MOBILITY IN GRAND JUNCTION

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EXECUTIVE SUMMARY

This report shows the results of an analysis to measure the mobility level in Grand Junction, Colorado. Researchers at the Texas Transportation Institute have monitored urban mobility levels in many of the nation's largest urban areas while refining a methodology that can be used in smaller areas and even applied at the individual roadway level. The Colorado Department of Transportation (CDOT) decided to test this methodology in Grand Junction. The purpose for the test was to obtain a mobility level for the roadways in the city and to refine the methodology for use in other cities within the state.

The local agencies in Grand Junction, in conjunction with CDOT, chose seven arterial street corridors for the analysis. In preparation for the analysis, a data collection plan was derived to collect all of the necessary data in each of these corridors. In October 2000, travel time data and traffic counts were collected along these corridors for use in the study.

The results of the analysis show that the average peak hour trip (7:00 to 8:00 a.m. and 5:00 to 6:00 p.m.) on these seven corridors in Grand Junction takes about seven percent longer to complete because of higher traffic demand. The amount of additional time required in each individual corridor varies from almost no additional time in one of the corridors (Horizon/12th) to about 25 percent more time in another (North Avenue). Figure 1 shows the overall results from the seven corridors. The performance measure used in the analysis was the Travel Rate Index that shows the additional time required to complete a trip during the peak period as compared with some other time of the day. This analysis focused on the traditional peak hours of the day, however, the analysis could be used to look at traffic conditions during the lunch hour or on weekends.

Since this study was one of the first to apply the methodology in the field, a great deal of information was learned in the process. This information is documented in this report so it will be available the next time a mobility analysis such as this is performed. Some of the lessons learned include:

- The data collection plan is critical to the study process.
- An inventory of existing data sources and collection capabilities should be made before data collection commences.
- Pre-collection and post-collection meetings should be scheduled.
- Detailed traffic counts are needed.
- Local feedback on raw data and findings are needed.
- This analysis is most useful at a corridor level and not on a segment-by-segment basis.
- The data collected in this analysis may be useful for other analyses as well.

The local agencies in Grand Junction are very optimistic about the benefits of this analysis and the use of the Travel Rate Index and are anticipating the continuation of this effort at the local level in the future.

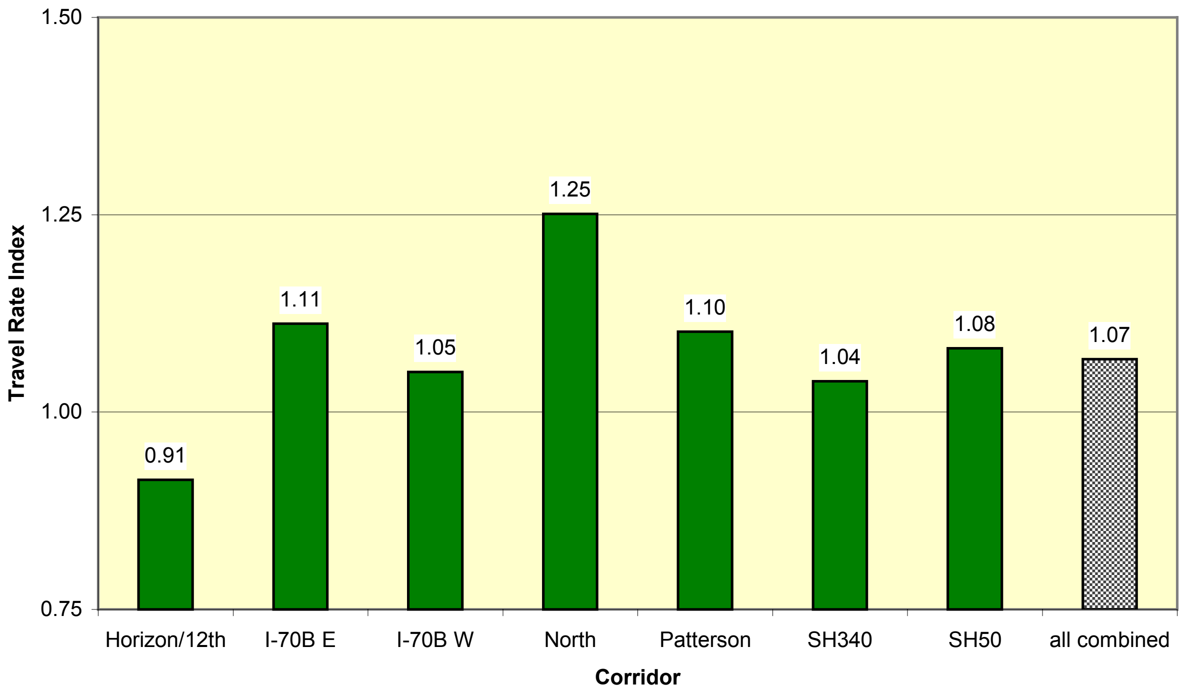


Figure 1. Peak Hour Mobility Levels on Grand Junction Arterial Streets

INTRODUCTION

In the mid-1980s, a project was begun at the Texas Transportation Institute (TTI) to develop a methodology to measure and monitor mobility levels in Texas urban areas. The project was very successful and by the late 1980s urban areas from outside of Texas were added to the study. Many other states, including Colorado, expressed interest in the study over the years while the study was sponsored solely by the Texas Department of Transportation (TxDOT). At TxDOT's urging, the research team and TxDOT placed a request to the Federal Highway Administration for the project to become a pooled fund study so that other states could join the research effort. The Colorado Department of Transportation (CDOT) was one of the first states to enter the study in 1998. Eleven state departments of transportation now sponsor the Urban Mobility Study (1) and others are considering joining this research effort.

In 2000, CDOT decided to test a portion of the methodology on the arterial street system in Grand Junction. There were several reasons for selecting Grand Junction as the test case. First, the city was relatively small with a population around 50,000. This meant that the size of the transportation system was not too big for testing purposes. There were seven major arterial roads that would need to be included in the study. Second, the transportation officials and agencies in the area were interested in the idea and would provide a great deal of help in collecting data and providing input to the project. Having local input and assistance is a critical component to any project like this. In the fall of 2000 the Grand Junction mobility project was started and the results are included in this report.

In October 2000, the data collection was begun on the seven arterial streets in Grand Junction. These seven corridors are shown in Figure 2. The travel time information was collected in a one week period. This travel time information, along with traffic counts and other materials were forwarded to the Texas Transportation Institute for analysis. The results of this analysis are included in this report.

WHY MONITOR MOBILITY LEVELS?

The persons and freight that move on the nation's transportation system have several factors that determine the basic parameters of the trip—departure time, route, travel mode and cost. Improvements to the transportation system show up in:

- Faster travel—due to more travel options or better travel conditions on the same facilities or modes.
- More reliable transportation—crashes and vehicle breakdowns are quickly moved so that they do not affect the system for long periods.

- More travel options—in terms of mode, route, time, and cost.
- Cheaper travel options—including the value of time, environmental impacts and other factors in addition to out-of-pocket expenditures.

The travelers and freight carriers that move on the network are concerned with a package of these attributes that most closely optimize their desires. Arriving at a destination on time and at a minimum cost can be thought of as a fairly typical goal; the choices made from that goal statement, however, are widely disparate. They are related to personal tastes, cost of the trip, trip purpose, mode availability and the trip time. Transportation agencies in the early part of the 21st century need to analyze the range of options and decisions and attempt to optimize the expenditure of limited transportation funds to improve the system.

WHY SHOULD WE USE TRAVEL TIME INFORMATION?

There are several keys to developing and applying mobility measures that are technically useful and generally understandable. The mobility measures that appear to have the most versatility are those based on travel time and speed. Travel time measures are relatively easy to comprehend, but they have not always been used because of data concerns, mandated reporting practices and other issues. Travel time and speed measures can serve many different uses and can be communicated to many different audiences.

Another reason for collecting travel time information is to take a look at how “reliable” the transportation system is. Reliability is commonly seen as the level of consistency in the transportation service provided by the roadway or, in other words, the quality of the service provided by the system. The persons and freight that move on the area roadways depend on the transportation system to be reliable. It is very difficult to plan ones trip, for example, if the time needed for a given trip varies by 100 percent from day to day. This makes it extremely difficult for manufacturers who use just-in-time inventory systems. They may have to store more inventory than desired to account for the lack of a reliable transportation system.

A reliability analysis requires more data than was collected in the Grand Junction mobility analysis. Enough data is needed to observe the variations in travel times from day to day and from hour to hour within a given day. The important point is that travel time data is a key component for this type of analysis and it may be important in the future to observe the reliability of the roadways in Grand Junction and other cities. So agencies need to begin to collect travel time information so that they have time series data for future needs.

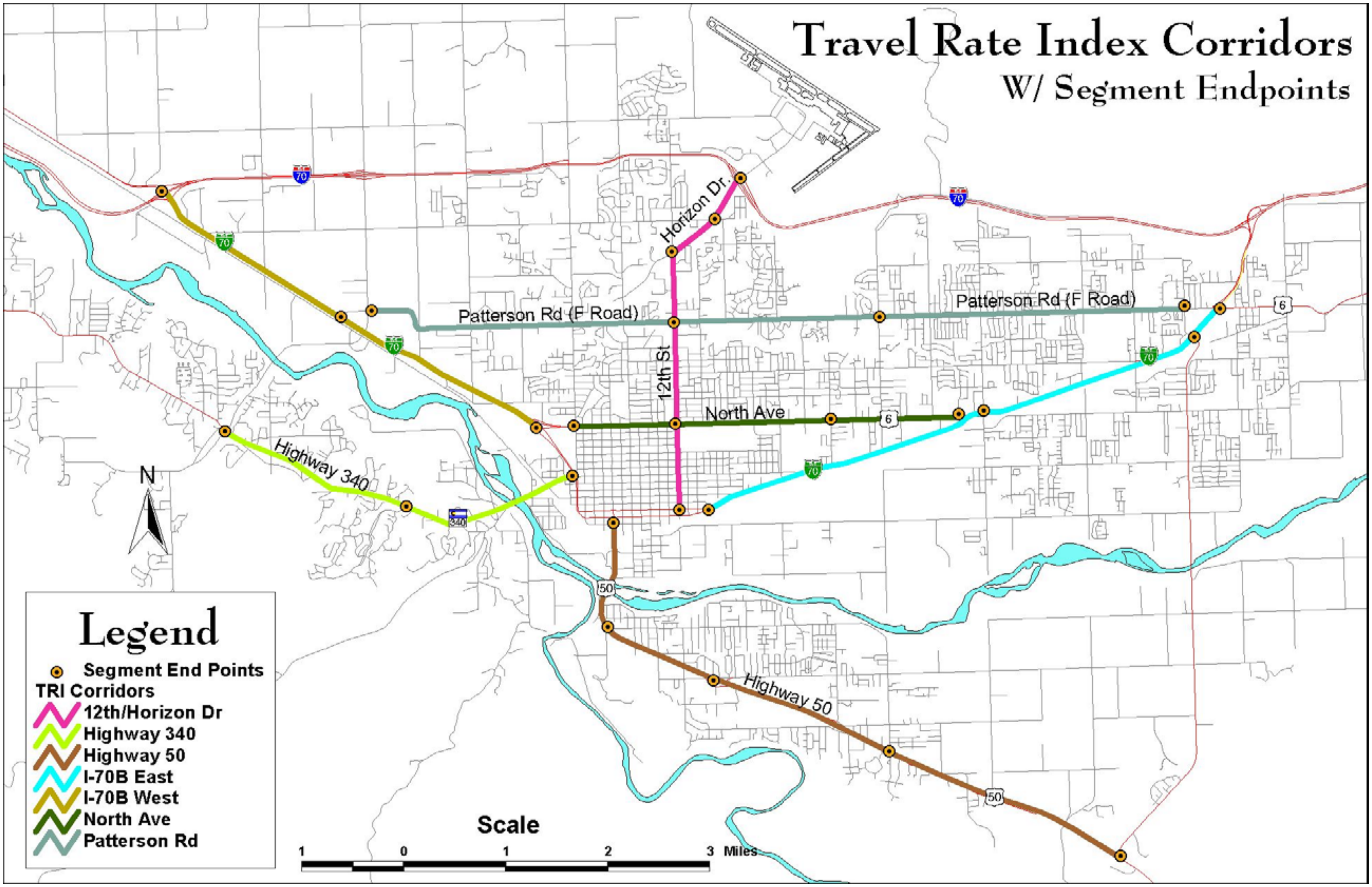


Figure 2. Seven Arterial Corridors in Grand Junction

HOW DO WE COLLECT TRAVEL TIME DATA?

Collecting the travel time data is key in a mobility analysis such as this. If the travel time data is not collected in a consistent and methodical manner, the results of the study may be questionable at best. Before any data is collected, a plan needs to be developed so that the data collection is done in a consistent manner. This is important since the data collection process generally requires many people working together. Appendix A to this report contains a section from the Travel Time Data Collection Handbook (2) written at TTI that discusses developing a travel time data collection plan.

THE GRAND JUNCTION TRAVEL TIME COLLECTION PLAN

Before any of the actual data was collected in Grand Junction, a plan, similar to the one described in Appendix A, was developed for the data collection activities. A process was put in place to collect travel time data that would be consistent across the different arterial corridors and between the various persons involved in the data collection. The guidelines established for the travel time data collection are shown in Figure 3. These guidelines established many of the rules for the data collection so that anyone could collect the data and have some consistency in how the data was collected.

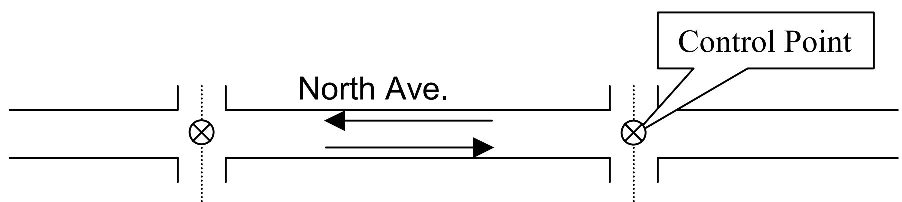
A good example of the importance of these guidelines is rule number seven—where a time value is actually recorded relative to a checkpoint along a roadway. If one data collection car reports the time at the center of an intersection and another reports the time at the entrance to the intersection, the results can be very different. For example, if data collection vehicle one is stopped at the entrance to the intersection (the stop bar) by a signal, the time the vehicle reaches the stop bar may be the time that gets reported by this vehicle. However, the other vehicle(s) making time runs may report the time when the center of the intersection is reached after the signal turns green again. This may give very different travel time results for the corridor.

In addition to the guidelines in Figure 3, a standardized Field Sheet was developed for use in recording the travel time data as it was collected in the field (Figure 4). This document plays a critical role so that the travel time data is recorded in a consistent manner so that it is easy to enter for analysis. This document helps to remove some of the “guessing-game” that is done back in the office when the data starts coming in for analysis and each data collection person has coded data in a different manner.

GRAND JUNCTION
TRAVEL RATE INDEX STUDY

TIME-RUN GUIDELINES

1. All time-runs are round trip
2. Time-run teams will consist of two persons: a driver and recorder.
3. Any type of vehicle may be used to conduct time-runs.
4. Each team will be equipped with a handheld stopwatch with a lap function or vehicle on-board DMI type device with similar functions.
5. Time-run teams will use the 'floating car' technique to conduct all runs. The team driver will float along with traffic and attempt to match the speed and mannerisms of adjoining traffic (go with the flow). Posted speed limits are not a factor—go with traffic.
6. Continuous clocked time-runs will be required for the full length of each corridor by direction. Each corridor is broken into segments. Each segment break is a control point. Time and observations for each control point will be recorded on the Travel Time and Delay Field Sheets. Information on the location and cause of delays encountered along a corridor will also be recorded under the Stops and Slows portion of the Field Sheet. Stops and slows can be defined as anything that delays what appears to be normal traffic flow. The Field Sheet shows coding for typical causes of delay.
7. Times will be recorded at the centerline of each control point.



8. Time-runs should be terminated if an event such as an accident or construction activity closes one or more lanes in the corridor. Any data collected prior to a time-run termination will be kept.
9. Time-runs will be conducted during the following periods for each corridor:

AM Peak		PM Peak		Free-Flow Periods	
Time	**Runs**	**Time**	**Runs**	**Time**	**Runs[1]**
6:45-7:15	1	4:30-5:00	1	9:30-11:30	Up to 4
7:15-8:15	4	5:00-6:00	4	1:30-3:00	Up to 4
8:15-8:45	1	6:00-6:30	1		

[1] Only 4 time-runs needed for any combination of free-flow periods.

Figure 3. Travel Time Data Collection Guidelines

Travel Time and Delay Study
Field Sheet

Date ____________ Weather ______________ Trip No. ______________

Route ________________________________ Direction ____________________

Trip Started ____________ AT ________________ ____________
Time Location Mileage

Trip Ended ____________ AT ________________ ____________
Time Location Mileage

Control Points		Stops or Slows		
Location	Time	Location	Sec. Delay	Cause

Trip Length ______________ Trip Time __________ Travel Speed __________

Running Time ____________ Stopped Time ________ Running Speed __________

Symbols of Delay Cause: S--Traffic Signals SS--Stop Sign LT--Left Turns
PK—Parked Cars DP--Double Parking T--General
PED--Pedestrians BP--Bus Passengers Loading or Unloading

Comments ____

Recorder ____________________

Figure 4. Travel Time Collection Field Sheet

THE MOBILITY PERFORMANCE MEASURE—THE TRAVEL RATE INDEX

A potential mobility measure should reflect motorists' perceptions of travel time on the roadway, transit facility or other transport network element. This comparison can be based on the travel time increase from either freeflow conditions or to the target (or acceptable) conditions. Thus, the same measure could be applied to various system elements with different freeflow speeds. Travel rate appears to be an excellent candidate to serve as the basis for this calculation. Travel rate (measured in minutes per mile) is a direct indicator of the amount of travel time, which makes it relevant to travelers. The Travel Rate Index (TRI) in Equation 1 compares measured travel rates to freeflow conditions using passenger-miles of travel (PMT) to weight the travel on different facilities or modes. Index values can be related to the general public as an indicator of the length of extra time spent in the transportation system.

$$\text{Travel Rate Index} = \frac{\left(\dfrac{\text{Freeway Travel Rate}}{\text{Freeway Freeflow Rate}} \times \text{Freeway Peak Period PMT}\right) + \left(\dfrac{\text{Principal Arterial Street Travel Rate}}{\text{Principal Arterial Street Freeflow Rate}} \times \text{Principal Arterial Street Peak Period PMT}\right)}{\left(\text{Freeway Peak Period PMT} + \text{Principal Arterial Street Peak Period PMT}\right)} \quad (1)$$

The measure can be averaged for streets, freeways, bus and carpool lanes, bus and rail transit, bicycle facilities and even sidewalks. All of these system elements have a freeflow travel rate and as usage increases, the travel rate increases. A corridor value can be developed with the number of persons using each facility or mode (measured with passenger-miles of travel) to calculate the weighted average of the conditions on adjacent streets, freeways, high-occupancy vehicle (HOV) lanes, bus routes and/or rail transit lines. The corridor values can be computed for hourly conditions and weighted by the number of travelers to estimate peak-period or daily index values.

One difficulty with the index can be summarized as "we do not have a rateometer in our cars, we have a speedometer." Travel rate is unfamiliar to the general public. It has an inverse relationship to speed which can be confusing, but when the index is explained in a simple footnote indicating comparison to the travel time in freeflow conditions, the concept is not difficult to grasp. The public and business operators make mode, route and departure time decisions based on travel time concerns more than on a speed value; the travel rate is consistent with this decision-making process.

One outcome of using the travel rate index is the ability to include directly collected travel time data from the various transportation system elements. Many areas do not collect this information, but the initial statistics can be developed from estimates of travel speed. As travel time studies are conducted, however, the actual data can be used to replace the estimates in the index, as well as to improve the estimation processes. The information derived from systems that automatically collect and analyze travel speed over sections of freeways provide a significant resource for the travel rate index calculation.

APPLYING THE TRAVEL RATE INDEX TO GRAND JUNCTION

The Colorado DOT and local agencies decided that the arterial street system should be the test bed for the mobility analysis. The freeway system (I-70) that generally runs along the north side of Grand Junction is typically uncongested and would not provide any real test data for a mobility analysis.

The Travel Rate Index (TRI), shown in Equation 1, is capable of including data from many modes or facilities. The example equation shows how freeway and arterial street data would be combined to generate a "system" mobility level. Since only the arterial street system is being analyzed in Grand Junction, the freeway portion of the equation can be removed leaving a simple ratio of the peak travel rate on a given arterial corridor to its freeflow travel rate.

In order to generate a "system" look at the arterial streets, the amount of travel on a given street would be used to weight the value of each street relative to others in the analysis (see Equation 2). Thus, the heaviest traveled arterial street, based on vehicle-miles of travel, would have the most weighted effect on the mobility level for the "arterial system" mobility level.

The same type of methodology is used to generate the TRI for a given corridor. Each segment of the roadway, for which data was collected, has a travel rate and associated traffic volume. This data for each segment is weighted together in the TRI equation by the traffic volumes to generate a TRI for the corridor. In reality, this is done before the "system" TRI is calculated.

$$\text{System TRI} = \frac{\left(\dfrac{\text{Arterial 1 Travel Rate}}{\text{Arterial 1 Freeflow Rate}} \times \begin{array}{c}\text{Arterial 1}\\ \text{Peak}\\ \text{Period}\\ \text{PMT}\end{array}\right) + \left(\dfrac{\text{Arterial 2 Travel Rate}}{\text{Arterial 2 Freeflow Rate}} \times \begin{array}{c}\text{Arterial 2}\\ \text{Peak}\\ \text{Period}\\ \text{PMT}\end{array}\right) + \ldots\ldots\ldots\ldots}{\left(\begin{array}{c}\text{Arterial 1}\\ \text{Peak Period}\\ \text{PMT}\end{array} + \begin{array}{c}\text{Arterial 2}\\ \text{Peak Period}\\ \text{PMT}\end{array} + \ldots\ldots\ldots\ldots\right)} \qquad (2)$$

TRAVEL TIME DATA NEEDS

A 1997 report (3)—Quantifying Congestion—made some recommendations on the sample sizes that are needed on arterial streets to ensure confidence in the results. Table 1 shows the sample size estimates for 80, 85, and 90 percent confidence levels with 10 percent relative error, and for 95 percent confidence with five percent error. The minimum sample sizes are suggested for different types of arterials. A minimum sample size of six travel time runs for each arterial segment is recommended to reflect the variability associated with individual drivers, random events, and lane choice which could have a disproportionate effect if encountered on one or two runs.

Table 1. Suggested Travel Time Variations and Sample Sizes on Arterial Streets

Signal Density Group	Average c.v. (%)	Minimum Runs for 80%, 10% [a]	Minimum Runs for 85%, 10% [b]	Minimum Runs for 90%, 10% [c]	Minimum Runs for 95%, 5% [d]
Low—less than 3 signals per mile	9	2(6)[e]	2(6)[e]	3(6)[e]	13
Medium—3 to 6 signals per mile	12	3(6)[e]	3(6)[e]	4(6)[e]	23
High—greater than 6 signals per mile	15	4(6)[e]	5(6)[e]	7	35

[a] 80% level of confidence, 10% relative error

[b] 85% level of confidence, 10% relative error

[c] 90% level of confidence, 10% relative error

[d] 95% level of confidence, 10% relative error

[e] Six runs needed to provide reasonable assurance that data are not affected by unusual conditions (e.g., driver behavior, signal malfunctions).

The average coefficients of variation are shown in Table 2 for the travel time runs made in Grand Junction. The number of runs made by direction and time of day are shown as well. The coefficients of variation are typically in the range of the suggested coefficients in Table 1. Since this is the general case, it appears that the sample sizes in Grand Junction are sufficient to draw conclusions at about a 90 percent confidence level for almost all corridors. This is due to the fact that most of the coefficients are at or below the 12 associated with a medium signal density arterial street. Two streets have coefficients that are relatively high—Horizon/12th and I-70 Business East—as compared to the other corridors. This means that a few additional travel time runs would have been helpful on these streets, but overall, the data is not too bad for Grand Junction.

Table 2. Travel Time Variations and Sample Sizes in Grand Junction

Corridor	Direction	Time of Day	Type of Trip	Number of Travel Time Runs	Coefficient of Variation (%)
Horizon/12th	NB	A.M.	Off-peak	4	7.5
	NB	A.M.	Peak	4	12.0
	NB	P.M.	Peak	4	10.1
	SB	A.M.	Off-peak	4	6.8
	SB	A.M.	Peak	4	15.1
	SB	P.M.	Peak	4	13.0
I-70 Business E	EB	A.M.	Off-peak	4	6.2
	EB	A.M.	Peak	4	15.4
	EB	P.M.	Peak	4	8.8
	WB	A.M.	Off-peak	5	15.0
	WB	A.M.	Peak	3	17.7
	WB	P.M.	Peak	3	10.6
I-70 Business W	EB	A.M.	Off-peak	4	5.6
	EB	A.M.	Peak	4	4.7
	EB	P.M.	Peak	4	3.5
	WB	A.M.	Off-peak	4	8.4
	WB	A.M.	Peak	4	5.3
	WB	P.M.	Peak	4	6.4
North	EB	A.M.	Off-peak	2	2.0
	EB	A.M.	Peak	4	6.6
	EB	P.M.	Off-peak	2	9.9
	EB	P.M.	Peak	4	11.7
	WB	A.M.	Peak	4	1.8
	WB	P.M.	Off-peak	2	3.1
	WB	P.M.	Peak	4	8.2
Patterson	EB	A.M.	Peak	4	7.0
	EB	P.M.	Off-peak	3	8.6
	EB	P.M.	Peak	4	17.4
	WB	A.M.	Peak	4	3.8
	WB	P.M.	Off-peak	3	7.6
	WB	P.M.	Peak	4	4.2
SH 340	EB	A.M.	Off-peak	4	9.1
	EB	A.M.	Peak	4	3.5
	EB	P.M.	Peak	4	5.1
	WB	A.M.	Off-peak	4	5.2
	WB	A.M.	Peak	4	6.6
	WB	P.M.	Peak	4	12.8
SH 50	EB	A.M.	Off-peak	4	2.0
	EB	A.M.	Peak	4	3.4
	EB	P.M.	Peak	4	6.4
	WB	A.M.	Off-peak	4	0.8
	WB	A.M.	Peak	4	5.8
	WB	P.M.	Peak	4	6.2

ADDITIONAL DATA NEEDS

Up until now all of the discussion has centered on the travel time data collection. However, there are some additional data that are required to complete the analysis. Detailed distance information regarding the roadway segments in each corridor is needed. The distance between checkpoints is not always the same depending on which direction one is traveling along a corridor. This may be due to the roadway geometry. In this case, the distances are the same between the opposite direction checkpoints. Table 3 shows this detailed distance information for each of the seven arterial corridors.

Table 3. Segment Distance Information

Corridor	Direction	Limits	Dist. (miles)	Direction	Limits	Dist. (miles)
Horizon/12th	South	I-70 to G Rd G Rd to 12th St 12th St to Patterson Patterson to North Ave North Ave to Pitkin	0.53 0.52 0.68 1.00 0.90	North	Pitkin to North Ave North Ave to Patterson Patterson to 12th St 12th St to G Rd G Rd to I-70	0.90 1.00 0.68 0.52 0.53
I-70 Business East	East	15th St to 30 Rd 30 Rd to 141 141 to F Rd	2.89 2.20 0.37	West	F Rd to 141 141 to 30 Rd 30 Rd to 15th St	0.37 2.20 2.89
I-70 Business West	East	I-70 to F Rd F Rd to North Ave	2.16 2.12	West	North Ave to F Rd F Rd to I-70	2.12 2.16
North	East	I-70B W to 12th St 12th St to 28.5 Rd 28.5 Rd to I-70B E	0.99 1.51 1.24	West	I-70B E to 28.5 Rd 28.5 Rd to 12th St 12th St to I-70B W	1.24 1.51 0.99
Patterson	East	24 Rd to 12th St 12th St to 29 Rd 29 Rd to 32 Rd	3.12 2.12 2.97	West	32 Rd to 29 Rd 29 Rd to 12th St 12th St to 24 Rd	2.97 2.12 3.12
SH 340	East	Parkway to Ridges Ridges to 1st St	1.94 2.75	West	1st St to Ridges Ridges to Parkway	2.75 1.94
SH 50	East	Pitkin to Unaweep Unaweep to B.5 Rd B.5 Rd to 29 Rd 29 Rd to 141	1.06 1.40 1.76 2.04	West	141 to 29 Rd 29 Rd to B.5 Rd B.5 Rd to Unaweep Unaweep to Pitkin	2.04 1.76 1.40 1.06

Another very important set of information that is needed is the traffic volume counts that accompany the travel time information. Not only do we need to know how fast the vehicles were traveling, but also how many vehicles were doing the traveling. This will allow the data from the different segments in each corridor to be combined into a corridor level TRI value based on the amount travel per segment. Additionally, the traffic volume data allows the individual corridor data to be combined to form a system TRI value.

The traffic counts were collected using portable road tubes at various locations along each of the corridors. Several potential problems arose with the traffic volume counts in this process. The first problem was that a single traffic count may or may not be reflective of the average count along the entire segment. Traffic volumes were collected at several locations along each corridor. It is very difficult to determine exactly which count should be used to represent the segment and to determine if the count was representative of the traffic flow in the entire segment. For the purposes of this analysis, some assumptions were made regarding the traffic counts. A single count could represent the entire segment. The traffic count that was located the closest to the middle of the segment would be used with the idea that it would represent an average of the traffic in the segment.

A second potential problem with the traffic counts was that the traffic volumes were summarized into hourly totals. With this level of aggregation, the entire traffic volume is assigned the average travel rate for the hour. In other words, all of the traffic is assumed to be evenly distributed throughout the hour and because of this, it is assigned the average travel rate for the entire hour. If the data were in 15-minute volumes, the data could potentially be matched with actual travel time runs that occurred closer to when the volumes occurred. In this way, as the traffic volumes grow during the peak driving times, the speeds will start to slow accordingly.

Vehicle occupancy may also be needed for an analysis using the Travel Rate Index. The Grand Junction analysis did not require vehicle occupancy because all of the corridors in the study had similar occupancy characteristics and no other modes besides autos were included. At the time of the study, the local transit service was in its early inception and was not included. An anecdotal automobile occupancy—of perhaps 1.1 persons per vehicle—could be used to convert the vehicle-miles of travel into passenger-miles of travel. When multiple modes are included in the study, vehicle occupancy data would be required. For example, a bus may carry 20 passengers thus accounting for 20 passenger-miles of travel for every mile of travel. An automobile with two persons in it would only account for two passenger-miles of travel for the same mile. By having the correct vehicle occupancy, the different modes can be combined together by passenger travel to determine the Travel Rate Index value for both modes together.

Vehicle occupancy data could be collected by sampling 100 cars in a corridor during the desired data collection times to count the number of passengers. The total passengers in those 100 cars divided by the 100 cars themselves would give the average vehicle occupancy. A different average occupancy value could be collected for each corridor or one sample could be used for all corridors if the characteristics of each corridor were very similar. This would be determined during the data collection planning stage.

RESULTS OF THE ANALYSIS

The Travel Rate Index is a valuable measure to monitor mobility levels for entire corridors or transportation systems. The purpose of a mobility monitoring study such as this one is not to analyze the operations of a single intersection or short section of roadway. The purpose is to analyze the overall performance of a longer stretch of roadway such as a Patterson Road or North Avenue. A more localized analysis with much greater detailed data would be needed to review the operations of an intersection or single block of on one of these roadways. Thus, the most useful level of detail provided by this analysis using the TRI would be to provide the TRI values for each corridor during the peak hours of operation or possibly to report the TRI by direction for each of the corridors.

However, in order to provide a better understanding of the value of travel time data and measures such as the TRI, some detailed analysis will be provided later in the report. The detailed analysis will show the TRI by travel time segment and by direction for each of the corridors. With the limited amount of data that was collected for this project, it is very difficult to ascertain exactly what is happening in a given segment of roadway other than to point out that travel time was greater or lower across a given segment during the peak hours of travel.

OVERALL RESULTS

The Travel Rate Index values were calculated for each of the arterial street corridors. The values (shown in Figure 4) represent the travel in both the morning and evening peak hours for both directions of travel. Some of the key points in Figure 5 include:

- North Avenue has the highest peak hour time penalty of the seven roadways with a 25 percent penalty added to peak hour trips.
- Horizon/12th Street had the lowest peak hour time penalty. A time surplus was actually noted for this corridor during the peak commuting hours. This will be discussed in more detail later in the report.
- All other corridors had a peak hour time penalty of between 4 and 11 percent.
- The average peak hour time penalty for the seven arterial streets analyzed in Grand Junction was seven percent.

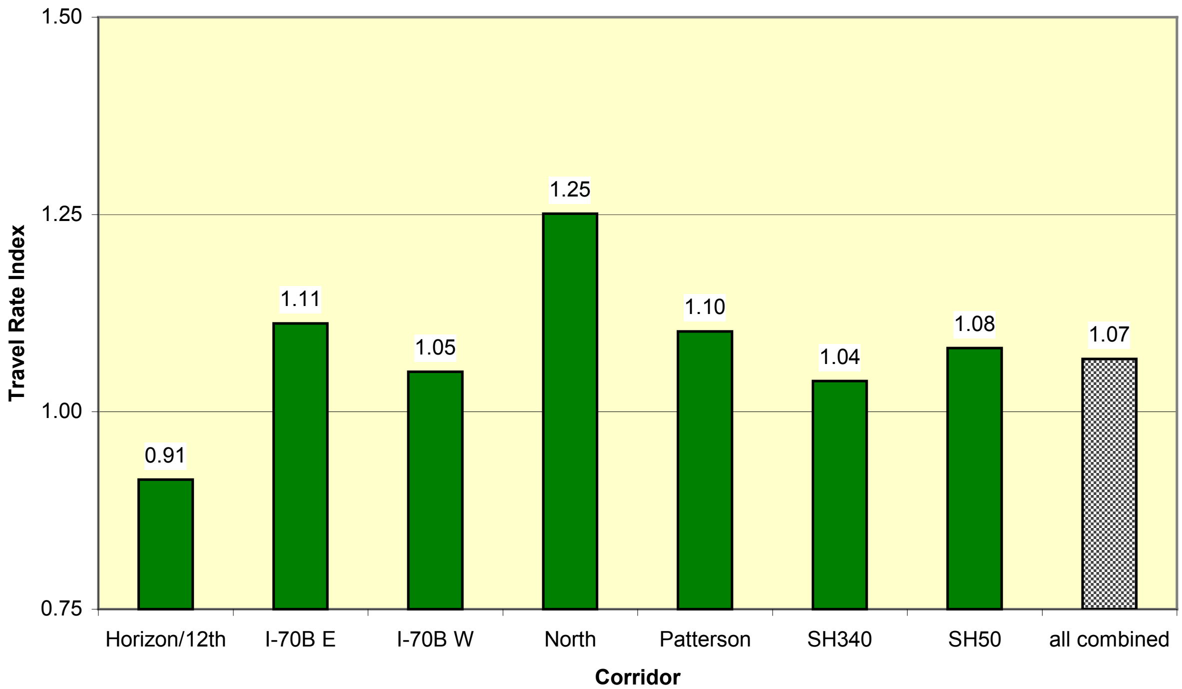


Figure 5. Peak Hour Mobility Levels on Grand Junction Arterial Streets

INDIVIDUAL CORRIDORS IN THE PEAK HOUR

The Travel Rate Index values were calculated for each peak hour of the day and each direction of travel for all seven arterial streets in the study. These values are shown in Figures 6 through 12. In each of these figures, the TRIs are given for each direction and time. In addition, the average TRI for the corridor is shown in the figure to provide some perspective. In general, the time penalties due to heavy traffic demand are greater in the evening peak hour than the morning. This is the case on the majority of the arterial streets.

Figure 6 shows the TRI values for I-70 Business East. Some of the key points in the figure include:

- The P.M. Eastbound peak trips have the highest time penalty associated with them at about 27 percent additional trip time due to heavy traffic.
- The other three time period-direction combinations have modest time penalties of between one and seven percent for peak hour trips.
- The average peak hour trip on I-70 Business East takes 11 percent longer than the equivalent trip at other times of the day.

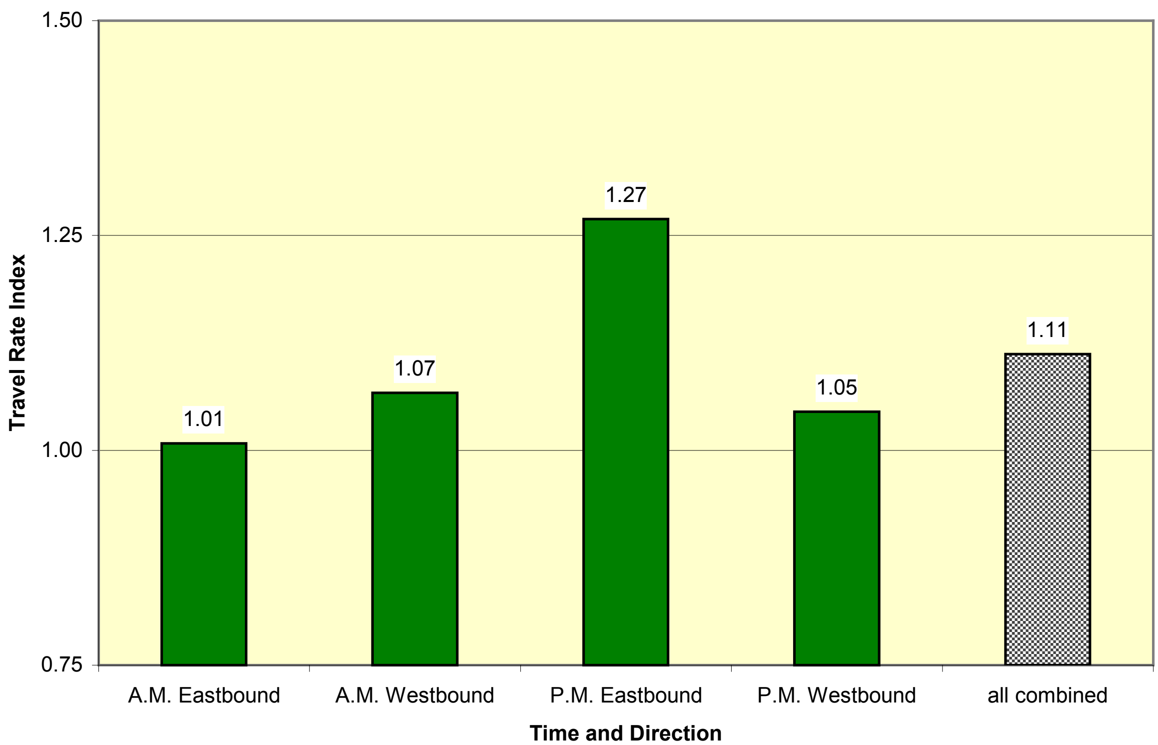


Figure 6. Peak Hour Mobility Levels on I-70 Business East

Figure 7 shows the TRI values for I-70 Business West. Some of the key points in the figure include:

- The P.M. Eastbound peak trips have the highest time penalty associated with them at about 20 percent additional trip time due to heavy traffic.
- The other three time-direction combinations have very little, if any, time penalties associated with peak hour trips.
- The average peak hour trip on I-70 Business East takes five percent longer than the equivalent trip at other times of the day.

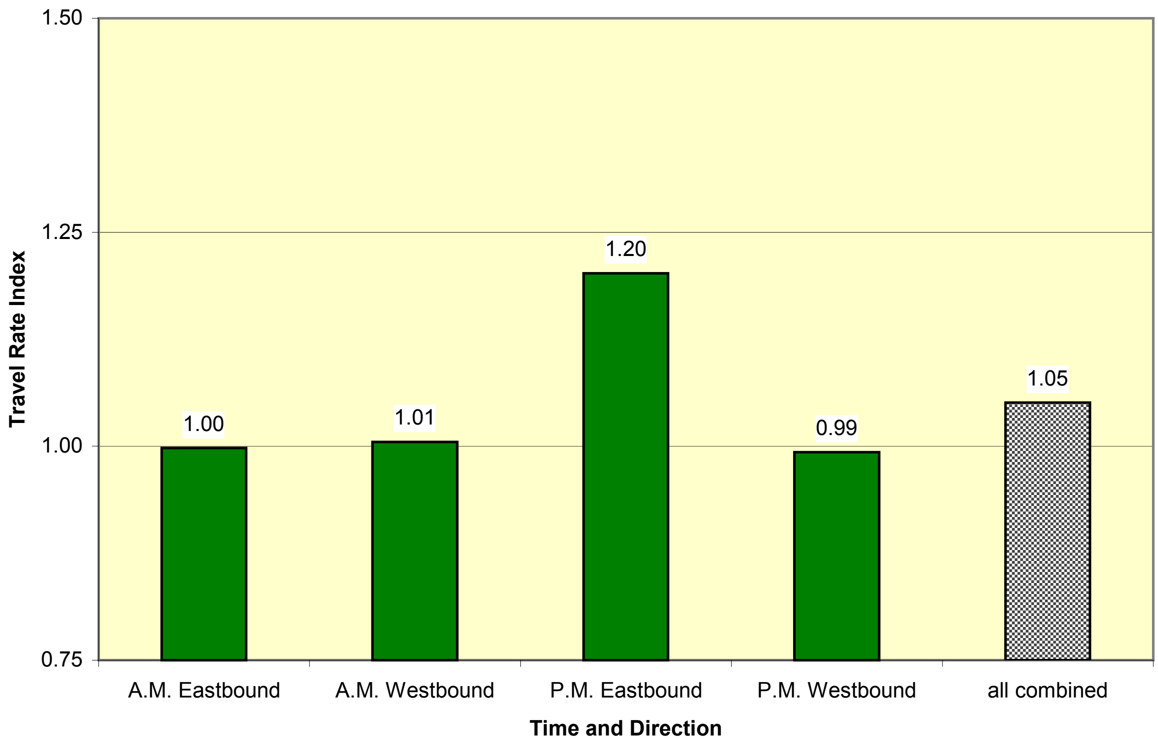


Figure 7. Peak Hour Mobility Levels on I-70 Business West

Figure 8 shows the TRI values for North Avenue. Some of the key points in the figure include:

- The evening westbound peak hour trips have the greatest time penalty associated with them due to heavy traffic. A peak hour trip takes 41 percent longer to complete than an off-peak trip due to heavy traffic.
- The evening eastbound peak hour trips also take a great deal more time to complete (29 percent longer) than trips at other times of the day.
- The morning peak hour trips don't appear to be quite as congested as the evening peak hour trips. The morning eastbound peak hour trip takes 16 percent longer due to heavy traffic while the morning westbound peak hour trip takes 12 percent longer to complete.
- The average peak hour trip on North Avenue takes 25 percent longer to complete in the peak as opposed to the off-peak due to heavy traffic conditions.

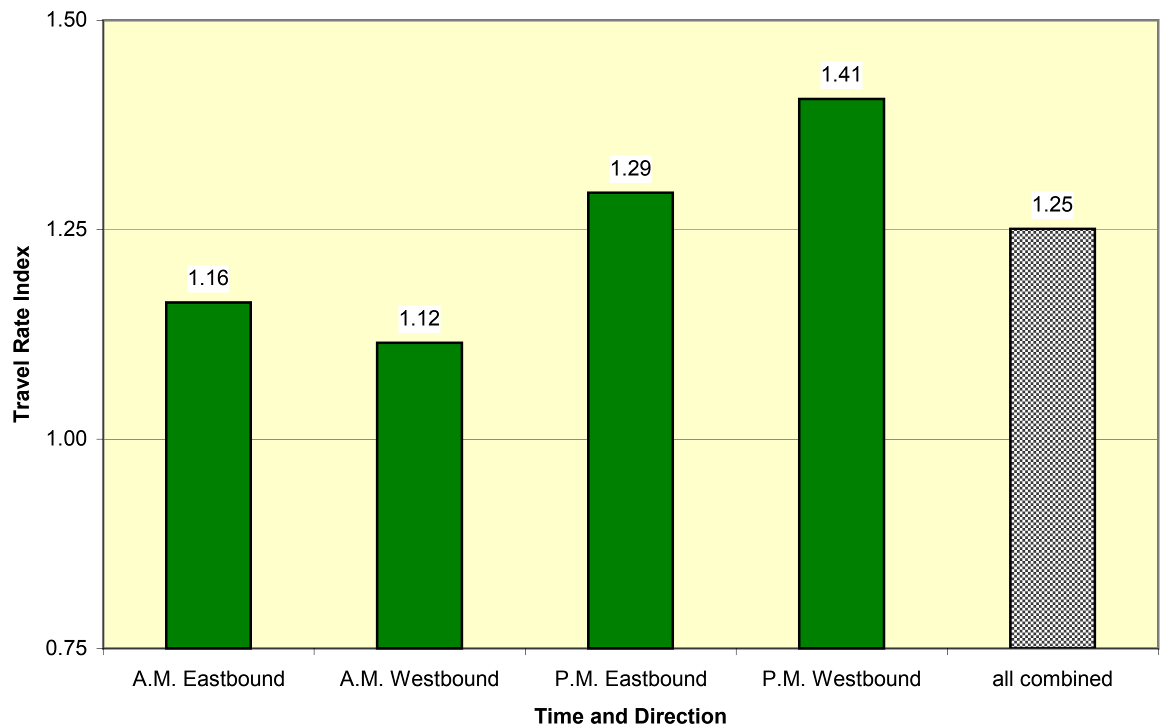


Figure 8. Peak Hour Mobility Levels on North Avenue

Figure 9 shows the TRI values for Patterson Road. Some of the key points in the figure include:

- The time penalties across the different times and directions were fairly consistent at about 10 percent. This held true for all peak hour trips except the morning eastbound trips that had a five percent time penalty.
- The average time penalty due to heavy traffic demand during the morning and evening peak hours was 10 percent.

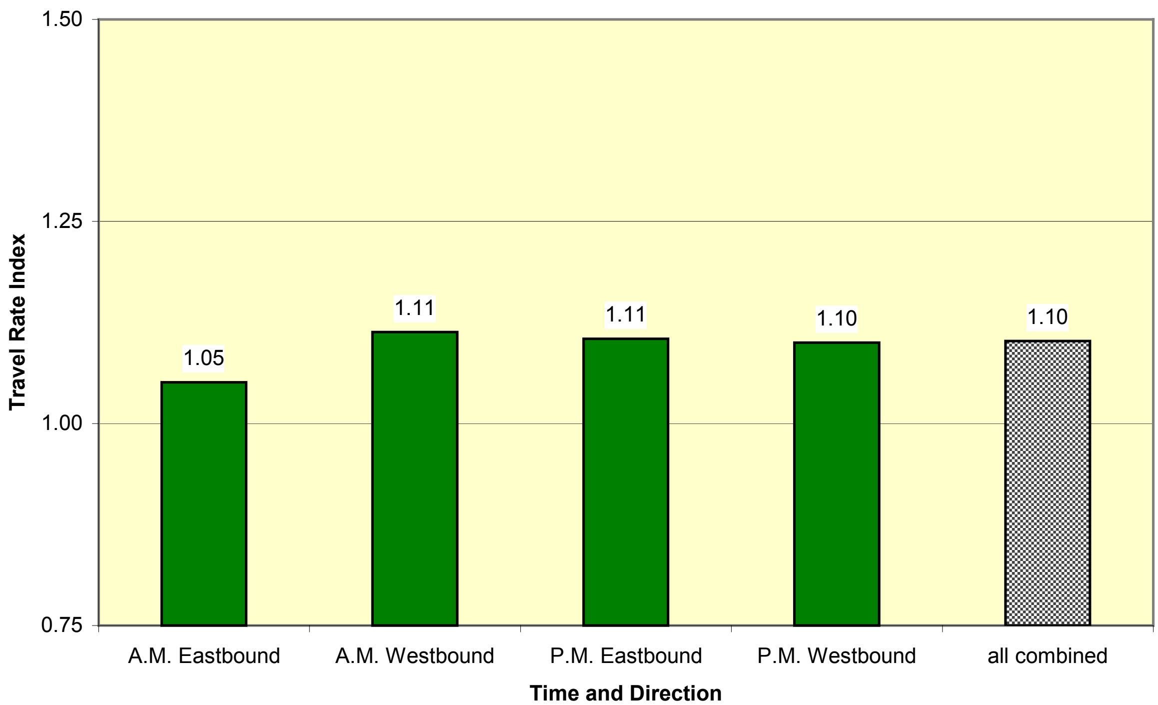


Figure 9. Peak Hour Mobility Levels on Patterson Road

Figure 10 shows the TRI values for SH 340. Some of the key points in this figure include:

- The greatest time penalty (nine percent) due to heavy traffic demand occurred in the evening eastbound trip.
- The morning westbound peak hour trips actually enjoyed speeds at or greater than those in off-peak times of the day.
- The average time penalty for the corridor was four percent.

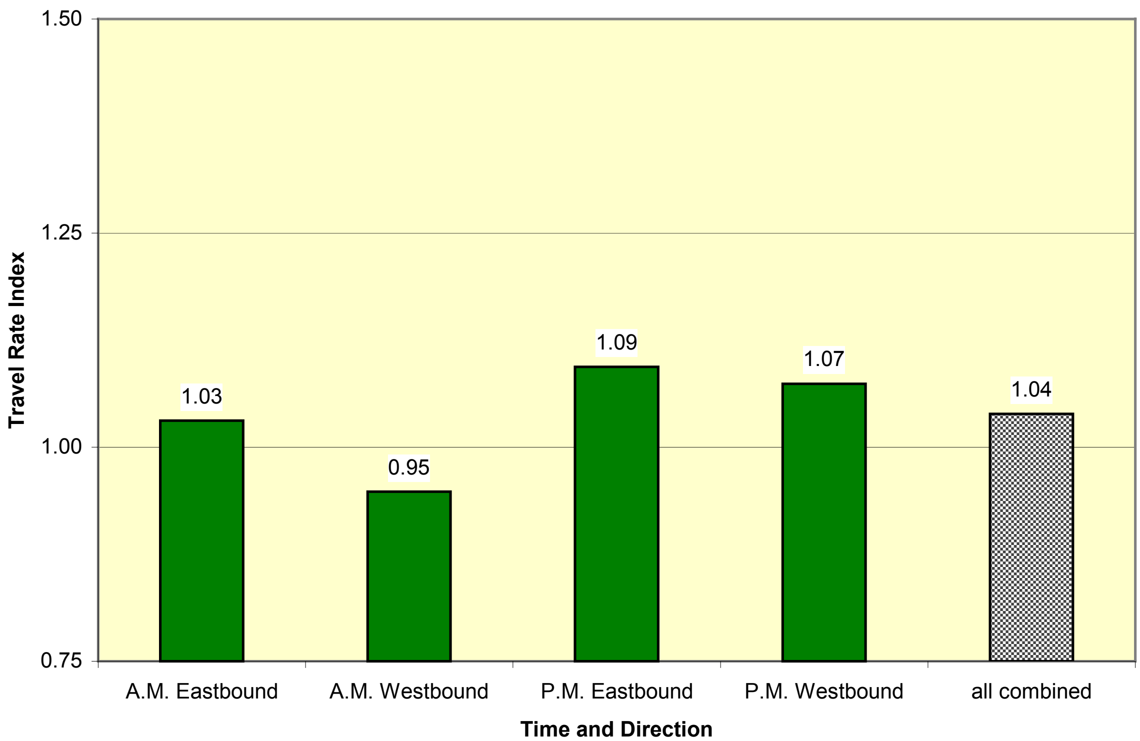


Figure 10. Peak Hour Mobility Levels on SH 340

The TRI values for SH 50 are shown in Figure 11. The key points from this figure include:

- The greatest time penalty occurred in the morning westbound trips with an additional 13 percent of time required to complete the trip. This is somewhat different from most of the other corridors where the largest time penalty occurred in the evening trips.
- The other three time-direction combinations had similar time penalties in the five to eight percent range.
- The average time penalty due to heavy traffic demand was eight percent.

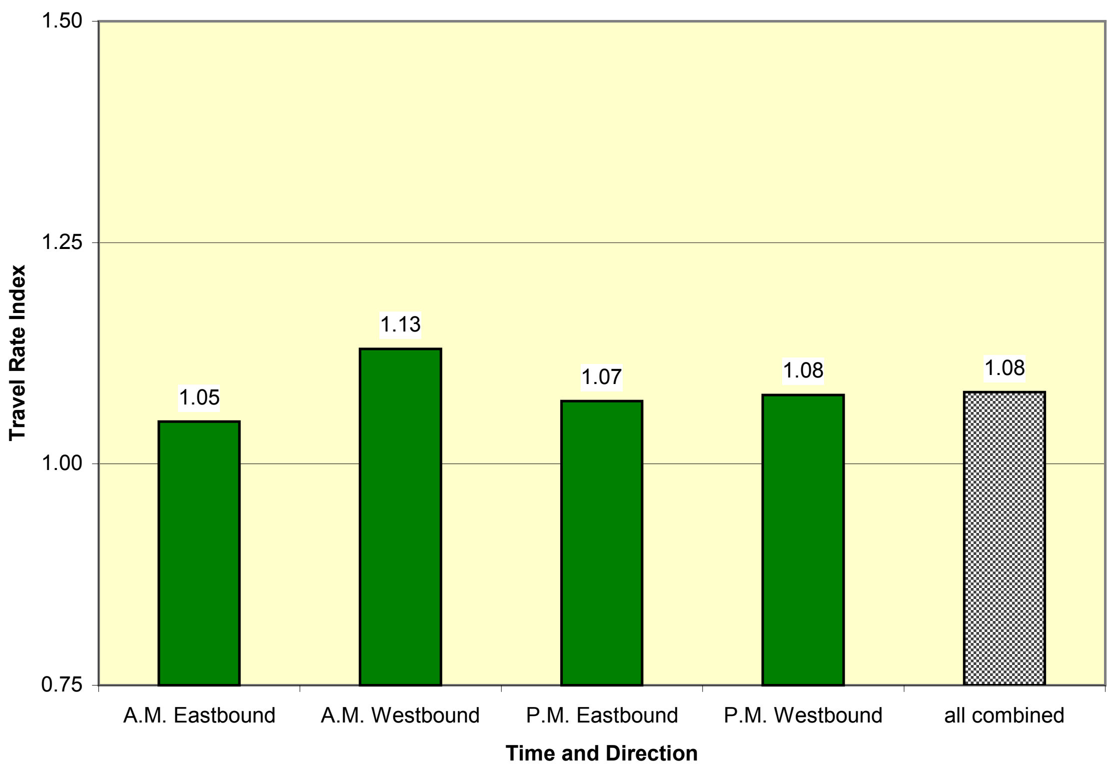


Figure 11. Peak Hour Mobility Levels on SH 50

Figure 12 shows the TRI values for Horizon Drive and 12th Street. This corridor showed time surpluses for trips made in the peak hour. There are many possible reasons for this and they will be discussed in more detail later in this report. Some of the key points in the figure include:

- The greatest TRI value (0.96) occurred with the morning northbound trips.
- Both the morning and evening southbound trips had TRIs of 0.89.
- The average TRI for the corridor was 0.91.

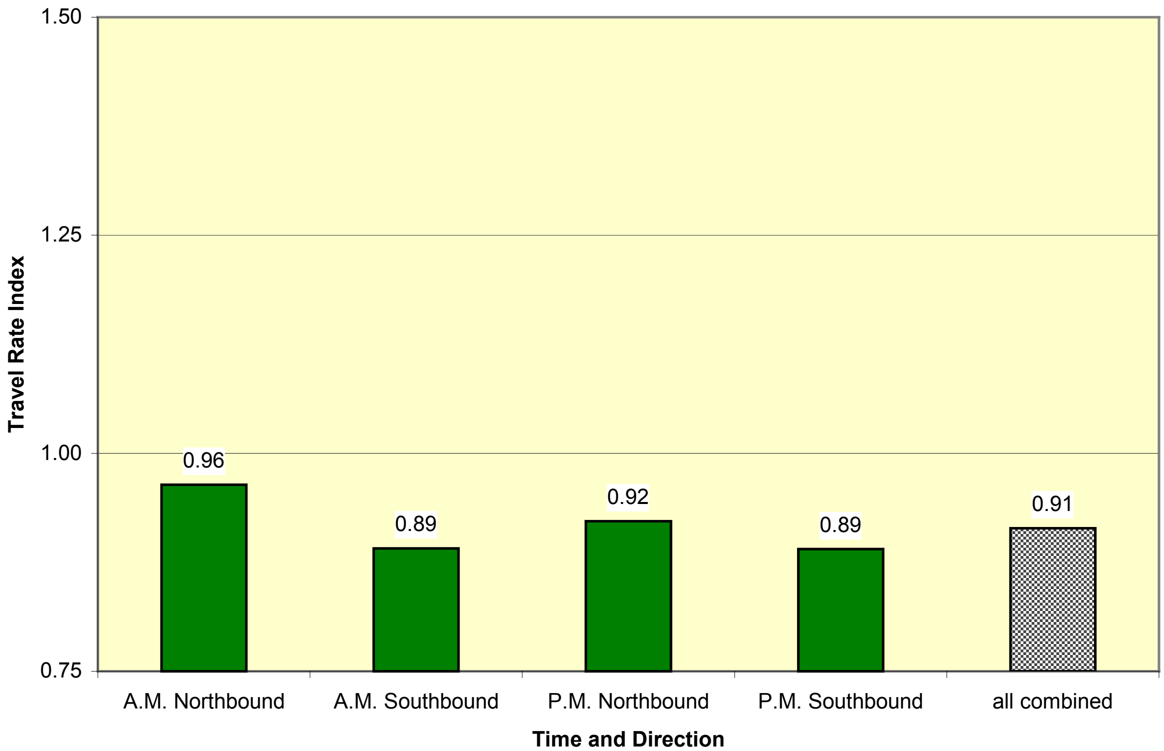


Figure 12. Peak Hour Mobility Levels on Horizon Drive / 12th Street

PEAK HOUR CORRIDOR ANALYSIS BY DIRECTION

This section of the report shows the TRIs by direction for each segment of road in the corridor. The purpose of this section is not to try to determine what is causing the slower or faster travel times in a given segment, but rather to demonstrate how each segment is performing. As stated earlier, a much more detailed operational analysis would have to be performed to optimize the capabilities of each corridor and the system as a whole.

I-70 Business East

Figures 13 and 14 show the directional TRIs by segment. Some of the information shown in these figures includes:

- The travel times in the eastbound direction appear to be a little longer, on average, than in the westbound direction due to heavy traffic.
- In the westbound direction, the two slowest segments are the 30 Road to SH141 and SH141 to F Road segments.
- In the eastbound direction, the slowest segment is the 30 Road to 15th Street segment.
- In the westbound direction, the time penalties appear to be getting larger the closer one gets to the downtown area.

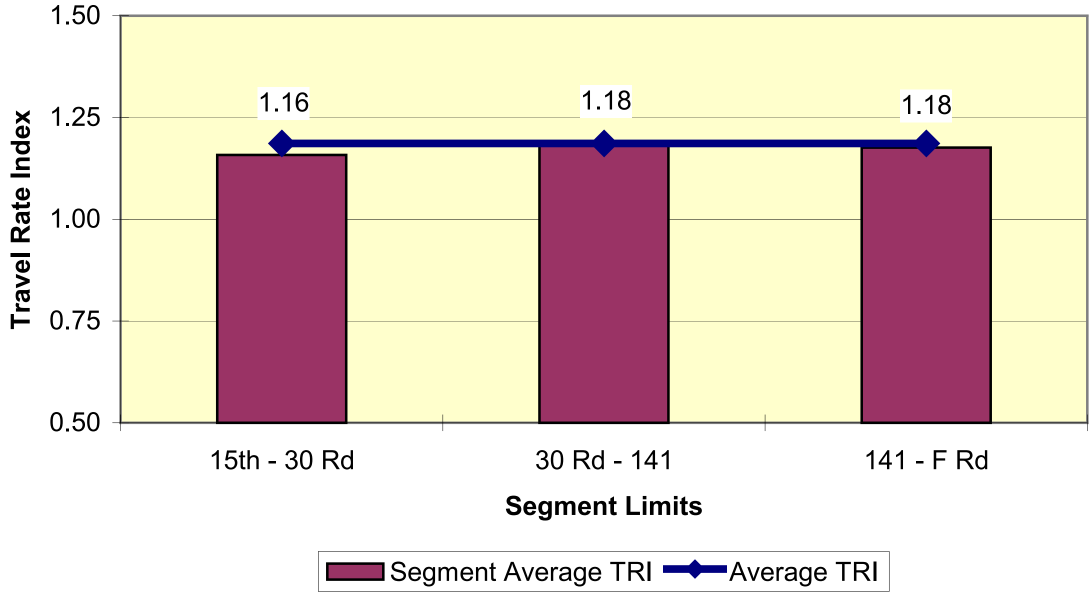


Figure 13. I-70 Business East – Eastbound

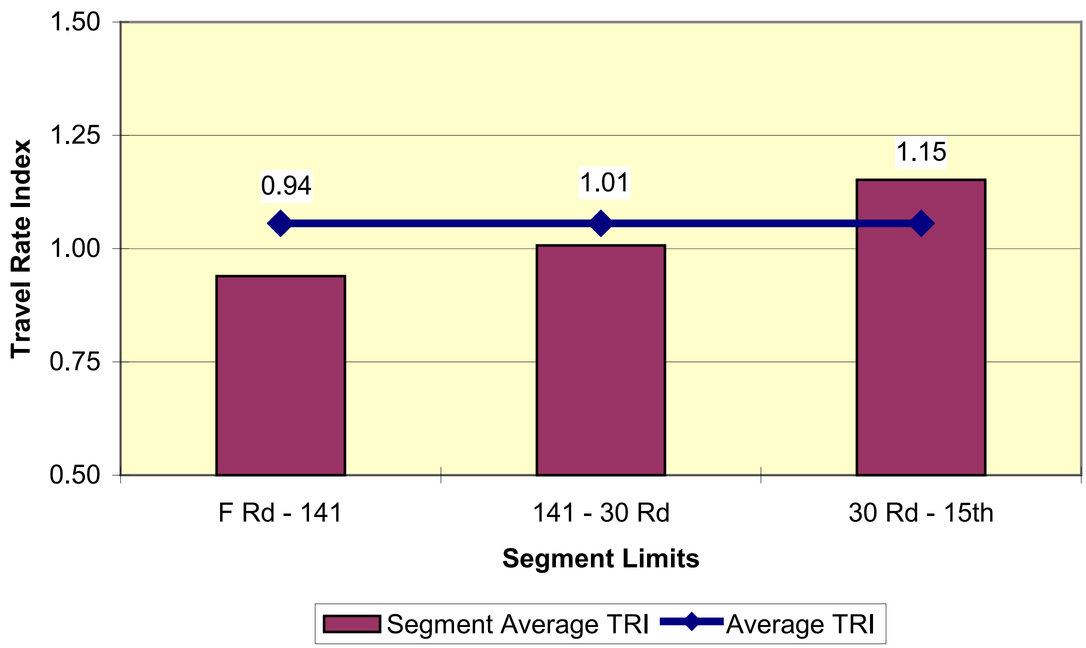


Figure 14. I-70 Business East – Westbound

I-70 Business West

Figures 15 and 16 show the directional TRIs by segment. Some of the information shown in these figures includes:

- The travel times in the eastbound direction appear to be a little longer, on average, than in the westbound direction due to heavy traffic.
- The greatest time penalty occurs in the segment F Road to North Avenue in the eastbound direction.
- There appears to be very little time penalty in the westbound direction.

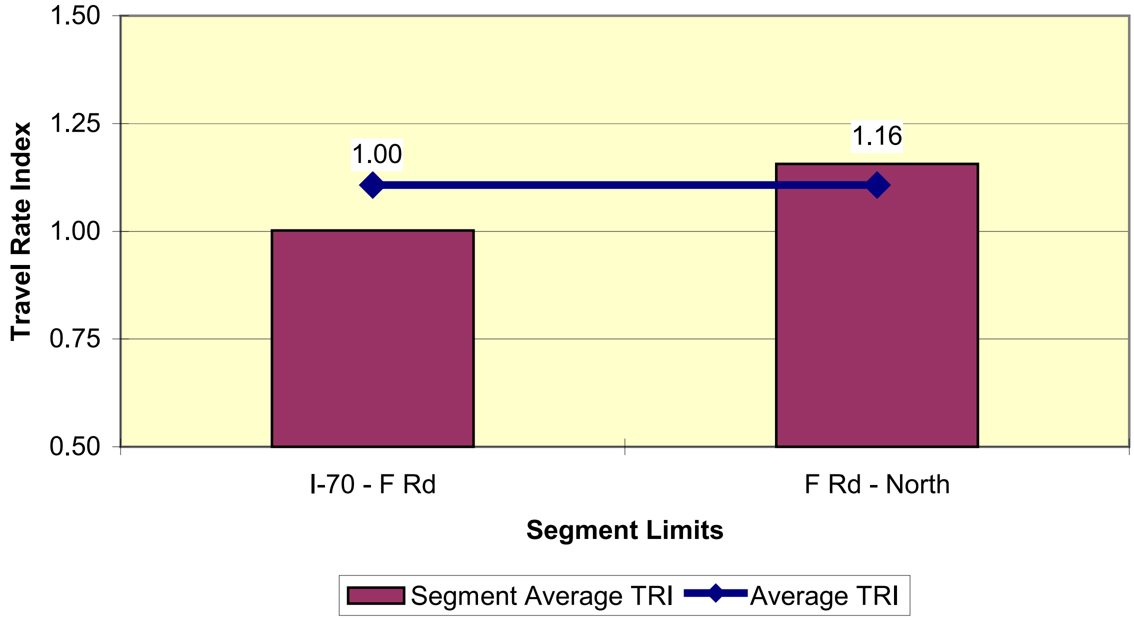


Figure 15. I-70 Business West - Eastbound

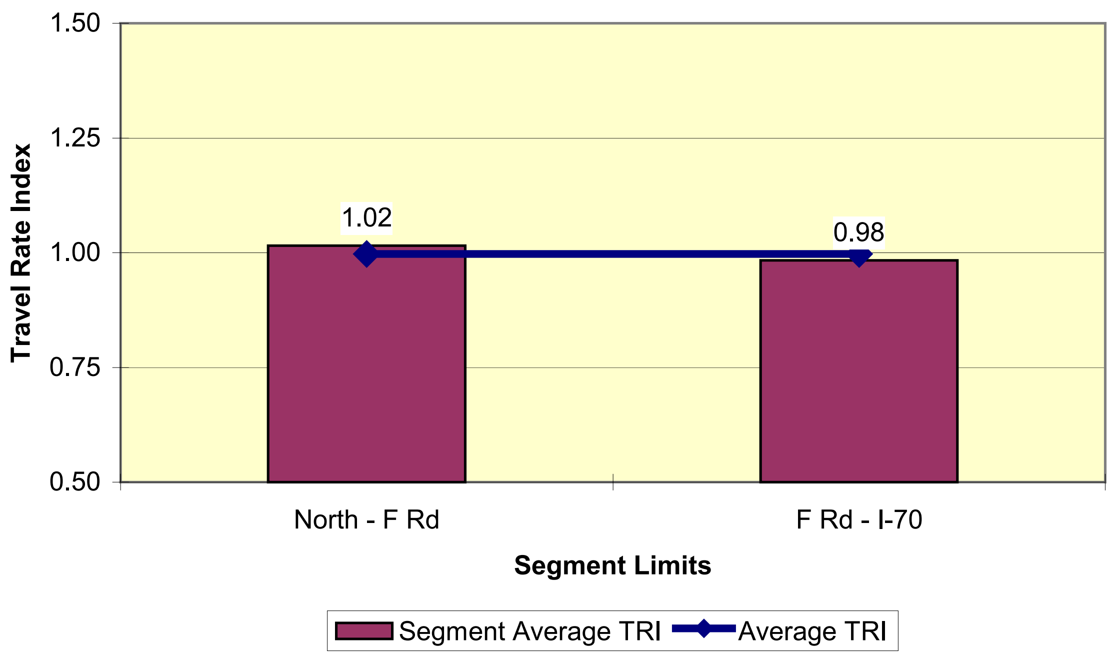


Figure 16. I-70 Business West - Westbound

North Avenue

Figures 17 and 18 show the directional TRIs by segment. Some of the information shown in these figures includes:

- The TRIs in both directions appear to have segments that have some fairly large time penalties incurred due to heavy traffic.
- The greatest time penalty occurs in the segment 28.5 Road to I-70 Business East in the eastbound direction and in the segment 28.5 Road to 12th Street in the westbound direction.
- In the eastbound direction, the middle segment 12th Street to 28.5 Road appears to have a much lower time penalty than in the westbound direction.

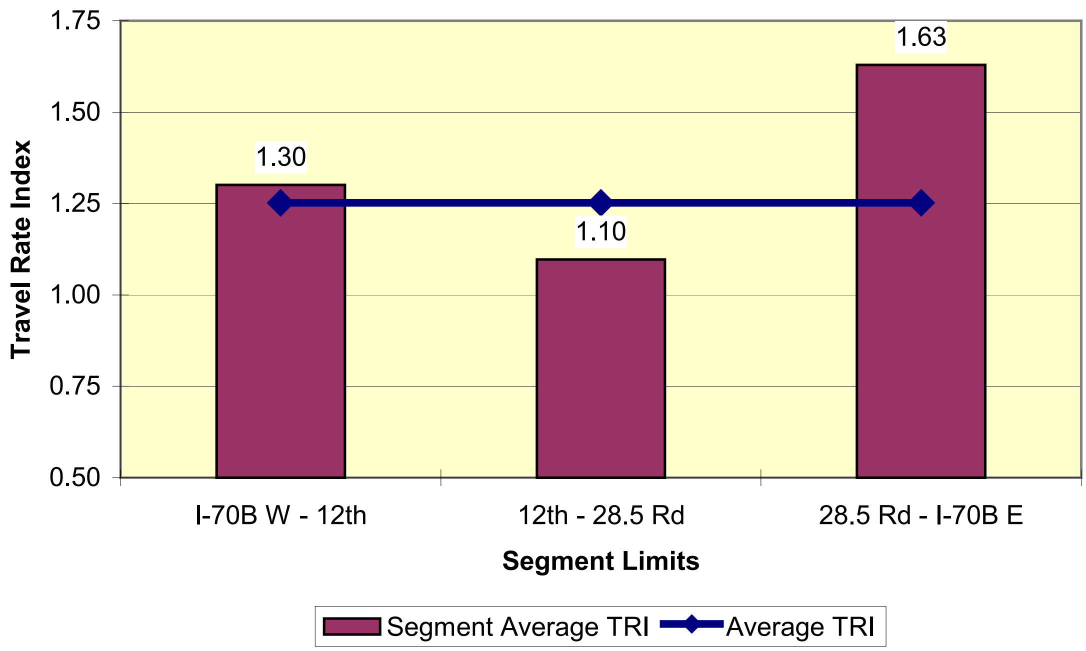


Figure 17. North Avenue - Eastbound

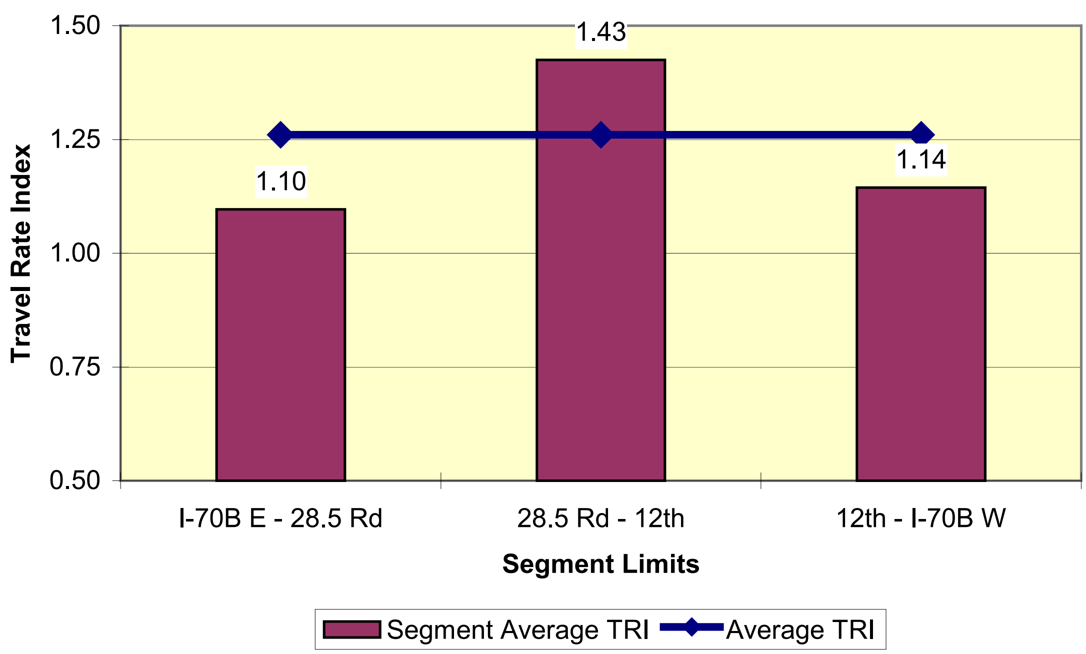


Figure 18. North Avenue - Westbound

Patterson Road

Figures 19 and 20 show the directional TRIs by segment. Some of the information shown in these figures includes:

- The TRIs in both directions appear to have segments that have some fairly large time penalties incurred due to heavy traffic.
- The greatest time penalty occurs in the segment 12th Street to 29 Road in the eastbound direction and in the segment 32 Road to 29 Road in the westbound direction.
- In the eastbound direction, the middle segment 12th Street to 29 Road appears to have a much lower time penalty than in the westbound direction.
- In the eastbound direction, the segment 24 Road to 12th Street appears to have a much higher time penalty than in the westbound direction.
- In the westbound direction, the segment 32 Road to 29 Road appears to have a much higher time penalty than in the eastbound direction.

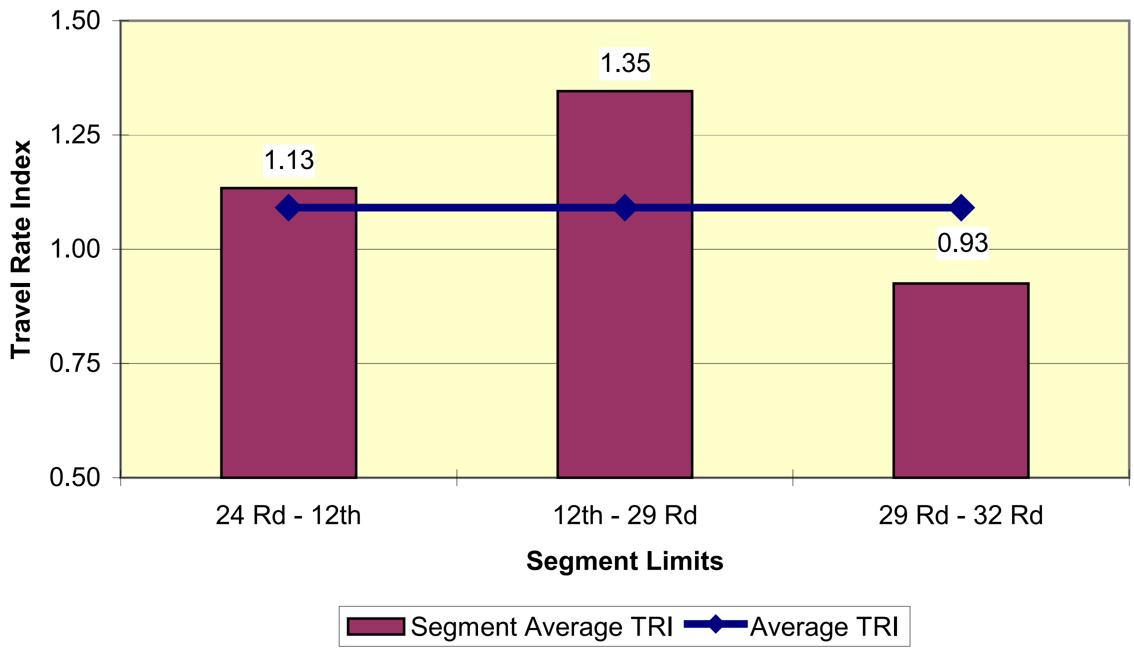


Figure 19. Patterson Road – Eastbound

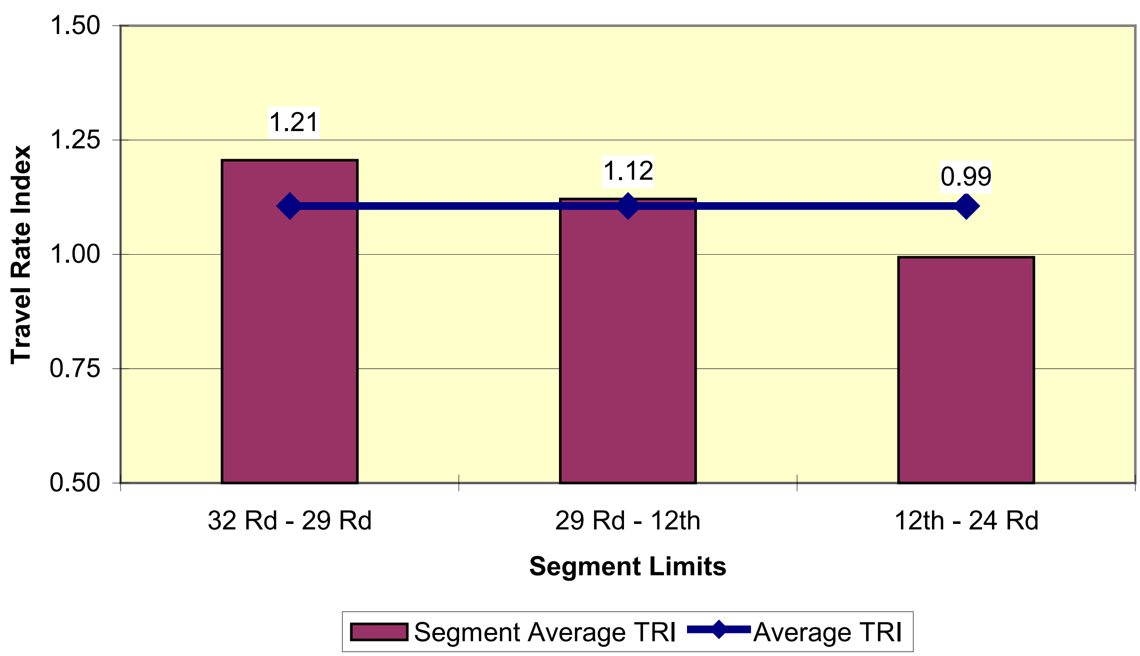


Figure 20. Patterson Road - Westbound

SH 340

Figures 21 and 22 show the directional TRIs by segment. Some of the information shown in these figures includes:

- The travel times in the eastbound direction appear to be a little longer, on average, than in the westbound direction due to heavy traffic.
- The greatest time penalty occurs in the segment Parkway to Ridges in the eastbound direction.
- There appears to be only a small amount of time penalty in the westbound direction.

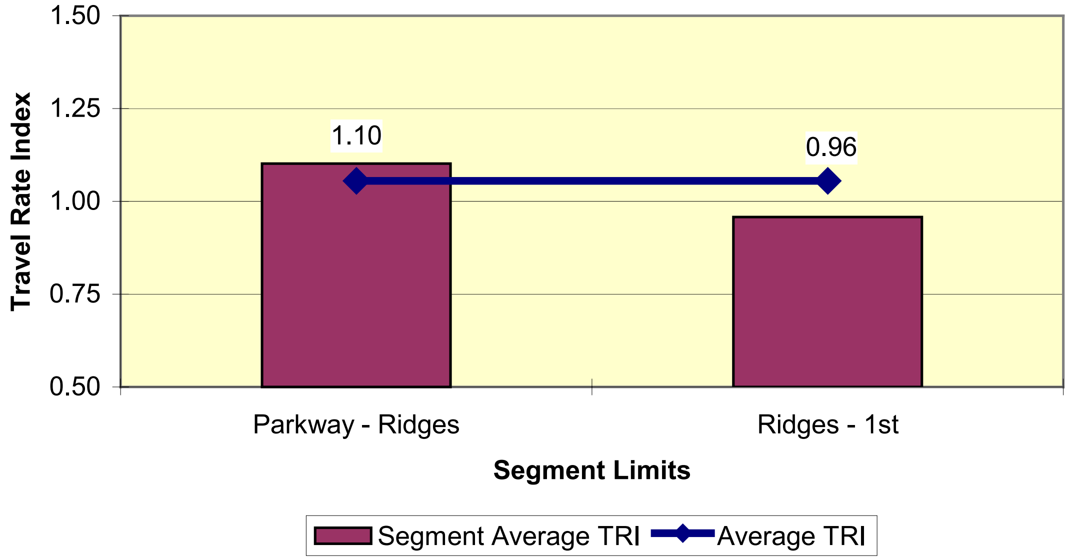


Figure 21. SH 340 - Eastbound

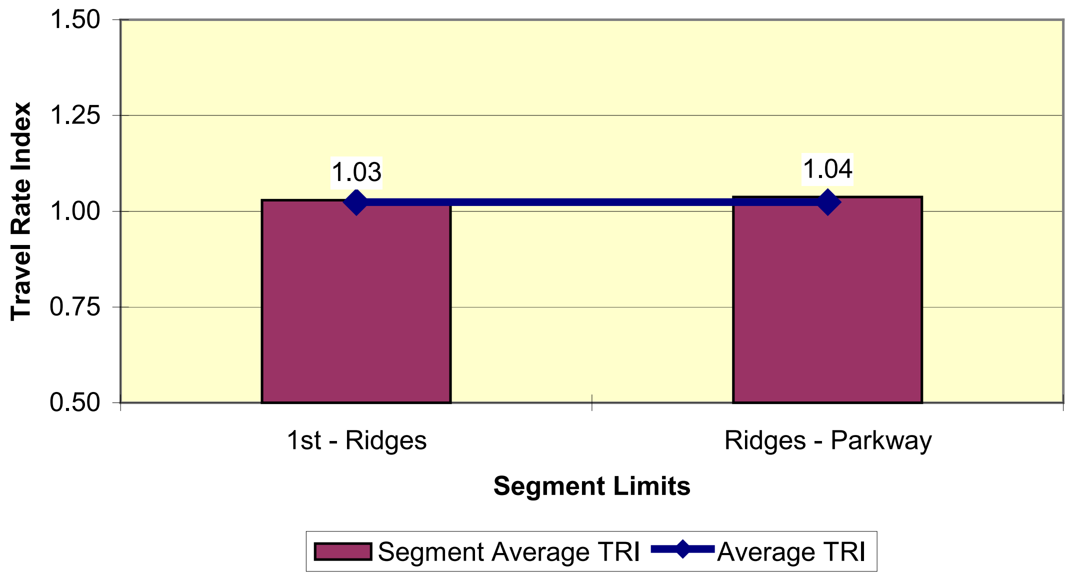


Figure 22. SH 340 - Westbound

SH 50

Figures 23 and 24 show the directional TRIs by segment. Some of the information shown in these figures includes:

- The travel times in the westbound direction appear to be a little shorter, on average, than in the eastbound direction due to heavy traffic except for the segment Unaweep to Pitkin. This segment is the only one in the westbound direction that incurs much time penalty.
- The greatest time penalty occurs in the segment Unaweep to Pitkin in the westbound direction.
- There appears to be much more of a time penalty in the Unaweep to Pitkin segment in the westbound direction than in the eastbound direction.
- In the eastbound direction, the greatest time penalty occurred in the Unaweep to B.5 Road segment.

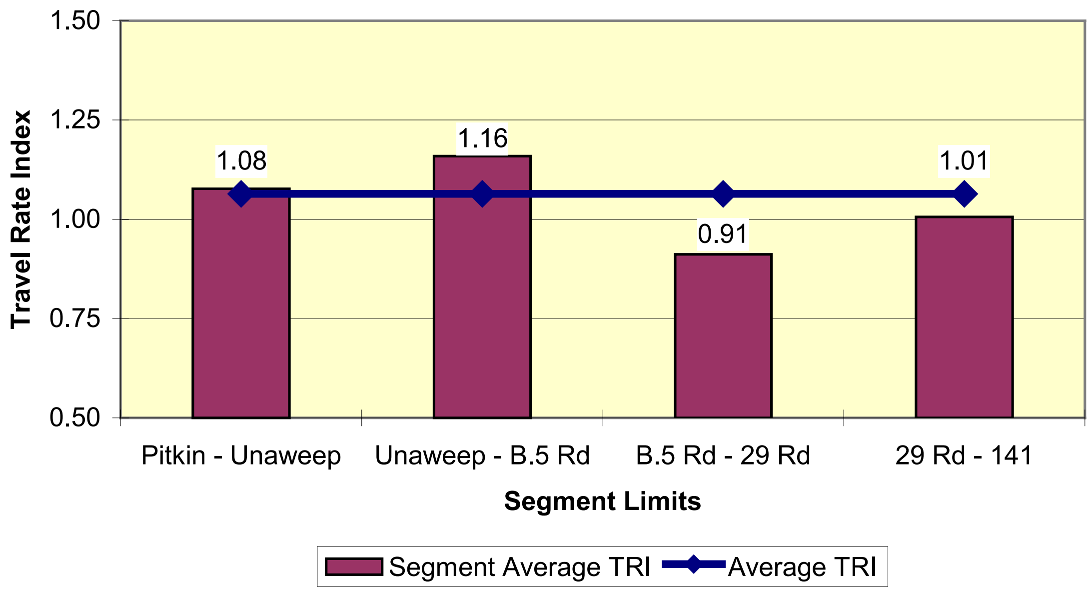


Figure 23. SH 50 – Eastbound

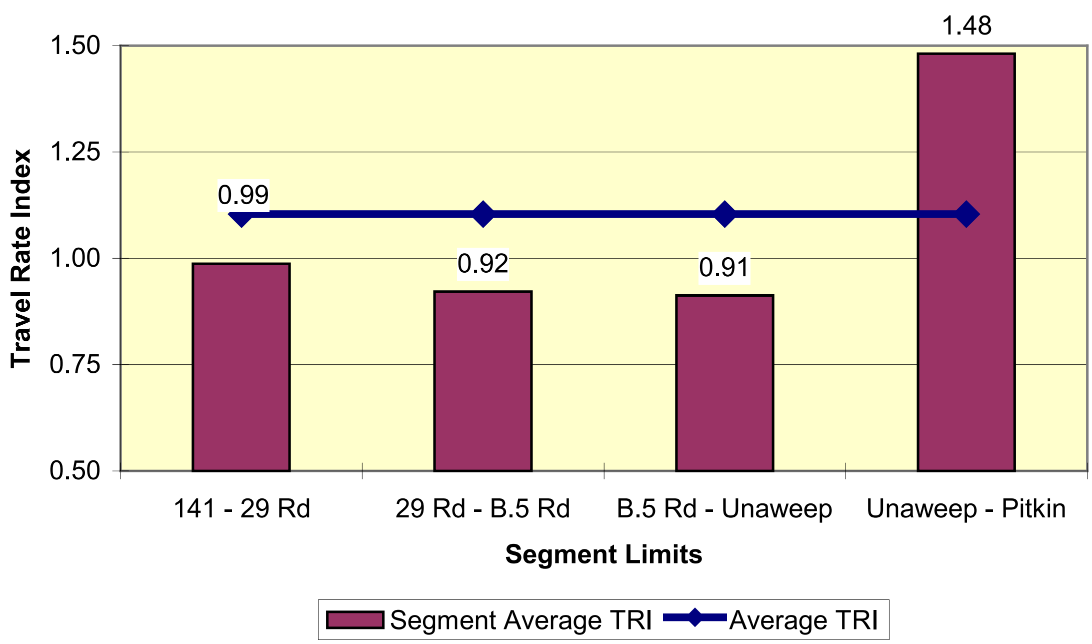


Figure 24. SH 50 – Westbound

Horizon Drive / 12th Street

Figures 25 and 26 show the directional TRIs by segment. Some of the information shown in these figures includes:

- This is the only corridor of the seven studied that had average TRI values below 1.0 in both directions.
- The average travel times in both directions appear to differ dramatically by segment.
- The largest time penalty occurred in the North Avenue to Pitkin Road segment in the southbound direction and in the North Avenue to Patterson Road segment in the northbound direction.
- More discussions regarding this corridor can be found in the next section of this report.

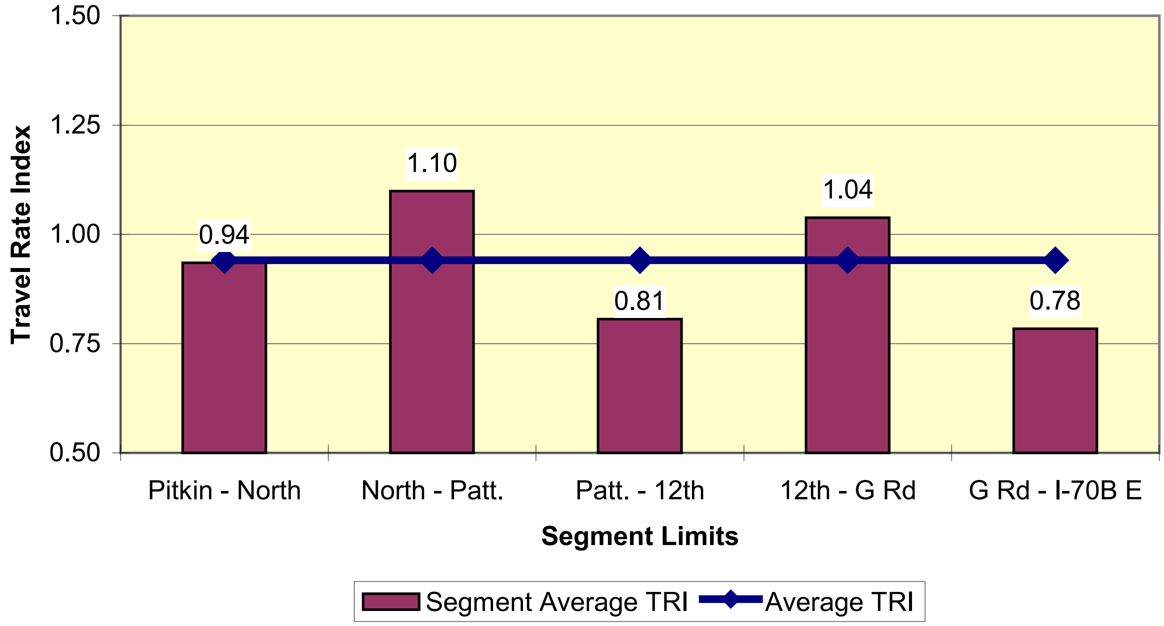


Figure 25. Horizon Drive / 12th Street – Northbound

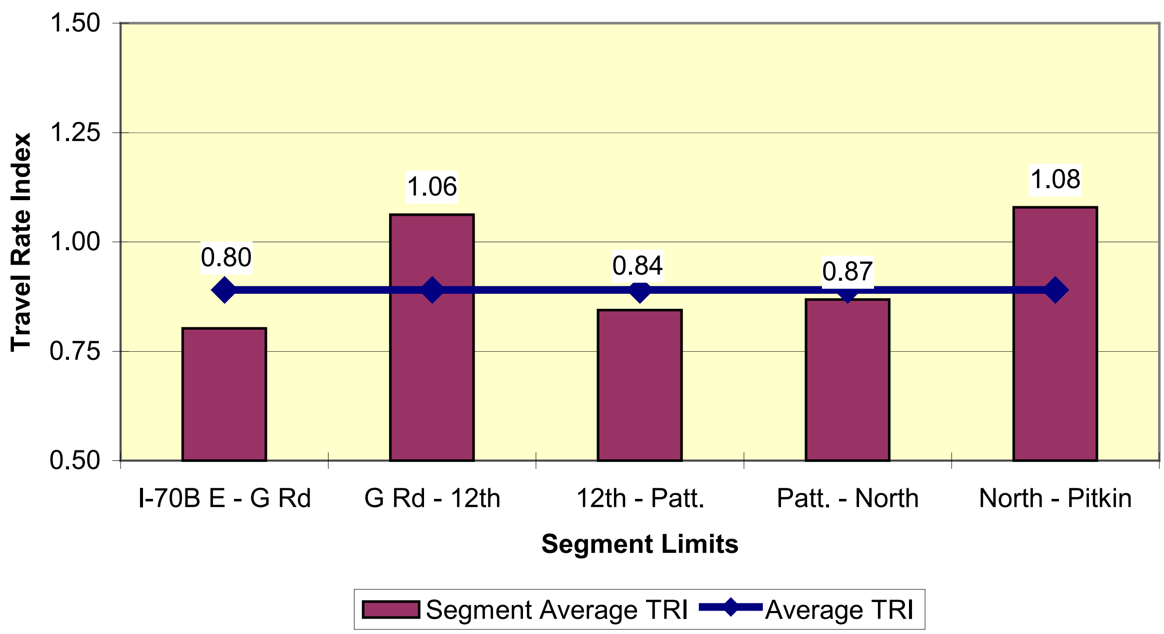


Figure 26. Horizon Drive / 12th Street - Southbound

THE HORIZON DRIVE / 12th STREET CORRIDOR

As mentioned previously, the Horizon/12th corridor is the only corridor that had an average TRI of less than 1.0. There could be many explanations for this occurrence; however, recall that it is not the purpose of this report to analyze this in too much depth. But, it is important from the standpoint of using the TRI to analyze mobility levels that some examination should be found to explain what is going on with this corridor.

In order to gain a better understanding of what is occurring in the corridor, some additional figures have been included showing the TRI values for each segment of roadway by direction and time of day. This information is shown in Figures 27 through 30.

The northbound data is shown in Figures 27 and 28. There is a wide range between the highest and lowest TRIs in the morning northbound data. However, every one of the TRIs in the evening northbound data is below 1.0. This could indicate that the signals have been timed in such a way as to optimize movements away from the downtown area in the evening peak hour.

The southbound data is shown in Figures 29 and 30. Again, there is a large range between the highest and lowest TRIs in the evening southbound data. Once again, every one of the TRIs in the morning southbound data is below 1.0. Again, this could indicate that the signals have been timed in order to optimize movements toward the downtown area in the morning peak hour.

Since most signal systems along arterial streets are timed to optimize the green time for the peak movements, this probably does not explain everything that is happening in the corridor. In the case of the seven arterial streets in Grand Junction, this was the only one in which this peak direction phenomenon occurred with all segments having TRI values less than 1.0.

Another factor that showed up frequently along the Horizon/12th corridor was that the off-peak traffic volumes in some segments were higher than those experienced in the peak hours for the same segments. This could be partially due to the traffic generation created by Mesa College between the hours of 8:00 a.m. and 5:00 p.m. (outside of the traditional peak commuting time). The student traffic coming and going from the college could create congestion along this roadway in the off-peak hours. The travel time runs made in the off-peak along 12th Street could have been affected by the at-grade pedestrian crosswalks or by the students searching for parking spots throughout the day. This may point to the fact that the travel time runs made between 7:00 and 8:00 a.m. that were considered peak were not the “true“ peak runs along the corridor. The peak of this corridor may actually occur when the students are attending their classes.

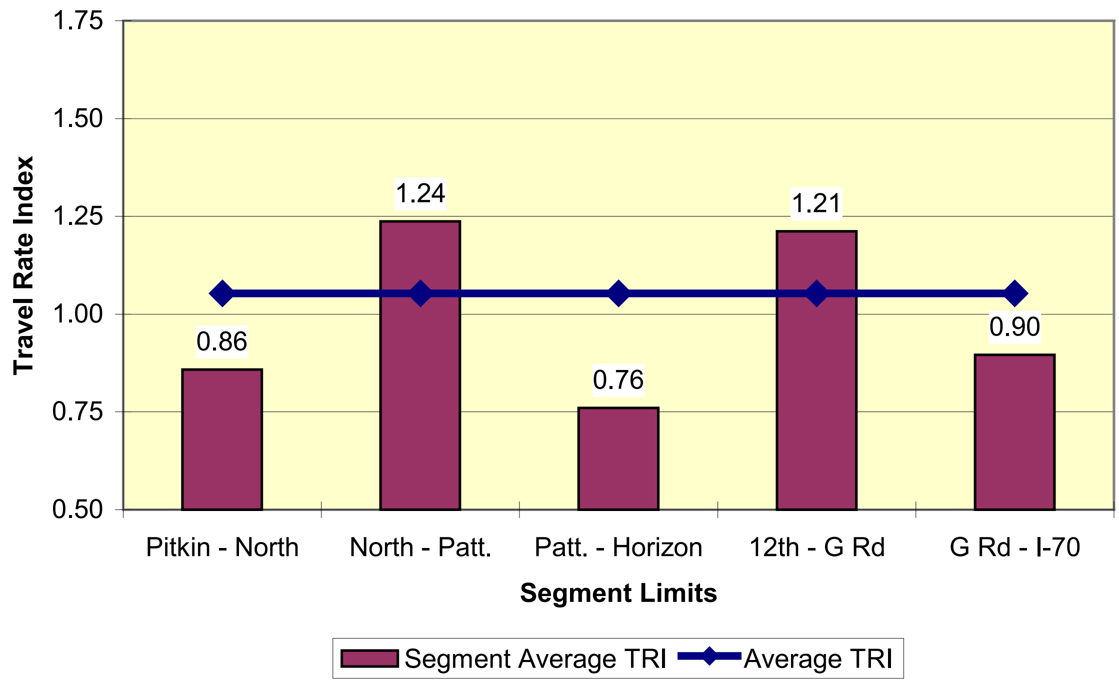


Figure 27. Horizon Drive / 12th Street – Morning Northbound

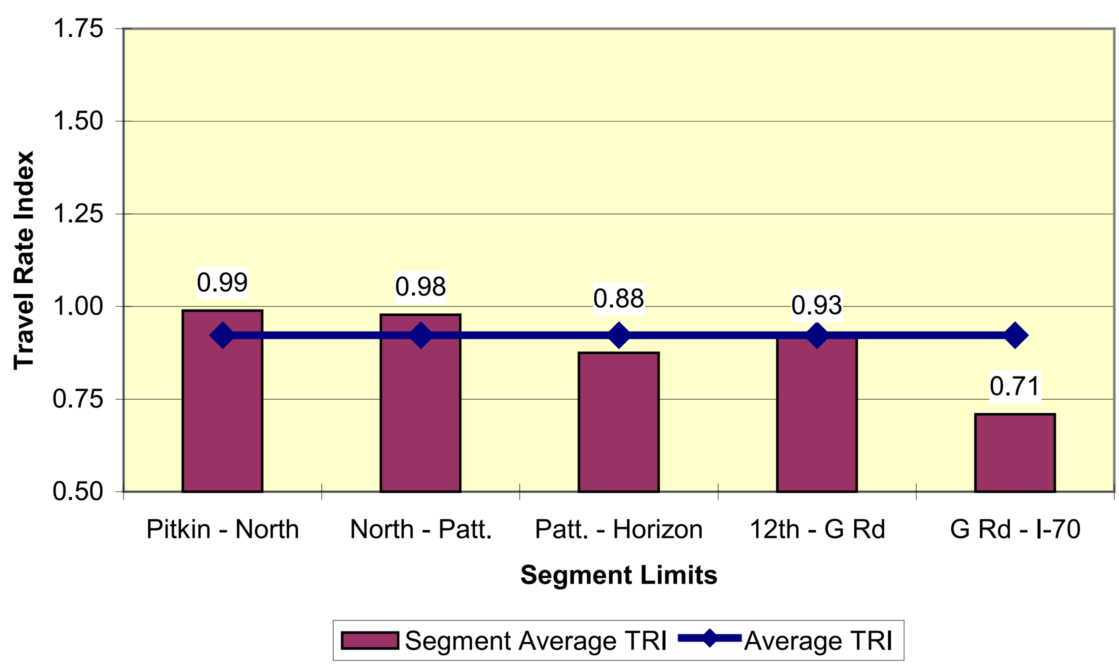


Figure 28. Horizon Drive / 12th Street – Evening Northbound

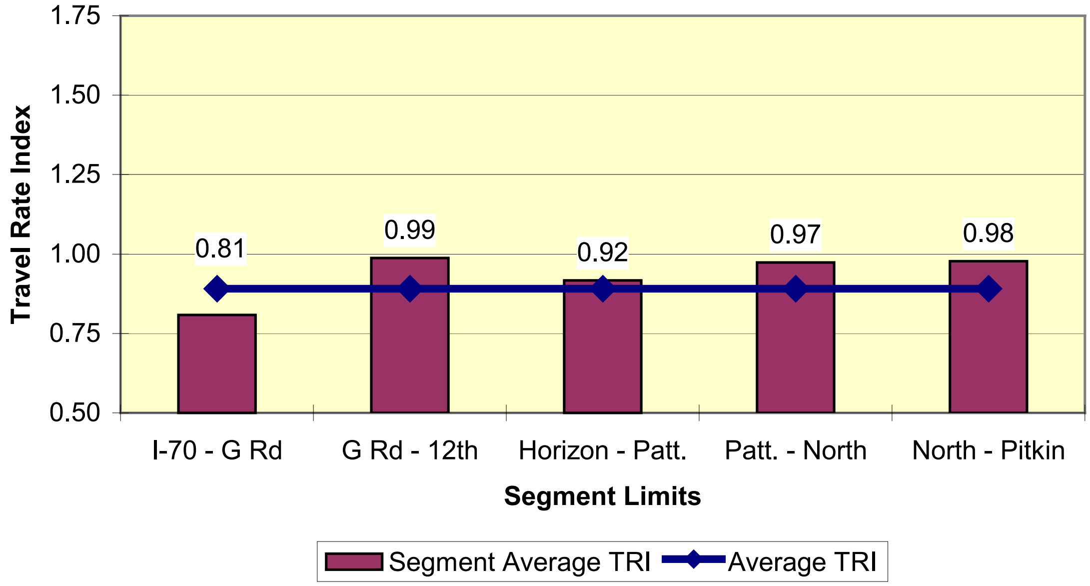


Figure 29. Horizon Drive / 12th Street – Morning Southbound

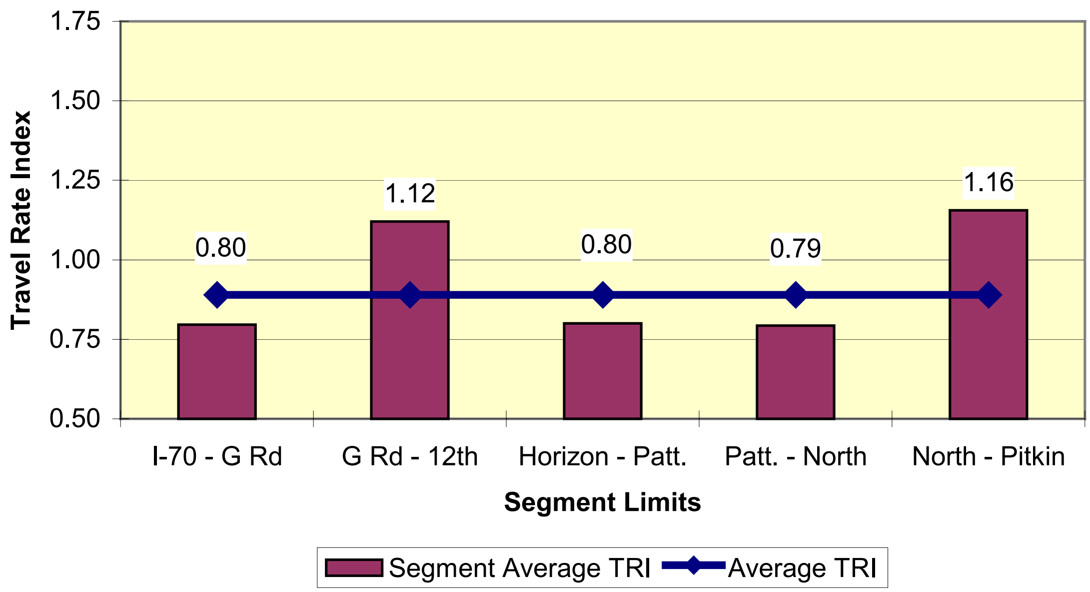


Figure 30. Horizon Drive / 12th Street – Evening Southbound

WHAT HAVE WE LEARNED IN GRAND JUNCTION?

Obviously from this effort, we have learned a great deal about mobility in Grand Junction. Additionally, we have learned more about the travel time data collection process on arterial streets—what data we need, how much we need, how to collect it, and how to analyze it—so this methodology can be applied elsewhere. We have also learned some additional items that need to be considered when performing such an analysis in the future as a result of this application.

The average time penalty—the additional time required to make a peak trip versus an off-peak trip—in Grand Junction on the seven arterial streets studied is about seven percent for trips during the morning or evening peak hours. Again, this means that the average trip took seven percent longer to make during the peak hours because of higher traffic demand. The arterial street with the greatest time penalty is North Avenue at 25 percent. The arterial street with the least time penalty is the Horizon Avenue/12th Street corridor with virtually no time penalty for morning or evening peak hour trips.

Approximately 220 travel time runs were made on the seven arterial streets in Grand Junction in order to complete this analysis. This sounds like a great deal of time and effort and to some extent it was. However, one travel time collection vehicle made up to 32 of these travel time runs in a single day. Thus, one can see that while the number of travel time runs required for such an effort is relatively large, the task is manageable.

At least two traffic counts (one for each direction of travel) were needed for each of the 22 segments in the seven arterial streets studied. Thus, approximately 44 traffic counts were needed to complete this study. One could get by with fewer counts but the accuracy would decline when less data is collected and more data is projected.

The 220 travel time runs and the 44 traffic counts comprised the vast majority of the data that was required for this study. As more corridors are added to the study these numbers will increase. When a corridor such as Horizon/12th is included in the study, additional data may be needed to determine what is happening specific to that corridor. However, that type of analysis tends to lean more toward an operational analysis rather than a planning level analysis that was the intent of this study.

A great deal of coordination is needed to perform an analysis such as this one. Pre-data collection planning needs to occur. In this planning, corridors such as Horizon/12th may show up as needing additional attention. This planning and coordination will ensure consistency in the data as it is collected. Consistency is a key element in travel time studies. The agencies involved in the data collection planning activities in Grand Junction did a fine job to ensure that the data collected was usable and accurate.

LESSONS LEARNED IN THE PROCESS

Some of the lessons that were learned in the application of the Urban Mobility Study methodology in Grand Junction are reported in this section of the report. These lessons are almost as important as the actual Grand Junction analysis itself since it is hoped that these lessons will help to refine the methodology and make it easier to apply the next time. Some observations from the Grand Junction analysis include:

- The data collection plan is critical to the study process. The plan will ensure that enough of the correct data is collected and will make the process easier. All of the agencies involved in the analysis need to be included in this planning process. See Appendix A of this report for ideas regarding the data collection process and to ensure that all of the necessary elements of the collection process have been addressed.
- An inventory of existing data sources and collection capabilities that is available in the area should be developed.
- If possible, a pilot set of travel time runs should be made to ensure that the data is accurately capturing the characteristics of the corridor. This was evident in the analysis of the Horizon/12th corridor in Grand Junction.
- A pre-collection meeting needs to be held to emphasize specific reporting and collection requirements (e.g., the segment checkpoints are located at the middle of the intersection). Consistency is important when collecting the travel time data. All of the data needs to be collected in the same manner and with the same detail. All of the necessary information needs to be included for each travel time run that is made.
- Periodic checks of the data already collected should be made to ensure the collection is going as planned or to determine if modifications are needed based on the data from the field.
- A post-collection meeting should be scheduled with the data collection members to discuss the process, develop any modifications for the future, and discuss anecdotal information that may be pertinent to the analysis (e.g., the pedestrian crosswalks created a great deal of delay along a given corridor but during the hours other than the peak hours).
- While not absolutely necessary, an automated data collection device such as an electronic distance measuring instrument (DMI) may make the data collection easier and more consistent thus reducing the collection errors and enhancing processing options.
- Detailed traffic count data is needed for every segment of roadway that is under study. Traffic counts for an entire 24-hour period should be collected. It is recommended that traffic count data be available in at least 15-minute increments in sufficient quantity to be able to extrapolate

to other counts along the corridor where 15-minute data may not be available.

- Where possible, the data that is collected should be reviewed by local agency staff to check for consistencies and validity (i.e., Does it make sense?). At this time in the process, data that violated a collection rule can be eliminated (e.g., travel times were collected in a construction zone, etc).
- Since we are dealing with arterial streets, this methodology is most useful at the corridor level and not at the segment level. Each individual traffic signal can have a huge effect and add a great deal of variability when looking at short sections of roadway. By analyzing the entire corridor, some of the variability with individual traffic signals is removed and should tend to be averaged out over the entire corridor. Some localized analysis was provided in this report to show what the results would look like, even though this level of detail is not necessarily desired with this type of mobility analysis.
- Sufficient review of the findings should be allowed by local agencies to validate the results and build consensus for the acceptance of the conclusions.
- The output should be in readily usable formats for disbursement to all interested agencies.
- The data collected for this analysis can serve as key data for other studies and can spawn further studies of other issues.

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3. Lomax , T., S. Turner, G. Shunk, H.S. Levinson, R.H. Pratt, P.N. Bay, and G.B. Douglas. Quantifying Congestion: User's Guide. NCHRP Report 398. Transportation Research Board, Washington, DC, November 1997.

APPENDIX A

Developing and Implementing a Data Collection Plan

(Reprinted with permission from the Travel Time Data Collection Handbook (2))

A. DEVELOPING AND IMPLEMENTING A DATA COLLECTION PLAN

This chapter contains information and guidance on developing and implementing a data collection plan for travel time studies. Adequate planning, training, and preparation are vital to successful data collection activities. Figure A-1 illustrates a generic travel time data collection process that can be used to plan and execute a travel time study.

The first several sections of this chapter describe the process of establishing study objectives and understanding the uses and users of the data being collected. Guidance is provided on setting the study scope, in terms of the geographic scale and inclusion of different time periods and facility types. The travel time data collection techniques are summarized and compared to assist in selecting the collection technique that is most appropriate. Data collection scheduling and data sampling are also discussed. The use of training and pilot studies are introduced as ways to improve the effectiveness and accuracy of data collection. The chapter concludes with general information about progress tracking, data reduction, and quality control.

A.1 Establish Study Purpose and Objectives

The study purpose and objectives establish the need for data and information in a transportation analysis and should be defined as the first step in any data collection activity. Once established, the study's purpose and objectives will help to guide the data collection to successful completion. Not only will the study's purpose and objectives be used to develop a data collection plan, they may also be used throughout the study process for clarification of tasks or resolution of ambiguous issues.

It is not uncommon for travel time data to be collected for several purposes with the main objective to establish a database of current roadway operating conditions. Similar steps should be taken to identify all required uses and ensure that the travel time data meet the minimum requirements (i.e., "smallest common denominator") for all applications. If the different studies or uses have competing needs, agency personnel may simply have to prioritize their data needs.

Examples of travel time study purpose or objective statements include the following:

> "The purpose of this study is to determine travel time information on major (Kansas City Metropolitan Region) streets and highways . . . The study will be used to . . . identify the extent and location of traffic congestion and specific problem areas . . ., serve as a data base to check speeds in the current computer networks. . ., allow comparisons with the 1987 and 1977 Travel Time and Delay studies. . ., and provide information . . . to determine areas where future studies are warranted. . ." (1);

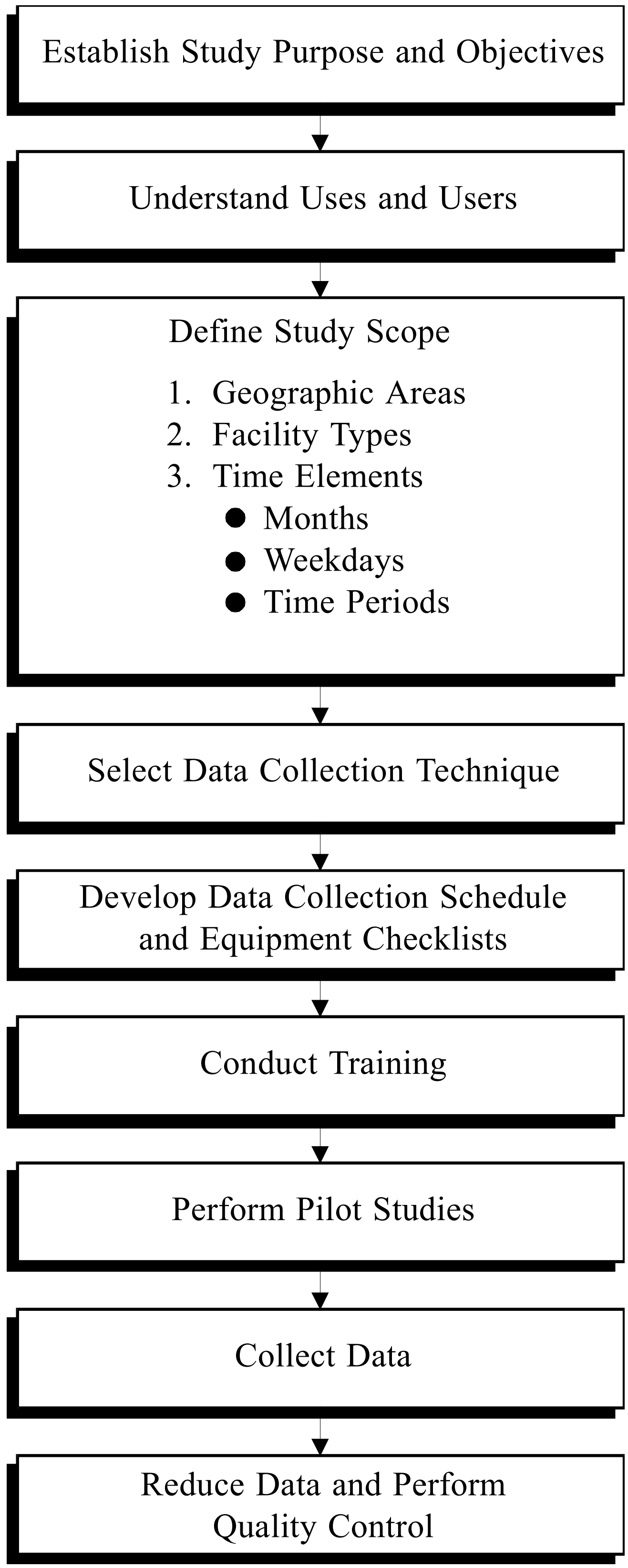


Figure A-1. Travel Time Data Collection Process

"The purpose of this study was to obtain effective travel times for representative links in the road network. These are used in computer models. . . In conjunction with the travel time runs, a vehicle delay study was also conducted to identify specific congested locations and also to determine the types and causes of delay . . ." (2).

A.2 Understand Uses and Users

The uses and users of the travel time data to be collected are as important as the study purpose and objectives. In many cases, the uses of the data are the motivation behind the study and should have been considered in establishing the study objectives. The users of the travel time data are an important consideration, as they affect several variables in the collection and presentation of data. Table A-1 provides a perspective on the uses and users of travel time data. The table matrix illustrates the wide number of uses, and also the different uses for technical and non-technical audiences.

Travel time data often are collected for several purposes or potential uses. For example, travel time data might be collected for the congestion management process and also be used to calibrate travel demand forecasting models or as input to mobile source emissions models. For situations in which the travel time data must be used for several purposes, the data should be collected for the use that requires the finest level of detail. The travel time data can then be aggregated or analyzed to meet other study needs. In the earlier example, the mobile source emissions model may require second-by-second speeds to capture the acceleration and deceleration patterns in congestion. Once the second-by-second speed data has been collected, it can be aggregated for less data-intensive uses such as calibrating a travel demand forecasting model or monitoring area-wide congestion trends.

The emerging practice of using data collected by intelligent transportation system (ITS) applications for planning and evaluation purposes illustrates an important point about understanding uses and users of data. Until recently, ITS components were seen as providing valuable data only for operating transportation facilities. Several transportation agencies have recognized the many uses of ITS data for planning and evaluation applications and are beginning to share data resources where ITS applications have been deployed.

IMPORTANT ☞ Clear identification of study objectives, uses and users, and audience are a critical, yet often overlooked, step in the study design process.

Table A-1. Uses and Users of Travel Time Data

Uses of Travel Time Data	Primary Users	
	Technical	Non-Technical
Planning and Design		
Develop transportation policies and programs		✔
Perform needs studies/assessments	✔	✔
Rank and prioritize transportation improvement projects for funding	✔	✔
Evaluate project-specific transportation improvement strategies	✔	
Input/calibration for air quality/mobile source emission models	✔	
Input/calibration for travel demand forecasting models	✔	
Calculate road user costs for economic analyses	✔	
Operations		
Develop historical travel time data base	✔	
Input/calibration for traffic models (traffic, emissions, fuel consumption)	✔	
Real-time freeway and arterial street traffic control	✔	
Route guidance and navigation	✔	✔
Traveler information		✔
Incident detection	✔	
Evaluation		
Congestion management system/performance measurement	✔	
Establish/monitor congestion trends (extent, intensity, duration, reliability)	✔	
Identify congested locations and bottlenecks	✔	✔
Measure effectiveness and benefits of improvements	✔	✔
Communicate information about transportation problems and solutions		✔
Research and development	✔	

A.3 Define Study Scope

A well-defined study scope that is clearly linked to the study objectives ensures that the travel time study will produce the necessary data. The study scope should answer three important questions:

1. Where do we collect travel time data? (Geographic Areas)
2. On what facilities do we collect travel time data? (Facility Types)
3. When do we collect travel time data? (Time Elements)

The study scope not only defines the ranges of effort during the travel time study, but also delineates the applicability of the results from data collection and analysis. Although this may appear to be a foregone conclusion, inadequate samples of data are often extended or extrapolated to make inaccurate conclusions about an entire population. Sampling procedures, however, can be used in travel time studies to collect statistically significant samples of data. Sampling procedures over both time and space are discussed later in this chapter and in subsequent chapters (for each technique).

A.3.1 Geographic Areas

The geographic scope defines the boundaries of the study. Examples of geographic scope include:

- A short section of roadway in the vicinity of a planned or implemented transportation improvement (e.g., before-and-after study);
- A transportation corridor between defined points, perhaps including a freeway, frontage roads, and parallel arterial street(s) (e.g., major investment study);
- Several transportation corridors that service a central business district or an activity center; and
- All major transportation corridors within a defined zone, sub-area, or region (e.g., congestion management system).

If a study's geographic scope only includes a selected number of corridors or roadways, travel time data would most likely be collected on each facility (i.e., no sampling). However, if the geographic scope encompasses an entire urban area or region, sampling procedures may be applied to achieve cost-effective data collection. Sampling procedures consist of collecting data for a statistically significant percentage of the entire roadway system being considered, then drawing conclusions about the entire roadway system from the sampled percentage. Sampling is most applicable for planning applications in which the required accuracy is typically less than that required for design or operational analyses.

A.3.2 Facility Types

The next step in defining the study scope is specifying the transportation facility types or functional classes of roadways. Like the geographic scope, the facility types considered in a travel time study should be based upon the study objectives. Facility types or classifications can be based upon different schemes, like those used in travel demand forecasting models, traffic operations models, or roadway inventory data bases. Table A-2 contains examples of common roadway classifications from a variety of different sources. Collector and local streets are typically not considered in travel time studies because of their decreased functional role in providing mobility or throughput (3).

Table A-2. Urban Roadway Functional Classification Categories

Travel Demand Forecasting Model (varies)	Highway Performance Monitoring System (HPMS), Urban (4)	AASHTO 1994 "Green Book," Urban (5)	1994 Highway Capacity Manual (HCM), Urban and Suburban (5)
Radial freeways Circumferential freeways Principal arterials (divided/undivided) Minor arterials (divided/undivided)	Interstate highways Other freeways and expressways Other principal arterials Minor arterials	Interstate highway Other freeways Other principal arterials Minor arterials	Freeways Multilane suburban highways Class I Arterial Class II Arterial Class III Arterial

The primary or ultimate use(s) of the travel time data will dictate the specific functional classification scheme to be used. For example, travel time data primarily collected for validating planning models will likely use classification categories corresponding to the specific travel demand forecasting model (i.e., similar to first column of Table A-2). If the data will be used for other purposes, such as congestion management, it can be reclassified into categories that may be more appropriate for operational purposes, such as the HPMS or HCM classifications. Classification schemes used by other state, regional, or local agencies may also influence the choice of classification categories. In addition, the Federal Highway Administration (FHWA) has published additional guidance on highway functional classification (6).

The functional classification scheme should group roadways so that all roadways within a given group have similar traffic and operating characteristics. Grouping roadways with similar operating characteristics into a single classification strata or group permits the use of stratified sampling (if so desired). With stratified sampling, the number of roadway samples collected within the classification groups can be varied based upon the variability of data for roadways within a particular group.

A stratified facility sampling plan (i.e., 100 percent sampling of all facilities versus statistical sampling from each functional class) may also be considered in this step. Sampling of travel times on a regional network of freeways and arterial streets may be desirable where funds are not available for the desired data collection frequency or where you wish to concentrate data collection resources on the most critical routes of the network. The use of a sampling plan may also depend upon the application(s) of the travel time data. For example, regional system performance monitoring efforts may only require travel time data on a sample of freeways and arterial streets in the region. A corridor or before-and-after study, however, may require more detailed travel time data and necessitate data collection on all facilities under study (100 percent sample).

CAUTION !!	Stratified sampling of data is typically considered when the desired precision can be achieved through sampling or when funds are not available for the complete roadway network. Proceed with caution and the assistance of a statistician.

The steps for establishing a stratified sampling plan are as follows:

1. **Establish the functional classification groups** to be used in the travel time study (Table A-2). This step was discussed on the previous page.

2. **Designate the routes** that are located within the geographic scope and a functional classification group. This step consists simply of designating corridors that are within the study boundaries.

3. **Sub-divide routes into "segments,"** which are shorter sections of roadway (lengths vary by functional classification) with similar operating characteristics and geometric cross sections. The segment lengths may vary depending upon the data collection technique, but should be no longer than the following general ranges:

Freeways/Expressways:	1.6 to 4.8 km (1 to 3 mi)
Principal Arterials:	0.6 to 3.2 km (1 to 2 mi)
Minor Arterials:	0.8 to 3.2 km (½ to 2 mi)

Shorter segment lengths than these maximum lengths can be used for specific operational analyses with the caveat that segments lengths less than 0.4 to 0.8 km (¼ to ½-mile) may produce travel times with greater variability. Segment breakpoints, or route checkpoints, may be located at major interchanges, major signalized intersections, jurisdictional boundaries, and transition points between different roadway cross sections or land uses. For freeways and expressways, on-ramp merge points and lane drop locations are the best breakpoints for matching the cause of the traffic speed to the effects. For arterial streets, segment breakpoints are best located at major intersections or where changes in roadside activity occur. Professional judgment and local knowledge of traffic conditions should be used in defining segments. Site surveys or corridor reconnaissance during peak periods can also help in defining segment termini.

4. **Use sample size and finite population correction equations** (Table A-3) to determine the number of roadway segments to sample within each functional classification group. The sample size calculations rely on three variables:

   - **Coefficient of variation (c.v.)** - a relative measure of variability, defined as the standard deviation divided by the mean. The c.v. can be estimated from existing data or the default values in Table A-3 can be used for estimates of c.v. (7).

- **Z-statistic** (or t-statistic for samples less than 30) - a function of the desired confidence level (e.g., 95 percent confidence level) for the sample mean (Table A-3). The most commonly used confidence levels for stratified segment sampling are typically in the 80 to 95 percent range, but may also depend upon budget constraints.

- **Relative permitted error** - expressed as a percentage, which is one-half of the desired confidence interval for the sample mean (e.g., ± five percent). The most commonly used error levels are between five and 10 percent, but vary depending upon the use of the travel time data (Table A-3).

5. **Select the roadway segments to sample** within each functional classification (stratification) group. Theoretically, stratified random sampling techniques are used to randomly select the necessary sample size of roadway segments. The random selection of roadway segments scatters data collection sites around the geographic area, significantly increasing the costs of data collection for methods such as test vehicle. An alternative to random sampling is presented in the following paragraphs.

   Prioritized sampling, in which 10 to 20 percent of the critical or most congested segments are fully sampled, while the remaining 80 to 90 percent of the roadway segments are randomly sampled from different routes. Although prioritized sampling may not conform to the thorough statistical methods that exist for stratified random sampling, it concentrates data collection efforts on the most critical or congested locations. One or more of the following factors can be used for prioritizing data collection:
   - perceived bottlenecks or congested locations;
   - percent change in congestion level (if available);
   - average daily traffic volume per lane; or
   - average daily traffic volume.

These factors should rank the roadway segments with the highest congestion or the fastest growing congestion as "high priority." Depending upon the number of roadway segments, the top 10 to 20 percent of segments could be designated as "high priority," thereby collecting data on these segments on an annual or frequent basis.

Once the top 10 to 20 percent of roadway segments have been designated as "high priority" for data collection, the remaining roadway segments should be randomly chosen from the routes to accomplish the sample sizes for each strata group as outlined earlier. With this technique, data will be collected on the "high priority" segments and some randomly selected segments on a frequent basis (e.g., annual).

The prioritized sampling technique ensures that reliable, timely data exists for severely congested segments, and that the remaining, less critical segments are sampled on a less frequent basis. It will ensure that travel times at major bottlenecks such as lane drops, bridge/tunnel approaches, and freeway entrance locations are measured.

Table A-3. Sample Size Estimation Equations

Coefficient of Variation, c.v.

$$c.v. = \frac{\sigma}{\mu} = \frac{s}{\bar{x}} \qquad \text{(A-1)}$$

where: σ = population standard deviation
μ = population mean
s = sample standard deviation
$\bar{x}$ = sample mean

Uncorrected Sample Size, n′

$$n' = \frac{c.v.^2 \times z^2}{e^2} \qquad \text{(A-2)}$$

where: z = z-statistic based on confidence level
e = relative permitted error level (%)

Sample Size, n (corrected for finite population):

$$n = \frac{n'}{1 + \frac{n'}{N}} \qquad \text{(A-3)}$$

where: n′ = uncorrected sample size
N = population size

Coefficient of Variation can be estimated from existing data or the following default values can be used for estimates of c.v. (7):

Freeways/Expressways: c.v.'s range from 15 to 25 percent (depending upon traffic volume)

Principal/Minor Arterials: c.v.'s range from 20 to 25 percent (depending upon traffic volume)

The **Z-statistic** is based on the desired confidence level. Z-statistics are provided below for commonly used confidence levels (7):

Desired Confidence Level	Z-statistic
99 percent	2.575
95 percent	1.960
90 percent	1.845
85 percent	1.440
80 percent	1.282

The **relative permitted error, e,** is expressed as a percentage of the sample mean, and is typically based upon the use of the data. Commonly used error levels are (7):

- ± 5 percent for design and operational analyses; and
- ± 10 percent for planning and programming studies.

A.3.3 Time Elements

There are several time elements that must be considered in establishing the scope for travel time data collection activities:

- months of the year;
- days of the week; and
- time periods, or time of day.

These three time elements are discussed in the following sections.

Months of the Year

Travel time data are commonly used to represent "typical" or "average" annual conditions, and should be collected during months that have typical or average traffic volume patterns. As with defining other time elements in the scope, traffic volume patterns from automatic traffic recorder (ATR) stations can be used to determine typical or average months for data collection. Table A-4 contains data from an ATR station in Houston, Texas, and illustrates how this data can be used to define typical or average months. Those months with traffic volumes within approximately two percent of the annual average daily traffic (AADT) volumes are candidate months for data collection. As a general rule of thumb, the spring (i.e., March, April and May) and fall months (i.e., September, October, and November) are commonly considered average conditions if no ATR traffic volume data is available for specific areas or corridors.

For special studies that seek to examine congestion associated with non-work trips, one may wish to look at specific times of the year in which traffic patterns differ from typical or average months. Examples include (but are not limited to): summer or winter months near high use recreational areas; the holiday shopping season (late November and December) near large retail shopping centers; months when large universities or schools are not in session; or months coinciding with regional festivals or special events. However, if travel time data are desired for typical daily traffic conditions, these times of the year should be avoided.

Table A-4. Using ATR Station Traffic Volume Data to Select Typical Months

ATR Station S-139, US 59, Houston, Texas				
Month and Season	Average Day		Average Weekday (Mon - Fri)	
	Volume	Percent AADT	Volume	Percent AADT
January	173,684	93.4	194,036	104.3
February	188,691	101.4	208,530	112.1
March	187,877	101.0	205,970	110.7
April	189,651	102.0	209,040	112.4
May	183,365	98.6	201,914	108.6
June	185,515	99.7	204,611	110.0
July	180,276	96.9	198,917	106.9
August	189,668	102.0	209,063	112.4
September	183,898	98.9	205,073	110.2
October	196,253	105.5	216,036	116.1
November	188,704	101.4	207,470	111.5
December	184,524	99.2	202,960	109.1
Annual Average	**186,009**	**100.0**	**205,302**	**110.4**

Source: adapted from reference (9).
Note: Shaded months ± two percent of annual average (e.g., candidates for data collection).

Days of the Week

Traditionally, data collection efforts for many transportation agencies have been focused on the middle weekdays (i.e., Tuesday, Wednesday, and Thursday). Monday and Friday are typically excluded from data collection because a small number of weekdays are sampled (typically less than 20 for most study budgets), and these days' high variation from conditions during the middle of the week would necessitate a much larger sample of weekdays.

ATR station data or other 24-hour traffic volume counts can also help to establish the day-to-day variation between weekdays. As a general rule, if study budgets only permit data collection to occur on a given facility less than five separate weekdays, then sampling should be concentrated between Tuesday and Thursday. If budgets permit sampling of five or more weekdays for a given facility, then data collection should be evenly distributed over all five weekdays (e.g., Monday through Friday). Weekend days (e.g., Saturday or Sunday) should be sampled if the study focus relates to recreational or weekend-based trips.

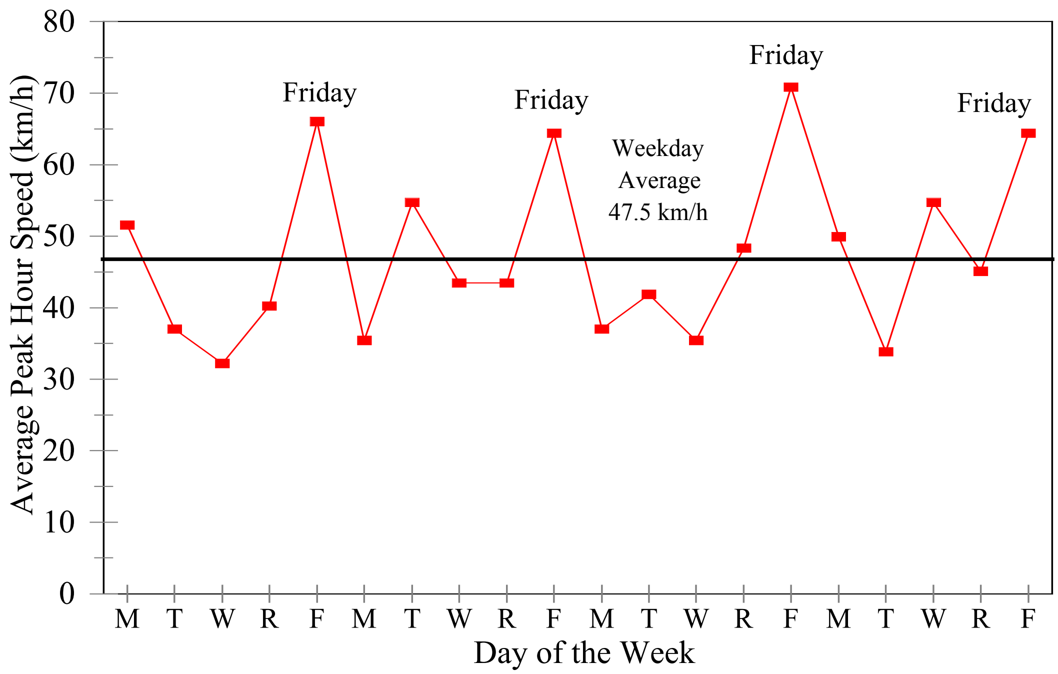
For example, Figure A-2 shows morning peak hour data from a Houston freeway (I-10, Katy Freeway). The average speeds were collected throughout the peak hour by about 20 passive probe vehicles equipped with AVI transponders. The figure illustrates that Friday speeds are consistently higher than other weekdays and the average weekday speed. If a study budget only permitted the sampling of speed data from, say two to three weekdays per facility, then those weekdays that exhibit conditions closest to average "typical" conditions would be chosen. For this example, the study should sample weekdays between Monday and Thursday. If, however, the study budget permitted the sampling of speed data from five or more weekdays, the data collection should be distributed over all weekdays.

EXPERT TIP ☺	When budgets only permit data collection on less than five weekdays, concentrate on Tuesday through Thursday. If data can be collected for five or more weekdays, use all five weekdays to obtain average travel times.

Recurring holidays or events should be considered when scheduling the specific days for data collection. These days are avoided when sampling a small number of weekdays because of their variance from "typical" day-to-day operating conditions. Unless data is desired specifically for these events, the following times should be avoided when sampling weekdays :

- established holidays (e.g., Memorial Day, Independence Day, Veteran's Day);
- other celebrated days (e.g., St. Patrick's Day, Valentine's Day);
- changes in local school schedules (e.g., spring break, summer recess);
- day after time changes (e.g., Daylight Savings, Standard Time changes); and
- special events (e.g., professional sports games, regional festivals).

If large samples of weekdays (i.e., 75 to 100 percent of all possible days) are available, as is the case with some ITS data collection technologies, data from all days should be included to provide a truly representative value for the "average" weekday.



Source: Turner, S., et al. *Travel Time Data Collection Handbook*. The Texas Transportation Institute. Federal Highway Administration Report No. FHWA-PL-98-0.35. March 1998.

Figure A-2. Illustration of Weekday Speed Variation (Morning Peak Hour Speeds, I-10 Freeway in Houston, Texas)

Time Periods

The time periods define the ranges in the time of day that travel time data will be collected. Like other elements of the study scope, the time periods will likely be determined by the study objectives. For travel time studies that are focused on identifying congestion trends and problems, three time periods are commonly considered:

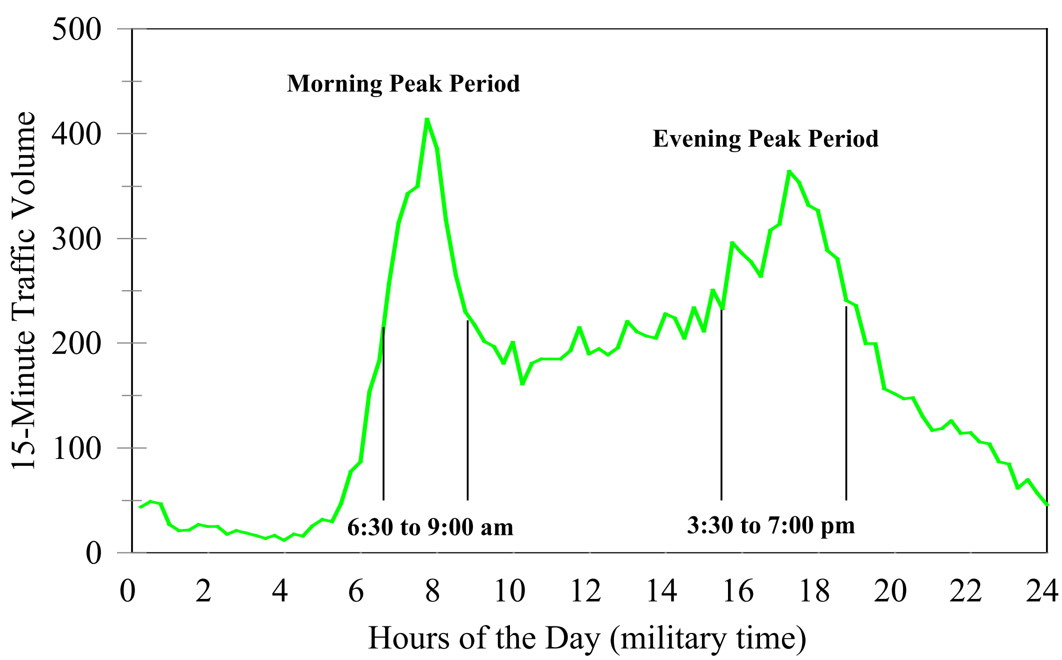
1. **Morning Peak Period** - encompasses all congestion during the peak morning commute, typically sometime between the hours of 6 a.m. and 9 a.m.;

2. **Off-Peak Period** - includes periods of free-flow traffic during the middle of the day or late in the evening, typically between 10 a.m. and 11 a.m., 1 p.m. to 3 p.m., or after 7 p.m. The hours before and after 12 noon (11 a.m. to 1 p.m.) should be avoided if the "lunch hour" traffic is significant. Off-peak travel times are used to establish free-flow conditions for calculating congestion measures; and

3. **Evening Peak Period** - encompasses all congestion during the peak evening commute, typically some time interval between the hours of 4 p.m. and 7 p.m.

For studies relating to weekend or recreational travel, these typical "commuter" time periods should be adjusted to coincide with the times of congestion or peak traffic conditions.
The time periods for data collection should be matched to local traffic conditions and congestion patterns for the geographic area under consideration. The time periods can be defined by examining travel time data from previous studies or traffic volumes from inductance loop detectors, ATR stations, or 24-hour counts. The traffic volumes should come from a representative sample of facilities on which data is to be collected. On single corridors, traffic volumes taken at both end points and the middle of the corridor can better establish predominant congestion and traffic patterns throughout the corridor.

Figure A-3 contains an illustration of defining time periods based upon traffic volume data. Note in the figure that the peak period includes both the build-up and dissipation of congestion, as evidenced by the peak volumes. The duration of the time period(s) depends upon the duration of congestion, which commonly varies by the population size of communities. In large metropolitan areas like Los Angeles, Houston, or New York, the peak periods may last two to three hours or more. In smaller towns and cities, congestion and the resultant peak period may last less than a single hour. The minimum duration of time for a peak period definition should be one hour (peak or "rush" hour).



Source: 15-minute loop detector data from TransGuide (San Antonio) web site: http://www.transguide.dot.state.tx.us/statistics.html"

Figure A-3. Defining Peak and Off-Peak Time Periods Using Traffic Volumes

A.4 Select Data Collection Technique

Several data collection techniques are available to measure travel times. A specific technique, or combination of techniques, should only be selected after considering the study and data needs and the advantages and disadvantages of each technique. The travel time data collection techniques in this handbook are grouped into four general categories:

- "active" test vehicle techniques;
- license plate matching techniques;
- "passive" ITS probe vehicle techniques; and
- emerging and non-traditional techniques.

The first step in selecting a data collection technique should be to **investigate any existing sources of travel time or speed data**. For example, travel time or speed data may be available from other agencies or through transportation management centers. The deployment of ITS in major urban areas is a potentially rich source of travel time and speed data for a number of operational and planning studies. Because data from ITS components may only be available for a limited geographic area or corridor, additional data collection may be necessary to supplement existing data for area-wide or regional studies.

Once all existing sources of data have been identified, the second step is to **consider all needs and potential uses** for the travel time data. Some studies or analyses may require detailed travel time and delay information for specific corridors. Test vehicle techniques are most appropriate when analyses require detailed data about intermediate travel times and delay. In these cases, detailed information can be obtained by active test vehicles that traverse the routes or corridors of interest. License plate matching techniques are not well-suited for gathering intermediate travel time and delay, but do gather large sample sizes and provide more insight into travel time variability among drivers and throughout the time period. For example, license plate matching techniques have been used in several instances to compare the travel time reliability of general-purpose freeway lanes and high-occupancy vehicle (HOV) lanes.

The final consideration is the **budget and equipment resources allocated to data collection or available to the agency**. Available equipment (e.g., portable computers, video cameras) or study budgets may limit the data collection to one of several techniques. Some agencies may have analysis tools that are capable of exploiting certain data collection techniques. For example, agencies with geographic information systems (GIS) capabilities should consider the many advantages of GPS data collection. The chosen data collection technique should also match personnel capabilities and experience. Some test vehicle and license plate matching techniques are technology-intensive and require adaptable, experienced personnel that have available time and/or resources.

Table A-5 contains a qualitative comparison of the travel time data collection techniques (Liu provides a complementary comparison in 11), and Table A-6 summarizes the major advantages and disadvantages of each technique. These tables can be used to determine which technique best fits your data needs.

EXPERT TIP ☺ Steps in selecting a data collection technique: investigate existing potential data sources, assess potential applications and data needs, and determine budget and equipment allocation. Then refer to Tables A-5 and A-6.

Survey or interview methods are also used to obtain estimates of travel times for various purposes, including development and calibration of planning models. Most travel survey methods require drivers to record or recall travel times for trips during a given time period. This handbook does not include descriptions for survey recall methods, as the accuracy level is not consistent with other techniques in this handbook (12). However, useful travel time data may be extracted if travel survey methods use vehicles instrumented with GPS devices or similar instrumentation. In these cases, the appropriate sections in this handbook may be used based upon the vehicle instrumentation. Readers should refer to FHWA's *Travel Survey Manual* for detailed documentation of survey methods (13).

The following criteria are used in Table A-5 to compare travel time data collection techniques:

- **Initial or capital costs** - typical costs of equipment necessary to perform data collection. For all ITS probe vehicle techniques except GPS, it is assumed that the vehicle-to-roadside communication infrastructure does not exist;

- **Operating efficiency** - relative costs of data collection per unit of data;

- **Required skill or knowledge level** - typical skill or knowledge level required for data collection personnel;

- **Data reduction and/or processing** - typical time and cost associated with reducing and/or processing field data;

- **Route flexibility** - transportability of data collection equipment to different routes in short periods of time;

- **Accuracy** - typical accuracy of the technique relative to the true average travel time (assumes adequate quality control procedures);

- **Sampling rate over time** - ability to collect travel time data at frequent time intervals (for a given facility) without excessive equipment;

- **Sampling rate over space** - ability to collect travel time data at closely-spaced distance intervals (for a given facility) without excessive equipment; and

- **Sampling rate of vehicles** - ability to collect travel time data that is representative of the numerous vehicle types and driving behaviors in the traffic stream.

Table A-5. Qualitative Comparison of Travel Time Data Collection Techniques

Technique	Initial or Capital Costs	Operating Costs (per unit of data collected)	Required Skill or Knowledge Level	Data Reduction and/or Processing	Route Flexibility	Accuracy and Representa-tiveness[a]	Sampling Rate		
							Time	Space	Vehicles
Test Vehicle									
Manual	low	high	low	poor	excellent	fair	low	moderate	low
DMI	moderate	moderate	moderate	good	excellent	good	low	high	low
GPS	moderate	moderate	moderate	good	excellent	good	low	high	low
License Plate Matching									
Manual	low	high	low	poor	good	fair	low	low	moderate
Portable Computer	moderate	moderate	moderate	good	good	good	moderate	low	high
Video with Manual Transcription	low	moderate	moderate	fair	fair	excellent	high	low	high
Video with Character Recognition[b]	high	low	high	good	fair	excellent	high	low	high
ITS Probe Vehicle[c]									
Signpost-Based	high	moderate	high	good	poor	good	moderate	low	low
AVI	high	low	high	good	poor	excellent	high	low	moderate
Ground-based Radio Navigation	high	low	high	fair	good	good	moderate	moderate	moderate
GPS	moderate	low	high	fair	good	good	moderate	high	moderate
Cellular Phone Tracking	high	low	high	fair	good	good	high	moderate	moderate

Rating scales are relative among the techniques: [high, moderate, low] or [excellent, good, fair, poor].

Notes: [a] Assumes that adequate quality control procedures are used.
[b] Assumes that necessary equipment is purchased (as opposed to contracting data collection services).
[c] Assumes that vehicle-to-roadside communication infrastructure does not exist.

Table A-6. Advantages and Disadvantages of Travel Time Data Collection Techniques

Data Collection Technique	Advantages	Disadvantages
Test Vehicle		
Manual	• low initial cost • low required skill level	• high operating cost per unit of data • limited travel time/delay information available • limited sample of motorists
Electronic DMI	• moderate initial cost • very detailed speed/delay data available	• lacks geographical referencing (e.g., GIS) • limited sample of motorists
GPS	• moderate initial cost • data easily integrated into GIS • detailed speed/delay data available • can provide useful data for travel surveys	• reception problems in urban "canyons", trees • limited sample of motorists
License Plate Matching		
Manual	• low initial cost	• high operating cost per unit of data • accuracy may be questionable • data reduction time-consuming
Portable Computer	• low operating cost per unit of data • travel times from large sample of motorists • continuum of travel times during data collection	• accuracy problems with data collection, spurious matches • limited geographic coverage on single day
Video with Manual Transcription	• travel times from large sample of motorists • continuum of travel times during data collection	• data reduction time-consuming • limited geographic coverage on single day
Video with Character Recognition	• low operating cost per unit of data • travel times from large sample of motorists • continuum of travel times during data collection	• high initial costs (if equipment purchased) • limited geographic coverage on single day
ITS Probe Vehicle		
Signpost-based Transponders	• low operating cost per unit of data	• typically used for transit vehicles (includes loading/unloading times) • sample dependent on equipped vehicles
AVI Transponders	• low operating cost per unit of data • very accurate	• very high initial cost for AVI infrastructure • limited to instrumented locations • sample dependent on equipped vehicles
Ground-based Radio Navigation	• available consumer product	• typically used for transit vehicles • sample dependent on equipped vehicles
GPS	• increasingly available consumer product • low operating cost per unit of data	• sample dependent on equipped vehicles • privacy issues
Cellular Phone Tracking	• widely available consumer product	• accuracy questionable for detailed applications • privacy issues

The comparability of average travel times from different data collection techniques may be of concern if agencies compare data from several different sources. Little research has been performed to quantitatively compare average travel time samples using different techniques to the true average travel time. To some degree, each technique may yield slightly different values for the same conditions. Steps should be taken to avoid biases that affect the representativeness of travel time data from certain techniques. Analysts should also recognize and understand the source of potential biases in the data they are using, especially in cases where biases may be suspected. For example, test vehicle techniques may yield data with less variability than license plate matching data (because the test vehicle driver purposefully minimizing variability by "floating" with traffic). Or, probe vehicle data may be biased toward higher speeds because of the driving characteristics of select groups of motorists.

UNKNOWN **??**	Travel times collected using different data collection techniques may yield slightly different results. Data managers and users should recognize the potential biases inherent in the technique(s) they are using.

A.5 Develop Data Collection Schedule and Equipment Checklists

A schedule of data collection activities should be developed once the study scope, data collection technique, and other major parameters have been determined. An example of a data collection schedule for test vehicle runs is shown in Table A-7. Similar tables showing date, time, and facilities being surveyed can be developed for other travel time collection techniques. A schedule is particularly helpful with implementing the data collection effort and in informing data collection personnel of their specific responsibilities. The content of the schedule includes the specific days and time of day that data is to be collected. If possible, the schedule should also contain the names of persons assigned to specific duties or stations for each day of data collection.

Equipment checklists should be used to ensure the proper assignment and continued operation of data collection equipment. These checklists are especially important for equipment-intensive travel time collection methods, such as computerized methods of test vehicle or license plate matching. A sample equipment checklist for video license plate matching is shown in Table A-Checklists typically have columns to record the following information:

- time, date, and location of use;
- make, model, or serial identification number;
- names or initials of person(s) using equipment (check-in and check-out); and
- instructions for any necessary field calibration.

Table A-7. Example of Data Collection Schedule for Test Vehicle Runs

Travel Time Runs--Week 1 (May 26, 1997)				
Day & Date	Time Period	Freeway Facility	VAN 3582 **HALF HR** Start by 3:30 pm Last run by 6:00 am	VAN 3583 **EVEN HR** Start by 4:00 pm Last run by 6:30 am
Monday, 5/27/97	PM	I-45	Bill S.	Jim R.
Tuesday, 5/28/97	AM	I-10	Dale T.	Sam P.
	PM	I-10	Bill S.	Jim R.
Wed., 5/29/97	AM	I-45	Dale T.	Sam P.
	PM	I-45	Bill S.	Jim R.
Thursday, 5/29/97	AM	US 59	Dale T.	Sam P.
	PM	US 59	Bill S.	Jim R.
Friday, 5/30/97	AM	I-45	Bill S.	Jim R.

Table A-8. Example of Equipment Checklist

Equipment Checklist and Sign-Out				
Route Number:		Equipment Set Number:		
Segment:		Survey Team Number:		
Location Description:		Date:		Time Period:
Equipment	**Person**	**Make**	**Model**	**ID/Serial #**
Hi-8 mm camcorder				
camera remote				
camera case				
CL-2x extender				
camera batteries				
camera remote batteries				
video leads (red and black)				
S-video cable				
linear polarizing filters				
UV lens filter				
DC-10 DC adaptor				
marine battery				
5" color monitor				
monitor cable				
monitor case				
Hi-8 mm video tapes				
tape labels				
Other Incidental Supplies: ☐ Watch ☐ Pen/Paper ☐ Safety Cones ☐ Cellular Phone ☐ Chains/Locks ☐ Phone Numbers ☐ Safety Vest ☐ Rain Gear ☐ Clipboard				

Source: adapted from reference (14)

A.6 Conduct Training

The attitude and knowledge of data collection personnel play a major role in the quality of collected data. All data collection personnel should be adequately trained on the travel time data collection technique to ensure a consistent level of knowledge. The training or briefing may be best accomplished in small groups in which each person has the ability to ask questions and practice using the data collection equipment. A training session should include the following key points:

- purpose(s) of the data collection, including sponsorship, analysis goals, and end uses of the data;

- step-by-step details of the data collection technique and equipment operation;
- troubleshooting techniques to fix equipment problems in the field; and
- specific procedures or requirements for canceling data collection because of weather, traffic incidents, or equipment problems.

> **IMPORTANT** ☞ Adequate training is necessary for a consistent level of quality data. Ensure that your data collection effort has training built into the budget.

Training sessions should also impart the following attitudes to data collection personnel ( ):

- *This job is important* - stress the importance of the study, how it is to be used in solving problems and meeting project needs;
- *I must follow instructions* - teach the importance of following instructions, the necessity of proper field procedures, and the importance of accuracy and consistency;
- *I am a professional* - each person collecting data should believe: "I have a job to do; I am a professional being paid for services rendered";
- *Research is important* - communicate the value of research, how research information improves our ability to make decisions, solve problems, and save money and resources; and
- *The accuracy and reliability of data is my responsibility* - stress that each person is responsible for collecting data that is accurate, reliable, and has been collected according to instructions provided.

A.7 Perform Pilot Studies or Trial Runs

Pilot travel time studies or trial runs should be conducted before the actual data collection begins. If the data collection personnel are experienced, pilot studies may be considered optional. Pilot studies can be performed over several days on a sample (approximately five to ten percent) of the facilities that will be included in the data collection effort. The purpose of pilot studies or trial runs are the following:

- become intimately familiar with the data collection equipment and process;
- become familiar with data collection corridors and cross streets;
- perform corridor or site surveys and measure exact distances; and
- identify problems or necessary resources as early as possible.

Also, travel time variability data obtained during pilot studies can potentially be used to check and/or adjust previously calculated sample sizes. After the pilot studies have been completed, all data collection personnel should provide feedback about the ease and utility of the data collection process. The feedback can then be used to modify the data collection procedures to ensure quality data.

A.8 Collect Data

Depending upon the scope of the study, data collection may extend through several months or even throughout the entire year. A manager of data collection activities should be assigned to track the progress of data collection, troubleshoot equipment and personnel problems, and supervise the data reduction and quality control measures.

The data collection supervisor should establish clear policies and procedures for canceling data collection in the field because of extreme or unusual conditions. Such extreme or unusual conditions that could merit field cancellation of data collection include:

- severe weather (e.g., heavy rain, tornados, ice);
- unusual traffic conditions (e.g., severe accidents, police chases); and
- equipment malfunction (e.g., dead batteries, broken video camera lens).

EXPERT TIP ☺ Define clear protocol for unusual circumstances prior to data collection. The use of cellular phones by data collection personnel in the field can save time and money.

Several other types of qualitative information should be gathered during data collection that could prove useful in the data reduction and analysis stages. Useful qualitative information includes:

- ♦ weather conditions (e.g., sunny, rain, foggy);
- ♦ pavement conditions (e.g., dry, wet, icy);
- ♦ observations about unique traffic conditions or incidents; and
- ♦ media reports about construction closures, incidents, or other special events that may affect traffic conditions.

Information that may be roadway or site-specific, such as weather or pavement conditions, should be recorded on data collection sheets or summaries. General area or regional information, such as special events, should be recorded in a common file location.

A.9 Reduce Data and Perform Quality Control

The first several days of travel time data should be reduced and analyzed soon after it has been collected to ensure that field personnel are collecting quality data. This early data reduction and quality control can potentially identify equipment problems or data discrepancies that are not obvious, particularly in electronic data collection systems. Data reduction or quality control records, such as those shown in Table A-9, can also help to track progress.

Table A-9. Example of Quality Control and Progress Tracking Forms

<table>
<tr><th colspan="11">Morning Peak Period Travel Time Runs (7 to 9 a.m.)</th></tr>
<tr><th rowspan="2">Freeway</th><th colspan="2">Run 1</th><th colspan="2">Run 2</th><th colspan="2">Run 3</th><th colspan="2">Run 4</th><th colspan="2">Run 5</th></tr>
<tr><th>Driver</th><th>Q.C.</th><th>Driver</th><th>Q.C.</th><th>Driver</th><th>Q.C.</th><th>Driver</th><th>Q.C.</th><th>Driver</th><th>Q.C.</th></tr>
<tr><td>I-10 (Katy)</td><td>S.T.</td><td>R.B.</td><td>S.T.</td><td>R.B.</td><td>S.T.</td><td>R.B.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>I-45N (North)</td><td>B.E.</td><td>R.B.</td><td>B.E.</td><td>R.B.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>I-45S (Gulf)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>US 59N (Eastex)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>US 59S (Southwest)</td><td></td><td></td><td colspan="8" rowspan="2">Note: Responsible personnel can either initial or place an “X” in each cell once the run/QC has been completed.</td></tr>
<tr><td>US 290 (Northwest)</td><td></td><td></td></tr>
</table>

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A.11 Additional Resources for Data Collection Planning

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