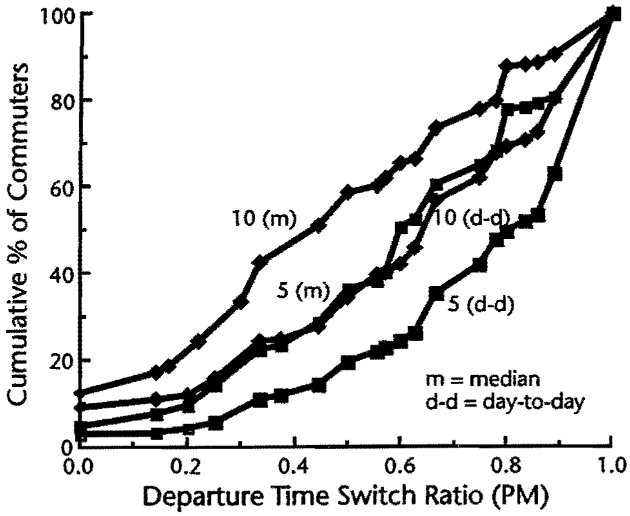


Figure 4.7 Cumulative distributions of departure time switch ratios for WEC case, by definition, PM commutes. Sample sizes are 147 for median and 145 for day-to-day (commuters included if had three or more switching opportunities)

Variability of Path-Choice Decisions

In this survey, commuter route decisions were observed in a real urban network, one containing several feasible routes between each commuter's home and workplace. The goal of this section is to explore the repetition and variability of the commuters' route choices during the two-week survey period.

Following Mahmassani, Hatcher, and Caplice (Ref 25), two definitions of a route switch are explored. First, a mode route switch is defined as a deviation from the "normal" or mode (most frequently used) network route, in which the commuter follows a "different than usual" set of nodes to arrive at work (or home). This criterion recognizes the observed dominance of one morning and one evening route over all others for most commuters. Second, a day-to-day route switch is defined when the chosen route is different from the previous day's route.

Results of the route switching analysis are summarized in Table 4.7. Route switching is not as frequent as departure time switching for AM or PM commutes. Like departure time switching, route switching is more frequent during PM commutes than during AM commutes for all definitions except definition two (relative to the mode route and only on days with no stops). Less than three-in-ten AM trips and two-in-five PM trips follow a non-mode (i.e., other than the usual) route, clearly reflecting the existence of a usual route for most workers. When trips with stops are excluded from the data (definition 2), non-mode trips account for 15.9 percent of the remaining AM and 13.0 percent of the remaining PM trips. The lower frequency of actual route switching relative to departure time switching is consistent with the results of stated preference experiments under simulated traffic conditions (Ref 19).

When all days are analyzed, 30.4 percent of the users never switch from the mode route during AM commutes, while only 16.8 percent never switch during the PM commute. In the AM, 17.5 percent of commuters and (32.4 percent in the evening) switch from the mode route with a frequency of more than one in two days. However, very little switching relative to the mode route occurs if only no-stop trips are considered, as 56.9 percent of the users never switch routes under these circumstances in the morning and 60.8 percent never switch routes in the evening. Clearly, the need to link one or more activities along the commute influences path selection and accounts for much of the variation in the selected routes. These results indicate the greater propensity of

Table 4.7 Results of route switching analysis (percent of trips that are switches)

Definition	% switches	Number of Trips
AM Trips		
1. Mode (all days)	26.6	1,725
2. Mode (days with no stops only)*	15.9	1,294
3. Day-to-day	36.9	1,528
PM Trips		
1. Mode (all days)	35.8	1,639
2. Mode (days with no stops only)*	13.0	1,050
3. Day-to-day	49.9	1,444

* Mode routes were redefined by selecting only days with no stops.

users to change departure times rather than routes, and would suggest the potential of real-time information to influence the temporal distribution of trips to a greater extent than the spatial distribution of trips over the network routes.

CONCLUDING COMMENTS

The survey has yielded information on the extent of trip chaining associated with the commute, as well as its variability from day to day. It has documented the extent of daily fluctuation in the departure times for the commuting trip chains. The results suggest that the picture obtained from conventional single-day surveys of household trip making is rather incomplete and of limited use in connection with travel demand management and congestion mitigation strategies. The journey to work, considered to be one of the more stable elements of urban travel demand, is itself quite variable from day to day, and the magnitude of this variability is not insignificant, especially in connection with the above-mentioned types of strategies. Similarly, the "symmetry" usually assumed between AM and PM trips is limited, with the PM commute subject to more variability than its AM counterpart.

Another unique feature of the survey is the level of detail of the information obtained, especially with regard to the selected paths through the network. Such information has been previously unavailable and is of utmost relevance to current studies of electronic route guidance systems.

It is remarkable that commuters have generally been able to provide the information requested at the desired level of detail. Our analyses have uncovered only a relatively small number of inconsistencies in the responses, and follow-up contacts with the participants have confirmed some of the answers obtained and the participants' general comfort with the survey instruments. Considerable effort was invested on our part to ensure clear and user-friendly instruments.

In retrospect, the short version of the second-stage survey was not as successful as anticipated. Its response rate was not higher than that for the longer, full diary. It would have been preferable to go only with the latter, which was done for the second-survey wave.

While the survey was intended for commuter trips, the insights gained suggest that the approach would be applicable in efforts to obtain a more complete record of trips and activities. The two-stage strategy was helpful in improving the cost-effectiveness of the second-stage survey by its better targeting of households likely to yield usable responses. In addition, the first-stage survey yielded very useful information in its own right, in terms of providing a reliable characterization of the population of interest and prevailing commuting patterns. The nature of the questions in the first questionnaire and the elapsed time between the first and second stages provide interesting opportunities to contrast the diaries of actual behavior with previously reported responses. Such questions, along with the fundamental processes underlying the dynamics of trip-maker decisions, are the subject of ongoing and future work in connection with the rich observational basis obtained in this survey.

CHAPTER 5. FRAMEWORK APPLICATION: THE EFFECTIVENESS OF CONTROL STRATEGIES

BACKGROUND

This section addresses issues in the development of effective controls for a freeway corridor system during peak periods—under normal operating conditions and in connection with a planned disruption. (The detailed description of the justification and development of the control strategies is the subject of a University of Texas doctoral dissertation, "Freeway Corridor Control in a Day-to-Day Dynamics Framework;" see Ref 6). Here these issues will be addressed only to the extent necessary (1) to demonstrate the application of the modeling framework described in Chapter 2, and (2) to illustrate the potential effectiveness of the kind of strategies considered.

The objective of surveillance and control of freeways during periods of peak demand is to improve the quality of vehicular flow through a traffic corridor consisting of both a freeway and the parallel surface streets serving as potential alternate routes for freeway traffic. The corridor control problem may be separated into three distinct problems: allocation, estimation, and regulation. The allocation problem consists in the determination of a desirable traffic volume to be allowed to enter the freeway from each ramp under normal circumstances taking the entire traffic corridor (freeway and adjacent streets) into consideration. Under these conditions, the specified on-ramp rates often result in nominal section speeds and densities. The estimation problem determines values of traffic variables (parameters) (e.g., speed and density) with the use of data from detectors located on the facility. The regulation problem is associated with returning the freeway in a near-optimal manner to nominal conditions after a disturbance.

Research on the allocation problem originated in the late 1960's. Wattleworth (Ref 29) was among the first to address this issue by developing a linear program to maximize the freeway outflow. Several variations of this basic effort have been proposed since (Refs 30, 31, 32, 33). Comprehensive control systems that address the allocation and regulation problems together have also been developed by some authors (Refs 34, 35). The problem is rather complex, and several major assumptions are usually made to simplify it to a level that is solvable with currently available tools. These assumptions are not necessarily valid in many situations. For example, all the above-referenced models consider a system under steady-state conditions. Although this assumption simplifies the analysis considerably, these conditions are not necessarily satisfied during the peak traffic periods. Furthermore, demand is assumed to be known or predicted through some means for the analysis. Since most control strategies are very sensitive to the demand pattern, the accuracy of demand prediction plays a key role in the effectiveness of the strategy. Also, user response and the day-to-day variations in demand produced through user switching are not considered explicitly in the analysis.

The control problem takes on a different dimension if user response and decision making are taken into consideration. While day-to-day variation in demand could only be assumed to be random in previous analyses, it can now be accounted for to some extent through models of user-switching decisions in response to service quality. In this case, the analysis of the day-to-day evolution of traffic conditions provides a more appropriate setting for studying the effectiveness of control strategies. In this setting, strategies should be evaluated based on a new set of performance measures that consider:

(a) the travel times on the facility on a day-to-day basis; and
(b) the user satisfaction level on a day-to-day basis, measured as the total number of users that are not satisfied with the service quality on a given day.

An effective strategy should not only generate low travel times on a daily basis, but should also allow users to "converge" in a reasonable time to a satisfactory trip schedule (i.e., a route and departure time that result in a satisfactory travel time as well as arrival time within some allowable bounds from one's work start time).

Keeping in mind the above criteria, two approaches were pursued for developing control strategies. They were:

(1) congestion prevention through access control; and
(2) information strategies.

By congestion prevention, it is meant that the traffic density in any given segment of the freeway is not allowed to cross some "critical density" for a prolonged period of time. It is well known that conditions of high traffic density are unstable, and that traffic tends to accelerate to 'jam' conditions when the density crosses a certain critical value. Under these "jam" conditions, the flow-carrying capability of the facility is reduced, thereby increasing travel times. If the traffic density is in some way prevented from increasing above the "critical value," the facility would continue to operate near its maximum stable operating capacity, with travel times remaining short. In addition to reducing the mean travel time, preventing the traffic density from going past a critical value would also reduce the variance of the travel time, because significant fluctuations in travel time usually occur at high traffic densities. Travel times tend to be shorter as well as less sensitive to traffic density at lower densities. Smaller variations in travel times will improve the prediction capability for users who switch frequently in search of better travel options. They should therefore "converge" to a satisfactory schedule more rapidly than in situations where congestion was allowed to set in.

One technique for preventing the traffic density from crossing into the congested regime is through the implementation of entrance control—or ramp metering—on the facility. A fixed ramp metering strategy (e.g., ramp metering based on time of day) will be subject to inefficiencies in a situation of daily varying demand patterns (a strategy that is optimal for one day may be ineffective for the next). The problem could be somewhat mitigated if the fixed rates were computed on a daily basis. However, demand prediction models would be required to provide the inputs to the optimization models that generate the optimal "fixed" ramp rates. The accuracy of the prediction models would then play a determining role on the quality of the solution. Because changes in the user decisions are generally of particular concern either with the introduction of new traffic facilities or when major modifications in supply (e.g., closure of a lane for reconstruction) are made to existing facilities, historical data are either not expected to be available or of limited use. Demand predictions can also be made on the basis of measurements of actual flows in the network that feed to the facility of concern. In this technique, generally, a certain period of time or "horizon" is considered and conditions are optimized based on all contributions of demand from the feeding facilities occurring during that horizon. There is a trade-off between the accuracy of demand prediction and the quality of the "optimal" solution. While one may be able to predict demand more accurately over smaller horizons, the optimal solutions generated are more "localized." The system performance over an extended period of time is less likely to be driven to a global optimum.

In light of the above discussion, a plausible alternative strategy is to provide entrance control through traffic-responsive ramp metering. The intent of this strategy would be solely to prevent congestion from setting in (by preventing the traffic density from moving past a critical density for prolonged periods of time), and not necessarily to optimize some performance index. However, the implicit underlying assumption is that such a strategy would result in efficient system performance and in values of the performance indices of interest that are satisfactorily close to their optimum levels. Several traffic responsive strategies have been developed and tested for preventing congestion. One commonly used strategy manipulates the entrance rates into a facility based solely on the measured traffic density prevailing on the facility. For example, if the density begins to increase beyond a specific value, the ramp entrance rates would be reduced as a function of the density. A second type of strategy varies the ramp entrance rates on the basis of the rate of change of density. This is a more elaborate strategy, one that requires considerably more data for implementation. A complete description of the strategies can be found elsewhere (Ref 6).

Individual users generally make trip-related decisions, i.e., departure time and route decisions, independently, without knowledge of the decisions made by other users of the system. Decisions made in this non-cooperative manner could lead to inefficient system performance in congested networks, especially if the system is not in equilibrium. The traffic-responsive strategies discussed above, while providing for efficient operation of the freeway facility itself, may result in long queues at the entrances to the facility. Information dissemination strategies have the potential to influence user behavior so that user decision making is consistent with the achievement of some common system-specific objectives, which are also mutually beneficial to the users. For instance, a queue that develops at a facility entrance could be prevented by scheduling the arrivals of the users at the facility entrance to coincide with the time at which they can actually enter the facility. This would be equivalent to making users wait for their turn at home rather than waste time and resources waiting on the road. Thus, all users could benefit from a reduction in their trip times brought about by the disappearance of the queue wait times. Obtaining this kind of information is, however, not trivial in the commuting context, since the users' trip decisions, i.e., route and departure time, are not only governed by the travel times, but are also anchored by the time interval within which they expect to arrive at their workplaces. Hence individual commuting characteristics (e.g., preferred arrival times at work) need to be incorporated to the extent possible in any technique used to generate this information.

Many of the currently available or proposed information dissemination strategies are "descriptive" in nature and do not necessarily influence the evolving conditions on the facility in a desirable direction. If system-wide objectives are to be pursued, a methodology is required to compute the information that is to be disseminated to the users of the facility. An approach that incorporates user characteristics has been developed in this study to generate the information required to achieve specific system-wide objectives. This approach consists of a linear mathematical programming model that maximizes the total "utility" of the network users; the utility measure is a function of the travel times and schedule delays (i.e., the difference between user arrival time and preferred arrival time at work). The system is expected to operate efficiently if all users comply with the information generated by the model, though meaningful improvement in operation could be attained if only a fraction of the users complied. Details of the developed methodology are found elsewhere (Ref 6). The remaining portion of this chapter provides an example illustration of the effectiveness of the combination of the two strategies discussed above, with the help of the modeling framework developed and described previously.

SIMULATION EXPERIMENTS

In this and the following sections, system performance under the above-mentioned control strategies is explored through a set of experiments. The experimental set-up is first described, including details of the specific behavioral model and control strategies that are used. It is followed by a discussion of the experiments and results.

The hypothetical freeway corridor under consideration consists of two parallel freeways. Freeway 1 has three lanes in each direction and freeway 2 has two lanes in each direction. Movement in a single direction alone is considered. The maximum speed on both freeways is 55 mph. For the simulation, both freeways are divided into seven sectors, each one mile in length. Sector 7 is considered a destination sector and all demand from the remaining six sectors is destined for this sector. The six sectors are numbered in increasing order in the direction of the destination. Each sector contains an entrance ramp where the demand originates to travel to the destination. As mentioned earlier, the simulation does not consider the time required for vehicles to arrive at the entrance ramp from their respective origins, since these are assumed to be constant. The simulation is conducted for a period of 30 days to study day-to-day switching and the evolution of traffic performance. In order to study the implications to changes in supply conditions, a long-term disruption, consisting of the closure of one of two lanes in sector 5 of freeway 2, is simulated from day 16 to day 30.

Demand Characteristics

The demand characteristics considered for the experiments are as follows. A total demand of 1,080 vehicles (over the arrival period of interest) exist along each sector, distributed equally (initially) among the two routes. The situation considered is one where all demand is composed of individuals commuting to work. The characteristics of the individuals, including age, gender, and preferred arrival times, are similar for all the sectors and follow the same distributions as those obtained from the Dallas survey (Table 4.1); in the case of the preferred arrival time, the distribution from case 2 was considered.

Behavioral Rules

Three types of users are considered, differing in terms of the behavioral principles governing their trip decisions. These include individuals who use: (a) "learning" rules; (b) "utility maximization" rules; and (c) supplied information, or "system optimal" rules, in their search for a satisfactory trip schedule. However, all three rules are implemented within the bounded rationality approach discussed in earlier chapters. In this approach, users are not necessarily searching for the optimal option, but simply a satisfactory one—in this context a route and departure time. The approach is made operational through the definition of an "indifference band," for the route and departure time, around the preferred time of arrival at the workplace. An arrival within this band is considered satisfactory, and no correction measures would be undertaken on the next trip. Thus, only users not satisfied with their trip outcomes on a given day (i.e., those who arrive outside their indifference bands) would resort to the "learning," "utility maximization," and "system optimal" rules to determine their departure time and route for the next day's commute.

There are two mechanisms necessary for the implementation of this approach. The first mechanism determines whether the commuter was satisfied with his/her arrival time for a specific trip. The second determines the new departure time and route for the next day, given that the current day's outcome was not satisfactory, according to the first mechanism. The first mechanism involves the computation of the indifference band. Commuters may perceive late arrivals (later than PAT) differently from early ones. This could be modeled by the use of separate indifference bands for late and early arrivals. Previous work conducted at The University of Texas at Austin, and confirmed by the survey results described in the previous chapter, has indicated that commuters tend to switch routes less frequently than departure time. The estimated mean indifference bands for routes were found to be approximately twice the corresponding departure time indifference bands in the case of late arrivals and three times in the case of early arrivals. The same will be assumed here and route indifference band will therefore not be computed explicitly. The following model, developed from the results of the survey, was used to compute the departure time indifference bands.

Departure Time Indifference Band (IBDT)

$$IBDT_{it} = b_1 + b_2\,AGE_i + b_3\,GENDER_i \quad \text{Initial band}$$
$$+\, b_4\,(NF_{it})^{b_5} \quad \text{Dynamic component}$$
$$+\, b_6\,\delta_{it}\left(\frac{\Delta TR_{it}}{\Delta DT_{it}}\right) \quad \text{Myopic component}$$
$$+\, \varepsilon_{it} \quad \text{Random component} \quad [5]$$

where:

NF_{it} = number of DT changes for user i up to day t, reflecting number of failures;

TR_{it} = actual travel time experienced by user i on day t, and $\Delta TR_{it} = TR_{it} - TR_{it-1}$;

DT_{it} = user i's departure time on day t, and $\Delta DT_{it} = DT_{it} - DT_{it-1}$; and

$$\delta_{it} = \begin{cases} 0 & \text{if } DT_{it} = DT_{it-1} \\ 1 & \text{otherwise} \end{cases}$$

Four components comprise the indifference band. The first component, the initial band, is dependent on such commuter characteristics as age, gender, and preferred arrival time (PAT) at the workplace. The second, or dynamic, component is a representation of the commuter's cumulative prior experiences. The third, or myopic, component represents the commuter's latest experience with the sensitivity of travel time to changes in departure time. The fourth component is a random term, capturing unobserved and omitted variables, and varying across commuters and decision days.

Table 5.1 lists the estimated values of the indifference band parameters (b_1,.........,b_6) obtained from the Dallas survey data and used in the experiments described here.

Table 5.1 Parameter values for the indifference band model

Parameter	Early	Late
b_1	23.26	17.82
b_2	7.61	4.51
b_3	-5.59	-6.57
b_4	5.49	4.36
b_5	1.16	.78
b_6	4.17	2.98

The second mechanism addresses the computation of a new alternative, once the decision is made to change the current schedule. In the present situation of a two-route corridor, the choice of alternative route, given that the commuter has decided to switch, is trivial. However, a model is required for the computation of a new departure time, once the decision is made to switch. It is for this purpose that the three types of rules mentioned above are used. The individuals who use the "learning" rules represent the population of commuters who consider only their own previous experience on the facility, with no external information, in making a decision for their next trip. The specific learning rules used here are those obtained from a model developed and calibrated from previous research at The University of Texas at Austin (Ref 36). First, an anticipated travel time ETR_{it}, for commuters i on day t, is given by the following expression:

$$ETR_{it} = a1TR_{it-1} + a_2 * TR_{it-2} + s_{it-1} * SFL_{it} + (1 - s_{it-1} * SFE_{it} + e_{it} \quad [6]$$

$$SFL_{it} = (a_3 + a_4 * NFL_{it-1} * SDE_{it-1} \quad [7]$$

$$SFE_{it} = (a_5 + a_6 * NFE_{it-1} * SDL_{it-1} \quad [8]$$

where:

TR_{it-1} = travel time experienced on day t-1
NFL_{it} = number of unacceptable late arrivals experienced by commuter i up to day t-1
NFE_{it} = number of unacceptable early arrivals experienced by the commuter i up to day t-1
SFE_{it} = "safety" factor against being early
SFL_{it} = "safety" factor against being late

$$s_{it-1} = \begin{Bmatrix} 1 & \text{if early} \\ 0 & \text{if late} \end{Bmatrix}$$

$a_1, a_2, a_3, a_4, a_5, a_6$ are estimated parameters.
e_{it} is a random error term (residual).

Given the anticipated trip time, the departure time for the commute on day t is determined so as to allow arrival at the commuters PAT, i.e.,

$$DT_{it} = PAT_i - ETR_{it} \quad [9]$$

The parameters obtained from previously calibrated models that have been used for the experiments are shown in Table 5.2.

Table 5.2 ***Parameter values for the departure time adjustment model***

Parameter	Value
a_1	1.001
a_2	.069
a_3	.031
a_4	.019
a_5	.403
a_6	.571

The second type of users, or "utility maximization" users, consider only the descriptive information provided for traffic conditions on the most recent travel day. Based on this information, all the possible options (e.g., route and departure times) are represented as joint alternatives. A value of the utility is computed for each alternative, and the alternative with the maximum utility is selected for the next trip.

The specific equation to compute the utilities is a modified version of a model proposed by Hendrickson and Planck (Ref 37), and is stated below:

$$V_{ij} = -.021TR_{ij} - .00042\, EARLY_{ij} - .148\, LATE_{ij} + .0014\, LATE_{i\,j}^{2} + \varepsilon_{ij} \quad [10]$$

where:

V_i = measure of utility or "attractiveness" of the trip characteristics for individual i and alternative j;
TR_i = travel time for individual i under alternative j;
$EARLY_i$ = the early schedule delay for individual i under alternative j;
$LATE_i$ = the late schedule delay for individual i under alternative j; and
ε_i = stochastic error term.

Note that all users are assigned the same parameter values.

The third type of users, or the "system optimal" users, are simply assigned a specific departure time and route. As discussed earlier, these assignments are computed through a process that optimizes a system-wide objective function, in this case the total utility (the individual utilities are given by Equation 10). Since the current set of experiments simulate operations under both normal and disrupted (lane closure) conditions, two sets of "system optimal" assignments are required (a system optimal assignment for normal operations is not likely to be optimal during disrupted conditions). A new system optimal allocation is computed for the disruption period. Consequently, those vehicles using "system optimal" rules are assigned new "optimal" departure times and routes during this period. A point to be noted in the context of the system optimal computations is that the maximization of the total system utility will tend to be associated with a large fraction of "satisfied" users in the context of the bounded rationality approach discussed above. For instance, the smaller the schedule delay, the higher the utility is expected to be. A small schedule delay corresponds to an actual arrival time that is close to the preferred arrival time (PAT), so there is a higher likelihood of a commuter arriving within his/her indifference band and, therefore, being satisfied with his/her trip schedule.

The effectiveness of the strategies is expected to be sensitive to the relative fraction of the different user-behavior types. A set of six experiments with different relative fractions of the three types of behavior in the commuting population (Table 5.3) was conducted and is described below:

Table 5.3 Behavioral type fractions for the six experiments

Exp:	"Learning"	"Utility Maximization"	"System Optimal"
1	.50	.50	.00
2	.33	.33	.34
3	.17	.17	.66
4	0.00	0.00	1.00
5	0.00	1.00	0.00
6	1.00	0.00	0.00

Entrance Control Strategy

The traffic-responsive ramp metering technique used to prevent congestion is based on a simple strategy that modifies the ramp rate in response to the value of an index T_d that is representative of traffic conditions at and around the vicinity of the ramp under consideration. This index is computed through an appropriate weighting technique that considers all the traffic density values within the vicinity of the entrance ramp. Noting with no loss of generality, that one detector and one entrance ramp are associated with each sector, the expression for T_d is given by:

$$T_d^{\,i} = w^{1i} * PD^1 + \cdots w^{ji} * PD^j + \cdots w^{Ni} * PD^N \qquad [11]$$

where:

PD^j= information (e.g., average traffic density) from detector j;
w^{ji}= the weight of sector j information on sector i; and
N= the total number of sectors.

The values of the weights w^{ji} are given by the following expressions:

For i < j: $$F^{ji} = \left(1 - \frac{j-i}{N+1}\right)\exp\left(e_u^i\right) \qquad [12]$$

$$w^{ji} = w_u^i * \frac{F^{ji}}{\sum_j F^{ji}} \qquad [13]$$

for i > j: $$F^{ji} = \left(1 - \frac{i-j}{N+1}\right)\exp\left(e_d^i\right) \qquad [14]$$

$$w^{ji} = w_d^i * \frac{F^{ji}}{\sum_j F^{ji}} \qquad [15]$$

for i = j: $$w^{ii} = 1 - \left(w_u^i + w_d^i\right)$$

$$w_u^i \le 1, w_d^i \le 1, w_u^i + w_d^i \le 1$$

The model has four parameters, denoted by w_u, w_d, e_u and e_d. The first two are involved in the computation of T_d; w_u and w_d represent the total weights allocated to traffic density values from all detectors located upstream and downstream of the entrance ramp under consideration, respectively. For example, a value of 0.25 for w_u and w_d indicates all upstream and downstream values of traffic density contribute to 25 percent of the value of T_d. The remaining 50 percent of T_d is through contributions from the detector placed in the sector that contains the entrance ramp under consideration (recall that one detector and one entrance ramp are associated with every sector). The other two parameters, e_u and e_d, are (exponential) factors that dictate the relative weights provided among all upstream and downstream sectors, respectively. A high positive value of e_u (e.g., 10) indicates that values associated with detectors that are closer to the entrance ramp under consideration contribute more than detectors further away. A value of zero for these parameters indicates that no distinctions are made between detectors, and all detectors contribute equally.

The expression to compute the new ramp rate is as follows:

$$R_{in}^i = RMAX, \text{ for } T_d^{\,i} < a \qquad [16]$$

$$R_{in}^i = \max\left\{\left[f_c\left(T_d^i\right)\right], RMIN\right\}, \text{ for } T_d^{\,i} > a \qquad [17]$$

$$f_c\left(T_d^i\right) = a' + b'T_d^i + c'\left(T_d^i\right)^2 \qquad [18]$$

where:

$$a' = RMAX - a\left[b + \frac{c}{2}\left[\frac{RMAX}{b} - a\right]\right] \qquad [19]$$

$$b' = b + \frac{c}{2}\left[\frac{RMAX}{b} - a\right] \qquad [20]$$

$$c' = \frac{c}{2} \qquad [21]$$

Figure 5.1 is an illustration of the strategy. The five sector-specific parameters displayed, namely, RMAX, RMIN, a, b, and c are required for the computation of a new ramp rate. RMAX represents the maximum ramp rate that is allowable into the sector from the entrance ramp, at any time. RMIN represents the minimum ramp rate required at an entrance ramp at any time. Parameter a is a critical quantity that represents the value of T_d below which ramp metering is not operational (the ramp rate remains at its maximum). If the value of

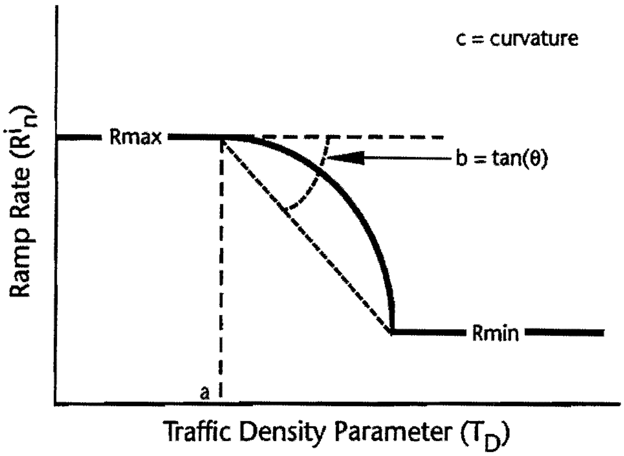


Figure 5.1 Traffic responsive ramp metering strategy

T_d exceeds a, the ramp rate is modified as a function of T_d. Parameters b and c dictate the functional form of the relationship between the desired rate and T_d. Parameter b is expected to be negative. Larger values of b will reduce the ramp rate more rapidly for relatively small increases of T_d above a. Parameter c governs the manner in which this change in ramp rate is made. A positive value of c indicates a convex relationship between the ramp rate and T_d, whereas a value of 0 for c indicates a constant rate of change of ramp rate with T_d. Each of the discussed parameters are sector-specific. Tables 5.4 and 5.5 display the ramp metering parameters used for the simulation experiments of both normal operations and operations that are disrupted. It should be noted that the only changes made during the lane closure period are for the values of a on the second route. The lower values of a (as compared with normal operations) indicate that ramp metering would become operational "earlier" at a lower value of T_d. These differences among the different sector values of a are based on judgment. As the results indicate, the selected parameters are not efficient for operations during the lane closure. A large base of numerical experiments and actual observation will be necessary in order to obtain more specific guidelines on this matter.

Initial Demand Pattern

The initial demand distribution for the first day was selected arbitrarily, though within the boundaries of realism and plausibility. Note that while the "utility maximization" and "learning rules" users follow this initial demand pattern, the "system optimal" users will follow the system optimal demand pattern, which remains constant until the beginning of the disruption (day 16). From the beginning of the disruption period, they follow a new system optimal distribution which remains constant until the end of simulation (day 30). The initial demand pattern and the system optimal demand pattern are shown in Figure 5.2.

DISCUSSION OF RESULTS

Three figures of merit were recorded from the simulation for the evaluation of the system performance:

(1) travel times;
(2) utilities; and
(3) number (or fractions) of unsatisfied commuters.

Table 5.4 Ramp metering parameter values for normal operation conditions (both routes)

Sector	RMAX	RMIN	a	b	c	W_d	W_u	e_d	e_u
1	30	0	25	-5	-.005	.25	.25	6	6
2	30	0	25	-5	-.005	.25	.25	6	6
3	30	0	25	-5	-.005	.25	.25	6	6
4	30	0	25	-5	-.005	.25	.25	6	6
5	30	0	25	-5	-.005	.25	.25	6	6
6	30	0	25	-5	-.005	.25	.25	6	6

Table 5.5 Ramp metering parameter values for lane closure conditions (route 2 alone)

Sector	RMAX	RMIN	a	b	c	W_d	W_u	e_d	e_u
1	30	0	10	-5	-.005	.25	.25	6	6
2	30	0	10	-5	-.005	.25	.25	6	6
3	30	0	15	-5	-.005	.25	.25	6	6
4	30	0	15	-5	-.005	.25	.25	6	6
5	30	0	20	-5	-.005	.25	.25	6	6
6	30	0	20	-5	-.005	.25	.25	6	6

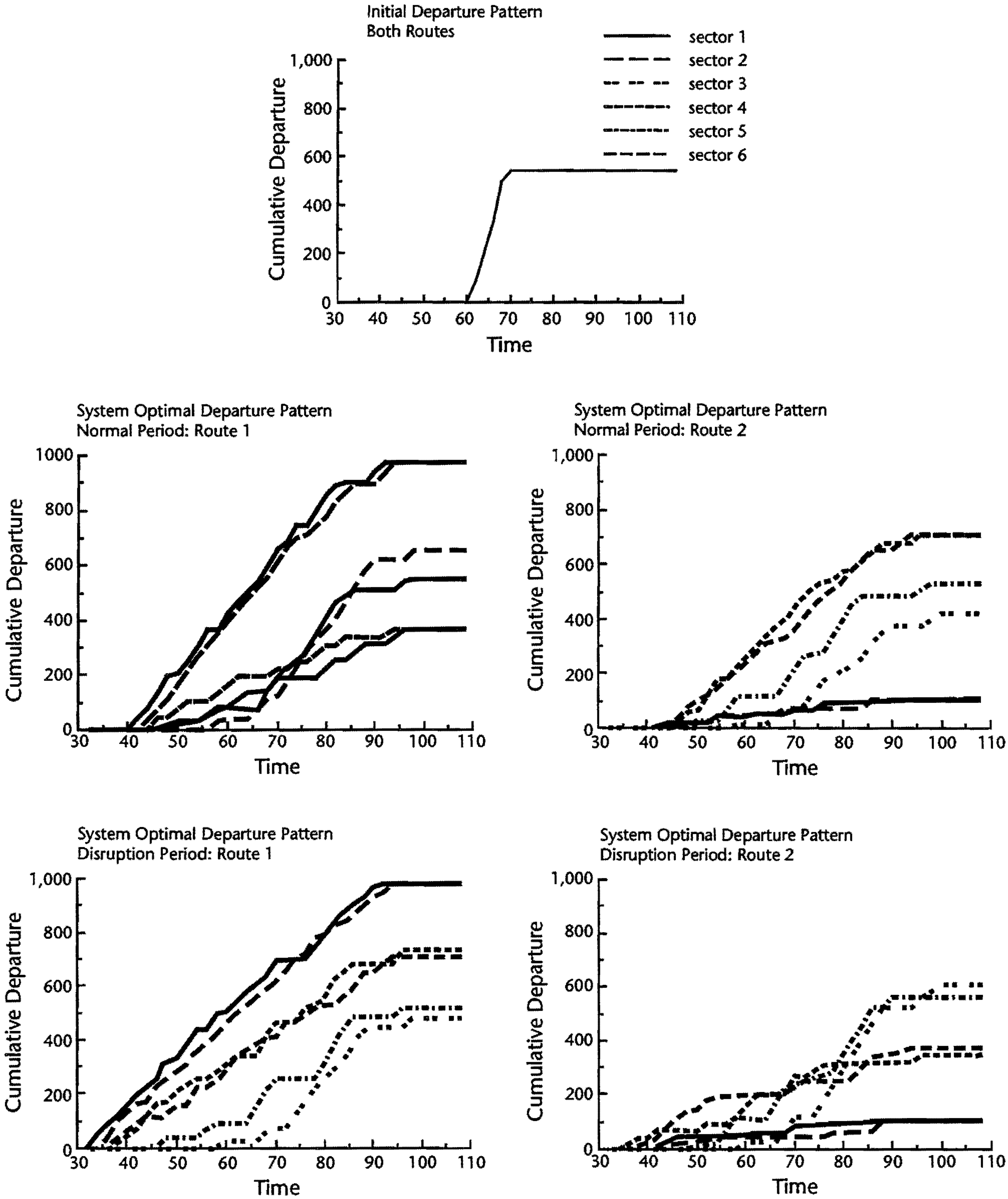


Figure 5.2 Initial and system optimal departure time patterns

The evolution of the averages of the above quantities (for all three types of users combined) were plotted over 30 days. In addition, sector-based average values for each type of user for all 30 days were plotted.

Figures 5.3a and 5.3b illustrate the evolution of the average travel times on routes 1 and 2, respectively. Two series of plots are associated with each experiment. Plots "a" represent a situation under no entrance control, while "b" represent the situation when the traffic-responsive ramp metering strategy was operational. An abrupt "peaking" of the average travel time is observed on freeway 2 in most of the plots, on day 16. This is due to the lane closure. In actual systems, some commuters may be aware of upcoming changes in supply conditions through the extensive planning involved. Appropriate precautionary actions taken by commuters with this knowledge may result in a smoother transition from the "normal" to the "disruption" period. However, this is not represented in the simulation. Users are therefore reacting to the lane closure as if without any previous warning of its occurrence.

Note that experiments 2, 3, and 4 of Figure 5.3 have increasing percentages of "system optimal" users. Also, experiments 1, 5, and 6 of Figure 5.3 have no "system optimal" users. The advantages of ramp metering, as observed through the evolution and final values of the average travel time, are evident during normal operating conditions (day 1-15) in situations with no or low "system optimal" users. As the percentage of "system optimal" users increases, there is less need to provide for real-time control, since the system performance without control by itself tends to become more efficient. Thus, ramp metering may only provide unnecessary restrictions and worsen system performance. This is evident from the results of experiment 4 of Figure 5.3. Without entrance control (Figure 5.3a) this experiment represents a situation where all vehicles comply with the system optimal instructions provided to them. Since congestion prevention is implicit in a system optimal solution, there is no need for additional control. Control through ramp metering adds unnecessary restrictions at the entrances to the freeway, thereby increasing the average travel times (experiment 4 of Figure 5.3b).

The evolution of the travel times during the disruption period, i.e., from day 16 to day 30, with and without the entrance control strategy, illustrates the importance of the selection of appropriate ramp metering parameters. As mentioned earlier, the selection of these parameters for implementation during the lane closure period on freeway 2 was somewhat arbitrary. They could not prevent congestion from occurring on freeway 2.

The occurrence of congestion, together with the additional restrictions contributed by the inefficient ramp metering strategy, caused a considerable worsening of the system performance — worse than what would have occurred without any entrance control. An interesting observation is made regarding the average travel times during the disruption in experiments consisting of "utility maximization" and/or "learning rules" users alone (1, 5, and 6 of Figure 5.3). During the period of the lane closure, operations become highly inefficient when the population consists of either the "utility maximization" or "learning rules" users alone (experiment 5 and 6 of Figure 5.3, respectively). This is indicated by the significantly higher average travel times on freeway 2, both with and without the entrance control. However, the operation is considerably more efficient when the population is composed of an equal number of the above two user classes, as indicated by the significantly lower travel times on freeway 2 in experiment 1 (as compared with 5 and 6 of Figure 5.3). This suggests that the presence of users of different behavioral types in the population is helpful in the prevention of possible extremes of adverse system performance.

Figure 5.4 displays the sector-based average values of the travel time for each of the three types of users. There is a significant difference in the patterns obtained with and without the entrance control strategy. Without entrance control, the average travel times generally follow a decreasing trend as we move away from the destination. This is not the case when the entrance control strategy is implemented. Since all demand travels to sector 7 with no users exiting in between, the average level of traffic density in each sector is expected to increase with proximity to the destination. The closer sectors are prime candidates for the occurrence of congestion. In an attempt to prevent congestion from occurring in these sectors, the strategy assigns a low entrance rate, thereby reducing the number of vehicles entering the sector from the ramps (since it has no control over the vehicles already in the sector). The higher average travel times observed in the closer sectors (experiment 6 of Figure 5.4b) are due to the additional queue times experienced at the entrances to these sectors because of the reduced ramp rates. In compensation, vehicles already on the facility experience efficient operations and consequently lower travel times. Thus, it can be seen that the strategy prioritizes traffic based on the distance to potential bottlenecks, i.e., users originating further away from the potential bottleneck sectors obtain the maximum benefits from this strategy. On the other hand, this strategy is likely to discourage short-trip travelers from using the freeway.

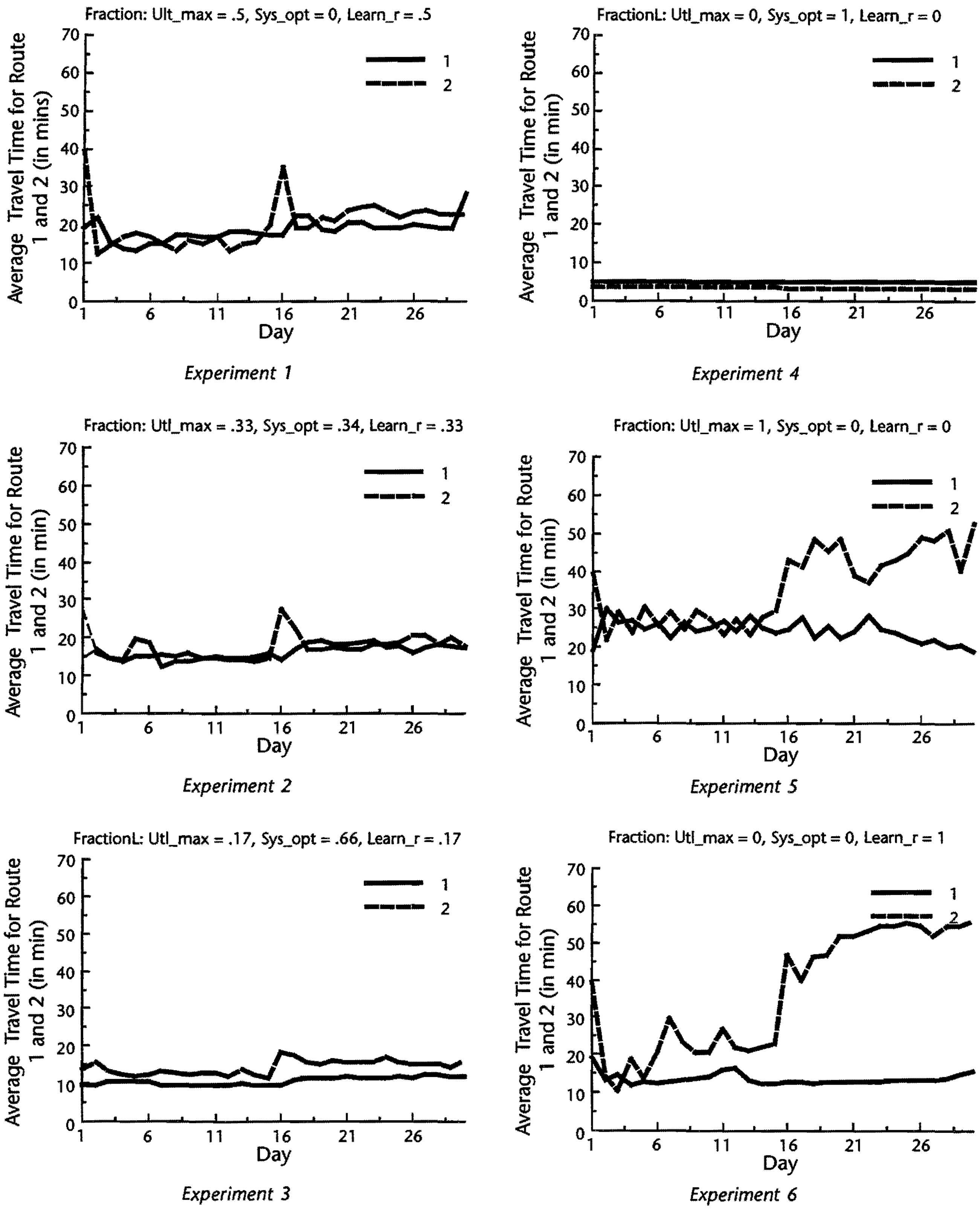
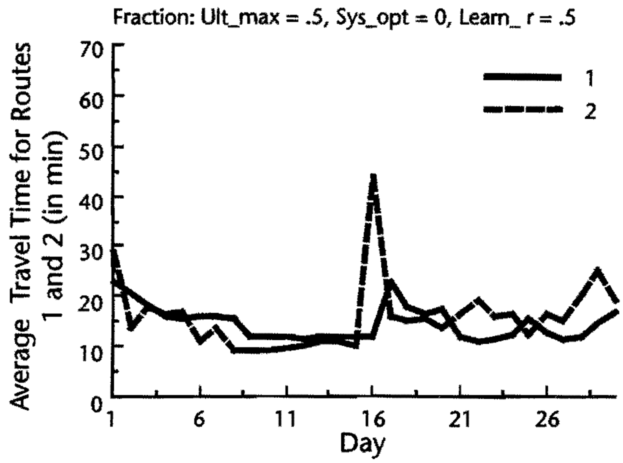
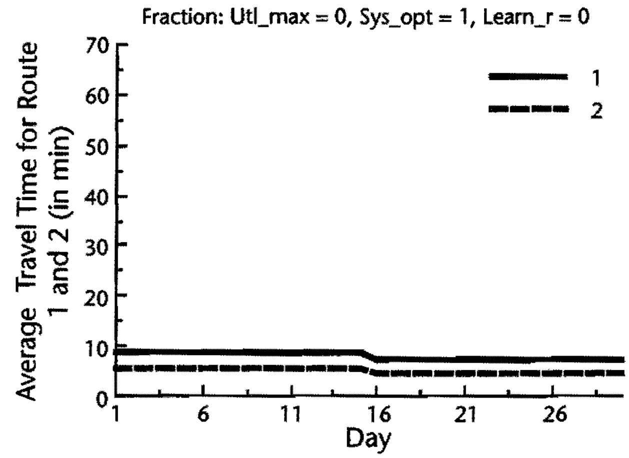


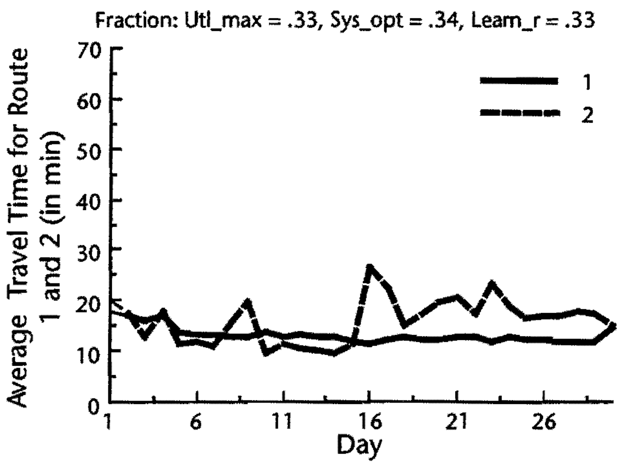
Figure 5.3a Evolution of the average travel time: no entrance control



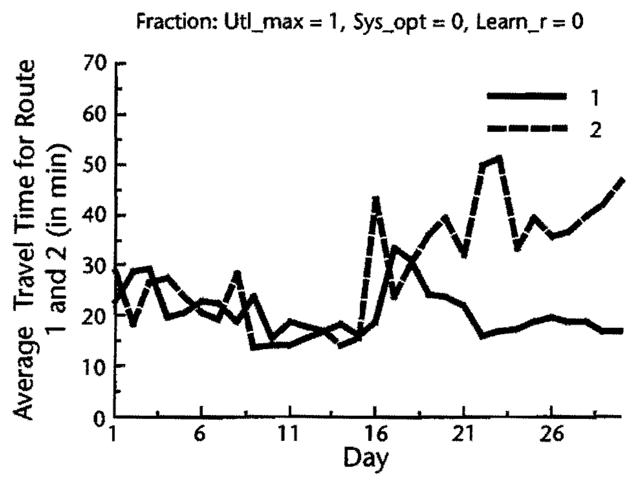
Experiment 1



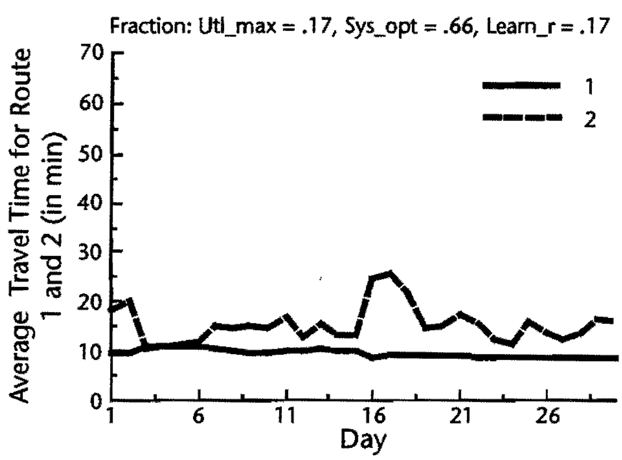
Experiment 4



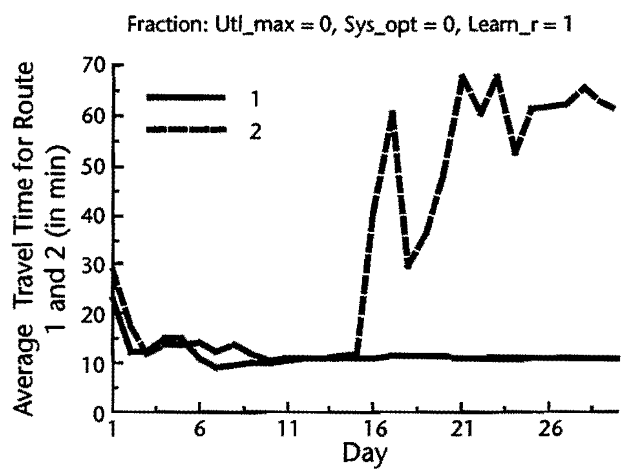
Experiment 2



Experiment 5



Experiment 3



Experiment 6

Figure 5.3b Evolution of the average travel time: with ramp metering

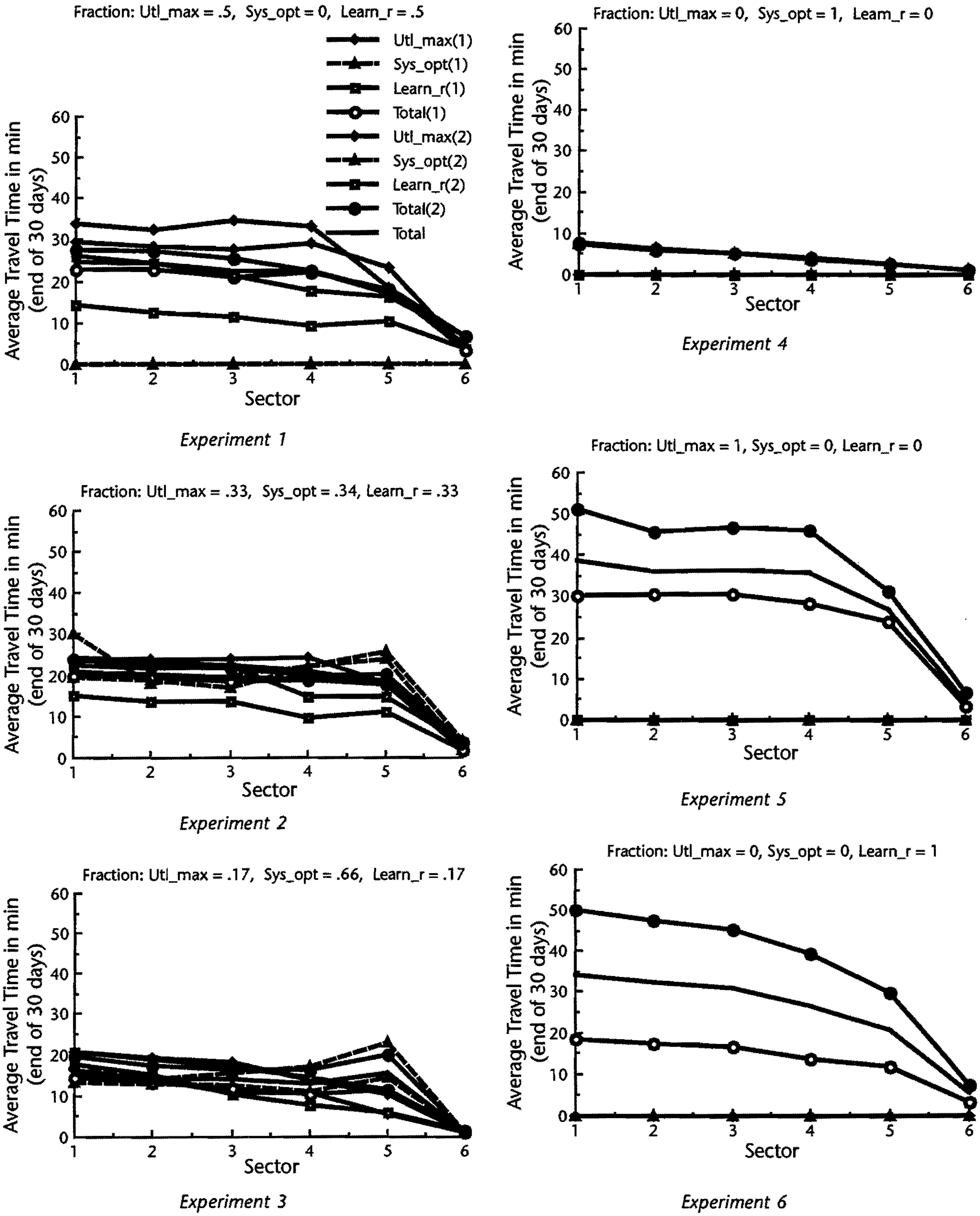


Figure 5.4a Average sector-based travel times: no entrance control

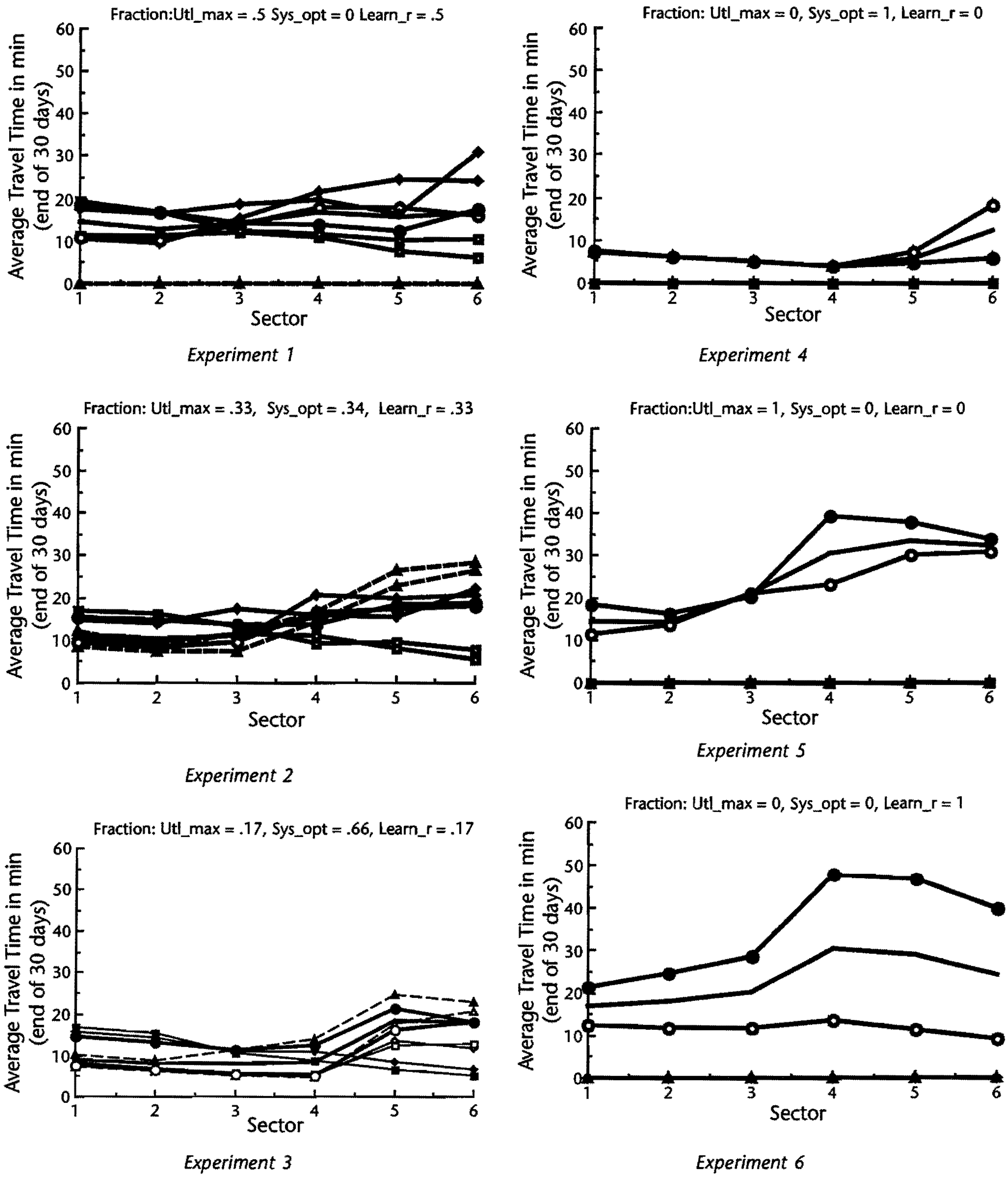


Figure 5.4b Average sector-based travel times: with ramp metering

It is also observed that the "system optimal" users are the most severely affected in any adverse situation with or without entrance control, as indicated by their high average travel times in sectors 5 and 6 (experiments 2 and 3 of Figure 5.4). On the other hand, users with "learning rules" achieve the lowest travel times among the three types of vehicles. This observation may suggest that the supplied information of the type considered in the experiments may not be effective. However, it is extremely important to realize that the supplied information is only a priori "system optimal" in that it is not adjusted in real-time to reflect current conditions, nor is it updated on a daily basis to respond to evolving conditions. Note that there is a significant difference between the average travel time values for the two routes in experiments 5 and 6 of Figure 5.4. Freeway 2 has a significantly higher travel time, mainly because of the lane closure from day 16 to day 30.

Figure 5.5 illustrates the evolution of the total fraction of users who are not satisfied with their departure and/or route. The observations made earlier regarding the average travel times are mostly applicable here as well. Ramp metering seems to be more effective in the situations with a low (or no) fraction of system optimal users, as indicated by the difference in the convergence of the curves "a" and "b" until day 15 in experiments 1, 5, and 6 of Figure 5.5. It should be noted that the convergence occurs as users find alternatives that allow them to arrive within their indifference bands, and that the indifference bands themselves increase with the increase in the number of "failures." In other words, the user may continue to "fail" until his/her band becomes large enough to accommodate the arrival. As discussed previously, ramp metering is expected to reduce the number of unsatisfied commuters more rapidly than one without entrance control, because of its ability to reduce the variability in travel times from day to day. This is confirmed in both experiments 5 and 6 of Figure 5.5, consisting respectively of "utility maximization" users only (experiment 5) and "learning rules" users only (experiment 6). The experiments clearly indicate that ramp metering provides a more rapid reduction in the number of unsatisfied commuters until day 15, i.e., prior to the disruption.

Experiment 4 of Figure 5.5a is the result of a system optimal allocation and illustrates the most attractive configuration with the least number of failures. Note that this assignment was obtained through the optimization of an objective function that maximized the utility, as defined previously. It was also noted previously that this optimization would also result in a relatively low fraction of unsatisfied users. The results of experiment 4 of Figure 5.5a clearly support this assertion. As expected, the fraction of unsatisfied users increases considerably at the beginning of the lane closure on freeway 2. The situation is not mitigated by the entrance control strategy and the fraction of unsatisfied users continues to remain high until the end of the simulation period. Observe that in some cases (experiments 1 and 4 of Figure 5.5), though freeway 1 is not affected directly by the disruption, the fraction of unsatisfied users increases during the initial stages of the disruption period, because of the significant number of route switches made by unsatisfied users of freeway 2.

Figure 5.6 displays the sector-based average number of failures for each of the three types of users. The trends discussed in connection with the average travel times are mostly applicable here as well. Implementation of the ramp metering strategy reduces the average number of failures in distant sectors and increases the same for the near sectors. Also apparent is the higher average number of failures for the "system optimal" users and the lower average number of failures for the "learning rules" users.

Figure 5.7 illustrates the evolution of the average utilities as computed through Equation 10. These trends are similar to those exhibited by the average travel time and the average number of failures. This is not surprising, since the travel times and the schedule delays (which are indirectly reflected in the number of failures) form the main components of the utility. A distinct improvement can be seen in the evolution of the average utilities until day 16 through the implementation of ramp metering for situations of low or no "system optimal" users (experiments 1, 5, and 6 of Figure 5.7). Plot 4 of Figure 5.7a represents the system optimal utilities, or the highest utilities that can be attained, since the "system optimal" assignments are generated through the maximization of the total systemwide utility. It is particularly interesting to note that the best values of the average travel time and the fraction of unsatisfied users are also attained as a consequence of the optimization of the utilities (experiment 4 of Figures 5.3a, 5.4a, 5.5a, and 5.6a), suggesting that these measures of effectiveness are strongly correlated. As expected, the average utilities decrease considerably after the onset of the disruption and the inefficient ramp metering parameters worsen the situation.

Figure 5.8 displays the sector-based average utilities for each of the three types of users. Trends similar to those described previously with respect to the average travel times and number of failures are exhibited here.

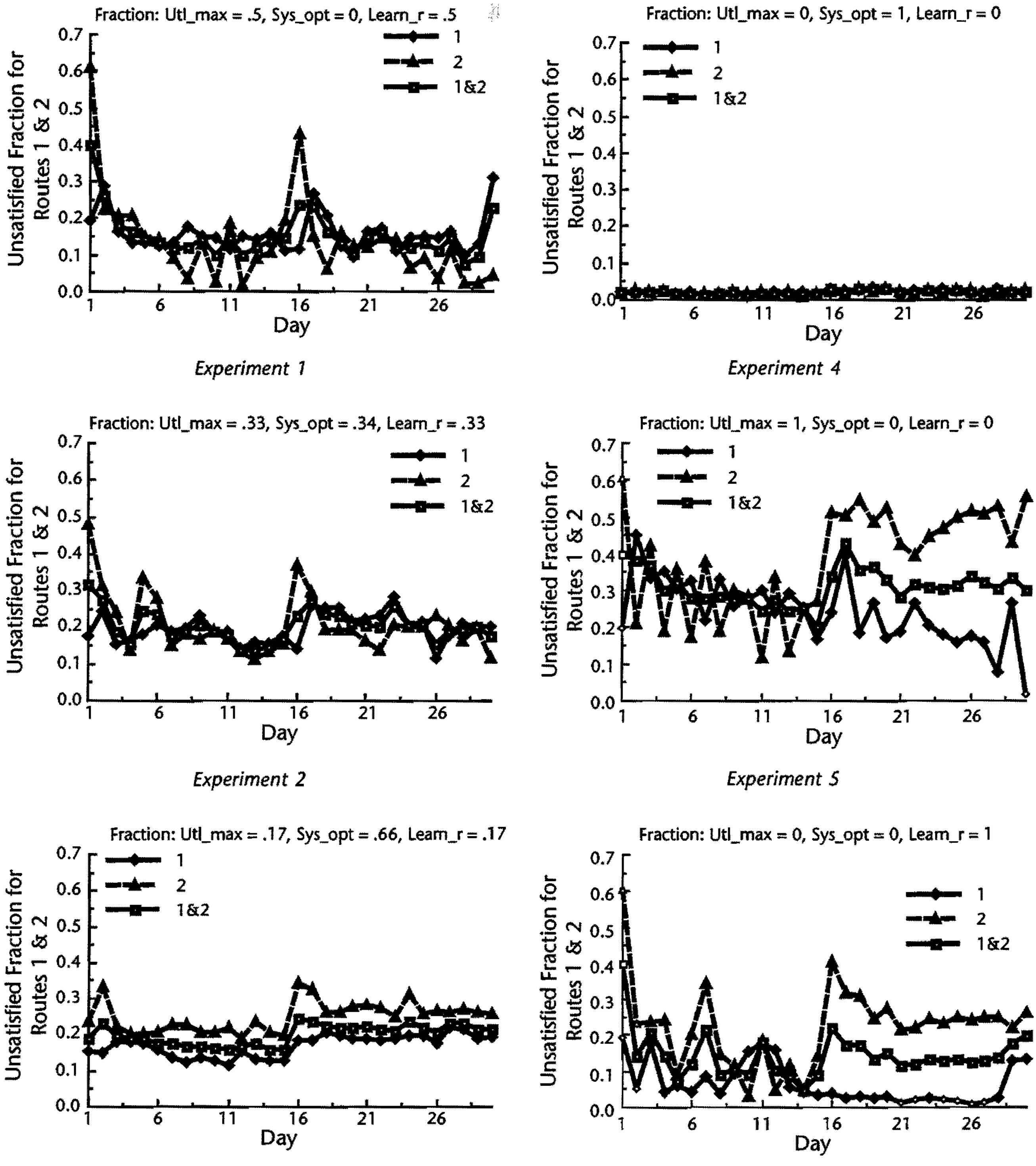
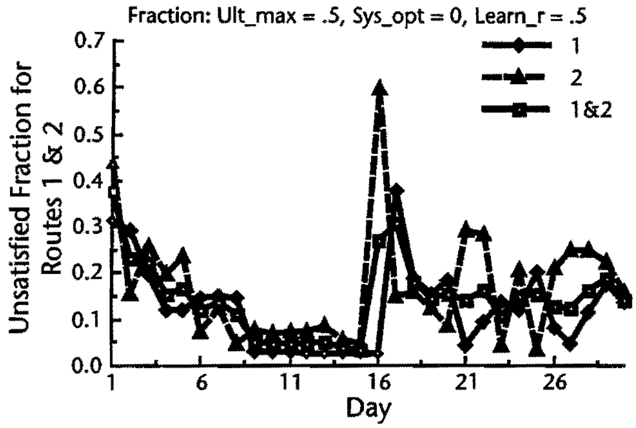
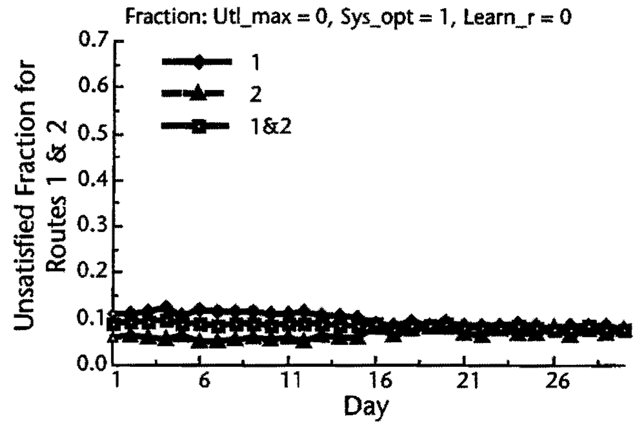


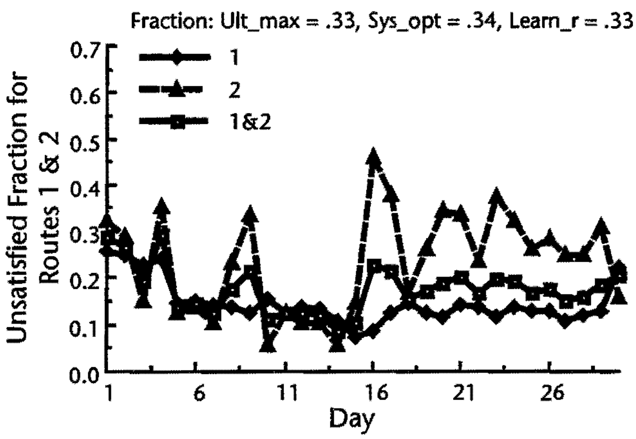
Figure 5.5a Evolution of the fraction of unsatisfied users: no entrance control



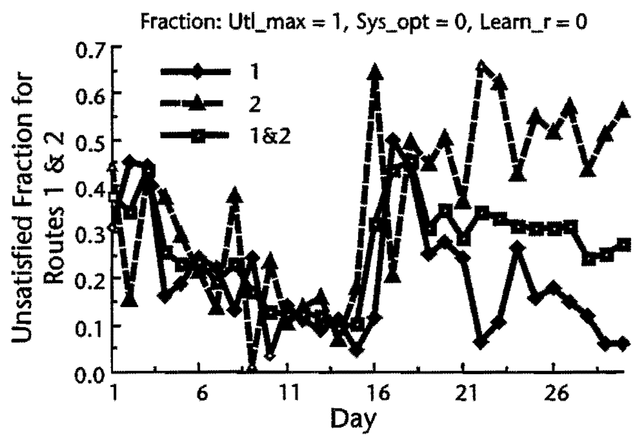
Experiment 1



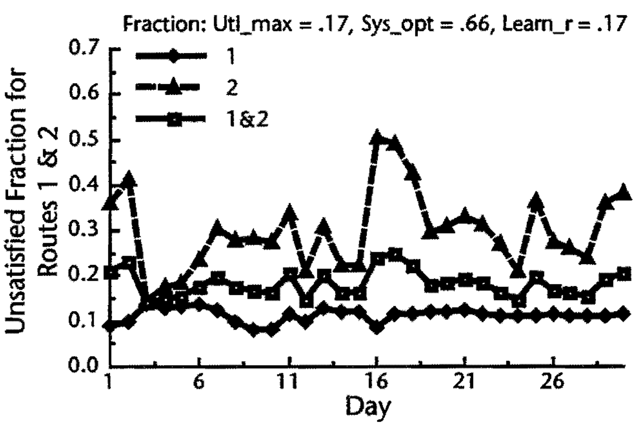
Experiment 4



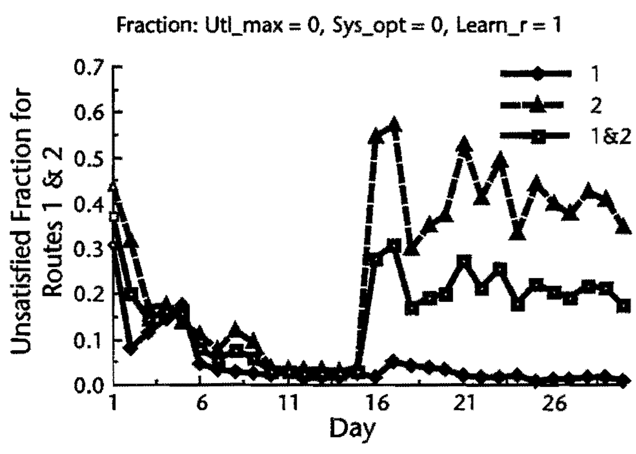
Experiment 2



Experiment 5



Experiment 3



Experiment 6

Figure 5.5b Evolution of the fraction of unsatisfied users: with ramp metering

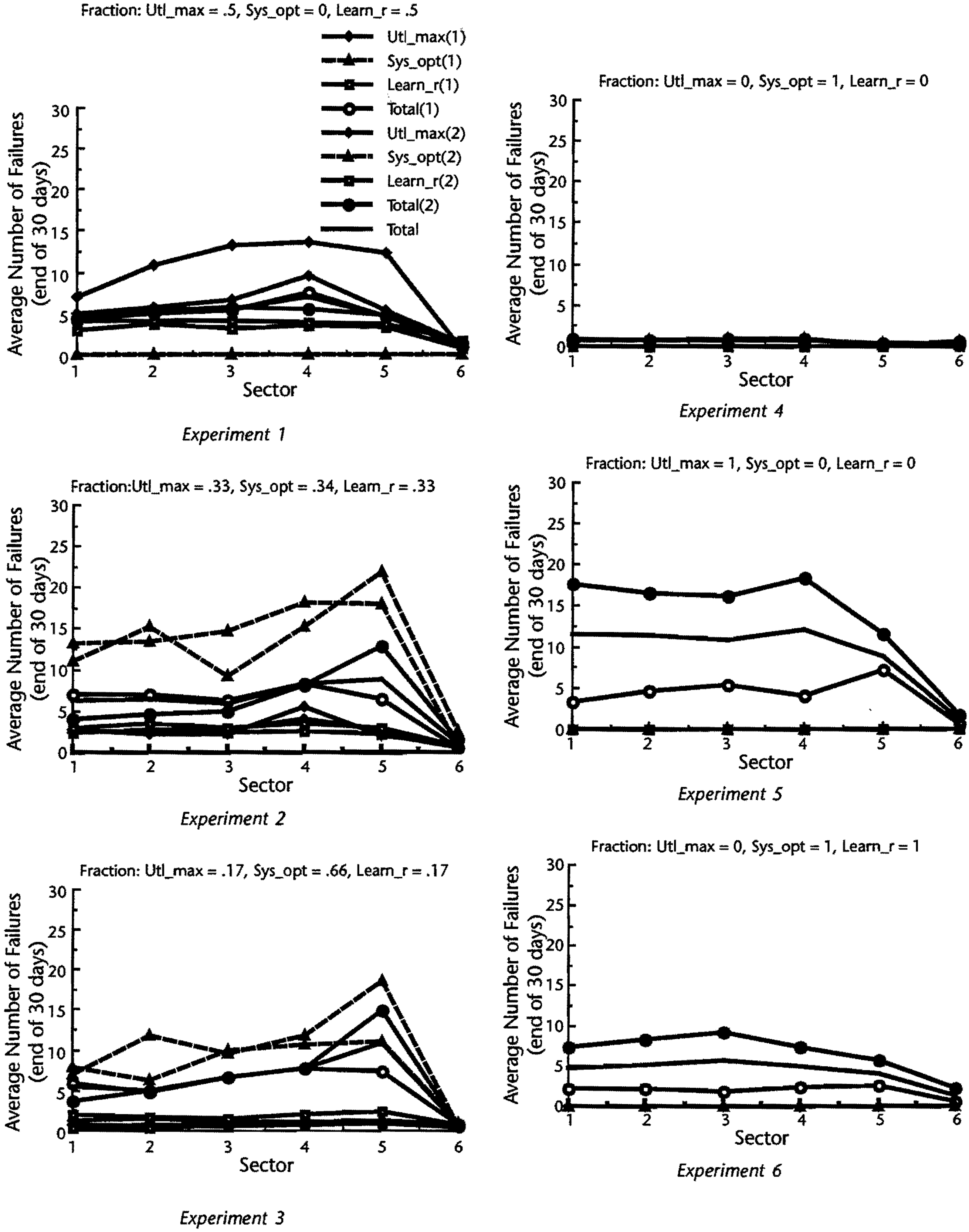


Figure 5.6a Average sector-based number of failures: no entrance control

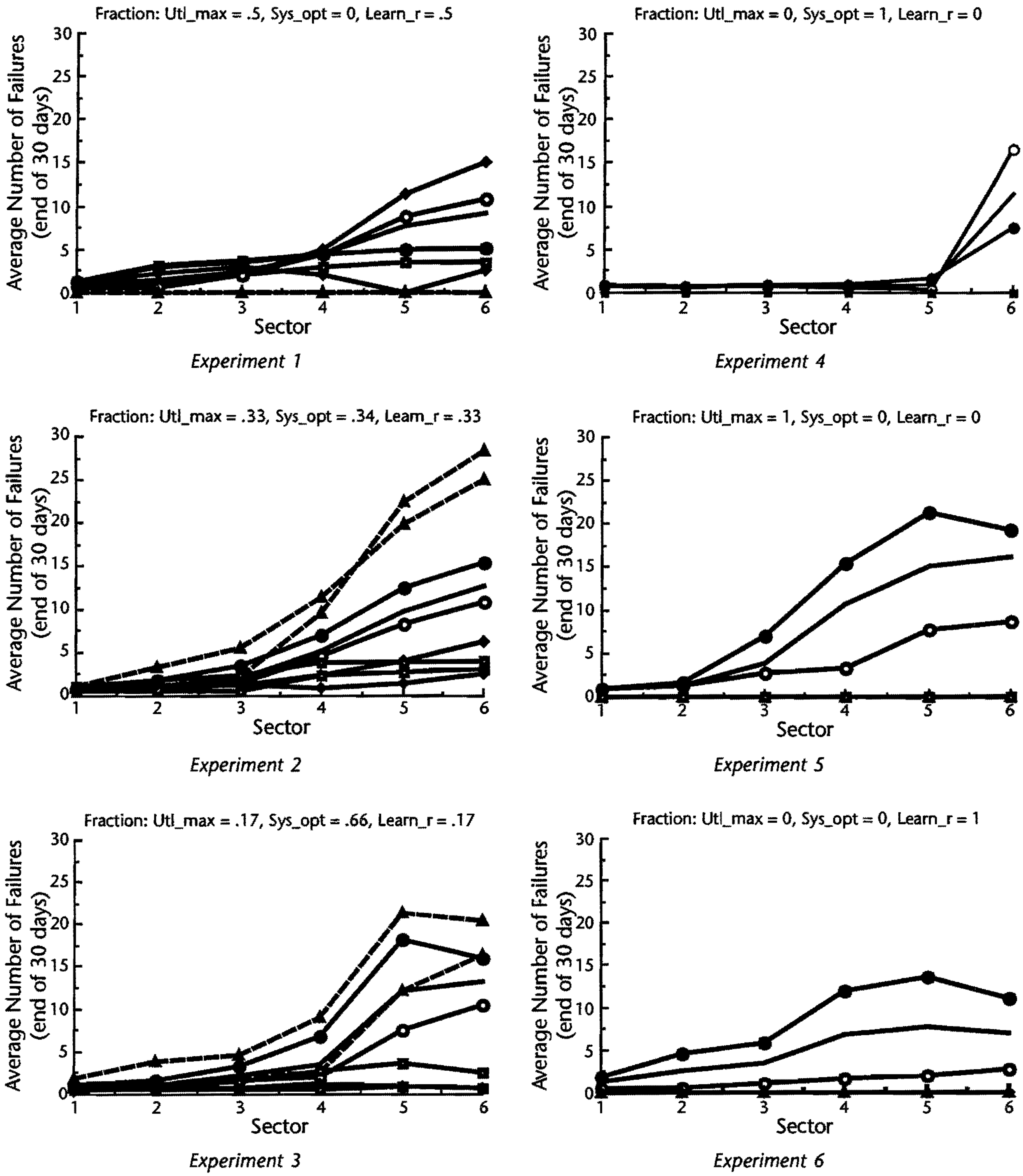
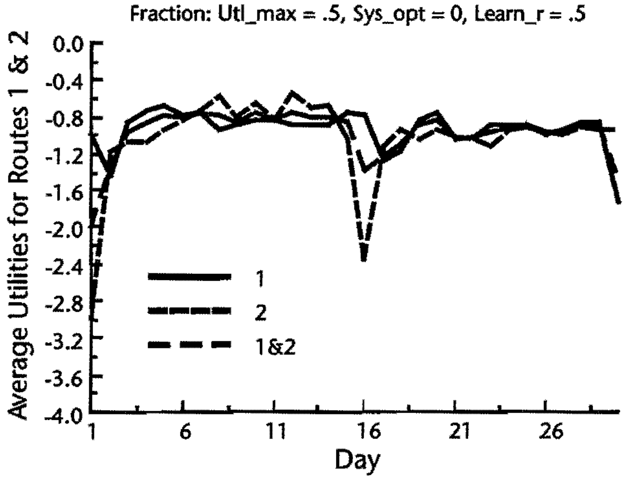
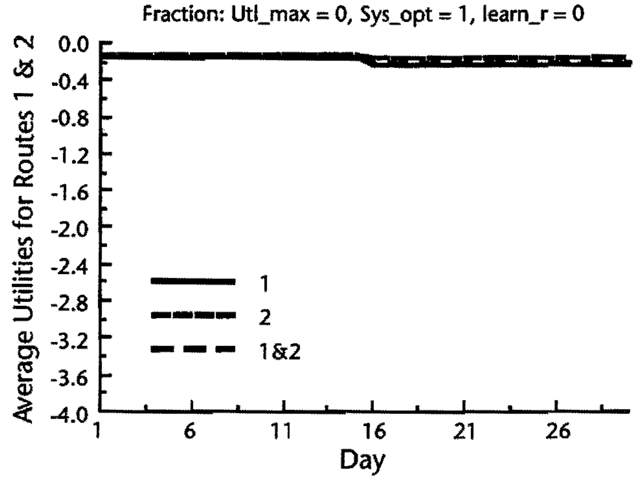


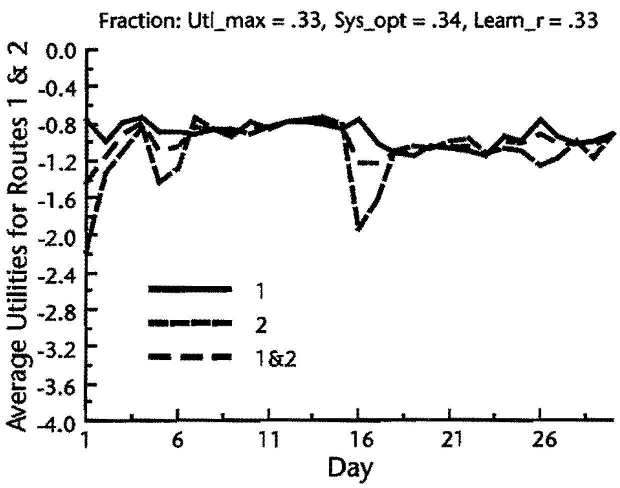
Figure 5.6b Average sector-based number of failures: with ramp metering



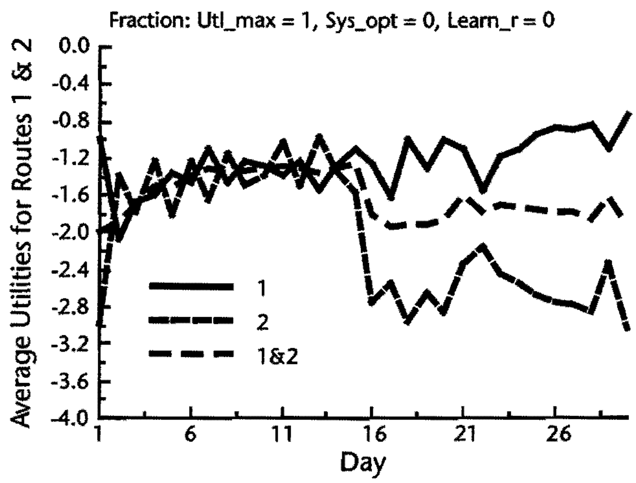
Experiment 1



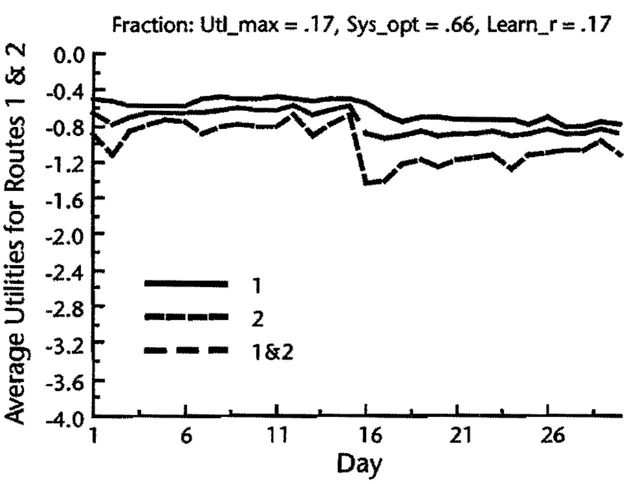
Experiment 4



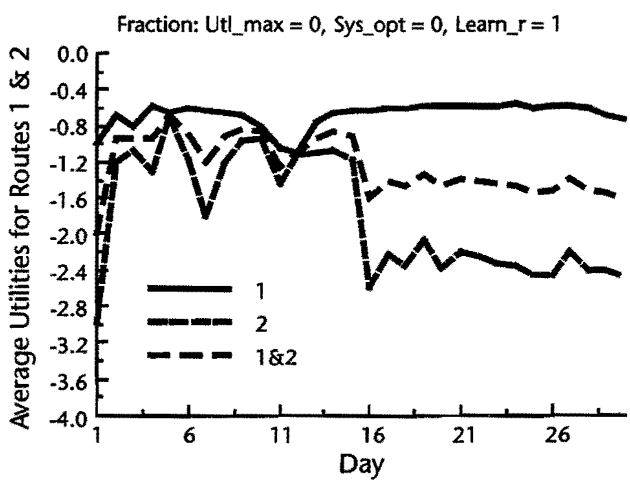
Experiment 2



Experiment 5

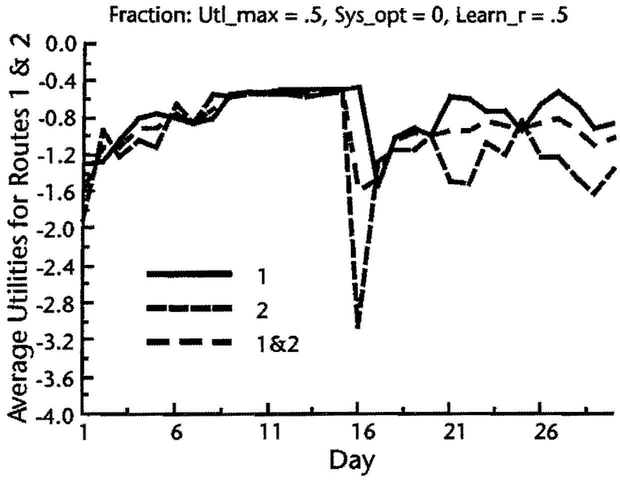


Experiment 3

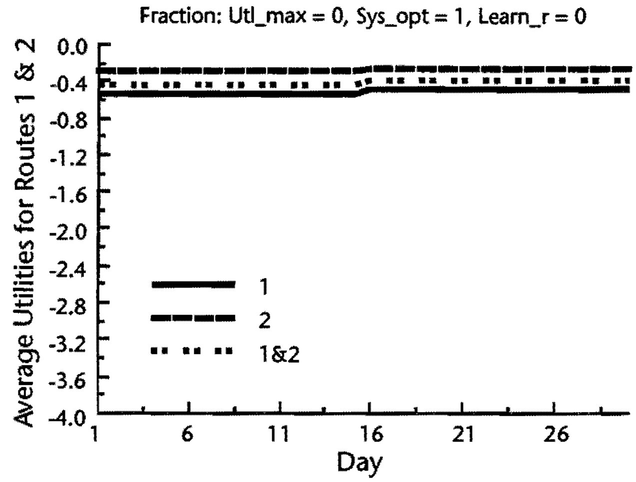


Experiment 6

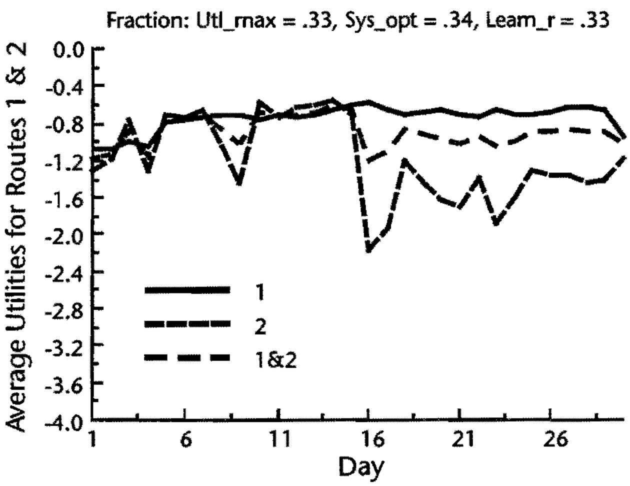
Figure 5.7a ***Evolution of the average utilities: no entrance control***



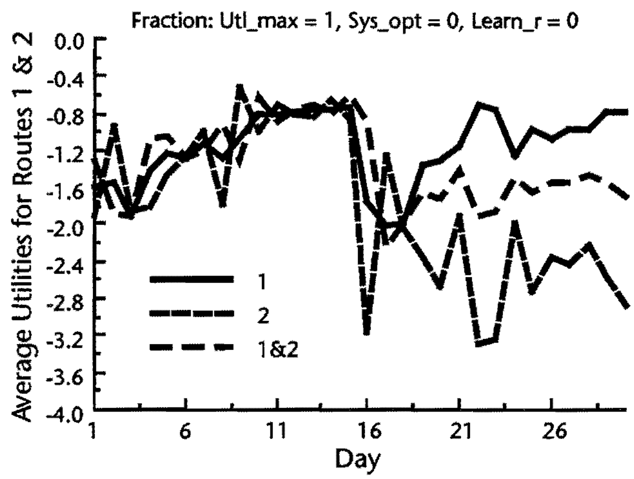
Experiment 1



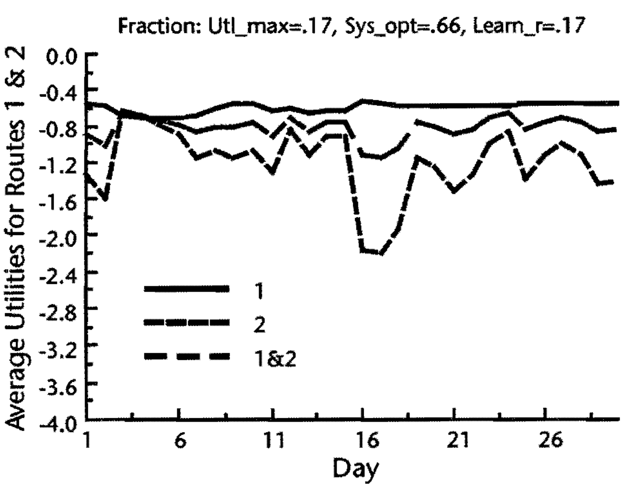
Experiment 4



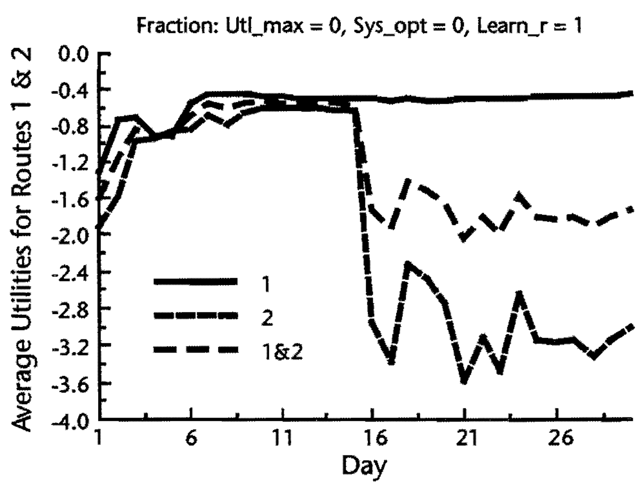
Experiment 2



Experiment 5

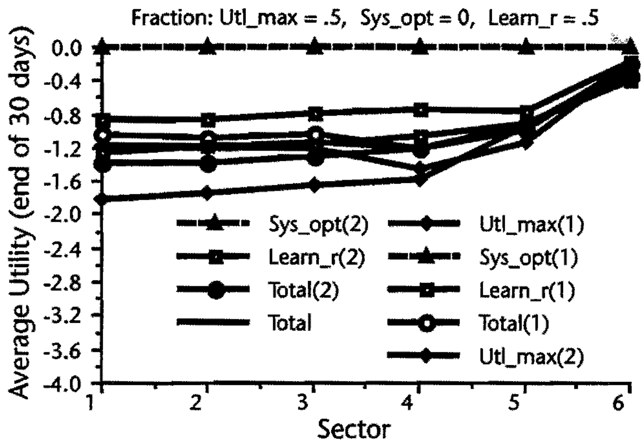


Experiment 3

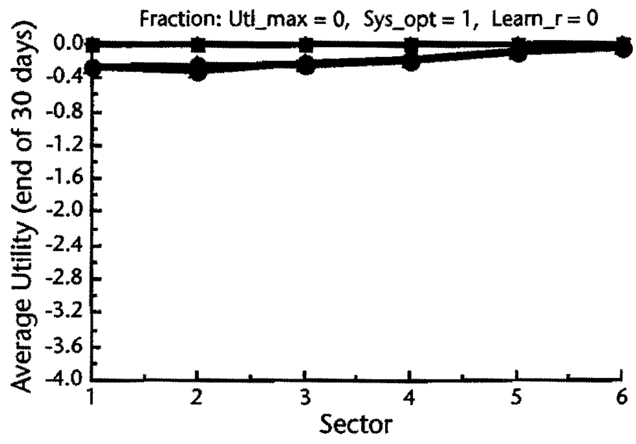


Experiment 6

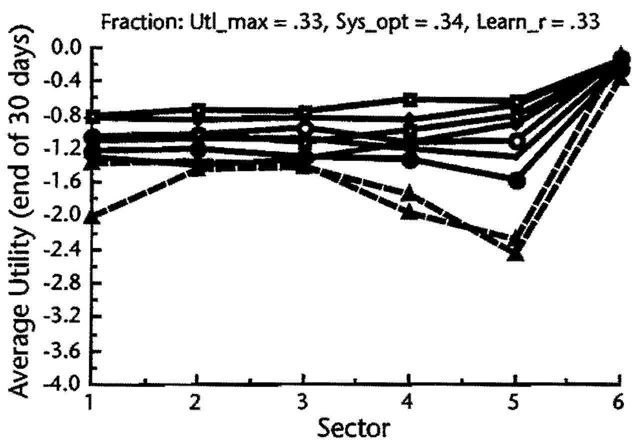
Figure 5.7b Evolution of the average utilities: with ramp metering



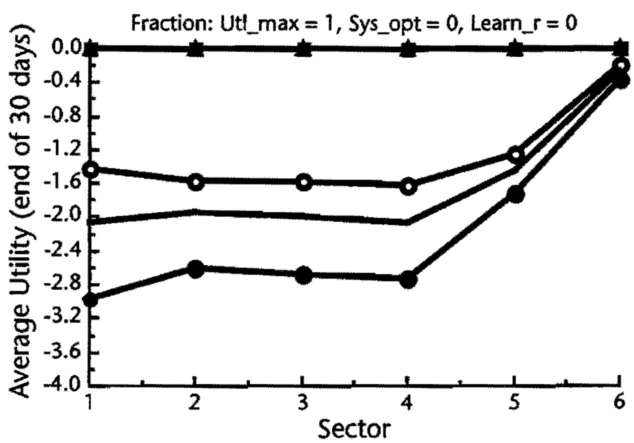
Experiment 1



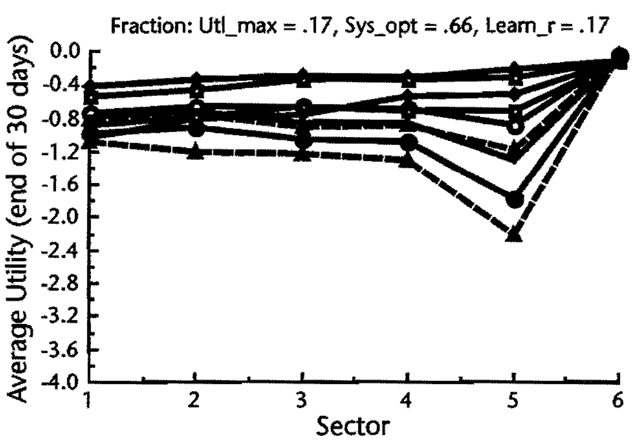
Experiment 4



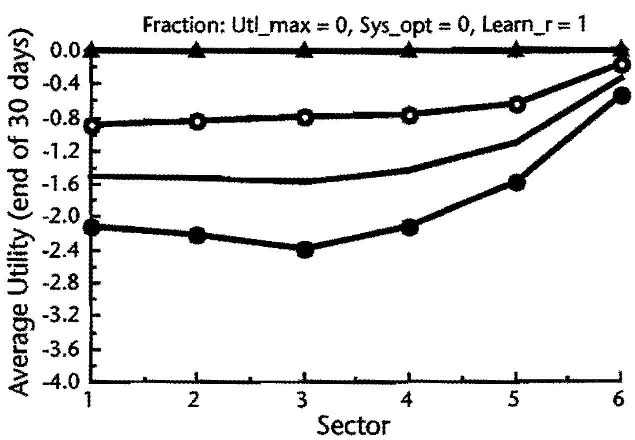
Experiment 2



Experiment 5

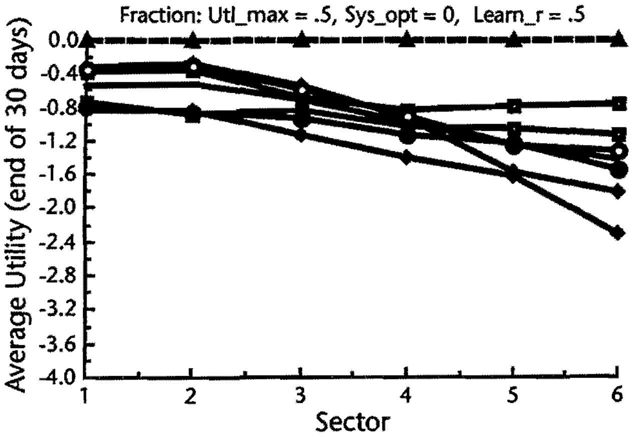


Experiment 3

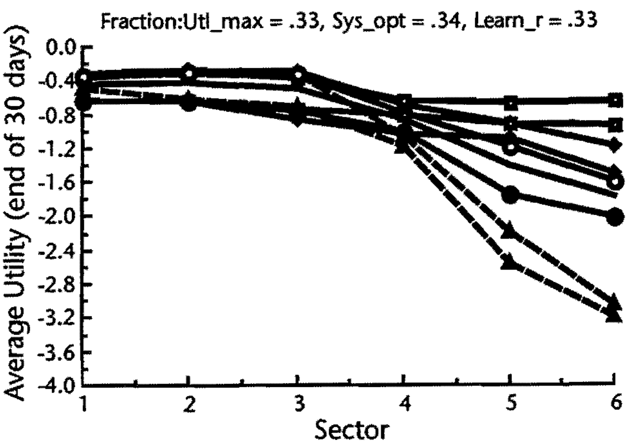


Experiment 6

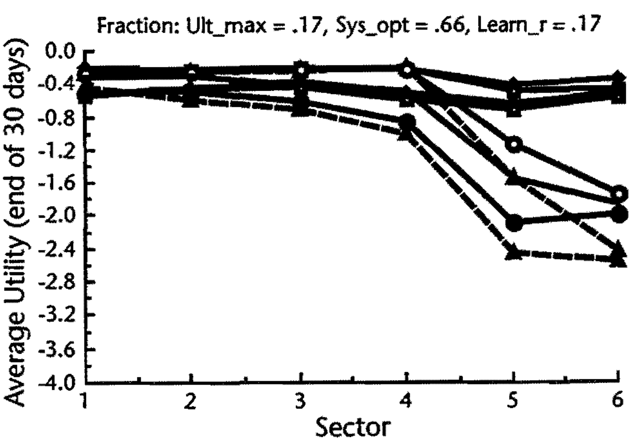
Figure 5.8a Average sector-based utilities: no entrance control



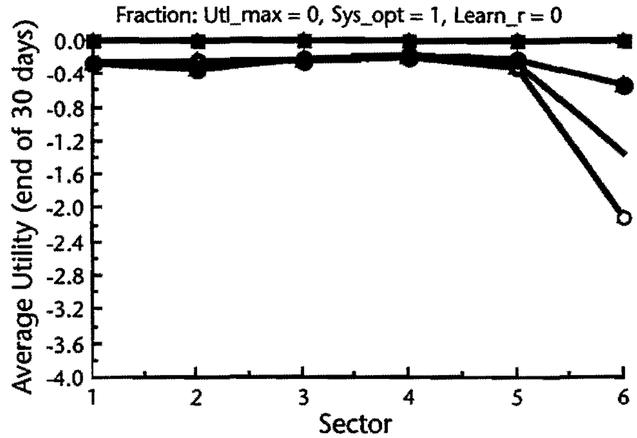
Experiment 1



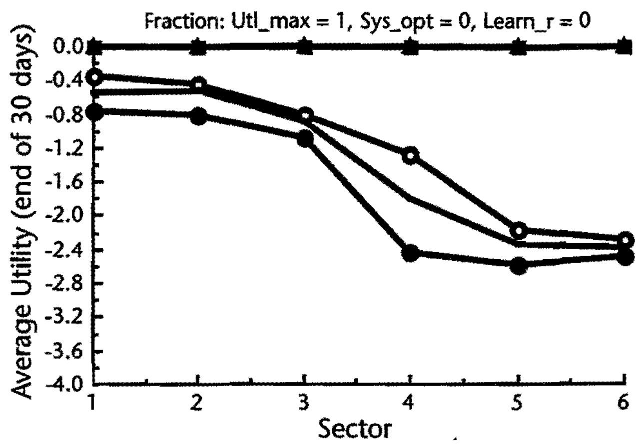
Experiment 2



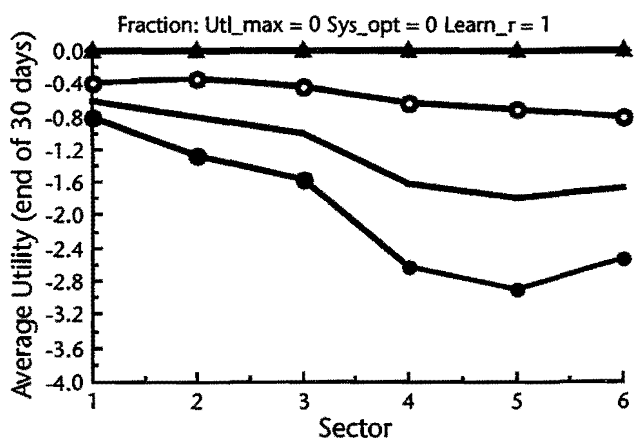
Experiment 3



Experiment 4



Experiment 5



Experiment 6

Figure 5.8b Average sector-based utilities: with ramp metering

Lastly, Figure 5.9 shows the sum of the average utilities for both routes combined, with and without entrance control. It can clearly be seen in Figure 5.9a that ramp metering yields the maximum benefit under normal operating conditions with a low or no fraction of "system optimal" behavior users (experiments 1, 2, 4, and 5 of Figure 5.9a). However, during the disruption period, this is considerably less noticeable because of the selection of inappropriate ramp metering parameters (Figure 5.9b).

CONCLUDING COMMENTS

The subject of user behavior and decision making is highly complex. The behavioral types considered in the above experiments are simplified for clarity in their assumptions of learning and information utilization. For example, the relative use of information and experience was assumed constant for a given user over time in the simulations. Further, the "system optimal" users were assumed to follow their assigned departure times and routes whether or not they were satisfied. The experiments conducted cover only a small fraction of the different scenarios possible. Nevertheless, these experiments provide a meaningful illustration of the capabilities made possible by the methodology developed in this study in terms of investigating the effectiveness of different control strategies through the simulation of the system performance and its evolution as a result of the users' decisions in response to the control and experienced conditions. While these experiments are intended primarily for illustrative purposes, several important substantive insights can be noted:

(1) Assignment of a fraction of users according to system optimal rule tends to improve the performance of the system. However, there seems to be an inequitable distribution of inconveniences. Those using the information seem to be inconvenienced the most with respect to longer travel times and number of failures.

(2) Ramp metering seems to be beneficial in a system with a relatively low fraction of "system optimal" users. When the fraction of these users increases, there is less need for entrance control, and ramp metering may therefore only be excessively restrictive.

(3) A system consisting of a heterogeneous population of users seems to be more robust to changes in supply conditions, though this does not mean the system is operating efficiently.

(4) Finally, it is crucial to select appropriate ramp metering parameters for efficient operation. A good set of parameters for a particular situation may prove to be largely inadequate in a different situation, e.g., during disruptions caused by lane closures.

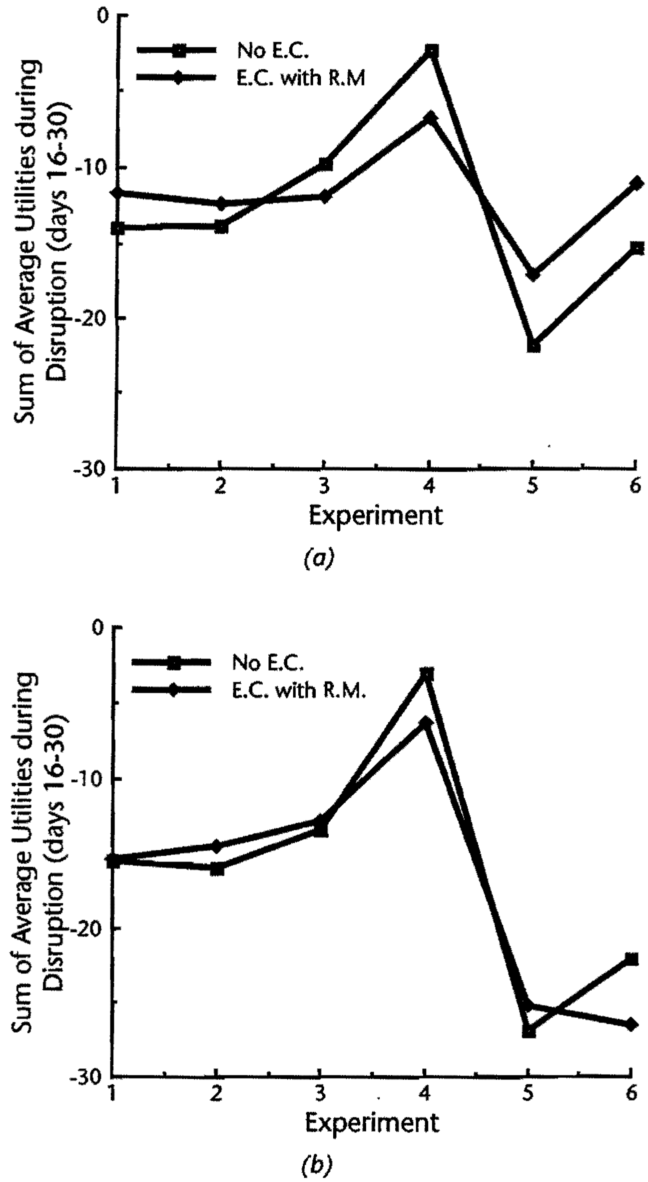


Figure 5.9 ***Sum of average utilities over duration of normal and disruption period***

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The emerging demand management methods have placed significant new requirements on our knowledge of user behavior and response to service quality. It is clear that user behavior on a day-to-day basis has significant implications for the evolution of conditions in the traffic system. Control measures to improve system performance should consider user response to the control in order to be effective. However, data required to understand the dynamics of user behavior are of a very detailed nature and have never been obtained until recently. This study is among the first systematic attempts to understand user behavior in the commuting context, with a view towards its consideration in the development of demand management strategies.

One of the significant achievements of the study was the development of a computer simulation model, the Day-to-day Dynamics Traffic Simulation Model (DDTSM), to study the interactions between user response, control strategies, and the evolution of system performance. The model is the only tool available to study the dynamics of system performance over an extended duration of time. The DDTSM consists of two main components: the traffic movement component, or Multi-route Macroparticle Simulation Model (MRMPSM); and the Vehicle Generation Component. MRMPSM is responsible for the movement of vehicles on the facility, based on well-known properties of traffic flow. An attractive feature available in the model is the capability of grouping vehicles into packets or macroparticles and simulating their movement as a single entity. This saves considerably on the memory and computational requirements that are generally associated with the tracking of individual vehicles. A module for the implementation of real time entrance control strategies is also incorporated within the MRMPSM. Currently, four different types of such strategies are available in the model.

The Vehicle Generation Component is the most significant distinguishing factor among the DDTSM and other currently available traffic simulation models. This component is responsible for the users' travel-related decision making with respect to when and how to switch route and/or departure time. An elaborate framework is already in place to model user decision making in two ways, using the bounded rationality and utility maximization approaches. The primary difference between the two approaches is that, while in the latter the users are assumed to search for the best possible trip schedule, in the former they settle for a satisfactory one. The component was designed to be very flexible, and new approaches can be incorporated easily with minimum modifications. The capability to model information dissemination strategies is another unique feature of DDTSM. Two types of information are possible in the model: descriptive and normative (or prescriptive) information. The descriptive information includes relevant time-dependent traffic parameters and characteristics that existed on previous trips. The normative information, on the other hand, assigns actions to users. The information is generated with the intention of improving overall system performance. An optimization framework has also been developed and integrated with DDTSM for generating the normative information. In essence, the behavioral framework in its current form is capable of modeling the influence of users' previous experience and supplied information on trip decisions.

The development of a survey methodology to obtain the detailed data necessary for studying the dynamics of commuter behavior is another important achievement of this study. Valuable experience was gained from an earlier survey of similar nature in the Austin area and used in the implementation of the survey conducted in the Dallas area for the purpose of this study. The two-stage strategy was helpful in improving the cost-effectiveness of the second-stage survey by better targeting of households likely to yield usable responses. In addition, the first-stage survey yielded very useful information in its own right, in terms of providing a reliable characterization of the population of interest and prevailing commuting patterns. A unique feature of the survey is the level of detail of the information obtained, especially with regard to the selected paths through the network. Such information has been previously unavailable and is of utmost relevance to current studies of electronic route guidance systems. It is very encouraging to note that commuters have generally been able to provide the information requested at the desired level of detail.

While the survey was intended for commuter trips, the insights gained suggest that the approach would be applicable to obtain a more complete record of trips and activities. The survey information has yielded information on the extent of trip chaining associated with the commute, along with its variability from day to day. It has also documented the extent of daily fluctuations in the departure times for the commuting trip chains. The results suggest that the picture obtained from conventional single-day surveys of household trip making is rather incomplete and of limited use in connection with travel demand management and congestion mitigation strategies.

The examples of day-to-day simulations, with and without the entrance control and information dissemination strategies, have illustrated the possible benefits from these strategies. They have also shown that a typical "single day" analysis of the system may be insufficient owing to the considerable day-to-day dynamics generated by user response to traffic conditions. It was noted in connection with these experiments that there exists a considerable difference between the "best" performance of the system (as indicated by the experiments with 100 percent system optimal vehicles) and the performance simulated under most other situations. These large differences may suggest meaningful opportunities for improvements in current system operations through information-based strategies and real-time control.

RECOMMENDATIONS FOR FURTHER STUDY

This study is an important step towards developing effective congestion management strategies. The information obtained has provided insights on the critical factors that must be considered in the development of such strategies. The framework developed in this study provides an organizing structure for continuing efforts in this regard. In particular, more complete and refined user behavior and response models can be incorporated as the supporting research is conducted. For instance, it is now realized that trip chaining plays a significant role in travel behavior, and should be eventually incorporated in a comprehensive model. Additional empirical evidence is also needed to support the development of models of user response to specific control strategies. Because of the difficulty of obtaining such data directly in actual systems, a strategy combining field observation with controlled laboratory experiments would be particularly appropriate. Similarly, the data from the survey have indicated considerable potential for information dissemination strategies. However, no significant advances have been made in the implementation of information strategies until recently, with the explosion of interest in Advanced Traveler Information Systems and Advanced Traffic Management Systems. However, actual observations of user responses to these strategies are still unavailable. For instance, the simulation experiments have illustrated that there is a considerable influence of the fraction of the driving population that is in compliance with prescriptive information on the evolution of traffic conditions on the facility. The most effective strategy for the development of advanced traffic management methods (as well as the necessary methodological support basis) appears to be in conjunction with a demonstration project that provides an actual test bed for experimentation and data collection, coupled with the kind of simulation framework developed in this study. The simulation could guide the design and operation of the demonstration projects, whereas the latter could provide the kind of data to support model development, as well as the kind of practical insights necessary for effective development.

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APPENDIX A. CONSTRUCTION DETAILS

The reconstruction project on a 9.3-mile section of the North Central Expressway from Woodall Rodgers Freeway to LBJ Freeway was initiated in the summer of 1990. The project is expected to take at least 7 years to complete at a cost of about $636 million. It will be accomplished in five phases:

Phase 1:	635/LBJ Freeway to Northaven Road: 1.7 miles, $40.46 million.	
	Begin: summer 1990	End: 1993
Phase 2:	Northaven to Walnut Hill Lane: 1.3 miles, $30.1 million.	
	Begin: summer 1990	End: 1993
Phase 3:	Walnut Hill to Southwestern Boulevard: 2 miles, $96.29 million.	
	Begin: early 1992	End: mid-1996
Phase 4:	Southwestern to Monticello Avenue: 1.9 miles, $96.72 million.	
	Begin: mid-1992	End: 1997
Phase 5:	Monticello to Woodall Rodgers Freeway: 2.4 miles, $124.65 million.	
	Begin: mid-1992	End: 1997

APPENDIX B. SURVEY QUESTIONNAIRE (STAGE ONE)

(Note: Two versions of the questionnaire were mailed. The only difference between the two versions is the framing of Question 6. Only side one of version two is included.)

TRANSPORTATION SURVEY

Thank you for participating in our survey. Before you begin, are there other people in the household who also commute to work? If so, please have them complete the additional enclosed survey. Please answer all questions to the best of your knowledge. All answers, of course will be kept strictly confidential. Thank you.

1. **What is your work address?** ______________ Number and street (work) ______ City

2. **How long have you worked at (or within a mile of) your current location?** ___ Years.

3. **How long have you lived at (or within a mile of) your current location?** ___ Years.

4. **Currently, how do you commute to work?**
   ___ Car (alone) ___ Car Pool
   ___ Transit ___ Park & Ride
   ___ Other (specify) ______________

5. **How would you best describe your work hours?**
   ___ Regular Work Hours: (___ am to ___ pm)
   ___ Scheduled Shift Work
   ___ Flexible hours: (___ hours a week)
   ___ Other ______________

6. **How many minutes before your work officially starts do you prefer to arrive at your workplace?** ___ Minutes.

7. **How important is it for you to not be late to work?**
   ___ I am expected to arrive on time.
   ___ I am allowed to arrive up to ___ minutes late.
   ___ It does not matter if I am late.

8. **On a typical day, how long is your commuting time:**
   from home to work? _______ Minutes.
   from work to home? _______ Minutes.

9. **Do you normally adjust the <u>time</u> at which you leave specifically with traffic conditions in mind on your trip:**
   from home to work? ___ Yes ___ No
   from work to home? ___ Yes ___ No

10. **Do you normally modify the <u>route</u> you drive specifically with traffic conditions in mind on your trip:**
    from home to work? ___ Yes ___ No
    from work to home? ___ Yes ___ No

11. **In the past two weeks, how many times have you arrived after your intended time of arrival at work?**
    ___ More than 5 times.
    ___ Between 1 and 5 times.
    ___ None.

12. **How important are the following characteristics in your selection of a travel route?**

	Extremely important	Somewhat important	Neutral
Construction activity	___	___	___
Familiarity of route	___	___	___
Driving time	___	___	___
Reliability of travel time	___	___	___
Environment (aesthetics)	___	___	___
Safety	___	___	___
Frequent traffic lights	___	___	___
Congested conditions	___	___	___

APPENDIX B — VERSION 1

(Please turn over)

13. **Do you normally obtain information on traffic conditions:**

before leaving home for work?	___ Yes	___ No
before leaving work for home?	___ Yes	___ No

14. **During your usual drive to and from your workplace, do you listen to traffic reports on the radio?**

___ Yes ___ No

15. **Do you have a cellular car phone?** ___ Yes ___ No

16. **How frequently do you use these roads (not necessarily to commute to work) ?**

	Never	Seldom	Frequently
North Central Expressway (HWY 75)	___	___	___
Tollway	___	___	___
Preston road	___	___	___
Coit road	___	___	___

17. **If you normally use the North Central Expressway (HWY 75) in your commute to work, where do you enter and exit:**

from home to work?	Enter ______	Exit ______
from work to home?	Enter ______	Exit ______

18. **If you are aware of the following sources of information related to the reconstruction of the North Central Expressway (HWY 75), have you had an occasion to use them?**

	Yes	No	Unaware
Video tapes produced by the Highway Department.	___	___	___
Periodic brochures printed by the Highway Department.	___	___	___
Information Phone numbers (eg. 'WIDEN 75').	___	___	___

19. **Are you satisfied with the availability and frequency of public transit service to your neighborhood?**

___ Yes
___ No
___ Do not know

20. **If you do not use public transit to commute to work, do you consider the existing service a convenient alternative to your current mode of travel?**

___ Yes
___ No
___ Do not know

The next six questions will only be used in determining our test sample demographics.

21. **What is your job title?** ______________________

(e.g.: Store Manager, Professor, Secretary, Coach)

22. **Do you rent or own your home?** ___ Rent ___ Own

23. **How many children (below age 16) presently live in your household?** ____

24. **If you drive a car to work, what is the year and make of the car?** ______________________ Year and Make

(e.g.: 1987 Ford Taurus)

25. **What is your age?** ___ under 18 ___ 18-29 ___ 30-44 ___ 45-60 ___ over 60

26. **What is your gender?** ___ Male ___ Female

---

27. **Would you be willing to assist in providing (through the mail) more detailed information on your commuting habits?**

___ Yes ___ No ___ Possibly

PLEASE RETURN THIS SURVEY IN THE ENCLOSED ENVELOPE, regardless of whether or not you choose to participate in any further studies. Thank you for your promptness and cooperation. Your assistance will help us better understand the problems of traffic congestion. If you have any questions, please feel free to enclose them. Thank you again for your time and effort.

TRANSPORTATION SURVEY

Thank you for participating in our survey. Before you begin, are there other people in the household who also commute to work? If so, please have them complete the additional enclosed survey. Please answer all questions to the best of your knowledge. All answers, of course will be kept strictly confidential. Thank you.

1. **What is your work address?** ______________ Number and street (work) ______ City

2. **How long have you worked at (or within a mile of) your current location?** ___ Years.

3. **How long have you lived at (or within a mile of) your current location?** ___ Years.

4. **Currently, how do you commute to work?**
   - ___ Car (alone)
   - ___ Car Pool
   - ___ Transit
   - ___ Park & Ride
   - ___ Other (specify) ______________

5. **How would you best describe your work hours?**
   - ___ Regular Work Hours: (___ am to ___ pm)
   - ___ Scheduled Shift Work
   - ___ Flexible hours: (___ hours a week)
   - ___ Other ______________

6. **If there were no congestion or parking problems, how many minutes before your work officially starts would you prefer to arrive at your workplace?** ___ Minutes.

7. **How important is it for you to not be late to work?**
   - ___ I am expected to arrive on time.
   - ___ I am allowed to arrive up to ___ minutes late.
   - ___ It does not matter if I am late.

8. **On a typical day, how long is your commuting time:**
   - from home to work? ______ Minutes.
   - from work to home? ______ Minutes.

9. **Do you normally adjust the <u>time</u> at which you leave specifically with traffic conditions in mind on your trip:**
   - from home to work? ___ Yes ___ No
   - from work to home? ___ Yes ___ No

10. **Do you normally modify the <u>route</u> you drive specifically with traffic conditions in mind on your trip:**
    - from home to work? ___ Yes ___ No
    - from work to home? ___ Yes ___ No

11. **In the past two weeks, how many times have you arrived after your intended time of arrival at work?**
    - ___ More than 5 times.
    - ___ Between 1 and 5 times.
    - ___ None.

12. **How important are the following characteristics in your selection of a travel route?**

	Extremely important	Somewhat important	Neutral
Construction activity	___	___	___
Familiarity of route	___	___	___
Driving time	___	___	___
Reliability of travel time	___	___	___
Environment (aesthetics)	___	___	___
Safety	___	___	___
Frequent traffic lights	___	___	___
Congested conditions	___	___	___

APPENDIX B — VERSION 2

(Please turn over)

APPENDIX C. TRIP ACTIVITY DIARIES (LONG AND SHORT VERSION)

TRANSPORTATION SURVEY/DIARY

11 - 22 JUNE 90

CENTER FOR TRANSPORTATION RESEARCH

TRANSPORTATION DIARY
11 TO 22 JUNE 1990

Thank you for participating in the second phase of our research! Our aim in this phase is to document daily driving habits of commuters. We are only concerned with your commutes to and from work, Monday through Friday, to include any intermediate or side trips. This phase is more time consuming than the first phase, but the results will be extremely valuable.

Instructions and a sample are on the following pages. These should answer most of your questions. If, however, you have a question that is not covered, please do not hesitate to call us collect at (512) 471-4379 (please identify yourself as a commuter survey participant) or write us at:

The University of Texas
Center for Transportation Research
ECJ 6.306
Austin Texas 78712

At the completion of the survey period, please mail the diary back to us in the enclosed envelope. If for some reason you cannot complete the entire diary, please return it anyway. Thank you in advance for your help. Your participation is key to our better understanding the problems of congestion and commuter behavior.

IMPORTANT

PLEASE, DO NOT MAKE ANY NOTATIONS IN THE DIARY WHILE DRIVING. FOR YOUR SAFETY AND THAT OF OTHERS, PLEASE ONLY WRITE IN DATA WHEN THE VEHICLE IS STOPPED. THANK YOU

INSTRUCTIONS

1. WRITE IN THE DEPARTURE TIME. This is the time when you are in your car, ready to start your drive. The accuracy is very important so please do not round off to the nearest 5 minutes.

2. WRITE IN THE TIME YOU WISH TO ARRIVE AT WORK (TARGET TIME). For example, if you have an early meeting, you may wish to arrive at work earlier than usual.

3. LIST THE ROUTE YOU TAKE STREET BY STREET. It is important that you write in each road sequentially. Try to list only one street per line. If you take a major highway, like the North Central expressway (HWY. 75), please write in the entrance/exit you use. The access roads are very important.

If you used transit on a specific day, please indicate this along with the bus number. If you car pooled, please indicate whether you where a driver or a passenger.

4. IF YOU NOTICED ANY ROAD CONSTRUCTION ACTIVITY ALONG THE ROUTE, MARK AN 'X' IN THE BOX UNDER THE COLUMN 'CONS' AND ADJACENT TO THE APPRORIATE STREET.

5. IF YOU MAKE AN INTERMEDIATE STOP DURING YOUR DRIVE, WRITE "STOP #" AND ENTER THE INFORMATION IN THE APPROPRIATE BOX. An intermediate stop is defined as an additional stop during which an activity is performed. For example dropping your kids off at school or using a drive-through bank teller are intermediate stops. Stopping at a traffic light is not. Some typical intermediate stop purposes are listed below. If, for instance you only pull into a parking lot, let your kids out and continue on, this is still an intermediate stop. If the stop was quick, the same time can be entered for both arrival and departure.

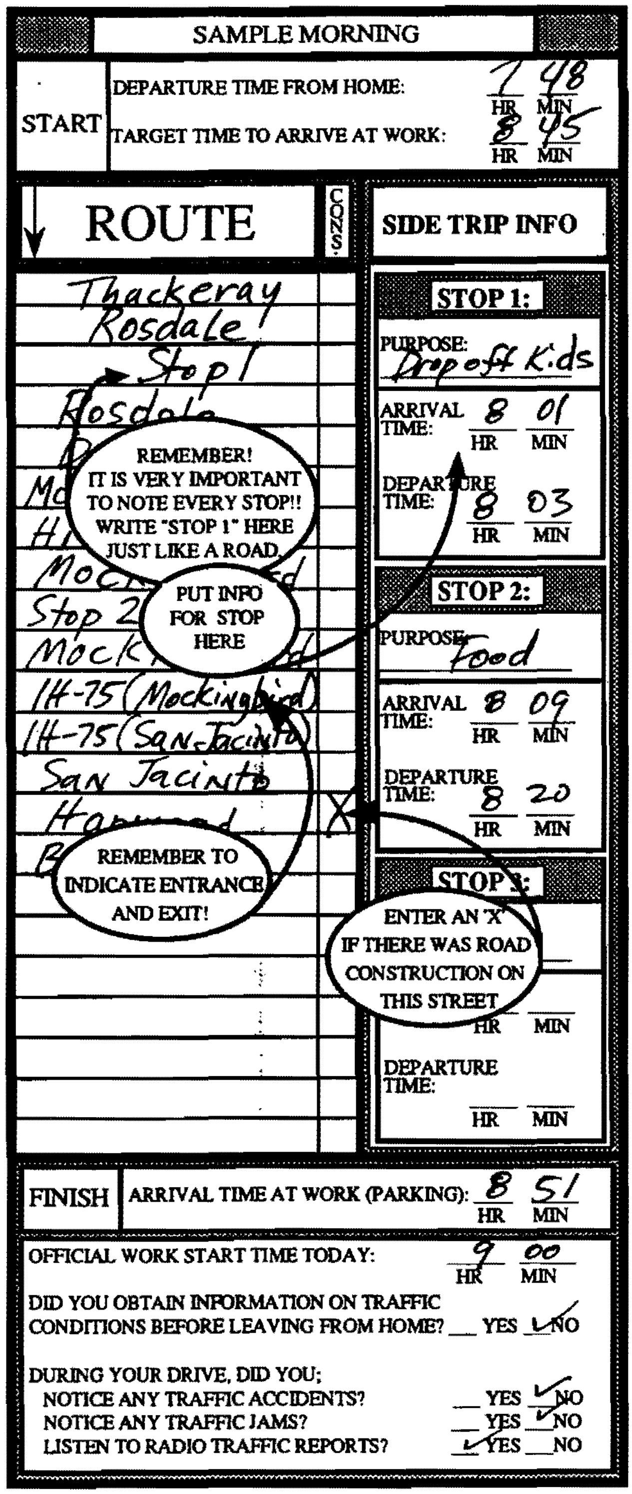
6. WRITE IN THE ARRIVAL TIME. This is when you have just arrived in your parking space, not your arrival time in the office. Again, accuracy is critical.

7. COMPLETE THE END OF DRIVE QUESTIONS. For the morning, this includes your official work start time. This is the time your workday starts and after which you would be considered late. For the evening, the official work end time is when you are free to leave. For both the morning and evening commutes check off applicable observations.

If you have any comments, please write them on the inside cover of this booklet. For example, if you commuted to different jobs on different days, please indicate so.

EXAMPLES OF INTERMEDIATE STOPS

pick up/drop off people	gas	bank
food	cleaners	shopping
recreation	social	medical
post office	other ____	



MONDAY MORNING 11 JUNE 90

START
DEPARTURE TIME FROM HOME: ___ HR ___ MIN
TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

↓ ROUTE	CONS

SIDE TRIP INFO

STOP 1:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 2:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 3:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

FINISH
ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

MONDAY EVENING 11 JUNE 90

START
DEPARTURE TIME FROM WORK: ___ HR ___ MIN

↓ ROUTE	CONS

SIDE TRIP INFO

STOP 1:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 2:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 3:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

FINISH
ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

TUESDAY MORNING 12 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ ___ HR MIN

TARGET TIME TO ARRIVE AT WORK: ___ ___ HR MIN

ROUTE | CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ______

ARRIVAL TIME: ___ ___ HR MIN

DEPARTURE TIME: ___ ___ HR MIN

STOP 2:

PURPOSE: ______

ARRIVAL TIME: ___ ___ HR MIN

DEPARTURE TIME: ___ ___ HR MIN

STOP 3:

PURPOSE: ______

ARRIVAL TIME: ___ ___ HR MIN

DEPARTURE TIME: ___ ___ HR MIN

FINISH

ARRIVAL TIME AT WORK (PARKING): ___ ___ HR MIN

OFFICIAL WORK START TIME TODAY: ___ ___ HR MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

TUESDAY EVENING 12 JUNE 90

START

DEPARTURE TIME FROM WORK: ___ ___ HR MIN

ROUTE | CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ______

ARRIVAL TIME: ___ ___ HR MIN

DEPARTURE TIME: ___ ___ HR MIN

STOP 2:

PURPOSE: ______

ARRIVAL TIME: ___ ___ HR MIN

DEPARTURE TIME: ___ ___ HR MIN

STOP 3:

PURPOSE: ______

ARRIVAL TIME: ___ ___ HR MIN

DEPARTURE TIME: ___ ___ HR MIN

FINISH

ARRIVAL TIME AT HOME: ___ ___ HR MIN

OFFICIAL WORK END TIME TODAY: ___ ___ HR MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

WEDNESDAY MORNING 13 JUNE 90

START
DEPARTURE TIME FROM HOME: ___ HR ___ MIN
TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

ROUTE | CONS. | **SIDE TRIP INFO**

STOP 1:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 2:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 3:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

FINISH
ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

WEDNESDAY EVENING 13 JUNE 90

START
DEPARTURE TIME FROM WORK: ___ HR ___ MIN

ROUTE | CONS. | **SIDE TRIP INFO**

STOP 1:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 2:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 3:
PURPOSE: ___
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

FINISH
ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

THURSDAY MORNING 14 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ HR ___ MIN

TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

↓ ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;

- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

THURSDAY EVENING 14 JUNE 90

START

DEPARTURE TIME FROM WORK: ___ HR ___ MIN

↓ ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY?

___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;

- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

FRIDAY MORNING 15 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ HR ___ MIN

TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

ROUTE | CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ____________

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ____________

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ____________

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___NO

FRIDAY EVENING 15 JUNE 90

START

DEPARTURE TIME FROM WORK: ___ HR ___ MIN

ROUTE | CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ____________

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ____________

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ____________

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY?

___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

MONDAY MORNING 18 JUNE 90

START
DEPARTURE TIME FROM HOME: ___ HR ___ MIN
TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

ROUTE | CONS.

SIDE TRIP INFO

STOP 1:
PURPOSE: ______
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 2:
PURPOSE: ______
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 3:
PURPOSE: ______
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

FINISH ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

MONDAY EVENING 18 JUNE 90

START DEPARTURE TIME FROM WORK: ___ HR ___ MIN

ROUTE | CONS.

SIDE TRIP INFO

STOP 1:
PURPOSE: ______
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 2:
PURPOSE: ______
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

STOP 3:
PURPOSE: ______
ARRIVAL TIME: ___ HR ___ MIN
DEPARTURE TIME: ___ HR ___ MIN

FINISH ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

TUESDAY MORNING 19 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ HR ___ MIN

TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

TUESDAY EVENING 19 JUNE 90

START

DEPARTURE TIME FROM WORK: ___ HR ___ MIN

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

WEDNESDAY MORNING 20 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ HR ___ MIN

TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

WEDNESDAY EVENING 20 JUNE 90

START DEPARTURE TIME FROM WORK: ___ HR ___ MIN

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

THURSDAY MORNING 21 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ HR ___ MIN

TARGET TIME TO ARRIVE AT WORK: ___ HR ___ MIN

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT WORK (PARKING): ___ HR ___ MIN

OFFICIAL WORK START TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;

- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

THURSDAY EVENING 21 JUNE 90

START

DEPARTURE TIME FROM WORK: ___ HR ___ MIN

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ HR ___ MIN

DEPARTURE TIME: ___ HR ___ MIN

FINISH

ARRIVAL TIME AT HOME: ___ HR ___ MIN

OFFICIAL WORK END TIME TODAY: ___ HR ___ MIN

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY?

___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;

- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

FRIDAY MORNING 22 JUNE 90

START

DEPARTURE TIME FROM HOME: ___ ___ (HR MIN)

TARGET TIME TO ARRIVE AT WORK: ___ ___ (HR MIN)

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ ___ (HR MIN)

DEPARTURE TIME: ___ ___ (HR MIN)

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ ___ (HR MIN)

DEPARTURE TIME: ___ ___ (HR MIN)

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ ___ (HR MIN)

DEPARTURE TIME: ___ ___ (HR MIN)

FINISH

ARRIVAL TIME AT WORK (PARKING): ___ ___ (HR MIN)

OFFICIAL WORK START TIME TODAY: ___ ___ (HR MIN)

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM HOME? ___ YES ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

FRIDAY EVENING 22 JUNE 90

START

DEPARTURE TIME FROM WORK: ___ ___ (HR MIN)

ROUTE	CONS.

SIDE TRIP INFO

STOP 1:

PURPOSE: ___

ARRIVAL TIME: ___ ___ (HR MIN)

DEPARTURE TIME: ___ ___ (HR MIN)

STOP 2:

PURPOSE: ___

ARRIVAL TIME: ___ ___ (HR MIN)

DEPARTURE TIME: ___ ___ (HR MIN)

STOP 3:

PURPOSE: ___

ARRIVAL TIME: ___ ___ (HR MIN)

DEPARTURE TIME: ___ ___ (HR MIN)

FINISH

ARRIVAL TIME AT HOME: ___ ___ (HR MIN)

OFFICIAL WORK END TIME TODAY: ___ ___ (HR MIN)

DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE LEAVING FROM WORK? ___ YES ___ NO

DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE) TODAY? ___ YES (___:___) ___ NO

DURING YOUR DRIVE, DID YOU;
- NOTICE ANY TRAFFIC ACCIDENTS? ___ YES ___ NO
- NOTICE ANY TRAFFIC JAMS? ___ YES ___ NO
- LISTEN TO RADIO TRAFFIC REPORTS? ___ YES ___ NO

FINAL QUESTIONS
PLEASE COMPLETE THESE QUESTIONS AT THE END
OF THE SURVEY PERIOD.

1. **Where do you park at work?**

__ Reserved Parking Space
__ Parking Lot/Garage
__ On the Street
__ Other ______________

2. **Do you pay for parking at work?**

__ Yes (Cost/month $ ____)
__ No, Employer pays
__ No, it is free

3. **On an average day, how long does it take for you to get to your office once you have parked your car?**

____ minutes

4. **If there were a telephone number you could call to compare current traffic conditions on your usual route with alternative routes, would you use it?**

__ Definitely
__ Probably
__ Maybe
__ Probably not
__ Definitely not

5. **If more accurate information were available, would you change your normal route if an alternative showed shorter time?**

__ Definitely
__ Probably
__ Maybe
__ Probably not
__ Definitely not

6. **If you obtained information on traffic conditions at any time during the survey period, please check the appropriate sources:**

__ Radio
__ T.V.
__ Telephone
__ Other ________

TRANSPORTATION
SURVEY/DIARY
18 - 29 JUNE 90

CENTER FOR
TRANSPORTATION
RESEARCH

CENTER FOR
TRANSPORTATION
RESEARCH

TRANSPORTATION DIARY
18 TO 29 JUNE 1990

Thank you for participating in the second phase of our research! Our aim in this phase is to document daily driving habits of commuters. We are only concerned with your commutes to and from work, Monday through Friday. This phase is more time consuming than the first phase, but the results will be extremely valuable.

Instructions, explanation of questions and a sample are on the following pages. These should answer most of your questions. If, however, you have a question that is not covered, please do not hesitate to call us collect at (512) 471-4379 (please identify yourself as a commuter survey participant) or write us at:

The University of Texas
Center for Transportation Research
ECJ 6.306
Austin Texas 78712

At the completion of the survey period, please mail the diary back to us in the enclosed envelope. If for some reason you cannot complete the entire diary, please return it anyway. Thank you in advance for your help. Your participation is key to our better understanding the problems of congestion and commuter behavior.

INSTRUCTIONS

BEFORE BEGINNING EACH TRIP...

1. If the trip is from home to work, respond to questions 1 and 2.
2. If the trip is from work to home, respond to question 1.

AT THE END OF EACH TRIP...
Respond to the remaining questions.

AT THE END OF THE SURVEY PERIOD...
Complete the final questions on the last page.

EXPLANATION OF QUESTIONS

1. WRITE IN THE DEPARTURE TIME. This is the time when you are in your car, ready to start your drive. The accuracy is very important so please do not round off to the nearest 5 minutes.

2. WRITE IN THE TIME AT WHICH YOU WISH TO ARRIVE AT WORK. This need not necessarily be the same everyday. If for example, on a specific day you have an important meeting scheduled early, you might wish to arrive at work earlier than usual to prepare for it.

3. CIRCLE THE APPROPRIATE MAJOR ROUTE(S) YOU TRAVELLED DURING THE TRIP. Your trip may involve more than one major route. If the trip did not include any of the listed routes, please circle the number 7 and write down the route(s) (road) that you consider major for your trip in the space provided next to it.

4. WRITE IN THE ARRIVAL TIME AT YOUR PARKING SPACE AT WORK. This is when you have just arrived in your parking space, not your arrival in the office. Again, accuracy is critical.

5. WRITE IN THE OFFICIAL WORK START TIME. This is the time your workday starts and after which you would be considered late.

6. WRITE IN THE OFFICIAL WORK END TIME. This is the time when you are free to leave from work.

7. WRITE IN THE ARRIVAL TIME AT HOME. Only your final time of arrival at home is required even if your trip involved intermediate destinations (see 9 for the explanation of intermediate destinations).

8. CIRCLE THE APPROPRIATE RESPONSE DEPENDING ON WHETHER OR NOT YOU HAD A TARGET TIME TO ARRIVE AT YOUR HOME OR ANY PLACE ELSE. IF YOU CIRCLE "Y", WRITE IN THIS TARGET TIME IN THE SPACE PROVIDED NEXT TO IT.

9. WRITE IN THE NUMBER OF INTERMEDIATE DESTINATIONS DURING YOUR TRIP. An intermediate destination is defined as a location along the route where the vehicle was stopped temporarily to perform an activity. For example, if you stopped to drop off your kids at school or pick up your clothes from the dry cleaners, these are intermediate destinations.

10. CIRCLE THE APPROPRIATE RESPONSE DEPENDING ON WHETHER OR NOT YOU OBTAINED INFORMATION ON TRAFFIC CONDITIONS BEFORE BEGINNING YOUR TRIP. Radio, TV, or phone calls are examples of sources from where traffic information could have been obtained.

11. CIRCLE THE APPROPRIATE RESPONSE DEPENDING ON WHETHER OR NOT YOU NOTICED ROAD CONSTRUCTION, AN ACCIDENT, AND LISTENED TO RADIO REPORTS DURING YOUR DRIVE.

12. CIRCLE THE APPROPRIATE MODE YOU USED FOR THE TRIP. If you car pooled, please circle 3 or 5 depending on whether you were the driver or a passenger respectively. If you used a mode that is not listed, please circle 6 and write in the mode you used.

13. WRITE IN ANY COMMENT YOU FEEL APPROPRIATE. For example, if you used transit to commute to work on a specific day, you are only required to circle 2 in question 12 and write in the bus route number in 13. If you worked at home or were out of town and therefore did not make a trip on a specific day, please indicate this in 13.

PLEASE, DO NOT MAKE ANY NOTATIONS IN THE DIARY WHILE DRIVING. FOR YOUR SAFETY AND THAT OF OTHERS, PLEASE ONLY WRITE IN DATA WHEN VEHICLE IS STOPPED. THANK YOU.

QUESTIONS	RESPONSES									
SAMPLE WEEK	MON HOME TO WORK	MON WORK TO HOME	TUE HOME TO WORK	TUE WORK TO HOME	WED HOME TO WORK	WED WORK TO HOME	THU HOME TO WORK	THU WORK TO HOME	FRI HOME TO WORK	FRI WORK TO HOME
1. DEPARTURE TIME (HR MIN):	7:21	5:05	__:__	__:__	7:19	5:42	__:__	__:__	7:31	5:01
2. TARGET TIME TO ARRIVE AT WORK:	7:55		__:__		7:45		__:__		7:55	
3. MAJOR ROUTE: 1. HWY 75 (N. CEN. EXPWY.) 2. TOLLWAY 3. COIT RD. 4. PRESTON RD. 5. HILCREST RD. 6. GREENVILLE AVE. 7. OTHER ____	1 2 3 4 5 (6) 7 ___	1 2 3 4 5 (6) 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	(1) 2 3 4 5 6 7 ___	1 2 3 4 5 6 (7) Abrams	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	(1) 2 3 4 5 6 7 ___	(1) 2 3 4 5 6 7 ___
4. ARRIVAL TIME AT WORK (PARKING):	7:52		__:__		7:41		__:__		7:58	
5. OFFICIAL WORK START TIME:	8:00		__:__		8:00		__:__		8:00	
6. OFFICIAL WORK END TIME:						5:00		__:__		5:00
7. ARRIVAL TIME AT HOME:		5:42		__:__		6:09		__:__		6:00
8. DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE)?		(Y) (5:45) N		Y (__:__) N		Y (__:__) (N)		Y (__:__) N		Y (__:__) (N)
9. NUMBER OF INTERMEDIATE DESTINATIONS:	2	1			1	0			0	1
10. DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE BEGINNING YOUR TRIP?	(Y) N	Y (N)	Y N	Y N	Y (N)	Y (N)	Y N	Y N	Y (N)	Y (N)
11. DURING YOUR DRIVE, DID YOU; NOTICE ANY ROAD CONSTRUCTION? NOTICE ANY TRAFFIC ACCIDENTS? LISTEN TO RADIO TRAFFIC REPORTS?	Y (N) Y (N) (Y) N	Y (N) Y (N) (Y) N	Y N Y N Y	Y	(N)	Y (N) Y (N) (Y) N	Y N Y N Y N	Y N Y N Y N	(Y) N (Y) N (Y) N	Y (N) Y (N) (Y) N
12. HOW DID YOU COMMUTE TO WORK TODAY ? 1. CAR(alone) 2. TRANSIT 3. CAR POOL(driver) 4. PARK & RIDE 5. CAR POOL(passenger) 6. OTHER ____	(1) 2 3 4 5 6	(1) 2 3 4 5 6	1 (2) 3 4 5 6	1 (2) 3 4 5 6	(1) 2 3 4 5	(1) 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6	(1) 2 3 4 5 6	(1) 2 3 4 5 6
13. COMMENTS:			Bus #351				Out of Town			

CIRCLE 7 AND WRITE THE MAJOR ROUTE IF IT DOES NOT EXIST IN LIST.

WRITE IN THE TIME IF 'Y' IS CIRCLED

WRITE IN THE NUMBER OF THE BUS ROUTE IF YOU USED TRANSIT.*

*NOTE: IF YOU USED TRANSIT FOR A SPECIFIC TRIP, PLEASE CIRCLE NUMBER 2 FOR QUESTION 12 AND WRITE IN THE NUMBER OF THE BUS ROUTE IN THE BOX FOR 13. ALL OTHER QUESTIONS CAN BE IGNORED.

QUESTIONS

WEEK 1   18 - 22 JUNE

1. DEPARTURE TIME (HR MIN):
2. TARGET TIME TO ARRIVE AT WORK:
3. MAJOR ROUTE:
   1. HWY 75 (N. CEN. EXPWY.) 2. TOLLWAY
   3. COIT RD. 4. PRESTON RD.
   5. HILCREST RD. 6. GREENVILLE AVE.
   7. OTHER ______________
4. ARRIVAL TIME AT WORK (PARKING):
5. OFFICIAL WORK START TIME:
6. OFFICIAL WORK END TIME:
7. ARRIVAL TIME AT HOME:
8. DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE)?
9. NUMBER OF INTERMEDIATE DESTINATIONS:
10. DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE BEGINNING YOUR TRIP?
11. DURING YOUR DRIVE, DID YOU;
    NOTICE ANY ROAD CONSTRUCTION?
    NOTICE ANY TRAFFIC ACCIDENTS?
    LISTEN TO RADIO TRAFFIC REPORTS?
12. HOW DID YOU COMMUTE TO WORK TODAY ?
    1. CAR(alone) 2. TRANSIT
    3. CAR POOL(driver) 4. PARK & RIDE
    5. CAR POOL(passenger) 6. OTHER
    ______ ______
13. COMMENTS:

RESPONSES

	MON 18 JUNE HOME TO WORK	MON 18 JUNE WORK TO HOME	TUE 19 JUNE HOME TO WORK	TUE 19 JUNE WORK TO HOME	WED 20 JUNE HOME TO WORK	WED 20 JUNE WORK TO HOME	THU 21 JUNE HOME TO WORK	THU 21 JUNE WORK TO HOME	FRI 22 JUNE HOME TO WORK	FRI 22 JUNE WORK TO HOME
1	__:__	__:__	__:__	__:__	__:__	__:__	__:__	__:__	__:__	__:__
2	__:__		__:__		__:__		__:__		__:__	
3	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___	1 2 3 4 5 6 7 ___
4	__:__		__:__		__:__		__:__		__:__	
5	__:__		__:__		__:__		__:__		__:__	
6		__:__		__:__		__:__		__:__		__:__
7		__:__		__:__		__:__		__:__		__:__
8		Y (__:__) N		Y (__:__) N		Y (__:__) N		Y (__:__) N		Y (__:__) N
9	____	____	____	____	____	____	____	____	____	____
10	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
11	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N
12	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___	1 2 3 4 5 6 ___
13										

QUESTIONS

RESPONSES

WEEK 2 25 - 29 JUNE	MON 25 JUNE HOME TO WORK	MON 25 JUNE WORK TO HOME	TUE 26 JUNE HOME TO WORK	TUE 26 JUNE WORK TO HOME	WED 27 JUNE HOME TO WORK	WED 27 JUNE WORK TO HOME	THU 28 JUNE HOME TO WORK	THU 28 JUNE WORK TO HOME	FRI 29 JUNE HOME TO WORK	FRI 29 JUNE WORK TO HOME
1. DEPARTURE TIME (HR MIN):	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___
2. TARGET TIME TO ARRIVE AT WORK:	___:___		___:___		___:___		___:___		___:___	
3. MAJOR ROUTE: 1. HWY 75 (N. CEN. EXPWY.) 2. TOLLWAY 3. COIT RD. 4. PRESTON RD. 5. HILCREST RD. 6. GREENVILLE AVE. 7. OTHER ________	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____	1 2 3 4 5 6 7 ____
4. ARRIVAL TIME AT WORK (PARKING):	___:___		___:___		___:___		___:___		___:___	
5. OFFICIAL WORK START TIME:	___:___		___:___		___:___		___:___		___:___	
6. OFFICIAL WORK END TIME:		___:___		___:___		___:___		___:___		___:___
7. ARRIVAL TIME AT HOME:		___:___		___:___		___:___		___:___		___:___
8. DID YOU HAVE A TARGET TIME TO ARRIVE AT HOME (OR ANY PLACE ELSE)?		Y (__:__) N		Y (__:__) N		Y (__:__) N		Y (__:__) N		Y (__:__) N
9. NUMBER OF INTERMEDIATE DESTINATIONS:	____	____	____	____	____	____	____	____	____	____
10. DID YOU OBTAIN INFORMATION ON TRAFFIC CONDITIONS BEFORE BEGINNING YOUR TRIP?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
11. DURING YOUR DRIVE, DID YOU; NOTICE ANY ROAD CONSTRUCTION? NOTICE ANY TRAFFIC ACCIDENTS? LISTEN TO RADIO TRAFFIC REPORTS?	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N	Y N Y N Y N
12. HOW DID YOU COMMUTE TO WORK TODAY ? 1. CAR(alone) 2. TRANSIT 3. CAR POOL(driver) 4. PARK & RIDE 5. CAR POOL(passenger) 6. OTHER ________	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____	1 2 3 4 5 6 ____
13. COMMENTS:										

COMMENTS

FINAL QUESTIONS
PLEASE COMPLETE THESE QUESTIONS AT THE END OF THE SURVEY PERIOD.

1. Where do you park at work?

- __ Reserved Parking Space
- __ Parking Lot/Garage
- __ On the Street
- __ Other ______________

2. Do you pay for parking at work?

- __ Yes (Cost/month $ ____)
- __ No, Employer pays
- __ No, it is free

3. On an average day, how long does it take for you to get to your office once you have parked your car?

___ minutes

4. If there were a telephone number you could call to compare current traffic conditions on your usual route with alternative routes, would you use it?

- __ Definitely
- __ Probably
- __ Maybe
- __ Probably not
- __ Definitely not

5. If more accurate information were available, would you change your normal route if an alternative showed shorter time?

- __ Definitely
- __ Probably
- __ Maybe
- __ Probably not
- __ Definitely not

6. If you obtained information on traffic conditions at any time during the survey period, please check the appropriate sources:

- __ Radio
- __ T.V.
- __ Telephone
- __ Other ________