Report No. CDOT-DTD-R-2000-15

ESTIMATING LINK TRAVEL TIME ON I-70 CORRIDOR: A REAL-TIME DEMONSTRATION PROTOTYPE

Sarosh I. Khan
Kittichai Thanasupsin

DEPARTMENT OF TRANSPORTATION
RESEARCH

December 2000

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOT-DTD-R-2000-15		

4. Title and Subtitle	5. Report Date
Estimating Link Travel Time on I-70 Corridor: A Real-Time Demonstration Prototype	December 2000
	6. Performing Organization Code CDOT-DTD-R-2000-15
7. Author(s) Sarosh I. Khan and Kittichai Thanasupsin	8. Performing Organization Report No.
9. Performing Organization Name and Address Colorado TransLab, Department of Civil Engineering University of Colorado at Denver Campus Box 113, PO Box 173364 Denver, Colorado 80217-3364	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Colorado Department of Transportation 4201 E. Arkansas Ave. Denver, Colorado 80222	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This report represents the findings of a study that demonstrates the feasibility of estimating link travel time and speed in real-time for rural, mountainous sections of interstate freeway in Colorado using vehicles instrumented with global positioning system receivers, serving as probes in traffic streams. The system configuration developed includes a cost-effective, portable GPS deployment unit, communication links to a server PC and an integrated prototype system for vehicle tracking and estimating link travel time statistics.

This study was carried out in two phases. The objective of the first phase was to identify a cost-effective means of monitoring traffic within a rural, mountainous stretch of the I-70 freeway. An algorithm was developed to estimate average link speed, travel time and the standard error of estimates to provide user information on the reliability of the estimates based on the probe data. The algorithm was tested for different traffic conditions and geometric characteristics of links.

In the second phase of the project, a real-time demonstrational prototype was developed to receive, process and estimate link travel time and speed statistics in real-time. The system was tested off-line and on-line based on field data received from the I-70 corridor. In addition, GPS receivers were deployed using a commercial vanpool service and the system was evaluated further.

Implementation

17. Key Words	18. Distribution Statement
global positioning systems (GPS), algorithms, communication links	No restrictions. This document is available to the public through: National Technical Information Service. 5825 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		77	

Estimating Link Travel Time on I-70 Corridor: A Real-Time Demonstration Prototype

by

Sarosh I. Khan
Kittichai Thanasupsin

Colorado Translab, Department of Civil Engineering
University of Colorado at Denver
Campus Box 113, PO Box 173364
Denver, Colorado 80217-3364

Report No. CDOT-DTD-R-2000-15

Prepared for
Colorado Department of Transportation
Research Branch

December 2000

Colorado Department of Transportation
Research Branch
4201 E. Arkansas Ave.
Denver, CO 80222
(303) 757-9506

EXECUTIVE SUMMARY

This study demonstrates the feasibility of estimating link travel time and speeds in real-time for a rural, mountainous section of an interstate freeway in Colorado using vehicles instrumented with global positioning system receivers, that serve as probes in traffic streams. The system configuration proposed and developed includes a cost-effective, portable GPS deployment unit, communication links to a PC server, and an integrated prototype system for vehicle tracking and estimating statistics on link travel time. The system also includes a user interface.

The section of the I-70 corridor in Colorado selected to evaluate the system is located in a mountainous terrain just east of the Eisenhower Tunnel, gateway to the ski resorts, including Winter Park, Vail, and Aspen, from the Denver International Airport. It carries a high traffic volume during the ski season and during the summer months. Currently there is very limited surveillance infrastructure to monitor traffic conditions on this critical corridor.

This study, funded by the Colorado Department of Transportation and carried out in two phases, explores the feasibility of monitoring this corridor using mobile surveillance technology. The objective of the first phase was to identify a cost-effective means of monitoring traffic within a rural, mountainous stretch of the I-70 corridor. In addition, an algorithm was developed to estimate average link speed, travel time, and the standard error of estimates that provides the user with information on the reliability of the estimates. The algorithm was tested based on simulated data for different traffic conditions and geometric characteristics of links.

In the second phase of the project, a real-time demonstrational prototype was developed to receive, process and estimate link travel time and speed statistics in real-time based on the algorithm proposed in the first phase. The system was tested off-line and on-line based on field data received from the I-70 corridor. In addition, GPS receivers were deployed using a commercial van pool service. This report presents an overview of the demonstration prototype developed, the surveillance technology selected, an evaluation of the system based on simulated and field data, procedures to install and maintain the system, and recommendations for larger scale implementation.

ACKNOWLEDGMENTS

We would like to acknowledge the guidance provided by Rich Griffin, Michelle Keyan, and Neil Lacey who served as Project Managers through the course of the study. We would also like to thank the study panel members John Kiljan, Lou Lipp, Pamela Hutton, Frank Kinder, and Bob Wycoff for their valuable comments and feedback.

PROJECT TEAM

Principal Investigator:

Sarosh I. Khan

Graduate Student Researchers:

Kittichai Thanasupsin, Lu Li, Charles Taylor, Pawan Maini

Undergraduate Student Researcher:

Malika Rana

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

OVERVIEW OF THE REPORT

The first chapter of this report presents an overview of the specifications of the GPS receivers and the modem selected. It also includes a description of the form of communication selected to transmit the GPS data from the field to a fixed-end central server.

The second chapter of the report presents details of the components of the real-time demonstration prototype system developed to track probe vehicles in the traffic stream, methods to estimate link travel time and speed based on probe data and the graphical interface of the system.

The third chapter presents an overview of the network selected to conduct both on-line and off-line tests based on simulated and field data to evaluate the demonstration prototype and the findings.

The fourth chapter presents conclusions and recommendations of the study.

The appendices include instructions on how to install, run and maintain the prototype system, the source code for the programs written, sample GPS data, sample output of the program, and the study proposal.

CHAPTER 1: SELECTION OF SURVEILLANCE TECHNOLOGY

1.1 GLOBAL POSITIONING SYSTEM (GPS)

Global Positioning Systems (GPS) allow instantaneous position and velocity of a moving vehicle to be determined. To provide continuous global positioning capability, 21 evenly spaced satellites placed in a circular, 12-hr orbit inclined at 55^0 to the equatorial plane provide the desired coverage. This constellation provides a minimum of four satellites in good geometric position, 24 hours a day, anywhere on the earth. Depending on the selected elevation angle, more than the minimum number of satellites are often available for use.

GPS satellites provide the capability of determining location in terms of longitude, latitude and elevation by the simple resection process using the distances measured to satellites. The space coordinates relative to the center of the earth of each satellite can be computed from the ephemerides broadcast by the satellite using an algorithm. The ground receiver, defined by its geocentric position vector, employs a clock that is precisely set to GPS time. The true distance range to each satellite may be accurately measured by recording the time required for the satellite signal to reach the receiver. Each range defines a sphere with its center at the satellite. Therefore, using this technique, ranges to three satellites are needed since the intersection of three spheres yields three unknowns (longitude, latitude, and height). GPS receivers use an inexpensive quartz clock set approximately to GPS time. The clock timing error or clock bias is overcome by measuring the distances to four satellites. Other errors include satellite position error (ephemeris error), ionospheric and tropospheric refraction, receiver noise, multi-path and selective availability, collectively referred to as the UERE, or User Equivalent Range Error. The cumulative UERE totals are multiplied by a factor of 1 to 6, a factor that represents the Dilution of Precision, or DOP. DOP is a measure of the geometry of the visible satellite constellation. The ideal orientation of the constellation would require all satellites to be equally spaced around the receiver, and one directly above. This would result in a low DOP. Selective availability is the highest source of error, an intentional error, imposed to limit accuracy to 95% probability of 328 ft. (100 m.) or less.

Instantaneous velocity of a moving vehicle is determined using the Doppler principle of radio signals. Due to the relative motion of the GPS satellites with respect to a moving vehicle, the frequency of a signal broadcast by the satellite is shifted when received at the vehicle. This measurable shift is proportional to the relative radial velocity. The radial velocity of the satellite is known, therefore the radial velocity of the moving vehicle can be deduced from the Doppler observable. The accuracy of velocity is $\pm$ 0.16 km/hr (0.1 mph) for receivers with location accuracy of 100 m. (328 feet), and with selective availability turned on. Since May, 2000 selective availability has been turned off and the accuracy has been reported to increase tenfold. The instantaneous GPS velocity reporting is independent of position fixes. Prices for GPS receivers range from $100-$50,000, depending on the additional features available and the reporting accuracy of the receivers. The GPS receiver selected for this study are capable of reporting location within a 100m accuracy, providing data in a non-proprietary format and is compatible with a Cellular Digital Packet Data (CDPD) modem (Trimble Navigation Limited 1996).

Figure 1. Placer 450 and Magnetic Antenna.

1.2 MODEM

The Cellular Digital Packet Data (CDPD) is a wireless, public access, packet data standard designed to operate over existing analog cellular phone systems. The Uniden Data 1000, a CDPD modem, was selected for this study. The selection of a modem is based on:

- Cost
- Reliability
- Compatibility with the GPS receivers selected.

Figure 2. Uniden Data 1000, CDPD Modem.

1.3 COMMUNICATION

CDPD is a connectionless network service that overlays the cellular voice network to wirelessly transmit data to mobile and fixed-end computing devices. The CDPD network operates as an extension of the TCP/IP data communication network. TCP/IP is the method by which data on the network is divided into packets of bytes. Then the CDPD network transmits the GPS data from the corridor to a PC server in an end-to-end system.

Key components of the end-to-end system used are the mobile system and the fixed-end host system. The mobile equipment, installed in the vehicle, comprises of a GPS receiver and a CDPD modem. The fixed-end host system, a PC, runs FleetVision (Trimble Navigation Limited 1998b). The PC server is connected to the internet and therefore the PC connects to the CDPD network through the internet. Messages received by the cellular from the GPS are processed and routed to an IP address. Additionally, the cellular carrier providing CDPD services accepts TCP/IP transmissions for IP addresses for units that are registered and operate in its CDPD network and passes those messages on to the units. The GPS receivers come with a SLIP interface driver to communicate with the CDPD modem and a TCP/IP stack to enable it to exchange messages over the CDPD network. The CDPD modem is registered with a CDPD service provider and configured with the IP address. The modem comes with software to allow easy setup. Figure 3 below shows the configuration of the communication network.

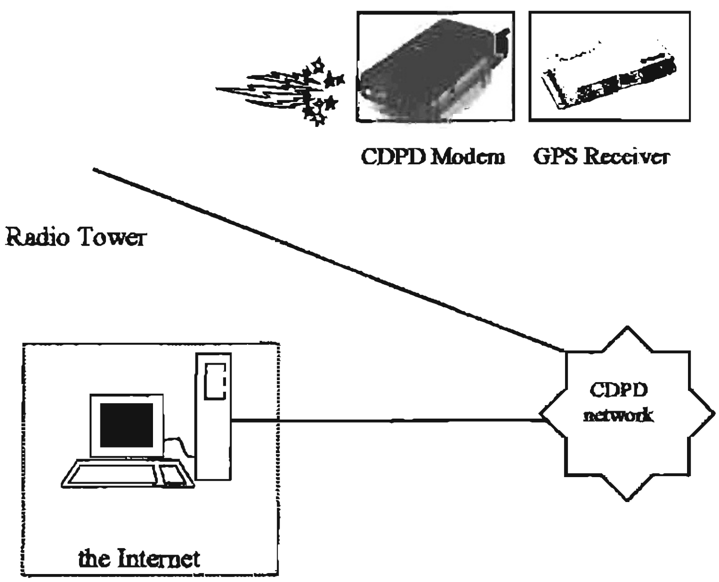


Figure 3. Communication Network.

1.4 PORTABILITY

The GPS receiver, CDPD modem, and their antennas assembled in a box provide a portable unit as shown in Figure 4. This unit is easy to install in a vehicle by slipping the adapter into a lighter/power source and mounting the magnetic antenna on the rooftop of a vehicle.

Figure 4. Assembled GPS Unit.

1.5 COST

The cost of the portable GPS receiver unit shown in Figure 4 was less than $1500 per unit during the study. Currently, the same unit could be assembled for less. The breakdown of costs per unit is presented in Table 1.

Table 1. Cost Breakdown Per Portable GPS Unit.

	Cost for Study	*Current Costs*
GPS Receivers	$800	$599
CDPD Modem	$350	$350
Antenna Kit	$180	$45
Cables	$60	$50
Antenna for Modem	$50	$50
Cigarette Lighter Adapter	$45	$45
Cash Box	$10	$10
TOTAL	$1,495	$1149

CHAPTER 2:
DESCRIPTION OF THE DEMONSTRATION PROTOTYPE

2.1 COMPONENTS OF THE PROTOTYPE

The real-time demonstration prototype system developed to receive GPS data from probe vehicles in real-time, process the data and estimate link travel time and speed consists of three integrated modules. They are:

1) Probe Vehicle Tracking Module
2) Link Travel Time/Speed Algorithm
3) Graphical Interface

Figure 5 shows a schematic of the components. A brief description of each module is provided below:

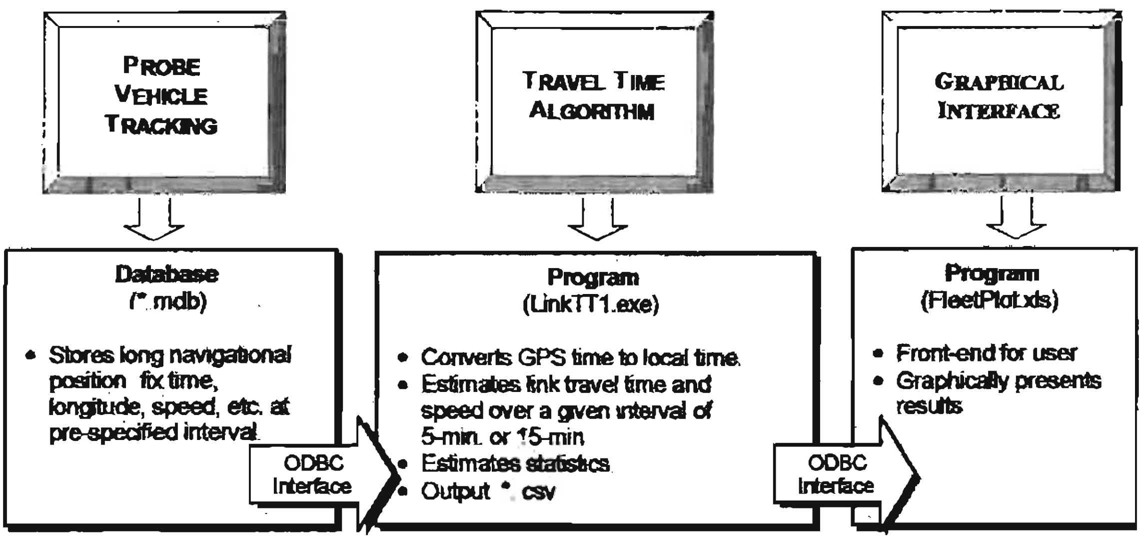


Figure 5. Components of the Real-Time Demonstrational Prototype System.

2.2 PROBE VEHICLE TRACKING SYSTEM

The Probe Vehicle Tracking Module receives GPS data in real-time from all vehicles instrumented with GPS receivers or probe vehicles operating within the test corridor using the communication network described in the previous section. This information is received as a data string at pre-specified time intervals and includes: Report Time and Position Fix Time in GPS time, latitude, longitude, altitude, horizontal and vertical speed, number of satellite vehicles used, and satellite vehicle ID. The navigational message may be received every second. For the prototype, the reporting interval is set to 5 seconds. This data is stored in a database file (*.mdb) and is passed to the Travel Time Estimation Module. Probe vehicles may be tracked and displayed on a map of the network using FleetVision (Trimble Navigation Limited 1998a).

2.2.1 Fleet Vision

FleetVision (Trimble Navigation Limited 1998b) tracks a fleet of vehicles equipped with GPS receivers in real-time. It also reports and stores the data, such as vehicle location and time, to a base computer via the CDPD modem. The reported GPS data contain vehicle ID, longitude, latitude, altitude, and speed for each vehicle every pre-specified interval. The reporting interval can be set to as frequent as 1 second. For this test network, the reporting interval was set to 5 seconds.

2.3 TRAVEL TIME AND SPEED ESTIMATION ALGORITHM

The link travel time and link speed are calculated by using a program written in Fortran language.

2.3.1 Fortran Program

The Fortran program has been developed to :

- Extract the GPS data for a selected network.
- Convert GPS time to Denver local time. The daylight saving time change and leap year are also taken into account. GPS time is the number of seconds elapsed after 00:00:00 AM January 6, 1980.
- Estimate the link travel time and link speed based on data received from probe vehicles that complete their journey through a link. The link travel time and link speed can be determined as follows:

$$LTT_{ij} = T_{out,ij} - T_{in,ij} \tag{1}$$

where,

LTT_{ij} = Travel time for probe vehicle i for link j

$T_{in,ij}$ = Time probe vehicle i enters the link j

$T_{out,ij}$ = Time probe vehicle i exits the link j

L_j = Length of link j

$$LSPD_{ij} = \frac{L_j}{LTT_{ij}} \tag{2}$$

where,

$LSPD_{ij}$ = Travel speed for probe vehicle i for link j

The probe vehicles completing their journey on a link within a given interval are used to estimate average link travel time and average link speed. For example, to estimate 15-minute average link travel time, all probe vehicles that complete their journey through the link are included. Probe vehicles are checked every 2.5 minutes, that is, the update interval is 2.5 minutes.

$$\overline{LTT_j} = \frac{\sum_{i=1}^{n} LTT_{ij}}{n} \tag{3}$$

$$\overline{LSPD_j} = \frac{L_j}{\overline{LTT}} \tag{4}$$

where,

$\overline{LTT_j}$ = Average travel time for link j

$\overline{LSPD_j}$ = Average travel speed for link j

n = number of probe vehicles for link j

For any given interval, the exact time a probe vehicle enters and exits a link is estimated by first converting the longitude, latitude, and altitude at any time to Earth Centered Earth-Fixed (ECEF) coordinates and estimating the distance traveled. This procedure is described in the next few sections.

2.3.2 Transformation from Geodetic Coordinates to Earth Centered, Earth-fixed (ECEF) Coordinates

The GPS reports data in longitude and latitude. To calculate the linear distance of the vehicles between two report locations, the longitude (ϕ), latitude (λ), and altitude (h) are converted to Earth Centered Earth-fixed (ECEF) Coordinates ((x,y,z) coordinates) (Figure 6).

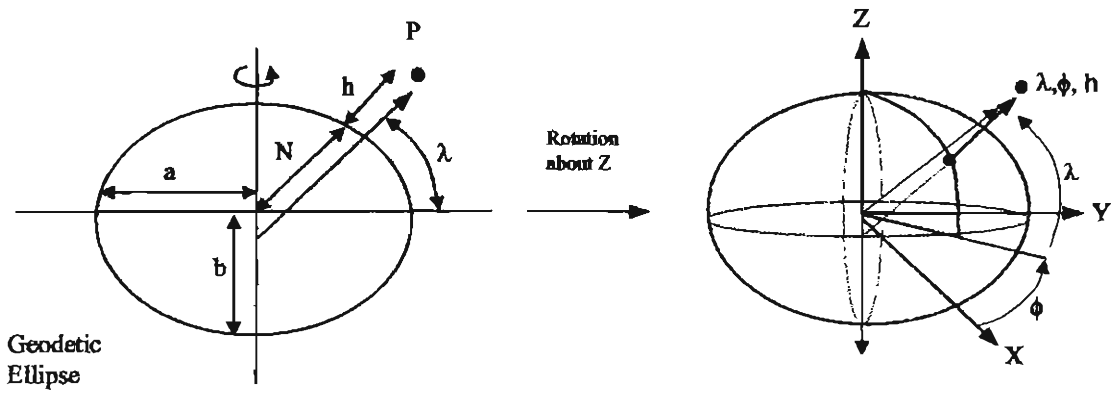


Figure 6. Geodetic Coordinates Transformation.

The flatness of the geodetic ellipsoid is defined as:

$$f = \frac{a-b}{a} = 0.0034 \tag{5}$$

where,

a = Semi-major axis length = 6378137.0 m

b = Semi-minor axis length = 6356752.3142 m

The eccentricity of the ellipsoid is defined as:

$$e = \sqrt{f(2-f)} = 0.0818 \tag{6}$$

The length of the normal to the ellipsoid, from the surface of the ellipsoid to its intersection

$$N(\lambda_t) = \frac{a}{\sqrt{1-e^2 \sin(\lambda_t)^2}} \tag{7}$$

The linear position in (x,y,z) coordinates is calculated as:

$$x_t = (N + h_t)\cos(\lambda_t)\cos(\phi_t) \tag{8}$$

$$y_t = (N + h_t)\cos(\lambda_t)\sin(\phi_t) \tag{9}$$

$$z_t = [N(1-e^2) + h_t]\sin(\lambda_t) \tag{10}$$

where,

λ_t = Latitude at time t

ϕ_t = Longitude at time t

h_t = Altitude at time t

2.3.3 Estimating the Entry and Exit Time For Probe Vehicles

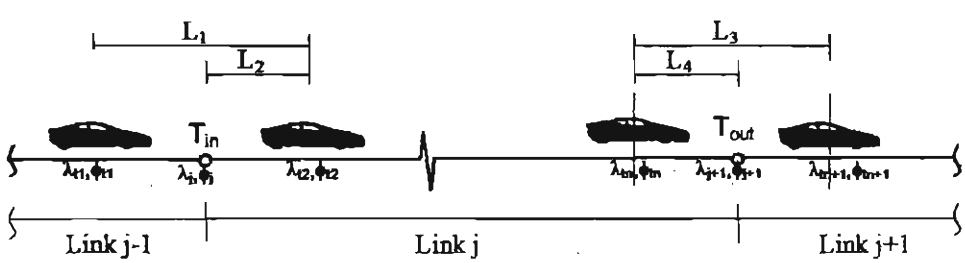


Figure 7. Probe Vehicle Entering and Exiting a Link.

The locations of vehicles in longitude (ϕ), latitude (λ), and altitude (h) are converted to (x,y,z) coordinates based on equation (8) , (9) , and (10). The time a probe vehicle enters and exits a link is estimated based on linearly interpolating between two consecutive 5-second reporting of location as follows:

$$L_1 = \left[\left(x_{t_1} - x_{t_2} \right)^2 + \left(y_{t_1} - y_{t_2} \right)^2 + \left(z_{t_1} - z_{t_2} \right)^2 \right]^{\frac{1}{2}} \tag{11}$$

$$L_2 = \left[\left(x_k - x_{t_2} \right)^2 + \left(y_k - y_{t_2} \right)^2 + \left(z_k - z_{t_2} \right)^2 \right]^{\frac{1}{2}} \tag{12}$$

$$L_3 = \left[\left(x_{t_n} - x_{t_{n+1}} \right)^2 + \left(y_{t_n} - y_{t_{n+1}} \right)^2 + \left(z_{t_n} - z_{t_{n+1}} \right)^2 \right]^{\frac{1}{2}} \tag{13}$$

$$L_4 = \left[\left(x_{t_n} - x_{t_{k+1}} \right)^2 + \left(y_{t_n} - y_{t_{k+1}} \right)^2 + \left(z_{t_n} - z_{t_{k+1}} \right)^2 \right]^{\frac{1}{2}} \tag{14}$$

where,

L_1 = Distance a probe vehicle travels between time t_1 and t_2

L_2 = Distance from upstream node for link j to the location of a probe vehicle at time t_2

L_3 = Distance a probe vehicle travels between time t_n and t_{n+1}

L_4 = Distance from the location of a probe vehicle at time t_n to node j+1

t_1 = Last reporting time before entering link j

t_2 = First reporting time after entering link j

t_n = Last reporting time before exiting link j

t_{n+1} = First reporting time after exiting link j

$\lambda_{t_1}, \lambda_{t_2}, \lambda_{t_n}, \lambda_{t_{n+1}}$ = Latitude at time t_1,t_2,t_n,and t_{n+1}, respectively

$\phi_{t_1}, \phi_{t_2}, \phi_{t_n}, \phi_{t_{n+1}}$ = Longitude at time t_1, t_2,t_n,and t_{n+1}, respectively

λ_j, λ_{j+1} = Latitude for node j and j+1, respectively

ϕ_j, ϕ_{j+1} = Longitude for node j and j+1, respectively

Therefore, the time a probe vehicle *i* enters and exits the link j are as estimated follows:

$$T_{in,ij} = t_1 + (t_2 - t_1)\frac{L_2}{L_1} \tag{15}$$

$$T_{out,ij} = t_n + (t_{n+1} - t_n)\frac{L_4}{L_3} \tag{16}$$

Based on equation (3), (4), (15) and (16) the average link travel time and speed are estimated. In addition, the standard error of the average link travel time estimates are estimated based on the average variance and covariance of the probe vehicle estimates as follows:

$$\sigma^2_{\overline{LTT}_j}(t_n) = v_j(t_n) + \frac{1}{n(t_n)}\left[\eta_j(t_n) - v_j(t_n)\right] \tag{17}$$

where,

$\sigma^2_{\overline{LTT}_j}(t_n)$ = standard error of average travel time estimate for link *j*, for a given analysis period (e.g. 5-min or 15-min)

$v_j(t_n)$ = average variance of average travel time for link j, , for a given analysis period

$\eta_j(t_n)$ = average covariance of average travel time for link j, , for a given analysis period

$n(t_n)$ = number of probe vehicles that travel link *j*, for a given analysis period

Similarly, the standard error for average travel speed estimate is also calculated. All estimates for every link in the network are stored in a file (*.csv) and passed to Graphical Interface Module.

2.4 GRAPHICAL INTERFACE

To display the average link travel time and speed estimates, their statistics and individual probe vehicle data in a user-friendly environment, a graphical interface was developed. The routines of this module use the Open Database Connectivity (ODBC) interface to receive data from the Travel Time Estimation Module.

2.4.1 FleetPlot

FleetPlot has been developed as an Excel application. The FleetPlot is used to plot vehicle link travel time, vehicle link speed, vehicle instantaneous speed, average link travel time and average link speed. The plots show the data for the test network. The plots are automatically updated every 2.5 minutes. This update can be stopped or restarted. The plots only show the time of the last update and the number of probe vehicles in a given analysis period. The plots or data display are delayed approximately by a maximum of 2.5 minutes. Figure 8 shows a snapshot of the Graphical Interface.

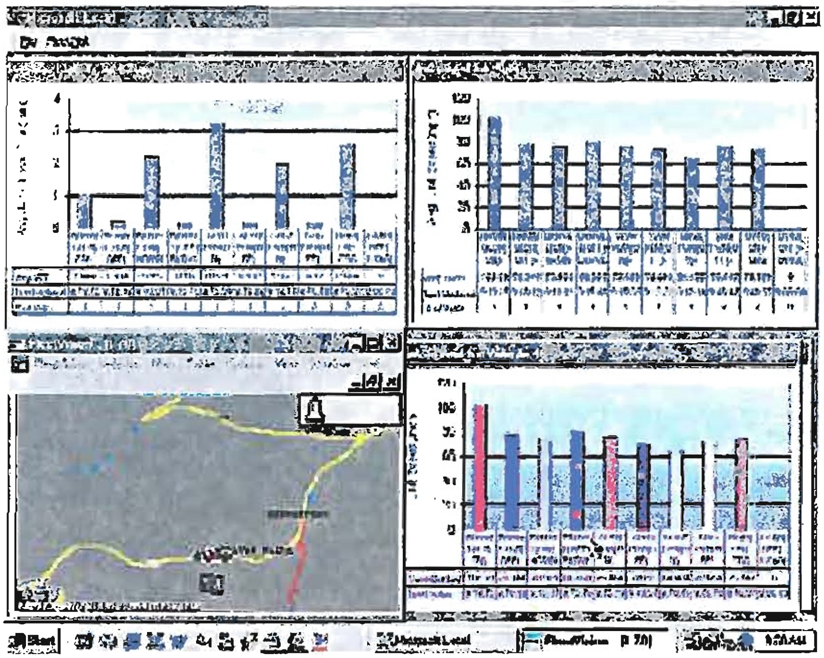


Figure 8. Sample Interface Showing the Integration of the Three Modules.

2.5 PROTOTYPE INTERFACE

The prototype consists of three modules: Probe Vehicle Tracking, Travel Time Algorithm, and Graphical Interface. The three modules are connected using Open Database Connectivity (ODBC) interface. The Travel Time Algorithm module receives data from the Probe Vehicle Tracking system. The Graphical Interface module receives data from the Travel Time

Algorithm as shown in Figure 5. The external program performs all the calculations such as time conversion, link travel time, link speed, etc. (Figure 9).

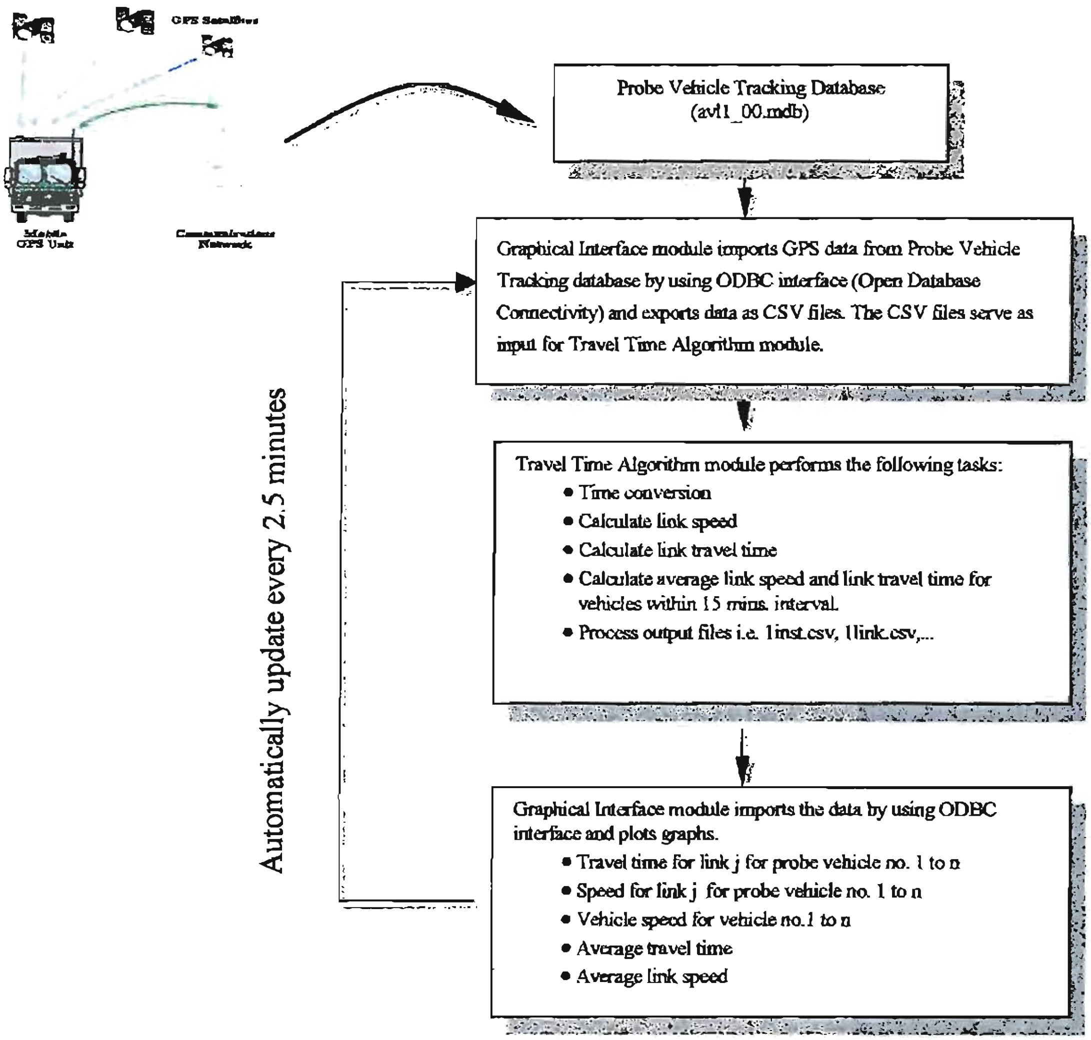


Figure 9. Flowchart.

CHAPTER 3:
EVALUATION OF THE DEMONSTRATION PROTOTYPE

To perform a comprehensive evaluation of the demonstration prototype, a section of the I-70 corridor between the Denver International Airport and the ski resorts was selected. The next few sections present details of the test section selected, a simulated representation of the test network, off-line tests conducted, on-line real-time field data collection procedures, and findings of these tests.

3.1 TEST NETWORK

Interstate 70 westbound between US 40 Exit (Winter Park) and US 6 Exit was selected as the test section. The length of the 2-lane test network is approximately 15.8 miles. The average grade is about 3% upgrade, with a maximum of 6%. The on-ramps and off-ramps within the test network include US 40, Georgetown, Silver Plume, Bakerville, Herman Gulch, and US 6. Figure 10 shows the test network. Figure 11 shows the elevation of the network.

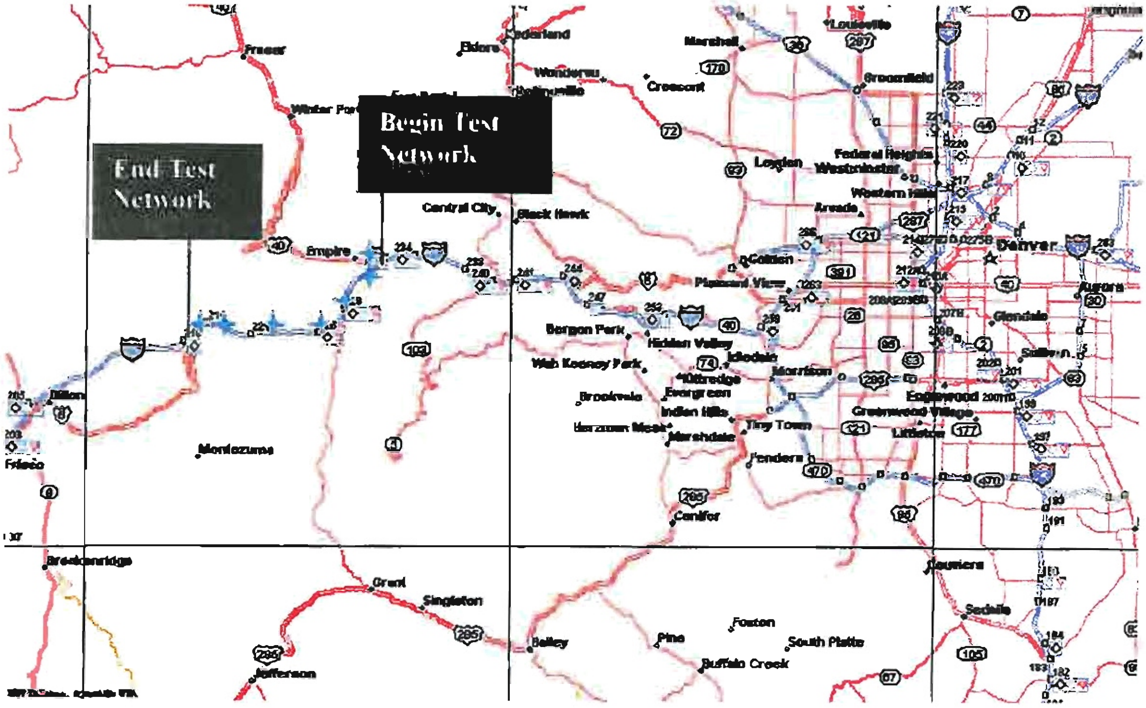


Figure 10. Test Network.

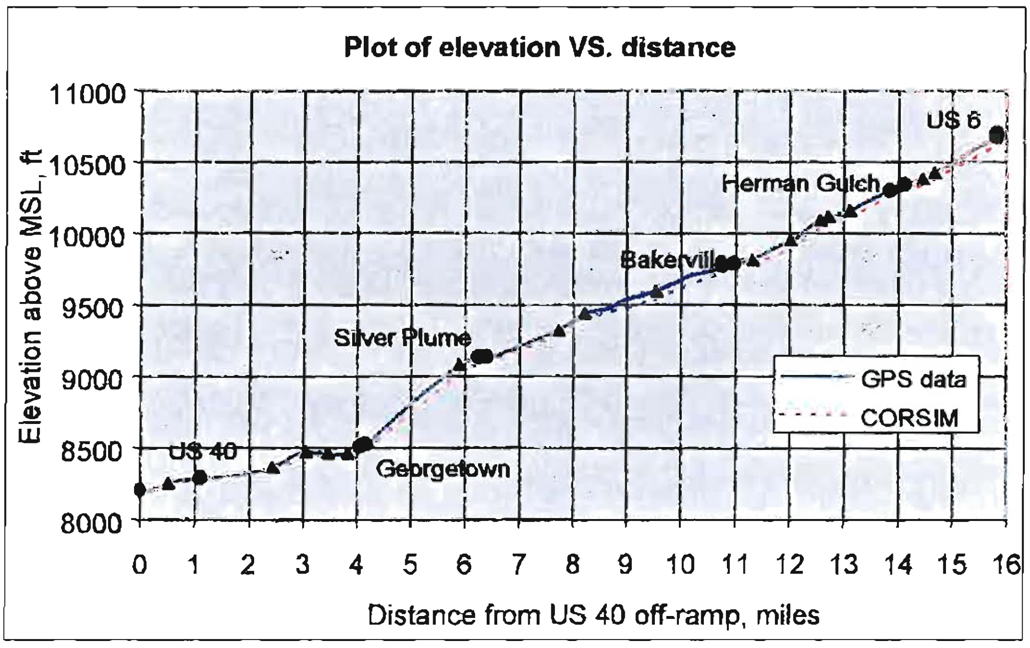


Figure 11. Elevation Profile.

3.2 NETWORK REPRESENTED IN SIMULATION

To develop and test the algorithms under different flow conditions, probe vehicle deployment, and probe report interval, the test network was simulated using CORSIM, a microsimulation model. Field data collected may often be limited. Therefore, a simulation provides extensive data for testing under a variety of operating conditions. The simulation model was calibrated based on field data to ensure that the network was well represented by the simulation model.

3.2.1 CORSIM

CORSIM (CORidor SIMulation) (Federal Highway Administration 1996), a micro-simulation, developed by the Federal Highway Administration (FHWA) consists of NETSIM and FRESIM and is used to simulate a surface street and freeway network, respectively.

The traffic environment of the network is represented to include the topology of the roadway system, roadway geometry, lane channelization, driver behavior, traffic control, traffic volumes entering the roadway system, turn movements, and fleet characteristics. A schematic of the representation is shown in Figure 12.

3.2.2 Calibrating CORSIM

To calibrate CORSIM, traffic flow was recorded at US 40 and Bakerville using video cameras as shown in Figure 13. A video image processing system was used to estimate traffic flow rate and speed at these locations. In addition, volunteer drivers with GPS receivers were deployed to collect travel time data along the same section as flow data was recorded.

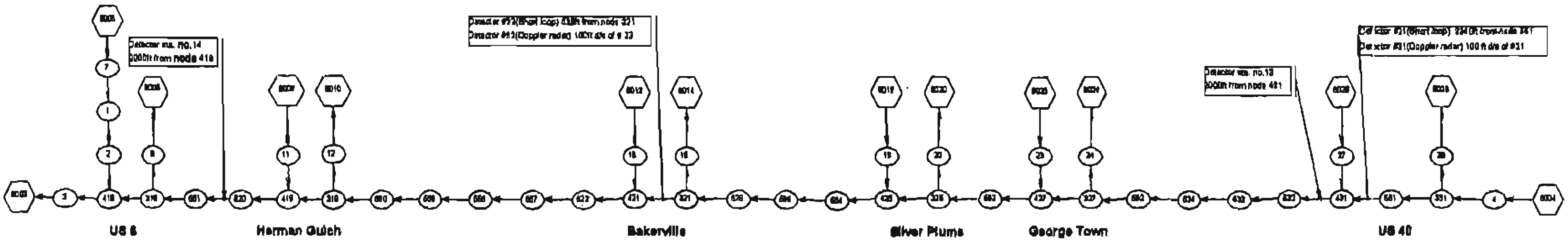


Figure 12. Nodes and Links Represented in CORSIM.

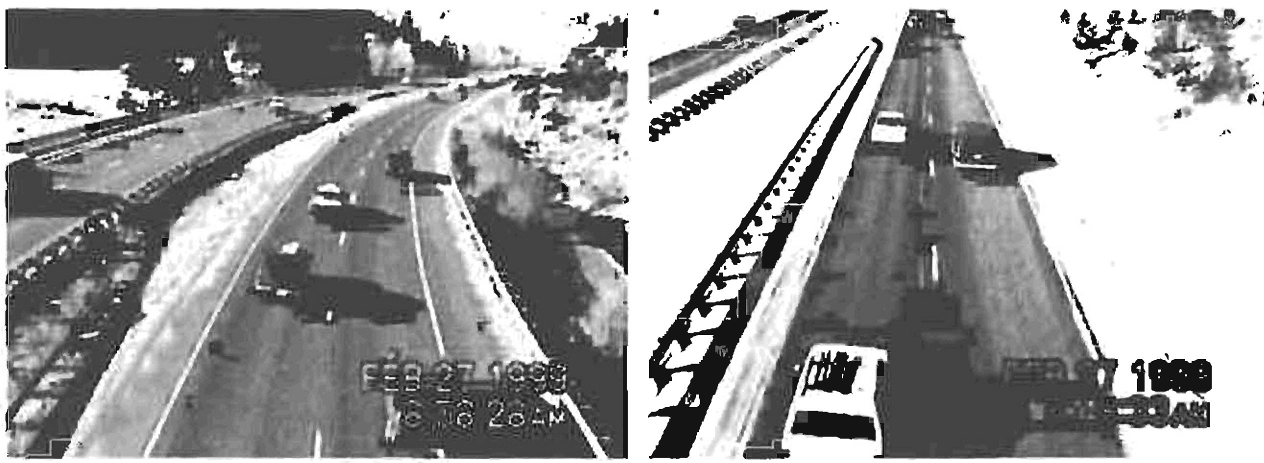


Figure 13. Cameras at US 40 and Bakerville to Monitor Traffic Flow on the I-70 Corridor to Calibrate CORSIM.

3.2.3 Results of Calibration

Details of the calibration results are presented in several papers. ((Khan (in preparation)), (Khan 1998), (Khan 2000b), and (Khan 2000a)).

3.3 OFF-LINE TESTING OF THE AVERAGE LINK TRAVEL TIME ESTIMATION ALGORITHM

Analysis of the standard error of the estimates of average link travel time based on Eq. (17) and probe vehicle data shows that increasing the number of probes beyond a certain level does not improve the accuracy of the estimates as shown in Figure 14. Here the curve flattens as the number of probes traveling a link increases, with very little marginal improvement in accuracy. In addition, the marginal improvement in the estimate of average link travel time also varies based on flow conditions and link characteristics. Details of these findings are reported separately (Khan 2000b). Figure 14 shows the standard error for a 833.63 m. (2,735 ft) link with a 3% grade between Bakerville and Herman Gulch for two flow conditions. Figure 15 shows the standard error for a short weaving section between an on and off-ramp. Figure 14 and Figure 15 show that the marginal improvement in error is higher for the weaving section for less than 5 probes, compared to a longer section.

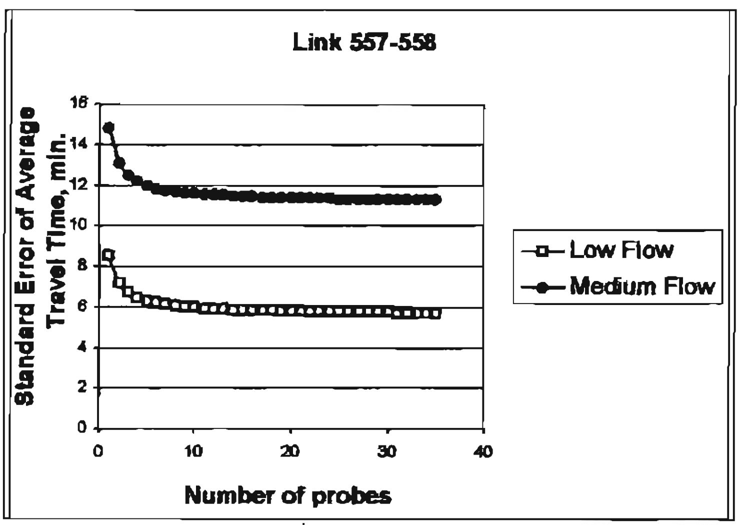


Figure 14. Standard Error of Average Link Travel Time Estimate for Link between Bakerville and Herman Gulch.

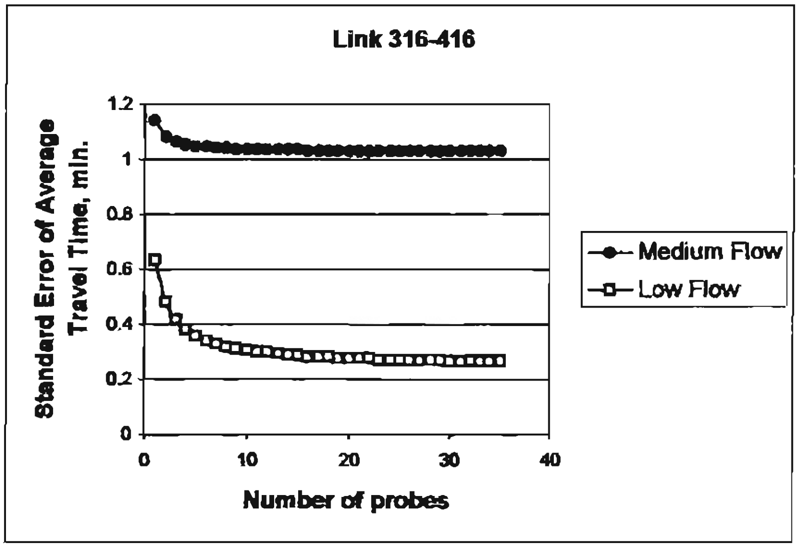


Figure 15. Standard Error of Average Link Travel Time Estimate for Link between US 6 On and Off-Ramp.

Therefore, using link travel time functions, average link travel time estimates based on probe data for an analysis period, and the number of probes used for the estimate, the standard error of the average travel time estimate may be reported. For example, for probe data collected within a 15-minute analysis period and using Eqs. (1) to (16), the average travel time for Link # 316-416 may be estimated. Based on the link travel time function as shown in Figure 16, the flow level may be identified as "Medium". Using standard error curves such as Figure 15 and the number of probes within the analysis period, the standard error of the link travel time may be estimated.

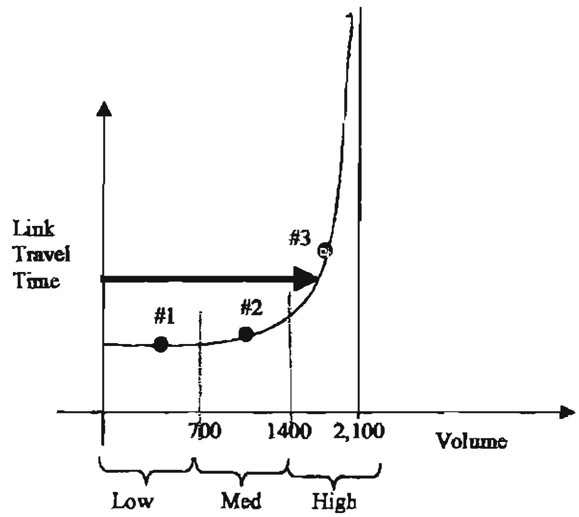


Figure 16. A Link Travel Time Function.

3.4 OFF-LINE AND ON-LINE TESTING OF THE DEMONSTRATION PROTOTYPE SYSTEM BASED ON CONTROLLED EXPERIMENTS

Several vehicles were equipped with the assembled GPS unit (Figure 4) and volunteer drivers were deployed for several weekends: March 25, April 1, and April 15, 2000. The data collection was performed during 7:00AM to 10:00AM. During this period traffic volume varied from 700 to 2200 vph westbound for the test network.

For the field study, the test network was divided into 10 links based upon the location of on-ramps and off-ramps. The length of links varies from 0.12 to 4.12 miles. The upstream and downstream locations and lengths are as follows:

1. US 40 off-ramp to US 40 on-ramp, 1.11 miles.
2. US 40 on-ramp to Georgetown off-ramp, 3.16 miles.
3. Georgetown off-ramp to Georgetown on-ramp, 0.22 miles.
4. Georgetown on-ramp to Silver Plume off-ramp, 2.11 miles.
5. Silver Plume off-ramp to Silver Plume on-ramp, 0.16 miles.
6. Silver Plume on-ramp to Bakerville off-ramp, 4.12 miles.

7. Bakerville off-ramp to Bakerville on-ramp, 0.21 miles.
8. Bakerville on-ramp to Herman Gulch off-ramp, 2.73 miles.
9. Herman Gulch off-ramp to Herman Gulch on-ramp, 0.24 miles.
10. Herman Gulch on-ramp to US 6 off-ramp, 1.73 miles.

3.4.1 GPS and Modem Coverage

Extensive testing of the prototype system has shown that the GPS coverage varies on the test network on I-70 depending on the season, with better coverage during the summer months. Based on a 5-second reporting interval, the GPS coverage statistics are summarized in Table 2. As shown in this table, the average consecutive seconds either the GPS signal or modem coverage is lost due to inadequate satellite coverage, mountainous terrain, or any obstructions is less than one minute during winter and approximately half a minute during summer. The average total duration signal is lost for a one-way, 16-mile trip is a little over two minutes during winter and less than two minutes during summer.

Table 2. Statistics on Loss of Probe Vehicle Data for the Test Network.

Winter		Summer	
Average consecutive seconds GPS or modem coverage is unavailable (seconds)	*Average total duration signal or modem connection for a one-way trip for test network is lost (seconds)*	*Average consecutive seconds GPS or modem coverage is unavailable (seconds)*	*Average total duration signal or modem connection for a one-way trip for test network is lost (seconds)*
53.5	134	34.5	104

3.5 ON-LINE, REAL-TIME TESTING BASED ON COMMERCIAL VANPOOL SERVICE AS PROBES

There are several van pool services from Denver International Airport (DIA) to ski resorts such as Colorado Mountain Express (CME) (Figure 17). For this study, Colorado Mountain Express was contacted to explore the feasibility of deploying several assembled GPS units from DIA to Vail to test the demonstration prototype in real-time. CME has 150 vans in their fleet operating on this route with an average headway varying from 20-30 minutes to an hour for winter and summer season respectively. CME agreed to participate in this study and 5 units were deployed between June 27, 2000 to July 17, 2000.

Figure 17. CME Vanpool Service.

Extensive on-line testing revealed a few software problems that were later resolved as part of this process. The demonstration prototype is now debugged and is fully operational and running in the Colorado TransLab.

CHAPTER 4:
CONCLUSIONS AND RECOMMENDATIONS

The study demonstrates the feasibility of estimating link travel time and speeds in real-time for a rural, mountainous section of an interstate freeway in Colorado using vehicles instrumented with global positioning system receivers, serving as probes in traffic streams. The system configuration proposed includes a cost-effective, portable GPS deployment unit, communication links to a PC server and an integrated prototype system for vehicle tracking, estimating statistics on link travel time and displaying the information in a user friendly environment.

Extensive testing of the prototype system has shown that the GPS coverage varies on the test network on I-70 depending on the season, with better coverage during the summer months. Based on a 5-second reporting interval, the GPS coverage statistics show that the average consecutive seconds either the GPS signal or modem coverage is lost due to inadequate satellite coverage, mountainous terrain, or any obstructions is less than one minute during winter and approximately half a minute during summer. The average total duration signal is lost for a one-way, 16-mile trip is a little over two minutes during winter and less than two minutes during summer.

The study also shows that average link speed, a measure independent of link length, is a better estimate to display and for an operator of the system to quickly draw inferences about traffic congestion. Link travel time estimates are also required for targeted traveler information for a given origin and destination pair. The design of the most efficient and user-friendly front-end to the prototype was not part of the scope of the study. This study may be further extended to address these issues.

A final project presentation was made on July 20, 2000 to the Project Manager, traffic engineers from the Mobility Group, DTD, ITS Group, Headquarters, Region 1 and Region 6, CDOT, and the Denver Regional Council of Governments (DRCOG). The prototype system presented was very well received by the attendees. Interest was expressed by several groups within CDOT to further extend this study for other applications. The groups that expressed an interest included: GIS, Mobility, ITS, Region 6 and Region 1. Several follow-up presentations were scheduled. One of the meetings arranged by the Mobility Analysis Group on August 23rd, 2000 included 20 attendees from the GIS, Mobility Analysis, ITS, and Region 6, CDOT. A separate meeting was scheduled by Region 1 to be held in October, 2000.

4.2 EXTENSION OF THIS STUDY

A proposal was submitted in December, 1999 to CDOT as part of the 2001 Problem Statements to extend this study to use the Regional Transit District (RTD) bus fleet already equipped with Automatic Vehicle Location System (AVL) to estimate freeway traffic speed. The proposal was very well received and has been recommended for funding. This new study is titled "Using RTD's Transit Vehicles as Probes to Develop Speed Maps for Colorado Freeways". Bruce Coltharp from the ITS Office, CDOT will serve as project manager.

APPENDIX A:
INSTALLING AND RUNNING THE PROTOTYPE SYSTEM

B.1 SYSTEM REQUIREMENTS

- Pentium 200 MHz class or higher with CD-ROM drive
- 96 MB of memory
- 2.0 GB hard disk drive
- Microsoft Windows 98
- Microsoft Excel 97
- A fixed-end host server with a static IP address

B.2 INSTALLING FLEETVISION

- Insert the FleetVision installation CD in the computer's CD-ROM drive.
- Click on Start and select Setting/Control Panel.
- Click Add/Remove Programs.
- In the Add/Remove Programs Properties dialog box click on Install and follow the on-screen instructions.

B.2.1 Communication Channel Setup

1. In FleetVision Taskbar, Click **Tools** and then **Channel Setup**.
2. Data layer should be set to **TAIP** as shown in Figure A-1.

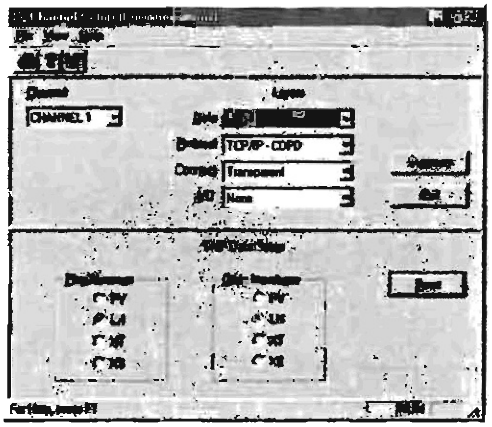


Figure A-1. Channel Setup Dialog-Data.

3. Protocol layer should be set to **TCP/IP CDPD** and the IP address is for the fixed-end host that will receive the GPS data.

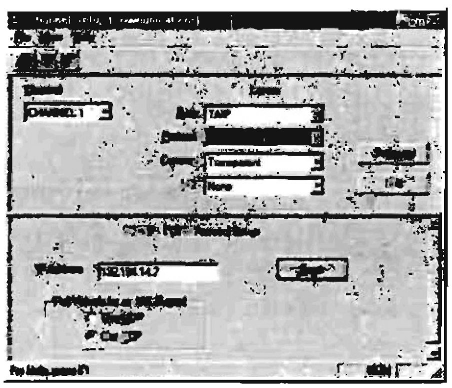


Figure A-2. Channel Setup Dialog-Protocal.

B.2.2 Vehicle Configuration

1. In FleetVision taskbar, Click **Fleet**, **Vehicle Configuration**, and then **Create a new vehicle or edit an existing vehicle.**
2. Click **Continue...**

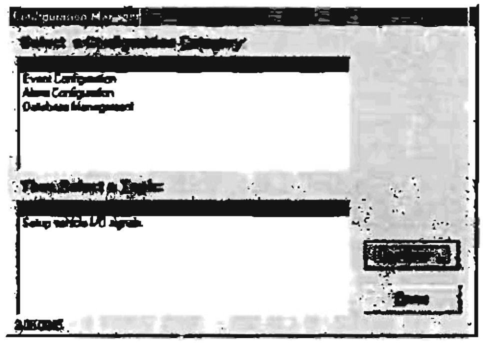


Figure A-3. Configuration Manager Dialog.

3. Enter Physical ID (a number to represent the vehicle), Name and select icon by clicking **Icon**.

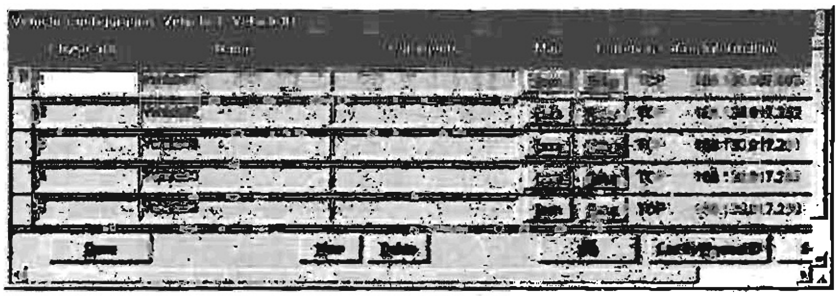


Figure A-4. Vehicle Configuration Dialog.

4. Enter communication information by clicking **Setup** to access to Vehicle Communication Configuration Dialog.

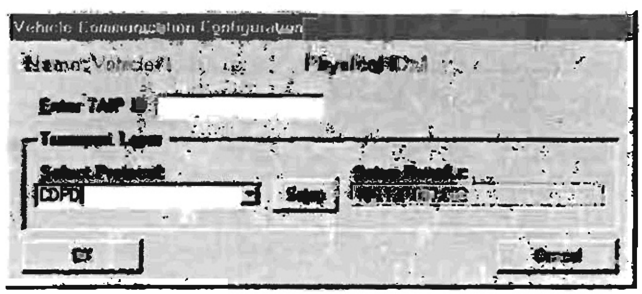


Figure A-5. Vehicle Communication Configuration Dialog.

5. Select **CDPD** in **Select Protocol** and then click **Setup** to enter the CDPD modem IP address.

B.2.3 Installing FleetPlot and Fortran Program

1. Insert the FleetPlot&Fortran program installation CD in the computer's CD-ROM drive.
2. Click on **Start** and select **Setting/Control Panel**.
3. Click **Add/Remove Programs**
4. In the **Add/Remove Programs Properties** dialog box click on **Install** and follow the on-screen instructions.

B.2.3.1 MS-Dos Prompt

MS-Dos prompt must be set to minimized as follows:

1. Click **Start**, **Programs**, and then **MS-DOS prompt**.
2. Click MS-DOS Prompt Properties dialog.
3. Set **Run** to **Minimized**.

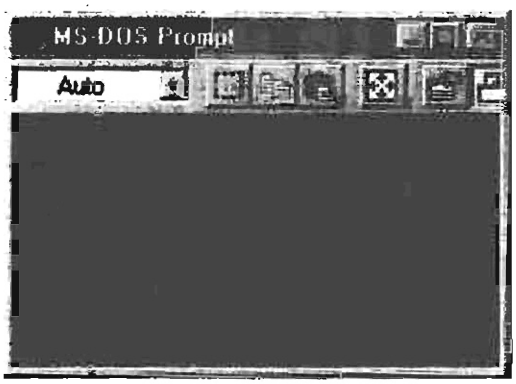


Figure A-6. MS-DOS Dialog.

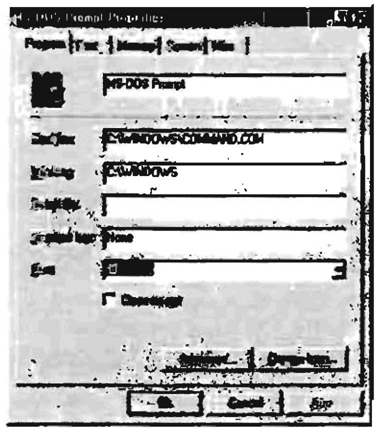


Figure A-7. MS-DOS Prompt Properties.

B.2.4 Installing GPS Receivers

B.2.4.1 Installing GPS in a Probe Vehicle:

1. Place GPS assembled unit (Figure 4) the GPS box in your car close to the cigarette lighter socket. The GPS unit may be placed on the front seat. The data modem's antenna should be in an upright position. .

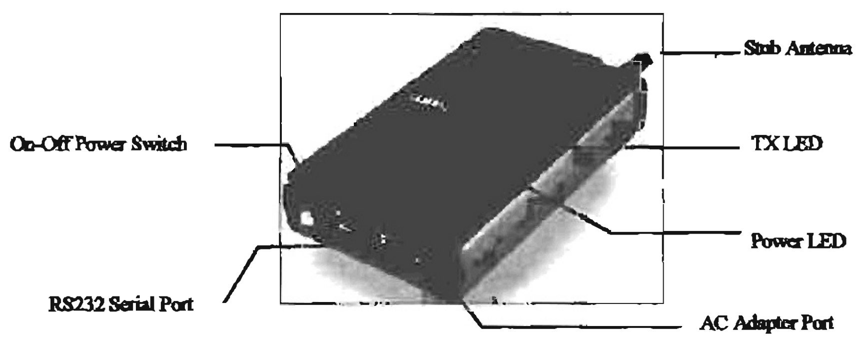


Figure A-8. Data Modem.

2. Attach the magnetic GPS antenna on probe vehicle's roof.

Figure A-9. GPS Unit (Placer 450) and GPS Antenna.

3. Plug the power cable to probe vehicle's cigarette lighter socket.
4. Turn the modem power switch on.
5. Check the data modem by following these steps:
    - Power LED- Solid red indicates power on and no light indicates power off.
    - TX LED indicates modem operational status.
        - Solid Orange indicates trying to acquire a CDPD channel.
        - Blinking Orange indicates trying to register on an acquired CDPD channel.
        - Solid Green indicates registered.
        - Flashing Green indicates transmitting while registered.

While operating, check the CDPD modem to make sure:
Power LED - is red all the time.
TX LED - is green most of the time.

B.3 SETTING UP THE MODEM

The fixed-end host computer receiving the probe vehicle data must be on the internet service with a static IP address. The power of the modem should be on. In order to set up the modem to report GPS data to the computer, the following steps should be performed:

1. Click **Start**, and then click **Run**.
2. Type **Telnet** and then click **OK**.
3. Click **Connect** and then click **Remote system**.
4. Enter the modem IP address. e.g. 166.130.7.3
5. Enter port **59100** and Terminal type **vt100**.
6. Click **Connect**
7. Type > **sda0c0xxx.xxx.xxx.xxx**< , replacing xxx.xxx.xxx.xxx with the fixed - end host computer's IP address i.e. > **sda0c0132.194.014.007** <
8. Type >**qda**< and then press Enter. A message should be displayed similar to the following. **>RDA0C0132.194.014.007;ID=0003<**
9. Close telnet dialog box.

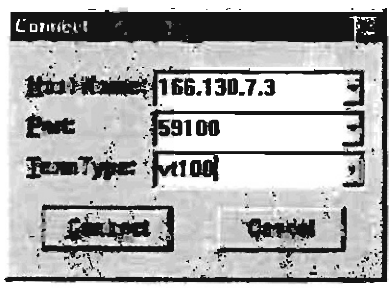


Figure A-10. Telnet Dialog Box.

B.4 RUNNING THE PROTOTYPE

To run the prototype, the FleetVision and FleetPlot program should be open while the external program is called by FleetPlot. The windows of two programs: FleetVision and FleetPlot will be displayed. The FleetVision tracks the vehicles. The FleetPlot displays the plots.

B.4.1 FleetPlot

In order to start FleetPlot, the macros should be allowed to run by clicking **Enable Macros**.

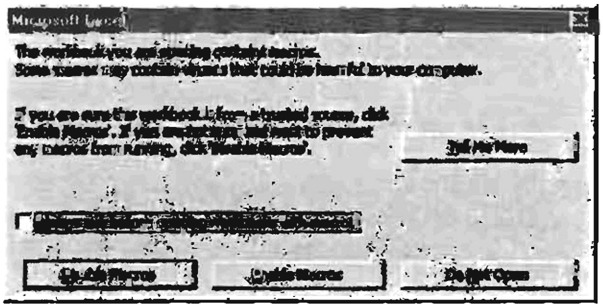


Figure A-11. Excel's Macros Protection Dialog.

B.4.1.1 FleetPlot menu

The charts show the vehicles traveling on I-70 from exit 232 (Winter Park exit) to US 6 off-ramp for a test network. The number of probe vehicles is currently set to 5 vehicles. Additional probe vehicles may be added as needed.

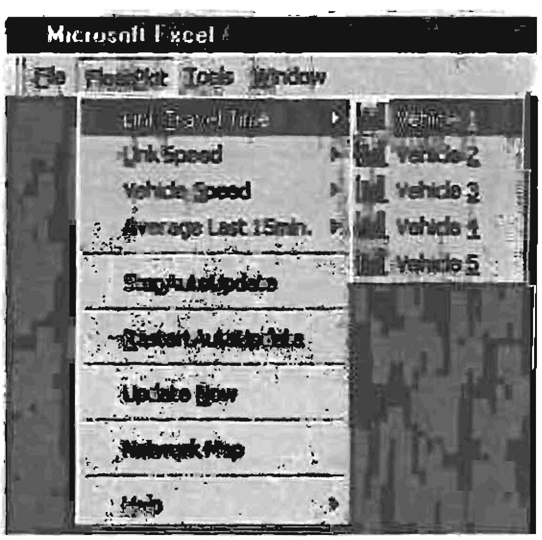


Figure A-12. Fleetplot Menu.

Link Travel Time and Link Speed

Under the FleetPlot menu, this selection allows a user to view the bar charts of link travel time (minutes) and link speed (mile per hour) for probe vehicles 1 to 5. The link travel time and link speed charts show data for the last westbound run. For any link if the data from the last run is not available, the data from previous run will be shown instead. The charts also show the last updated time for each link or the last reported time before the vehicles move across the link to the next link. The link travel time and link speed for each link is represented in different color.

Vehicle speed

Under the FleetPlot menu, this selection allows a user to show a plot of speed of the probe vehicles every 5 seconds. Each color will represent the data for each link. There are currently 10 links on the test network. The charts show the GPS speed data for the last run on WB I-70. The upstream links are on the right of the chart and downstream links are on the left of the chart.

Average Last 15 min.

Under the FleetPlot menu, this selection allows a user to show the average speed and average travel time of the vehicles for each link within a 15-minute analysis period. The number of vehicles on the link within a 15-minute period is also shown on the table below the chart.

StopAutoUpdate

Once the FleePlot starts, the data is automatically updated every 2.5 minutes. This function may be disabled by clicking "StopAutoUpdate".

RestartAutoUpdate

Under the FleetPlot menu, this selection allows a user to enable the auto update function. The data may be automatically updated every 2.5 minutes.

Update Now

Under the FleetPlot menu, this selection allows a user to start update function immediately. The updated plots are displayed after 2.5 minutes. The automatic update function is disabled. To automatically update the charts, click "RestartAutoUpdate".

Network Map

Under the FleetPlot menu, this selection allows a user to show a map of the test network on I-70 from US 40 off-ramp to US 6 off-ramp.

Help

Under the FleetPlot menu, this selection allows a user to show information about the FleetPlot.

APPENDIX B:

MAINTAINING THE PROTOYPE SYSTEM

C.1 FLEETVISION AND FLEETPLOT MAINTENANCE

The Probe Vehicle Tracking module runs FleetVision (Trimble Navigation Limited 1998a) and its database. The Graphical Interface module runs a program FleetPlot. Depending on the frequency of probe data collection, the database may require regular maintenance. The maintenance routine requires the probe data to be exported as text files and saved. The schedule for maintenance depends on the number of probe vehicles in the fleet. The following steps are recommended:

- Click **Fleet** on FleetVision taskbar (Figure B-1).
- Select Database Management and Export or Delete data from the database and then click Continue button in the Configuration Manager dialog box.(Figure B-2).

Figure B-1. FleetVision Taskbar.

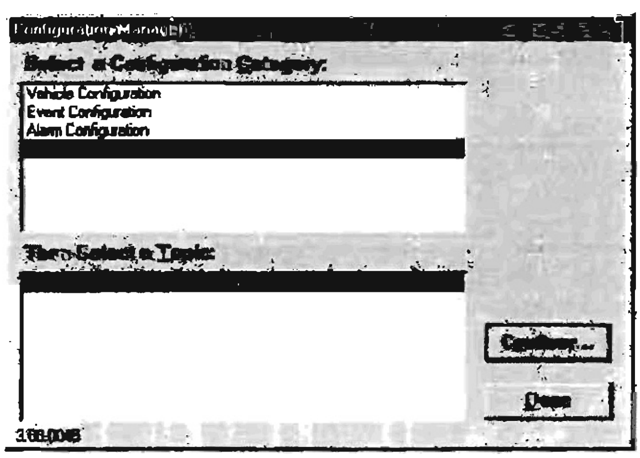


Figure B-2. Configuration Manager Dialog Box.

C.1.1 Export Data

- To export data, click button **(Export Data to Text Files)** in the **Database Administrator** dialog box (Figure B-3).
- Enter the export date for one day of data in the **Export Date** (Figure B-4) and then click **OK**.

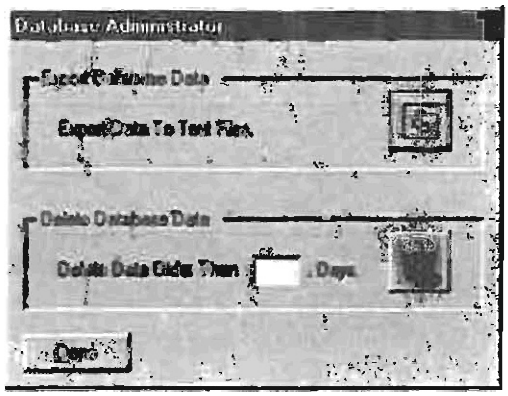


Figure B-3. Database Administrator Dialog Box.

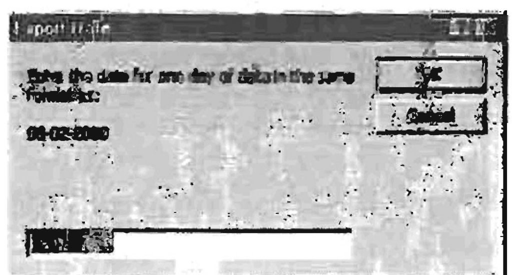


Figure B-4. Export Date Dialog.

C.1.2 Delete Data

- To delete data, on the **Database Administrator** dialog box, enter number of days i.e. enter 0 days to delete all the previous data from database.

- Click button on **Database Administrator dialog box** to delete data.

- When finished, Click **Done** on **Database administrator** dialog box.

C.1.3 Compact AVL Database

- Click **Start**, and then click **Programs**.
- Click **FleetVision**, and then click **Compact AVL database**.

To maintain the database, perform the following on a regular schedule:

- Export data from database to text files.
- Delete data from database.
- Compact AVL database

APPENDIX C:
EXTERNAL PROGRAM

```
!  Last change: T   13 Dec 1999   1:44 pm
C  Last change: T   6 Sep 2000   11:25 am
   PROGRAM LINK TRAVEL TIME
C  This program is used to perform the following tasks:
c    - Extract WB data on the test network
c    - Convert GPS time to local time. Daylight saving has also
c    been taken into account.
c    - Calculate Link travel time, link speed, their average, and instantaneous
c    speed.
   CHARACTER IMOID,IREPTIME,ILAT,ILONG,IALT,ISPEED
  1,INFILE(5)*12, OUTFILE1(5)*9, OUTFILE2(5)*9,OUTFILE3(5)*9
  1,TEMP1(5)*11,TEMP2(5)*11,TEMP3(5)*10
   CHARACTER*25 REALTIME(9999),L1RTIME(9999),L2RTIME(9999)
  1,L3RTIME(9999),L4RTIME(9999),L5RTIME(9999),L6RTIME(9999)
  1,L7RTIME(9999),L8RTIME(9999),L9RTIME(9999),L10RTIME(9999)
  1,Z21,Z22,Z23,Z24,Z25,Z26,Z27,Z28,Z29,Z30
   REAL*8 MOI(20000),REP(20000),LA(20000),LO(20000),ALT(20000)
  1,SPE(20000),rep1(20000)
  1,TMOI(18000),TREP(18000),TLA(18000),TLO(18000),TALT(18000)
  1,TSPE(18000),MOID1(9999),REPTIME1(9999),LAT1(9999)
  1,LONG1(9999),ALTITUDE1(9999),SPEED1(9999),RLONG(11),RLAT(11)
  1,TD(11),PD(11),TTN(11),T(11)
  1,LTT1,LSP1,LTT2,LSP2,LTT3,LSP3,LTT4,LSP4,LTT5,LSP5,LTT6,LSP6
  1,LTT7,LSP7,LTT8,LSP8,LTT9,LSP9,LTT10,LSP10
  1,A,B,X1,Y1,C1 ,P1,P2,P3 ,PP1,PP2,PP3,dlo(20000),dlo1(20000)
  1,DLO2(20000)
  1,L1SPD(10800),L2SPD(10800),L3SPD(10800)
  1,L4SPD(10800),L5SPD(10800),L6SPD(10800)
  1,L7SPD(10800),L8SPD(10800),L9SPD(10800),L10SPD(10800)
  1,DIFTIME,difftime
  1,Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,Z10
  1,Z11,Z12,Z13,Z14,Z15,Z16,Z17,Z18,Z19,Z20
  1,Z31,Z32,Z33,Z34,Z35,Z36,Z37,Z38,Z39,Z40
  1,HDEN(10800) ,HDEN2(10800),HDEN3(10800)
  1,GPSHOUR(10800),GPSTIME(10800),DENH(10800)
  1,RX(11),RY(11),RZ(11),X(10800), Y(10800),Z(10800)
  1,DLAT1(10800),DLONG1(10800),DHEIGHT(10800), TN(10800)
   INTEGER DENYEAR(10800),DENMONTH(10800),DENDATE(10800)
  1,DENHOUR(10800),DENMINUTE(10800),DENSECOND(10800)
  1,MOTH(13),J, NN(10)
c  ------------------------------------------------------------
C  ------------------------------------------------------------
C  PART I EXTRACTING WEST BOUND LAST RUN DATA
C  ------------------------------------------------------------
C  DO LOOP 5 TIMES DUE TO THERE ARE 5 INPUT FILES(5 VEHICLES)
   DO NNNN=1,5
C  FILE 1 = INPUT FILE
C  FILE 10 AND 11 ARE OUTPUT FILES, THE REST ARE TEMP. FILES
   INFILE(1)= "VEHICLE1.CSV"
   INFILE(2)= "VEHICLE2.CSV"
   INFILE(3)= "VEHICLE3.CSV"
   INFILE(4)= "VEHICLE4.CSV"
   INFILE(5)= "VEHICLE5.CSV"
   OUTFILE1(1) = "1INST.CSV"
   OUTFILE1(2) = "2INST.CSV"
   OUTFILE1(3) = "3INST.CSV"
   OUTFILE1(4) = "4INST.CSV"
   OUTFILE1(5) = "5INST.CSV"
   OUTFILE2(1) = "1LINK.CSV"
   OUTFILE2(2) = "2LINK.CSV"
   OUTFILE2(3) = "3LINK.CSV"
   OUTFILE2(4) = "4LINK.CSV"
   OUTFILE2(5) = "5LINK.CSV"
C  OUTFILE3'S ARE THE FILES THAT CONTAIN LINK SPEED, LINK TRAVEL
TIME,AND
C  CLOCK TIME FROM PREVIOUS UPDATE. THE DATA FROM PREVIOUS
UPDATE WILL BE USED IF
C  THE LINKS CONTAIN PARTIAL DATA.(FOR PRESENT RUN, LINK
TRAVEL TIME AND
C  LINK SPEED WILL BE CALCULATED FOR ONLY FULL DATA LINKS.
   OUTFILE3(1) = "P1LNK.txt"
   OUTFILE3(2) = "P2LNK.txt"
   OUTFILE3(3) = "P3LNK.txt"
   OUTFILE3(4) = "P4LNK.txt"
   OUTFILE3(5) = "P5LNK.txt"
   TEMP1(1) = "1WBLAST.CSV"
   TEMP1(2) = "2WBLAST.CSV"
   TEMP1(3) = "3WBLAST.CSV"
   TEMP1(4) = "4WBLAST.CSV"
   TEMP1(5) = "5WBLAST.CSV"
   TEMP2(1) = "1WBALLR.CSV"
   TEMP2(2) = "2WBALLR.CSV"
   TEMP2(3) = "3WBALLR.CSV"
   TEMP2(4) = "4WBALLR.CSV"
   TEMP2(5) = "5WBALLR.CSV"
   TEMP3(1) = "1WBLRT.TXT"
   TEMP3(2) = "2WBLRT.TXT"
   TEMP3(3) = "3WBLRT.TXT"
   TEMP3(4) = "4WBLRT.TXT"
   TEMP3(5) = "5WBLRT.TXT"
   OPEN(1,FILE = INFILE(NNNN))
   OPEN(2,FILE = TEMP1(NNNN))
   OPEN(3,FILE = TEMP2(NNNN))
   OPEN(5,FILE = TEMP3(NNNN))
   OPEN(10,FILE= OUTFILE1(NNNN))
   OPEN(11,FILE= OUTFILE2(NNNN))
   OPEN (12,FILE = OUTFILE3(NNNN))
C  BELOW ARE LONG/LAT OF EACH NODE 1 = US40OFFRAMP,10 =
US6OFFRAMP
   RLONG(1) = -105647973
   RLONG(2) = -105663047
   RLONG(3) = -105696491
   RLONG(4) = -105696940
   RLONG(5) = -105724720
   RLONG(6) = -105727350
   RLONG(7) = -105803200
   RLONG(8) = -105806990
   RLONG(9) = -105855212
   RLONG(10) = -105859695
   RLONG(11) = -105885278
   RLAT(1) = 39761585
   RLAT(2) = 39751714
```

```
      RLAT(3) =39717166
      RLAT(4) =39714134
      RLAT(5) =39695444
      RLAT(6) =39694400
      RLAT(7) =39693106
      RLAT(8) =39692285
      RLAT(9) =39701951
      RLAT(10)=39701809
      RLAT(11)=39685833
C   (X,Y,Z)EARTH CENTERED EARTH-FIXED(ECEF) COORDINATES FOR
NODE 1 TO 11
      RX(1)=-1324786.37064104;RY(1)=-4729559.25316836
      RZ(1)=4059279.00397136
      RX(2)=-1326224.23709527;RY(2)=-4729901.04239826
      RZ(2)=4058449.37683902
      RX(3)=-1329662.11125545;RY(3)=-4731535.96098373
      RZ(3)=4055540.11206678
      RX(4)=-1329756.46763308;RY(4)=-4731729.35424924
      RZ(4)=4055278.15985105
      RX(5)=-1332452.45530786;RY(5)=-4732511.69251608
      RZ(5)=4053811.28702252
      RX(6)=-1332688.85773879;RY(6)=-4732518.60449557
      RZ(6)=4053719.28519985
      RX(7)=-1339019.84667679;RY(7)=-4730987.26987959
      RZ(7)=4053736.98968364
      RX(8)=-1339349.52256452;RY(8)=-4730957.79373987
      RZ(8)=4053669.45909586
      RX(9)=-1343175.84205272;RY(9)=-4729280.35867963
      RZ(9)=4054594.17085953
      RX(10)=-1343550.26335670;RY(10)=-4729193.70795796
      RZ(10)=4054587.01094864
      RX(11)=-1345993.14559220;RY(11)=-4729757.83927683
      RZ(11)=4053285.58720716
C   END OF REFERENCES LONG/LAT
C   RESET ALL THE VALUES TO ZERO
      DO I= 1,9999
      MOI(I)=0;REP(I)=0;LA(I)=0;LO(I)=0;ALT(I)=0;SPE(I)=0
      TMOI(I)=0;TREP(I)=0;TLA(I)=0;TLO(I)=0;TALT(I)=0;TSPE(I)=0
      MOI(I)=0;REP(I)=0;LA(I)=0;LO(I)=0;ALT(I)= 0;SPE(I)=0
      L1SPD(I)=0.0;L2SPD(I)=0.0;L3SPD(I)=0.0;L4SPD(I)=0.0;L5SPD(I)=0.0
      L6SPD(I)=0.0;L7SPD(I)=0.0;L8SPD(I)=0.0;L9SPD(I)=0.0;L10SPD(I)=0.0
      L1RTIME(I)="";L2RTIME(I)="";L3RTIME(I)="";L4RTIME(I)=""
      L5RTIME(I)="";L6RTIME(I)="";L7RTIME(I)="";L8RTIME(I)=""
      L9RTIME(I)="";L10RTIME(I)="" ;MOID1(I)=0.0; reptime1(i)=0
      END DO

      READ(1,*)IMOID,IREPTIME,ILAT,ILONG,IALT,ISPEED
C     PART I.I
C   INPUT DATA WERE FILTERED TO OBTAIN
C   LONG/LAT IN STUDY AREA, AND TO DISTINGUISH WB FROM
C   WB,EB
      M=0
      k=0
      DO I= 1, 20000
      READ(1,*,END=24)MOI(I),REP(I),LA(I),LO(I),ALT(I),SPE(I)
c   Line below will be used if PosFixTime is constant(Vehicle is
c   not moving), the number of seconds equal to report interval will
c   be added to PosFixtime. If report interval change, this need to
c   be changed as well. Currently, set to 5 seconds.
      if (rep(I) .eq. rep(I-1)) then
      rep1(I)=rep1(I-1)+5.0
      else
        rep1(i) = rep(I)
      end if
      rep(I) = rep(I)
      dlo(i) = 0
      dlo1(i) = 0
      IF (LO(I) .LE. RLONG(1) .AND. LO(I) .GE. RLONG(11)) THEN
      IF (LA(I) .LE. RLAT(1) .AND. LA(I) .GE. RLAT(11)) THEN
      Dlo(i) = (LO(I)-LO(I-1))
      dlo1(i) = (LO(I-2)-LO(I-3))
      dlo2(I) = (LO(I-3)-LO(I-4))
c     difftime = rep1(I)-rep1(I-1)
      IF ((dlo(i) .LT.0.0).AND. dlo1(i) .LT.0.0 .AND. DLO2(I) .LT.0)THEN
      WRITE(3,25)MOI(I),REP1(I),LA(I),LO(I),ALT(I),SPE(I)
      M = M+1
   20 END IF
       ENDIF
       END IF
   24 END DO
   25 FORMAT(6(F14.3,","))
C   FILE 3 CONTAINS WB DATA FOR ALL RUN
C   BELOW IS TO OBTAIN I70-WB ONLY LAST TRIP
      NEWRUN = 1
      REWIND (3)
      DO I = 1,M
      READ(3,*,END=27)TMOI(I),TREP(I),TLA(I),TLO(I),TALT(I),TSPE(I)
      TREP(0) = 0
      DIFTIME = TREP(I)-TREP(I-1)
c   diftime below is the time between runs IN ORDER TO GET ONLY LAST RUN
C
      IF (DIFTIME .GT. 1500 .AND. TLO(I) .LE. TLO(I-1)) THEN
      NEWRUN = I
      END IF
      IF (TLO(I) .GE. TLO(I-1)) THEN
      NEWRUN = I
      END IF
      MOID1(I)= TMOI(I)
      REPTIME1(I)= TREP(I)
      LAT1(I)= TLA(I)
      LONG1(I) = TLO(I)
      ALTITUDE1(I)= TALT(I)
      SPEED1(I)= TSPE(I)
   27 ENDDO
      REWIND(3)
C
      N1=0;N2=0;N3=0;N4=0;N5=0;N6=0;N7=0;N8=0;N9=0;N10=0
      NN(1) =0;NN(2)=0;NN(3)=0;NN(4)=0;NN(5)=0;NN(6)=0
      NN(7) = 0;NN(8)=0;NN(9)=0;NN(10)=0
      DO J =NEWRUN,M
c   GROUPING THE DATA TO EACH LINK(WITHIN THE BLOCK)
C   LINK 1 US40 OFF-RAMP AND US40 ON-RAMP
      IF ((LONG1(J)-RLONG(2).GE. 0) .AND.(LONG1(J)-RLONG(1) .LE.0 ))then
      WRITE(2,25)MOID1(J),REPTIME1(J),LAT1(J),LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N1=N1+1
      END IF
C   LINK 2 US40 ON-RAMP AND GEORGETOWN OFF-RAMP
      IF ((LONG1(J) .LE. RLONG(2)) .AND.( LAT1(J) .GE. RLAT(3))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N2=N2+1
      END IF
C   LINK 3 GEORGETOWN OFF-RAMP AND ON-RAMP
```

```
      IF ((LAT1(J) .LE. RLAT(3)) .AND. (LAT1(J) .GE. RLAT(4))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N3=N3+1
      END IF
C   LINK 4 GEORGETOWN ON-RAMP AND SILVER PLUME OFF-RAMP
      IF ((LAT1(J) .LE. RLAT(4)) .AND.(LONG1(J) .GE. RLONG(5))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N4=N4+1
      END IF
C   LINK 5 SILVER PLUME OFF-RAMP AND ON-RAMP
      IF ((LONG1(J) .LE.RLONG(5)) .AND. (LONG1(J) .GE. RLONG(6))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N5=N5+1
      END IF
C   LINK 6 SILVER PLUME ON-RAMP AND BAKERVILLE OFF-RAMP
      IF ((LONG1(J) .LE. RLONG(6)) .AND.( LONG1(J) .GE. RLONG(7))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N6=N6+1
      END IF
C   LINK 7 BAKERVILLE OFF-RAMP AND ON-RAMP
      IF ((LONG1(J) .LE. RLONG(7)) .AND.(LONG1(J) .GE. RLONG(8))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N7=N7+1
      END IF
C   LINK 8 BAKERVILLE ON-RAMP AND HERMAN GLUCH OFF-RAMP
      IF ((LONG1(J) .LE. RLONG(8)) .AND.(LONG1(J) .GE. RLONG(9))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N8=N8+1
      END IF
C   LINK 9 HERMAN GLUCH OFF-RAMP AND ON-RAMP
      IF ((LONG1(J) .LE. RLONG(9)) .AND.(LONG1(J) .GE. RLONG(10))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N9=N9+1
      END IF
C   LINK 10 HERMAN GLUCH ON-RAMP AND US6
      IF ((LONG1(J) .LE. RLONG(10)) .AND.(LONG1(J) .GE. RLONG(11))) THEN
      WRITE(2,25)MOID1(J), REPTIME1(J), LAT1(J), LONG1(J)
     1,ALTITUDE1(J),SPEED1(J)
      N10=N10+1
      END IF
      K = MAX(N1,N2,N3,N4,N5,N6,N7,N8,N9,N10)
      NN(1) = N1
      NN(2) = NN(1)+N2
      NN(3) = NN(2)+N3
      NN(4) = NN(3)+N4
      NN(5) = NN(4)+N5
      NN(6) = NN(5)+N6
      NN(7) = NN(6)+N7
      NN(8) = NN(7)+N8
      NN(9) = NN(8)+N9
      NN(10) = NN(9)+N10
C   NN1 = NUMBER OF POINTS AT END OF LINK 1,NN2=END OF LINK2
      END DO
      REWIND(2)
C   ABOVE==> WB DATA FOR LAST RUN WERE SAVED IN FILE 2
C   ---------------------------------------------------------------
C   PART II CONVERT GPSTIME TO DENVER TIME
C   ---------------------------------------------------------------
      IF (NN(10) .EQ. 0) THEN
       GOTO 200
      END IF
      DO I = 1, NN(10)
      READ(2,*,END=30)MOI(I),REP(I),LA(I),LO(I),ALT(I),SPE(I)
      ENDDO
C # OF SECONDS TO 01/01/97 12:00:00AM+7HRS.=536137200 SEC OR
148927HRS.
c   Day light saving: between 1st sunday of April and last sunday of October
c   add another 1 hour.
 30   DO I = 1, NN(10)
      GPSTIME(I) = REP(I)
      GPSHOUR(I) =GPSTIME(I)/3600-148927
      N = 0
      MN =0
      M = 0
      DO II = 8760,999999,8760
      N = N+1
      DENH(I) = II
      DO III = 0,9999,4
      IF (N .EQ. III) THEN
      DENH(I) = II+24
      END IF
      END DO
      IF (DENH(I).LT. GPSHOUR(I)) THEN
      MN = MN+1
      ELSE
        GOTO 32
      END IF
         HDEN(I) = DENH(I)
      END DO
 32   DENYEAR(I) = 1997+MN
      HDEN2(I) = GPSHOUR(I)-HDEN(I)
C   DENYEAR DEFINES YEAR
C   HDEN2 = # OF HOURS(MAX. = # OF OUR IN THAT YEAR)
      DO IK = 3,MN,4
      IF (IK .EQ. MN) THEN
      M = 1
      ELSE
       M =0
      END IF
      END DO
C   IF M = 1 INDICATES LEAP YEAR(366 DAYS A YEAR)
      IF (M .EQ. 0) THEN
      MOTH(0) = 0.0
      MOTH(1) = 744.0
      MOTH(2) = 1416.0
      MOTH(3) = 2160.0
      MOTH(4) = 2880.0
      MOTH(5) = 3624.0
      MOTH(6) = 4344.0
      MOTH(7) = 5088.0
      MOTH(8) = 5832.0
      MOTH(9) = 6552.0
      MOTH(10) = 7296.0
      MOTH(11) = 8016.0
      MOTH(12) = 8760.0
      ENDIF
      IF (M .EQ. 1) THEN
```

```
      MOTH(0) = 0.0
      MOTH(1) = 744.0
      MOTH(2) = 1440.0
      MOTH(3) = 2184.0
      MOTH(4) = 2904.0
      MOTH(5) = 3648.0
      MOTH(6) = 4368.0
      MOTH(7) = 5112.0
      MOTH(8) = 5856.0
      MOTH(9) = 6576.0
      MOTH(10) = 7320.0
      MOTH(11) = 8040.0
      MOTH(12) = 8784.0
      END IF
      DO L = 1,12
      DENMONTH(I)=L
      IF (HDEN2(I) .LT. MOTH(L)) THEN
      GOTO 34
      END IF
      END DO
C     HDEN3 = # OF HOURS IN THAT MONTH(MAX = #OF DAY IN THAT
MONTH*24)
 34   N = DENMONTH(I)-1
      HDEN3(I) = HDEN2(I)-MOTH(N)
      DENDATE(I) = INT(HDEN3(I)/24)+1
      DENHOUR(I) = INT(HDEN3(I)+24-DENDATE(I)*24)
      DENMINUTE(I) =INT((HDEN3(I)-DENDATE(I)*24+24)-DENHOUR(I))*60)
      DENSECOND(I)=NINT((((HDEN3(I)-DENDATE(I)*24+24)-DENHOUR(I))*60
     *-DENMINUTE(I))*60)
c     Add 1 hour due to daylight saving
      if (denmonth(i) .ge. 4 .and. denmonth(i) .le. 10) then
      denhour(i) = denhour(i)+1
      end if
      if (denyear(i) .eq. 2000) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 2) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 29) then
          denhour(i) = denhour(i)-1
        end if
      end if
c
          if (denyear(i) .eq. 2001) then
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 28) then
          denhour(i) = denhour(i)-1
        end if
      end if
c
          if (denyear(i) .eq. 2002) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 7) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 27) then
          denhour(i) = denhour(i)-1
        end if
      end if
.
          if (denyear(i) .eq. 2003) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt.6) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 26) then
          denhour(i) = denhour(i)-1
        end if
      end if
c
          if (denyear(i) .eq. 2004) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 4) then
          denhour(i) = denhour(i)-1
        end if
      end if
.
          if (denyear(i) .eq. 2005) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 3) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt.30) then
          denhour(i) = denhour(i)-1
        end if
      end if
c
          if (denyear(i) .eq. 2006) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 2) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 29) then
          denhour(i) = denhour(i)-1
        end if
      end if
c
          if (denyear(i) .eq. 2007) then
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 28) then
          denhour(i) = denhour(i)-1
        end if
      end if
C
          if (denyear(i) .eq. 2008) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 6) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 26) then
          denhour(i) = denhour(i)-1
        end if
      end if
C
          if (denyear(i) .eq. 2009) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt. 5) then
          denhour(i) = denhour(i)-1
        end if
        if (denmonth(i) .eq. 10 .and. dendate(i) .gt. 25) then
          denhour(i) = denhour(i)-1
        end if
      end if
C
          if (denyear(i) .eq. 2010) then
        if (denmonth(i) .eq. 4 .and. dendate(i) .lt.4) then
          denhour(i) = denhour(i)-1
        end if
      end if
C
      denhour(i) = denhour(i)
      IF (DENMONTH(I) .LT. 10) THEN
      WRITE(5,35)MOI(I),REP(I),LA(I),LO(I),ALT(I),SPE(I),DENMONTH(I)
     1,DENDATE(I),DENYEAR(I),DENHOUR(I),DENMINUTE(I),DENSECOND(I)
```

```
 35 FORMAT(T1,F5.0,T10,F14.3,T25,F14.3,T41,F14.3,T56,F10.2,T70,F10.3
   1,T81,I1,"/",T83,I2,"/",T86,I4,T91,I2,":",T94,I2,":",T97,I2 )
   ENDIF
   IF (DENMONTH(I) .GE. 10) THEN
   WRITE(5,36)MOI(I),REP(I),LA(I),LO(I),ALT(I),SPE(I),DENMONTH(I)
   1,DENDATE(I),DENYEAR(I),DENHOUR(I)
   1,DENMINUTE(I),DENSECOND(I)
 36 FORMAT(T1,F5.0,T10,F14.3,T25,F14.3,T41,F14.3,T56,F10.2,T70,F10.3
   1,T81,I2,"/",T84,I2,"/",T87,I4,T92,I2,":",T95,I2,":",T98,I2 )
   END IF
   ENDDO
C   END OF TIME CONVERTING;WB LASTRUN DATA WITH DENVER TIME
WERE SEVED IN FILE 5
c  ================================================================
C   PART III    COMPUTE LINK TRAVEL TIME AND LINK SPEED
c  ================================================================
C   NODE 1 =US40 AND NODE 11= US6
   REWIND (5)
   DO I= 1,NN(10)
   READ (5,49,END=50)MOID1(I),REPTIME1(I),LAT1(I),LONG1(I)
   1,ALTITUDE1(I),SPEED1(I),REALTIME(I)
 49 FORMAT(T1,F5.0,T10,F14.3,T25,F14.3,T41,F14.3,T56,F10.2,T70,F10.3
   1,T81,A25)
   ENDDO
C   CONVERTING LONG, LAT TO X,Y,Z(METERS)
   DO I= 1,NN(10)
   DLAT1(I)= LAT1(I)*3.141592654/180/1000000
   DLONG1(I)= LONG1(I)*3.141592654/180/1000000
   DHEIGHT(I) = ALTITUDE1(I)/100.0
   TN(I) = 6378137.0/(SQRT((1-0.0818**2*SIN(DLAT1(I))**2)))
   X(I) = (TN(I) +DHEIGHT(I) )*COS(DLAT1(I))*COS(DLONG1(I))
   Y(I) = (TN(I) +DHEIGHT(I))*COS(DLAT1(I))*SIN(DLONG1(I))
   Z(I) = (TN(I) *(1-0.0818**2)+DHEIGHT(I) )*SIN(DLAT1(I))
   END DO
c   CONVERTING INSTANTANEOUS SPEED FROM CM/S TO MPH
   IF (NN(1) .NE. 0) THEN
 50 DO I = 1,NN(1)
   L1SPD(I) = SPEED1(I)*3600/160934.4
   L1RTIME(I) = REALTIME(I)
   END DO
   END IF
   IF (NN(2) .NE. 0) THEN
   DO I = NN(1)+1, NN(2)
     L2SPD(I) = SPEED1(I)*3600/160934.4
     L2RTIME(I) = REALTIME(I)
   END DO
   END IF
   IF (NN(3) .NE. 0) THEN
   DO I = NN(2)+1,NN(3)
     L3SPD(I) = SPEED1(I)*3600/160934.4
     L3RTIME(I) = REALTIME(I)
   END DO
   END IF
   IF (NN(4) .NE. 0) THEN
   DO I = NN(3)+1,NN(4)
     L4SPD(I) = SPEED1(I)*3600/160934.4
     L4RTIME(I) = REALTIME(I)
   END DO
   END IF
     IF (NN(5) .NE. 0) THEN
   DO I = NN(4)+1,NN(5)
     L5SPD(I) = SPEED1(I)*3600/160934.4
     L5RTIME(I) = REALTIME(I)
   END DO
   END IF
     IF (NN(6) .NE. 0) THEN
   DO I = NN(5)+1,NN(6)
     L6SPD(I) = SPEED1(I)*3600/160934.4
     L6RTIME(I) = REALTIME(I)
   END DO
     END IF
     IF (NN(7) .NE. 0) THEN
   DO I = NN(6)+1, NN(7)
     L7SPD(I) = SPEED1(I)*3600/160934.4
     L7RTIME(I) = REALTIME(I)
   END DO
     END IF
     IF (NN(8) .NE. 0) THEN
   DO I = NN(7)+1, NN(8)
     L8SPD(I) = SPEED1(I)*3600/160934.4
     L8RTIME(I) = REALTIME(I)
   END DO
     END IF
     IF (NN(9) .NE. 0) THEN
   DO I = NN(8)+1, NN(9)
     L9SPD(I) = SPEED1(I)*3600/160934.4
     L9RTIME(I) = REALTIME(I)
   END DO
     END IF
     IF (NN(10) .NE. 0) THEN
   DO I = NN(9)+1, NN(10)
     L10SPD(I) = SPEED1(I)*3600/160934.4
     L10RTIME(I) = REALTIME(I)
   END DO
     END IF
C   OUTPUT INSTANTANEOUS SPEED FOR EACH LINK
   WRITE(10,51)"MOID","NO.1","LINK1TIME","US40(OFF)-US40(ON)"
   1,"NO.2","LINK2TIME","US40(ON)-GEORGE TOWN(OFF)"
   1,"NO.3","LINK3TIME","GEORGE TOWN(OFF)-GEROGE TOWN(ON)"
   1,"NO.4","LINK4TIME","GEORGE TOWN(ON)-SILVER PLUME(OFF)"
   1,"NO.5","LINK5TIME","SILVER PLUME(OFF)-SILVER PLUME(ON)"
   1,"NO.6","LINK6TIME","SILVER PLUME(ON)-BAKERVILLE(OFF)"
   1,"NO.7","LINK7TIME","BAKERVILLE(OFF)-BAKERVILLE(ON)"
   1,"NO.8","LINK8TIME","BAKERVILLE(ON)-HERMAN GLUCH(OFF)"
   1,"NO.9","LINK9TIME","HERMAN GLUCH(OFF)-HERMAN GLUCH(ON)"
   1,"NO.10","LINK10TIME","HERMAN GLUCH(ON)-US6(OFF)"
   1,"US40(OFF-RAMP)"
 51 FORMAT( 31(A,","),A)
   DO I= 1,K
   I1 = NN(1)+I
   I2 = NN(2)+I
   I3 = NN(3)+I
   I4 = NN(4)+I
   I5 = NN(5)+I
   I6 = NN(6)+I
   I7 = NN(7)+I
   I8 = NN(8)+I
   I9 = NN(9)+I
   I10 = NN(10)+I
   WRITE(10,52)MOID1(I),I,L1RTIME(I),L1SPD(I)
   1,I1,L2RTIME(I1),L2SPD(I1)
   1,I2,L3RTIME(I2),L3SPD(I2)
   1,I3,L4RTIME(I3),L4SPD(I3)
   1,I4,L5RTIME(I4),L5SPD(I4)
```

```
   1,I5,L6RTIME(I5),L6SPD(I5)
   1,I6,L7RTIME(I6),L7SPD(I6)
   1,I7,L8RTIME(I7),L8SPD(I7)
   1,I8,L9RTIME(I8),L9SPD(I8)
   1,I9,L10RTIME(I9),L10SPD(I9)
 52 FORMAT(F14.3,10(',',I10,',',A,"AMPM",',',F14.3))
   END DO
C  CALCULATE TIME FOR EACH NODE BY INTERPOLATION
C  TD2 = TOTAL DISTANCE BET.GPS LOCATION BEFORE AND AFTER
NODE==>NODE2
C  PD2 = DISTANCE BET. GPS BEFORE NODE2 AND NODE2
C  TTN2 = TIME BETWEEN GPS BEFORE NODE2 AND NODE2
   P1=0
   P2=0
   P3=0
C  NODE 1 AND NODE 11 ARE CALCULATED BY EXTRAPOLATION
   TD(1)= SQRT((X(2)-X(1))**2+(Y(2)-Y(1))**2+(Z(2)-Z(1))**2)
   A = (X(NN(10))-X(NN(10)-1))**2
   B = (Y(NN(10))-Y(NN(10)-1))**2
   C = (Z(NN(10))-Z(NN(10)-1))**2
   TD(11)=SQRT(A+B+C)
   IF (LONG1(NN(10)) .EQ. 0) THEN
   TD(11) = 0
   END IF
C  PD1 = DISTANCE FROM NODE 1(US40OFFRAMP) TO FIRST POINT
C  TD1 = DISTANCE BETWENN 1ST AND 2ND POINTS OF GPS DATA
   PD(1)=SQRT((RX(1)-X(1))**2+(RY(1)-Y(1))**2+(RZ(1)-Z(1))**2)
   PP1 =(RX(11)-X(NN(10)))**2
   PP2 =(RY(11)-Y(NN(10)))**2
   PP3 = (RZ(11)-Z(NN(10)))**2
   PD(11)=SQRT(PP1+PP2+PP3)
   IF(LONG1(NN(10)) .EQ. 0) THEN
   PD(11) = 0
   ENDIF
   TTN(1)=(REPTIME1(2)-REPTIME1(1))*PD(1)/TD(1)
   TTN(11) = (REPTIME1(NN(10))-REPTIME1(NN(10)-1))*PD(11)/TD(11)
   IF (TD(11) .EQ. 0) THEN
   TTN(11)=0
   END IF
C  END EXTRAPOLATION OF NODES 1 AND 11
   DO I = 1,9
   IF (NN(I+1) .NE. NN(I)) THEN
C ***  IF THAT LINK CONTAINS FULL DATA ==> LINK TT AND LINK SPEED
WILL BE CALCULATED
   X1 = (X(NN(I)+1)-X(NN(I)))**2
   Y1 = (Y(NN(I)+1)-Y(NN(I)))**2
   c1 = (Z(NN(I)+1)-Z(NN(I)))**2
   TD(I+1)=SQRT(X1+Y1+c1)
   P1 = (RX(I+1)-X(NN(I)))**2
   P2 = (RY(I+1)-Y(NN(I)))**2
   P3 = (RZ(I+1)-Z(NN(I)))**2
   PD(I+1)=SQRT(P1+P2+P3)
   IF (LONG1(NN(I)) .EQ. 0 .OR. LAT1(NN(I)) .EQ. 0) THEN
   PD(I+1) = 0
   END IF
   TTN(I+1) = (REPTIME1(NN(I)+1)-REPTIME1(NN(I)))*PD(I+1)/TD(I+1)
   IF (PD(I+1) .EQ. 0 .OR. TD(I+1) .EQ. 0) THEN
   TTN(I+1)=0
   END IF
   END IF
c
   ENDDO
   READ (12,57)Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,Z10
   READ (12,57)Z11,Z12,Z13,Z14,Z15,Z16,Z17,Z18,Z19,Z20
   READ (12,58)Z21,Z22,Z23,Z24,Z25,Z26,Z27,Z28,Z29,Z30
   READ (12,59)Z31,Z32,Z33,Z34,Z35,Z36,Z37,Z38,Z39,Z40
 57 FORMAT (10(F7.3))
 58 FORMAT (10(A19))
 59 FORMAT (10(F14.3))
   REWIND(12)
   CLOSE(12)
C=====END INTERPOLATION ==LINK CONTAINS PARTIAL DATA -LINKTT
AND LINK SPEED
C=====WILL BE SET TO ZERO
   DO J = 2,11
    T(J) = REPTIME1(NN(J-1))+TTN(J)
   END DO
   IF (PD(1) .GE. 1000) THEN
    T(1) = 0
   ELSE
    T(1) = REPTIME1(1)-TTN(1)
   END IF
C  IF THERE IS NO DATA ON THAT LINK T(N) = T(N-1), LTT AND LSP = 0
C  LTT = LINK TRAVELE TIME(MINUTES), LSP=LINK SPEED(MPH)
   IF (NN(1) .NE. 0) THEN
   IF (NN(1) .NE.0 .AND. NN(2) .GT. NN(1))THEN
   if (ttn(1) .ne. 0 .and. ttn(2) .ne. 0) then
   IF (T(1) .NE. 0) THEN
   LTT1= (T(2)-T(1))/60
   LSP1=(5843.428/5280)/LTT1*60
   END IF
   END if
   ELSE
   LTT1 = Z1
   LSP1 = Z11
   L1RTIME(NN(1)) = Z21
   REPTIME1(NN(1)) = Z31
   ENDIF
   END IF
C
   IF (NN(2) .NE. 0) THEN
   IF (NN(2) .GT. NN(1).AND. NN(3) .GT. NN(2)) THEN
     if (ttn(2) .ne. 0 .and. ttn(3) .ne. 0) then
   LTT2= (T(3)-T(2))/60
   LSP2=(16725.59/5280)/LTT2*60
   END if
   ELSE
   LTT2=Z2
   LSP2=Z12
   L2RTIME(NN(2)) = Z22
   REPTIME1(NN(2)) = Z32
   ENDIF
   END IF
C
   IF (NN(3) .NE. 0) THEN
   IF (NN(3) .GT.NN(2) .AND. NN(4) .GT. NN(3)) THEN
    if (ttn(3) .ne. 0 .and. ttn(4) .ne. 0) then
    LTT3= (T(4)-T(3))/60
    LSP3=(1139.125/5280)/LTT3*60
    END if
   ELSE
   LTT3=Z3
   LSP3=Z13
   L3RTIME(NN(3)) =Z23
```

```
      REPTIME1(NN(3)) = Z33
      END IF
       END IF
C
       IF (NN(4) .NE. 0) THEN
      IF (NN(4) .GT. NN(3) .AND. NN(5) .GT. NN(4)) THEN
         if (ttn(4) .ne. 0 .and. ttn(5) .ne. 0) then
           LTT4= (T(5)-T(4))/60
           LSP4=(11158.396/5280)/LTT4*60
        END if
        ELSE
        LTT4 = Z4
        LSP4= Z14
        L4RTIME(NN(4)) = Z24
      REPTIME1(NN(4)) = Z34
      END IF
       END IF
C
       IF (NN(5) .NE. 0) THEN
      IF (NN(5) .GT. NN(4) .AND. NN(6) .GT. NN(5)) THEN
         if (ttn(5) .ne. 0 .and. ttn(6) .ne. 0) then
           LTT5= (T(6)-T(5))/60
           LSP5=(838.457/5280)/LTT5*60
        END if
        ELSE
        LTT5 =Z5
        LSP5=Z15
        L5RTIME(NN(5)) = Z25
      REPTIME1(NN(5)) = Z35
      END IF
       END IF
C
       IF (NN(6) .NE. 0) THEN
      IF (NN(6) .GT. NN(5) .AND. NN(7) .GT. NN(6)) THEN
         if (ttn(6) .ne. 0 .and. ttn(7) .ne. 0) then
           LTT6= (T(7)-T(6))/60
           LSP6=(21776.219/5280)/LTT6*60
         END if
        ELSE
        LTT6 =Z6
        LSP6 =Z16
        L6RTIME(NN(6)) = Z26
      REPTIME1(NN(6)) = Z36
      END IF
       END IF
C
       IF (NN(7) .NE. 0) THEN
      IF (NN(7) .GT. NN(6) .AND. NN(8) .GT. NN(7)) THEN
         if (ttn(7) .ne. 0 .and. ttn(8) .ne. 0) then
           LTT7= (T(8)-T(7))/60
           LSP7=(1134.646/5280)/LTT7*60
        END if
        ELSE
        LTT7=Z7
        LSP7=Z17
        L7RTIME(NN(7)) = Z27
      REPTIME1(NN(7)) = Z37
      END IF
       END IF
C
       IF (NN(8) .NE. 0) THEN
      IF (NN(8) .GT. NN(7) .AND. NN(9) .GT. NN(8)) THEN
         if (ttn(8) .ne. 0 .and. ttn(9) .ne. 0) then
           LTT8= (T(9)-T(8))/60
           LSP8=(14421.616/5280)/LTT8*60
         END if
         ELSE
           LTT8 =Z8
           LSP8=Z18
           L8RTIME(NN(8)) = Z28
      REPTIME1(NN(8)) = Z38
      END IF
       END IF
C
       IF (NN(9) .NE. 0) THEN
      IF (NN(9) .GT. NN(8) .AND. NN(10) .GT. NN(9)) THEN
         if (ttn(9) .ne. 0 .and. ttn(10) .ne. 0) then
           LTT9= (T(10)-T(9))/60
           LSP9=(1267.546/5280)/LTT9*60
         END if
         ELSE
      LTT9 =Z9
      LSP9=Z19
      L9RTIME(NN(9))= Z29
      REPTIME1(NN(8)) = Z39
      END IF
       END IF
C
       IF (NN(10) .NE. 0) THEN
      IF (NN(10) .GT. NN(9) .AND. NN(9) .GT. NN(8)) THEN
         if (ttn(10) .ne. 0 .and. ttn(11) .ne. 0) then
           LTT10=(T(11)-T(10))/60
           LSP10=(9156.001/5280)/LTT10*60
         END if
         ELSE
      LTT10=Z10
      LSP10=Z20
      L10RTIME(NN(10)) =Z30
      REPTIME1(NN(10)) = Z40
      END IF
       END IF
c     IF LINK TRAVEL TIME FROM PREVIOUS RUN EQUALS TO ZERO THEN
C     SET IT EQUAL TO DATA FROM PREVIOUS RUN.
      IF (LTT1 .EQ. 0 .AND. NN(1) .NE. 0) THEN
      LTT1 =Z1
      LSP1= Z11
      L1RTIME(NN(1)) = Z21
      END IF
      IF (LTT2 .EQ. 0 .AND. NN(1) .NE. 0) THEN
      LTT2 = Z2
      LSP2=Z12
      L2RTIME(NN(2)) = Z22
      END IF
      IF(LTT3 .EQ. 0 .AND. NN(1) .NE. 0) THEN
      LTT3=Z3
      LSP3=Z13
      L3RTIME(NN(3)) =Z23
      END IF
      IF (LTT4 .EQ. 0 .AND. NN(1) .NE. 0) THEN
      LTT4 = Z4
      LSP4= Z14
      L4RTIME(NN(4)) = Z24
      END IF
      IF (LTT5 .EQ. 0 .AND. NN(1) .NE. 0) THEN
```

```
      LTT5 =Z5
      LSP5=Z 15
      L5RTIME(NN(5)) = Z25
      END IF
      IF (LTT6 .EQ. 0 .AND. NN(1) .NE. 0) THEN
      LTT6 =Z6
      LSP6 =Z16
      L6RTIME(NN(6))  = Z26
      END IF
      IF (LTT7 .EQ. 0 .AND. NN(1) .NE. 0) THEN
      LTT7=Z7
      LSP7=Z17
      L7RTIME(NN(7)) = Z27
      END IF
      IF (LTT8 .EQ. 0 .AND. NN(1) .NE. 0) THEN
         LTT8 =Z8
         LSP8=Z18
         L8RTIME(NN(8))  =Z28
      END IF
      IF (LTT9 .EQ. 0 .AND. NN(1) .NE. 0) THEN
         LTT9 =Z9
         LSP9=Z19
         L9RTIME(NN(9))= Z29
      END IF
      IF (LTT10 .EQ. 0 .AND. NN(1) .NE. 0) THEN
                          LTT10=Z10
         LSP10=Z20
         L10RTIME(NN(10)) =Z30
      END IF
C    *******OUTPUT*******
C    NODE 1 = US40OFF ,NODE 11 = US6OFF
  60 FORMAT(11(F15.3,","))
  70 FORMAT (10(",",F15.3))
      WRITE(11,80)"TIME US40-US6","US40(OFF)-US40(ON)"
     1,"US40(ON)-GRG TWN(OFF)"
     1,"GRG TWN(OFF)-GRG TWN(ON)"
     1,"GRGE TWN(ON)-SLVR PLM(OFF)"
     1,"SLVR PLM(OFF)-SLVR PLM(ON)"
     1,"SLVR PLM(ON)-BKRVLL(OFF)"
     1,"BKRVLL(OFF)-BKRVLL(ON)"
     1,"BKRVLL(ON)-HRMN GLCH(OFF)"
     1,"HRMN GLCH(OFF)-HRMN GLCH(ON)"
     1,"HRMN GLCH(ON)-US6(OFF)"
  80 FORMAT(A, 10(",",A))
  90 FORMAT (9(A25,"AMPM",","),A25,"AMPM")
      DO I = 1,10
      IF (NN(I) .EQ. 0) THEN
        NN(I) =I
        L1RTIME(I) = '0/0/0000 00:00:00'
        L2RTIME(I) = '0/0/0000 00:00:00'
         L3RTIME(I) = '0/0/0000 00:00:00'
         L4RTIME(I) = '0/0/0000 00:00:00'
         L5RTIME(I) = '0/0/0000 00:00:00'
         L6RTIME(I) = '0/0/0000 00:00:00'
         L7RTIME(I) = '0/0/0000 00:00:00'
          L8RTIME(I) = '0/0/0000 00:00:00'
           L9RTIME(I) = '0/0/0000 00:00:00'
            L10RTIME(I) = '0/0/0000 00:00:00'
        REPTIME1(I) =0
      END IF
      END DO
      WRITE(11,70)LTT1,LTT2,LTT3,LTT4,LTT5,LTT6,LTT7,LTT8,LTT9,LTT10
      WRITE(11,70)LSP1,LSP2,LSP3,LSP4,LSP5,LSP6,LSP7,LSP8,LSP9,LSP10
      WRITE(11,'(A,"AMPM")')L1RTIME(NN(1))
      WRITE(11,'(A,"AMPM")')L2RTIME(NN(2))
      WRITE(11,'(A,"AMPM")')L3RTIME(NN(3))
      WRITE(11,'(A,"AMPM")')L4RTIME(NN(4))
      WRITE(11,'(A,"AMPM")')L5RTIME(NN(5))
      WRITE(11,'(A,"AMPM")')L6RTIME(NN(6))
      WRITE(11,'(A,"AMPM")')L7RTIME(NN(7))
      WRITE(11,'(A,"AMPM")')L8RTIME(NN(8))
      WRITE(11,'(A,"AMPM")')L9RTIME(NN(9))
      WRITE(11,'(A,"AMPM")')L10RTIME(NN(10))
      open (12, file = outfile3(nnnn))
      WRITE(12,57)LTT1,LTT2,LTT3,LTT4,LTT5,LTT6,LTT7,LTT8,LTT9,LTT10
      WRITE(12,57)LSP1,LSP2,LSP3,LSP4,LSP5,LSP6,LSP7,LSP8,LSP9,LSP10
      WRITE(12,58)L1RTIME(NN(1)) ,L2RTIME(NN(2))
     1,L3RTIME(NN(3)) ,L4RTIME(NN(4)) ,L5RTIME(NN(5))
     1,L6RTIME(NN(6)) ,L7RTIME(NN(7)) ,L8RTIME(NN(8))
     1,L9RTIME(NN(9)) ,L10RTIME(NN(10))
      WRITE(12,59)REPTIME1(NN(1)) ,REPTIME1(NN(2))
     1,REPTIME1(NN(3)) ,REPTIME1(NN(4)) ,REPTIME1(NN(5))
     1,REPTIME1(NN(6)) ,REPTIME1(NN(7)) ,REPTIME1(NN(8))
     1,REPTIME1(NN(9)) ,REPTIME1(NN(10))
  95  FORMAT (9(F7.3,","),F7.3)
  96  FORMAT (9(A19,","),A19)
  97  FORMAT (9(F14.3,","),F14.3)
 100 FORMAT(9(A18),A18)
      CLOSE(2,STATUS ='delete' )
      CLOSE(3,STATUS = 'delete' )
      CLOSE(5,STATUS = 'delete' )
      REWIND(1)
      REWIND(10)
      REWIND(11)
      REWIND(12)
      CLOSE(1)
      CLOSE(10)
      CLOSE(11)
      close(12)
c     close (15)
 200  end do
      CALL SMS()
C    ABOVE END DO IS FOR THE LOOP TO READ 5 INPUTFILES VEHICLE1-
5.CSV
      END PROGRAM
c    SUBROUTINE SMS BELOW IS TO CALCULATE SPACE MEAN SPEED IN
CASE MORE THAN 1 VEHICLE EXIST
C    ON THAT LINK WITHIN 15 MINUTES.
      SUBROUTINE SMS()
      DOUBLE PRECISION TIME(5,10),SPD(5,10),GTIME(5,10),DD(10)
     1,ATTIME(10),ASPEED(10),LASTRUN(10),TTIME(10),N(10),tspd(10)
      CHARACTER RTIME(5,10)*19, TRTIME(10)*19
      OPEN (20, FILE = "PILNK.txt")
      READ (20, 110)TIME(1,1),TIME(1,2),TIME(1,3),TIME(1,4)
     1,TIME(1,5),TIME(1,6),TIME(1,7),TIME(1,8),TIME(1,9)
     1,TIME(1,10)
      READ (20,110)SPD(1,1),SPD(1,2),SPD(1,3),SPD(1,4),SPD(1,5)
     1,SPD(1,6),SPD(1,7),SPD(1,8),SPD(1,9),SPD(1,10)
      READ (20,120)RTIME(1,1),RTIME(1,2),RTIME(1,3),RTIME(1,4)
     1,RTIME(1,5),RTIME(1,6),RTIME(1,7),RTIME(1,8),RTIME(1,9)
     1,RTIME(1,10)
      READ (20,130)GTIME(1,1),GTIME(1,2),GTIME(1,3),GTIME(1,4)
     1,GTIME(1,5),GTIME(1,6),GTIME(1,7),GTIME(1,8),GTIME(1,9)
     1,GTIME(1,10)
```

```
C
  OPEN (21, FILE = "P2LNK.txt")
  READ (21,110)TIME(2,1),TIME(2,2),TIME(2,3),TIME(2,4)
  1,TIME(2,5),TIME(2,6),TIME(2,7),TIME(2,8),TIME(2,9)
  1, TIME(2,10)
  READ (21,110)SPD(2,1),SPD(2,2),SPD(2,3),SPD(2,4),SPD(2,5)
  1,SPD(2,6),SPD(2,7),SPD(2,8),SPD(2,9),SPD(2,10)
  READ (21,120)RTIME(2,1),RTIME(2,2),RTIME(2,3),RTIME(2,4)
  1,RTIME(2,5),RTIME(2,6),RTIME(2,7),RTIME(2,8),RTIME(2,9)
  1,RTIME(2,10)
  READ (21,130)GTIME(2,1),GTIME(2,2),GTIME(2,3),GTIME(2,4)
  1,GTIME(2,5),GTIME(2,6),GTIME(2,7),GTIME(2,8),GTIME(2,9)
  1,GTIME(1,10)
C
  OPEN (22, FILE = "P3LNK.txt")
  READ (22,110)TIME(3,1),TIME(3,2),TIME(3,3),TIME(3,4)
  1,TIME(3,5),TIME(3,6),TIME(3,7),TIME(3,8),TIME(3,9)
  1, TIME(3,10)
  READ (22,110)SPD(3,1),SPD(3,2),SPD(3,3),SPD(3,4),SPD(3,5)
  1,SPD(3,6),SPD(3,7),SPD(3,8),SPD(3,9),SPD(3,10)
  READ (22,120)RTIME(3,1),RTIME(3,2),RTIME(3,3),RTIME(3,4)
  1,RTIME(3,5),RTIME(3,6),RTIME(3,7),RTIME(3,8),RTIME(3,9)
  1,RTIME(3,10)
  READ (22,130)GTIME(3,1),GTIME(3,2),GTIME(3,3),GTIME(3,4)
  1,GTIME(3,5),GTIME(3,6),GTIME(3,7),GTIME(3,8),GTIME(3,9)
  1,GTIME(3,10)
C
  OPEN (23, FILE = "P4LNK.txt")
  READ (23,110)TIME(4,1),TIME(4,2),TIME(4,3),TIME(4,4)
  1,TIME(4,5),TIME(4,6),TIME(4,7),TIME(4,8),TIME(4,9)
  1, TIME(4,10)
  READ (23,110)SPD(4,1),SPD(4,2),SPD(4,3),SPD(4,4),SPD(4,5)
  1,SPD(4,6),SPD(4,7),SPD(4,8),SPD(4,9),SPD(4,10)
  READ (23,120)RTIME(4,1),RTIME(4,2),RTIME(4,3),RTIME(4,4)
  1,RTIME(4,5),RTIME(4,6),RTIME(4,7),RTIME(4,8),RTIME(4,9)
  1,RTIME(4,10)
  READ (23,130)GTIME(4,1),GTIME(4,2),GTIME(4,3),GTIME(4,4)
  1,GTIME(4,5),GTIME(4,6),GTIME(4,7),GTIME(4,8),GTIME(4,9)
  1,GTIME(4,10)
C
  OPEN (24, FILE = "P5LNK.txt")
  READ (24,110)TIME(5,1),TIME(5,2),TIME(5,3),TIME(5,4)
  1,TIME(5,5),TIME(5,6),TIME(5,7),TIME(5,8),TIME(5,9)
  1, TIME(5,10)
  READ (24,110)SPD(5,1),SPD(5,2),SPD(5,3),SPD(5,4),SPD(5,5)
  1,SPD(5,6),SPD(5,7),SPD(5,8),SPD(5,9),SPD(5,10)
  READ (24,120)RTIME(5,1),RTIME(5,2),RTIME(5,3),RTIME(5,4)
  1,RTIME(5,5),RTIME(5,6),RTIME(5,7),RTIME(5,8),RTIME(5,9)
  1,RTIME(5,10)
  READ (24,130)GTIME(5,1),GTIME(5,2),GTIME(5,3),GTIME(5,4)
  1,GTIME(5,5),GTIME(5,6),GTIME(5,7),GTIME(5,8),GTIME(5,9)
  1,GTIME(5,10)
 110 FORMAT (10(F7.3))
 120 FORMAT (10(A19))
 130 FORMAT (10(F14.3))
C  SORT GPS TIME FROM LASTEST TO EARIEST
  OPEN (30, FILE="AVGLTT.CSV")
  DD(1) = (5843.428/5280)
  DD(2) = (16725.59/5280)
  DD(3) = (1139.125/5280)
  DD(4) = (11158.396/5280)
  DD(5) = (838.457/5280)
  DD(6) = (21776.219/5280)
  DD(7) = (1134.646/5280)
  DD(8) = (14421.616/5280)
  DD(9) = (1267.546/5280)
  DD(10) = (9407.86/5280)
  DO J = 1,10
  TTIME(J) = 0.0
  N(J) = 0.0
  LASTRUN(J)= MAX(GTIME(1,J),GTIME(2,J),GTIME(3,J),GTIME(4,J)
  1,GTIME(5,J))
          DO I = 1,5
c  WITHIN 15 MINUTES(900 SECONDS) AFTER LAST RUN
  IF (LASTRUN(J)-GTIME(I,J) .LE. 900 .and. time(i,j) .ne. 0) THEN
   TTIME(J) = TTIME(J)+TIME(I,J)
   Tspd(j) = tspd(j) + spd(I,J)
   N(J) = N(J)+1.0
   else
   ttime(j) = ttime(j)
   tspd(j) = tspd(j)
   n(j) = n(j)
  END IF
  IF ((LASTRUN(J)-GTIME(I,J)) .EQ. 0) THEN
   TRTIME(J) = RTIME(I,J)
  END IF
   END DO
C  CALCULATE AVG. TIME MEAN SPEED OF VEHICLE WITHIN 15MINS.
RANGE
   ATTIME(J) = TTIME(J)/N(J)
   ASPEED(J) = (DD(J))*60/ATTIME(J)
   if (attime(j) .eq. 0.0) then
    aspeed(j) = 0.0
   end if
   if (n(j) .eq. 0.0) then
    aspeed(J) = 0.0
    attime(j) = 0.0
   end if
   if (n(j)-1.0 .EQ. 0) then
    ASPEED(j)= tspd(j)
   end if
  END DO
C
  WRITE(30,'(A,10(",",A))')"TIME(US40-US6)","US40(OFF)-US40(ON)"
  1,"US40(ON)-GRG TWN(OFF)"
  1,"GRG TWN(OFF)-GRG TWN(ON)"
  1,"GRGE TWN(ON)-SLVR PLM(OFF)"
  1,"SLVR PLM(OFF)-SLVR PLM(ON)"
  1,"SLVR PLM(ON)-BKRVLL(OFF)"
  1,"BKRVLL(OFF)-BKRVLL(ON)"
  1,"BKRVLL(ON)-HRMN GLCH(OFF)"
  1,"HRMN GLCH(OFF)-HRMN GLCH(ON)"
  1,"HRMN GLCH(ON)-US6(OFF)"
  WRITE(30,200) ATTIME(1),ATTIME(2),ATTIME(3),ATTIME(4),ATTIME(5)
  1,ATTIME(6),ATTIME(7),ATTIME(8),ATTIME(9),ATTIME(10)
  WRITE(30,200) ASPEED(1),ASPEED(2),ASPEED(3),ASPEED(4)
  1,ASPEED(5),ASPEED(6),ASPEED(7),ASPEED(8),ASPEED(9),ASPEED(10)
  WRITE(30,200)N(1),N(2),N(3),N(4),N(5),N(6),N(7),N(8),N(9),N(10)
  WRITE(30,201)TRTIME(1)
  WRITE(30,201)TRTIME(2)
  WRITE(30,201)TRTIME(3)
  WRITE(30,201)TRTIME(4)
  WRITE(30,201)TRTIME(5)
  WRITE(30,201)TRTIME(6)
```

```
      WRITE(30,201)TRTIME(7)
      WRITE(30,201)TRTIME(8)
      WRITE(30,201)TRTIME(9)
      WRITE(30,201)TRTIME(10)
200   FORMAT(10(",",F7.3))
201   FORMAT(A,"AMPM")
      END SUBROUTINE
```

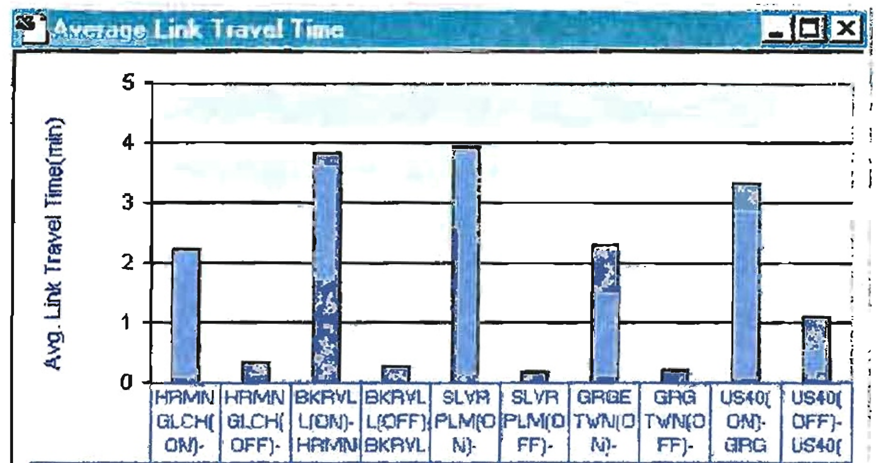
APPENDIX D:

SAMPLE GPS DATA

```
"MobileKey","MobileID","ReportTime","PosFixTime","PTTmsec","Latitude","Longitude","Altitude","Speed","
Course","PosAgeFlag","GpsFixSrc","Status1","Status2","StatusTime","NumOnOff","OnOff1","OnOff2","OnOff3
","OnOff4","OnOff5","OnOff6","OnOff7","OnOff8","NumReading","Reading1","Reading2","Reading3","Reading4
","LenExtended","Extended","EventID","Flags"
376758,5,645151515,645151320,0,39754272,-105142979,160118,2678,3593,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376759,2,645151515,645151320,0,39504039,-105195321,309917,3290,929,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376760,5,645151515,645151325,0,39765568,-105142997,157570,2652,3595,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376761,2,645151516,645151325,0,39504057,-105193407,309380,3241,892,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376762,5,645151518,645151330,0,39765944,-105143000,157221,2634,3595,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376763,2,645151518,645151330,0,39504680,-105191364,309004,3120,892,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376764,5,645151520,645151340,0,39769804,-105143037,155327,2643,3598,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376765,2,645151533,645151340,0,39504551,-105187955,308050,3151,982,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376766,5,645151533,645151345,0,39770771,-105143054,155912,2820,3593,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376767,2,645151533,645151345,0,39504380,-105186152,307917,3142,1023,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376768,2,645151536,645151350,0,39504085,-105184303,306279,3000,1047,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376769,5,645151538,645151350,0,39772047,-105143069,155710,2870,3595,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376770,5,645151542,645151355,0,39773345,-105143005,155568,2678,3597,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376771,2,645151542,645151355,0,39503732,-105182556,307698,3000,1061,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376772,5,645151548,645151360,0,39774535,-105143095,155659,2870,3599,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376773,2,645151548,645151360,0,39503290,-105180943,306565,3155,1059,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376774,5,645151553,645151365,0,39775945,-105142950,155775,2954,225,1,1,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376775,2,645151553,645151365,0,39502010,-105179176,306332,3221,1104,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376776,2,645151556,645151370,0,39502321,-105177422,305447,3187,1079,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376777,5,645151562,645151370,0,39777150,-105142299,153664,2835,907,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376778,2,645151563,645151375,0,39501975,-105175644,304412,3150,1029,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376779,5,645151565,645151375,0,39778152,-105141250,155104,2642,472,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376780,5,645151568,645151380,0,39779077,-105139875,155051,2887,526,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376781,2,645151568,645151380,0,39501657,-105173864,303190,3150,983,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376782,2,645151573,645151385,0,39501388,-105172003,302709,3170,925,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
376783,5,645151573,645151385,0,39779444,-105138356,155060,2853,645,1,2,,,-1,0,,,,,,,,,0,,,,,0,,0,0
```

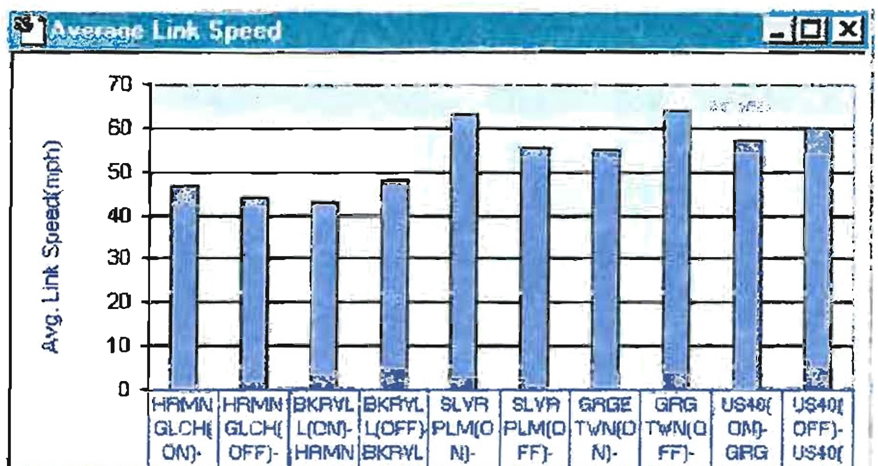
APPENDIX E:

SAMPLE OUTPUT



	HRMN GLCH(ON)-	HRMN GLCH(OFF)-	BKRVL L(ON)- HRMN	BKRVL L(OFF)- BKRVL	SLVR PLM(O N)-	SLVR PLM(O FF)-	GRGE TWN(O N)-	GRG TWN(O FF)-	US40(ON)- GRG	US40(OFF)- US40(
Avg. LTT	2.223	0.329	3.82	0.269	3.926	0.172	2.305	0.202	3.326	1.107
Last Updated	12:42:20	12:40:05	12:39:45	12:36:00	12:35:40	12:31:45	12:31:25	12:29:15	12:29:05	12:25:45
# of Veh's	1	1	1	1	1	1	1	1	1	1

Figure E-1. Average Link Travel Time.



	HRMN GLCH(ON)-	HRMN GLCH(OFF)-	BKRVL L(ON)- HRMN	BKRVL L(OFF)- BKRVL	SLVR PLM(O N)-	SLVR PLM(O FF)-	GRGE TWN(O N)-	GRG TWN(O FF)-	US40(ON)- GRG	US40(OFF)- US40(
Avg. LSPD	46.807	43.81	42.907	47.946	63.037	55.5	55.016	64.195	57.152	59.958
Last Updated	12:42:20	12:40:05	12:39:45	12:36:00	12:35:40	12:31:45	12:31:25	12:29:15	12:29:05	12:25:45
# of Veh's	1	1	1	1	1	1	1	1	1	1

Figure E-2. Average Link Speed.

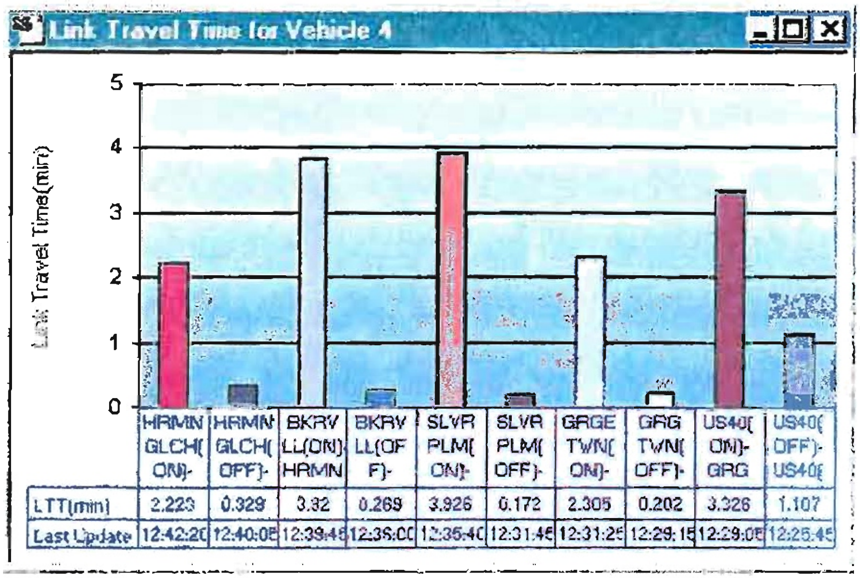


Figure E-3. Link Travel Time for Vehicle No. 4.

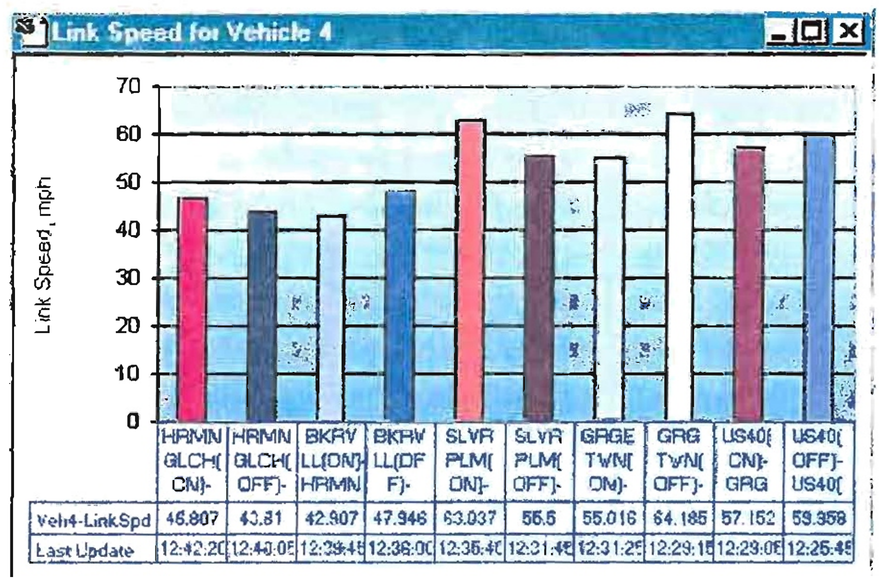


Figure E-4. Link Speed for Vehicle No. 4.

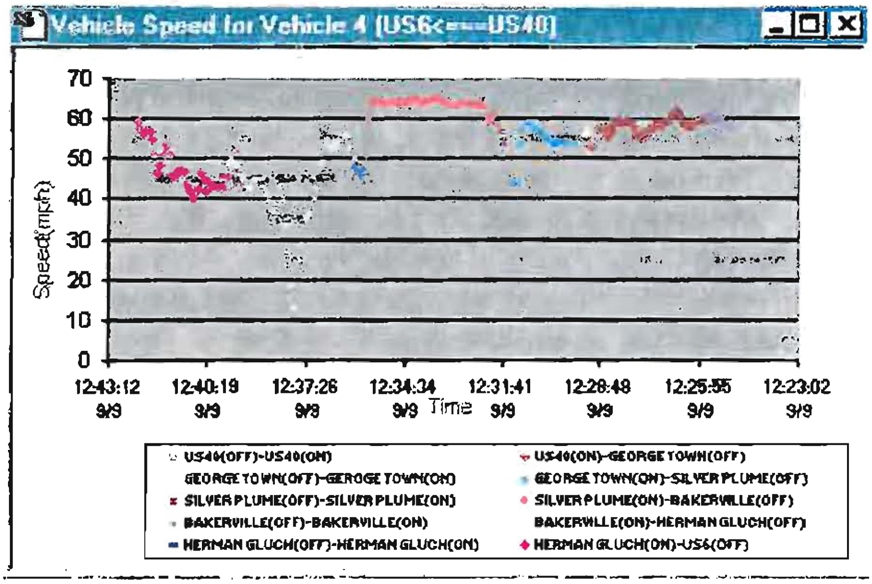


Figure E-5. Instantaneous Vehicle Speed for Vehicle No. 4.

REFERENCES

Trimble Navigation Limited. *Placer GPS 450/455 : Installation and Operations Manual.* , Sunnyvale, CA, 1996.

Trimble Navigation Limited. *FleetVision : Software User's Guide.* , Sunnyvale, CA, 1998.

Trimble Navigation Limited. *Fleet Vision : Software Reference Manual.* , 1998.

Federal Highway Administration. *CORSIM User Guide.* Technical Report Version 1.0, Federal Highway Administration, US-DOT, McLean, Virginia, 1996.

S.I. Khan, and K. Thanasupsin. Accuracy of Link Travel Time Estimates Based on Probe Data. *Journal of Transportation Engineering, American Society of Civil Engineers,* (in preparation).

S.I. Khan, Li, L, and Hoeschen, B. Vehicles as Probes in CORSIM to Estimate Travel Time. *International Conference on Transportation Into the Next Millennium,* Singapore, 1998.

S.I. Khan, P. Maini, and K. Thanasupsin. A Re-examination of car-following and collision constraint models for uninterrupted traffic using high precision global positioning system. *Transportation Research Record: Journal of the Transportation Research Board,* Vol. No. 1710, 2000.

S.I. Khan, Thanasupsin, K. and Griffin, R. A Real-Time Demonstration Prototype to Estimate Travel Time and Speed on the Rural I-70 Corridor. *Intelligent Transportation Society of America's 11th Annual Meeting and Exposition,* ITS America, Miami Beach, Florida, USA, 2000.