TRansportation ANalysis SIMulation System (TRANSIMS)

The Dallas Case Study

January 1998

TMIP

Travel Model Improvement Program

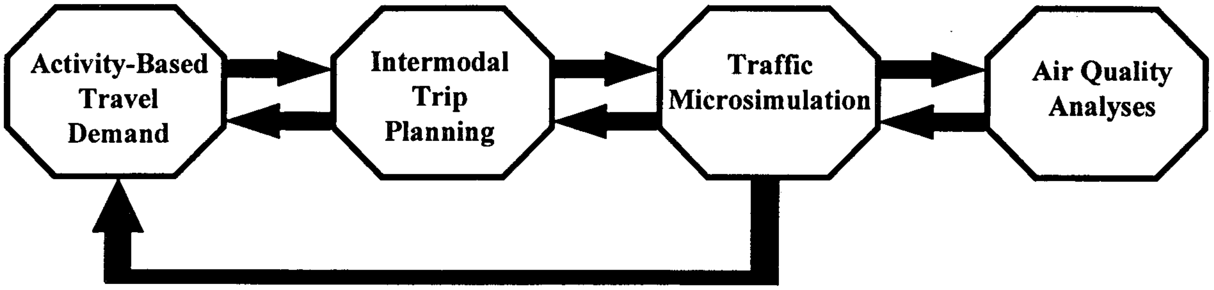
Department of Transportation
Federal Highway Administration
Federal Transit Administration
Assistant Secretary for Transportation Policy
Environmental Protection Agency

U.S.Department of Transportation

U.S.Environmental Protection Agency

WHAT IS TRANSIMS

TRANSIMS is a new system of travel forecasting models being developed by the Los Alamos National Laboratory for the Travel Model Improvement Program. The TRANSIMS models are a wholly new approach to travel forecasting, specifically designed to meet the needs of today's transportation decision makers for more accurate information on traffic congestion, differential impacts and motor vehicle emissions. TRANSIMS is composed of four basic modules.



Activity-Based Travel Demand estimates the number and characteristics of activities in which individuals will participate during the forecast period. Activities are work, shopping, recreation, etc. These activity estimates are based on characteristics of individuals, their households and vehicles determined by a *synthetic population generator.*

Intermodal Trip Planning determines where travelers will go to accomplish their desired activities. The likely route traveled and mode chosen to reach the chosen locations are determined at this stage. Intermediate activities such as shopping may occur during the routing of a principal trip such as work. TRANSIMS maintains the identities and characteristics of individual drivers, vehicles and other travelers throughout the trips they make. Trips are identified by specific points of origin and destination.

Traffic Microsimulation loads the trips on the transportation network second by second during the forecast period. The microsimulation continuously monitors the operating status of the vehicle and engine throughout the trip, including location, speed, acceleration or deceleration. Every motor vehicle in the study area is monitored in this way, thereby indicating where there are traffic congestion and emission concentrations.

Air Quality Analyses identify the kind of emissions and calculate the effects of emissions on the atmosphere in the study area. The air quality module estimates the nature, amount and conditions of emissions by each motor vehicle. That information is combined with observations on atmospheric conditions to determine the air quality effects of traffic on the study area.

TRANSIMS is a considerable departure from traditional, four-step travel forecasting procedures. The new technical approaches in TRANSIMS permit assessing equity of transportation impacts, service reliability and forecast uncertainty. Yet all of the analyses conducted by the best current 4-step models can be conducted with TRANSIMS.

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January 1998

Case Study Conducted by
Los Alamos National Laboratory

Prepared by
Los Alamos National Laboratory
Texas Transportation Institute

Prepared for
U.S. Department of Transportation
    Federal Highway Administration
    Federal Transit Administration
    Assistant Secretary for Transportation Policy
U.S. Environmental Protection Agency

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

EXECUTIVE SUMMARY

This report summarizes the procedure, results and conclusions of a case study application of the TRANSIMS microsimulation procedure in Dallas, Texas. The microsimulation is part of the larger TRANSIMS transportation simulation system. The purpose of this case study was to test the capabilities of the TRANSIMS microsimulation to track the movement of simulated individual vehicles through a simulated representation of a transportation network. The case study successfully demonstrated those capabilities using real travel data to address actual planning issues. An additional case study now underway in Portland, Oregon, will test other components of TRANSIMS.

The case study examined how two different kinds of roadway improvements would relieve traffic congestion in an intensely developed suburban area in north Dallas. The case study area is served by north-south and east-west freeways that intersect near office buildings, hotels and the largest shopping mall in Dallas. The roadway network changes considered were (1) adding a lane in each direction to one of the freeways and (2) modifying arterial street operations, intersections and capacity. The microsimulation results illustrated the effects on traffic flow of the two improvement options. The network performance measures compared for the two improvement options and the base existing condition were travel time, speed, average vehicle hours, and average vehicle miles and network reliability. The first two of these performance measures were prepared for two sets of comparisons. One compared mall and non-mall travelers. The other compared internal, internal-external and through trips.

The simulation study results indicated that both improvement options reduced the median travel times from those in the base existing condition for all travelers. The reductions in travel times were about equal for the two improvement options, but the effects of the arterial improvements were observed about half an hour earlier than the effects of the freeway improvements. Both improvement options reduced travel times for trips that did not stop at the shopping mall, and those reductions were nearly equal. The arterial street improvements induced greater travel time reductions than the freeway improvements for persons with destinations at the shopping mall. Travel times resulting from the arterial street improvements were more reliable than for the freeway option. These results must be balanced with consideration of the magnitude of the arterial and freeway system investments implied by the two improvements.

The microsimulation applications in this case study demonstrated four important conclusions:

1) the simulations successfully reproduced observed traffic patterns in the study area;
2) effects of both infrastructure and operational improvements were demonstrated;
3) estimates of travel time reliability were developed; and
4) impacts of transportation changes on population sub-groups were demonstrated.

The remainder of this report describes the Dallas case study and results in more detail.

CASE STUDY DESCRIPTION

The purpose of this case study was to test and demonstrate the capabilities of the microsimulation module of the TRANSIMS travel forecasting model system. Since the intended use for the model is to forecast traffic patterns and dynamics in metropolitan regions, an actual location in a real urban region was selected as the test site. Also, a real problem situation in the selected region was chosen to provide the information used to drive the microsimulation module for this case study.

The case study examined traffic patterns in a five-mile square area centered on the Galleria shopping mall, the largest mall in Dallas. Other development in the study area includes Valley View shopping mall and several high-rise hotels and office buildings. This area is reputed to have the worst traffic congestion in the Dallas/Fort Worth region. The case study simulated approximately 200,000 vehicle trips within, into, out of, and through the study area during five hours of the morning peak traffic period with special attention to trips to and from the Galleria mall.

The study area is crossed by two freeways: Interstate Highway 635 (I.H.635), the Lyndon B. Johnson Freeway, which runs east-west; and the Dallas North Tollway, which runs north-south. The freeways intersect next to the Galleria. Figure 1a shows the principal roadways in the study area and the locations of the two shopping malls. Figure 1b shows the location of the case study area in the Dallas-Fort Worth area.

The real situation examined in this case study was the degree to which two different kinds of roadway improvements relieved traffic congestion in an intensely developed suburban area. The roadway network improvement options considered were (1) one lane added to I.H.635 in each direction and (2) modified arterial street operations, intersections and capacity. The arterial roadway improvements included one lane added in each direction on four major arterial streets, additional frontage road capacity to access the Galleria mall, one grade-separated arterial street intersection, and additional turn lanes at several major intersections. All other roadway facilities remained as they are today. The base case condition against which the improvement options were compared was the existing roadway network and operations in the study area.

Selection of the study area also considered the following other factors:

- There is a good mix of residences and work places in the area, which provides a realistic mix of trip purposes.
- There is a full range of roadway types, from alleys and cul-de-sacs in residential areas to the two freeways.
- There are both recurring and non-recurring peak periods of traffic congestion.
- Current transit and pedestrian activities are minimal. This is acceptable because this test deals only with simulation of motor vehicle traffic.

Roadway in the Study Area

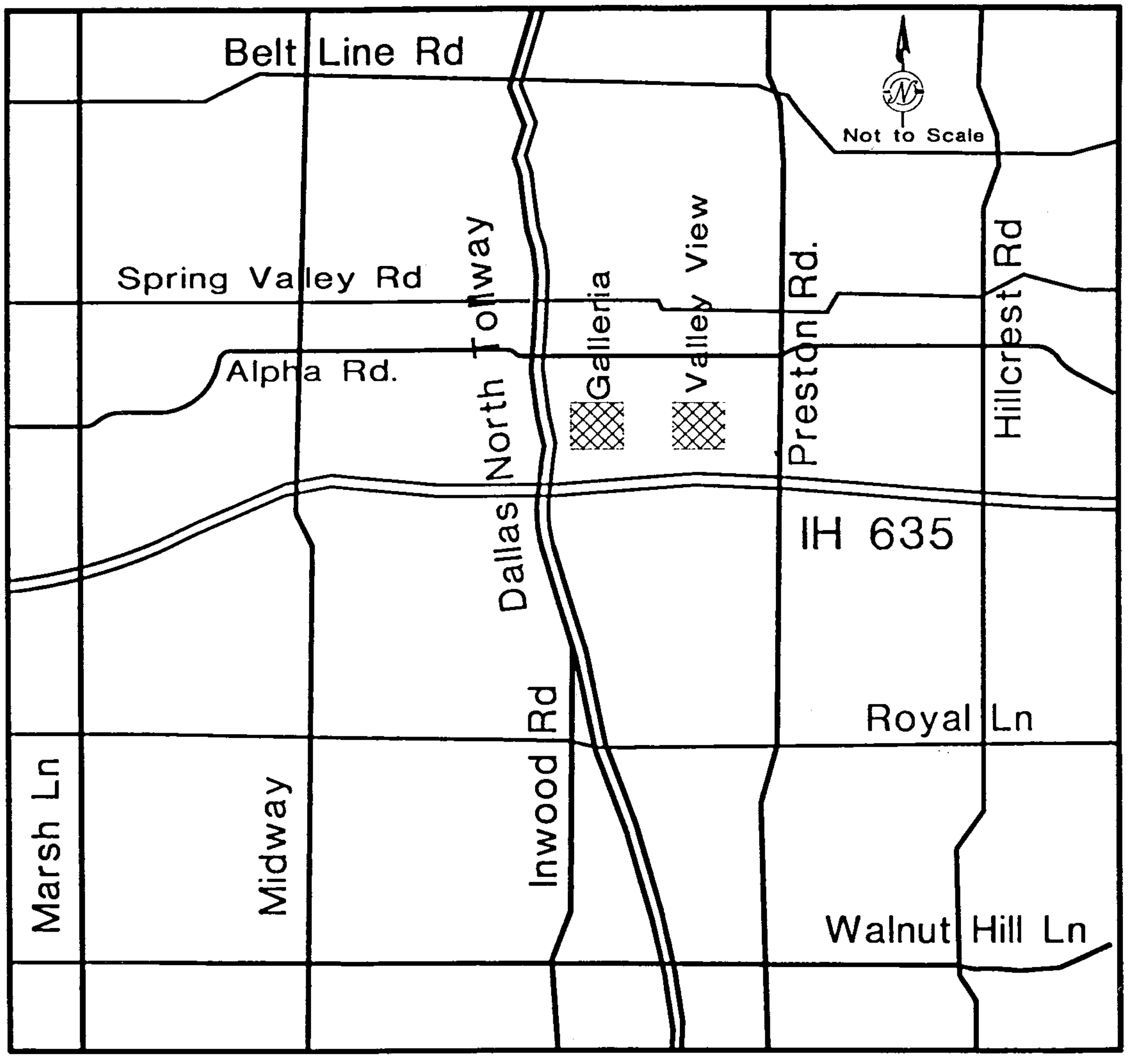

Figure 1a

Dallas-Fort Worth Area

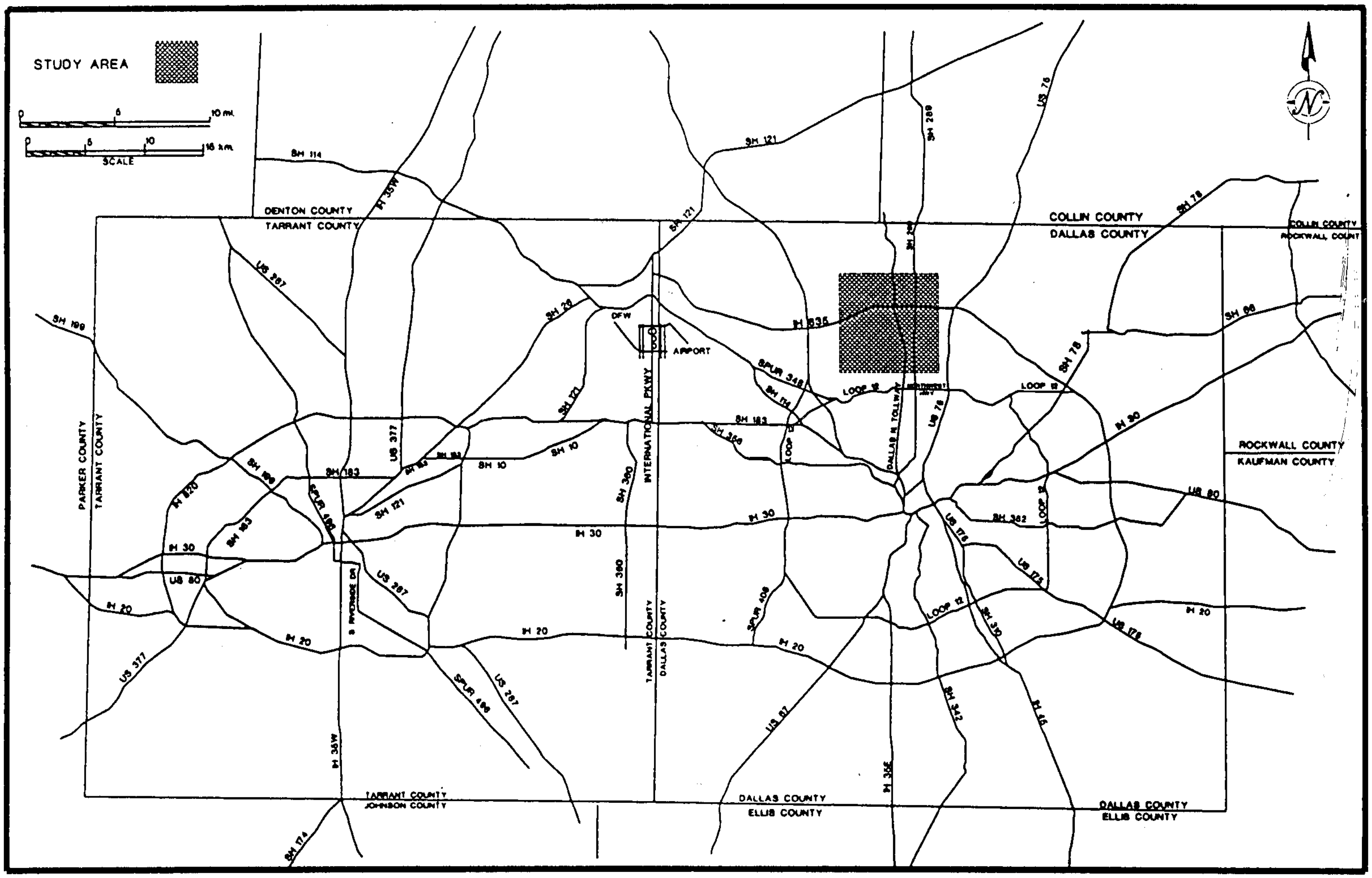

Figure 1b

This case study design is based on and used data from a recent NCTCOG[1] travel model application known as the I.H.635 (LBJ Freeway) Major Investment Study (MIS). The study design described here was jointly developed by Los Alamos National Laboratory and the North Central Texas Council of Governments.

INTERIM METHODOLOGY

The TRANSIMS Trip Planner normally produces the trip data used for the microsimulation, but the Planner is not yet operational. Therefore, the data used for this case study were derived from a vehicle trip table developed by NCTCOG for the Dallas/Fort Worth area and modified to meet the requirements of the microsimulation module. While the roadway network and trip tables for the full 3218 square-mile Dallas/Fort Worth transportation planning area shown in Figure 1b were used for route planning, the smaller five square mile study area shown in Figure 1a was the focus of the traffic simulation.

Actual applications of TRANSIMS will simulate multimodal person trips, but the multimodal planner and simulation capabilities are not yet ready for testing. For this case study, only vehicle trips were used by the microsimulation because that was sufficient information to test the operation of the simulation module. In addition, virtually all peak period travel in the study area is by motor vehicle.

In actual TRANSIMS applications the trips produced by the Planner will be described by the coordinates of their points of origin and destination. The testing described in this report required that trips be supplied to the microsimulation at that level of detail. Loading the trips at zone centroids such as those used in four-step models would not have adequately tested the complexity of the microsimulation. Therefore, the aggregated zonal trip ends from the NCTCOG vehicle trip table were randomly assigned origin and destination coordinates in their original traffic analysis zones (TAZs).

The tests reported here also required that the starting time to the second of each trip be supplied to the microsimulation. These starting times were randomly assigned to individual trips based on a distribution of trip starting times observed in an NCTCOG survey.

DATA PREPARATION

The same TAZs used in the MIS were used within the study area. NCTCOG uses a focusing process for subarea studies so the size of the TAZs increased as they were further from the study area.

The vehicle trip tables provided for the simulation were obtained by dividing the person trip tables by average vehicle occupancy factors. NCTCOG used the same trip tables to prepare vehicle traffic forecasts in the study area for comparison to the simulation results.

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[1] NCTCOG: North Central Texas Council of Governments, Metropolitan Planning Organization for the Dallas/Fort Worth metropolitan area.

The transportation network used for the case study was the 1990 base year network used for the I.H.635 MIS. All existing arterial, collector and local streets(i.e., neighborhood streets) in the study area were added in the roadway network for the base case as were traffic signalization characteristics at 100 street intersections.

The steps for modifying the 1990 base line roadway network were as follows:

1) **Revise network geometrics**. The NCTCOG roadway network had not always been literally coded so it was modified to represent more truly real-world geometrics.

2) **Add local streets**. Local streets were added to the base line network in the study area to represent more accurately access to locations in TAZs ("parking places") at which trips were to start or end. A GIS procedure was used to incorporate local streets from the TIGER files into the base line network.

3) **Add intersection and signal details.** Intersection and signal data were obtained by field checking or from local traffic engineers.

4) **Add parking place loading points.** Parking places were added on links in the study area other than freeway and ramp links and links on bridges; individual trips were loaded on (or removed from) the network at these nodes to enter the simulation.

In addition to the base line network, two roadway improvement options were coded:

1) **Freeway improvement option**. The 1990 base line network was modified by adding one eastbound lane and one westbound lane to I.H.635 from I.H.35E to U.S.75. No other changes were made to the base line network.

2) **Arterial improvement option**. The base line network was modified by adding a series of improvements to arterial roadways:

   - new roadways (three segments, two of which were frontage road links);
   - widened roadways (four long routes);
   - new signalized intersections (three locations);
   - median closures (four unsignalized intersections); and
   - intersection improvements (double left turns, free right turns, and a grade separation)

ACTIVITY-BASED TRAVEL DEMAND

The initial information normally used by TRANSIMS is the number, residence location, and characteristics of travelers and the characteristics and location of vehicles registered at that household. That information is prepared using data from the National Personal Transportation Survey (NPTS) and the Public Use Microdata Samples (PUMS) from the U.S. Census. TRANSIMS uses those traveler characteristics to determine the activities those travelers want to pursue. Each individual is represented by a list of demographic characteristics, and a set of desired activities is assigned to each individual. Each activity is assigned both a spatial and a temporal component that indicate where and when the activity will take place.

Table 1: Network Coding Details (Information Used for Microsimulation)

File	Information to be Coded
Node	Location (X-Y coordinate)
Link	• End nodes (node A and node B) • Length • Setback distance from center of intersection to stop line, by direction • Number of permanent lanes in each direction • Pocket lanes in each direction - Number to the left of the permanent lanes - Number to the right of the permanent lanes • Speed limit in each direction
Pocket Lane	• Node into which the pocket lane leads • Link ID on which the pocket lane lies; lane number of the link • Type: turn, pull-out, or merge • Starting position and/or length
Parking Places	Location of traffic loading nodes/points
Lane Connectivity	Identification of all allowed movements through an intersection
Unsignalized Node	Sign control on each incoming link (stop, yield, or none)
Signalized Node	• Seconds of offset from a base intersection • ID# of the timing plan • Start time for the timing plan
Phasing Plan	• ID# of the timing plan • Incoming link, outgoing link, and turn protection indicator (protected or unprotected) for each movement allowed in a particular phase number
Timing Plan	Length of green, yellow, and red clearance interval for each signal phase number

With TRANSIMS a trip is inferred when two separate activities are scheduled at two different times and two different locations, the traveler going from one activity to the other. Conversely, a list of known trips can be used to generate a set of hypothetical activities by defining two activities for each trip: one activity at the trip origin, and the other at the trip destination. Because activities and populations were not the focus of this case study, activities were inferred in this way from the trip ends for the trips in the NCTCOG trip tables.

In TRANSIMS all trips begin and end at a "parking place." (These are trip loading points that function similarly to "centroids" in the four-step travel forecasting process except that there may be more than one parking place in any zone.) For this case study each link in the simulation network, except freeway links, ramps and bridges, was assigned at least one such parking place. The trip ends from the NCTCOG trip tables were randomly assigned as inferred activities to parking places in the TAZs where their origins and destinations had originally been located. Parking places on major roads or streets were given a higher probability of being assigned a parking place.

In early simulation runs, unexpected congestion on some local streets resulted from an inappropriate number of trips assigned to some of the parking places. This congestion was apparently the result of multiple land uses in some of the TAZs. A TAZ that included both residential and commercial land uses may have had too many trip destinations assigned to residential parking places and too many trip origins coming from commercial parking places. This problem was alleviated by changing the probability of selecting affected parking places to account for land uses and the trip types as follows:

- The parking places were manually assigned commercial and/or residential land uses based on the uses in the affected TAZ.
- Residential parking places were assigned a higher probability of having trip productions.
- Higher probabilities of trip attractions were assigned to commercial parking places.

The timing of trips was established differently at the two trip ends. The time of the trip initiation was determined from observed trip start time distributions supplied by NCTCOG. The time of the trip conclusion was determined by adding estimated travel time to the trip start time. This scheme of assigning start times also led to unexpected congestion in the early simulation. The trip start time distributions supplied by NCTCOG were in one-hour segments. For example, 35 percent of trip attractions occurred between 7:00 and 8:00 a.m., while 17 percent occurred between 8:00 and 9:00 a.m. These abrupt changes in the proportion of trips at different start times produced anomalies in the microsimulation results. To correct this, the trip start time distributions were smoothed while maintaining the same relative proportion of trips observed in the one-hour periods.

NCTCOG does not distinguish between shopping and non-shopping trips in their home-based non-work trip table. As a result, there were too many trips arriving at the shopping centers between 7:30 and 9:00 a.m. To overcome this problem, NPTS data were used to estimate the start time distribution of home-based non-work trips to parking places that represent the shopping centers.

The steps for modifying the four initial 24-hour production-attraction person trip tables included the following:

1) Convert the 24-hour person trip tables to vehicle trip tables by applying the travel model-calculated occupancy factors.
2) Convert the 24-hour production-attraction vehicle trip tables to time-sliced origin-destination tables by applying time-specific P-A and A-P factors obtained from NCTCOG's regional travel survey data.
3) Allocate each zone-based trip end to a random point (X-Y coordinate) within the zone boundary.

INTERMODAL TRIP PLANNING

TRANSIMS prepares specific trip routing plans to satisfy activity desires of individual travelers. Each person (or vehicle) to be processed in the simulation is assigned the sequence of street links to use to reach his or her desired activity. TRANSIMS runs on fixed route plans. "For this case study" only, a traveler cannot change its assigned sequence of street links once the simulation has started – even if the vehicle is stuck in a traffic jam.

Also for this case study only, the TRANSIMS Trip Planner includes a trip "router" that identifies the minimum time path for each trip and assigns trips to those minimum time paths. TRANSIMS used a preliminary router for this case study because development of the final router has not been completed. This preliminary router consisted of two parts: an *initial planner* and a *replanner*.

The *initial planner* generated a set of routings, a series of street links, for all desired trips using free traffic flow. The routes chosen were randomly selected from among paths with the lowest total travel time between the travelers' activities. The method in the initial planner was similar to a conventional traffic assignment procedure except that the trips were routed individually. After each trip was routed, the link travel times were updated using a demand-dependent link travel time function (e.g., the "BPR curve"), and the next trip was routed. The router used a time-dependent, fastest-path algorithm. (More detail on the routing algorithm is provided in Nagel and Barrett (1997)).

The first simulation used the set of trip plans that resulted from the initial routing process. After each full simulation, the *replanner* changed the routings of some trips using the link speeds that resulted from the previous simulation, and the simulation was rerun with the new trip routings. This process continued through several iterations between the simulation and the *replanner* until both the routings and traffic speeds were stable and reasonable.

The well-known problem faced by the *initial planner* is that a simple demand-dependent link travel time function is not realistic during congestion. Therefore, the *replanner* uses more realistic link travel time information from the simulation to correct for that problem. The simulation is more capable than the older procedure of dealing with complicated situations such as queue spillback and complicated geometrics.

Figures 2, 3 and 4 show the status of traffic on the network at 10:00 a.m. after simulation of the initial plan set, the revised plan set after the first iteration, and the revised plan set after ten iterations, respectively. The black dots on those plots represent individual vehicles, and the entirely black links indicate congestion. Initially, there was massive congestion on the local streets (Figure 2). Figure 3 indicates that the previous congestion in the northeast and southwest quadrants cleared in the first iteration. By the tenth iteration (Figure 4), all local street congestion had cleared.

The number of iterations and the percentages of replanned trips were parameters of the router. Different router parameters produced different plan sets. The acceptability of a set of plans was determined by the number of lanes blocked for more than ten minutes at 10:00 a.m. and the number of *off-plan* vehicles. (A vehicle became off-plan in the simulation when congestion prevented it from accomplishing its plan.)

For this case study the initial plan set had 22 percent off-plan vehicles and 270 lanes blocked at 10:00 a.m. After five iterations, the first two iterations with 20 percent replanned trips and the last three with 10 percent, 75 lanes were blocked and 7 percent of the vehicles were off-plan. The total number of trips in the plan set was reduced at random by 5 percent and iterated three more times with 5 percent replanning. The last microsimulation of this series had 45 lanes blocked and 7 percent off-plan vehicles. All of the case study runs used this iteration scheme.

For the case study, the plan set produced by the planner was preprocessed to:

- include only plans that were in the study area during the simulation time interval,
- truncate those plans to the series of links that were in the study area, and
- sort the plans by time of entry into the study area.

The router produced plans for the entire region from the NCTCOG regional trip table. The simulation for the case study used a study area that is a subset of the regional network.

TRAFFIC MICROSIMULATION

TRANSIMS simulates the movement and interactions of travelers in the transportation system. The simulation attempts to execute each traveler's trip according to the trip plan developed by the Planner. Vehicles executing trip plans accelerate, decelerate, turn, change lanes, pass, respond to traffic controls and interact with other vehicles. Randomness is used to produce realistic traffic dynamics, such as jam waves, from the individual vehicle interactions. The combined traveler interactions yield "emergent" behavior that is a *result* of the simulation and is not predisposed or otherwise programmed to occur. So, for example, the link speed produced in the microsimulation is a result of the vehicle interaction, not the BPR curve described earlier.

Cellular automata was used for the simulation in this case study because it is capable of simulating individual trips in a large urban region while maintaining a fast execution speed. For the cellular automata simulation used here, each link in the transportation network was divided into a number of sequential cells. At each time step (each second) of the simulation, every cell was examined to see if it contained a vehicle. If a vehicle was present in the cell, it could move to another cell according to the following simple rules. These rules determine the position of vehicles on the roadway and govern vehicle movement and lane changes.

Accelerate when you can; slow down if you must; sometimes do not accelerate.

These rules were used to update the speed and position of each vehicle on the roadway at each second of the simulation.

The rules were as simple as possible in order to maintain the computational speed necessary to update positions of the large number of vehicles involved in the simulation while still accurately simulating traffic behavior. Increasing the fidelity or detail of the simulation by decreasing the cell size, adding vehicle attributes, and expanding the simulation rule set would slow computation speed.

Traffic Distribution Before Replanning

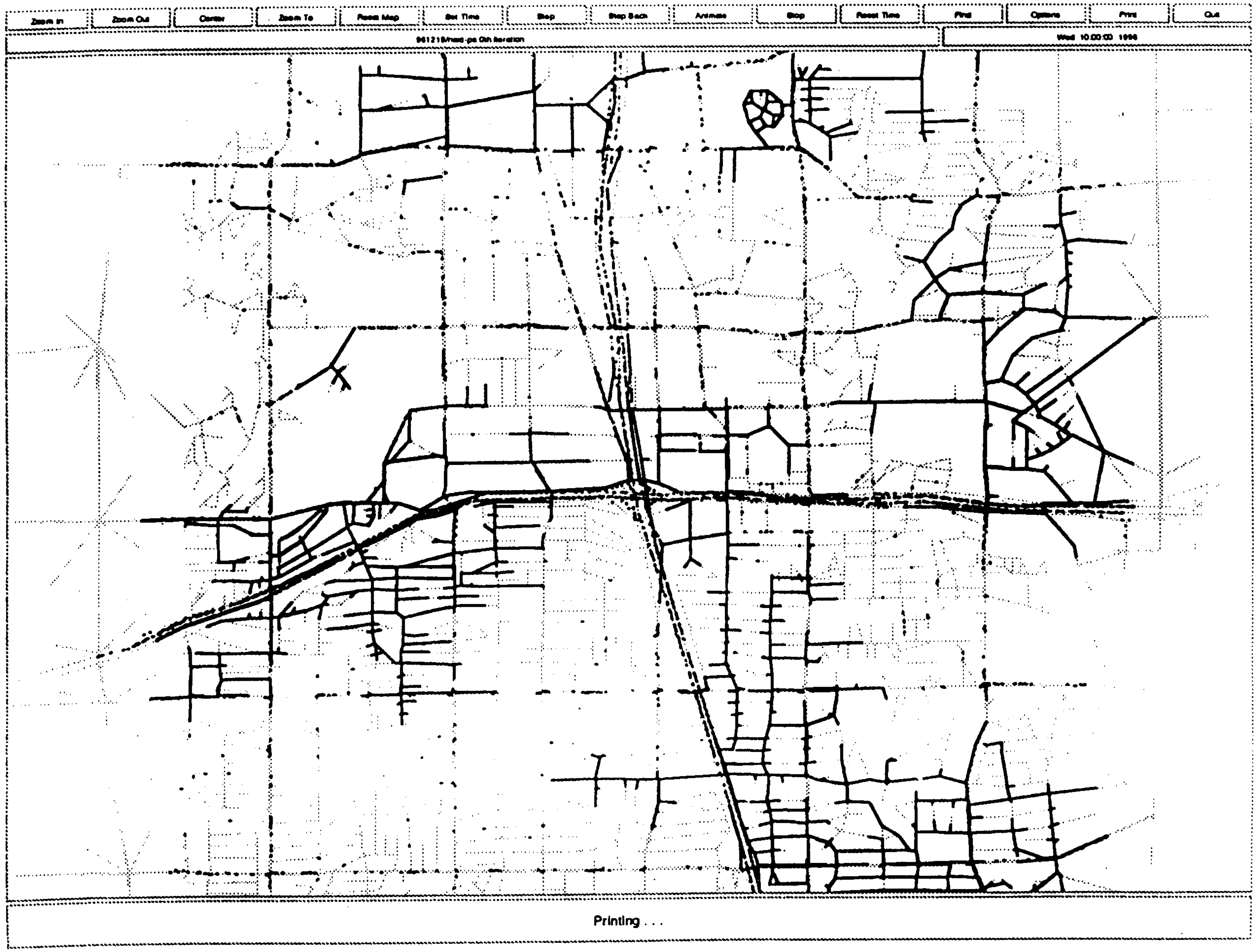

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Figure 2

Traffic Distribution After First Replanning

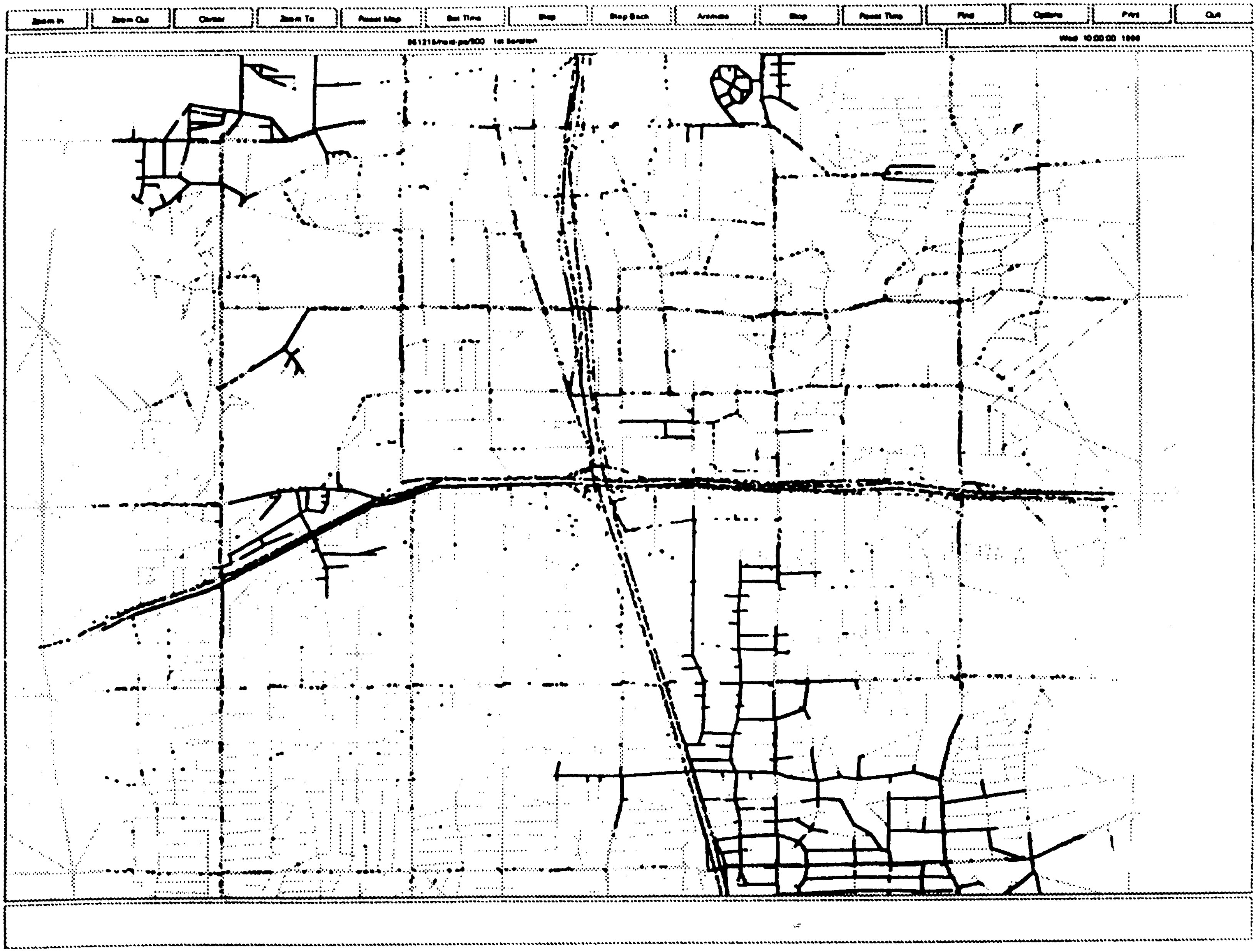


Figure 3

Traffic Distribution After Tenth Replanning

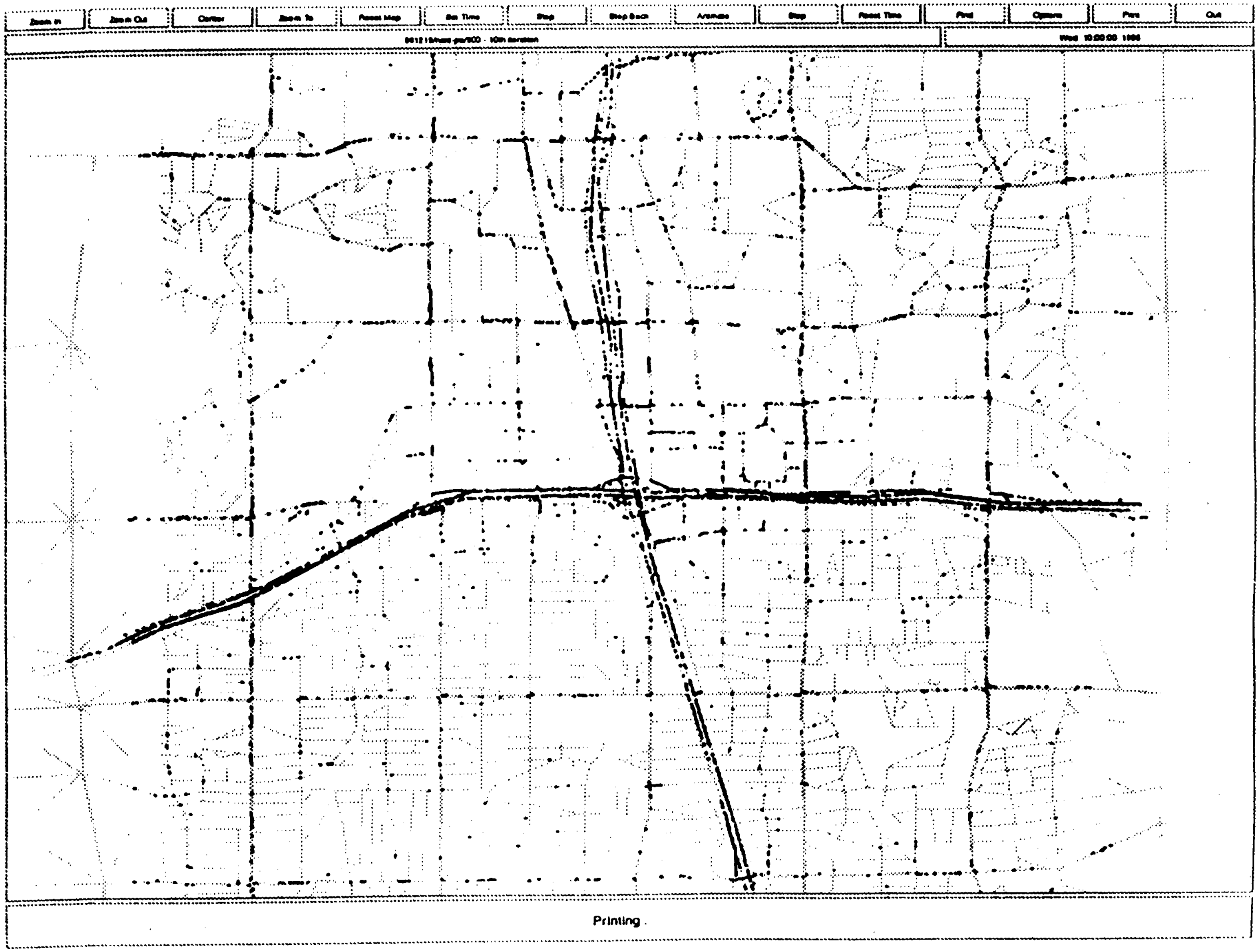


Figure 4

The cells used in the simulation were 7.5 meters long. Vehicle speed was measured as the number of cells moved per second. The maximum speed allowed in the simulation was five cells per second, which corresponds to 135 kph.

The simulation began by locating the starting point of each trip. The trips were randomly assigned to begin and end at a parking place on a link in the TAZ from which the trip had come. Each trip was placed in a queue of trips at its parking place. As the simulation time advanced, the trips were removed from the parking place queue at their assigned start times and placed on the link. The vehicle then moved across the roadway network second by second following the links in its trip plan until it reached its destination parking place in the study area or until it completed its sequence of links in the study area.

The gap between vehicles was measured by the number of cells between two vehicles. Each vehicle could accelerate if the gap was greater than necessary for the desired speed. The vehicle speed was limited to the speed limit on each link. If the gap was smaller than the current speed, the vehicle slowed until its speed was equal to the gap, thus preventing a collision. Each vehicle also was given a random probability of being slower than otherwise possible, which is called the *deceleration probability*.

Vehicles changed lanes for two reasons:

1) To pass a slower vehicle in their current lane and

2) To turn at an intersection according to its trip plan.

The decision to change lanes in order to pass a slower vehicle was based on the gap in the current lane, the gap backward in the new lane, and the gap forward in the new lane. If the gap in the current lane was short, it restricted the speed of the following vehicle and encouraged that vehicle to change lanes. If the gap backward in the new lane was greater than the gap in the new lane, the subject vehicle could move into the new lane. If the gap forward in the new lane was greater than the cap in the current lane, the subject vehicle could change lanes if it so desired. Rickert, Nagel, Schreckenberg, and Latour (1996) show the lane change logic for two-lane traffic simulated with a cellular automata.

A vehicle that must make a turn at the next intersection along its trip plan starts to consider a lane change when it is within a specified distance from the intersection. As the vehicle approaches the intersection, the urgency to change into an appropriate turn lane to follow its plan increases. Vehicles that fail to make the lane changes required to follow their plan are marked as *off-plan* and removed from the network at the nearest parking place. The latter trips are not completed.

Unsignalized intersections with stop or yield traffic controls require vehicles to consider oncoming traffic before they can move onto the next link. The vehicles use the gap between the oncoming vehicles and the intersection to determine whether the intersection can be entered. If the gap is acceptable, the vehicle traverses the intersection and arrives on the destination link during a single time step.

Vehicles at signalized intersections behave differently than those at unsignalized intersections. When a vehicle reaches an intersection, it is queued until traffic control permits it to proceed. The time that the vehicle spends in the queue is equal to the time necessary to proceed through the intersection. Vehicles whose movements are not protected by the intersection traffic control must await an acceptable gap in oncoming traffic before entering the intersection. Further information on the characteristics of the simulation process can be found in Nagel (1996a) and Nagel (1996b).

The TRANSIMS simulation was run on multiple CPUs to maximize computational speed. Updating of vehicle positions was done in parallel on the individual CPUs, which was faster than updating on a single CPU. The transportation network was partitioned among the CPUs with each CPU receiving a set of nodes and links, which resulted in some links that were split in the middle between two CPUs. The partitioning algorithm tried to minimize the number of split links. Vehicles were transferred between the CPUs as they traversed the split links. The case study simulations were run on five networked SUN SPARC workstations. The five-hour simulation of traffic between 5:00 and 10:00 a.m. ran in real time with this configuration.

MICROSIMULATION CALIBRATION

Calibration is the process of determining the parameters of the model's equations or rules. In traditional models, parameters such as the coefficients of the trip generation equations are calibrated during the model development phase.

TRANSIMS requires a much finer level of detail and more detailed time representation than traditional models. This presents new challenges for model calibration. These challenges are the result of both the types of data regularly collected for travel model development (limited mainly to major transportation facilities and aggregated to one hour time slices) and theoretical questions on how to calibrate a microsimulation model for an urban region. Work will continue on these issues, but for this case study, focused on the microsimulation, the following calibration process was used.

Various parameters in the microsimulation, such as deceleration and lane changing probabilities, are fixed in advance of running the simulation. Those parameters control the traffic dynamics resulting from the simulation. To study the effects of those parameters in a systematic way, TRANSIMS includes a series of tests of traffic flow characteristics that test aspects of driving behavior in isolation from other conditions. Situations are selected to be comparable to similar real world conditions, such as those reported in the Highway Capacity Manual and to other simulations.

The tests used here address quantities most relevant for traffic engineering applications. Those quantities are all related to capacity, such as the capacity of a freeway, the capacity of a traffic light, or the merge capacity of flow on a major road.

The traffic flow condition of concern here is demand exceeding capacity, which leads to queue build-up and traffic delays. In rush hour traffic, demand rarely exceeds capacity by much; thus, dynamics for traffic at or near capacity are especially important. The following dynamics were investigated in the tests used here.

Four simplified situations were tested:

1) *One-lane traffic in a circle*, which tested simple car-following behavior. The outputs of these runs were the standard fundamental diagrams (i.e., the relation between density, flow, and speed).

2) *Three-lane traffic in a circle*, which tested the addition of lane-changing behavior to the first condition. The outputs of these runs were lane occupancy and the standard fundamental diagrams.

3) *Unsignalized intersections* (stop signs, yield signs, freeway ramps, and unprotected left turns), which tested gap-acceptance behavior. Figure 5 is a diagram of this situation. Vehicles labeled "blue" travel around the inner circle, and vehicles labeled "red" merge into traffic on the left side of the figure and are removed on the right side. The outputs of these runs were the flow from the minor road as a function of the flow on the major road.

4) *Three-lane signalized intersections* (where one lane is for left turns, one lane goes straight, and one lane is for right turns). This fulfills two functions: testing of traffic signal cycle capacity and testing trip plan following behavior. The latter is achieved by vehicles entering on randomly selected lanes with a plan to turn or to go straight. Vehicles that fail to be in the correct lane at the signal are counted as off-plan vehicles. Outputs of this test case were two values: the number of vehicles that traversed an intersection during a green phase of a given length and the number of off-plan vehicles.

Figure 6 is a typical flow versus density fundamental diagram recorded for a simulated freeway traffic flow situation with a speed limit of 75 mph. Figure 7 shows the flow through a stop sign-controlled intersection crossing a three-lane road versus the flow on that three-lane road. The gap acceptance that was used for this calibration run was used for the case study. Figure 8 shows the flow through a stop sign-controlled intersection crossing a one-lane road versus the flow on the one-lane road for an enhanced gap acceptance logic. Future studies will use this enhanced gap acceptance logic. The curve from the Highway Capacity Manual is added in Figure 8 for comparison.

TRAVEL VALIDATION

Validation is the process of checking the model results against known travel data. An example of validation in traditional models is to test the model-produced link volumes against roadway volume counts. In this case study, however, the validation process compared traffic volumes forecasted by the microsimulation model to traffic volumes estimated by the NCTCOG travel forecasting model rather than to traffic counts. This was done because the NCTCOG trip table was the data used for both traffic estimates.

The validation conducted here compared trip volumes from the two sources on several network links from 7:00 to 8:00 a.m. The 24-hour volumes from NCTCOG were factored to this time period using the trip time distribution from the NCTCOG survey. Figure 9 compares the traffic volumes estimated by the microsimulation to the volumes estimated by NCTCOG for freeway, principal arterial, minor arterial, and collector links. The solid lines in Figure 10 indicate where the two traffic volume estimates would be equal. The dashed lines indicate where the two volume estimates differed by plus or minus 50 percent.

The results for freeways, principal arterials, and minor arterials are reasonably similar with slightly fewer freeway trips estimated by TRANSIMS than by NCTCOG. TRANSIMS estimated more traffic on collectors than was predicted by NCTCOG, which is probably due to NCTCOG using centroid connectors. Fewer trip volume estimates were available from NCTCOG for local streets, frontage roads, and ramps, so plots comparing the two estimates for those situations are not shown. These results were considered an adequate demonstration of the ability of the simulation to reproduce a trip volume estimate produced by the conventional four-step travel forecasting process.

EXPERIMENT DESIGN AND RUN STATISTICS

Traffic was simulated on the following three networks in the case study area. Trip routes were planned over the entire Dallas-Ft. Worth metropolitan area, then truncated to the boundaries of the study area.

1) **Base Case (BC)** – The roadway network as it was in 1990.
2) **Freeway Improvements (IC-1)** – The same as the base case with an extra lane added to both the east- and westbound lanes on the LBJ Freeway.
3) **Arterial Improvements (IC-2)** – The same as the base case with physical and operational changes to arterial streets and intersections (IC denotes Infrastructure Change).

Because the roadway improvement options added capacity, which affected trip route planning, new trip plans were prepared for simulations on networks IC-1 and IC-2. The activity sets remained constant for all but one base case simulation (described below).

The case study highlights three analysis capabilities of TRANSIMS. The availability of information on individual travelers and the TRANSIMS modular structure make possible studies of model uncertainty, network reliability, and traveler equity. Each of these studies is a different application of variability and requires a different experiment design and simulation.

Model Uncertainty

Uncertainty is the variation in TRANSIMS results due to inherent variation in the several modules of the system. Uncertainty tells the user of TRANSIMS that a forecast produced by the system is not a single fixed value but a range of values within which the true value can be expected to lie. This property of TRANSIMS is an advance from the traditional travel models that typically produce one value for a forecast with no indication of the possible variation that may be inherent in that forecast process-separate from any changes in input data or parameters.

Microsimulation Module Calibration

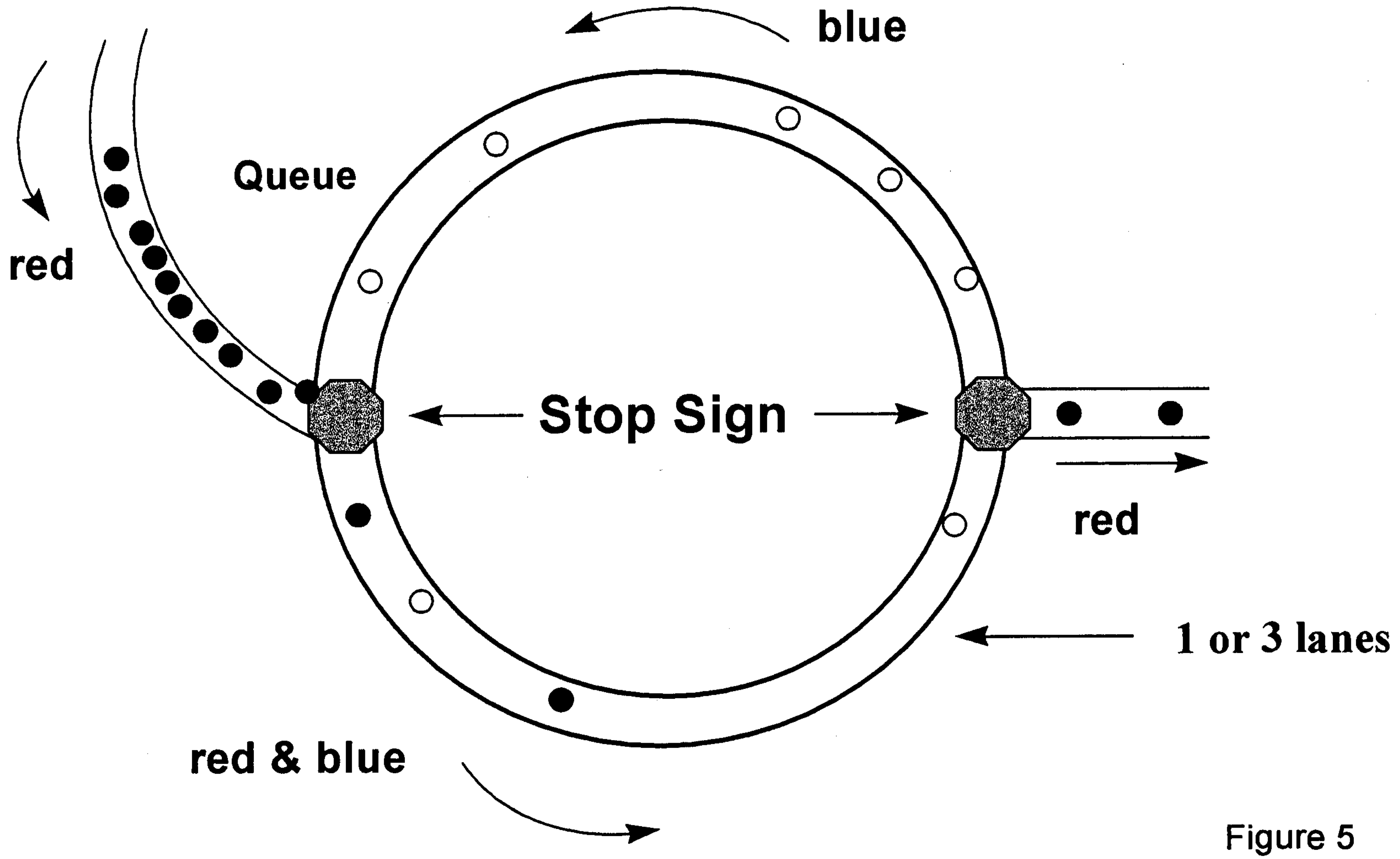


Figure 5

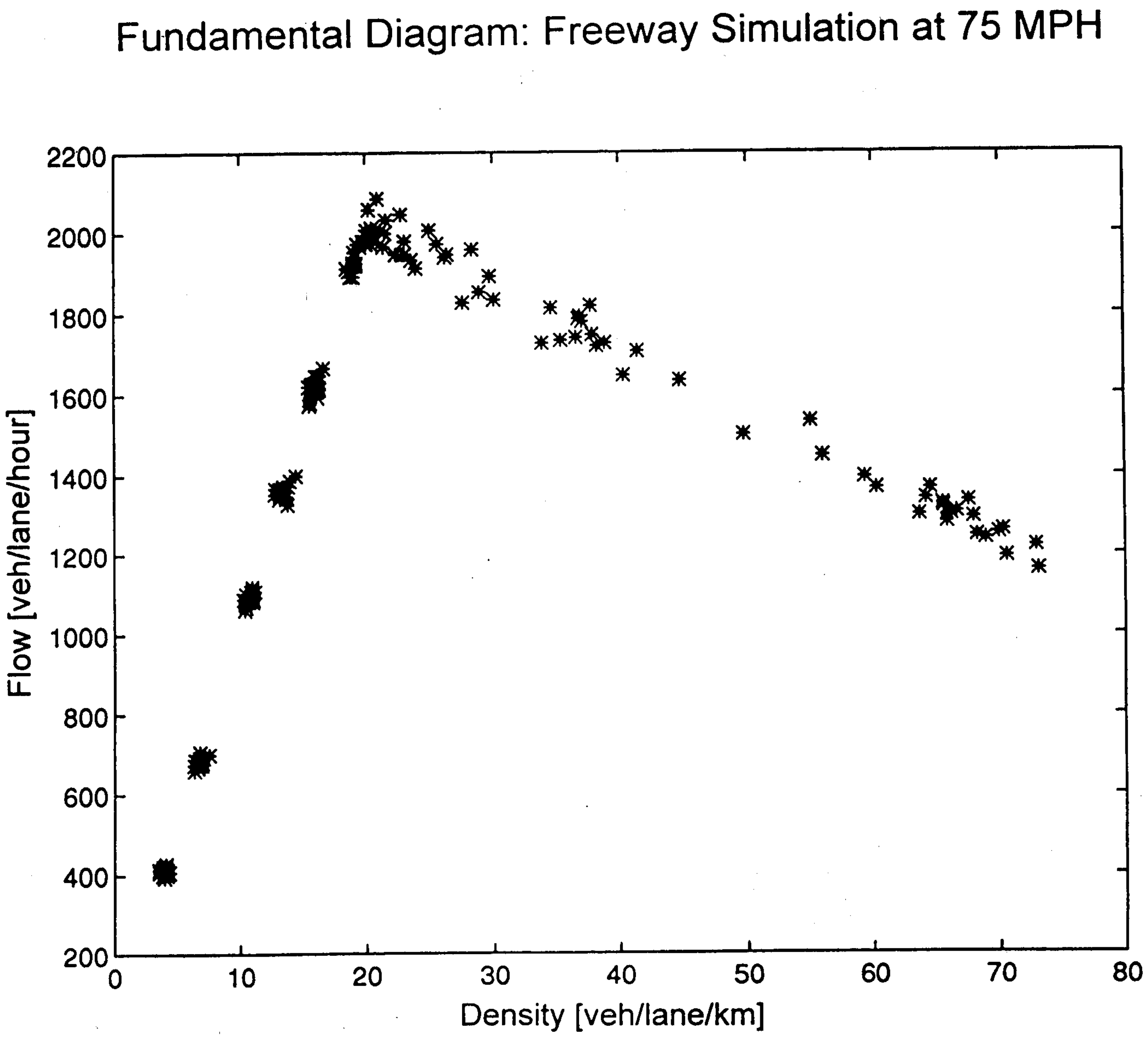

Fundamental Diagram: Freeway Simulation at 75 MPH
Flow [veh/lane/hour]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
10
20
30
40
50
60
70
80
Density [veh/lane/km]

Figure 6

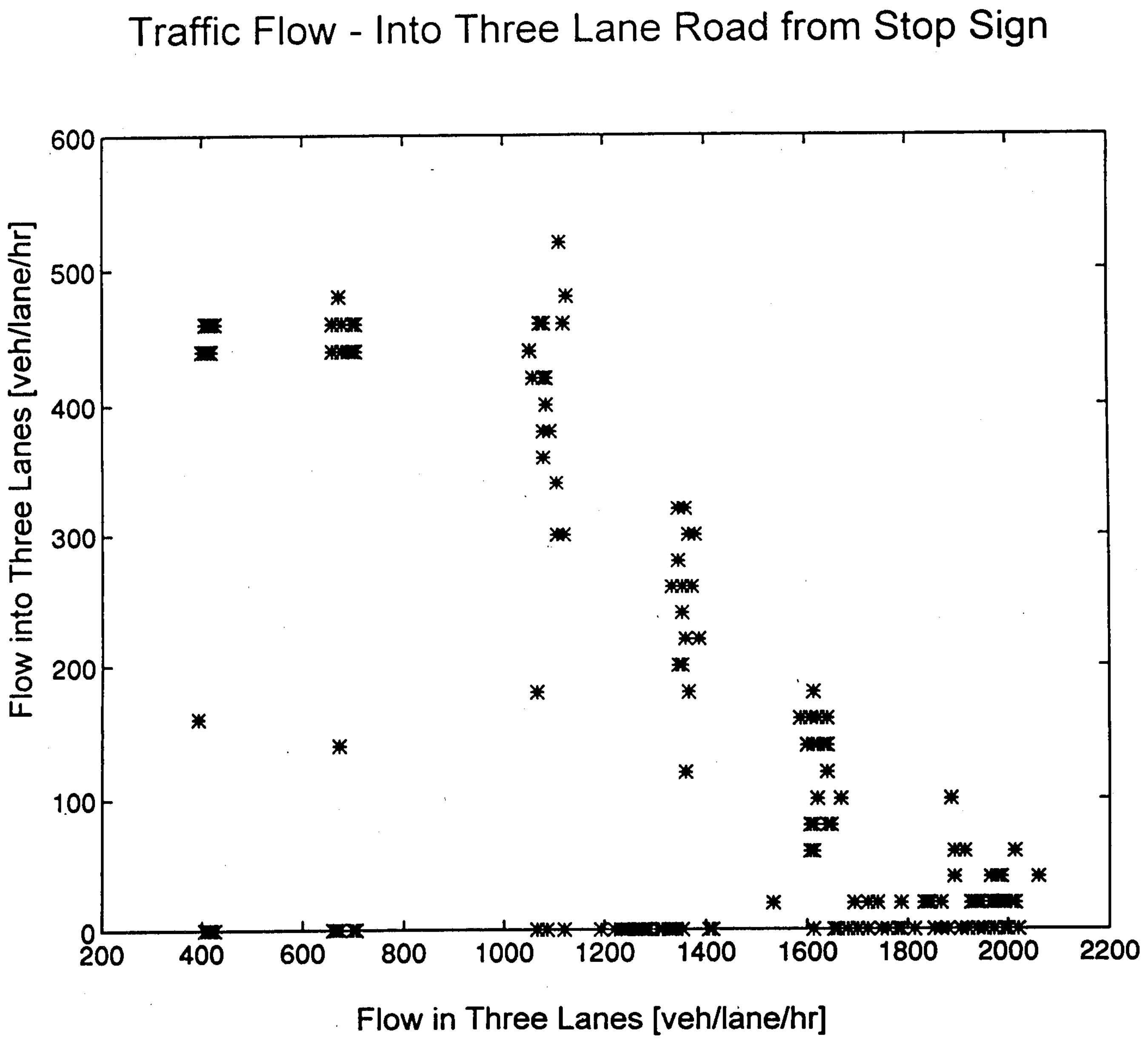
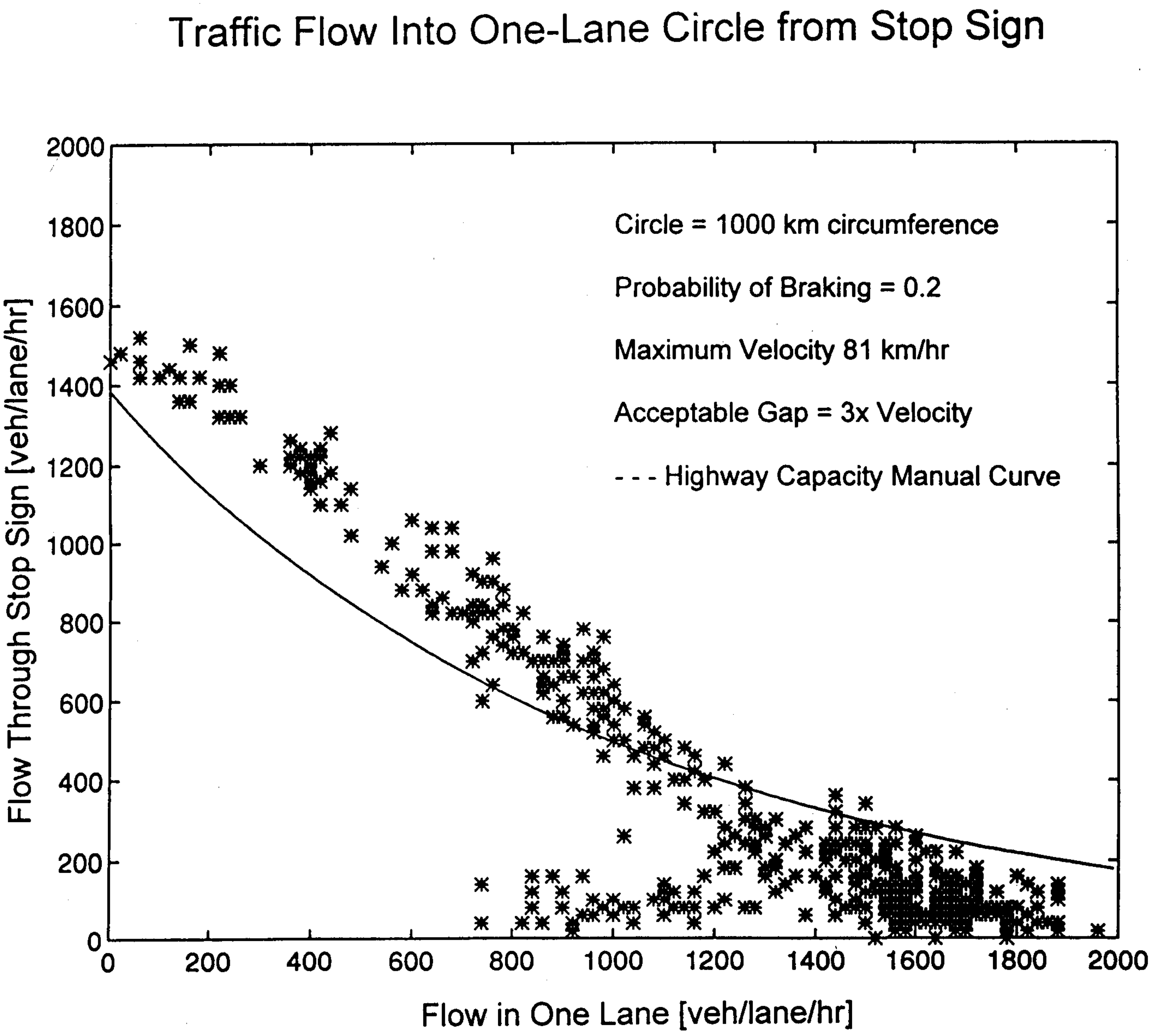

Traffic Flow - Into Three Lane Road from Stop Sign
Flow into Three Lanes [veh/lane/hr]
600
500
400
300
200
100
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Flow in Three Lanes [veh/lane/hr]

Figure 7



Traffic Flow Into One-Lane Circle from Stop Sign

Figure 8

Validation - Traffic Volume Comparisons

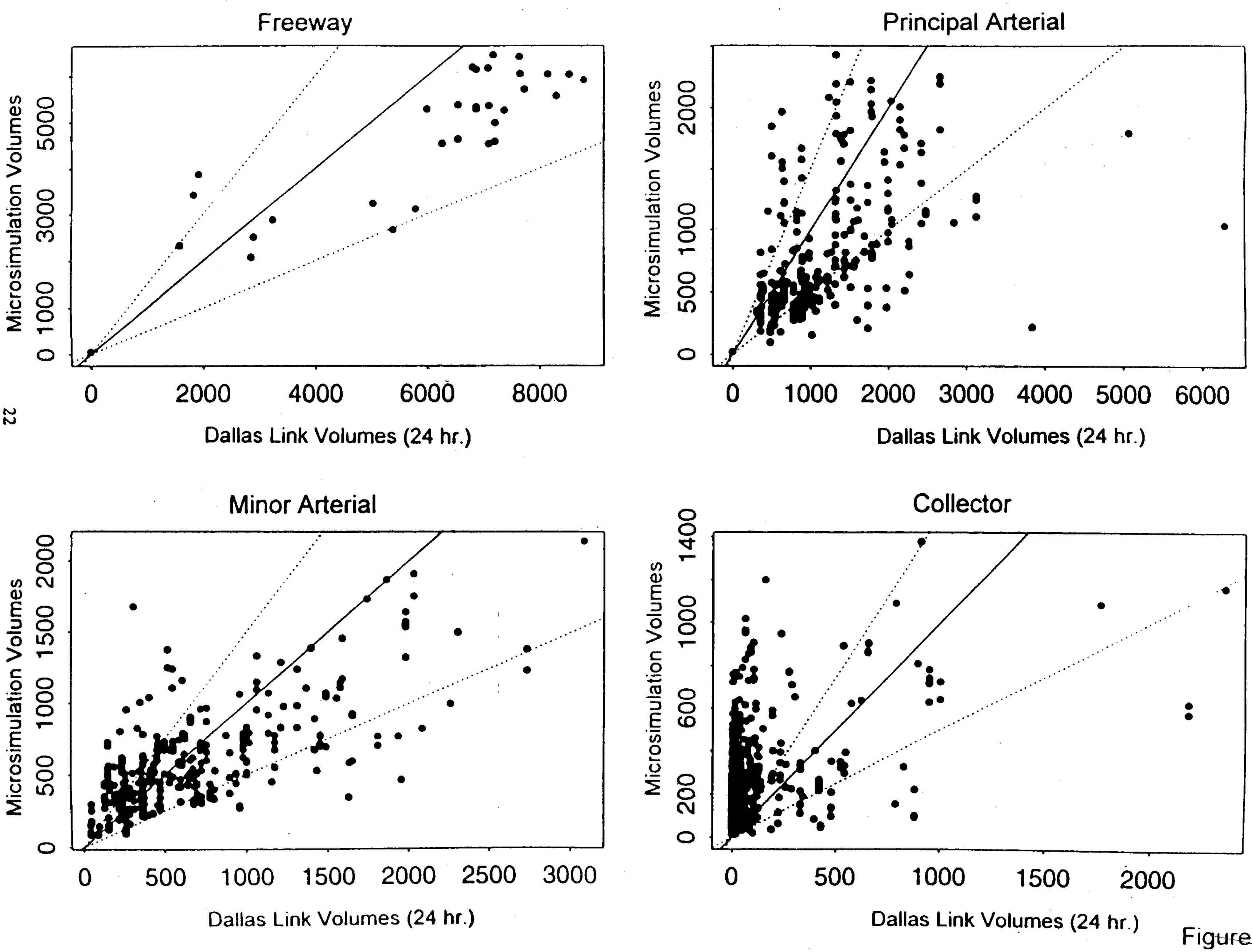


Figure 9

To estimate the uncertainty in the travel estimates, a special experiment with variations on the base case was conducted. For this experiment, the base case was simulated under four different conditions:

1) **BC-1-1-1** – Used the final trip plans resulting from the original Base Case simulation.
2) **BC-1-1-2** – Used the same trip plans as BC-1-1-1 but with different random numbers for the simulation.
3) **BC-1-2-1** – Used a different set of trip plans than the two cases above.
4) **BC-2-1-1** – A new set of activities was used by the planner to generate trips.

Figure 10 shows the experiment design for the uncertainty analysis. The shaded boxes represent the four simulations conducted for this experiment. The top level of the chart shows two sets of activities generated with different starting times. For each set of activities, two sets of trip plans were produced (middle level) where the random selection of trips to be planned was changed. Each set of trip plans was simulated twice (bottom level) using different random numbers for the simulation. The implications of these alternative simulations for estimating uncertainty are discussed in the later section of this report entitled "Base Case: Uncertainty."

Network Reliability

Reliability is another variation that can be expected in the TRANSIMS forecast. This is a measure of the variability of conditions encountered on the transportation system being simulated. This variation is not due to variation in the TRANSIMS models themselves. Again, this estimate cannot readily be produced by the traditional models that yield only one single forecast value.

To estimate network reliability, two simulations were executed for each of the three roadway networks (BC, IC-1, and IC-2). The first such simulation was supplemented by a second where the travelers' start times were modified slightly. Differences in travel characteristics between the two simulations were then measured. Details on the results of the network reliability tests are given in the later section of this report entitled "Base Case: Network Reliability."

Traveler Equity

The third area of investigation was equity analysis. This analysis permits the user to examine differential effects of the transportation system on alternative groups. This capability, too, is unique to models such as TRANSIMS because they can partition individuals and groups to better understand how they are affected. To illustrate the versatility of TRANSIMS for conducting comparative studies between groups, the effects of the roadway improvement options on the following two sets of sub-populations of travelers were investigated. The first set dealt with travelers who did or did not go to the mall:

1) **Galleria travelers** - Whose origins or destinations were in the Galleria Mall.
2) **Non-Galleria travelers** - Whose origins and destinations were outside the Galleria Mall.

Traffic conditions on the three alternative networks encountered by travelers to the mall and other travelers were examined together and separately. This analysis provided insight on the effects of these two groups on one another. The later section entitled "Equity Analysis: Galleria and Non-Galleria travelers" describes these results.

To further show the flexibility of TRANSIMS, an analysis of the following other three sub-populations of travelers was conducted.

1) **Through trips** – Traveling entirely through the study area.
2) **Internal-External trips** – Only one end of the trip in the study area.
3) **Internal trips** – Both ends of the trip in the study area.

For this analysis the simulation results for the three networks described previously were partitioned according to these three trip groups. The performance measures for each trip group and network were then compared. The later section entitled "Infrastructure Comparisons: All Trips."

Comparisons

Completed trips are those where the vehicle reached its destination before the simulation stopped. Simulations which produce more congestion and therefore longer travel times would result in fewer completed trips. The numbers of completed trips in the study area differed for each simulation because a network change produced a new set of trip plans. The number of completed trips also differed if simulations using the same trip plan set started with different random numbers. A trip also could have been completed in one simulation and not in another if the latter simulation ended before its trip ended.

Table 2 shows trips completed for the four base case runs (BC-1-1-1, BC-1-1-2, BC-1-2-1, and BC-2-1-1) and the two infrastructure runs (IC-1 and IC-2). This table also breaks down the number of completed trips for each sub-population investigated.

Table 2: Completed Trips Under Alternative Conditions

	BC-1-1-1	BC-1-1-2	BC-1-2-1	BC-2-1-1	IC-1	IC-2
All Trips	194,174	193,727	201,752	198,920	204,779	199,657
Galleria	11,700	11,658	12,325	12,190	11,963	12,082
Galleria Only	12,945	N/A	N/A	N/A	13,290	13,435
Non-Galleria	182,474	182,069	189,427	186,730	192,843	187,575
Non-Galleria Only	183,010	N/A	N/A	N/A	196,080	189,101
Through	41,958	41,857	43,708	42,384	47,022	45,211
Internal-External	117,307	117,008	121,525	120,156	122,324	118,666
Internal	34,909	34,862	36,519	36,380	35,433	35,780

Uncertainty Experiment Design
Base Case Comparisons

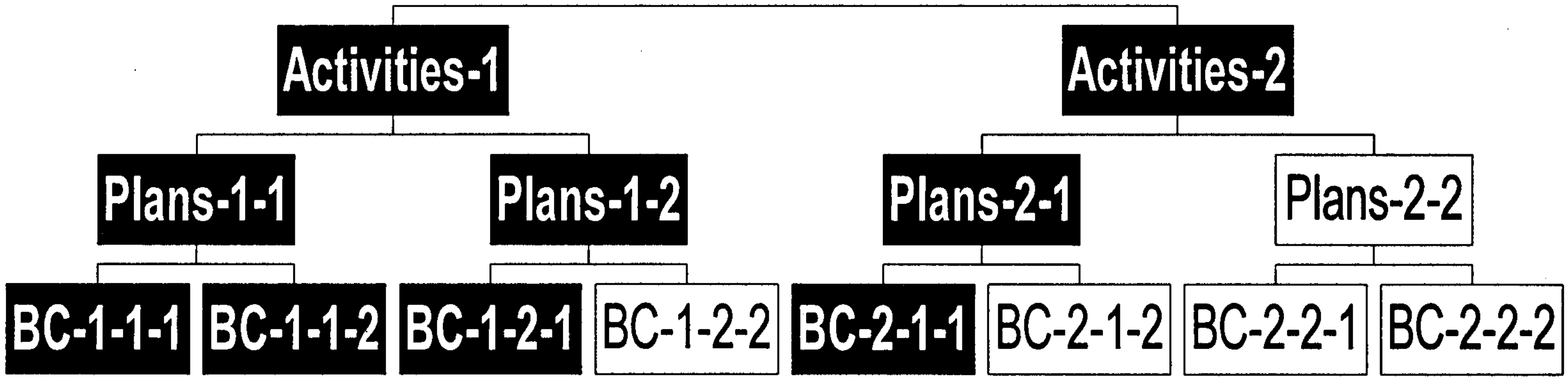


Figure 10

Figure 11 shows the percentage increase in the number of trips relative to the BC-1-1-2 run, which is the simulation with the fewest completed trips. The BC-2-1-1 run is not in the plot because it was based on a different set of activities. Figure 11 also shows that the largest increase in completed trips (6 percent) comes with the freeway improvement. There were 12 percent more through trips with this improvement option than in the base case (BC-1-1-2). There was also a significant increase in the number of trips through the study area in the arterial simulation. All other increases in completed trips were within the range of the increase for BC-1-2-1, the base case with a second set of plans. Hence, they are not significantly different from the base case.

MEASURES OF PERFORMANCE AND STATISTICAL DISPLAYS

Each simulation produced the following measures of travel performance:

1) **Vehicle miles traveled.**
2) **Vehicle hours traveled.**
3) **Travel time** – The total time of travel in the study area.
4) **Speed** – The average speed of travel in the study area.

Travel times and speeds of individual travelers were measured on each link and summarized for three-minute periods, and medians and variances of those measures were computed for each link for the same periods. The data were then smoothed and plotted at the starting time for each three-minute interval. Figure 12 is a plot of the median travel times at three-minute intervals and the smoothed function fit to them. These measures are summarized for each of the sub-populations described in the previous section and are reported in subsequent sections of this report.

Simulations were run for traffic moving between 5:00 and 10:00 a.m., and performance measures were calculated for travel in the study area completed before 10:00. These measures are shown in subsequent displays at the time the trips either originated in or entered the study area. To avoid anomalies caused by end conditions, displays of the statistics show trips starting between 6:00 and 9:00 a.m. The measures of effectiveness pertain only to travel in the study area.

Figure 13 displays measures of effectiveness in two ways for the same sample of travel time data. One of these is a box plot which is effective in comparing several parameters of distributions. The outer bars of the box plot are for the ninety-fifth and fifth percentiles of the distribution. The box encloses data between the twenty-fifth and seventy-fifth percentiles. The bar in the middle of the box marks the median, and the "x" marks the mean of the distribution. A histogram is shown in that figure as well, and it can be seen that the histogram is not as well suited for such a comparison

BASE CASE: UNCERTAINTY

To make informed transportation decisions, policy boards must understand the uncertainty in information produced by travel forecasting models. Typically, complex models do not give absolutely correct answers or any indication of the potential error in that answer. With TRANSIMS, the degree of uncertainty can be quantified. It is the result of the variability or uncertainty in the structure, components, and procedures of TRANSIMS – the activity generator, the planner, and the simulation.

For the uncertainty analysis conducted here, four different base case conditions were simulated as part of the designed experiment described in the previous section entitled "Experiment Design, Etc." (see Figure 10). The measures of effectiveness cited in the "Measures of Performance, Etc." section were prepared for these simulations and were compared to see how they were affected by changes in forecast conditions. Of specific interest was how much variability in the travel forecast occurred under the changed conditions. Such a comparison is critical to the evaluation of the transportation improvement alternatives. Without knowing the amount of variability that can be expected from TRANSIMS runs with identical input data, it is impossible to know what part of the difference in travel characteristics is due to the difference in transportation alternatives and what part is due to model variability. The number of planned trips initially provided to the simulations for this analysis was the same for all runs, but the trip plans were not identical. This was because each run of the trip planner started with a different random number. This approach introduced variability into the trip planning process. Consequently, for the same set of activities, multiple executions of the planner produced multiple sets of trip plans.

The four conditions for simulations that were run to estimate uncertainty were:

1) **BC-1-1-1** – Used the *final trip plans* resulting from the original Base Case simulation.
2) **BC-1-1-2** – Used the same trip plans as BC-1-1-1 but with *different random numbers* for the simulation.
3) **BC-1-2-1** – Used a *different set of trip plans* than the two cases above. (The different trip plans were produced by starting the planner with a different random number.)
4) **BC-2-1-1** – A *new set of activities* was used by the planner to generate trip plans.

Four simulations were run to estimate the different variability that causes uncertainty. Differences between simulations BC-1-1-1 and BC-1-1-2 demonstrate the effect of changing the random number seed that started the simulation. Comparison of BC-1-1-1 to BC-1-2-1 shows the effect of different trip plans. This variability is important for comparing the improvement options to the base case because each simulation was computed with a different plan set. The effect of changes in the activities is gauged with the comparison of BC-2-1-1 to BC-1-1-1

Percentage Increase in Trips Compared to Base Case 1-1-2

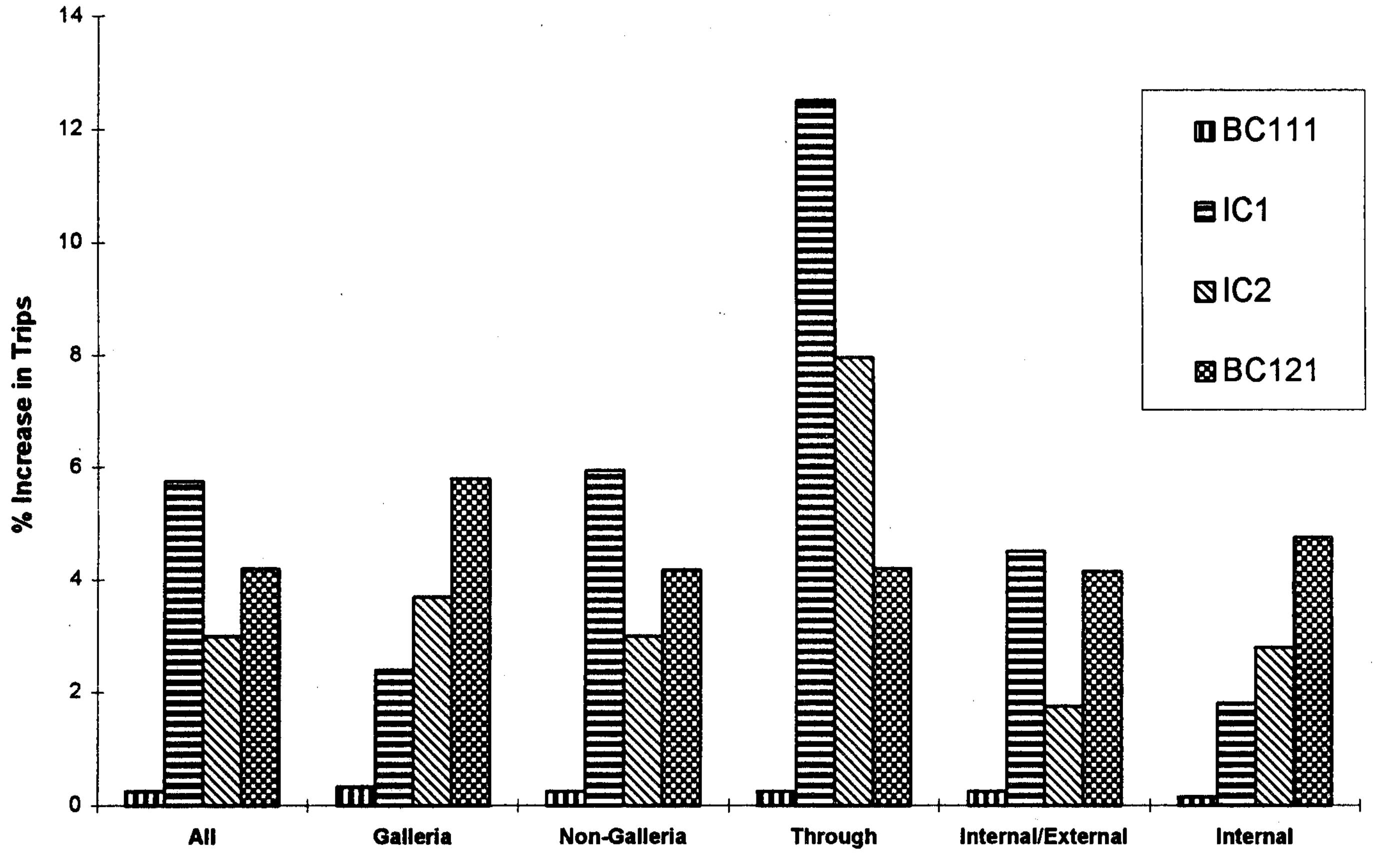
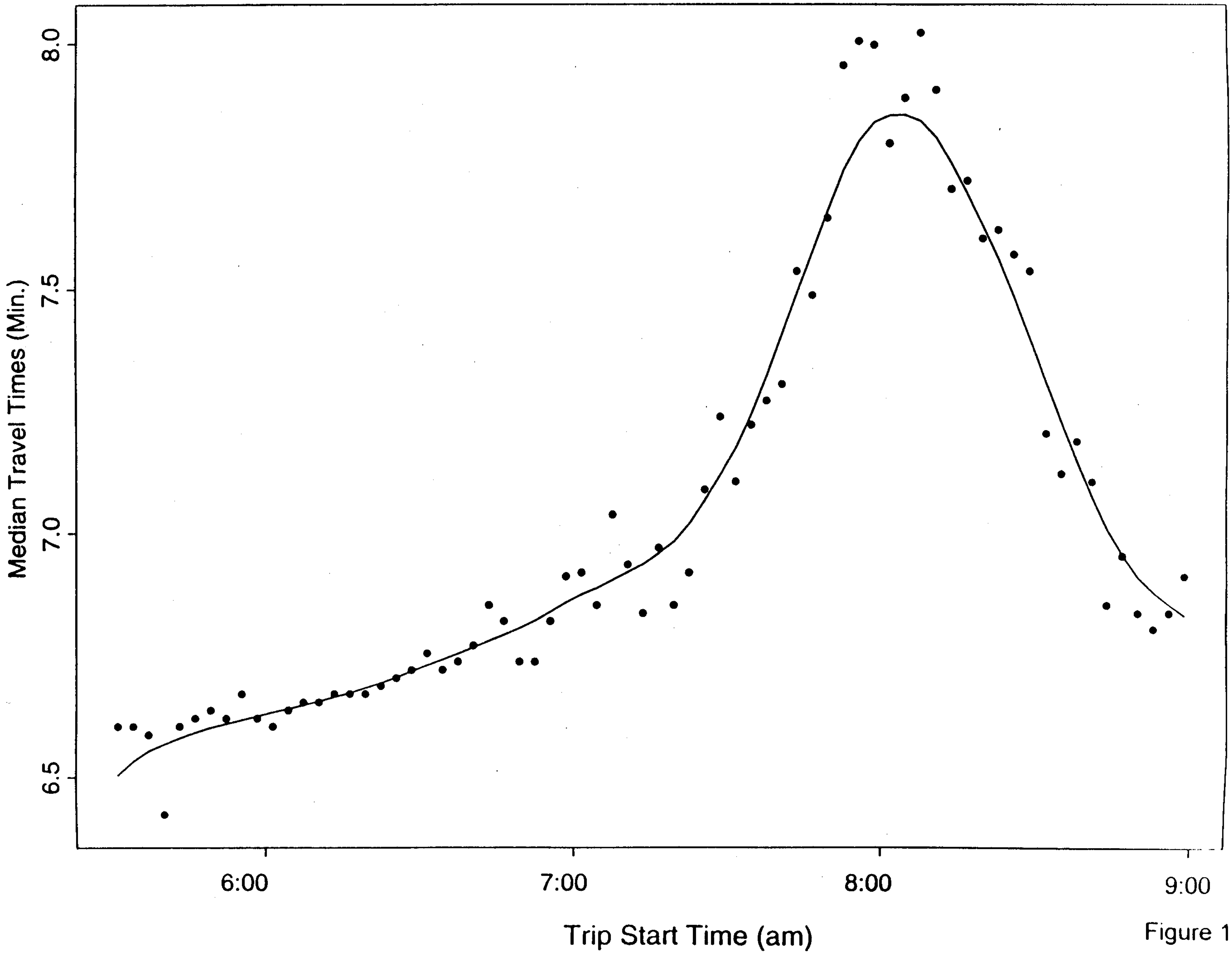
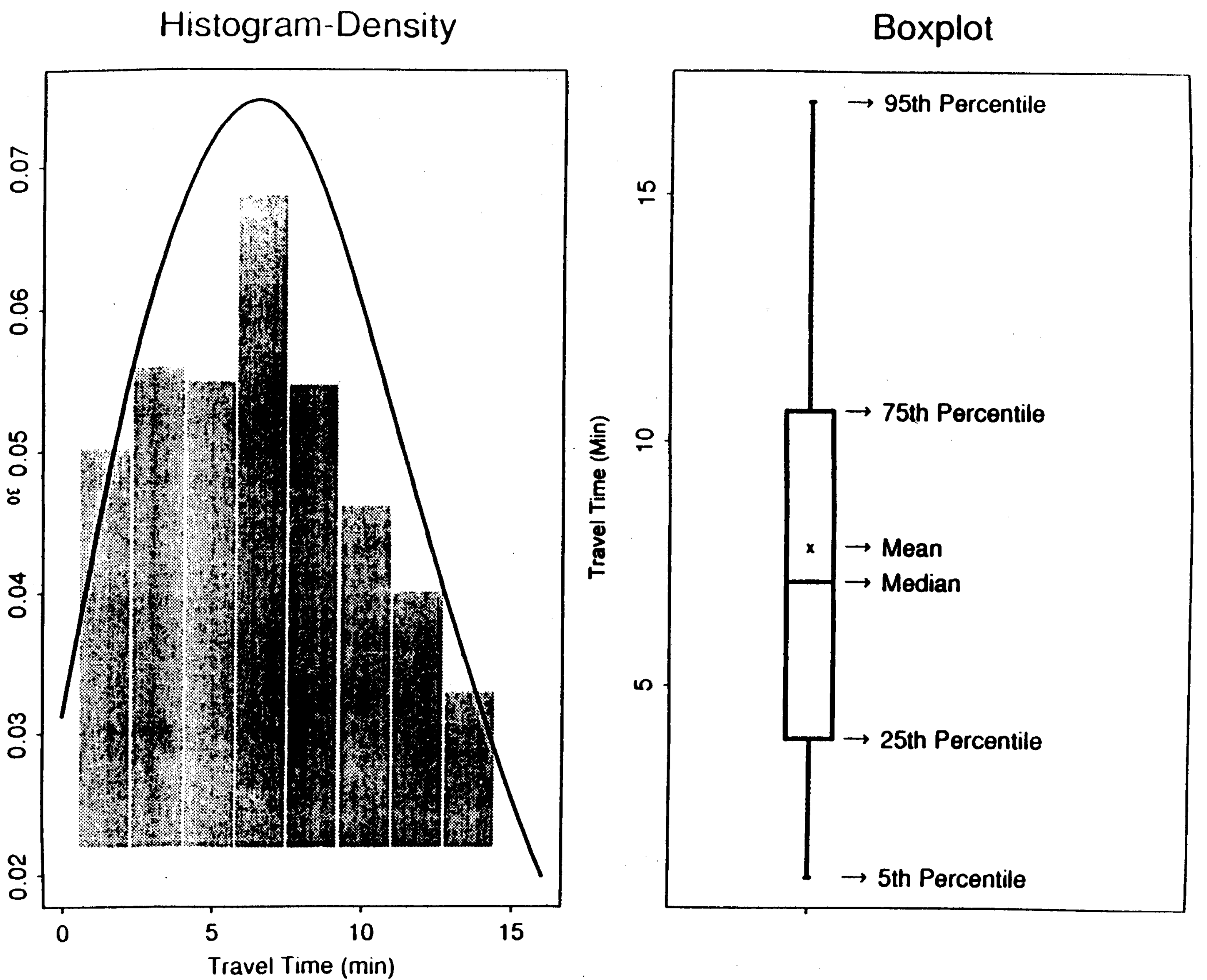


Figure 11



Smoothed Median Travel Times (3 Minute Groups)

Figure 12



Histogram-Density

Boxplot

Figure 13

Travel Times and Speeds - Base Case Comparisons: Uncertainty

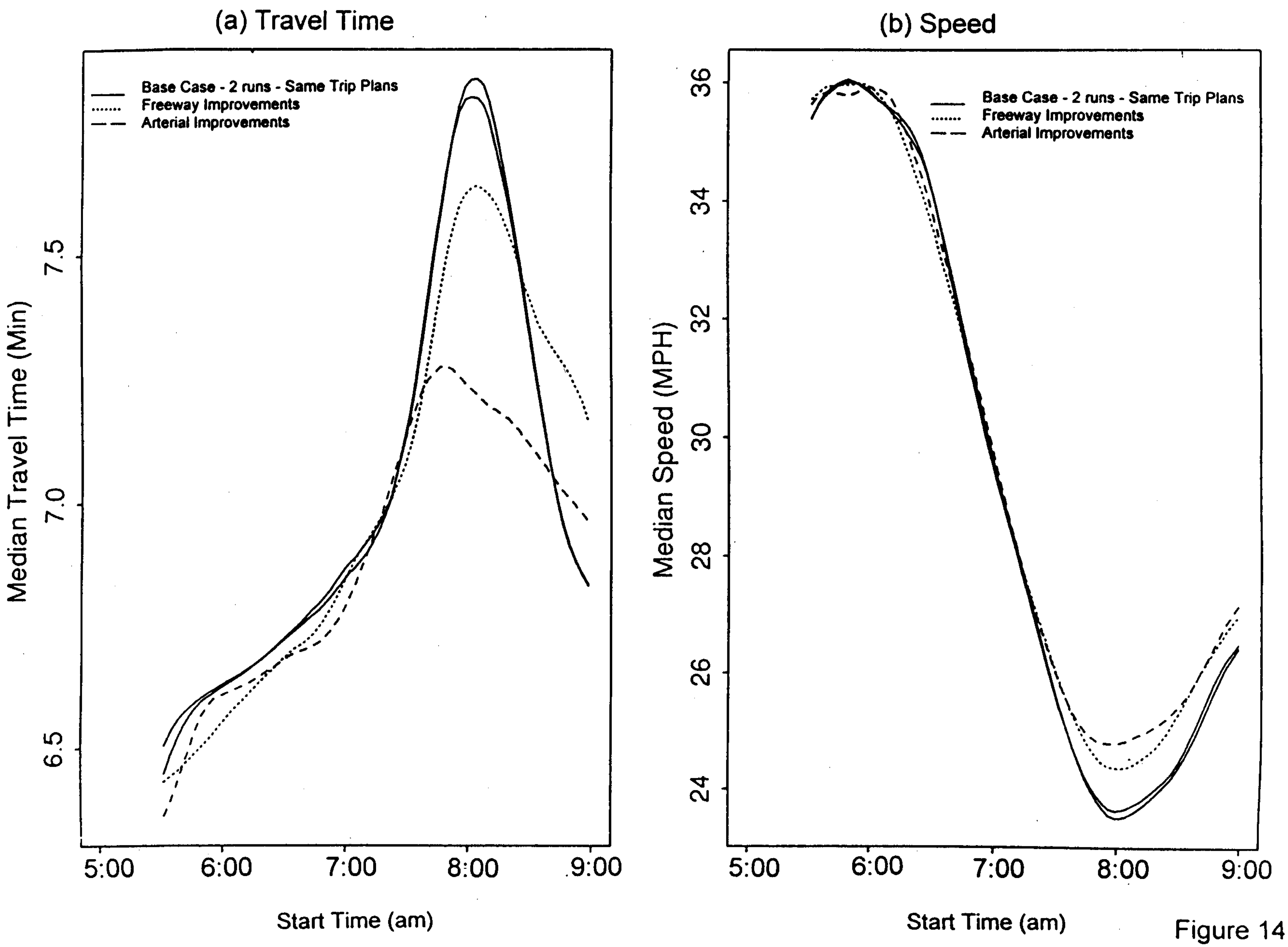


Figure 14

Figure 14 shows the median travel times and speeds for travelers in the uncertainty simulations for five minute periods during the period of analysis[2]. Differences in those plots occur for travelers whose trips started between 7:30 and 9:00 a.m. As expected, there was very little difference between simulations BC-1-1-1 and BC-1-1-2, both of which used the same trip plans. The largest differences occurred between simulations where different activities were used by the trip planner, for example BC-1-1-1 compared to BC-2-1-1. There were intermediate degrees of difference when the activities were held fixed and the trip plans changed.

Analyzing the effectiveness of the roadway improvement options required comparing performance measures for those options to similar measures for the base case. This was necessary to determine if the results of those improvements were statistically significant. To be significant, the measures of effectiveness for the improvement options had to be outside the uncertainty envelope produced by the base case simulations described here. But the trip plans and simulations for those options differed from the ones used for the base case. Therefore, the effects of different trip plans and simulations had to be eliminated from the comparisons. This was done by comparing the results for the improvement options to results for each of three base case runs, BC-1-1-1, BC-1-1-2 and BC-1-2-1. Comparison to BC-2-1-1 was not necessary because the activity conditions were the same for all other model runs.

BASE CASE: NETWORK RELIABILITY

Large day-to-day differences in travel time and speed experienced by travelers following the same route at approximately the same time every day are frustrating. The traveler's sense of the relative reliability of alternative transportation modes or travel routes may greatly affect travel decisions. For example, a traveler whose arrival time is critical and who perceives potentially widely different travel times may gradually adjust his or her departure time to assure arriving on time. Another example is a traveler who must decide between an auto trip with a very unreliable travel time and a rail trip on a separate right of way (with more reliable travel time). Depending on the time sensitivity of the trip and other characteristics of the two potential options, the relative reliability might weigh heavily in the mode choice decision.

Experiment Design

TRANSIMS provides an opportunity to estimate that day-to-day variability that demonstrates network reliability. Two methods for estimating network reliability using TRANSIMS are presented in this section. Both methods measure the reliability of the roadway network as the day-to-day difference in travel time and speed along the same route.

One of these methods compared the results of simulations of base case alternatives BC-1-1-1 and BC-1-1-2, described in the previous section. The sole difference between those alternatives was that different random numbers had been used to start the simulations. Because each traveler had the same starting time and route in both simulations, the variability in travel times or speeds, due to randomization, were measures of network reliability.

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[2] All performance data presented here and in the remainder of this report are for travel only within the case study area shown in Figure 1b.

The second method used in the case study assessed the differences in travel times and speeds when travelers with the same trip plans started their trips at slightly different times. In this method, vehicles became involved in different congestion conditions and arrived at traffic control devices at different times. In both of these methods the differences in the simulations also produced variations in lane changing and decelerations.

To assess the second method another set of base case travel plans was constructed in which the start times of the trips were changed from those in the BC-1-1-1 simulation by adding or subtracting random times less than five minutes. The simulation based on this plan set was called BC-1-1-1R. The average absolute difference in start times between the vehicles in the BC-1-1-1R plan set and the plan set for the BC-1-1-1 simulation was 2.5 minutes.

Results

The resulting travel times and average speeds in BC-1-1-1R differed from those in BC-1-1-1. The absolute values of the differences were calculated, and the percentiles of those differences versus trip starting times were computed. Figure 15 shows the differences in travel times between these two simulations for five minute periods between 7:00 and 9:00 a.m. (see Figure 15a). Note the marked difference for the ninety-fifth percentile of the difference in travel times. During that same period the variability in travelers' speeds were less than consistent (Figure 15b).

Analysis

Figure 15 demonstrates the value of using one of the upper percentiles, rather than the median, of the distribution of absolute differences in travel time as a measure of network reliability. The median measures the network satisfaction or dissatisfaction of only fifty percent of the travelers. The seventy-fifth and ninety-fifth percentiles indicate the dissatisfaction of the twenty-five and five percent, respectively, of the most affected travelers. Figure 15 shows that twenty-five percent of the travelers experience variation in travel times of more than one minute and variation in average speeds of four mph during the peak hour. The ninety-fifth percentile indicates that five percent of the population experienced a four minute variation in travel time and a nine miles per hour variation in average speeds within the case study area.

The network reliability estimated by comparing runs BC-1-1-1 and BC-1-1-1R is more realistic than the comparison of BC-1-1-1 with BC-1-1-2. This is because the former comparison accounts for changes in travelers' starting times, whereas the latter presents only random variation.

Figure 16 shows the differences in the seventy-fifth (Figures 16c and 16d) and ninety-fifth (Figures 16a and 16b) percentile estimates of travel times and average speeds for these two methods. The simulations with the adjusted start times had greater differences in travel times. For both percentile levels (seventy-five percent and ninety-five percent) the gap between the speed difference curves was greater than the gap between the travel time difference curves. The differences between these percentiles decrease as congestion increases

Base Case Network Reliability - Different Start Times (Percentiles)

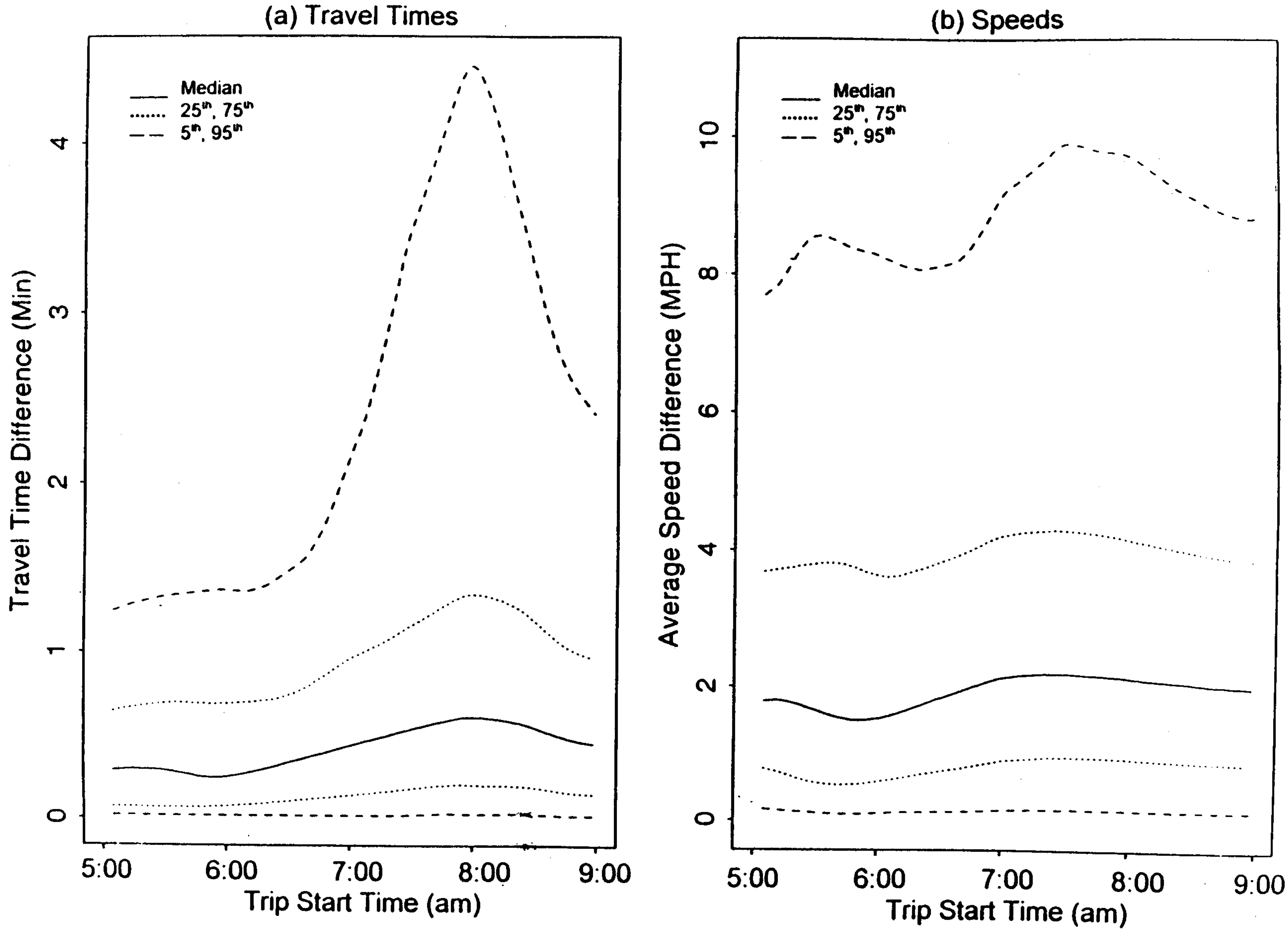
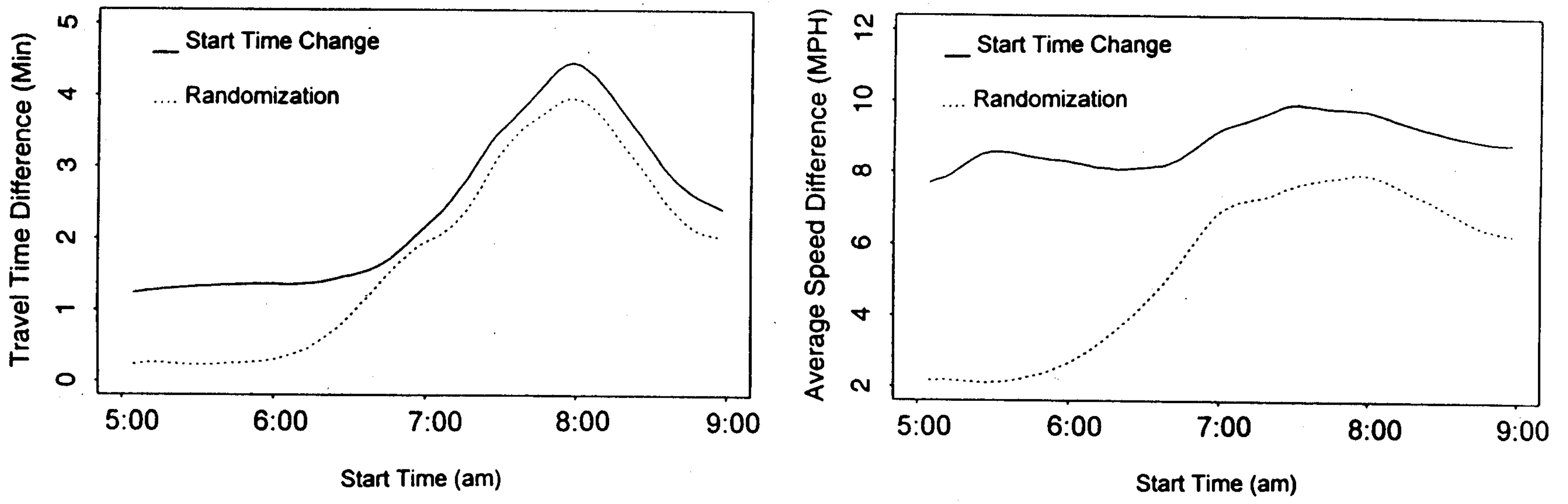


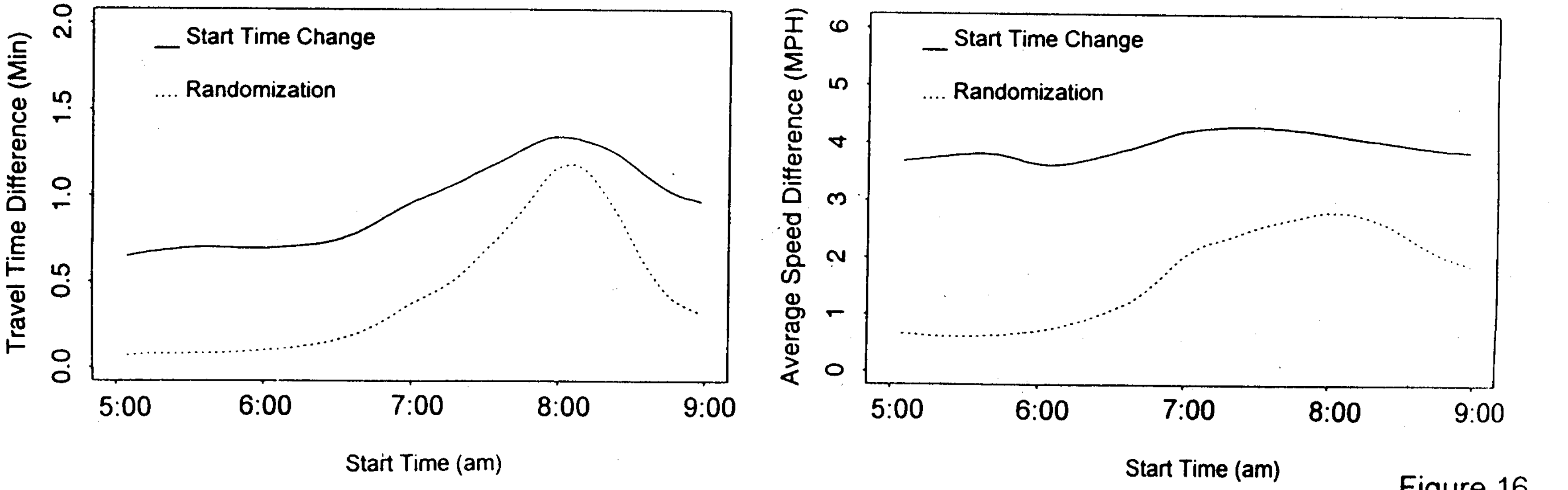
Figure 15

Base Case Network Reliability Percentile Differences - Start Time vs Randomization



(a) 95th Percentile Travel Times

(b) 95th Percentile Speed



(c) 75th Percentile Travel Times

(d) 75th Percentile Speed

Figure 16

from 7:30 to 8:30 a.m. This implies that during congestion, lane changing and speed fluctuations have almost the same effect on travel time and average speed differences as do small changes in trip starting times.

This ability to show a more robust picture of trips experienced by travelers, rather than just the mean or median differences in travel time or speed, is one of the important strengths of TRANSIMS.

INFRASTRUCTURE COMPARISONS

In this figure and all subsequent figures the three solid lines labeled BC are the three uncertainty runs; illustrating the variability in the model results. This section illustrates how TRANSIMS can be used to compare the differing impacts of alternative transportation improvements. The studies reported here examined the effects on travel behavior of two different roadway improvements. The effects reported were analyzed with data produced by the TRANSIMS microsimulation.

Travel behavior on three alternative roadway networks described previously was investigated.

1) **Base Case** (BC) – The roadway network as it was in 1990.
2) **Freeway Improvements** (IC-1) – Adding an extra lane both east- and westbound on the LBJ Freeway in the base case.
3) **Arterial Improvements (IC-2)** – Physical and operational changes to arterial streets and intersections in the base case.

All Trips Total Miles and Hours

Figure 17(a) shows the *total vehicle miles* traveled in the study area for trips starting in sequential five-minute intervals from 5:00 to 9:00 a.m. Figure 17(b) shows the *total vehicle hours* for the same periods. In Figure 17(a), it can be seen that during the morning peak period, more total vehicle miles were traveled in the freeway improvement option than in the arterial option or base case. This is probably due to trips traveling farther to use the improved freeway in order to avoid congestion on other roadways. The vehicle miles traveled in the arterial option and the base case were similar during the period studied.

Figure 17(b) shows that during much of the 5:00 to 9:00 a.m. period, the freeway option had fewer vehicle hours of travel than the base condition until about 8:00 a.m., again reflecting the time saved by using the improved, faster freeway. After 8:00a.m., the freeway option had more vehicle hours, perhaps because travel on the base case dropped dramatically as travelers reached their destinations. The arterial option had fewer vehicle hours than both the freeway option and the base case from about 7:30 until nearly 9:00 a.m., indicating that the arterial improvements were more successful in reducing congestion delay than the freeway improvement. These results indicate that both the freeway and arterial options traveled faster than trips on the base case roadways even though trips on the freeway option were longer.

Base Case Traditional Comparisons - Totals

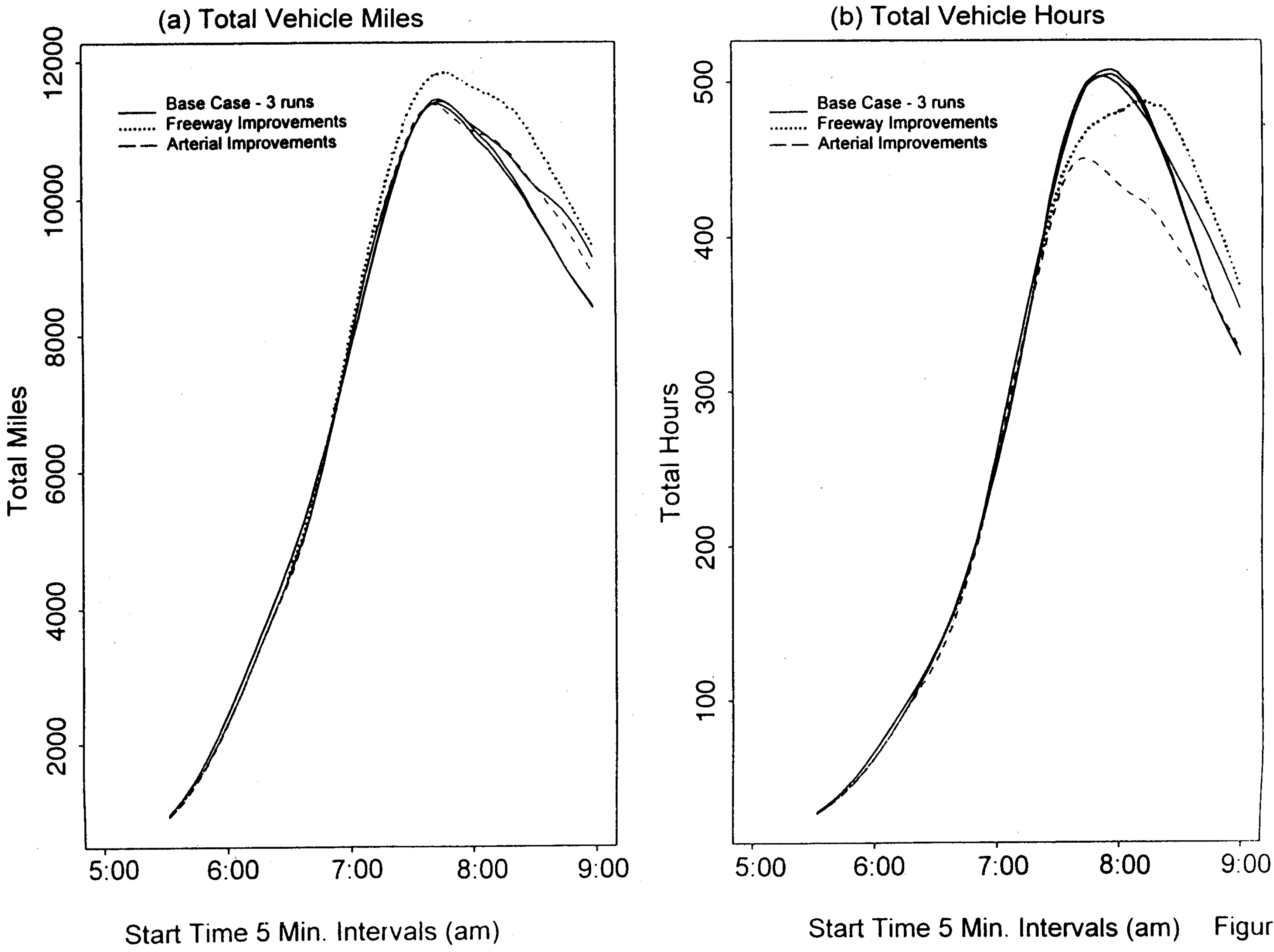


Figure 17

Figure 18(a) shows the *average completed trip distances*, and Figure 18(b) shows the *average completed trip times* for all trips starting in sequential five-minute intervals between 5:30 and 9:00 a.m. Figure 18(a) shows a similar drop in average trip distance during that period for all of the roadway options being studied. Average trip distance after 7:00 a.m. was greater for the freeway and arterial options than for the base case, reflecting the situation observed for total trips in Figure 17(a). Figure 18(b) shows that from about 7:00 until about 8:30 a.m., both improvement options have better trip times than the base case.

Figure 19(b) shows the average trip distances initially estimated by the trip planner for each of the improvement options in each five-minute start time interval. The patterns in this plot are similar to Figures 17(a) and 18(a). The curves produced by the final are shown in Figure 19(a) for comparison to the initially planned trips in Figure 19(b). The drop in planned trip lengths between 6:30 and 7:30 a.m. were caused by the trip. The line marked "IT-0" (iteration zero, i.e., the initial trip plans) in Figure 19(b) shows the average trip distances for the initial trip plans before results of the microsimulation were iterated with the trip planner to adjust trip routing. Comparing the plots in Figures 19(a) and 19 (b) demonstrates how the trip distance distribution is tightened by iterating between the microsimulation and the trip planner.

Through Trips

Figure 20(a) shows the total number of trips that started during the 5:00 to 9:00 a.m. period for each of the improvement options, and Figure 20(b) shows the percentages of those trips that went entirely through the study area. This percentage by starting time is distributed similarly to both the planned trip lengths (Figure 19(b)) and the trip lengths produced by the microsimulation (Figure 18(a) and 19(a)). These figures demonstrate that the iterations between the microsimulation and the trip planner shorten the trip distances, and some of the longer trips are routed around the study area.

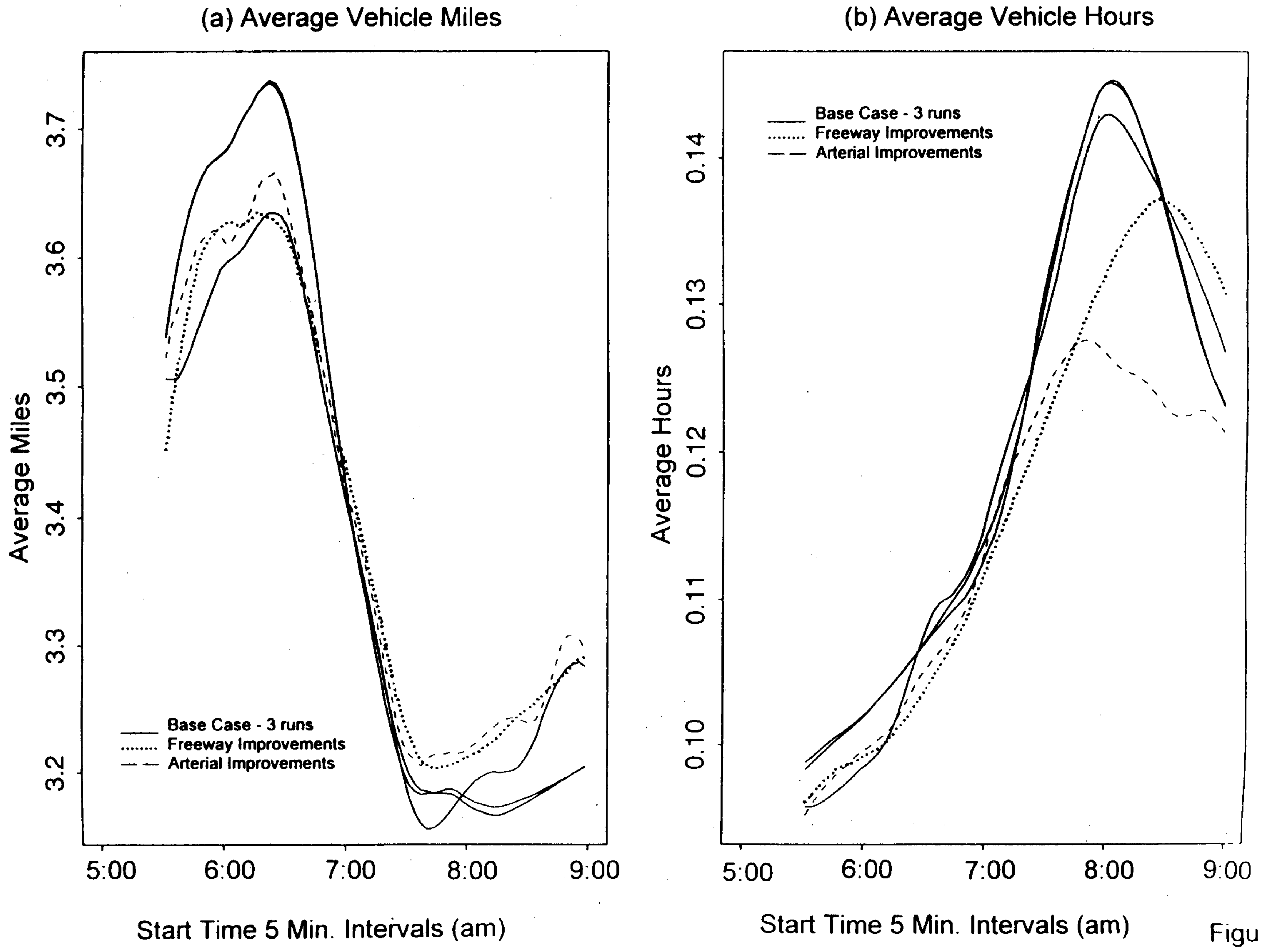
All Trips Median Times and Speeds

Median travel times and speeds are shown in Figure 21. The median values are used here because they represent a true "middle ground" since half of the observations are above and half are below the median value. The median travel times display a pattern similar to that observed for average travel times in Figure 18(b), but the significance of the two roadway improvement options is more pronounced in Figure 21(a). Figure 21(b) demonstrates how speed decreases as the number of trips increases (see Figure 20(a)) and hence congestion increases. The median speeds on the three improvement options are very similar until near 8:00 a.m. at which time speeds for the arterial option increase. Speeds for the freeway option continue dropping at that point and do not begin increasing until some time after 8:00.

Effectiveness of Distributions

One important opportunity afforded by TRANSIMS is the ability to examine distributions of measures of effectiveness rather than just averages. Thus, the analyst can consider effects on segments of the traveling population rather than being restricted to examining only the average traveler. So, in addition to the mean, measures such as the median, percentiles and other measures of effectiveness are available from TRANSIMS. The distributions presented

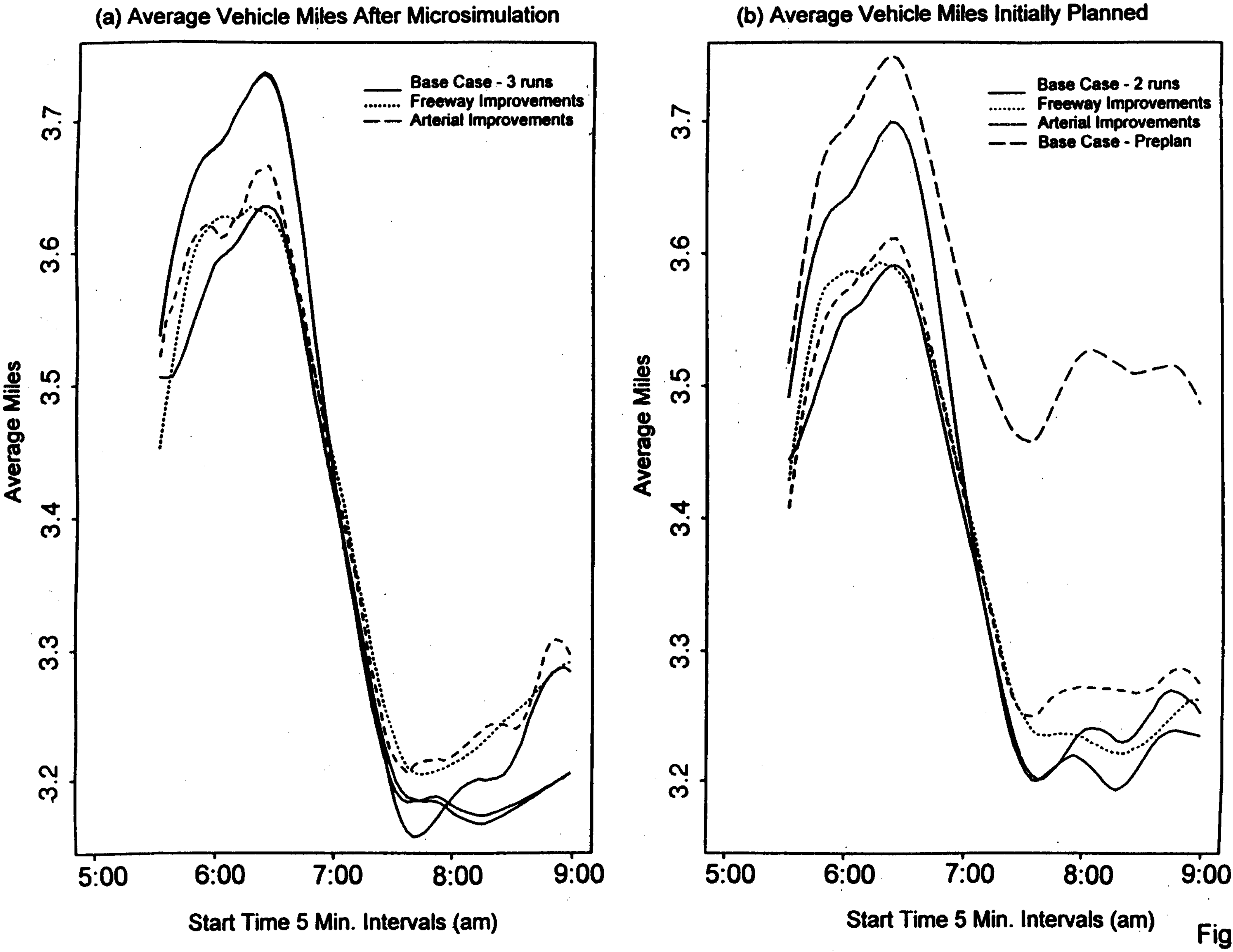
Base Case Traditional Comparisons - Averages


(a) Average Vehicle Miles

(b) Average Vehicle Hours

Figure 18

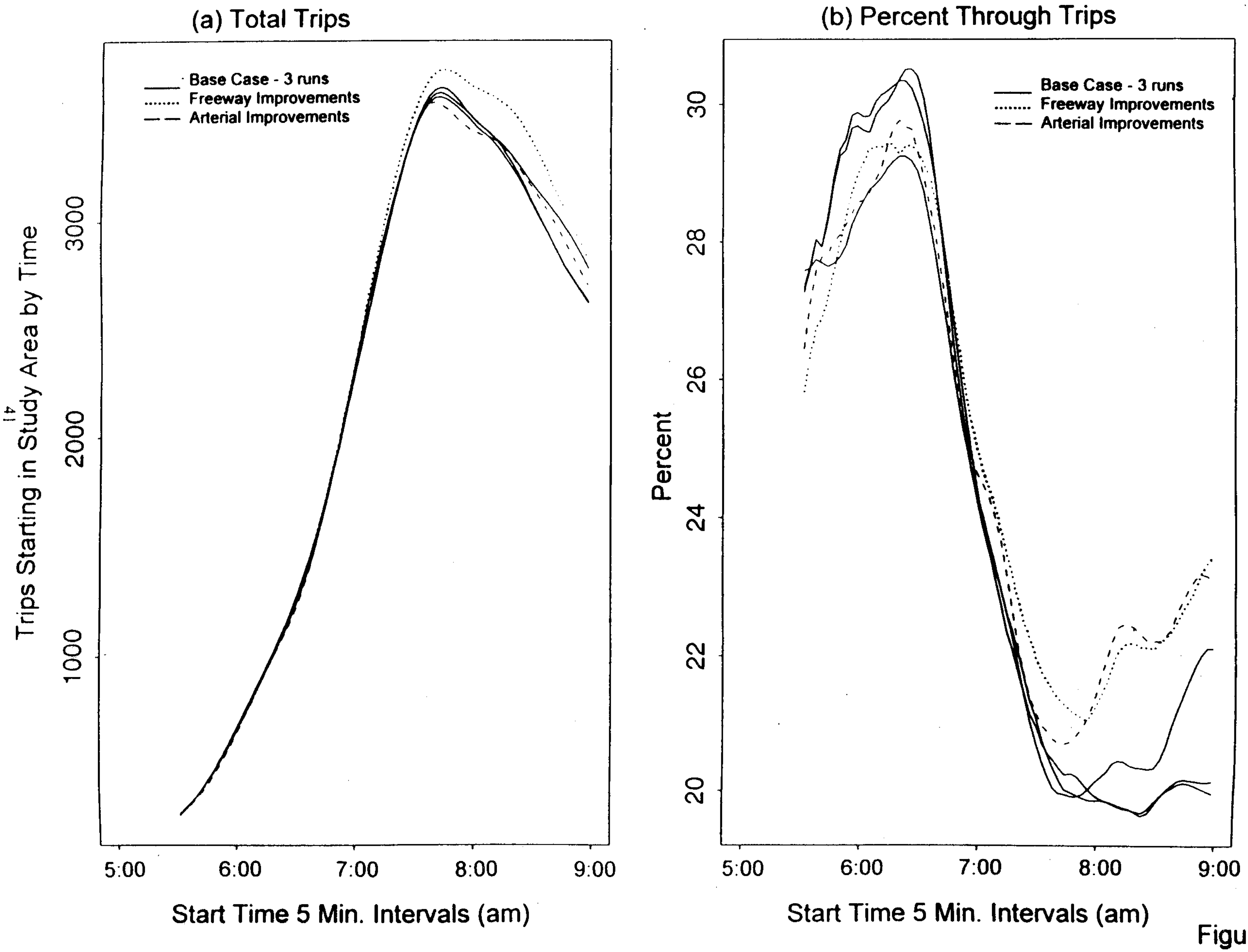
Before and After Planning Comparisons



(a) Average Vehicle Miles After Microsimulation

(b) Average Vehicle Miles Initially Planned

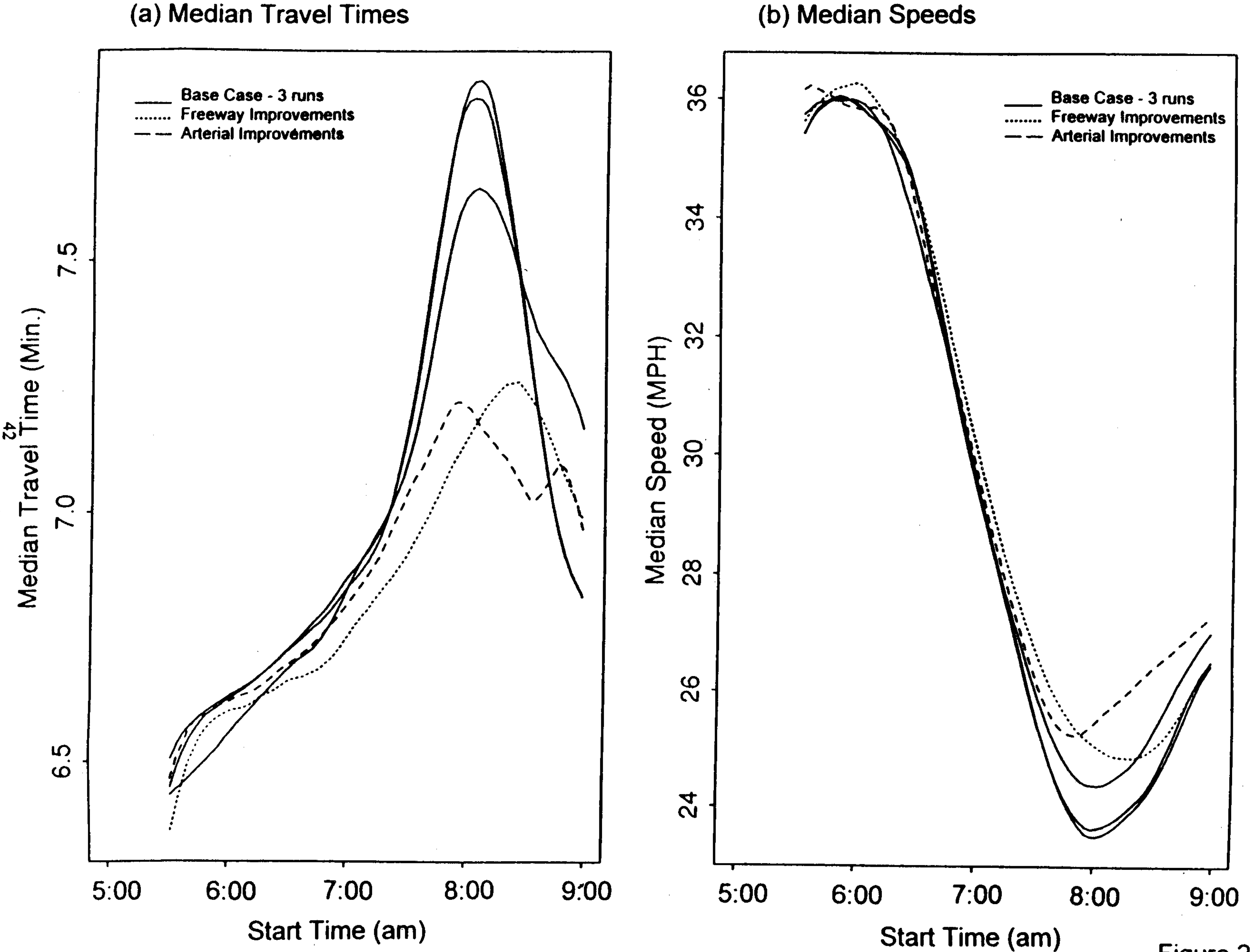
Figure 19



Trips in the Study Area

Figure 20

Comparison of Median Travel Times and Speeds


(a) Median Travel Times

(b) Median Speeds

Figure 21

Travel Time Comparisons Between Improvement Options

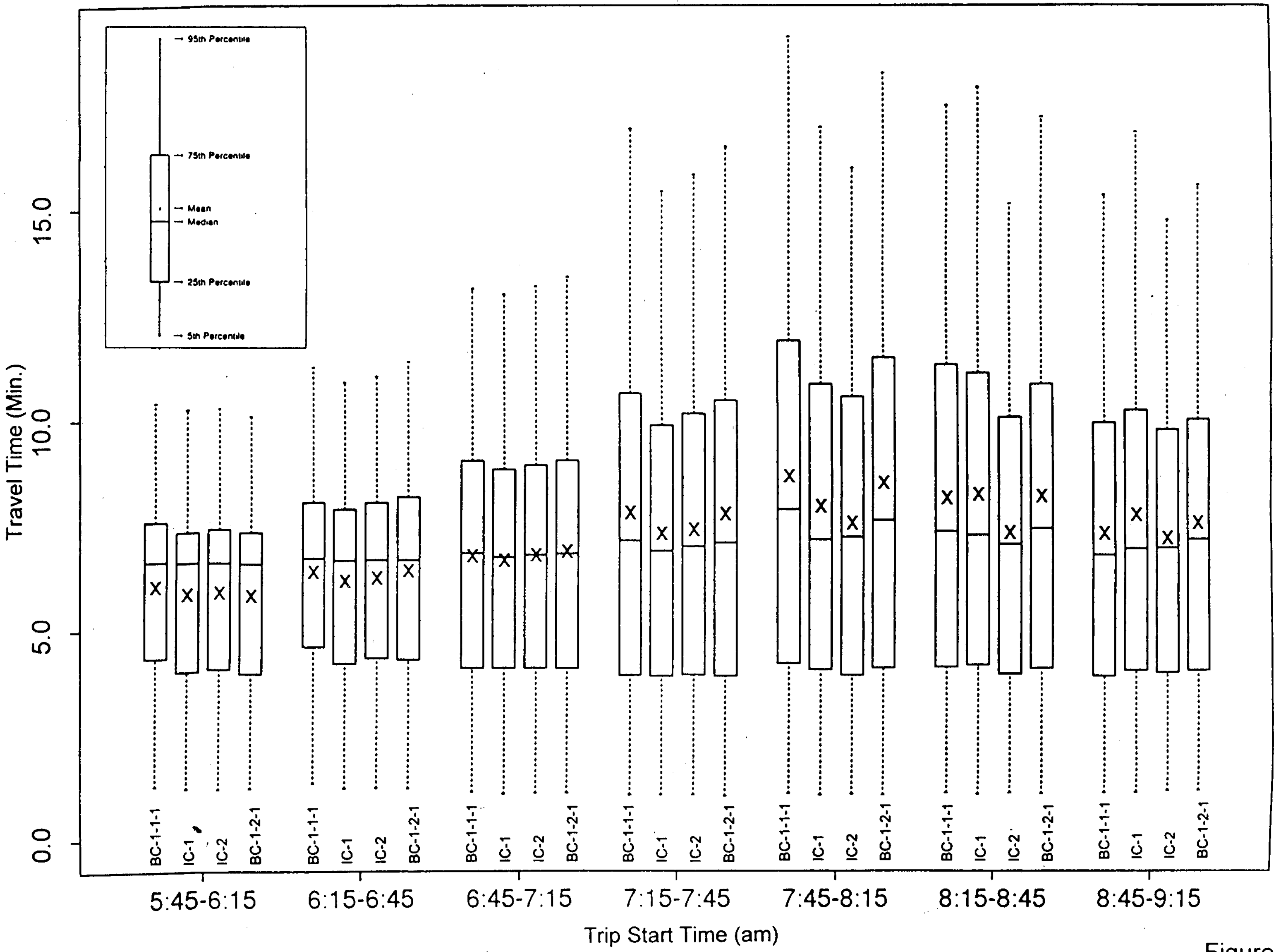
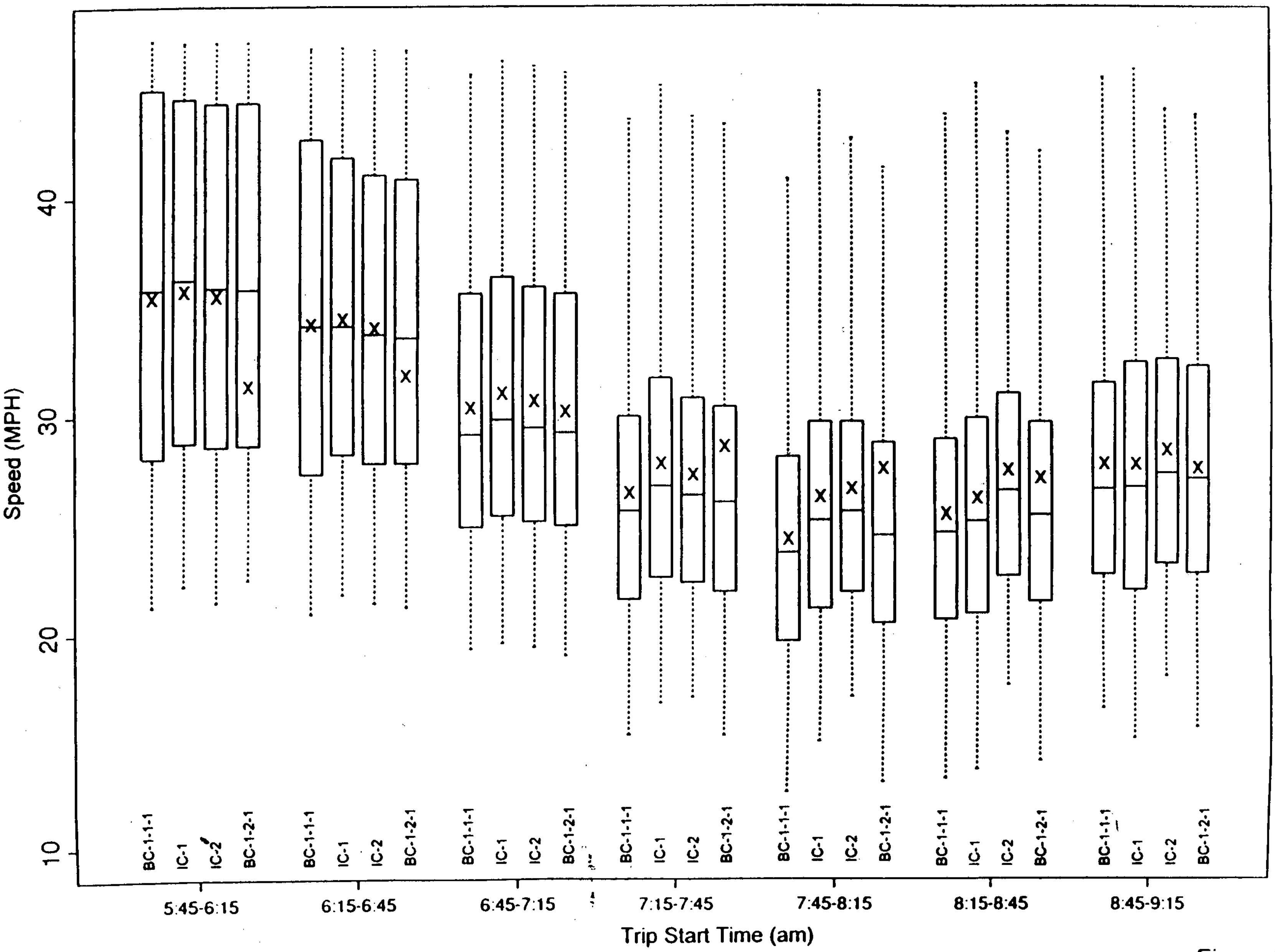


Figure 22



Speed Comparisons Between Improvement Options 30 Minute Intervals

Figure 23

previously in this report show how average travel times can decrease while travel times of some travelers increase. This situation can only be examined using the distributions of such measures.

Speed Comparisons

Distributions of travel times and speeds are displayed in box plots in Figures 22and 23 for two base case runs (BC-1-1-1 and BC-1-2-1) and the two roadway improvement options. The box plots show subtle changes in the distributions in half-hour segments between 7:00 and 9:00 a.m. In particular, the box plots display interesting variations among the percentiles of greater travel times and the percentiles of lower speeds for the roadway improvements. Those variations indicate that the greatest improvements in travel in the study area can be made by reducing the longest travel times and increasing the slowest speeds, and the roadway improvements are intended to accomplish that.

Speed and Time Percentiles

To investigate the changes that the roadway improvements cause, the ninety-fifth and seventy-fifth percentiles of travel times and speeds were computed for all improvement options. Plots of the travel times are shown in Figures 24(a) and 24(b). The upper percentiles of travel times correspond to travelers with the longest travel times. Both roadway improvement options reduce the ninety-fifth and seventy-fifth percentile travel times, but the arterial improvements have greater impact than the freeway option. There is also a shift in the time when the highest travel times occur between the three improvement options.

The fifth and twenty-fifth percentiles of the speed distributions, which represent travelers with the slowest speeds, are shown in Figures 24(c) and 24(d). Those plots are consistent with the upper percentiles of the travel times in that the arterial improvements have a greater impact than the freeway improvements. The greater impact of the arterial improvements is more pronounced in the plots of the percentiles than in the mean or median speeds.

Travel Time and Speed Differences

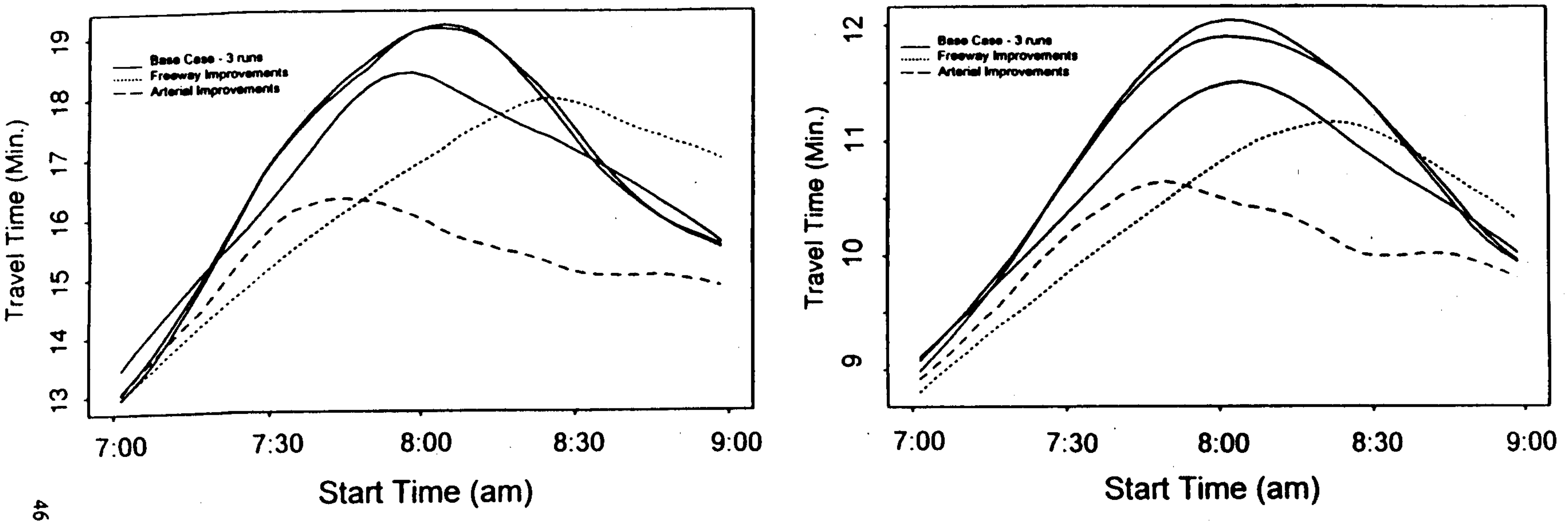
It is possible for a roadway improvement to increase average travel time but reduce the day-to-day variability so network reliability can be used as a measure of effectiveness along with the time and speed distributions. To estimate the network reliability for each of the roadway improvement options, the starting time of each traveler was modified randomly within five minutes of their original starting time. Then the upper percentiles of the absolute differences in each traveler's travel time and speed were obtained. Figure 25 shows those percentiles. From Figure 25, it is clear that the arterial option, more than the freeway option, decreases day-to-day variability in both the longest travel times and the slowest speeds.

After 7:45 a.m. for all travelers, the arterial improvements were more beneficial than the freeway option. Both roadway improvement options decreased travel times and increased speeds when compared to the base case; they were also more reliable than the base case.

Travel Times and Speeds Comparison Between Improvement Options - Percentiles

(a) Travel Time: 95th Percentiles

(b) Travel Time: 75th Percentiles



(c) Speed: 5th Percentiles

(d) Speed: 25th Percentiles

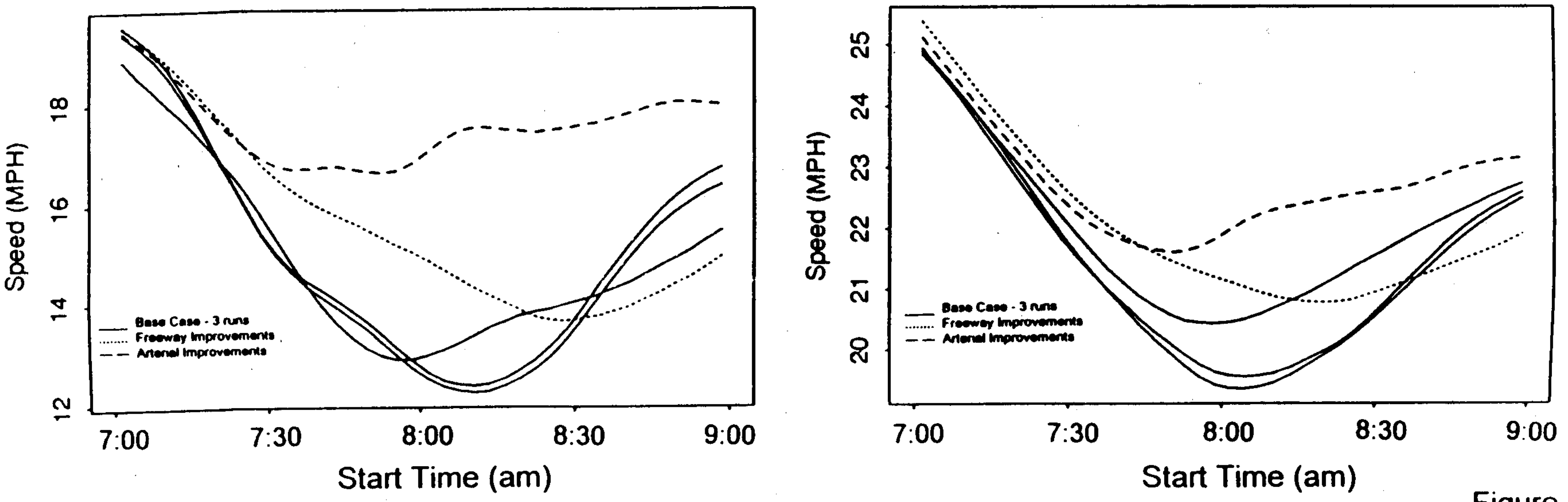
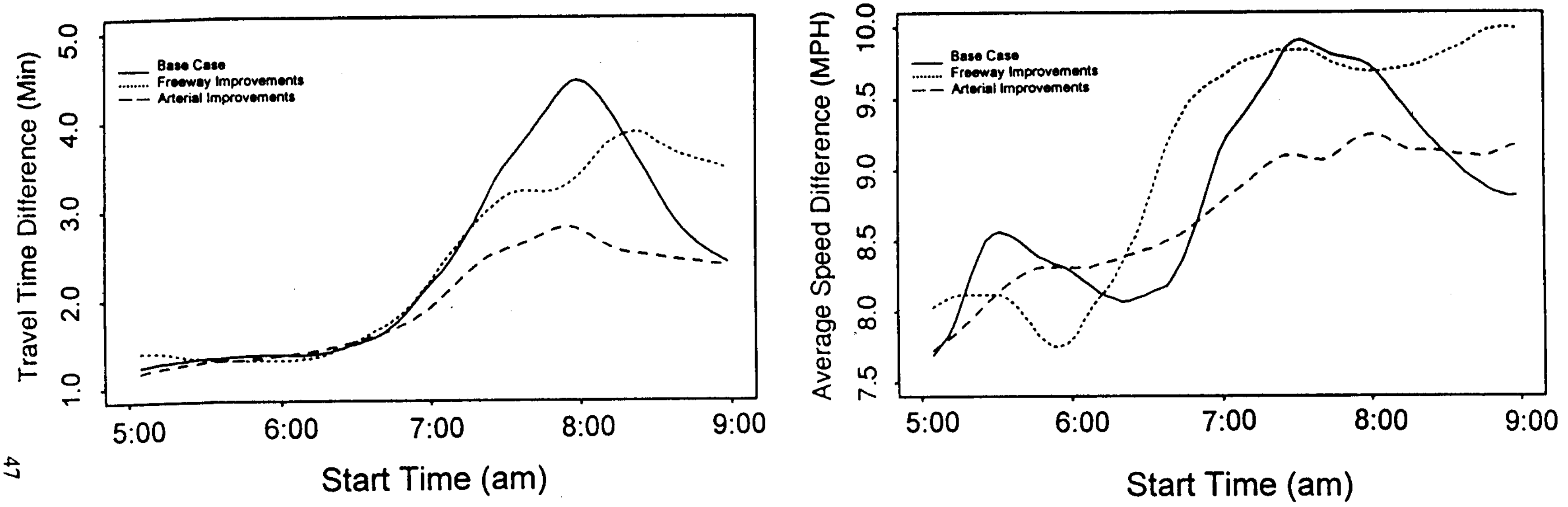


Figure 24

Reliability: Comparison Between Improvement Options - Percentiles



(a) Travel Time: 95th Percentiles

(b) Speed: 95th Percentiles

(c) Travel Time: 75th Percentiles

(d) Speed: 75th Percentiles

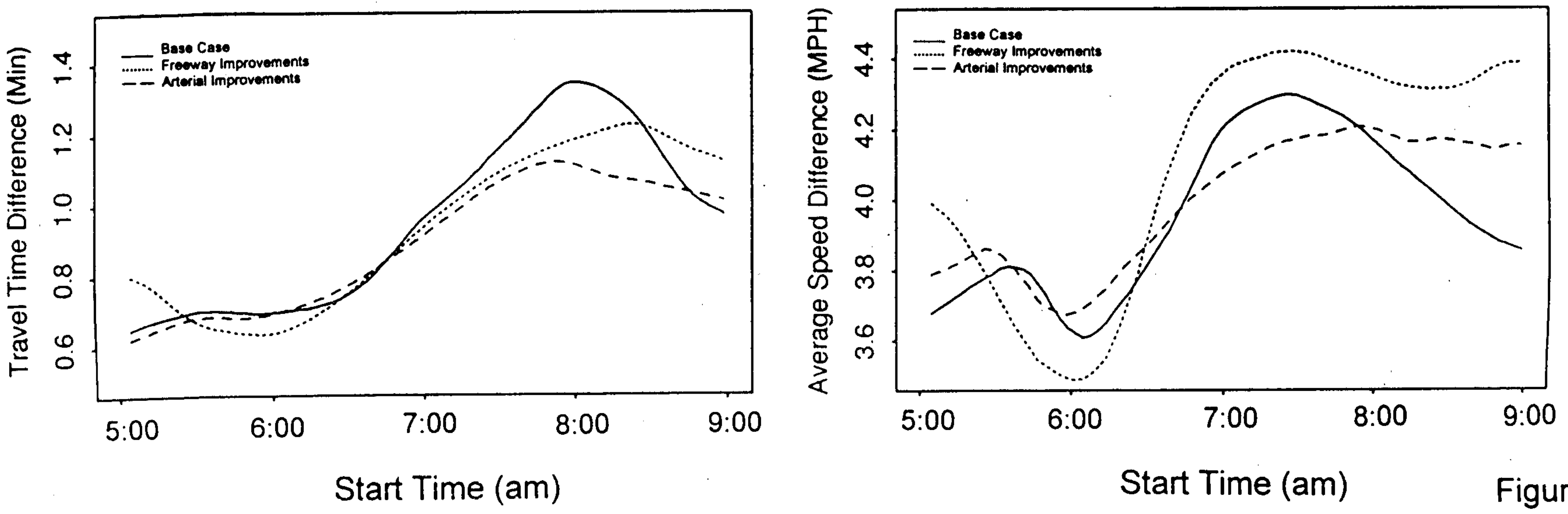


Figure 25

EQUITY ANALYSIS: GALLERIA AND NON-GALLERIA TRAVELERS

Methods for studying equity analysis or differential impact analysis are presented in this section. These methods involve examining the median and percentiles of travel times and speeds experienced by different groups of travelers. The upper percentiles of travel times and the lower percentiles of speeds are critical but typically unused in traditional analyses. Before judging one roadway improvement to have an adverse or beneficial effect on one or another portion of the population, it is wise to make sure that this effect pertains to a high percentage of the population. Studies of means and medians do not reveal those facts. The case study examined the effects of the freeway and arterial improvements on two sub-populations of travelers: travelers whose *either origin or destination was in the Galleria Mall* and other travelers whose *origins and destinations were not* in the Galleria. In Table 2 it was shown that Galleria travelers were approximately five percent of all travelers in the study area.

Simulations of travel on the three transportation networks (BC, IC-1 and IC-2) were performed for the following two sub-populations of travelers:

1) **"Non-Galleria only"** – Galleria travelers were removed from the population of all travelers .

2) **"Galleria only"** – Galleria travelers were simulated alone.

Travel times and speeds produced by simulations of the Galleria-only and non-Galleria-only trips were compared to the results of the simulations of all trips. These same three trip plans were used for the simulations on all three networks. The travelers' routes in these simulations were *not replanned,* as in the earlier simulations, in order to measure the effect one sub-population had on another. The results of these simulations were compared among several combinations of sub-populations and roadway improvement options.

Median Travel Times and Speeds

The median travel times of the non-Galleria and Galleria travelers are given in Figure 26. These plots show the results of simulating non-Galleria only and Galleria only trips. Also shown are the results for non-Galleria and Galleria travelers when simulated along with all other trips, i.e., competing for space on the roadways. The plots of non-Galleria travel times in Figure 26(a) are interesting. Both roadway improvement options produced better travel times for non-Galleria trips between 7:30 and 8:30 a.m. than would result from removing Galleria travelers from the simulation. The freeway improvement option was more effective than the arterial option for reducing travel times of non-Galleria travelers until approximately 8:15 a.m. After that time, the arterial option slightly dominated the freeway option.

Figure 26(b) shows that before 8:00 a.m. the freeway improvement option produced only slightly better travel times for Galleria travelers than the arterial option. After 8:00, however, the arterial option proved much better than the freeway option. Figure 26(b) also shows that neither roadway option improves travel times for Galleria travelers as well as completely

Median Travel Time Comparisons Between Improvement Options

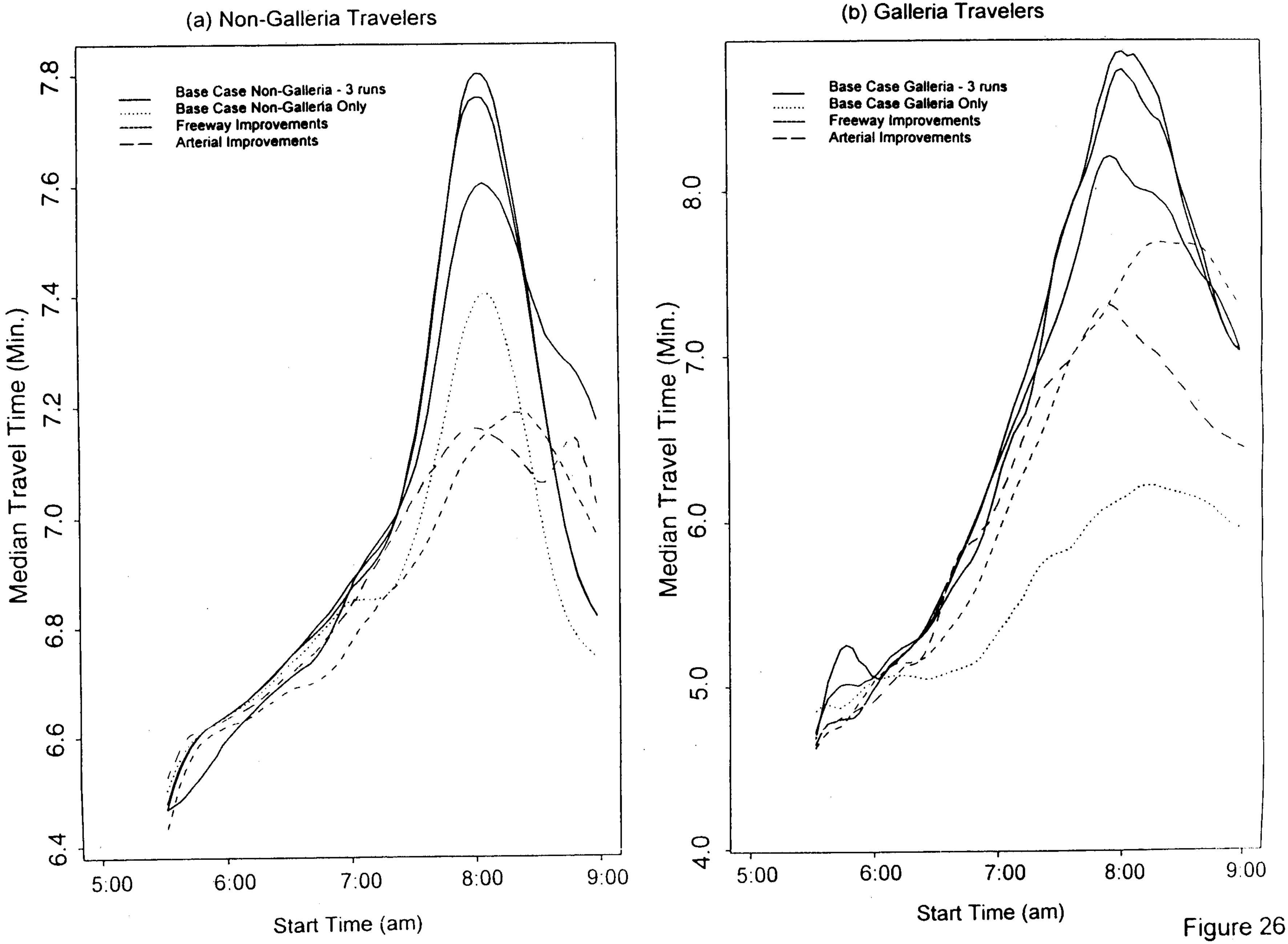


Figure 26

removing non-Galleria trips from the network (an admittedly trivial observation).

Figure 27 shows the median speeds of travelers in the two sub-populations. After 8:00 a.m., travelers from both sub-populations had higher speeds in the arterial improvement option. Before 8:00 a.m., slightly higher speeds were seen on the freeway option.

Percentile Travel Times and Speeds

Figure 29 shows the upper percentiles of travel times and the lower percentiles of speeds for non-Galleria travelers are shown in Figure 28. The patterns of the percentiles differ from those of the medians. Here, the relative advantage of the arterial option started earlier in the morning. The higher the travel time percentile or the lower the speed percentile, the earlier the arterial option dominated. This means that the arterial option is more effective in reducing travel times and increasing slow speeds of non-Galleria travelers.

A similar but more pronounced result was observed for the higher percentiles of travel times and the lower percentiles of speeds for Galleria travelers in Figures 29(a) and 29(c). Once again, the arterial option dominated the other roadway situations beginning at 7:30 a.m.

Overall, the freeway option slightly improves the travel times and speeds of both Galleria and non-Galleria travelers but only very early in the morning. The arterial option increases the speeds and decreases travel times of both sub-populations thereafter. With the arterial option longer trips and trips with slower speeds are better if made by 7:30 a.m. for Galleria travelers and by 7:45 a.m. for non-Galleria travelers. Both improvement options are better for non-Galleria travelers than removal of Galleria travelers from the traffic stream. The reverse is not true for Galleria travelers.

INFRASTRUCTURE COMPARISONS: SUPPLEMENTAL STUDIES

There is a wealth of data in the output of the case study simulations. The analyses reported to this point have only scratched the surface of available possibilities. This section amplifies the results given so far and suggests possible additional analyses to persons interested in pursuing them.

The baseline simulations with one sub-population removed from the simulation are available for the Galleria and non-Galleria sub-populations only. However, even in the absence of the baseline simulations, the effects of the roadway improvement options on other sub-populations are interesting. This is demonstrated by comparing the results for travelers who have trip ends in the study area to the results for those who do not. In this case the total population is partitioned into the three groups cited previously:

1) **Through trips** – Trips that travel entirely through the study area.
2) **Internal-External trips** – Either trip origin or destination in the study area, but not both.
3) **Internal trips** – Both the trip origin and destination in the study area.

Median Speed Comparisons Between Improvement Options

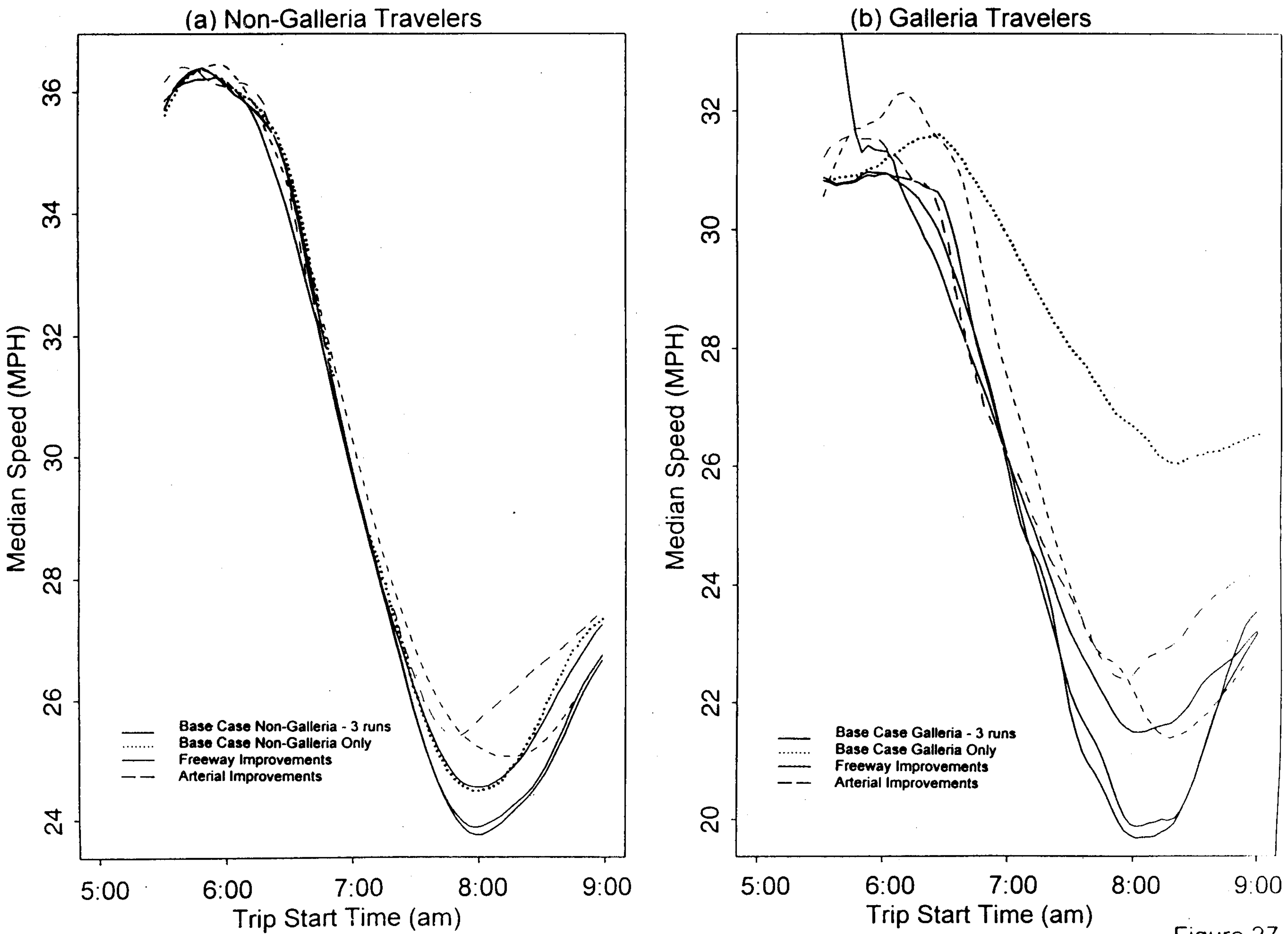
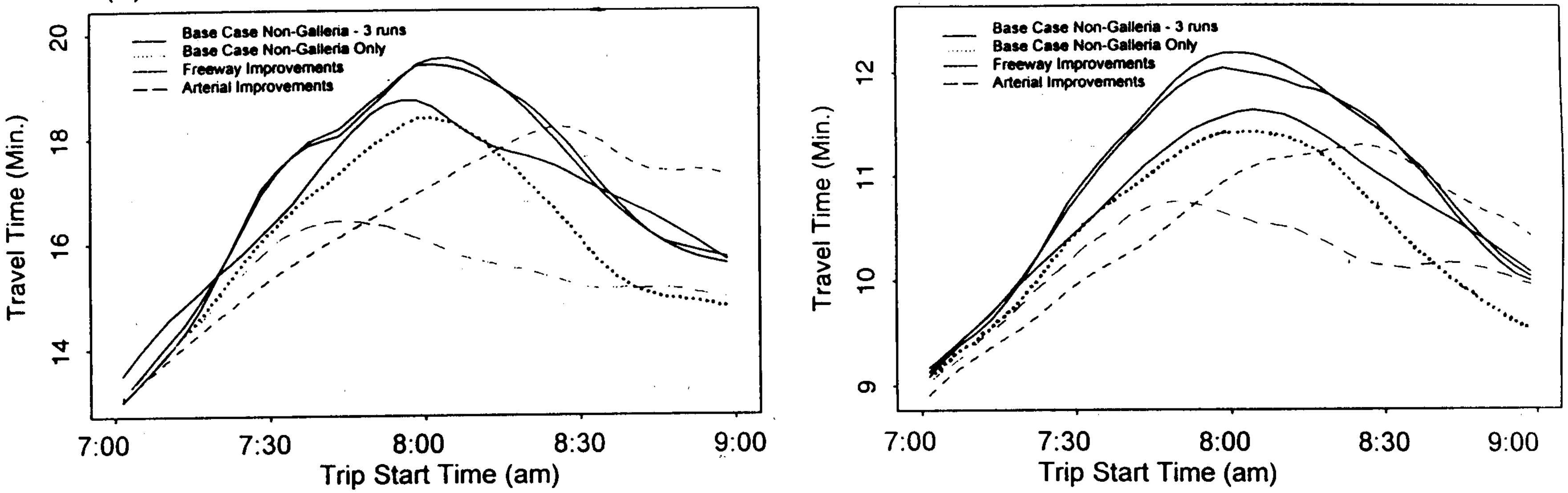


Figure 27

Non-Galleria Trip Comparisons of Travel Time and Speed Between Improvement Options

(a) Travel Time: 95th Percentiles

(b) Travel Time: 75th Percentiles



(c) Speed: 5th Percentiles

(d) Speed:25th Percentiles

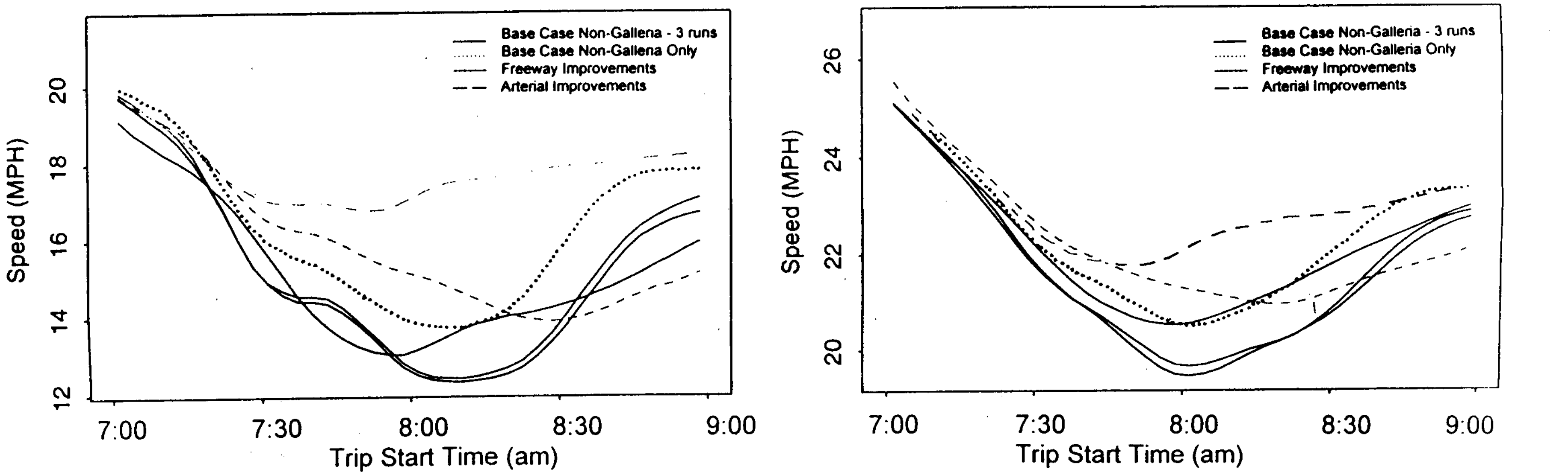
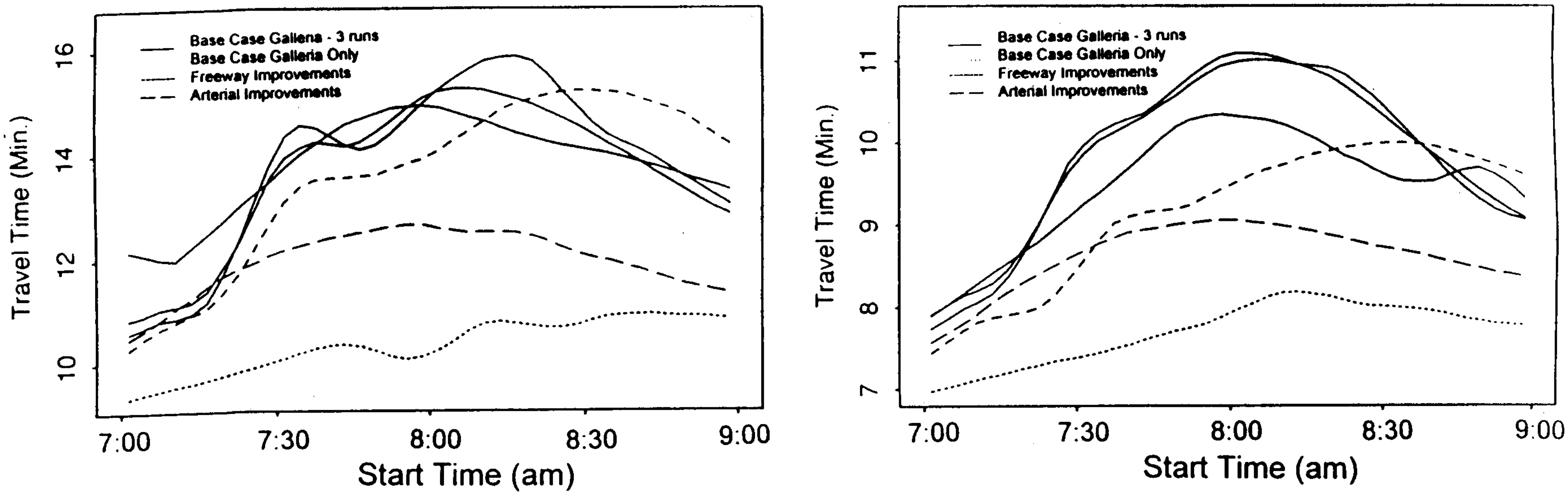


Figure 28

Galleria Trips - Percentile Comparisons of Travel Times and Speeds

(a) Travel Time: 95th Percentiles

(b) Travel Time: 75th Percentiles



(c) Speed: 5th Percentiles

(d) Speed: 25th Percentiles

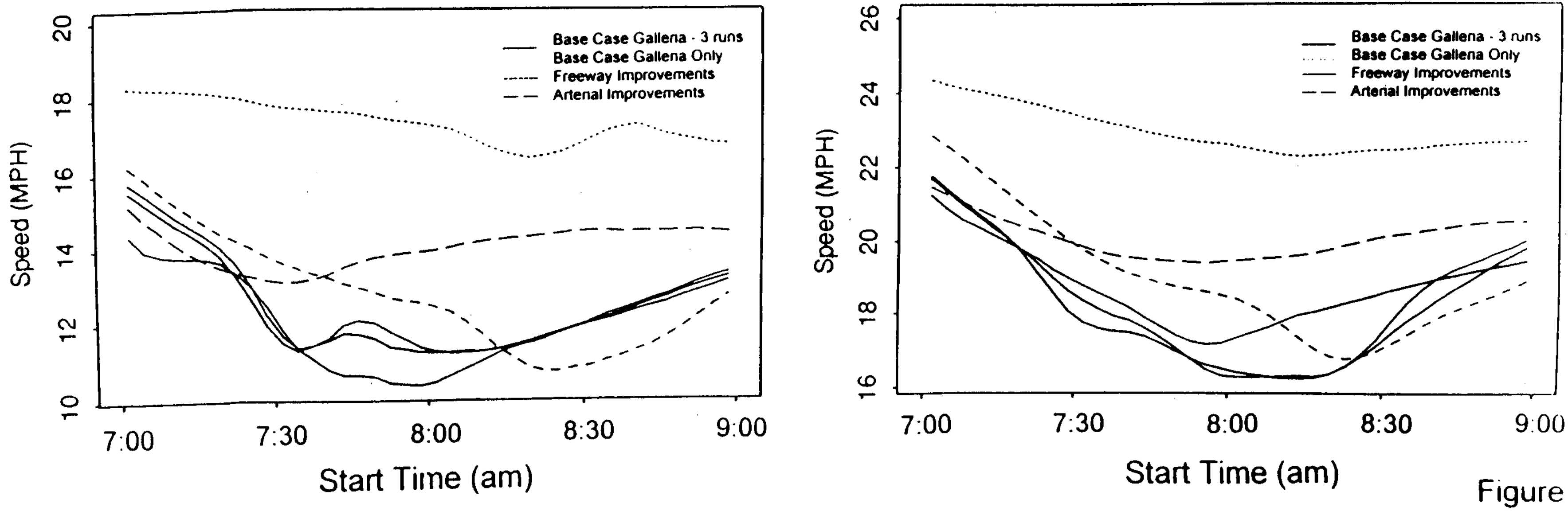


Figure 29

Plots of the median travel times and speeds for these three sub-populations from 5:00 to 9:00 a.m. are shown in Figures 30 and 31 . Figures 30(a) and 31(a) show the median travel times and speeds for Internal trips, Figures 30(b) and 31(b) show the same for internal-external trips, and Figures 30(c) and 31(c) show the same for through trips.

Figures 30(d) and 31(d) show median travel times and speeds for all trips traveling in the study area. The different effects of the roadway improvement options on the three sub-populations is striking. The arterial option improved the travel time and speed of both the internal and internal-external sub-populations. But the greatest effect of the arterial option was reduction of travel times after 7:30 a.m. Both options improved median speeds and travel times of through trips, and the improvements are approximately the same but shifted in time.

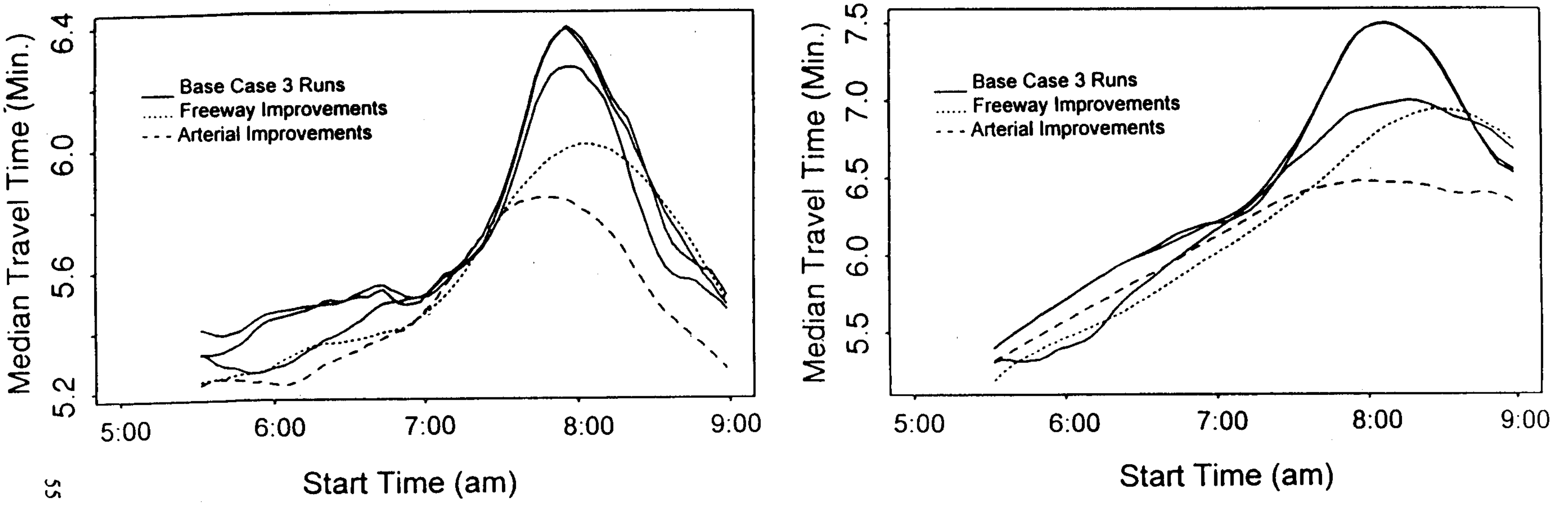
Other partitions of the travelers could be studied in a similar manner. For example, one could create sub-populations that use the LBJ Freeway and those who do not. Or the population could be divided into eight hundred sub-populations based on the traveler's zone of origin or destination. The population could also be partitioned according to traveler demographics such as income. Each of those partitions would give additional information about the travel characteristics of the potential improvement options being considered.

The results of the TRANSIMS simulations are collected on every link in small time intervals. The sampling and output times to collect that information are specified by the analyst. In this case study link attributes were collected every three minutes. The data collected were link travel times (from which average speed was calculated), travel time variability, the number of vehicles exiting each link, and the vehicle density for 150-meter segments on the link. These data may be used to investigate the effects of changes in the base conditions of the simulation for a particular link or several links.

A series of links on Alpha Road and the LBJ Freeway were chosen to demonstrate an analysis based on some of the link data. Additional lanes were added to Alpha Road in the arterial option and to the freeway in the freeway option. Figures 32 through 35 show the speeds and traffic volumes on those roadways. Those plots present data for two half-hour time periods, 7:30 to 8:00 a.m. and 8:00 to 8:30 a.m. for traffic in both directions. The complexity of this type of analysis is apparent from the figures. The LBJ Freeway speeds in Figure 32 show different results depending on the time of day, the direction of travel, and the location on the roadway for which data were collected. There are two times, locations, and directions where one or the other of the improvement options out-performs the base case roadways. One of those is in the west-to-east direction prior to the Dallas North Tollway between 8:00 and 8:30 a.m. At that location, speeds on the freeway option were much greater than on either the base case or the arterial option. For both time periods in the east-to-west direction both the freeway and arterial options, improve travelers' speeds on links prior to Preston Road.

The traffic on the LBJ Freeway is represented in Figure 33. As expected, the flows were greatest for the freeway improvement option.

All Trips: Comparisons of Median Travel Time Between Improvement Options


(a) Internal Trips

(b) Internal-External Trips

(c) Through Trips

(d) All Trips

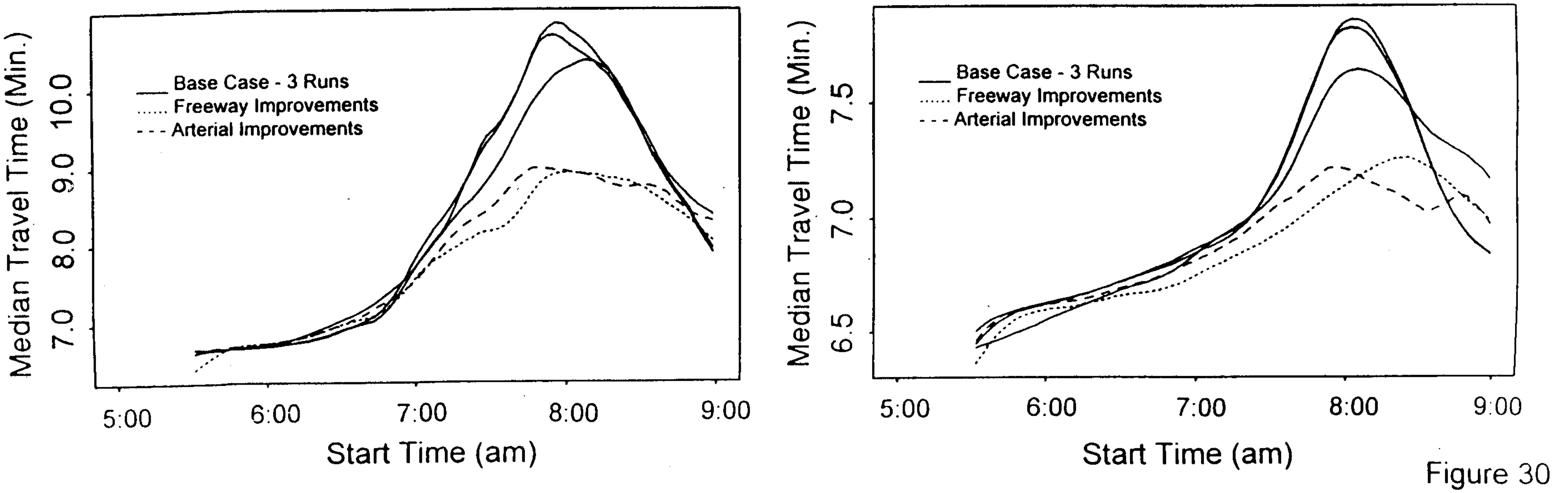
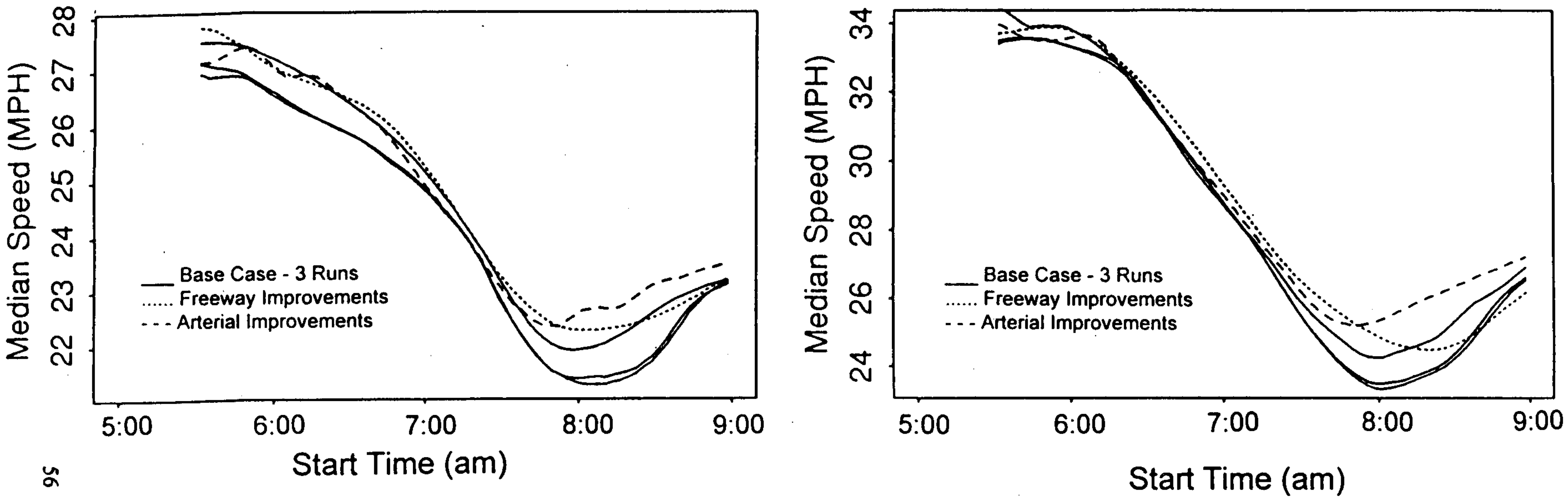


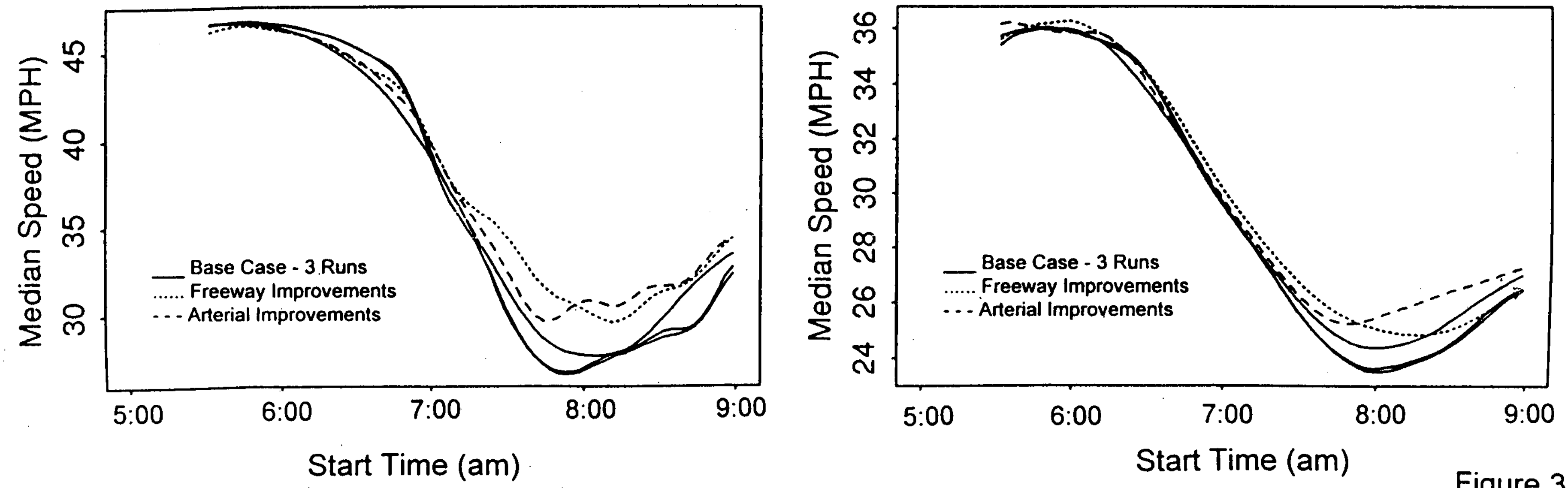
Figure 30

All Trips: Comparisons of Median Speeds Between Improvement Options



(a) Internal Trips

(b) Internal-External Trips

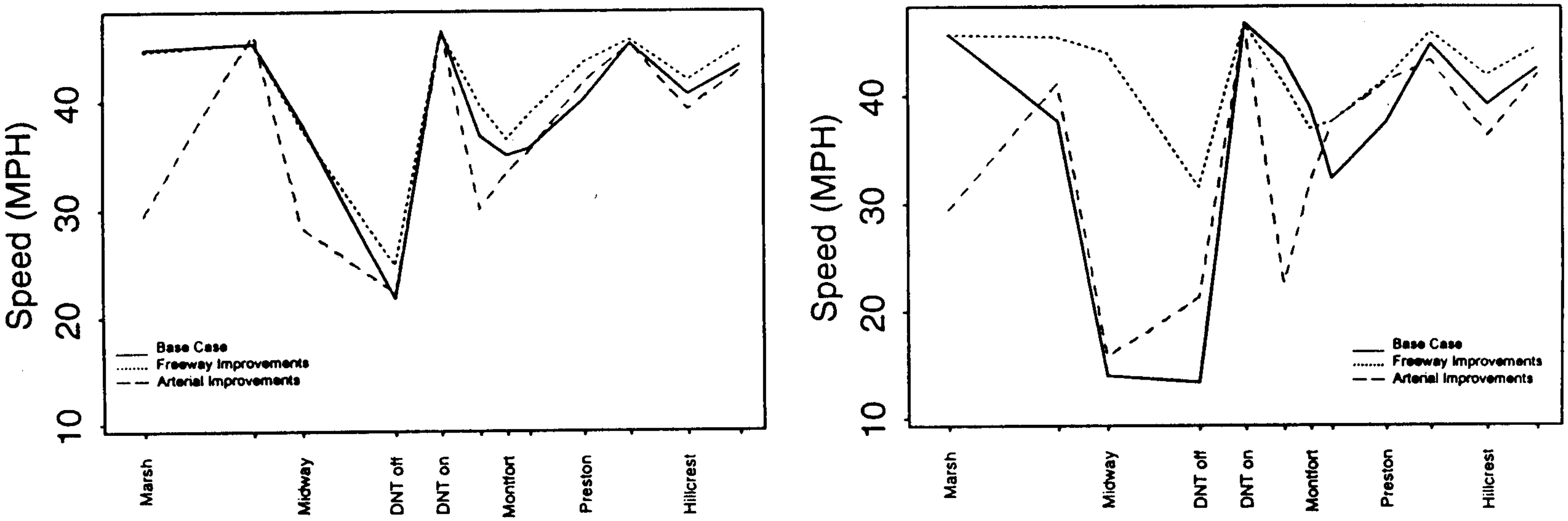


(c) Through Trips

(d) All Trips

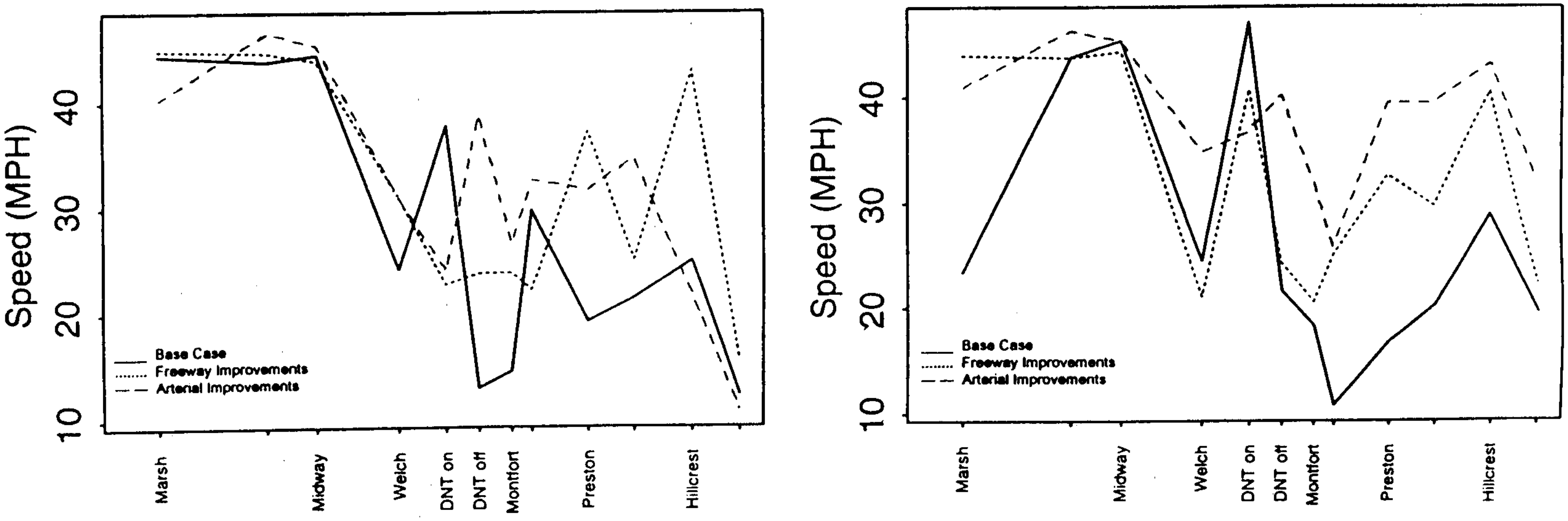
Figure 31

LBJ Freeway: Speed Comparisons Between Improvement Options



(a) 7:30-8:00 am West-East

(b) 7:30-8:00 am West-East

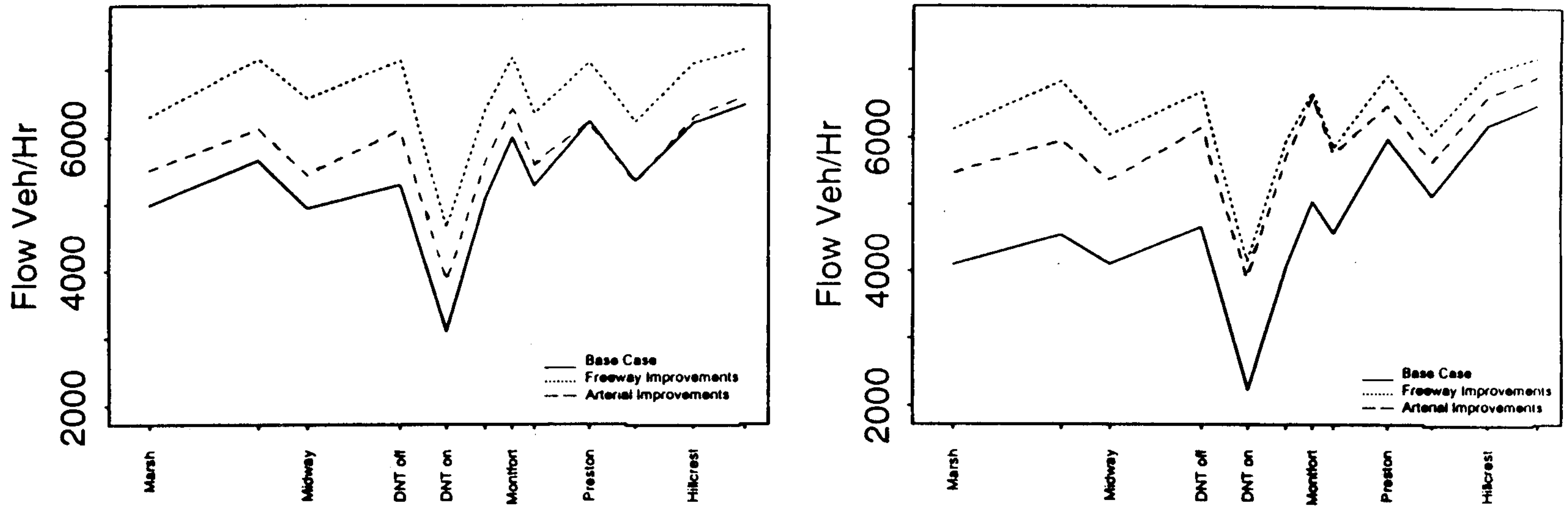


(c) 7:30-8:00 am East-West

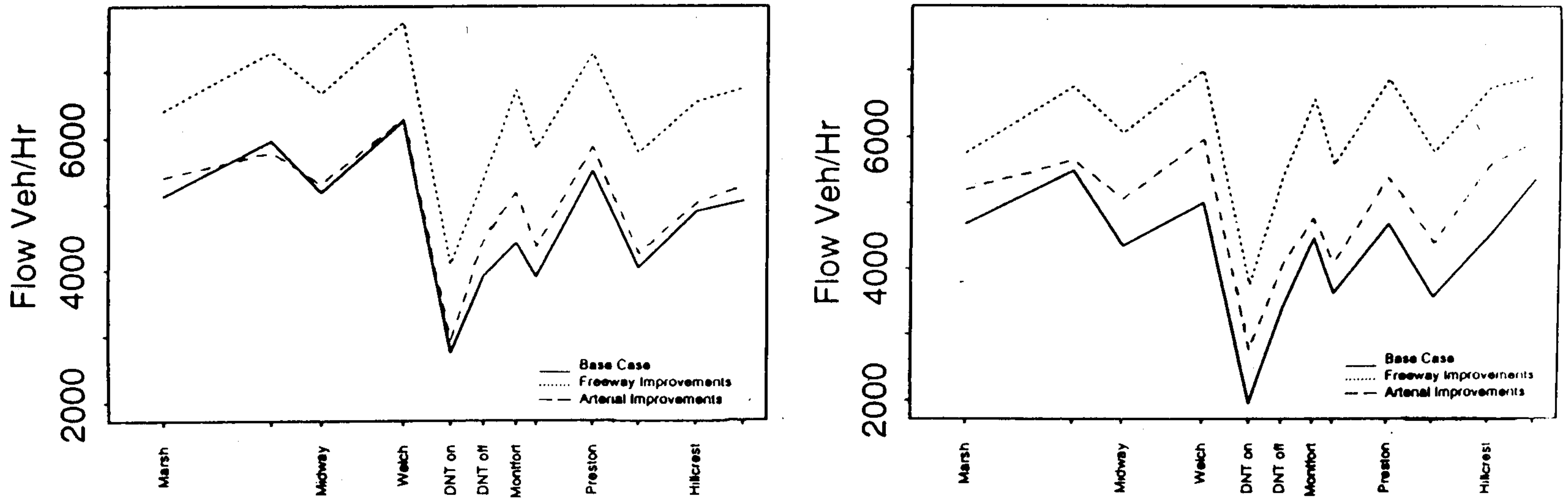
(d) 7:30-8:00 am East-West

Figure 32

LBJ Freeway: Flow Comparisons Between Improvement Options


(a) 7:30-8:00 am West-East

(b) 7:30-8:00 am West-East

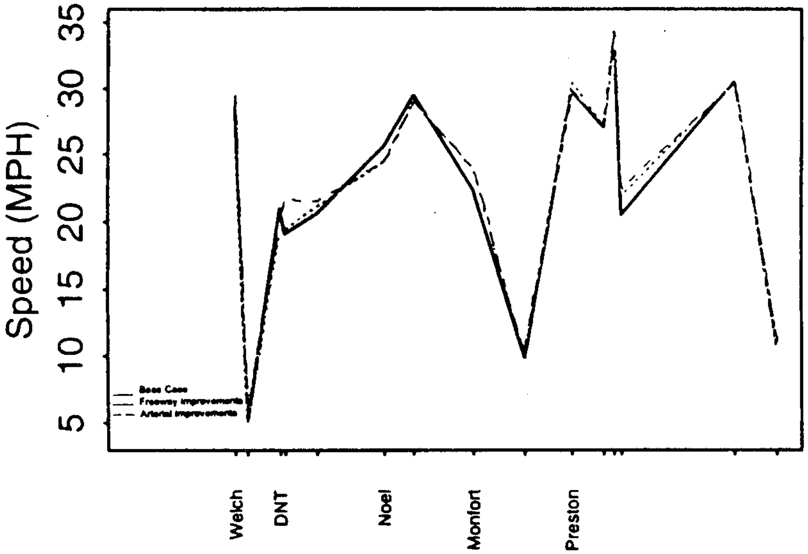

(c) 7:30-8:00 am East-West

(d) 7:30-8:00 am East-West

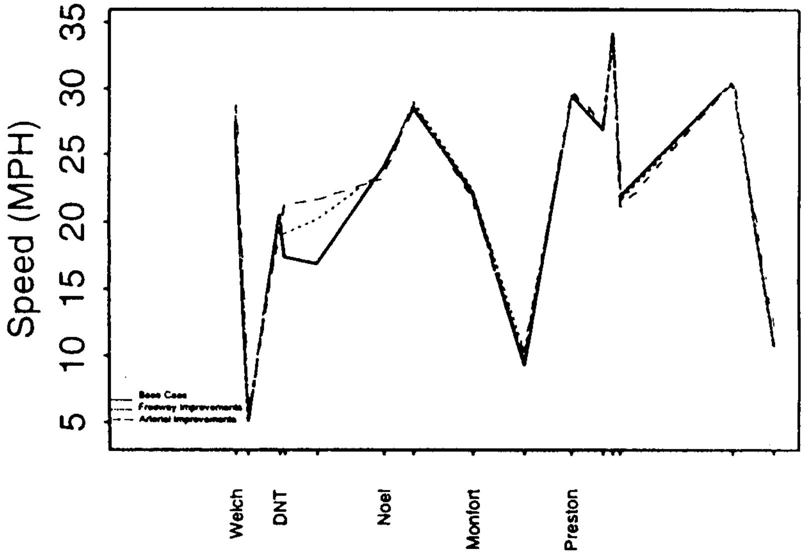
Figure 33

Alpha Road: Speed Comparisons Between Improvement Options

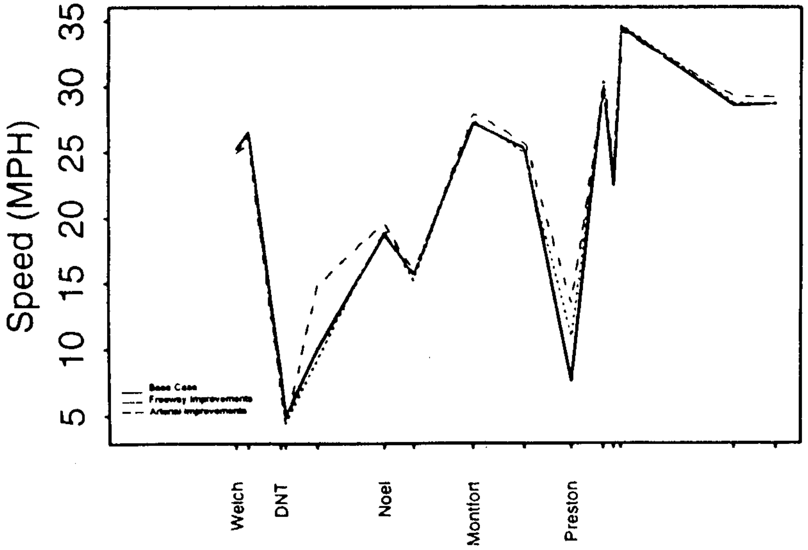
(a) 7:30-8:00 am West-East



(b) 7:30-8:00 am West-East



(c) 7:30-8:00 am East-West



(d) 7:30-8:00 am East-West

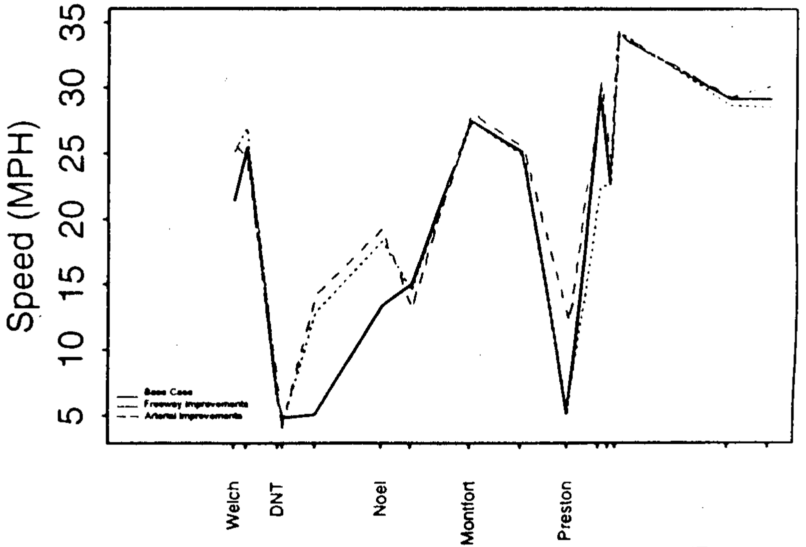
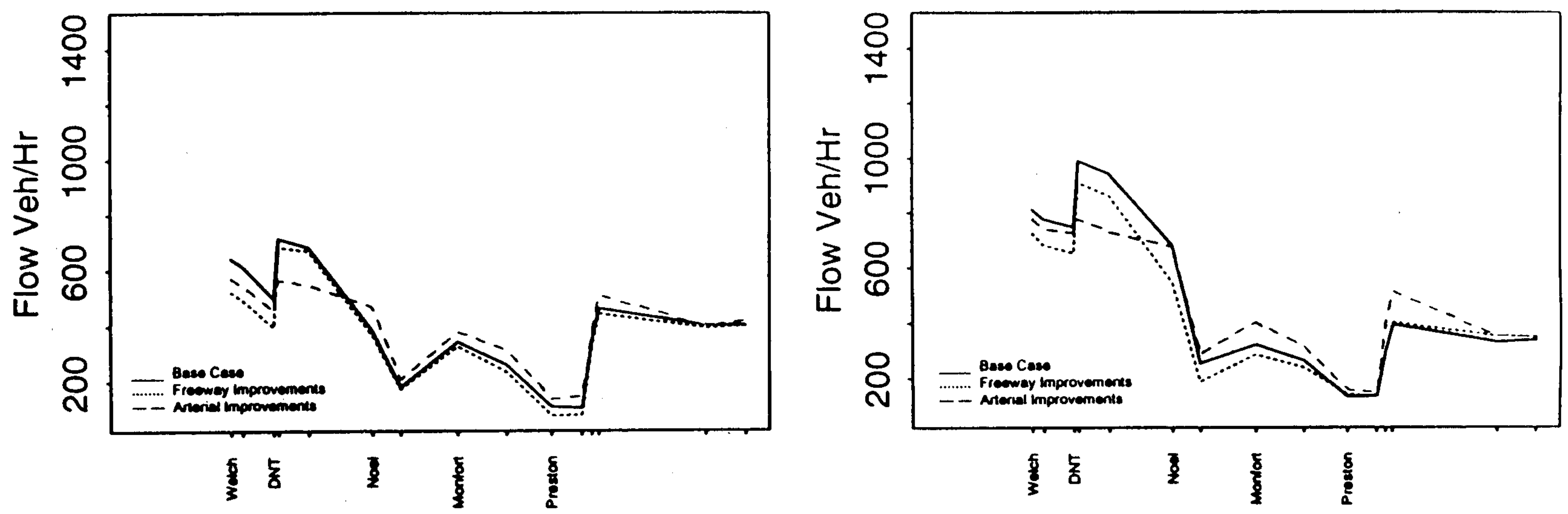


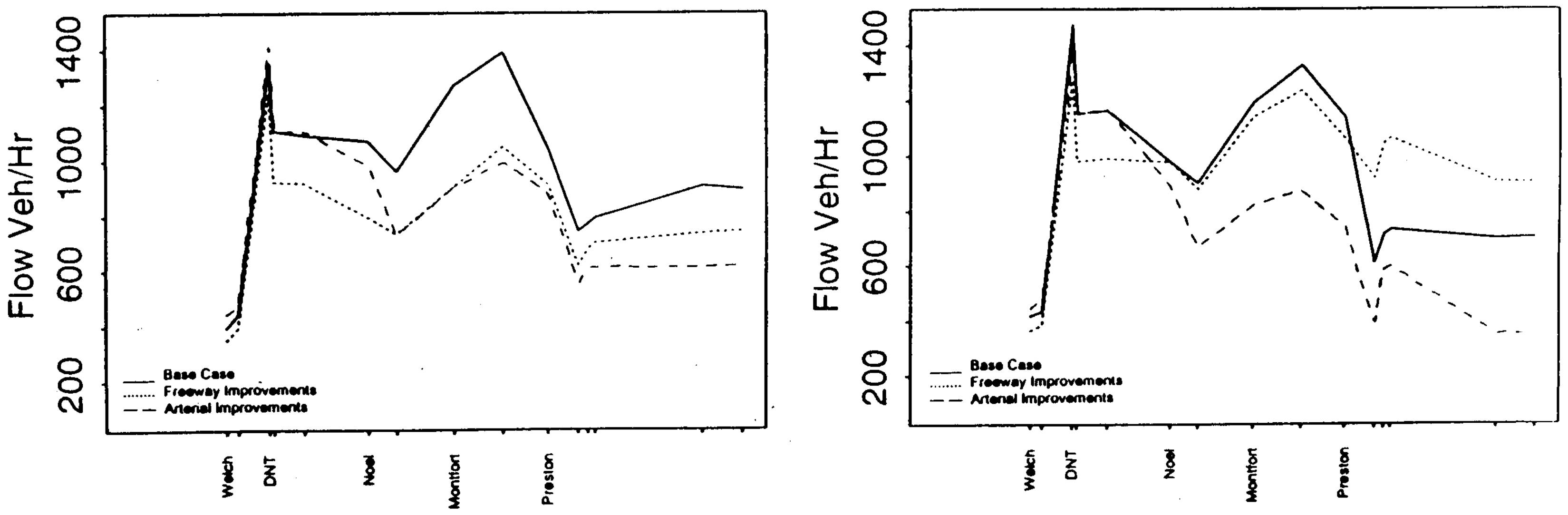
Figure 34

Alpha Road: Flow Comparisons Between Improvement Options



(a) 7:30-8:00 am West-East

(b) 7:30-8:00 am West-East



(c) 7:30-8:00 am East-West

(d) 7:30-8:00 am East-West

Figure 35

The speeds and traffic on Alpha Road are shown in Figures 34 and 35 and indicate little difference between the improvement options. The speeds on Alpha Road are primarily controlled by the delays at traffic signals.

At this time, all link summary data should be viewed with caution because this data is strongly influenced by the trip planning router. Even though the traffic volume estimates shown previously are considered accurate, the accuracy of the traffic counts for the links examined here is not clear.

Other interesting analyses could be conducted with the speeds, variances of speeds, traffic flows and densities produced by the simulation for particular links or intersections. Also, a comparison of the travel times and speeds from the simulations of the three improvement options where either Galleria or non-Galleria travelers have been removed would be instructive. In particular such an analysis would show whether the base case, when viewed alone, is as good for the Galleria travelers as the other two options.

PARAMETRIC AND SENSITIVITY STUDIES

Many of the inputs to the TRANSIMS models have the potential to change the simulation output. Studies of the effects of those inputs will guide future development of TRANSIMS. Some of those inputs are the structure of the roadway network, the method of activity generation, the trip planner parameters, and the parameters of the simulation itself. This section describes possible studies to judge the effects of some of those inputs. The base case of the case study is the basis for those studies.

Most of the TRANSIMS parametric and sensitivity studies require simulation of a set of trip plans. The results of running the simulation with a new set of parameters are compared to the results from the simulation run for the base case. Differences in the results are judged with consideration of the uncertainty in the simulations. If the analysis requires a new set of trip plans, the statistics resulting from the simulation must be compared with the results of the simulations of BC-1-1-1 and BC-1-2-1. If a new set of trip plans is not required, the comparisons are with the differences in BC-1-1-1 and BC-1-1-2.

The roadway networks for the case study include local streets. The characteristics of local streets are hard to acquire and will be burdensome if required in TRANSIMS. Additionally, TRANSIMS becomes computationally slower as the number of roadway network links increases. Therefore, it is important to assess the differences in the simulation that result from increasing the number of local streets in the simulation network. The straightforward approach of fixing a set of activities and obtaining routes for each network may not answer the question. This scheme will have the variability of the planner in addition to the variability of the simulation. This variability may be large enough to mask differences between the local and non-local street networks.

Except for freeways, ramps, and bridges, every link on each network has a loading point of trip origin and/or destination called a parking place that is similar to a zone centroid in the 4-step planning process. There are a few exceptions where links in the Galleria area had more than one loading point. The effect of placing multiple loading points on a link is unknown. It could easily be studied by randomly assigning activities to each of those points individually. The differences between results from simulations with the multiple loading points and BC-1-1-1 are expected to be no greater than the differences between BC-1-1-1 and BC-1-1-2 if there are no effects caused by having multiple loading points.

Traffic signal phasing plans must be defined for each signalized intersection in a simulation network. This is a difficult task, but it is possible to create a generic algorithm to do this. A simulation network with "generic" signal phasing would be compared to the results from a simulation of a network with actual phasing. Without replanning, differences between the results of the two simulations would have to be greater than the differences between BC-1-1-1 and BC-1-1-2 to be considered significant.

The case study simulation covered a 25-square mile study area surrounded by a buffer area. Routes were determined for every traveler in the entire Dallas-Fort Worth metropolitan area. For trips that started outside the study area, starting times in the buffer area were estimated from the expected travel times of the links outside the study area. An expanded microsimulation area would change the vehicles' arrival times at what was previously a buffer link. The consequences of simulating such a larger area should be studied.

The desirability of taking one link rather than another is measured in the trip planner by a cost function. This cost function includes the monetary cost of taking the link, the link length, and the link travel time. Relative weights for those inputs are based on traveler demographics. This case study used only travel time in the planner cost function, ignoring traveler demographics. The effects of producing a set of plans based on a cost function weighted by traveler demographics are unknown.

The sensitivity and parametric studies listed in this section are underway. As changes are made to the TRANSIMS components, sensitivity tests will be performed to judge the effectiveness of those changes. Many other sensitivity tests are possible, but the tests mentioned in this section have the most immediate and direct impact on future development of TRANSIMS.

CASE STUDY SUMMARY

The effects of three roadway options on various sub-populations of travelers were investigated in this study. The first improvement option was the 1990 roadway network around the Galleria Mall in Dallas. The other two options were roadway improvements that consisted of additional lanes on the LBJ Freeway in one case and a series of improvements to arterial roads in the other. The effects of these two improvements were studied on two sub-populations of travelers:

1) Galleria and non-Galleria travelers.

2) Internal trips, external trips, and internal-external trips.

Measures of the effectiveness of the improvement options were prepared in a manner unique to transportation analysis methods like TRANSIMS, which consider individual travelers. Network reliability was estimated by computing the absolute difference in travel times and speeds of individual travelers. Analysis of the complete distribution of travel times and speeds, and averages of these quantities, was shown to increase understanding of impacts of different improvements on the transportation network. The analysis showed that reducing travel times of travelers with the longest trips and increasing the speeds of travelers with the slowest speeds produced the greatest net improvements in roadway system performance. This was accomplished by investigating changes in the percentiles of the travel time and speed distributions of the improvement options.

Overall, the arterial improvements had the greatest potential for reducing travel times and increasing speeds for almost all of the sub-populations. Travelers passing through the study area benefited equally from both improvement options.

Although the greatest reductions in travel times and increases in speeds resulted from the arterial improvements, all of those improvements occurred after 7:30 a.m., with some occurring as late as 8:00 a.m. Before 7:30 a.m., the extra lanes on the LBJ Freeway reduced travel times and increased speeds.

Both improvement options reduced the travel times and increased the speeds of the non-Galleria travelers more than occurred by removing the Galleria travelers from the traffic stream. The reverse was not true for the Galleria travelers. Non-Galleria travelers made up ninety-five percent of the travelers in the study area.

The distributions of travel times on the three roadway options shifted in time. The longest travel times for the arterial option occurred before 7:30 a.m. The longest travel times for the freeway option occurred after 8:00 a.m. The longest travel times for the base case were between these two times. This temporal shift between the improvement options was unexpected, but it can be explained. Fewer vehicles traveled completely through the study area after 7:30 a.m., yet the number of trips in the study area increased until 8:00 a.m. As a result, more travelers were leaving the freeways and were on local streets between 7:30 and 8:00 a.m., which increased the effectiveness of the freeway option during the early period and of the arterial option later in the morning.

CONCLUSIONS

This paper presents a case study based on the first Interim Operational Capability (IOC) of TRANSIMS, which is the microsimulation. Traffic in a 25-square mile area of highly congested roadways around the Galleria Mall in Dallas, Texas was simulated. The microsimulation was applied to three networks supplied by the North Central Texas Council of Governments (NCTCOG). The networks represented were:

- The actual 1990 roadway network as the base case for comparisons,
- A change to the base network that added one lane in each direction to the LBJ Freeway, and
- A change to the base network that improved physical and operational characteristics or arterial streets .

The simulation was carried out for the hours between 5:00 and 9:00 a.m. Approximately 200,000 vehicle trips were simulated for each network. Each of the simulations was executed in real time on a network of five Sun SPARC workstations.

TRANSIMS tracked each traveler in the simulation. The availability of information on individual travelers permitted innovative analysis methodologies, including new methods for the study of uncertainty, network reliability, and equity.

The microsimulation was calibrated using simple networks, which included a circle, an on-ramp, a left turn, and a signalized intersection. The results of the calibration simulations on each of these simple networks were similar to the results on similar real networks.

The TRANSIMS microsimulation moved individual vehicles on predetermined routes. The method for determining those routes was not part of this IOC, but routes for each vehicle are necessary inputs to the simulation. A method of determining routes that was used only for this case study used an optimal routing algorithm and iterated between the simulation and the trip planner. The structure of TRANSIMS requires a population of travelers, their trips and their activities. The origins and destinations of trips were determined from trip tables supplied by NCTCOG, and the trip tables were converted to pseudo-activities for use by the router. Vehicle counts prepared simulations using those routes, and pseudo-activities were compared with volumes produced by the NCTCOG travel forecasting model. That comparison showed the routed trips to be in close agreement with the NCTCOG forecasts.

An experiment design was developed to assess the effects of the alternative roadway improvements on sub-populations of travelers. The travel of all travelers was simulated on each of the three alternative roadway networks. The experiment design required simulations of two sub-populations, Galleria travelers and non-Galleria, done separately on each network. The sub-population simulations established a baseline for comparison with the simulations of the full population.

Most models like TRANSIMS produce results with some degree of uncertainty, but the amount of uncertainty is usually difficult if not impossible to define. In TRANSIMS this uncertainty can be quantified. Randomness in the activity starting times, the routing algorithm, and the simulation itself contributed to the uncertainty in the final results. An experiment design was developed to assess this uncertainty. Simulation uncertainty was assessed by two simulations with different random number seeds but using the same set of trip plans. The trip plans were iteratively replanned to determine the uncertainty caused by replanning. Uncertainty induced by the activities themselves was ascertained by simulating trip plans based on a different set of activities. The resulting estimated uncertainty was used to judge the significance of differences among the simulations of the three alternative roadway networks.

Several measures of effectiveness were prepared in this case study. Those measures included total vehicle miles, total vehicle hours, travel time, and average speeds. Other information and important measures of effectiveness that are unique to models like TRANSIMS, which track the individual travelers, were also prepared. Of greatest importance among these may be an estimate of network reliability. To estimate network reliability, the starting time of each traveler was randomly modified a small amount. The trips with modified starting times were then used by TRANSIMS to simulate traffic on the base case network. The results of that simulation were compared to the results of the original simulation on the base case network. Both simulations used the same trip routings prepared by the TRANSIMS trip planner, but the trip plans differed only by the starting times of those trips. To measure network reliability, the absolute differences between individual travel times and speeds from the two simulations were computed. Travelers with the largest day-to-day variation in speed or travel times are likely the most dissatisfied with their travel times. That dissatisfaction was based on the measure of network reliability, presented as the upper percentiles of travel time differences and the lower percentiles of speed differences.

Differences in the distributions of travel times and speeds across the three roadway networks for Galleria and non-Galleria travelers showed that the arterial roadway improvements benefited both populations after 7:30 a.m. This was true whether the effects were measured with the mean, median, or percentiles of the distribution. Both roadway options improved the travel of the non-Galleria travelers more than removing the Galleria travelers from the traffic stream. Therefore the cost imposed on the non-Galleria travelers by the Galleria travelers was less than the cost of the roadway improvements. The opposite was not true for the Galleria travelers. The roadway improvements were not equivalent to removing the non-Galleria travelers.

Supplemental analyses compared conditions for all travelers to those for travelers in three sub-populations: internal, internal-external, and through travelers. The results of those comparisons demonstrated almost the same pattern as was seen in comparisons between the Galleria and non-Galleria travelers. The arterial improvement option benefited both the internal and internal-external travelers after 7:30 a.m. Both roadway improvement options benefited the through travelers.

Network reliability studies showed the same effects of the roadway improvements. The arterial option produced more reliable improvements than the freeway option or the base case after 7:30 a.m. This was particularly true when reliability was based on travel times.

The case study successfully demonstrated the TRANSIMS microsimulation. The next IOC will focus on activity generation, planning and routing, and the environmental modules of TRANSIMS.

COMMENTARY

Three fundamental aspects of current transportation planning establish the context for future improvements in both process and product. For the purpose of this discussion, process relates to the technical tools used to assist policy leaders in decision making, and the product is transportation systems.

The first aspect establishing the context for an enhanced urban transportation decision-making process derives from the three branches of the U.S. government. Recent trends at the federal level have emphasized more technical and systematic decision making. Congress has made this desire clear with the 1990 passage of the Clean Air Act and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Federal courts in Chicago and San Francisco have placed greater weight on the technical elements of the transportation planning process. The executive branch has issued regulations and executive orders ranging from equity analysis to air quality conformity.

The second aspect for transportation planning is the "reality" of decision-making. Constraints on land availability, the environment, and financial resources have placed greater emphasis on consensus-building. In addition, the increased attention to quality-of-life and sustainable communities has made public involvement even more important. The expectations, information demands, quality control, and validation standards of a fully operational public involvement process may often be overwhelming. Within this "reality" it is not uncommon for the cost of major transportation corridor improvements to exceed half a billion dollars!

The third element, and the one which gets the most attention, is the ability of current modeling and technical tools to respond to questions and to meet requirements not envisioned when such tools were developed. For example, authors of the Highway Performance Monitoring System never imagined its use in constraining vehicle miles of travel estimates for air quality purposes. Current tools were developed in a time when the questions before planners were mostly concerned with roadways. The focus has changed dramatically, and so should the technical tools. Today's level of technology can provide a response to these fundamental changes.

Transportation Implementation Partnerships

It is rare today that a single public entity can design, fund, and obtain public support for transportation projects without the assistance of other entities. It requires the support of impacted neighborhoods, the private sector, goods-movement interests, transportation authorities, state agencies, and the federal government. This partnership "reality" is at the hub of both the Clean Air Act and ISTEA. Through ISTEA, partnerships are being developed and enhanced, and new technical tools are being created to respond to the interests and changing needs of all partners.

It has been two decades since the federal government has been willing to assume a leadership position in responding to the need for improved transportation planning tools. The U.S.

Department of Transportation (U.S. DOT) has established a Travel Model Improvement Program (TMIP) to address five specific areas for improvement: near-term model needs, data collection, land-use models, long-term model needs, and technology transfer. No one area of the five is more important than the others. This multi-track approach is designed to address the changing demands summarized previously and the partnership "reality" in constructing tomorrow's transportation systems today.

TRANSIMS

TRANSIMS is the tool being developed by Los Alamos National Laboratory, with assistance from metropolitan planning organizations, state authorities, and research institutes, to address the long-term modeling needs in urban transportation planning. U.S. DOT sponsors the project through the Federal Highway Administration, the Federal Transit Administration, and the Office of the Assistant Secretary for Transportation Policy. The Environmental Protection Agency also provides support for this project.

TRANSIMS is an approach with tremendous positive impact. It is not intended to be used to respond to every transportation inquiry, but it will be able to better identify the behavioral elements of our transportation choices. Its application will focus more on regional system planning uses and major investment studies.

The case study presented here is corridor-specific and tests the microsimulation module and the fundamental behavior of a vehicle driver that has the socio-economic characteristics of real world drivers. Although one may think that at this point in our understanding of transportation we already know driving behavior and microsimulation pretty well. Nothing could be further from the truth. Driving behavior has very significant implications for air quality planning (e.g., hard acceleration and stop-and-go traffic), as well as activity planning and selection of route choice from origin to destination.

Dallas Case Study Results

The following points highlight the case study findings:

1. Travel time feedback to the trip planner is necessary and impacts activity plans and route choice.

2. The uncertainty analysis confirms that the order of model sensitivity is a) assignment of trip activities, b) feedback to the route choice, and c) microsimulation randomness.

3. New performance measures, such as transportation reliability or percent time under engine load, can be established.

4. Arterial street improvements, including traffic engineering operations, can be simulated in the same model system as traditional transportation systems.

5. The study findings show that freeway improvements were better for certain hours of the day, whereas arterial improvements were better for other hours.

6. Equity analysis was demonstrated by land-use type as well as by travel orientation (i.e., through or local).

7. Network coding is very detailed, with sensitivity analysis yet to be conducted to determine network requirements.

8. Computer simulations were conducted in real time with second-by-second movements of 200,000 planned activities over a five-hour period.

9. The case study results are applicable for both regional (to support air quality needs and system planning) and corridor specific (to support financial decisions and consensus building in major investments studies).

Implications

This case study on microsimulation began with a roadway network in which geometric conflicts were resolved with literal representation of roadway pavement, local and neighborhood streets, intersection detail, traffic signals, and traffic loading nodes coded. The result was a second-by-second microsimulation on a robust network. It is premature to conclude if all the representations will be necessary. Subsequent sensitivity testing will determine the feasibility, accuracy, and overall value of less-detailed networks.

Improvements in the interim software have already been developed in response to the case study. One set of improvements updates the driver's behavior logic, while a second set establishes feedback to the trip planner for improving route choice. In addition to the sensitivity testing of network detail, parametric testing of driver behavior rules and microsimulation fidelity will be conducted. Finally, new performance measures and techniques are under review to enhance decision making, with work begun in Portland to develop the trip planner module. Additional improvements in microsimulation will be developed after the other TRANSIMS modules have progressed to the completion level of the microsimulation module.

As you will see from the case study reported here, technology is responding to the changing context of transportation planning today and the "reality" of constraints in urban transportation system planning. TRANSIMS is a national initiative that has brought together interested partners in a collaborative process. In conjunction with improvements to data collection, land use integration, near-term model needs, and technology transfer, the first steps are being taken towards a better understanding and application of transportation solutions. The research is far from complete, but this case study on the first module is preparing us for the twenty-first century. The journey has begun.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1998 - 446-840/91021

NOTICE

Publication No. FHWA-PD-99-006
HEP-22/12-98(1.5M)QE