FINAL EVALUATION REPORT

For The

CAPITAL-ITS Operational Test and Demonstration Program
Conducted by

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by the

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Glossary

ATMS -- Advanced Traffic Management System
BANM -- Bell Atlantic NYNEX Mobile (Formerly Bell Atlantic Mobile or BAM)
CAPITAL -- Cellular APplied to ITS Tracking And Location
CMS -- Congestion Management System
DF -- Direction Finding
DFS -- Direction Finding System
ES -- Raytheon E Systems
FHWA -- Federal Highway Administration
GCS -- Geolocation Control System
ITS -- Intelligent Transportation Systems (formerly Intelligent Vehicle/Highway
        Systems(IVHS))
MNCPPC -- Maryland National Capital Park and Planning Commission
MSHA -- Maryland State Highway Administration
OI -- Operator Interface
OT -- Operational Test
SOC -- State Operations Center
TAS -- Transmission Alert System
TIC -- Traffic Information Center
TMC -- Traffic Management Center
TTS -- Travel Time Study
UM -- University of Maryland
USDOT -- United States Department of Transportation
VDOT -- Virginia Department of Transportation
Historical UMD -- University of Maryland speed data, averaged over several days

EXECUTIVE SUMMARY

The CAPITAL (Cellular APplied to ITS Tracking And Location) Project was an ITS operational test conducted through a cooperative agreement between the Federal Highway Administration (FHWA), the Virginia Department of Transportation (VDOT), the Maryland State Highway Administration (MSHA), Raytheon E-Systems (ES), Farradyne Systems Inc. (FSI) and Bell Atlantic NYNEX Mobile (BANM). The project focused on geopositioning vehicles equipped with cellular telephones over time to measure traffic conditions (speed on traffic links and incidence detection) over a wide geographic area. The test was conducted over a 27 month period in the Washington DC area, including I-66, I-495, and various state routes in the Virginia suburbs. It concluded in November, 1995. Raytheon E-Systems served as the prime contractor and supplied the equipment to geolocate and track the cellular telephones. FSI supplied the traffic management information system which converted cellular positioning probe data to traffic data. BANM supplied the network infrastructure and communications links using their cellular network in the Baltimore-Washington region. FHWA, VDOT and MSHA served as the public sector sponsors for the project, and the University of Maryland served as the independent evaluator.

The CAPITAL project was undertaken to assess the viability of using cellular-based traffic probes as a wide area vehicular traffic surveillance technique. From the test, cellular technology demonstrated the technical potential to provide vehicle speed and geolocation data that, under the proper circumstances, can provide additional information on freeway traffic conditions. However, due to the changing configuration of cellular technology, definitive cost effectiveness cannot be accurately determined at this time. The specific objectives of the test were:

1. To determine if the use of cellular telephone technologies provide a cost effective means of wide area traffic surveillance.

2. To determine if information from cellular telephone traffic can be effectively integrated into a real-time area-wide traffic system management (surveillance/control) system, with specific applications for Advanced Traffic Management Systems, Advanced Traveler Information Systems, and Advanced Public Transportation Systems.

3. To determine if packet data transmission over the cellular telephone communications network provides an effective means of disseminating real-time-area-wide traffic information.

To collect the necessary data to measure performance against these objectives, a geolocation and traffic management system was constructed and operated live in the test area. The network consisted of eight sites of cellular call detection and geolocation equipment located at the BANM base station sites, a geolocation control subsystem located at the BANM switch office, a traffic management system located at the Farradyne facility, and a number of fixed and mobile terminals to disseminate the traffic data. The network detected cellular call initiations in the test area and geolocated the calls. If the calls were on roadways of interest, the calls would be geolocated over time to estimate vehicle speed. If the calls were emergency in nature (911, #77, etc.), they would be given priority for geolocation and reporting. The vehicle speeds and emergency call origins were used to report speeds on traffic links and warn of potential traffic incidences   Once the network was declared

operational, the University of Maryland collected data on the network to assess its performance. This data collection consisted of independent measurement of the positioning accuracy, travel time runs for speed estimating, and incident monitoring of police and other sources to establish ground truth.

The evaluation of the network is summarized below.

1. The cellular telephones operating in the test area were geolocated to just over 100 meters on the last test day. These results are based on data collection at multiple sites in the test area. This geolocation accuracy resulted in speed estimation of cellular equipped (and in use) vehicles only about 20% of the time. These results are based on at least 4 to 5 geolocations on a vehicle. As technology progresses and prices for the direction finding equipment continues to fall, the CAPITAL approach to wide area traffic surveillance may become economically viable. Furthermore, as cellular providers move toward compliance with the FCCs recent ruling on location based on Enhanced-9 11 (the continually emitted cellular signal enhances the ability to locate the phone), the potential for sharing of information resources and capital and operating costs continues to grow.

2. Link speed estimates and speed trend data cannot be accurately estimated automatically by the system (the output was accurate only about 20% of the time). Incident detection was found to be best determined manually by an operator trained in using the system. Computer automated assessment of the geolocation data to estimate traffic condition and incident detection was found to produce inconsistent results. More robust algorithms which take into account the statistical nature of the geolocation data must be developed to completely automate the process.

3. Objective 3, above, was not evaluated because of the inconsistent operation of the automated traffic management function.

The CAPITAL test demonstrates that the population of the cellular equipped vehicles is sufficient to serve as data points. The geolocation technology accuracy is adequate to assign vehicles to the correct link and direction of travel but does not appear to be accurate enough to adequately estimate speed. It appears that the costs of the cellular based system can be competitive with other technologies. If the geolocation accuracy can be reduced to 5 to 25 meters and the signal can be consistently received, the system shows promise if the costs of doing this are not overwhelming. Unfortunately this project did not produce results as accurately as hoped, due to several factors, including:

    1) Geolocation accuracy
    2) Speed estimation algorithm
    3) Incident detection algorithm

It is recommended that the cellular based surveillance system be further studied as an alternative to other more traditional types of traffic surveillance particularly as technological developments occur in geolocation and signal receiving.

I. INTRODUCTION

This paper reports the results of the evaluation of the CAPITAL ITS Operational Test and Demonstration Project; The Evaluation Plan (July, 1994) and the Evaluation Design (Nov , 1994) contain a detailed description of the project goals and objectives as well as the evaluation goals and objectives. Exhibit G. at the end of this chapter, shows the evaluation goals and objectives.

Description of the Operational Test

The Washington, D.C. Area CAPITAL ITS Operational Test and Demonstration Program is a complete end to end test from the collection and processing of wide area surveillance data to the dissemination of traffic data from cellular phone intercepts to remote users and in-vehicle equipment. The program is based on a unique partnership between the Federal Highway Administration and a team made up of public and private partners. This team led by Raytheon E Systems (ES), included Bell Atlantic Mobile (which is now Bell Atlantic NYNEX Mobile or BANM), P.B. Farradyne, the Maryland State Highway Administration, and the Virginia Department of Transportation.

The architecture to support this Operational Test makes extensive use of the in-place cellular in&structure for both wide area surveillance and communications. ES equipment was co-located at selected BANM towers to collect cellular phone usage statistics and geolocate active phones on designated roadways. This co-location saved substantial infrastructure costs and the (in place) cellular users provided data points or probes for traffic information. Although system integration/redesign was required for the Direction Finding System (DFS), Transmission Alert System (TAS), Geolocation Control System (GCS), and Traffic Information Center (TIC), the geolocation equipment is based on technology currently produced by ES for other U.S. Government applications,

As originally envisioned, the distinguishing features of the cellular-based wide area surveillance technique as compared to loops, video cameras or other techniques are:

- Area coverage based on square kilometers, not vehicle counts or road kilometers

- No disruption of road service for installation or repair

- Order of magnitude lower in cost than loop-based approaches

- Very high reliability with low maintenance costs

- Secondary uses including fleet vehicle management and emergency assistance

- Immediate activation and privatization by cellular service providers.

This Operational Test was undertaken to move key technologies associated with Wide Area Traffic Flow Management and Vehicle Communication out of the test laboratory and into the public sector.

The three key facets of the test system are:

- The deployment of a wide area surveillance system where a limited number of BANM towers in the Northern Virginia area were populated with geolocation equipment. These systems were then utilized to locate and monitor the progress along roadways of anonymous, cellular equipped vehicles randomly chosen for the purpose of collecting real-time traffic data.
- The establishing of a Traffic Information Center (TIC) in Rockville. MD to collect and process the raw geolocation data into usable data on traffic flow, count, speed, and incidents.
- The testing of an in-vehicle data distribution network based on the use of data transmitted with cellular technology.

System Description

The CAPITAL system has three primary components:
- Geolocation
- Traffic Information
- Data Distribution.

The relationship of the components is shown in Exhibit A, "Major System Functions". A more detail description of the system operation is shown in Exhibit B, "System Functional Flow".
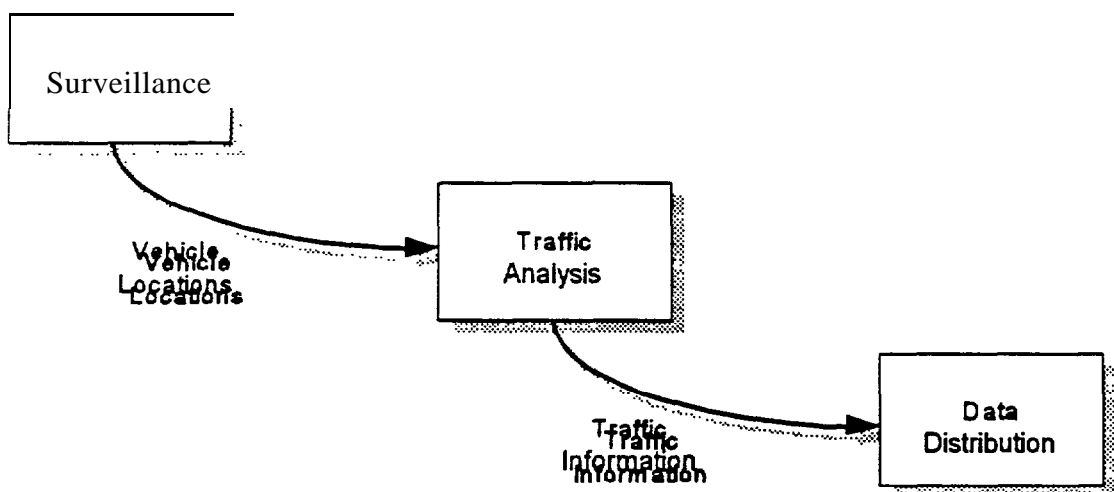
Exhibit A, Major System Functions
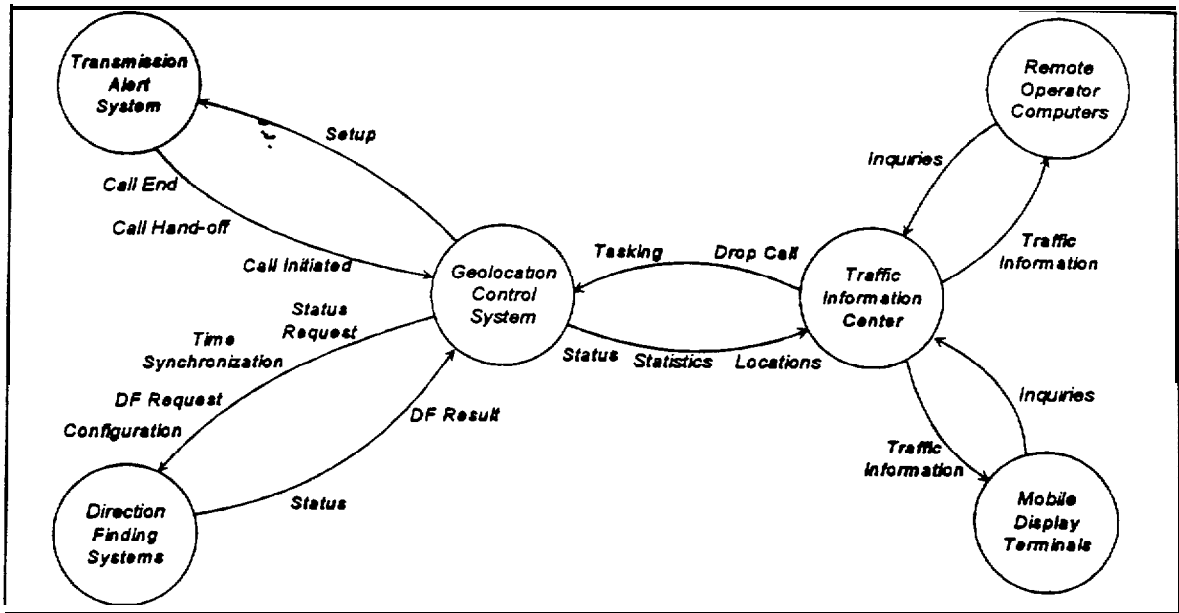
Exhibit B, System Functional Flow

1.2.1 Geolocation

The Geolocation component is composed of the Transmission Alert System (TAS), Direction Finding Systems (DFS). and the Geolocation Control System (GCS). It looks for mobile users to make phone calls. This is done by monitoring the cellular reverse control channels and identifying when a mobile phone transmits a call initiation message. Once identified, the forward control channel is examined for the assignment of voice channels to the mobiles. This information is combined to produce a Call Initiation message for a phone. The Geolocation component then uses direction finding equipment collocated at multiple sites throughout the geographic area of coverage to determine from which direction the call is coming. These results can be used to locate the vehicle by triangulation and time-difference-of-arrival techniques. Exhibit C, "Triangulating to the vehicle", depicts the method of using intersecting lines of bearing to determine the vehicle location. The time-difference-of-arrival method uses a similar approach with intersecting curves instead of lines. This project used a combination of lines of bearing and time-difference-of-arrival to geolocate. The location of the vehicle is then passed to the Traffic Information Center to perform the velocity calculation.

The Geolocation component locates vehicles transmitting at cellular band frequencies (824 megahertz to 894 megahertz) within the line-of-sight of specific cellular telephone towers. For the purposes of the Operational Test the Geolocation component consisted of two TASs, a GCS and seven DFS's . The Geolocation block diagram is shown in Exhibit D.

- The Geolocation component performs several major functions:
- TAS - Recognizes new calls, determines call hand-offs and call terminations.
- GCS - Schedules tasking for DFS's and calculates geolocations
- DFS - Calculates line-of-bearing and time of arrival for signals.

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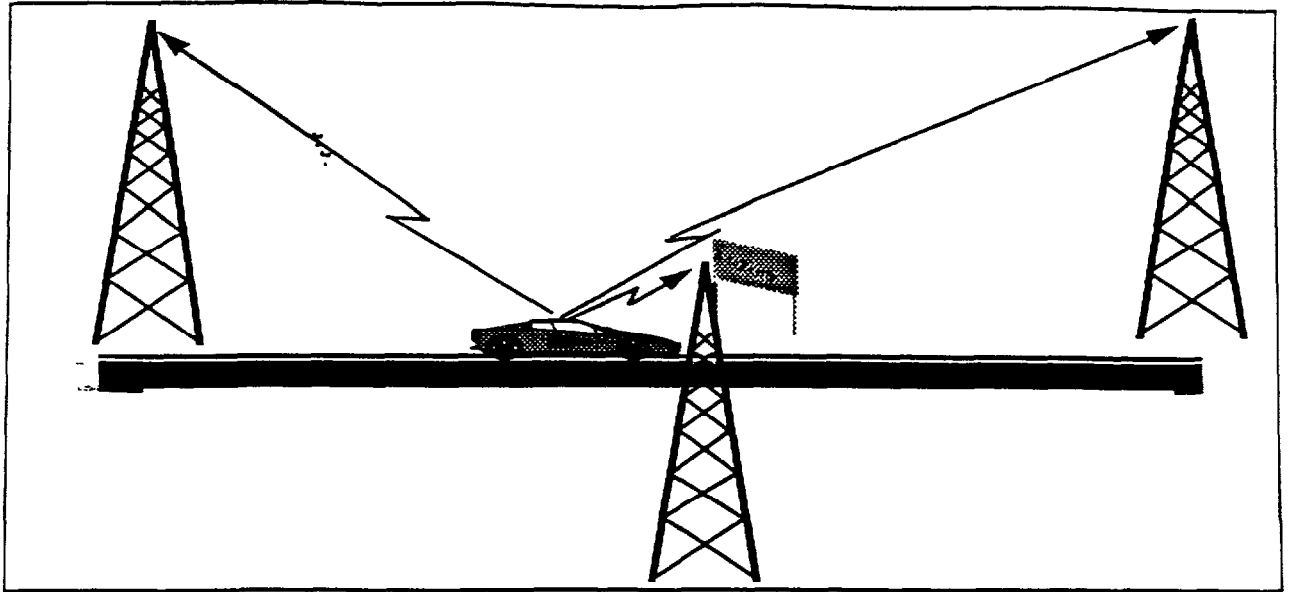
Exhibit C, Triangulating to the vehicle

1.2.1.1 Transmission Alert System

The TAS uses wideband and digital narrowband receivers to process control data **on** the forward (tower-to-mobile) and reverse cellular communication channels for call initiations, hand-offs and terminations, When a call is initiated, the TAS sends a message to the GCS. This message consists of the encrypted identifier for the mobile, the priority of the call, the cell site of the call, the time of the call, and the assigned channel. The TAS assigns a narrowband receiver to process the forward channel to determine when the call is handed off to another channel or when the call is terminated. When a call is handed off, the TAS will send a message to the GCS that contains the time of the hand-off, the new channel and the encrypted ID. The GCS then updates its internal tables to use this new channel for this mobile. The TAS also sends a message when the call ends. The TAS reassigns the receiver when the call ends or when the GCS requests the TAS to reassign the receiver.

The TAS can be tasked to mark as high priority those call initiation messages resulting from the dialing of specific phone numbers (e.g., 911 & #77.) This insures that system resources are available to focus on calls which may be strong indicators of traffic incidents and treat typical telephone calls as lower priority.

1.2.1.2 Geolocation Control System

The GCS has two functions:

- Tasking and coordinating the DFS's
- Calculate the geolocation using results from the DFS's

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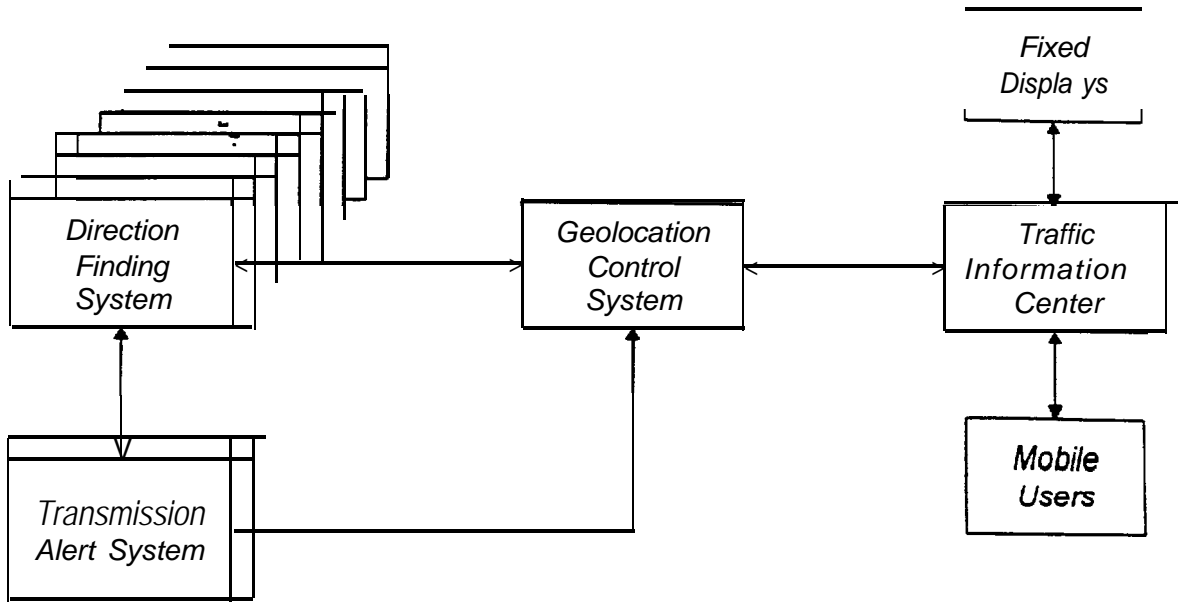
Exhibit D, System Operation Flow Chart

Type	Description	Source	Priority
New call	A new phone call is identified by the TAS	TAS	Low
New emergency call	A mobile user dials a designated emergency number	TAS	High
Probe of Interest Tasking	The TIC requests additional geolocation for a vehicle of interest	TIC	High

Table I Summary of Tasking for GCS

In the tasking and coordinating role, the GCS receives messages from the TAS and translates them into DF request messages that it sends to the DFS's. The GCS also receives tasking messages from the TIC that are translated into DF request messages. The tasking messages from the TIC have a higher priority than the messages from the TAS. A summary of the tasking messages is shown in Table 1.

The GCS schedules the tasks in the order that the phone calls occur. The exceptions are for emergency phone calls, and additional tasking for vehicles of interest. These calls are placed at the front of the scheduling list.

The GCS uses a combination of the lines-of-bearing and times of arrival calculated by the DFS's to geolocate a vehicle. This utilizes the best features of each method and results in better location. This geolocation is reported to the TIC. If the TIC determines that the location of the vehicle is of interest, then the TIC requests additional geolocations of the vehicle from the GCS.

Many of the vehicles will be on roads that are not designated as "roads of interest." The GCS uses a configuration file to determine the area of coverage. If a location is not in that area, then the vehicle information is discarded from the GCS' internal tables and a Drop Call message is sent to the TAS.

The GCS requests status from the DFS's at periodic intervals. This is done to ensure that the system is fully operational. The GCS can remotely restart a DFS if it determines that there is a malfunction in a DFS.

The GCS sends statistics and status messages to the TIC each minute. The GCS counts the number of new calls, hand-offs, hang-ups and vehicles of interest identified by the system. The TIC then uses this information to establish a baseline of traffic patterns. Exhibit E shows the proposed system with these elements.

1.2.1.3 Direction Finding System

The DFS uses an eight element antenna to determine from which direction a cellular signal is coming. Each antenna element feeds a 10 megahertz wide channel in a wideband receiver. This data is down-converted to baseband or intermediate frequency data and then converted from analog to digital data. Eight digital receivers then collect the data and supply it to a fast math processor. This processor compares the antenna voltages to a large database to determine the line-of-bearing and time of arrival for the signal.

The DFS waits for DF request and status request messages from the GCS. When a DF request message is received, the system is tuned to the correct 10 megahertz band of the cellular reverse channels. Then, an Octal Digital Receiver collects narrowband RF data at the assigned channel frequency. A line-of-bearing, and the time-of-arrival for the signal are computed and placed into a DF results message. The DF results message is then passed to the GCS. When a status request message is received, the DFS evaluates its current status, and returns a status message to the GCS.

Each of the DFS systems' clocks must be set to the same relative time (within 100 milliseconds) in order for the combination of the lines-of-bearing to produce an accurate location in the GCS. For the time-difference of arrival processing, the DFS's' clocks must be accurate to within 100 nanoseconds. The time reference is provided by a GPS receiver located at each DFS. The Operational Test system layout is depicted in Exhibit F.
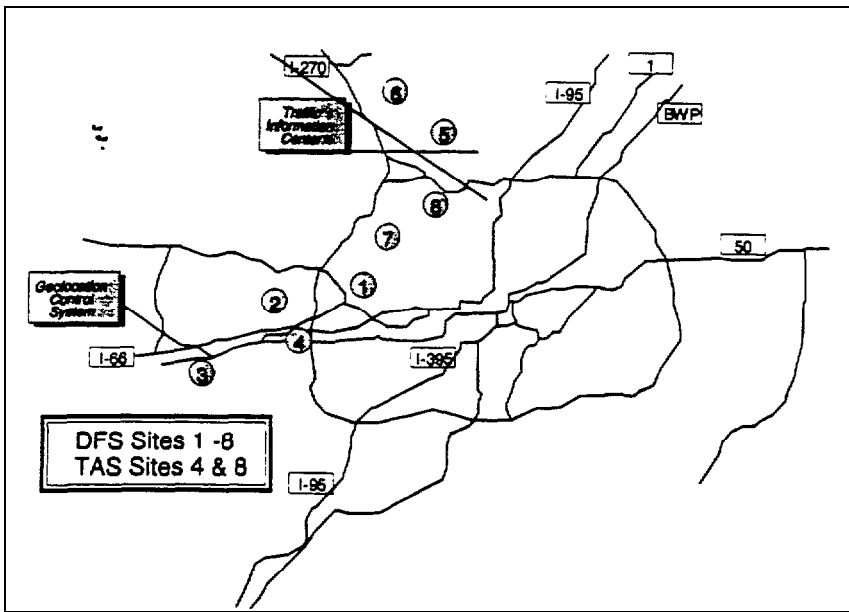
Exhibit E, Proposed System Layout
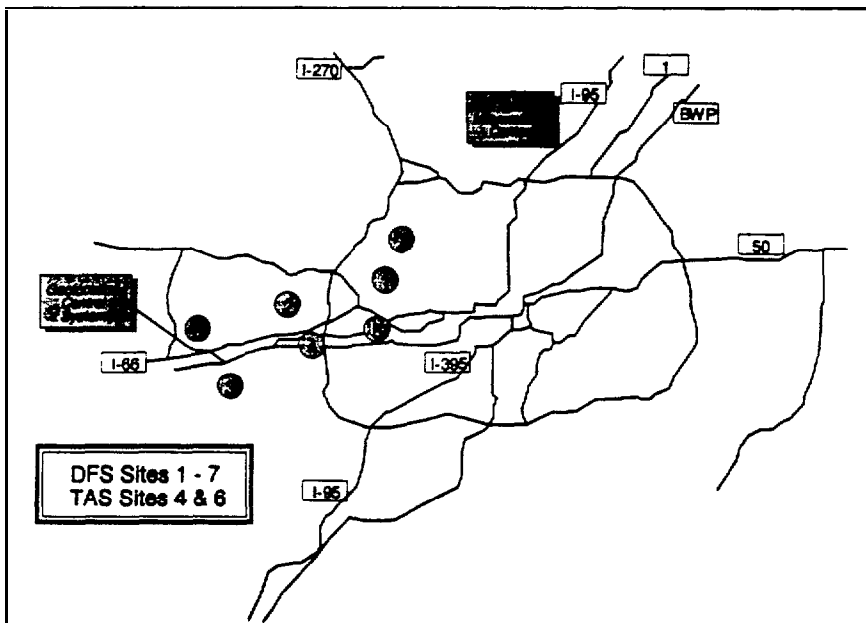
Exhibit F, Operational Test System Layout (Actual)

1.2.2 Traffic Information

The Traffic Information component is performed by the Traffic Information Center. It uses vehicle locations to produce a variety of traffic information. It determines the roadway location of the vehicle, the speed of the vehicle, and any unusual traffic flow.

1.2.3 Data Distribution

The Data Distribution component is provided by the Remote Operator Computers and the Mobile Display Terminals. Together, they display traffic information graphically to local and remote users and allow mobile users to periodically receive traffic information. Telephone connections, both land-line and cellular, are used to deliver traffic information to operators at remote computers or in vehicles.

1.2.4 The Changing Cellular Environment

The cellular system in 1995 was different from the system existing when this project was envisioned. The two changes to the cellular environment which have impacted the CAPITAL Project most directly are the explosion in the user population and the transition from vehicle based to portable cellular phones. It was these fundamental changes which caused such symptoms as dropped calls, calls of insufficient RF strength, and a severe multipath environment.

The basic premise of the CAPITAL system, the ability to receive RF energy from an individual cellular phone at three or more Directional Finding System (DFS) sites is in conflict with the fundamental design principle of a cellular network. Cellular providers are allocated a finite amount of the radio spectrum for providing cellular phone service for an entire region. In the case of the CAPITAL Project, BANM provided coverage for the Washington - Baltimore metropolitan service area The radio spectrum allocated to BANM is divided into channels, with each cellular phone call requiring two channels: receive and transmit. With over 100,000 customers the BANM network had to be designed to reuse these channels in order to service customer demand. Channel reuse is accomplished by managing the power and direction of the signal being transmitted to the cellular phone by the tower and managing the power of the signal from the cellular phone back to the tower. **The management of these characteristics is critical for both the cellular network and the CAPITAL System since as the power of the signal being transmitted from the tower/phone is decreased, the range at which that signal can be "heard" is reduced.** Failure to provide this network management leads to crosstalk. This is when two phones are assigned the same transmit or receive channels in different cells and portions of each conversation is heard by the other phone. Therefore, the ideal power level for the cellular provider is one strong enough to be heard by the phone for which the call is intended but too weak to be heard by phones/towers using the same channel in other cell sites. As the number of users has increased over time, the ability to reuse channels has become more and more critical. With the number of channels each tower can handle being limited and as channel reuse has increased, the number of towers has increased and the distance between towers has decreased This further reduces the average distance between the tower and the phone, thereby allowing the tower to use less and less power to communicate with the phone. The lower power levels mean that towers utilizing the same transmit or receive channel can now be closer together.

The second fundamental shift in the celluIar population has been in the cellular handset. Prior to 1993, 95% of all phones in use were fill power (3 watts) vehicle installed or transportable (i.e., bag) phones. Beginning in 1994 the number of hand-held portable phones has increased substantially. The impact of this change is once again transmit power. The standard hand-held portable has a

maximum transmit power of 0.6 watts, just one fifth that of the standard vehicle installed phone, Therefore in order for portable phones to effectively communicate with the cellular towers it was necessary for them to be much closer to the tower. Since having areas of poor or reduced cellular coverage is not acceptable to cellular providers, the answer once again was to install more tower sites, thereby decreasing the distance between each site and the average distance between the tower and the phone.

The final fundamental shift in the cellular population was in the tower antenna. Before power management and channel reuse were issues, cellular providers typically transmitted to a phone using an omnidirectional antenna. This antenna is much like a radio station antenna in that it transmits its message to all 360 degrees of the surrounding environment. As the need for channel reuse became more acute, cellular providers began moving to directional antennae. This allows them to sectorite a tower into 120 degree slices, which further reduces the hearability of the transmitted signal since now it is only being transmitted in one direction.

1.2.5 Evaluation Goals and Objectives

As an "independent evaluator" our objectives were driven by the "Evaluation Goals" established by the Evaluation Sub-Committee, Working Group (see Exhibit G). They include:

- Determining the accuracy and coverage of the Cellular Telephone Network to:

  - Identify incidents

  - Obtain traffic flow data (e.g. speed, travel time, etc.)

  - Disseminate user information to:

    . In-vehicle users (possibly Fleet Users)

    • Remote users (Team/partner "Users")

- Overview evaluation of the Technology in meeting the goals in Exhibit G

  - The overall objectives included:

    - To determine if the use of cellular telephone technologies provide a cost-effective means of area-wide traffic surveillance.

    - To determine if information from cellular telephone traffic can be effectively integrated into a real-time area-wide traffic control system, with specific applications for Advanced Traffic Management Systems, Advanced Traveler Information Systems, and Advanced Public Transportation Systems.

- To determine if the packet data transmissions over the cellular telephone communication network provide an effective means of disseminating real-time area-wide traffic information.

II. EVALUATION APPROACH

It was determined early that the evaluation of the CAPITAL ITS Operational Project was to be conducted within the MITRE guidelines (FHWA Nov. 1993) recommending a process for evaluation. Since the major objective of the Operational Test is to demonstrate the ability of a cellular based system to provide wide area surveillance, the major evaluation measure is the accuracy of speed data. Also, ability to use speed data to identify incidents was to be evaluated. Thus the major approach to evaluation was to obtain a definitive sample of travel time (speed) data on the links in the test network. Then a comparative analysis of the test run speeds with speeds calculated by the TIC was planned.

Prior to establishing the final design for conducting each test, the test boundaries were fully identified and the durations of the each test were established in order to coordinate evaluation testing, particularly the speed (travel time) test needed for wide area surveillance. Historical data on traffic volumes by hour (and 15 minutes), speeds, and density data were obtained and reviewed to determine the evaluation design.

It was determined that incident free traffic data (Density data from Metropolitan Washington Council of Governments) were relatively consistent over a 15 minute time period and the 15 minute time intervals between 6:30 am to 9:30 am and between 3:30 pm to 6:30 pm were established as the sampling frames for travel time and surveillance testing. Similarly, incident free hourly data were determined to be consistent during off-peak times of 9:30 am to 3:30 pm and evening (after 6:30 pm) times; thus, hourly time intervals were used for off-peak data collection.

The evaluation was designed to follow the goals shown in Exhibit G, utilizing the evaluation framework presented in the FHWA working paper, "Guidelines," November, 1993. This Evaluation Report mostly follows the order given in our Evaluation Design report, November, 1994.

Exhibit G. Evaluation Goals and Objectives

1   Determine the accuracy of geolocation data.

    a.   Within how many meters can cars be located on various roads?

2   Determine the accuracy and completeness of traffic information derived from geolocation data.

    a.   Is there sufficient geolocation data to derive traffic information?

    b.   Can differential traffic flows on adjacent and parallel streets be determined?

    c.   What is the accuracy of the speed information?

    d.   What is the availability of the derived traffic information?

    e.   Can cars on major roads be distinguished from those on nearby and crossing roads?

    f.   What are the three incident detection parameters (i.e. Percent of Incidents Detected, Mean Time to Detect, and False Alarm Rate)?

3   Determine the appropriate role of the derived traffic information for operational use in TMC or SOC operations.

    a.   What is the accuracy of the volume (flow) information at various levels of volume?

4   Determine the appropriate role of the derived traffic information for operational use in TMC or SOC operations.

    a   Was the presentation format effective?

    b.   Which TMC or SOC applications (e.g. incident detection, ramp metering, information source for VMSs) can be supported by the information?

    c.   What changes would have to be made to accommodate the new information and integrate it into the TMC or SOC operations?

    d.   Would the new information source replace or supplement loop detectors and wide area surveillance systems?

    e.   How often was the information used?

5   Establish criteria for deciding which roads can be monitored by cellular techniques as a part of a full-scale traffic monitoring program.

    a.   What types of roads (arterials. freeways, etc.) are amenable to area coverage?

    b.   Are there minimum flow rates required on these roads?

c.   What is the effect of traffic signals on arterial highways?

d.   What are the physical criteria, such as line-of-sight to the transmitter sites?

6.   Determine the system's capacities.

    a.   How many vehicles can the current system design geolocate simultaneously?

    b.   What are other limiting factors in the current system design?

7.   Determine the costs associated with deploying a wide area traffic monitoring system.

    a.   What are the design, hardware, software, and installation costs?

    b.   What are the operational costs, including communications?

    c.   What are the maintenance costs?

    d.   What are the incremental costs for increasing miles of road and geography covered?

    e.   How do these costs compare to those of other, more conventional techniques?

    f.   What are the costs for the cellular provider to disseminate the information?

    g.   What are the costs for incorporating the new information into the TMC or SOC operations?

8   Assess public acceptance of the wide area traffic monitoring system.

    a.   What concerns were raised by the public regarding privacy issues?

    b   What are the associated legal and institutional issues?

    c   Assess the public education process that was used.

9   Assess the requirements for and the usefulness of information disseminated to individual and fleet vehicles.

    a.   Was the disseminated information timely and accurate?

    b.   How often was the information used?

    c.   What type of information was perceived as most useful?

10.   Determine the role of the wide area traffic monitoring system data for planning needs.

    a.   What is its role in a Congestion Management System?

    b.   What is its role in travel demand model validation?

    c.   What is its role in distinguishing between recurring and non-recurring congestion?

III. GEOLOCATION ACCURACY

Static geolocation accuracy tests were conducted by establishing several (about ten) locations which had known latitude/longitude (e.g. USGS markers or state benchmarks obtained from VDOT or Fairfax County). A few locations were selected and the lat/long was obtained using differential GPS Having established accurate locations for all sites (unknown to the OT), a vehicle with a cellular phone was parked over or near the marker. The phone was then placed over the site, and the OT took at least five readings (fixes) on the signal. It was anticipated the TIC speed estimates would be based on at least five fixes. The testing team then moved to another site and this was repeated (static locations) for four to seven locations during each field test (four different dates beginning in December 1994). The tests conducted on June 15 and June 27, 1995 were with two towers/antenna locations in the vicinity. The final test was conducted using three towers; the third tower was relocated from the Rockville area but was not yet operational in June. The reasons for this was to determine whether the third tower increased the accuracy. The average error for the last day of testing was 108 meters, with a range of 24 to 185 meters, close to the 100 meter goal. The results shown below in Exhibit H are based on an average of at least five geolocation fixes for each site. The individual results are shown in Appendix A. One reason for the variation in the geoiocation site accuracy was a gradual change in the locational software and equipment modifications. This is especially true for the Dec. 21 tests Other variations may be due to the site specific characteristics-- **poor** line of sight, etc.

Exhibit H. Geolocation Accuracy

Date	Number of Locations Tested	Average Error (meters)
Dec. 21, 1994	4	649
June 15, 1995 (2 towers)	7	121
June 27, 1995 (2 towers)	7	146
Aug. 8, 1995 (3 towers)	6	107.6

The goal of the project was to have accuracy in the range of 50 to 100 meters. Although the last test was just over 100 meters, the accuracy proved to be adequate for the system to determine when a probe was on a road of interest but to estimate reasonably accurate speeds, only about 20% of the time. Multiple fixes on a probe gave accurate information on direction and part of the time on speed. At a few locations the geolocation equipment was not able to obtain a fix on the cellular phone signals, which was mostly due to topography and/or line of sight problems. Some modifications to the system *may* result in accuracy within the 50-100 meter range. This may come about with recent FCC requirements and other technological changes. The capability to obtain locational accuracy of 5 to 25 meters would provide location improvement as well as improve speed estimation accuracy.

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3.2 Geolocation: Cross Roads and Adjacent Roads (Dynamic)

The purpose of this test was to determine whether a vehicle on a cross road or a parallel adjacent road could b&distinguished from vehicles on a freeway link.

The test was set up for the evening and ES personnel obtained the UM signals before they went to the TIC, performed the geolocation, and downloaded that information. Several different facilities. either crossing or adjacent to 1-66 were selected in the 1-66/US 29 corridor (mostly between Nutley Street and I-495). The researchers chose one of ten streets (See Appendix B) and the direction of travel. After starting to drive the facility the telephone was activated continuously throughout the run. Then, another facility was selected, randomly, and the process was repeated The E Systems personnel monitoring the geolocation process did not know which facility was being driven, nor the direction. The test was conducted between 11 pm and 1 am. Ten locations were tested and the results showed no improperly assigned vehicles. Appendix B shows the assignments, both street and direction of travel were all correct. It should be noted that this test was conducted in the late evening hours when there was little cellular traffic, but, nevertheless, the results were correct assignments to facility and direction. The tests were developed only to determine if vehicles on the arterials could be properly located. Tests were not run to determine if freeway vehicles were misassigned to an arterial.

IV. WIDE AREA SURVEILLANCE

Due to changes in the BANM cellular network, explosion of the user population and transition from vehicle based to portable cellular (which resulted in calls of insufficient RF strength, a severe multipath problem. and dropped calls), the original 32 freeway link network, I-270 to I-495 to I-66, (Exhibit E) was reduced to 6 freeway links and 4 arterial links and additional transmission alert system (TAS) and geolocation control system (GCS) stations (moved from Maryland sites) were installed in the Fairfax-Tysons area to monitor I-495 from VA Rt 7 to I-66 and I-66 from I-495 to VA Rt 123 (Exhibit I). The Virginia sub-network was selected because of the denser spacing of towers and better cellular reception. In addition, the processing power/speed at each geolocation tower was doubled.

Wide area surveillance is the heart of the Operational Test and was approached in a comprehensive fashion. The evaluation process required a relatively large sample of travel times on each of the six freeway Iinks (see Exhibit L) for each 15 minute time interval during the AM and PM peak periods (6:30 am - 9:30 am and 3:30 pm - 6:30 pm) and for each hour during the off-peak periods. The following hypothesis was tested:

$$\bar{s}_t^1 \underset{\text{TTS}}{=} \bar{s}_t^1{}_{\text{TIC}}$$

where:

$\overline{S}_{t\ _{TTS}}^{i}$ = average speed calculated from the travel time study for link i during time t_i, and

$\overline{S}_{t\ _{TIC}}^{i}$ = average speed derived from the OT cellular probes for link i during time t_i

In order to be established as the "expected value", the average speed from the travel time studies, $\overline{S}_{t\ _{TTS}}^{i}$ was required to meet the 90% confidence level. In other words, the point of interest is: is the sample of travel time runs (speeds) adequate to estimate the average speed at a 90% confidence level at ± 5 mph (8.05 KPH):

$$1.645\ \frac{\sigma_{TTS}}{\sqrt{N}} \le 8.05\ , \text{where}$$

σ_{TTS} = standard deviation of UMD travel time derived speed,

1.645 = t statistic for 90% confidence level

8.05 = selected error to tolerate (± 5 mph)

Exhibit I. Link Identification Number, Roadway Section and Boundaries

Link number	Roadway	Boundaries
14003	I-66 EB	VA Rt 123 to VA Rt 243
14004	I-66 EB	VA Rt 243 to I-495
14103	I-66 WB	VA Rt 243 to VA Rt 123
14104	I-66 WB	I-495 to VA Rt 243
19016	I-495 SB	VA Rt 7 to I-66
19116	I-495 NB	I-66 to VA Rt 7
11014	US Rt 29 EB	VA Rt 243 to VA Rt 698
11015	US Rt 29 EB	VA Rt 698 to VA Rt 699
11115	US Rt 29 WB	VA Rt 699 to VA Rt 698
11114	US Rt 29 WB	VA Rt 698 to VA Rt 243

Five vehicles, each equipped with JAMAR travel time meters, consisting of a keyboard, microprocessor with accurate time clock, and connection to the transmission to record accurate

distance, departed on a tour (randomly selected) every 3 minutes during the peak period and every 12 minutes during the off peak. This resulted in replication for each time slice (one hour, during the off-peak), and allowed statistical analysis of the speed on each link/time slice cell. The floating car travel time studies were conducted by random selection of not only the peak period tour for that day but also by selection of the day. For example, one could select MWF for one week, TWT for another week and MTW or WTF for a third week. Considering the costs of vehicles, drivers, and scheduling, we conducted these runs over a one month period during the summer of 1995.

Several drivers and recorders were selected and trained on the use of the travel time meters, using test runs established near the University of Maryland. One series of *runs* was also made on the network in order to familiarize each person with the exact beginning and end of each link.

Data from the travel time meters interfaces with a computer and a travel time analysis program back in the office; thus the analysis was conducted in a very timely fashion. A print-out of a travel time run and analysis are shown in Exhibit J and Exhibit K. Exhibit J shows the travel time for a complete tour of the six freeway links (14003 thru 19116, above) including turnaround (Link 5, at VA Rt 123 & I-66), and ramps (Link 2, I-495 to I-66; Link 8, from I-66 to I-495).

4.2 Statistical   Methods

The travel time runs were analyzed to yield for each link and time slice:

mean speed
standard deviation
90% confidence limits.
sample adequacy at 95% confidence level

The acceptable error was 8.05 kph (5.0 mph). AlI samples (15 min peak, 1 hour off-peak) were adequate for the 90% confidence level;. and all except 2 were adequate for the 95% confidence level. The mean travel time (speed) was compared to the mean speed derived by the cellular based OT.

Speeds from floating car travel time runs (taken over the 4 week field tests - July to August, 1995) were analyzed to produce the mean speed for each identified freeway link (6 links--3 inbound and 3 outbound) and for each 15 min time interval from 6:30 to 9:30 a.m. and from 3:30 to 6:30 p.m. These values are noted as UM Historical or Historical Speeds. During the same "Field Test" time frame, speeds calculated by the TIC (OT) were saved. Because of sampling, the UM runs were not made for every 15 min time slice during the entire test. Likewise, for various reasons, the TIC did not obtain speeds for every time slice, and for other days the calculations were incomplete (e.g. less than 6 of the 12 time slices in a 3 hour peak period had speed data). Thus the example comparisons, such as Exhibit M, have TIC speeds vs. UM, TIC vs Historical UMD or all 3 speeds may be shown for comparison.

Exhibit J. Sample JAMAR Output

Number	Section Length	Travel Time	Stops	Speed	Speed 1	Speed 2	Speed 3	Delay	Fuel (gal.)	HC (grams)	CO (grams)	NOx (grams)	Travel Time	Stops	Speed
Overall Statistics															
1	5042	61 4	0	56	0	0	0	0	0 059	5 6287	109 4846	3 6694	60	0	57 3
2	2375	27 4	0	59	0	0	0	0	0 0281	2 3679	47 7788	1 4712	29	0	55 8
3	12865	142 9	0	61 4	0	0	0	0	0 1577	13 5539	280 7848	8 5126	146	0	60 1
4	9520	106 6	0	60 9	0	0	0	0	0 1142	9 4512	192 3911	5 8905	109	0	59 5
5	11069	312 1	2 3	24 2	83 7	103 9	180 7	161 1	0 1456	15 675	199 8055	10 0305	299	1	25 2
6	10018	143	0 4	47 8	2 4	5 6	24 6	20	0 1169	10 8813	194 7469	7 0184	123	0	55 5
7	12682	374	4	23 1	30 7	96	277 3	205 3	0 1624	16 1667	187 2568	9 914	155	0	55 8
8	1956	129 7	4	10 3	11	93 4	119 3	103 1	0 0363	3 7195	32 8871	1 7819	95	1	14
9	7960	169 7	0 9	32	0 6	20 1	86 1	63 9	0 0983	10 4216	145 2784	7 0717	145	0	37 4
OVERALL		1466 9	11 6	34 2	128 4	319	688	466 5	0 9184	87 8697	1390 4021	55 3625	1161	2	43 2
Speed 1	0	Speed 2	10	Speed 3	30										

Detailed Statistics By Run

Travel Time (sec) by Section

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OVERALL
1	60	29	146	109	299	123	155	95	145						1161
2	62	28	143	105	570	137	262	49	163						1519
3	61	29	140	107	228	187	352	211	201						1516
4	63	28	141	105	254	227	573	196	215						1802
5	57	28	146	107	261	117	685	244	199						1844
6	66	27	147	107	338	118	401	120	177						1501
7	62	25	145	100	246	109	202	64	146						1099
8	59	27	138	115	288	106	143	24	87						987

Stops by Section

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OVERALL
1	0	0	0	0	1	0	0	1	0						2
2	0	0	0	0	3	0	1	0	1						5
3	0	0	0	0	1	1	4	6	1						13
4	0	0	0	0	2	2	6	4	2						16
5	0	0	0	0	1	0	13	12	0						26
6	0	0	0	0	3	0	4	5	1						13
7	0	0	0	0	2	0	0	1	1						4
8	0	0	0	0	4	0	0	0	0						4

Speed (mph) by Section

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OVERALL
1	57	56	60	60	25	56	56	14	37						43 2
2	55	58	61	62	13	50	33	27	33						33
3	56	56	63	61	33	37	25	6	27						33 1
4	55	58	62	62	30	30	15	7	25						27 8
5	60	58	60	61	29	58	13	5	27						27 2
6	52	60	60	61	22	58	22	11	31						33 4
7	55	65	60	65	31	63	43	21	37						45 6
8	58	60	64	56	26	64	60	56	62						50 8

Time Below 0 mph by Section

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OVERALL
1	0	0	0	0	62	0	0	2	0						64
2	0	0	0	0	331	0	16	0	0						347
3	0	0	0	0	2	5	24	27	1						59
4	0	0	0	0	13	12	100	21	2						148
5	0	0	0	0	18	0	71	20	0						109
6	0	0	0	0	101	0	4	6	0						111
7	0	0	0	0	23	0	0	3	1						27
8	0	0	0	0	98	0	0	0	0						98

Time Below 10 mph by Section

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OVERALL
1	0	0	0	0	77	0	0	53	10						140
2	0	0	0	0	366	0	26	7	10						409
3	0	0	0	0	14	11	65	175	27						292
4	0	0	0	0	34	28	175	143	60						440
5	0	0	0	0	38	0	334	221	8						601
6	0	0	0	0	123	0	72	78	19						292
7	0	0	0	0	33	0	0	30	17						80
8	0	0	0	0	119	0	0	0	0						119

Exhibit K. Sample Statistical Analysis of Speed Data

LINK 2 I-66 from I-495 to VA Rt 243

9:30-10:30		10:30-11:30	
Column 1		**Column 1**	
Mean	61.615385	Mean	61.566667
Standard Error	0.5351547	Standard Error ·	0.77561
Median	62	Median	62
Mode	63	Mode	62
Standard Deviation	2.7237642	Standard Deviation	4.248191
Sample Variance	7.4461539	Sample Variance	18.047126
Kurtosis	-0.396166	Kurtosis	0.3792627
Skewness	-0.673344	Skewness	0.0105139
Range	9	Range	20
Minimum	56	Minimum	52
Maximum	65	Maximum	72
Sum	1602	Sum	1847
Count	26	Count	30
Confidence Level(95.000%)	1.0468823	Confidence Level(95.000%)	1.5201654

Link 5 I-66 from VA Rt 243 to I-495

9:30-10:30		10:30-11:30	
Column 1		**Column 1**	
Mean	57.16	Mean	57.653846
Standard Error	0.8340264	Standard Error	0.8245135
Median	57	Median	58
Mode	60	Mode	60
Standard Deviation	0.1701319	Standard Deviation	4.2042103
Sample Variance	1739	Sample Variance	17.675385
Kurtosis	0.0169581	Kurtosis	0.4262781
Skewness	-0.145162	Skewness	-0.555751
Range	16	Range	18
Minimum	49	Minimum	48
Maximum	65	Maximum	66
Sum	1429	Sum	1499
Count	25	Count	26
Confidence Level(95.000%)	1.6346592	Confidence Level(95.000%)	1.6160143

Finally, as presented in the Discussion Section, below, a revised algorithm was developed by ES to obtain better speed estimates in certain conditions. Some comparisons also show the ES speeds.

4.3 Disc-

Appendix C contains several tables showing speeds by link, by time of day and date from the UM travel time studies (TTS) as well as similar speed from the OT for each link. The "Historical UMD" speeds are the average speeds by 15 minute time periods obtained by many travel time runs over the four week field tests as shown by Exhibit L. Links 19106 and 19116 on I-495 had fewer travel time runs due to: determining that the round trip time on the two I-66 links took about 15 minutes and; fewer probes were noted on I-495 (possibly because this link is further from the DFS towers).

Exhibit L. Number of Travel Time Runs, by Link and Time Period

	LINK (Refer to Exhibit I)			
	19106 & 19116	14104 & 14004	14103 & 14003	US Rt 29 all links
AM peak 6:30 am - 9:30 am	191	488	488	67
PM peak 3:30pm - 6:30pm	246	495	442	
Off peak 9:30 am-12:30 pm	92	166	74	
Off peak 12:30 pm-3:30 pm	124	153	82	
Evening 10:00 pm-2:00 am	19	19	19	

A selected typical day with no incidents is shown in Exhibit M. The speeds for that day (7/3 1/95) were slightly higher than the historical UMD speeds for link 14003 (I-66 EB from VA Rt 123 to VA Rt 243). The speeds shown in Exhibit M for link 14 103 (I-66 WB from VA Rt 243 to VA Rt 123) are slightly higher for most time slices but are lower for three time periods. However the differences in speeds are slight.

During some time periods, the difference in speeds between the TIC results and the TTS speeds was substantial. An analysis of the TIC results showed that in some cases the algorithm used to calculate speeds would not drop a fix which had an obviously incorrect reading (i.e. a speed which was impossible to achieve in the time since the previous fix), resulting in an inaccurate estimate of

Exhibit M. Speeds for Representative Day (without incidents)

link 14003 (I-66 EB from VA Rt 123 to VA Rt 243) 07/31/95

link 14103 (I-66 WB from VA Rt 243 to VA Rt 123) 07/31/95
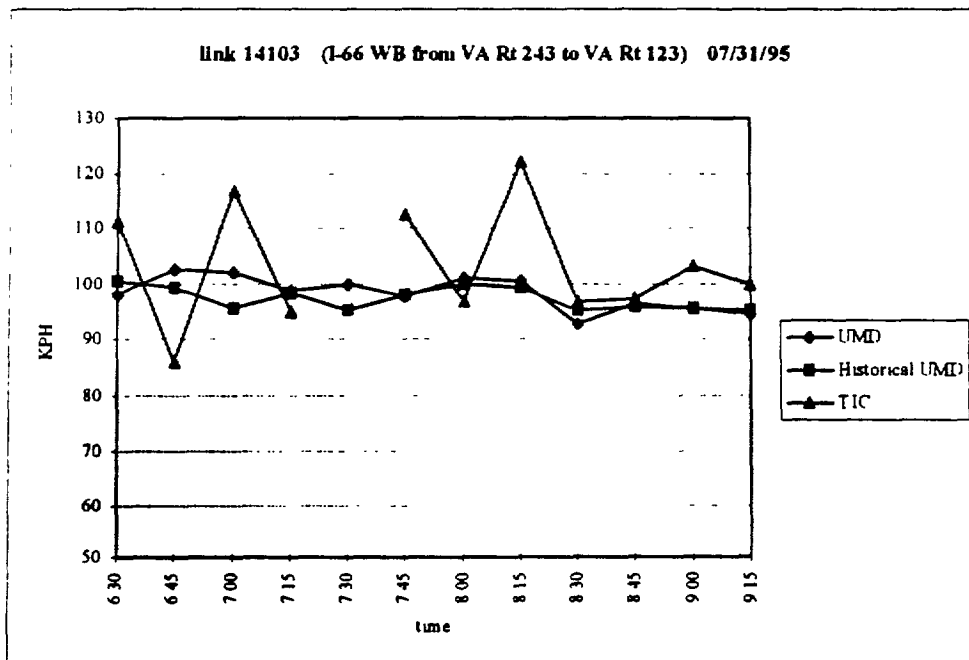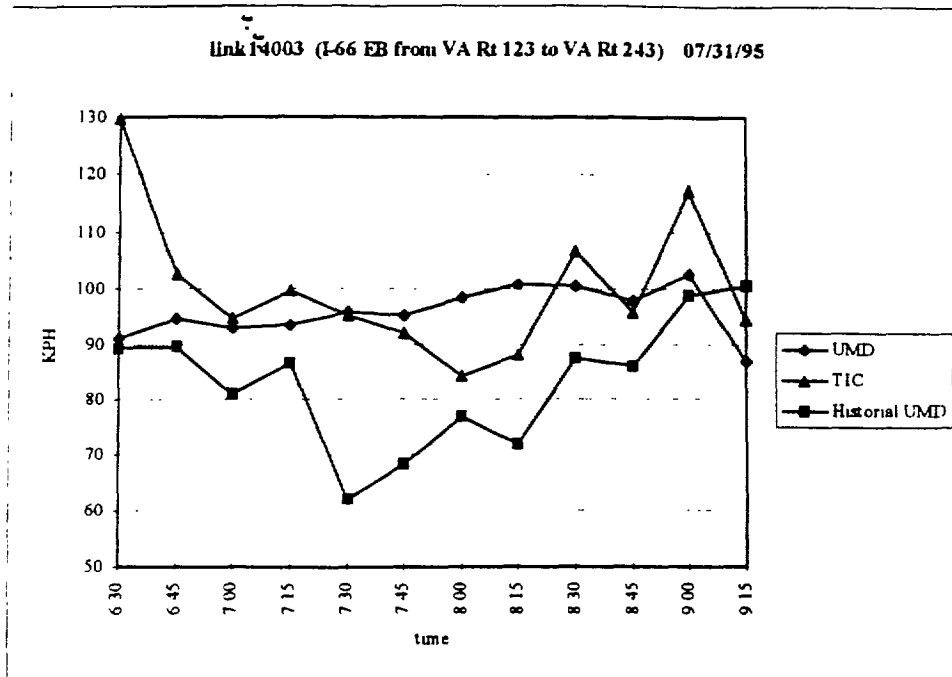
vehicle and link speeds. In an attempt to modify this situation. a special test was conducted on Nov 14, 1995, with a revised algorithm that was created by Raytheon E Systems (shown on graph as ES).

This revised algorithm was based on the original TIC (or OT) algorithm, but had one basic modifications, it would use "logic" to determine if the fixes for a particular vehicle were all possible For example, nine out of ten fixes may give nine locations of a vehicle so that its speed, from fix to fix, can be determined to be in the area of 100 KPH, but the tenth fix may give a location that would generate a speed calculation between its ninth and tenth fixes in the area of 250 KPH, an unlikely and impossible speed The revised algorithm takes into account this type of situation and uses some "logic" to determine whether to use all available fixes when determining the speed of the vehicle or to drop any that are highly likely to be incorrect. Due to the creation of this revised algorithm, all travel time data analysis from that point on not only included the field data run by the original TIC algorithm, but also analysis with the revised algorithm, which is labeled in exhibits as ES.

As should be expected, speeds during an incident usually drop substantially, depending on the severity (number of lanes blocked) of the incident. Exhibit N shows the speeds for the AM peak (7/13/95) when a minor incident occurred. The characteristics of the incident are shown below the graph, The TIC, ES and UMD speeds are shown to track the incident with lower speed at 7:45, when the incident occurred Appendix D contains additional graphs for this day. Although the incident was reported in the log provided by the VA State Police as 8: 15, it was later determined to have happened about 7:45 by notes taken by the UM travel time teams. This graph illustrates what appears to be a combination of normal recurrent congestion and a minor incident. The scatter of travel speeds by 15 minute increments reflects the fiction in a heavy traffic stream, and the difficulty of seperating congested flow from incident flow.

Exhibit 0 shows that the TIC (OT), ES (using a revised algorithm) and UMD estimated a speed reduction at 7:45 am, recovering at 8:15 am. The actual incident occurred at approximately 7:30 am, according to the VA State Police. The historical speed is shown on the exhibit, for comparison, since this link was not sampled by UMD during this AM peak incident. The historical speeds at 7 45 and 8:00 am are 40 to 55 KPH, but the ES speeds during the low point of the incident (7:45 - 8:00 am) were about 18 KPH, a very significant reduction.

Exhibit P shows the speed comparison for another day with an incident. The speeds dropped, but the time of the speed changes do not always match the actual time of the incident, in this case at 7: 15. Some reasons for this are: (1) an incident (right or shoulder lane) may not cause a huge shock wave immediately but may reach a long queue in 5 to 10 minutes, (2) the time of detection by UMD travel time vehicles could be about 15 minutes (time for a round trip tour of 4 links), or (3) the speeds of probe vehicles have some lag before being classified as an incident by the TIC. The UMD run stopped at 8:45 because the congestion would not allow turning around and making another round trip for four links.

The speed data available for both the UMD travel time study and for the OT for the same time period/link varied from less than three days to a maximum of six days. An analysis was conducted to compare the speed for three link/time periods (with six observations) testing the hypothesis:

$$S_t{}^1{}_{TTS} = S_t{}^l{}_{OT}$$

Exhibit N. Representative Day, with an incident

Travel Time Speeds 07/13/95 link 14003
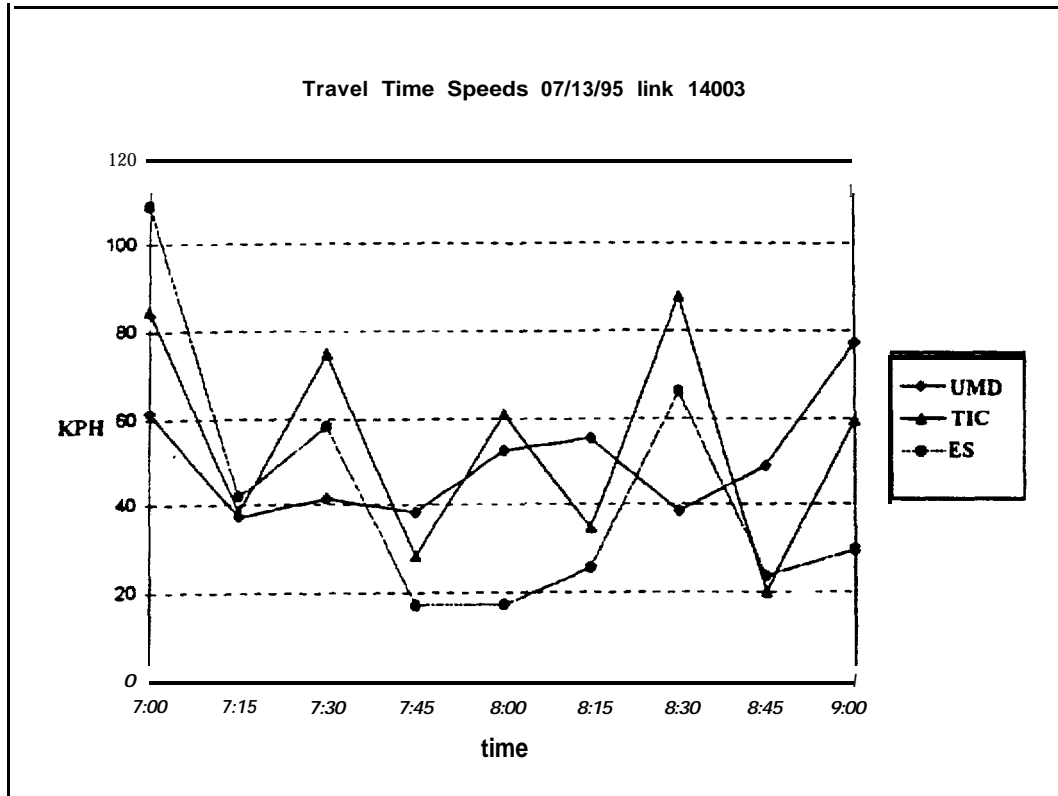
Incident 303

TIC -- incident log (7/13)

-- alarm on link 14003 at 08: 19 by SBIDA
-- confirmed on link 14003 at 08: 19 by SBIDA
-- terminated on link 14003 at 08:26 by SBIDA
-- TIC showed a decrease in travel speeds for the 08: 15 time period (from graph)

VDOT

-- incident occurred on7/13 at 08:15 on I-66 EB, 0.75 miles West of RT243
-- occurred in Iane 3 (next to "green arrow lane" shoulder lane)
-- three car incident (rear end)

Fairfax County

-- no record of incident

UMD

-- UMD showed a decrease in travel speeds from the 08: 15 time period (from graph)

Exhibit O. Morning with Incident without UMD speed

Travel Time Speeds 07/24/95 link 14003
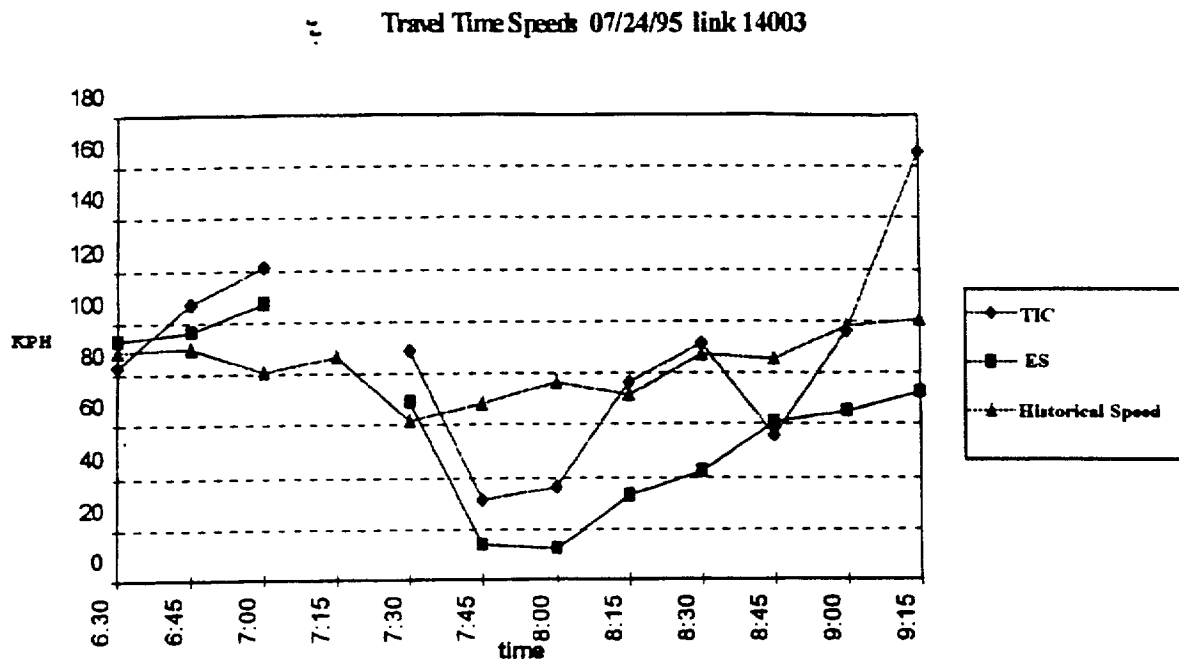
Exhibit P. Morning with Incident with UMD Speed

Travel Time Speeds 07/25/95 link 14003
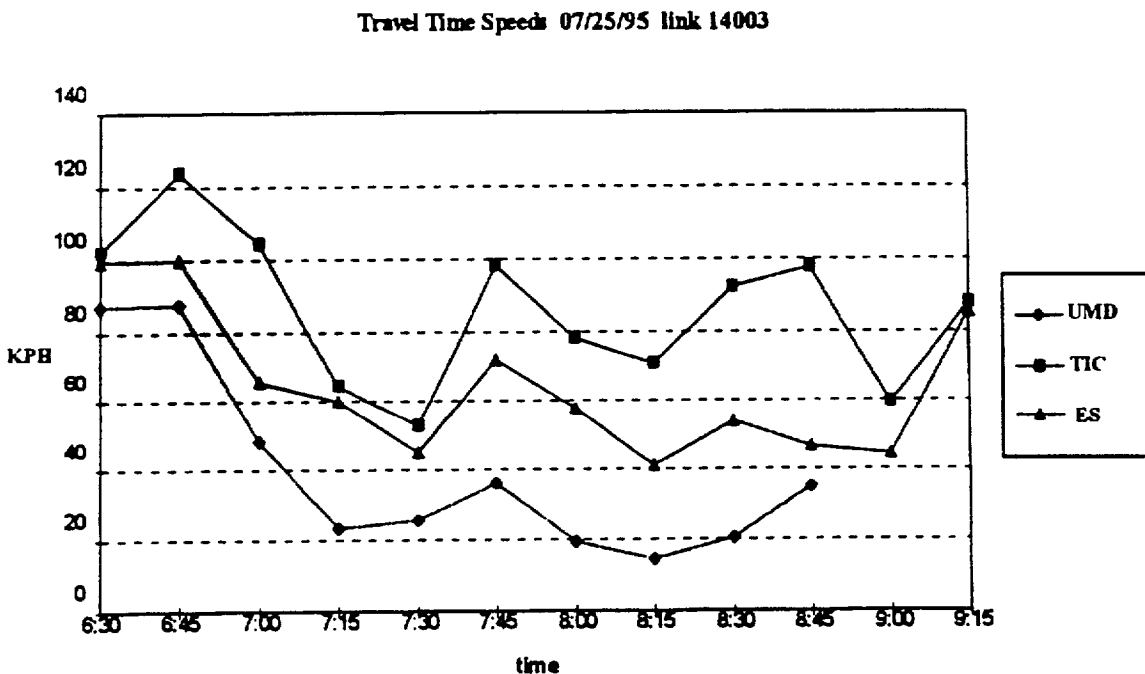
The result of this analysis are shown in Exhibit Q. The high t value for the 95% confidence limit for the TIC data indicates that the speeds do not compare favorably, even when the numerical values are (e.g. link 14103, 8:45 to 9 -- 95.3/vs 97.6 kmph), very close. Because of the scarce data and wide variation in data, further statistical analysis would not be worthwhile. Thus the graphs presented in the report were felt to be the best presentation method.

4.4 Wide Area Surveillance: Signalized Arterials

This test is a special case of surveillance capabilities of the technology on a signalized arterial. US Rt 29, roughly parallel to I-66, between Prosperity Avenue (VA Rt 699) and Nutley Street (VA Rt 243) was selected for testing. The same fleet of vehicles equipped with the travel time meters was used to conduct this test on July 27, 1995. Similar to the freeway links, the test was divided into 15 minute time intervals during the AM peak period. Speeds were obtained on each of four links along the arterial. Exhibit R shows the speeds from this test. The intent was to compare the TIC speeds from cellular probes with those from the Travel Time Study. Unfortunately, no TIC data were available for the actual test period/date.

The data samples from the OT for other days for these arterial links are sparse, and not large enough to make a good comparison. However, Appendix E shows the link speeds determined by the TIC for 12 different days and the speeds determined by the Travel Time Study for this one day of testing. Because of inadequate data, a comparison similar to that of the freeway data was not done.

The experience with the US Rt 29 arterial is that not many probes were identified, possibly because of limited cellular use on a facility requiring more driver attention than on a freeway. This could change with improved automated features such as: voice dialing, radio fade out, speaker use, etc Otherwise, surveillance on signalized arterials may be difficult with a cellular system.

If a signalized arterial is integrated as part of an ATMS, the cellular system can serve to provide additional information, such as verification of an incident. However if the arterial is not part of an ATMS, the cellular technology may be capable of providing surveillance, but only with other technology improvements and the development of a location specific algorithm for identifying incidents.

V. INCIDENT DETECTION

An important element of freeway management is "Incident Management" (IM). The first step in IM is incident detection, and since the cellular system is monitoring speed on each freeway link, it is logical to determine significant changes in speed. However, a sudden drop in speed does not necessarily mean that an incident has occurred. Speed changes occur due to recurring congestion, especially at points where the network geometry changes, such as at a lane drop or a two lane on-ramp with poor lane balance, etc. Thus, careful attention must be given to establishing an algorithm that has an acceptable alpha error (fails to identify a true incident) as well as beta error (false alarm, identifies an incident when there is none).

Exhibit Q. Selected Comparison of UMD and TIC Speeds

link 14103
time period 8:45 - 9:00 am

UMD

	Column 1	
88 6		
92.9		
94.2	Mean	95 316667
98.2	Standard Error	1 818134
101 4	Median	95 4
96.6	Mode	#N/A
	Standard Deviation	4.4535005
	Sample Variance	19.833667
	Kurtosis	-4.75E-05
	Skewness	-0.228609
	Range	12.8
	Minimum	88.6
	Maximum	101 4
	Sum	571.9
	Count	6
	Confidence Level (95.000%)	3.5634718

TIC

	Column l	
84 5		
118 1		
95.1	Mean	97 583333
118 2	Standard Error	7 4671019
72 1	Median	96 3
97.5	Mode	#N/A
	Standard Deviation	18 29059
	Sample Variance	334.54567
	Kurtosis	-1.19074
	Skewness	-0.06886
	Range	46. I
	Minimum	72.1
	Maximum	118.2
	Sum	585.5
	Count	6
	Confidence Level (95.000%)	14.635229

Link 14103
time period 5:00 - 5:15

UMD

	Column l	
95.8		
88.9		
96.6	Mean	93.2
95.3	Standard Error	1 6682326
89.4	Median	95.3
	Mode	#N/A
	Standard Deviation	3 73028 15
	Sample Variance	13 915
	Kurtosis	-3 163561
	S kewness	-0.54776
	Range	7 7
	Minimum	88.9
	Maximum	96.6
	Sum	466 y
	Count	5
	Confidence Level (95.000%)	3.269671

TIC

	Column 1	
120 8		
90 7		
97.1	Mean	108.06
118 3	Standard Error	5.9882051
113 4	Median	113.4
	Mode	#N/A
	Standard Deviation	13.390034
	Sample Variance	179.293
	Kurtosis	-2.423687
	Skewness	-0.564843
	Range	30. I
	Minimum	90.7
	Maximum	120.8
	Sum	540.3
	Count	5
	Confidence Leve1 (95.000%)	II.736649

link 14003
time period 6:15 - 6:30 pm

UMD

	Column 1	
101.5		
101.9		
99.8	Mean	101.16
98.6	Standard Error	0.9255269
104	Median	101.5
	Mode	#N/A
	Standard Deviation	2.06954 1
	Sample Variance	4.283
	Kurtosis	-0.385979
	Skewness	0.1907637
	Range	5.4
	Minimum	98.6
	Maximum	104
	Sum	503.8
	Count	5
	Confidence Level (95 000%)	I 8139967

TIC

	Column l	
101.2		
112		
109.8	Mean	109.46
102.7	Standard Error	3.6597268
121.6	Median	109.8
	Mode	#N/A
	Standard Deviation	8.1833978
	Sample Variance	66.968
	Kurtosis	-0.054771
	Skewness	0.7094701
	Range	20.4
	Minimum	101.2
	Maximum	121.6
	Sum	547.3
	Count	5
	Confidence Level (95 000%)	7 172922

Exhibit R Speed Data for U.S. 29 : Signalized Arterial, Thursday,   7/27/96

UM = University of Maryland Travel Time Meter Average Speed for each time interval

TIC: See Appendix E ,for best comparable data

Link 11014	Link 11015	Link 11115	Link 11114
63.3	50.1	58.5	68.9
61.7	70.2	62.6	69.4
66.3	71.3	65.4	65.2
55.2	50.1	59.6	59.7
47.5	48.0	52.7	63.6
45.1	25.8	45.9	58.0
48.8	10.9	54.3	66.0
64.1	17 7	59.9	58.8
54.9	39.0	62.8	58.9
51.5	48.9	56.0	67.3
68.8	60.0	52.3	58.8

- All speed in KPH

Link No	Description
11014	EB - from Nutley to Cedar
11015	EB - from Cedar to Prosperity
11115	WB - from Prosperity to Cedar
11114	WB - from Cedar to Nutley

In order to determine how well the cellular system identified incidents. arrangements were made with the traditional incident sources to provide log reports of all incidents during the operational test. Those providing data were:

- Virginia State Police
- Fairfax County Police
- Virginia Traffic Management Center
- Media
- MSHA

During the 10 week OT, few incidents (accidents) were reported by the two police agencies and the Virginia TMC. However, shoulder incidents (stalled vehicles, flat tire) were not reported by the police agencies, even though they had been requested to keep a log of all incidents Appendix G shows an example log from the Virginia State Police and from the Fairfax County Police. Some remote users noted that they used this system to verify incidents reported by 91 1 or *#77.* indicating some delay in detection by the system.

On the other hand, output from the OT through the TIC showed many alerts for substantial speed changes with several instances being identified as possible incidents. Many of these possible incidents terminated if the speed reduction did not continue or if the speeds began to rise.

During the 10 week OT over 500 potential incidents were identified by the TIC. In looking at July 24, 1995, 57 alarms were sent from the TIC as potential incidents. Of these, one was a false alarm set off by a remote user to test the system. Of the remaining 56, eight were identified by the TIC as incidents. Within 12 minutes of each alarm being set off, all of the incidents and potential incidents were terminated. Examining the eight confirmed incidents, they had an average duration of 7.25 minutes before the "incident" was terminated by the TIC. More importantly. only one of these eight was verified by examining the police reports. The fact that the speeds began to increase toward normal indicate that these (48) "incidents" were probably false alarms. Also, seven of the eight may be false alarms. However the possibility does exist that the other seven identified incidents were shoulder incidents that were not recorded by the police. In any case, the false alarm rate, based on potential incidents, is at least 48/56 initially, and may be as high as 55/56. However, since the system verified 8 "incidents" the false alarm rate may be as high as 7/8. Similar to the potential incidents, some of these seven could be shoulder incidents, not recorded by the police agencies. Thus, the available data simply does not allow definitive conclusions on false alarm rate. On the other hand, out of 30 incidents from police logs during the 10 week long OT, the TIC identified 28 of 30.

On July 31, 1995, the TIC reported 28 potential alarms for incidents, but none of these were confirmed as incidents and all were terminated. In comparison the police data logs reported no incidents in the network for this date. However some of these could have been shoulder incidents, not included in the police logs.

Such a high false alarm rate indicates either occasional inaccurate speed data and/or an incident detection algorithm that is based on data (speed) that is too erratic. A better algorithm using only speeds could consider speed upstream and downstream as well as a trend of speed change over the past (say 1 to 5 minute) time interval. As discussed in Section IV, revision of the algorithm for calculating speed from a series of fixes on a probe (5 or more) could eliminate (drop) speeds that are illogical or otherwise highly unlikely, and would very likely eliminate some inaccurate speed estimates, which would also reduce false alarms.

No good measure of time to detect was available, but there were indications from remote users that the system identification logged 911 (# 77) calls. That is the 911 and #77 calls reported incidents-by-voice before the system would work through the problems and software to estimate a speed reduction and thus declare a probable incident.

VL CAPACITY/LIMITS OF TEE SYSTEM

The cellular system, as configured for this operational test, could handle all the probes that send a signal strong enough and long enough to obtain 3 or more fixes (e.g. calls O 15 seconds). The calling magnitude has doubled in the past three years and the changes in the cellular environment (substantial increases in user population and the move from vehicle based to portable cellular phones) and resulting lower powered signals both from the phones and from the BANM towers led to a denser system than the originally conceived system of 1 DFS/4 towers and 1 TAS/4DFS sites to a 1 to 2 ratio. With this infrastructure there is no practical limitation, since it can handle at least 50 signals, with overlap, at one time - which is more than enough probes to estimate speeds. Because of changes in the cellular environment (Section 1,2,3), there is not always sufficient probe data to derive an accurate speed estimate. Data provided to UM by Farradyne was not adequate to determine the number of probes required for accurate speed estimation. However, revision of the speed algorithm by E Systems indicated that about 5 fixes/signal (vehicle) was adequate for determining the speed of that one vehicle (Section IV, 4.3). Based on the UM travel time speeds, a sample of 5 speeds/l5 minutes was adequate for the 90 and 95% confidence level + 5 mph. Thus, five accurate speeds (probes) should be adequate for monitoring or surveillance We found that some speed estimates were reasonable with as few as four to six probes per time interval. During the peak periods, there was never a lack of probes. Even during the off peak/evening when the time slice was one hour, the number of probes was adequate for non-incident speed estimation.

Freeways have more than enough potential probes to provide traffic data. On the other hand, the number of speed calculations for 12 days on one arterial (US 29) was marginal for surveillance. With continued cellular growth, this number is very likely to increase and probably will be sufficient in a short time. Cellular activity increases immediately after an incident, providing more probes during an incident. Thus, it appears that properly configured and located DFS/TAS elements has quite adequate capacity for wide area surveillance. Better geolocation and an improved algorithm for estimating speeds will result in even higher system capacity and accuracy.

VIL ROLE OF DERIVED TRAFFIC INFORMATION

The final operational test did not result in widespread use of derived traveler information or traffic information for agency users, as originally envisioned. We used a questionnaire (Exhibit S) and requested that agencies complete a log (Exhibit T) of use of the derived data. The limited number of users resulted in data that is more indicative of use rather than definitive use data.

Exhibit S. CAPITAL IVHS Questionnaire

CAPITAL IVHS Questionnaire

(Cellular telephone based Operational Test/Wide Area surveillance)

Name _____   Agency _____

1. How did you use the information from the cellular based surveillance system?
    a) To identify incidents _____   b) To verify incidents _____
    c) To alert patrol _____   d) To modify/active VMS/HAR _____
    e) To verify system status _____ f) To determine system status _____
    g) Other (please discuss) _____

2. How frequently did you use the system?
    a) Several times per day _____   b) Daily _____
    c) Weekly _____   d) Only for incidents _____
    e) Other (please verify) _____

3. If you did not use the information frequently, why?
    a) Did not yet know its reliability _____
    b) Existing system determines status and detects incidents _____
    c) Output is too difficult to interpret _____
    d) The system is too difficult to use _____
    e) Other (please discuss) _____

4. What difficulty, if any, did you experience in understanding the data format?

5   What suggestions do you have for changing the data format?

6. How useful was the data for your activities?

7. What could be changed to make the data more useful to you?

8. What changes could be made in your operation (TMC) to make this data more useful?

9   What the information accurate enough for your use?

10. Was the system easy to learn how to operate? Why or why not?

11. What problems did you have with the system?

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Exhibit T. Example Operational Test Log Derived Data Sheet

CAPITAL IVHS OPERATIONAL TEST LOG OF USE OF DERIVED DATA

Agency _____

Date	Time	User	Purpose/Specific Use

COMMENTS:

Copies of the questionnaires received from remote users are included in Appendix F. In addition, interviews were conducted with personnel at each remote site. In general, there were early "start up" problems with the system crashing, false alarms for incidents and the like. Toward the end of the operational test, the system was used to verify incidents identified by cellular 9 11 (and by other means, #77).

The Fairfax County Police used the system to verify incidents and the status of their current system, which already identifies and detects incidents. There were problems of the system "locking up". The Virginia State Police used the derived data daily, but only to verify incidents identified by their existing system. They experienced similar problems early on of their system also "locking up".

The limited number of users generally expressed relative satisfaction with the system but were disappointed with the system being "down" in the early stages and providing rather limited user options/capacity. Thus, the cellular based wide area detection system appears capable of being used in providing "derived" data (speed, possible incident, etc.) to traffic operations/traffic management units. Unfortunately, the early problems in deploying the OT and early problems with computer stations resulted in not enough use for a definitive analysis.

VIII. ROLE IN TRANSPORTATION PLANNING

This element of the evaluation was almost an afterthought. Discussions were held with transportation planning persons at MSHA and MNCPPC, who agreed to participate. However, when the operational test was restricted to northern Virginia, they were not contacted again. The remaining agencies are:

1   Metropolitan Washington Council of Governments

2   Fairfax County Transportation Division

3.   VDOT, District Office/Richmond Office

Primary responsibility for air quality monitoring and congestion management in the Northern Virginia area is with the Metropolitan Washington Council of Governments (Wash-COG). Interviews (based on their viewing the system, attending steering committee meetings and briefings), with Wash-COG personnel identified two activities where CAPITAL data might be useful, as follows:

1. Congestion Management System (CMS)

For the CMS, Wash-COG evaluates, on an annual basis, the locations and extent of congestion in the region. For the limited access highway system (freeways and expressways) they have relied on an aerial survey which provides densities used to estimate average speeds on the links. Because of cost limitations the surveys are limited to peak period coverage on a three year cycle. If the Capital-IVHS system could provide average speeds it could be a direct measurement instead of an estimation and speeds should be available on a 24 hour basis.

For arterial highways they have been relying on the demand model forecasts to provide them with average speeds. This is supplemented by periodic travel time/speed measurements on a limited number of facilities. There is a great need for speed/travel time data on arterial highways in order to perform an assessment of existing conditions. They hoped the Capital ITS project could provide the information on the arterial system in addition to the freeway system. However, the arterial test runs (US 29) were not definitive enough to ascertain whether arterial speeds could be obtained without some system modifications.

Presently, they do not include any estimates of non-recurring congestion. The annual report could indeed be enhanced if they can provide an assessment of the impact of non-recurring congestion. Maryland and Virginia are implementing incident management programs which would have air quality implications if indeed the delay from incidents is reduced. The data, when available (from a CAPITAL ITS type system or conventional surveillance system), could enable them to quantify the benefits of an incident management program.

2. Demand Model

Wash-COG is in the midst of a model improvement program which will improve the way demand modelling is done in the region. In order to validate the model, volume and speed data will be required on many of the facilities in the region. In addition the demand is periodically validated to meet Federal requirements. Speed data from the cellular system could satisfy some of the needs.

The data which can be provided to transportation planning agencies from the cellular system include:

- Frequency distribution of non-recurring congestion - along with the reduced speed; duration of incidents; other

- Speed profiles by time of day (real time) data by freeway link.

It appears that cellular derived data could be reliable and accurate enough to use for congestion management and air quality monitoring; thus, the region could benefit from better transportation management using the cellular based system, if the cost to Wash COG is the marginal cost of remote unit installation.

No surveillance system has yet claimed the capability to distinguish between recurring congestion and non-recurring congestion (incidents), except a well staffed and dense video system which is quite expensive to install and operate.

IX. PUBLIC ACCEPTANCE

BANM assumed responsibility for "Public Relations" including handling inquiries from the public, press releases, and in general all public contacts for the CAPITAL Team.   The primary objective of the public relations effort was to ensure that responses to inquiries were timely, accurate and consistent. BANM fielded no direct inquiries from its customer base regarding the operational test, in spite of a number of articles in the local press, national trade magazines, and two local radio interviews.

Inquiries from the press to any member of the CAPITAL Team were handled in a coordinated fashion. Early in the project an executive summary was developed which described the test objectives, implementation plans, and the project approach to insuring caller privacy. This document, approved by the project Steering Committee, was available to each team member and was pre-approved for distribution to the media and general public. In most instances press inquires could be satisfied with a copy of the project Executive Summary, and some supplementary information on the current status of the project. All other printed material concerning the project (papers, promotional brochures, briefings, etc.) were subject to review and approval by the Steering Committee prior to release. On two occasions requests for radio interviews were received by Raytheon E-Systems. Following discussions with members of the Steering Committee, both of these requests were handled by BAM's public relations staff.

In an attempt to address the primary concern of most organizations inquiring about the project, any printed material. or oral briefs on the project were required to include a statement concerning the measures undertaken to ensure caller privacy. The following statement, contained within the Executive Summary was typical.

"The manufacture and use of the system in this test is in compliance with the Telephone Disclosure and Disputes Resolution Act and FCC Docket 93-1 implementing this act, given that the receiving equipment is being used pursuant to a contract with the Federal Government and in concert with a licensed cellular carrier. The privacy of individual cellular users is completely protected throughout the Operational Test and Demonstration. At no time is the identity of the cellular phone (phone number or electronic serial number) accessible to any patties operating the system, and at no time are the voice conversations monitored. The transmissions are assigned random id numbers which are used by the system to compile traffic data, but do not allow any information on specific individual cellular users to be obtained."

While members of the CAPITAL team sought to make the ITS community aware of the status and findings of the project, no organized effort was made to disseminate this information to the general public. It is felt that the technical nature of the project, and the general public's lack of understanding of RF communications in general, and cellular communications specifically, contributed to a lack of interest on the part of both the press and general public.

X. REQUIREMENTS OF INDIVIDUALS/FLEET USERS

The activities being assessed here include:

1.   Fleet operator (NOVA) consisting of

a - GMU shuttle transit vehicular

b - Package delivery vehicles

2.   Information for individual travelers-FHWA setup at the Turner-Fairbank Highway Research Center

Final logs and interviews were conducted in April. NOVA Transportation used the information several times per day to identify incidents and to verify incidents identified by the media. The fleet operators see many incidents almost "as they happen" - before the OT system identified them. They indicated the system was easy to use, "once the modem problem was fixed". The concept of the informational kiosk at the FHWA Turner-Fairbank Research Center was excellent, but the large percentage down time discouraged most potential users. Nevertheless, several individuals expressed a positive attitude about the "information center". In summary, those who participated or viewed the system felt that it could be useful in providing information on traffic operations and travel conditions.

In summary the logs and interviews with FHWA and NOVA personnel were all positive. However not enough data were available for an analysis.

XL COSTS

11.1 - Cellular Based System Costs

As with most new systems and new applications, there are development (or R&D) costs that do not reflect the system costs for subsequent systems (or applications). This is representative of the cellular system. Since this is a new system, unexpected problems also developed. As described in Section I., Introduction, the 1995 cellular system was substantially different from the system which existed when the CAPITAL-IVHS Project was proposed. The explosion in the population of cellular users and the switch from vehicle based to portable (with very low power) cellular phones were the fundamental changes. Added to these changes was a modification in the tower transmissions. Before, the typical transmission from the towers to a phone used an omni-directional antenna. Now the transmission is by directional antenna, reducing the hearability, and resulting in many dropped calls (by the OT, TIC).

Each of these changes, either by design or result, has had the effect of reducing the range from which a cellular phone transmission could be heard. When the CAPITAL System was conceived, ES knew that placing Direction Finding equipment at every tower would not be economically practical. The original estimates were that one in four cellular towers would be equipped with a DFS and one in four DFS sites would need a TAS. However, the 1995 cellular environment required the system

to place direction finding equipment at 1 in 2 vs. 1 in 4 sites. While more equipment is needed, the impact of falling semiconductor and other electronic equipment prices makes this approach a viable consideration for future systems. For the OT. this led to additional cost per square mile monitored.

The estimated costs of system elements in production (with the R&D costs removed) are shown in Exhibit U. The costs of the project "system" are shown in Exhibit V. Other system costs include Tower leasing and tower site preparation which included:

 Environmentally Controlled Room
 Electrical Power
 T- 1Facility and Interface (TP-9000)
 Standard Phone Line
 10 Mhz Reference Source
 Pre-existing Tower/Mounting infrastructure

The costs actually incurred (average per site) were:

Room	$3,000
10 MHZ Reference	$1,500
T- 1 interface	$3,000
Tower Mounting	$600
Total One-Time Cost	$8,100

Monthly Leasing:	Tower	$750
	T- 1 Facility	$560
	Phone Line	$24

Total Monthly Cost	$1,334

In addition, there are on-going operation/maintenance costs, which were not estimated by the OT.

Exhibit U. Production/Installation Costs

	No. of Units	Labor	Material	Total Cost	Non-Recurring*
DFS	7	570,229	1,600,2 16	2,170,445	754,053
GCS	1	113,018	34,905	147,923	405,217
TAS	2	101,375	299,525	400,900	361,264
TIC	1	10,000	55,000	65,000	484,457
Remote 01	4	Included in TIC			Included in TIC
TOTAL		$794,622	$1,989,646	$2,784,268	$2,005,19 1

Non Recurring Subsystem Costs - Operational Test

Exhibit V. Estimated Unit Costs for Production Units

	QTY 1	QTY 3	QTY 18	QTY > 50
DFS	n/a	0.125M	0.l00M	0.085M
TAS	Included	in	DFS	Pricing
GCS	0.075M	0.065M	0.060M	0.057M

Assumptions: minimum 3DFS units required
One GCS is required for every 10 DFS's

11.2 Cellular Based Versus Loop Based Cost Comparison

Cost data for traditional loop based surveillance was obtained from MSHA and from consultants involved with surveillance systems. The rounded, in place, costs for a two loop pair in each lane of an 8 lane freeway is $50,000 (MSHA estimate); $10,000 (FHWA estimate); and an intermediate value of $25,000. The higher values reflect actual bid contract prices, including WZTC costs for installing under heavy traffic (even for off peak work). We assumed a l/2 (0.8 km) mile spacing of these loops.

We selected the Baltimore-Washington D.C. corridor which has about 24 miles (38.6km) between beltways, and contains: I-95, an 8 lane freeway; Maryland 295, a 4 lane parkway; US 29 and; US 1, two major arterials. This corridor was used as a case example to compare the costs of the cellular network with a loop detector based network. Exhibit W depicts the cellular network covering 24 miles (38.6 km) with 23 towers. Exhibit X shows the cellular system costs.

The capital costs for the information system can be rather low, as in the case of a TIC, which would have a monthly cost of approximately $l,334/month for a dedicated telephone line, tower and T-l leasing. The OT costs for the TIC included development costs of about $500,000 and installation/materials costs of $65,000. If a TMC is used, it could have either a low initial cost or a high initial cost, with lower monthly costs depending on owned cable versus leased cable and it may be bare bones versus the state of the art SOC in Maryland - very expensive but with multi-purposes.

Costs for the loop based network are shown in Exhibit Y. For the two arterials with traffic signals, we assumed that many existing loops could be used and that 3/4 of a full set of loops would be required. In addition, cable (fiber optic, telephone line) is required to connect each loop and controller into a TMC. For incident detection for either system, it would be desirable to have a system such as CCTV available for incident verification. However, this is a cost for all systems assumed to be the same regardless of the system.

As can be seen, the cellular system is significantly less expensive than a loop based system, based on MSHA costs. It is slightly less expensive, based on the $25,000/mi and more than double the FHWA costs (No WTZC costs), $2,736,300 Vs. $1,132,000.

Exhibit W. Example Cellular Network
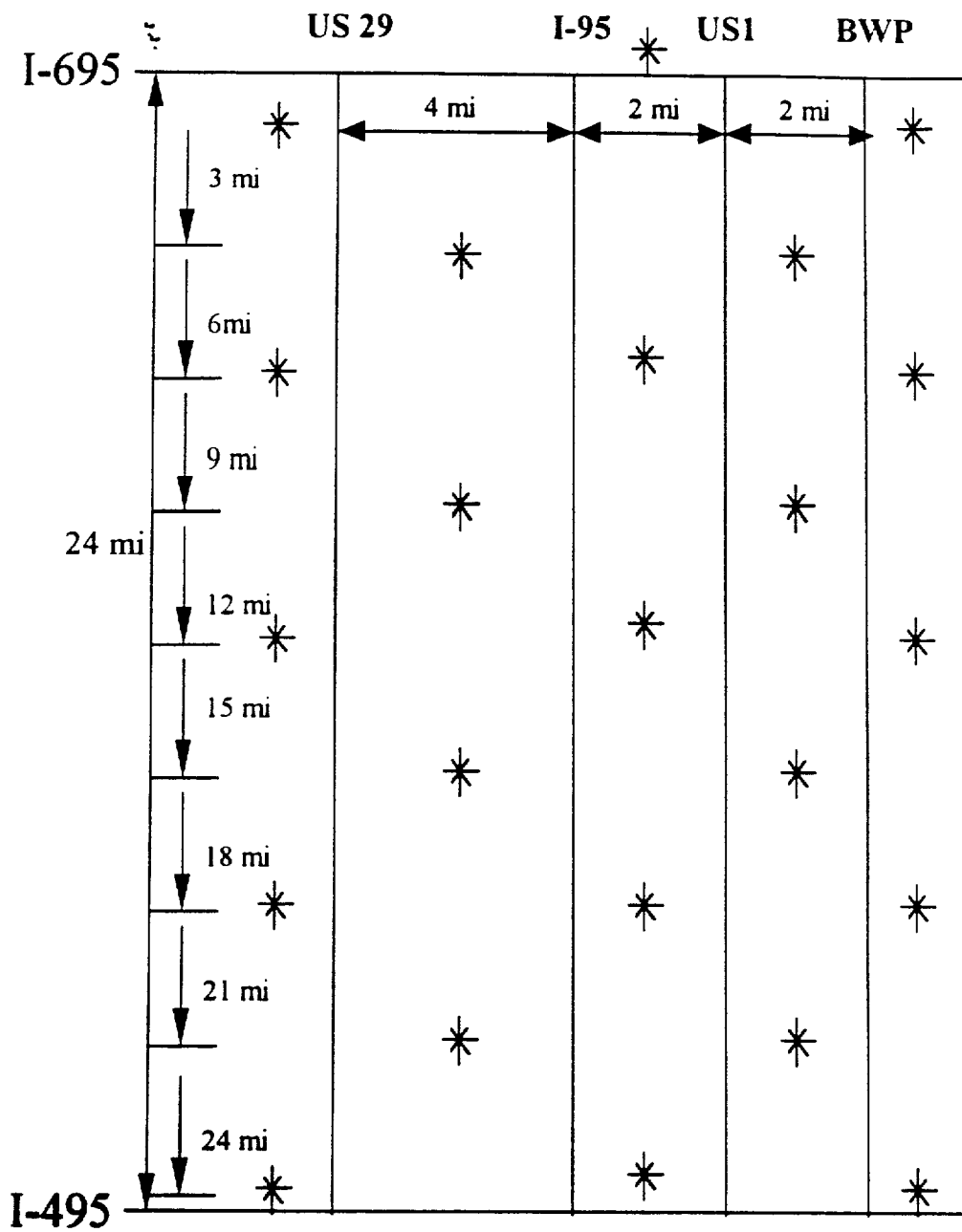
BWP = Baltimore - Washington Parkway

✳ = Cellular Tower

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Exhibit X. Example Costs of Cellular Based Network

network area	192 sq. miles (497 sq.km)
23 towers with 23 DFSs (w/TAS) @ 100,000 each	2,300,000
1 GCS per 6 DFSs	250,000
Site Costs ($8,100 each) (23 towers)	186,300
Total	**$2,736,300**

Exhibit Y. Example Costs of Loop Based Network

	$50,000/mi	$10,000/mi	$25,000/mi
1-95 24 miles $/mile/8 lanes (2 loops/lane) w/ loops @ l/2 mile	2,400,000	480,000	1,200,000
MD-295 24 miles l/2 cost $/mile/4 lanes (2 loops/lane) w/loops @ l/2 mile	1,200,000	240,000	600,000
US-29* 15 miles with 10 signals 10 miles with 15 signals Total 29 miles	375,000 563,000 938,000	75,000 112,600 187,600	187,500 281,500 469,000
US-1* 25 miles with 30 signals	1,125,000	225,000	562,500
Grand Total	**$5,663,000**	**1,132,600**	**2,831,500**

*   There are signals on the arterials and many loops are already installed and can be used. Taking this into account for this example, we assume that only half of the loops would have to be installed since the other half already exist.

The communication links to loops use many miles of cable at a lower cost/mile Vs. telephone connection to each tower at a higher cost/mile, but many towers would be colocated at existing cellular towers at no cable requirements. On the other hand the loops can perform other functions (e.g. better signal timing with additional sensors on the arterials). Thus the total connection to each tower at other system costs are both site specific and quite complex.

XII. SUMMARY

The CAPITAL ITS Operational Test demonstrated a system using cellular phone signals to monitor traffic on a freeway network. Although the changing cellular environment, especially the magnitude of use and operational characteristics, created substantial problems, modifications to the system infrastructure resulted in a system that was capable of monitoring traffic on the freeway network to produce speeds with acceptable accuracy part of the time. Although it appears that the system might be able to obtain enough probes to monitor signalized arterials. this operational test did not obtain enough probes to estimate speeds. The development of a dynamic historical speed (travel time) profile will be required for the particular arterial to begin to distinguish between normal congestion and an incident.

Special findings include:

- Geolocation accuracy achieved was 108 meters, with a range of 24 to 185 meters. almost meeting the 100 meter goal.

- Cross Roads and Adjacent Road Geolocation showed no mis-assignment of probes to either roadway or direction.

- The accuracy of the speed estimates by the OT was disappointing (accurate and available only an estimated 20% of the time). The following would help to achieve accurate speed estimates:

  - Improved algorithm
  - Improved geolocation accuracy
  - Better probe tracking ability

- Incident Detection. Over 93% of the incident recorded by log during the OT were identified by TIC.

- False Alarm - A surprising false alarm rate over 80% was calculated for a one day sample.

- Probes on Arterials. while promising did not show enough probes (e.g. speed estimates) to prove that the cellular system could provide arterial surveillance.

- The cost analysis shows that the cellular based surveillance system is competitive with the traditional loop based system at a loop system cost of about $25,000 per mile. The operating and maintenance costs are assumed to be about equal for either system. Also provision of a traffic management center (or TIC) is assumed to be equal for either system.

The major modification required for the operational test was to increase the density of (1) towers (shorter distance between towers), (2) Directional Finding Systems (DFS) to 1 for every 2 towers, and (3) TAS to 1 for every 2 DFS sites.

Referencing the evaluation of the CAPITAL Project to specific goals/objectives is summarized by Table 2. This table refers to each goal/objective in Exhibit G and provides a brief description and the appropriate section of the report where it is addressed.

The future outlook for cellular technology appears to be one of continued high growth particularly for cellular based handsets. Depending on the future assignment of bandwidth and allied technology (such as pagers), the wide-area surveillance system would certainly have enough probes, but would probably require closer spacing of towers. Since the infrastructure costs are quite reasonable even with installation of a high density of towers, and an expected drop in costs for Directional Finding System, Geolocation Control System, and Transmissions Alert System, and other components, the cellular system might be very cost competitive with loop (or other electronic sensor) based systems, depending on installation costs. When one considers the user costs for disruption during installation (not accounted for in the costing), the cellular system looks even more attractive, if the problems identified in this report can be overcome. These include:

· Geolocation accuracy
· Improved cellular signal hearability
· Improved algorithm for estimating speeds

XIII. RECOMMENDATION

It is recommended that the cellular based surveillance system be studied further as a potential alternative to other, more traditional types of traffic surveillance systems. Future technology developments and applications might change the viability of the system in either direction, and this should be monitored. Personal phones may add to the difficulty. For example, (1) a passenger using a personal phone in a vehicle, exiting the vehicle and entering a building near a roadway, all the while continuing to use the phone, or (2) someone jogging on the sidewalk at 15 KPH, using a phone. On the other hand, a breakthrough in geolocation accuracy (e.g. military accuracy), should result in excellent link assignment and better speed estimates.

XIV. CONCLUSIONS

Available data were not sufficient to conduct a complete evaluation for some of the goals. For those elements, the best analysis possible was performed and the element evaluation needs were discussed. The following are examples.

Variation in speeds was too great to provide confidence in TIC speed values for purposes of either average speed or incident detection. Three factors may have influenced the TIC speed.

a) Accuracy of geolocation
b) Cellular signal hearability
c) Algorithm for calculating speeds

Tabie 2: Goals/Objectives Matrix (Refer to Exhibit G)

Goal/Objective	Description/Response	Report Section Reference
1a	System output $\pm$ -100 meters	Section III
2a	On Freeways, Limited on Signalized Arterials	Section III
b	Data Insufficient to Evaluate	Discussion, Section III
c	UM Speed from Travel Tie Meters is very accurate; OT Speeds have great variation	Section IV
d	Derived date was not available early in the O.T. but was during the last month	Section VII
e	Correct assignment of cars to cross and adjacent roads indicates Yes	Section III, Subsection, Cross Roads & Adjacent Roads
f	% incidents detected Good; False Alarm Rate - Very High; Mean time to detect - not determined.	Section V
3a	Project did not produce volumes	None
4a	The format was acceptable	Section VII, X
b	No remote user units were installed at a TMC. Thus, this could not be evaluated	**None,** Discussed in Section III
c	Was not evaluated, could be integrated in various ways	None, Discussed, Section VII
d	Not evaluated, inadequate data	None
e	Not used	None, Discussed, Section VII
5a	Freeways can be monitored by this system. Arterial monitoring will require improvements & probably more probes	Discussion, Section IV
b	The minimum number of probes needed for monitoring, depends on the accuracy and variation in speeds. Typically a minimumof 10 to 15 probesina 15 minute period would be required	None
c	Traffic signals disrupt travel times, in general. The field tests on US 29 did not experience any problems, however.	Section IV, Subsection: Wide Area: Signalized

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Table 2 (Continued)

Goal/Objective	Description/Response	Report Section Reference
d	Line of Sight is important to receiving probe signals (such as tall buildings)	None
6a	Up to 50 vehicles can be tracked simultaneously with the system tested	Section VI
6b	Geolocation Accuracy, ability to receive cellular signal; speed/incident detection algorithm	Sections I, VI, V
7a	Section on Costs	Section XI
b	Section on Costs	Section XI
c	Maintenance Costs Not Determined	None
d	Exhibit V	Section XI
e	Section on Costs	Section XI
f	Not Determined by this project	None
g	Not Determined by the project	None
8a	No concerns were raised	Section IX
b	Legal & institutional issues were discussed and were included in the project design.	Section IX
c	Press releases and interviews were held	Section IX
9a	Some incident alerts on time. Some verified 911 (or #77) notices of incidents	Section X, VII
b	Limited sample - early computer problems resulted in limited use	Section X, VTI
c	Sample inadequate for evaluation	Section X, VII
10a	Conceptual evaluation only - Wash COG did **not** have a remote unit	Section VIII
b	Conceptual Only	Section VIII
c	Conceptual only but No System has successfully addressed this problem	Section VIII

Incident detection was not acceptable because the algorithm (operating on very variable speed data) was too sensitive to speed change, resulting in a high false alarm rate. More than one traffic parameter (e.g. density) should be utilized. However almost all police recorded incidents were identified.

For the testing of signalized arterials, the TIC speeds were too sparse to allow comparison with UM travel speeds, thus indicating doubt that the cellular system could provide surveillance on these facilities.

The test showed that if only a small percentage (< 5%) of vehicles in the traffic stream can be accurately geolocated at frequent time intervals (say every 5 seconds), directional speeds can be obtained leading to wide-area surveillance. But this test was unable to prove this definitively due to the factors described above. There are many positive indicators but not indisputable proof of concept. Nevertheless this technology bears tracking and monitoring.

References

1. FHWA, Office of Traffic Management and IVHS Operational Tests Division (HTV-20), ***IVHS Operational Test Evaluation Guidelines,*** November 1993.

2. Evaluation Plan for the CAPITAL IVHS Operational Test and Demonstration Program, University of Maryland, July, 1994

3. Evaluation Design for the CAPITAL IVHS Operational Test and Demonstration Program, University of Maryland, Nov., 1994

APPENDIX   A

Geolocation Field Tests

Cumulative geolocation field test results (all distances are in meters)

21 December 1994 Field Tests

Test 1.1   *actual location:* 38.871852 N   77.262382 *W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.265683	38.870130	-285.866715	191.267999	343.95236
77.265663	38.870565	-284.134714	142.951170	318.06850
77.265467	38.870671	-267.161107	131.177414	297.62824
77.265804	38.870549	-296.345319	144.728341	329.79818
77.265756	38.870540	-292.188517	145.727999	326.5 1306
77.265218	38.870663	-245.597698	132.065999	278.85419
77.265524	38.870584	-272.097309	140.840780	306.38713

Average distance from actual location = 314.4574 m

Test 1.2   *actual location: 38.862043 N   77.295298 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.297967	38.867222	-23 1.135493	-575.247947	619.94662
77.298779	38.859171	-301.454721	319.002144	438.90468
77.298872	38.858019	-309.508524	446.958436	543.66108
77.299103	38.86655 1	-329.5 13 132	-500.717850	599.41411
77.299171	38.861923	-335.401934	13.328780	335.66667
77.298259	38.867624	-256.422703	-619.899362	670.84113
77.299337	38.862437	-349.777540	-43.762829	352.50463
77.298515	38.863164	-278.592312	-124.513024	305.15106

Average distance from actual location = 483.2612 m

Test 1.3   *actual location*: 38.858957 N   77.305505 w

Longitude	atitude	Longitude Error	Latitude Error	Total Error
77.304467	38.869625	89.890836	-1184.928578	1188.33333
77.305117	38.869073	33.600813	-1123.616188	1124.11848
77.305368	38.868859	11.864205	-1099.846529	1099.91052
77.303633	38.870334	162.115265	-1263.679455	1274.03576
77.304320	38.869750	102.621041	-1198.812724	1203.19700
77.303986	38.870034	131.545453	-1230.357504	1237.36971
77.304640	38.869478	74.909030	-1168.600822	1170.99925
77.304267	38.869796	107.210843	-1203.922090	1208.68630

Average distance from actual location = 1188.33 13 m

Test 1.4   *actual location: 38.875572 N   77.288503 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.300067	38.874533	-1001.442801	115.405024	1008.07044
77.288629	38.882482	-10.911604	-767.515605	767.59316
77.295286	38.876780	-587.408035	-134.176389	602.53755
77.291282	38.878888	-240.661496	-368.318632	439.97337
77.290935	38.878851	-210.611284	-364.208924	420.71992
77.291380	38.878594	-249.148300	-335.663120	418.02465

Average distance from actual location = 609.4865 m

15 June 1995 Field Tests

Test 2.1   *actual location: 38.533333 N   77.296389 W*

no geolocation fixes

Text 2.2   *actual location: 38.863611 N   77.278056 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.278843	38.863198	-68.154227	45.873219	82.15443
77.279442	38.862962	-120.027648	72.086487	140.01106
77.280168	38.863945	-182.899273	-37.098439	186.62379
77.280334	38.862802	-197.274879	89.858195	216.77609
77.278579	38.864374	-45.291818	-84.748829	96.09221

Average distance from actual location = 144.33 15 m

Test 2.3   *actual location: 38.844860 N   77.265203 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.263656	38.865875	133.970254	-112.739268	175.09475
77.264049	38.864495	99.936440	40.541707	107.84675
77.264030	38.864350	101.581841	56.647317	116.30902
77.264277	38.864588	80.191632	30.211902	85.69397
77.266047	38.864695	-73.090429	18.327073	75.35312

Average distance from actual location = 112.0595 m

Test 2.4   *actual location: 38.863889 N   77.2361 I I W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.234016	38.864154	181.427073	-29.434390	183.79925
77.235589	38.865397	45.205218	-167.498340	173.49123
77.234917	38.864334	103.400441	-49.427561	114.60687
77.234520	38.864437	137.780655	-60.868097	150.62680
77.235362	38.865005	64.863426	-123.957658	139.90270

Average distance from actual location = 152.4854 m

Test 2.5   *actual location: unknown*

Longitude	Latitude
77.247336	38.870397
77.248541	38.869700
77.247780	38.870847
77.247291	38.870811
77.247487	38.870267

Test 2.6   *actual location: 38.864722 N   77.265000W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.264866	38.864062	11.604405	73.308292	74.22107
77.264669	38.864655	28.664611	7.441902	29.61489
77.264412	38.864404	50.920820	35.321268	61.97194
77.264544	38.863370	39.489616	150.170926	155.27632
77.265047	38.863954	-4.070202	85.304195	85.40124

Average distance from actual location = 8 1.297 1 m

Test 2.7   *actual location: 38.841026 N 77.305707 W*
no geolocation fixes

Test 2.8   *actual location: 38.858957 N   77.305505 W*

no geolocation fixes

Test 2.9   *actual location: 38.877778 N   77.281389 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.282855	38.879132	-126.955651	-150.393072	196.81416
77.282634	38.877522	-107.817043	28.434732	111.50358
77.283388	38.877622	-173.113469	17.327415	173.97848
77.283925	38.877138	-219.617688	71.086829	230.83602
77.282880	38.877101	-129.120652	75.196536	149.42109

Average distance from actual location = 172.5107 m

Test 2.10   *actual location: 38.877421 N   77.305891 W*
no geolocation fixes

Test 2.11   *actual location: 38.879028 N   77.272702 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.272490	38.878790	18.359207	26.435414	32.18527
77.272720	38.878938	-1.558801	9.996585	10.11739
77.272536	38.878897	14.375606	14.550585	20.45428
77.272379	38.878978	27.971811	5.553659	28.51781
77.272607	38.878947	8.227003	8.996927	12.19132

Average distance from actual location = 20.6932 m

Test 2.12   *actual location: 38.872361 N   77.251868 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.248908	38.871216	256.336103	127.178780	286.15143
77.250262	38.871659	139.079656	77.973365	159.44590
77.25 1976	38.873076	-9.352804	-79.417317	79.96615
77.250635	38.872054	106.777843	34.099463	112.09050
77.250181	38.871438	146.094259	102.520536	178.47687

Average distance from actual location = 163.2262 m

Test 2.13   *actual location: 38.86611 I N   77.227083 W*
no geolocation fixes

27 June 1995 Field Tests

Test 3.1   *actual location: 38.879949 N   77.247552 W*
no geolocation fixes

Test 3.2   *actual location: 38.878859 N   77.246975 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.246979	38.879882	-0.346400	-113.627853	113.62838
77.248235	38.880978	-109.116044	-235.364047	259.42734
77.247883	38.879529	-78.632832	-74.419024	108.26501
77.246512	38.879348	40.095816	-54.3 14780	67.51126
77.247075	38.879078	-8.660003	-24.325024	25.82058

Average distance from actual location = 114.9305 m

Test 3.3   *actual location: 38.863469 N   77.285805 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.285251	38.862564	47.976419	100.521219	111.38336
77.285804	38.861598	0.086600	207.817901	207.81792
77.285693	38.862664	9.699204	89.413902	89.93843
77.284351	38.864789	125.916450	-146.616584	193.26504
77.284709	38.861555	94.913638	212.594047	232.81930

Average distance from actual location = 167.0448 m

Test 3.4   *actual location: 38.841026 N   77.305707 W*
no geolocation fixes

Test 3.5   *actual location: 38.877421 N   77.305891 W*
no geolocation fixes

Test 3.6   *actual location: 38.865059 N   77.250776 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.248979	38.865864	155.620262	-89.413902	179.47844
77.250961	38.865880	-16.021006	-91.191073	92.58771
77.249428	38.865246	116.736847	-20.770683	118.57029
77.249856	38.866031	79.672032	-107.963121	134.17775
77.250398	38.866511	32.734813	-161.278243	164.56682

Average distance from actual location = 137.8762 m

Test 3.7   *actual location: 38.865019 N   77.267615 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.267103	38.865453	44.339218	-48.205756	65.49627
77.266746	38.864527	75.255430	54.648000	93.00421
77.265975	38.864304	142.024057	79.417317	162.72044
77.268352	38.863357	-63.824226	184.603609	195.32543
77.265613	38.866486	173.373269	-162.944340	237.92677

Average distance from actual location = 150.8946 m

Test 3.8   *actual location: 38.864402 N   77.2 75460 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.275654	38.862266	-16.800407	237.252291	237.84639
77.276413	38.862103	-82.529833	255.357218	268.36259
77.275016	38.864423	38.450415	-2.332537	38.52110
77.274971	38.863610	42.347417	87.969951	97.63204
77.274700	38.866253	65.816026	-205.596438	215.87414

Average distance from actual location = 171.6473 m

Test 3.9   *actual location: 38.877778 N   77.281368 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.282610	38.878357	-107.557243	-64.311365	125.31765
77.282493	38.878491	-97.425039	-79.195170	125.55283
77.282496	38.879260	-97.684839	-164.610438	191.41297
77.281472	38.879695	-9.006404	-212.927267	213.11766
77.284020	38.875621	-229.663292	239.584828	331.88269

Average distance from actual location = 197.4568 m

Test 3.10   *actual Location: 38.879949 N   77.247071 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.245646	38.879598	123.405049	38.986683	129.41703
77.246521	38.880224	47.630019	-30.545122	56.58289
77.245733	38.879558	115.870846	43.429609	123.74241
77.247029	38.880586	3.637201	-70.753609	70.84704
77.246769	38.880238	26.153210	-32.100146	41.40543

Average distance from actual location = 84.3990 m

Test 4.1   *actual location: 38.879028 N   77.272702 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.272604	38.879025	8.486803	0.333220	8.49334
77.272700	38.879096	0.173200	-7.552976	7.55496
77.272545	38.879151	13.596205	-13.662000	19.27452
77.272649	38.878783	4.589802	27.212927	27.59728
77.273154	38.878661	-39.143216	40.763853	56.51445

Average distance from actual location = 23.8869 m

Test 4.2   *actual location: 38.864860 N   77.265203 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.265171	38.864026	2.771201	92.635024	92.67647
77.264620	38.864139	50.487820	80.083756	94.67010
77.263443	38.864851	152.416061	0.999659	152.41934
77.263784	38.864482	122.885449	41.985658	129.86004
77.266558	38.863066	-117.343047	199.265267	23 1.24886

Average distance from actual location = 140.1750 m

Test 4.3   *actual location: 38.863469 N   77.285805 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.286610	38.862146	-69.713028	146.949804	162.64732
77.284845	38.862228	83.136033	137.841804	160.97193
77.286035	38.862663	-19.918008	89.524975	91.71395
77.285323	38.862100	41.741217	152.059170	157.68424
77.284163	38.862691	142.197257	86.414926	166.39591

Average distance from actual location = 147.8827 m

Test 4.4   *actual location: 38.853333N   77.296389 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.296008	38.853167	32.994613	18.438146	37.79695
77.296663	38.853206	-23.728410	14.106293	27.60480
77.297404	38.853068	-87.899035	29.434390	92.69641
77.297464	38.852732	-93.095037	66.754975	114.55528
77.297385	38.852776	-86.253635	61 .867756	106.14758

Average distance from actual location = 75.7602 m

Test 4.5   *actual location: 38.864722 N   77.265000 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.265413	38.864192	-35.765814	58.868780	68.88198
77.263072	38.863430	166.964867	143.506536	220.16220
77.263245	38.863344	151.983061	153.058828	215.69853
77.264454	38.863795	47.283619	102.964829	113.30268
77.263190	38.862331	156.746063	265.575949	308.38274

Average distance from actual location = 185.2856 m

Test 4.6   *actual location: 38.888333 N   77.241667 W*

Longitude	Latitude	Longitude Error	Latitude Error	Total Error
77.240752	38.889036	79.239032	-78.084439	111.24749
77.240865	38.888680	69.453228	-38.542390	79.43089
77.241436	38.889048	20.004608	-79.4173 17	81.89807
77.241642	38.888089	2.165001	27.101853	27.18819
77.241638	38.888909	2.511401	-63.978146	64.02742

Average distance **from actual** location = 72.7584 m

APPENDIX B

**Field Tests Run On Parallel And Cross Streets:
Geolocation Accuracy For Facility And Direction
Determination**

Moving geolocation accuracy test results: Parallel and Cross Streets

Time	Path Taken
11:55 pm	Old Lee Highway from Rt 236 to Fairfax Circle
12:00 midnight	EB on Blake Lane
12:07 am	EB on Five Oaks Road
12:15 am	EB on Rt 50, Nutley to Prosperity
12:20 am	EB on Country Creek Road
12:35 am	SB on Cedar Lane starting at Thoreau Intermediate School
12:40 am	EB on Cottage starting at DePaul Drive
12:45 am	SB on Gallows Road starting south of Rt 29
1:15 am	WB on Rt 29 from Cedar to Nutley
1:24 am	NB on Nutley from Rt 29 to I-66

APPENDIX C

Link Speed Data by Time Incremental (l5 Min - Peak Periods and Hour for Off-Peak) and Date

UMD = Travel Time Speeds, that date/time

TIC = Speeds from OT, that date/time

Daily speed output (TIC and actual) for each link by time period.

I-495 SB - from VAT to I-66 - link 19016
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN {KPH)

Start Time	Calculated Avg	7/12 Wed UMD	TIC	7/13 Thur UMD	TIC	7/14 Fri UMD	TIC	7/17 Mon UMD	TIC	7/18 Tue UMD	TIC	7/19 Wed UMD	TIC
6 30am	94 6	n/a	n/a	n/a	n/a	92.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6 45am	95 0	90 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7 00am	97 8	92.6	n/a	n/a	n/a	91.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7 15am	95 7	97 7	n/a	n/a	n/a	92.6	30.0	n/a	n/a	n/a	n/a	n/a	n/a
7 30am	95 7	96 2	n/a	n/a	n/a	90 2	8 0	n/a	n/a	n/a	n/a	n/a	n/a
7 45am	96.5	94 2	n/a	n/a	n/a	92.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 00am	97.2	99.2	n/a	n/a	n/a	88 6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 15am	95 8	93 9	n/a	n/a	n/a	94 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 30am	98.6	98.8	n/a	n/a	n/a	95 0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 45am	94.4	94.6	n/a	n/a	n/a	89 4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9 00am	99 0	93 4	n/a	n/a	n/a	93.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9 15am	93 4	n/a	n/a	n/a	n/a	90 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/20 Thur UMD	TIC	7/21 Fri UMD	TIC	7/24 Mon UMD	TIC	7/25 Tue UMD	TIC	7/26 Wed UMD	TIC	7/27 Thur UMD	TIC
6 30am	n/a	n/a	99.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6 45am	n/a	n/a	95.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7 00am	n/a	n/a	94.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7 15am	n/a	n/a	98 6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7 30am	n/a	n/a	96 1	n/a	n/a	8 0	n/a	n/a	n/a	n/a	n/a	n/a
7 45am	n/a	n/a	98 8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 00am	n/a	n/a	92 6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 15am	n/a	n/a	92 6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 30am	n/a	n/a	98 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 45am	n/a	n/a	105 7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9 00am	n/a	n/a	98.2	80.0	n/a	121	n/a	n/a	n/a	n/a	n/a	n/a
9 15am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/28 Fri UMD	TIC	7/31 Mon UMD	TIC	8/1 Tue UMD	TIC	8/2 Wed UMD	TIC	8/3 Thur UMD	TIC	8/4 Fri UMD	TIC
6 30am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	111.1	n/a
6 45am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	86.2	n/a
7 00am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	99.0	n/a
7 15am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	121.	n/a	n/a	98.2	n/a
7 30am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	90.2	n/a
7 45am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	91.8	n/a
8 00am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	99.8	n/a
8 15am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	99.8	n/a
8 30am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	97.6	n/a
8 45am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	89.4	n/a
9 00am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	109.5	n/a
9 15am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

I-46 WB - from 1495 to RT 243 link 14104
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start Time	Calculated Avg. Speed	7/12 Wed		7/13 Thur		7/14 Fri		7/17 Mon		7/18 Tue		7/19 Wed	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6 30am	100.2	n/a	n/a	106 3	n/a	99.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6 45am	101.5	101.5	n/a	105 7	121 0	99 0	65 0	n/a	n/a	n/a	n/a	n/a	n/a
7 00am	99.5	94.2	n/a	102.3	94 0	97 7	56 8	n/a	n/a	n/a	n/a	n/a	n/a
7 15am	100 1	102.5	n/a	99 8	n/a	98.8	31.0	n/a	n/a	n/a	n/a	n/a	n/a
7 30am	98 7	97 0	n/a	101.5	n/a	96 6	51 4	n/a	n/a	n/a	n/a	n/a	n/a
7 45am	100 4	96 2	n/a	101 5	61 0	100.4	n/a	n/a	62.0	n/a	n/a	n/a	n/a
8 00am	98.7	99 0	n/a	n/a	n/a	97 7	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 15am	99 1	94 2	n/a	101 5	28 0	99.8	n/a	n/a	n/a	n/a	44.0	n/a	38 0
8 30am	98.8	102.0	n/a	97 4	81 0	94.5	n/a	n/a	n/a	n/a	112.7	n/a	n/a
8 45am	100.5	95 8	n/a	96.6	n/a	96.1	25.0	n/a	52.7	n/a	n/a	n/a	30 0
9 00am	97 3	98 2	n/a	96.6	19 0	95.5	48.7	n/a	38.5	n/a	n/a	n/a	121
9 15am	100.9	n/a	n/a	n/a	n/a	98.2	37 0	n/a	119	n/a	n/a	n/a	n/a

Start Time	7/20 Thur		7/21 Fri		7/24 Mon		7/25 Tue		7/26 Wed		7/27 Thur	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6 30am	n/a	n/a	100.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6 45am	n/a	n/a	100 2	n/a	n/a	n/a	n/a	91.2	n/a	n/a	n/a	n/a
7 00am	n/a	n/a	99 0	n/a	n/a	45.0	n/a	105	n/a	n/a	n/a	n/a
7 15am	n/a	n/a	101 0	n/a	n/a	62 0	n/a	17.0	n/a	n/a	n/a	n/a
7 30am	n/a	n/a	102.7	n/a	n/a	41 0	n/a	77.7	n/a	n/a	n/a	n/a
7 45am	n/a	n/a	103 9	n/a	n/a	47 2	n/a	64.7	n/a	n/a	n/a	n/a
8 00am	n/a	n/a	100 4	n/a	n/a	26.3	n/a	46.0	n/a	n/a	n/a	n/a
8 15am	n/a	n/a	105 5	105 0	n/a	50.8	n/a	n/a	n/a	n/a	n/a	n/a
8 30am	n/a	n/a	100 6	49 6	n/a	45.0	n/a	17.0	n/a	n/a	n/a	n/a
8 45am	n/a	n/a	107 4	61 0	n/a	64.0	n/a	39.0	n/a	n/a	n/a	n/a
9 00am	n/a	n/a	98 2	59 5	n/a	59 0	n/a	28.0	n/a	n/a	n/a	n/a
9 15am	n/a	n/a	93.4	n/a	n/a	n/a	n/a	56 5	n/a	n/a	n/a	n/a

Start Time	7/28 Fri		7/31 Mon		8/1 Tue		8/2 Wed		8/3 Thur		8/4 Fri	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6 30am	n/a	n/a	n/a	n/a	n/a	n/a	100.8	90.0	n/a	n/a	104.7	n/a
6 45am	n/a	n/a	n/a	n/a	n/a	88 0	105.2	n/a	n/a	n/a	103.1	n/a
7 00am	n/a	n/a	n/a	n/a	n/a	150.	105.3	46.0	n/a	n/a	103.9	n/a
7 15am	n/a	n/a	n/a	14.0	n/a	67 0	98.2	62.5	n/a	n/a	108.7	n/a
7 30am	n/a	32.0	n/a	n/a	n/a	n/a	97.3	117.	n/a	n/a	98.2	n/a
7 45am	n/a	n/a	n/a	n/a	n/a	n/a	102.4	n/a	n/a	n/a	102.0	n/a
8 00am	n/a	n/a	n/a	111.5	n/a	97.5	93.4	n/a	n/a	n/a	102.3	n/a
8 15am	n/a	55.2	n/a	n/a	n/a	n/a	103.1	n/a	n/a	n/a	106.3	n/a
8 30am	n/a	46.5	n/a	65.0	n/a	n/a	97.9	109.	n/a	n/a	100.6	n/a
8 45am	n/a	n/a	n/a	n/a	n/a	n/a	102.7	67.2	n/a	n/a	100.9	n/a
9 00am	n/a	n/a	n/a	n/a	n/a	91.0	97.7	115.	n/a	n/a	109.5	n/a
9 15am	n/a	117.	n/a	n/a	n/a	n/a	n/a	93.7	n/a	n/a	n/a	n/a

I-66 WB . from R T 243 to R T 123 link 14103

Calculated Average Speed Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start Time	Calculated Avg. Speed	7/12 Wed UMD	TIC	7/13 Thur UMD	TIC	7/14 Fri UMD	TIC	7/17 Mon UMD	TIC	7/18 Tue UMD	TIC	7/19 Wed UMD	TIC
6:30am	100.6	n/a	n/a	103.6	116.2	100.2	88.5	n/a	n/a	n/a	n/a	101.1	n/a
6:45am	99.2	n/a	n/a	100.9	n/a	99.8	92.4	n/a	n/a	95.0	n/a	99.3	113.8
7:00am	95.6	n/a	n/a	74.1	112.8	96.6	96.7	n/a	n/a	91.8	n/a	99.0	n/a
7:15am	98.4	n/a	n/a	104.7	88.3	97.2	97.0	n/a	n/a	96.4	n/a	97.6	97.1
7:30am	95.2	n/a	n/a	99.3	114.6	91.8	112.4	n/a	n/a	94.7	n/a	93.4	96.1
7:45am	97.9	n/a	n/a	97.7	105.2	96.6	112.6	n/a	n/a	97.2	n/a	100.9	97.5
8:00am	99.7	n/a	n/a	n/a	112.7	96.6	61.5	n/a	125.2	98.2	93.7	101.1	n/a
8:15am	99.3	n/a	n/a	100.6	102.6	95.0	107.4	n/a	n/a	100.1	89.5	99.2	121.4
8:30am	95.3	n/a	n/a	69.2	100.6	95.4	131.3	n/a	111.4	98.6	68.0	99.8	88.9
8:45am	95.8	n/a	n/a	88.6	84.5	92.9	118.1	n/a	n/a	94.2	95.1	98.2	118.2
9:00am	95.6	n/a	n/a	78.1	83.0	96.6	156.5	n/a	103.8	94.3	238.2	96.1	110.
9:15am	95.1	n/a	n/a	n/a	70.0	97.4	113.6	n/a	105.6	94.2	125.6	93.9	99.4

	7/20 Thur UMD	TIC	7/21 Fri UMD	TIC	7/24 Mon UMD	TIC	7/25 Tue UMD	TIC	7/26 Wed UMD	TIC	7/27 Thur UMD	TIC
6:30am	n/a	n/a	n/a	n/a	n/a	n/a	96.6	n/a	n/a	n/a	n/a	n/a
6:45am	n/a	n/a	n/a	n/a	n/a	119.4	92.6	113.	n/a	n/a	n/a	n/a
7:00am	n/a	n/a	n/a	n/a	n/a	115.5	82.9	88.6	n/a	n/a	n/a	n/a
7:15am	n/a	n/a	n/a	n/a	n/a	124.0	100.6	48.0	n/a	n/a	n/a	n/a
7:30am	n/a	n/a	n/a	n/a	n/a	106.6	92.2	93.4	n/a	n/a	n/a	n/a
7:45am	n/a	n/a	n/a	n/a	n/a	100.7	95.0	110.	n/a	n/a	n/a	n/a
8:00am	n/a	n/a	n/a	n/a	n/a	82.1	96.6	1373	n/a	n/a	n/a	n/a
8:15am	n/a	n/a	n/a	118.5	n/a	68.3	95.0 I	99.2 I	n/a I	n/a I	n/a	n/a
8:30am	n/a	n/a	n/a	112.5	n/a	112.4	82.1	114.	n/a	n/a	n/a	n/a
8:45am	n/a	n/a	n/a	124.0	n/a	106.7	101.4	72.1	n/a	n/a	n/a	n/a
9:00am	n/a	n/a	n/a	105.6	n/a	n/a	n/a	66.7	n/a	n/a	n/a	n/a
9:15am	n/a	n/a	n/a	n/a	n/a	143.8	n/a	n/a	n/a	n/a	n/a	n/a

	7/28 Fri UMD	TIC	7/31 Mon UMD	TIC	8/1 Tue UMD	TIC	8/2 Wed UMD	TIC	8/3 Thur UMD	TIC	8/4 Fri UMD	TIC
6:30am	n/a	n/a	97.9	111.2	n/a	n/a	n/a	92.6	n/a	n/a	106.3	n/a
6:45am	n/a	94.0	102.7	86.0	n/a	99.5	n/a	84.5.	n/a	n/a	101.4	n/a
7:00am	n/a	n/a	101.9	116.8	n/a	128.	n/a	100.	n/a	n/a	100.6	n/a
7:15am	n/a	107.	98.7	94.8	n/a	107.	n/a	81.7	n/a	n/a	103.9	n/a
7:30am	n/a	n/a	99.8	n./a	n/a	162.	n/a	137.	n/a	n/a	99.0	n/a
7:45am	n/a	109.	97.8	112.5	n/a	113.	n/a	100.	n/a	n/a	96.6	n/a
8:00am	n/a	106.	101.2	96.8	n/a	119.	n/a	109.	n/a	n/a	98.2	n/a
8:15am	n/a	116.	100.6	122.0	n/a	87.0	n/a	176.	n/a	n/a	111.1	n/a
8:30am	n/a	96.8	92.9	96.7	n/a	106.	n/a	107.	n/a	n/a	94.2	n/a
8:45am	n/a	100.	96.6	97.5	n/a	118.	n/a	100.	n/a	n/a	101.4	n/a
9:00am	n/a	103	95.5	103.2	n/a	118.	n/a	110.	n/a	n/a	104.7	n/a
9:15am	n/a	114.	94.5	99.8	n/a	104.	n/a	n/a	n/a	n/a	n/a	n/a

I-66 EB - from RT123 to RT 243 - link 14003
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC). ALL SPEED IN (KPH)

Start	Calculated	7/12	Wed	7/13	Thur	7/14	Fri	7/17	Mon	7/18	Tue	7/19	Wed
Time	Avg. Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UM	TIC
6 30am	89.2	n/a	n/a	100.6	n/a	95 8	n/a	n/a	n/a	n/a	n/a	71 9	n/a
6 45am	89 7	n/a	n/a	87 8	n/a	88.2	69 7	n/a	n/a	77 3	n/a	59 9	71 4
7 00am	81.1	n/a	n/a	61 2	84 7	80.5	91 6	n/a	n/a	69.2	n/a	41 9	28 8
7 15am	86 5	n/a	n/a	37 2	38 5	67 3	88 0	n/a	n/a	50 2	n/a	41.9	59 7
7 30am	62.1	n/a	n/a	41 9	74 6	70 9	56.1	n/a	n/a	41.9	n/a	35.8	74.8
7 45am	68 3	n/a	n/a	38 7	28 4	58 0	70 9	n/a	n/a	75 9	n/a	38 3	n/a
8 00am	77.0	n/a	n/a	52 6	61 0	68 4	55 1	n/a	n/a	70 5	n/a	54 0	n/a
8 15am	71.7	n/a	n/a	55 6	34 8	96.1	69 9	n/a	n/a	57.2	58.9	38.7	67 9
8:30am	87 5	n/a	n/a	38.7	87 6	95.0	92.0	n/a	n/a	91.3	76.0	55.4	42.7
8 45am	85 9	n/	n/a	49 1	20.1	94.2	54 0	n/a	84.2	96.3	40.9	66.0	51.6
9 00am	98 6	n/a	/a	77 3	59 5	96 2	63.9	n/a	n/a	100.5	378.0	98.5	69.5
9 15am	100.5	n/a	n/a	n/a	77.9	100.2	n/a	n/a	n/a	n/a	114.0	n/a	90.5

	7/20	Thur	7/21	Fri	7/24	Mon	7/25	Tue	7/26	Wed	7/27	Thur
		TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6 30am	n/a	n/a	n/a	n/a	n/a	83.0	87.0	102.	n/a	n/a	n/a	n/a
6 45am	n/a	n/a	n/a	n/a	n/a	107.6	87 5	124.	n/a	n/a	n/a	n/a
7 00am	n/a	n/a	n/a	n/a	n/a	121 3	48.8	104.	n/a	n/a	n/a	n/a
7 15am	n/a	n/a	n/a	n/a	n/a	n/a	23.3	64.8	n/a	n/a	n/a	n/a
7 30am	n/a	n/a	n/a	n/a	n/a	89.3	25 8	53.2	n/a	n/a	n/a	n/a
7 45am	n/a	n/a	n/a	n/a	n/a	31.6	36.2	98.4	n/a	n/a	n/a	n/a
8 00am	n/a	n/a	n/a	n/a	n/a	36.7	19.3	78.3	n/a	n/a	n/a	n/a
8 15am	n/a	n/a	n/a	n/a	n/a	77 0	14 5	70.8	n/a	n/a	n/a	n/a
8 30am	n/a	n/a	n/a	106 0	n/a	91.5	20.9	91.8	n/a	n/a	n/a	n/a
8 45am	n/a	n/a	n/a	n/a	n/a	56.3	35.4	97.7	n/a	n/a	n/a	n/a
9 00am	n/a	n/a	n/a	129 4	n/a	96.8	n/a	59.6	n/a	n/a	n/a	n/a
9 15am	n/a	n/a	n/a	100.6	n/a	166.	n/a	87.7	n/a	n/a	n/a	n/a

	7/28	Fri	7/31	Mon	8/1	Tue	8/2	Wed	8/3	Thur	8/4	Fri
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6 30am	n/a	n/a	91.1	129.6	n/a	102.	n/a	87.6	n/a	n/a	98.2	n/a
6 45am	n/a	94.6	94.7	102.6	n/a	n/a	n/a	84.5	n/a	n/a	101.4	n/a
7 00am	n/a	57.7	92.8	94.7	n/a	107	n/a	88.9	n/a	n/a	n/a	n/a
7 15am	n/a	122.	93.4	99.5	n/a	n/a	n/a	93.9	n/a	n/a	99.8	n/a
7 30am	n/a	18.0	95.7	95.2	n/a	91.7	n/a	177.	n/a	n/a	104.7	n/a
7 45am	n/a	n/a	95.3	91.9	n/a	n/a	n/a	88.2	n/a	n/a	101.4	n/a
8 00am	n/a	77.0	98.5	84.2	n/a	n/a	n/a	165.	n/a	n/a	99.8	n/a
8 15am	n/a	n/a	100.9	88.2	n/a	n/a	n/a	115.	n/a	n/a	99.8	n/a
8:30am	n/a	56.1	100.5	106.6	n/a	102.	n/a	119.	n/a	n/a	103.1	n/a
8 45am	n/a	n/a	97 9	95.7	n/a	99 9	n/a	100.	n/a	n/a	103.1	n/a
9 00am	n/a	114.	102.6	117 3	n/a	125.	n/a	136.	n/a	n/a	102.4	n/a
9 15am	n/a	95 9	87 0	94 2	n/a	113.	n/a	111.	n/a	n/a	n/a	n/a

I-66 EB from RT 243 to I-495 link 14004
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC). ALL SPEED IN (KPH)

Start Time	Calculated Avg. Speed	7/12 Wed		7/13 Thur		7/14 Fri		7/17 Mon		7/18 Tue		7/19 Wed	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6:30am	94.2	n/a	n/a	86.2	n/a	92.6	n/a	n/a	n/a	n/a	n/a	n/a	35.0
6:45am	85.4	n/a	n/a	50.7	58.9	67.2	92.2	n/a	n/a	n/a	n/a	n/a	n/a
7:00am	87.6	47.2	n/a	32.2	109.7	46.7	67.0	n/a	104.	n/a	n/a	n/a	n/a
7:15am	68.5	48.3	n/a	37.8	35.2	41.9	68.8	n/a	98.0	n/a	n/a	n/a	n/a
7:30am	48.4	48.3	n/a	31.4	46.9	34.6	54.5	n/a	27.0	n/a	n/a	n/a	n/a
7:45am	63.6	75.2	n/a	25.0	60.9	20.1	47.4	n/a	83.0	n/a	n/a	n/a	n/a
8:00am	67.4	68.3	n/a	25.8	110	20.4	34.8	n/a	n/a	n/a	n/a	n/a	46.5
8:15am	35.0	45.1	n/a	12.9	33.1	35.4	39.9	n/a	n/a	n/a	29.1	n/a	60.4
8:30am	57.3	42.1	n/a	29.5	63.9	16.1	92.0	n/a	69.0	n/a	113.	n/a	45.5
8:45am	54.8	42.7	n/a	30.6	n/a	41.9	31.1	n/a	45.7	n/a	57.0	n/a	46.1
9:00am	92.0	89.7	n/a	25.8	68.7	35.0	63.9	n/a	52.6	n/a	274.	n/a	90.0
9:15am	75.5	n/a	n/a	n/a	54.2	56.4	82.9	n/a	81.8	n/a	91.0	n/a	93.6

	7/20 Thur		7/21 Fri		7/24 Mon		7/25 Tue		7/26 Wed		7/27 Thur	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6:30am	n/a	n/a	81.2	n/a	n/a	97.4	n/a	88.5	n/a	n/a	n/a	n/a
6:45am	n/a	n/a	89.0	n/a	n/a	91.6	n/a	97.1	n/a	n/a	n/a	n/a
7:00am	n/a	n/a	79.5	n/a	n/a	86.4	n/a	67.4	n/a	n/a	n/a	n/a
7:15am	n/a	n/a	53.5	n/a	n/a	71.5	n/a	31.3	n/a	n/a	n/a	n/a
7:30am	n/a	n/a	35.4	n/a	n/a	37.0	n/a	47.2	n/a	n/a	n/a	n/a
7:45am	n/a	n/a	21.3	n/a	n/a	34.6	n/a	48.5	n/a	n/a	n/a	n/a
8:00am	n/a	n/a	20.1	n/a	n/a	43.5	n/a	40.4	n/a	n/a	n/a	n/a
8:15am	n/a	n/a	20.1	29.8	n/a	64.8	n/a	47.1	n/a	n/a	n/a	n/a
8:30am	n/a	n/a	19.3	53.6	n/a	32.0	n/a	37.0	n/a	n/a	n/a	n/a
8:45am	n/a	n/a	25.0	44.8	n/a	34.0	n/a	37.9	n/a	n/a	n/a	n/a
9:00am	n/a	n/a	63.2	74.0	n/a	42.5	n/a	103.1	n/a	n/a	n/a	n/a
9:15am	n/a	n/a	81.3	89.1	n/a	52.3	n/a	103.3	n/a	n/a	n/a	n/a

	7/28 Fri		7/31 Mon		8/1 Tue		8/2 Wed		8/3 Thur		8/4 Fri	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6:30am	n/a	100.	n/a	n/a	n/a	n/a	101.1	114.	n/a	n/a	82.1	n/a
6:45am	n/a	93.1	n/a	88.6	n/a	n/a	101.0	103.	n/a	n/a	85.3	n/a
7:00am	n/a	104.	n/a	n/a	n/a	120.	92.3	93.4	n/a	n/a	75.7	n/a
7:15am	n/a	125.	n/a	70.9	n/a	117.	67.8	76.4	n/a	n/a	83.2	n/a
7:30am	n/a	n/a	n/a	90.5	n/a	106	52.8	70.6	n/a	n/a	87.0	n/a
7:45am	n/a	55.6	n/a	57.7	n/a	88.4	56.0	n/a	n/a	n/a	99.8	n/a
8:00am	n/a	34.9	n/a	91.8	n/a	93.6	66.0	83.0	n/a	n/a	87.8	n/a
8:15am	n/a	68.6	n/a	29.5	n/a	n/a	n/a	n/a	n/a	n/a	78.9	n/a
8:30am	n/a	57.5	n/a	72.3	n/a	100.	79.2	83.3	n/a	n/a	106.3	n/a
8:45am	n/a	71.7	n/a	116.3	n/a	102.	68.6	82.5	n/a	n/a	62.8	n/a
9:00am	n/a	85.3	n/a	121.0	n/a	105.	92.4	89.1	n/a	n/a	82.9	n/a
9:15am	n/a	112.	n/a	97.7	n/a	133.	67.6	101.	n/a	n/a	103.1	n/a

I-495 NB - from I-66 to R T link 19116
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN tKPH)

Start Time	Calculated Avg Speed	7/12 Wed		7/13 Thur		7/14 Fri		7/17 Mon		7/18 Tue		7/19 Wed	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UM	TIC
6:30am	96.1	n/a	n/a	n/a	n/a	94.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:45am	87.4	n/a	n/a	n/a	n/a	85.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00am	83.3	86.2	n/a	n/a	n/a	56.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:15am	75.7	80.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:30am	72.1	82.9	n/a	n/a	n/a	59.0	132.	n/a	n/a	n/a	n/a	n/a	n/a
7:45am	70.1	68.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:00am	65.9	64.8	n/a	n/a	n/a	80.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:15am	62.2	63.9	n/a	n/a	n/a	53.1	n/a	n/a	n/a	n/a	56.0	n/a	n/a
8:30am	62.6	63.9	n/a	n/a	135.0	58.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:45am	68.4	64.4	n/a	n/a	n/a	46.7	33.0	n/a	n/a	n/a	n/a	n/a	n/a
9:00am	74.8	64.8	n/a	n/a	n/a	65.2	80.0	n/a	n/a	n/a	n/a	n/a	n/a
9:15am	95.3	n/a	n/a	n/a	n/a	79.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/20 Thur		7/21 Fri		7/24 Mon		7/25 Tue		7/26 Wed		7/27 Thur	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6:30am	n/a	n/a	91.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:45am	n/a	n/a	85.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00am	n/a	n/a	79.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:15am	n/a	n/a	70.9	n/a	n/a	40.0	n/a	n/a	n/a	n/a	n/a	n/a
7:30am	n/a	n/a	70.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:45am	n/a	n/a	69.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:00am	n/a	n/a	66.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:15am	n/a	n/a	63.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:30am	n/a	n/a	69.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8:45am	n/a	n/a	64.4	n/a	n/a	n/a	n/a	62.0	n/a	n/a	n/a	n/a
9:00am	n/a	n/a	85.7	63.5	n/a	113	n/a	n/a	n/a	n/a	n/a	n/a
9:15am	n/a	n/a	103.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/28 Fri		7/31 Mon		8/1 Tue		8/2 Wed		8/3 Thur		8/4 Fri	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
6:30am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	93.4	n/a
6:45am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	85.3	n/a
7:15am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	75.7	n/a
7:30am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	63.6	n/a
7:45am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	73.5	n/a
8:00am	n/a	62.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	70.0	n/a
8:15am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	70.9	n/a
8:30am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	58.0	n/a
8:45am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	75.2	n/a
9:00am	n/a	n/a	n/a	n/a	n/a	n/a	n/a	158.	n/a	n/a	91.0	n/a
9:15am	n/a	n/a	n/a	80.0	n/a	n/a	n/a	n/a	n/a	n/a	98.2	n/a

Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

I-495 SB - from RT29 to I-66 .- link 19016

Start	Calculated	7/25	Tue	7/28	Fri	8/2	Wed	8/3	Thur
Time	Avg Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
9 30am	95.1	n/a	n/a	n/a	n/a	n/a	n/a	95.1	n/a
10 30am	93.8	n/a	n/a	n/a	n/a	n/a	n/a	93.8	n/a
11 30am	97 1	n/a	n/a	n/a	n/a	n/a	n/a	97 1	n/a
12 30pm	94 8	92 97	n/a	n/a	n/a	96 8	n/a	n/a	n/a
1 30pm	91 3	91 3	n/a	n/a	n/a	91 0	n/a	n/a	n/a
2 30pm	94.5	92.6	n/a	n/a	n/a	96.5	n/a	n/a	n/a

I-66 WB--from RT243 to RT123 -- 14103

Start	Calculated	7/25	Tue	7/28	Fri	8/2	Wed	8/3	Thur
Time	Avg Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
9 30am	99 7	n/a	n/a	100.6	95.3	n/a	n/a	98.8	n/a
10 30am	98 4	n/a	n/a	101.1	97.2	n/a	n/a	95.7	n/a
11 30am	102.0	n/a	n/a	100.6	102.5	n/a	n/a	103.3	n/a
12 30pm	103 5	99 2	n/a	n/a	n/a	107.7	n/a	n/a	n/a
1 30pm	105 7	101 6	83 0	n/a	n/a	109.8	n/a	n/a	n/a
2 30pm	103 2	100.1	n/a	n/a	n/a	106 3	n/a	n/a	n/a

I-66 WB - imm RT243 to RT123 -- 14103

Start	Calculated	7/25	Tue	7/28	Fri	8/2	Wed	8/3	Thur
Time	Avg Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
9 30am	98 7	n/a	n/a	98.7	106 8	n/a	n/a	n/a	n/a
10 30am	95 8	n/a	n/a	95.8	121.7	n/a	n/a	n/a	n/a
11 30am	98 0	n/a	n/a	98 0	110.0	n/a	n/a	n/a	n/a
12 30pm	99 6	99 4	116.	n/a	n/a	99 7	n/a	n/a	n/a
1 30pm	99 4	97.0	109.	n/a	n/a	101.8	n/a	n/a	n/a
2 30pm	99.0	99.8	n/a	n/a	n/a	98 7	n/a	n/a	n/a

I-66 EB - from RT123 to RT243 – 14003

Start	Calculated	7/25	Tue	7/28	Fri	8/2	Wed	8/3	Thur
Time	Avg Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
9 30am	103.3	n/a	n/a	103.3	108 3	n/a	n/a	n/a	n/a
10 30am	103.3	n/a	n/a	103.3	144 7	n/a	n/a	n/a	n/a
11:30am	100 0	n/a	n/a	100 0	110 9	n/a	n/a	n/a	n/a
12 30pm	102 5	99 8	103.8	n/a	n/a	105.2	n/a	n/a	n/a
1 30pm	101 2	100 3	104 9	n/a	n/a	102.1	n/a	n/a	n/a
2 30pm	108 1	109 8	n/a	n/a	n/a	106 3	n/a	n/a	n/a

I-66 WB from RT243 to I-495 - - 14004

Start Time	Calculated Avg Speed	7/25 Tue		7/28 Fri		8/2 Wed		8/3 Thur	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
9:30am	92.9	n/a	n/a	100 1	104 3	n/a	n/a	85 7	n/a
10:30am	91.6	n/a	n/a	101 4	112.1	n/a	n/a	81.8	n/a
11:30am	97 6	n/a	n/a	102.5	115 9	n/a	n/a	91 8	n/a
12:30pm	101.0	97 7	107 0	n/a	n/a	104.3	n/a	n/a	n/a
1:30pm	98 0	96 1	103 9	n/a	n/a	99 8	n/a	n/a	n/a
2:30pm	101.6	100.9	n/a	n/a	n/a	102.3	n/a	n/a	n/a

I-495 NB - from I-66 to RT7 -- 19016

Start Time	Calculated Avg Speed	7/25 Tue		7/28 Fri		8/2 Wed		8/3 Thur	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
9 30am	88.8	n/a	n/a	n/a	n/a	n/a	n/a	88.8	n/a
10 30am	93.9	n/a	n/a	n/a	n/a	n/a	n/a	93.9	n/a
11:30am	95.0	n/a	n/a	n/a	n/a	n/a	n/a	95.0	n/a
12:30pm	97 8	97 7	n/a	n/a	n/a	97.9	n/a	n/a	n/a
1:30pm	97 5	100.0	86 0	n/a	n/a	94.8	n/a	n/a	n/a
2:30pm	98.3	100.2	n/a	n/a	n/a	96 5	n/a	n/a	n/a

Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN tKPH)

Start Time	Calculated Avg Speed	7/12 Wed UMD	TIC	7/13 Thur UMD	TIC	7/14 Fri UMD	TIC	7/17 Mon UMD	TIC	7/18 Tue UMD	TIC	7/19 Wed UMD	TIC
3:30pm	84.0	78.1	n/a	n/a	n/a	90.2	n/a	n/a	95.0	n/a	n/a	n/a	n/a
3:45pm	87.8	91.0	n/a	n/a	n/a	87.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:00pm	86.4	92.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:15pm	84.1	76.5	n/a	n/a	n/a	88.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:30pm	83.6	90.2	n/a	n/a	n/a	87.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:45pm	76.6	70.9	n/a	n/a	n/a	86.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:00pm	74.6	69.2	n/a	n/a	n/a	83.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:15pm	70.9	75.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:30pm	70.1	59.6	n/a	n/a	n/a	88.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:45pm	70.7	62.0	n/a	n/a	n/a	87.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:00pm	74.7	65.0	n/a	n/a	n/a	93.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:15pm	82.1	n/a	n/a	n/a	n/a	87.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/20 Thur UMD	TIC	7/21 Fri UMD	TIC	7/24 Mon UMD	TIC	7/25 Tue UMD	TIC	7/26 Wed UMD	TIC	7/27 Thur UMD	TIC
3:30pm	79.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3:45pm	87.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:00pm	83.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:15pm	89.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:30pm	83.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:45pm	85.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:00pm	73.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:15pm	69.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:30pm	97.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:45pm	69.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:00pm	72.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:15pm	78.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/28 Fri UMD	TIC	7/31 Mon UMD	TIC	8/1 Tue UMD	TIC	8/2 Wed UMD	TIC	8/3 Thur UMD	TIC	8/4 Fri UMD	TIC
3:30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	90.2	n/a	n/a	n/a
3:45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	85.3	n/a	n/a	n/a
4:00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	81.3	n/a	n/a	n/a
4:15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	76.9	n/a	n/a	n/a
4:30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	80.5	n/a	n/a	n/a
4:45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	64.4	n/a	n/a	n/a
5:00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	80.5	n/a	n/a	n/a
5:15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	65.2	n/a	n/a	n/a
5:30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	87.0	n/a	n/a	n/a
5:45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	67.0	n/a	n/a	n/a
6:00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	82.1	n/a	n/a	n/a
6:15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

I-66 WB from I-495 to RT243 - - link 14104
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start Time	Calculated Avg Speed	7 12 Wed UMD	TIC	7/13 Thur UMD	TIC	7/14 Fri UMD	TIC	7/17 Mon UMD	TIC	7/18 Tue UMD	TIC	7/19 Wed UMD	TIC
3 30pm	95 0	91.0	n/a	91 8	n/a	43 9	65 2	93 9	n/a	n/a	n/a	n/a	n/a
3 45pm	96 5	98.2	102 2	89 4	n/a	67 2	n/a	99 4	107 0	n/a	100.0	n/a	n/a
4 00pm	100 3	103.5	102.0	95 0	n/a	n/a	n/a	101 5	102.0	n/a	n/a	n/a	n/a
4 15pm	100 6	98.2	98 0	102.3	n/a	92.6	n/a	107 9	n/a	n/a	n/a	n/a	n/a
4 30pm	100 2	101 5	67 0	88 6	n/a	n/a	n/a	104 3	61.0	n/a	n/a	n/a	n/a
4 45pm	99 2	96 1	n/a	87 5	n/a	95 5	n/a	104 1	n/a	n/a	n/a	n/a	102.0
5 00pm	98 8	101 1	n/a	88 6	n/a	90.2	n/a	102 3	n/a	n/a	n/a	n/a	n/a
5 15pm	98 8	98 6	144 0	91 3	n/a	104.7	n/a	101 5	111 0	n/a	n/a	n/a	37 5
5 30pm	98 9	101.5	n/a	89 8	n/a	106.3	112.0	101.1	n/a	n/a	n/a	n/a	n/a
5 45pm	97 7	93 4	n/a	100 6	n/a	98.8	n/a	96 6	n/a	n/a	n/a	n/a	123 0
6 00pm	100.1	104 7	90 0	92.6	n/a	101.5	n/a	98.2	n/a	n/a	n/a	n/a	n/a
6 15pm	98.5	98 2	114.5	93.4	n/a	96.6	n/a	n/a	n/a	n/a	n/a	n/a	58.0

	7/20 Thur UMD	TIC	7/21 Fri UMD	TIC	7/24 Mon UMD	TIC	7/25 Tue UMD	TIC	7/26 Wed UMD	TIC	7/27 Thur UMD	TIC
3.30pm	94.4	n/a	n/a	n/a	n/a	120.0	n/a	n/a	101.4	n/a	n/a	n/a
3 45pm	95.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	101.0	n/a	n/a	n/a
4 00pm	91 8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	102.3	n/a	n/a	n/a
4 15pm	95.0	n/a	n/a	n/a	n/a	460.5	n/a	n/a	111.1	n/a	n/a	n/a
4 30pm	91 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	103.1	n/a	n/a	n/a
4 45pm	92 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	100.6	n/a	n/a	n/a
5 00pm	89 1	n/a	n/a	49 0	n/a	n/a	n/a	n/a	100.2	n/a	n/a	109
5 15pm	90 2	n/a	n/a	35 5	n/a	n/a	n/a	n/a	102.3	n/a	n/a	n/a
5 30pm	93 0	n/a	n/a	95 0	n/a	n/a	n/a	n/a	99.8	n/a	n/a	130
5 45pm	92.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	98.2	n/a	n/a	n/a
6 00pm	96 6	n/a	n/a	42 2	n/a	n/a	n/a	n/a	105.2	n/a	n/a	n/a
6 15pm	104.7	n/a	n/a	33.0	n/a	78.0	n/a	n/a	98.2	n/a	n/a	n/a

	7 28 Fri UMD	TIC	7/31 Mon UMD	TIC	8/1 Tue UMD	TIC	8/2 Wed UMD	TIC	8/3 Thur UMD	TIC	8/4 Fri UMD	TIC
3 30pm	n/a	n/a	n/a	n/a	n/a	72.0	n/a	n/a	97.7	n/a	n/a	n/a
3 45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	98.2	n/a	n/a	113.0
4 00pm	n/a	54.6	n/a	n/a	n/a	n/a	n/a	n/a	106.3	n/a	n/a	104.0
4 15pm	n/a	n/a	n/a	104.0	n/a	n/a	n/a	n/a	101.4	n/a	n/a	n/a
4 30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	101.4	n/a	n/a	75.0
4 45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	98.2	n/a	n/a	n/a
5 00pm	n/a	n/a	n/a	98.0	n/a	n/a	n/a	n/a	104.7	n/a	n/a	147.0
5 15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	93.4	n/a	n/a	64.6
5 30pm	n/a	130.0	n/a	n/a	n/a	n/a	n/a	n/a	104.7	n/a	n/a	n/a
5 45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	99.3	n/a	n/a	75.6
6 00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	97.4	n/a	n/a	n/a
6 15pm	n/a	104.0	n/a	93.7	n/a	41.0	n/a	n/a	n/a	n/a	n/a	n/a

I-66 WB . from RT243 to RT123 -- link 14103
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start Time	Calculated Avg. Speed	7/12 Wed		7/13 Thur		7/14 Fri		7/17 Mon		7/18 Tue		7/19 Wed	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3 30pm	96.2	n/a	108.0	80 5	n/a	27 0	53.0	95.0	111.5	90.8	106.1	n/a	109 7
3 45pm	95 4	n/a	100 2	69 2	n/a	n/a	85.7	97.4	103.7	91 1	107 4	n/a	120.7
4 00pm	93 5	n/a	95 3	89 4	n/a	28 2	47 8	101.5	102.3	91 6	117.8	n/a	105.8
4 15pm	94 9	n/a	98 0	92.3	n/a	26.3	57.0	101.5	101.6	96.0	89.1	n/a	116.5
4 30pm	95 6	n/a	103	100 4	n/a	30 6	96.9	100.6	119.9	94.8	102.8	n/a	98 5
4 45pm	92 8	n/a	80 3	96.6	n/a	39 7	111 0	99.0	n/a	96.0	114 0	n/a	93 7
5 00pm	95 4	n/a	n/a	95.8	120 8	51 5	61.6	96.6	97.1	95.3	118.3	n/a	81.6
5 15pm	92 6	n/a	n/a	102.0	112 5	43 5	83 7	96.1	n/a	93.7	n/a	n/a	116.3
5 30pm	91.0	n/a	101 8	98 8	101 7	63 6	101.1	90.7	n/a	90.4	100.3	n/a	n/a
5 45pm	92.5	n/a	118 4	89 4	156 5	99 0	87 0	97.2	122.9	89 1	106.2	n/a	99.1
6 00pm	94 9	n/a	97 7	80 5	82.3	100.6	109.7	91.8	110.5	94.3	n/a	n/a	128.6
6:15pm	93 2	n/a	106.5	96.6	127.3	100.6	115.0	n/a	120.1	85.4	64.1	n/a	102.1

		7/20 Thur		7/21 Fri		7/24 Mon		7/25 Tue		7/26 Wed		7/27 Thur	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3 30pm		n/a	n/a	n/a	38.1	98 2	95.8	n/a	n/a	103.5	n/a	n/a	83.0
3 45pm		n/a	n/a	n/a	74 9	95 7	104 2	n/a	n/a	97.0	n/a	n/a	n/a
4 00pm		n/a	n/a	n/a	52 0	91 8	115 5	n/a	n/a	97.1	n/a	n/a	n/a
4 15pm		n/a	n/a	n/a	58 3	87 8	109 7	n/a	n/a	103.1	n/a	n/a	n/a
4 30pm		n/a	n/a	n/a	67 5	61.8	157 7	n/a	n/a	99 8	n/a	n/a	134.4
4 45pm		n/a	n/a	n/a	82 5	67 0	76 4	n/a	n/a	97 7	n/a	n/a	161.6
5 00pm		n/a	n/a	n/a	85 3	89 4	113.4	n/a	n/a	106.3	n/a	n/a	100.2
5 15pm		n/a	n/a	n/a	79 1	70 3	141 0	n/a	n/a	45 1	n/a	n/a	81.1
5 30pm		n/a	n/a	n/a	30 7	38 3	84 0	n/a	n/a	46.7	n/a	n/a	76.2
5 45pm		n/a	n/a	n/a	67 2	20 1	59 2	n/a	n/a	88.6	n/a	n/a	52.1
6 00pm		n/a	n/a	n/a	65 9	n/a	59 6	n/a	n/a	99 8	n/a	n/a	77.0
6 15pm		n/a	n/a	n/a	61 7	n/a	71 2	n/a	n/a	99.0	n/a	n/a	81 9

		7/28 Fri		7/31 Mon		8/1 Tue		8/2 Wed		8/3 Thur		8/4 Fri	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3 30pm		n/a	n/a	n/a	109.5	88.9	91.7	n/a	n/a	94.5	n/a	n/a	n/a
3 45pm		n/a	45.1	n/a	64.0	93.9	92.0	n/a	n/a	102.3	n/a	n/a	51.7
4 00pm		n/a	52.0	n/a	75.4	94 2	92.0	n/a	n/a	94 2	n/a	n/a	56.4
4 15pm		n/a	51.4	n/a	89.0	93.4	72 0	n/a	n/a	96.6	n/a	n/a	54.8
4 30pm		n/a	45.1	n/a	99.7	92.1	101	n/a	n/a	97.7	n/a	n/a	58.4
4 45pm		n/a	52.3	n/a	139.0	95.5	112.	n/a	n/a	95.8	n/a	n/a	38.2
5 00pm		n/a	59.6	n/a	n/a	88.9	90 7	n/a	n/a	93.4	n/a	n/a	53.2
5 15pm		n/a	50.6	n/a	n/a	91 0	95 5	n/a	n/a	87.4	n/a	n/a	51.3
5:30pm		n/a	57.2	n/a	n/a	95.0	90.0	n/a	n/a	91.8	n/a	n/a	60.2
5 45pm		n/a	60 3	n/a	n/a	92.1	92.2	n/a	n/a	96.6	n/a	n/a	81.9
6 00pm		n/a	138.6	n/a	100.5	91.3	84 3	n/a	n/a	43.5	n/a	n/a	84.9
6 15pm		n/a	106.4	n/a	112.4	55.2	81.3	n/a	n/a	20.9	n/a	n/a	58.7

c-11

I-66 EB . from RT123 to RT243 -- link 14003
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start	Calculated	7/12	Wed	7/13	Thur	7/14	Fri	7/17	Mon	7/18	Tue	7/19	Wed
Time	Avg. Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	101.0	n/a	n/a	n/a	n/a	62.0	125.2	63.9	11.6	99 5	n/a	n/a	n/a
3 45pm	99.1	n/a	107.2	103 6	n/a	69.2	69 0	99.8	n/a	95 9	25 0	n/a	107.5
4 00pm	98 9	n/a	99 5	101 5	n/a	101.4	46 5	100.4	88.7	93 4	n/a	n/a	105 2
4 15pm	98.9	n/a	90 8	100 4	n/a	101.4	91.2	102.7	95.0	99 4	138.0	n/a	114.5
4:30pm	98 5	n/a	n/a	94 6	n/a	97.7	91 7	104.7	125 0	103.7	111.0	n/a	75 5
4 45pm	99.9	n/a	n/a	87 0	n/a	100.6	n/a	101.9	105.0	103.9	19 0	n/a	100 2
5 00pm	97 0	n/a	103 7	102.0	138.0	93.4	81.9	102.5	n/a	92.9	n/a	n/a	75 5
5:15pm	95 7	n/a	68.9	83 2	134 8	99.0	36.7	100.9	109.7	96 4	n/a	n/a	109 0
5 30pm	95.2	n/a	106.2	78 9	71.0	106.3	63.2	102.0	108.1	92.6	119.0	n/a	n/a
5:45pm	99 1	n/a	115.0	97 4	101.0	108 4	101.9	101.5	97.0	93.1	105.5	n/a	130.0
6:00pm	102.7	n/a	102 3	99 0	n/a	96.6	n/a	106.8	n/a	102.0	103.2	n/a	158.5
6:15pm	100.6	n/a	51.5	101 5	101.2	101.9	112.0	99.8	109.8	98.6	102.7	n/a	n/a

	7/20	Thur	7/21	Fri	7/24	Mon	7/25	Tue	7/26	Wed	7/27	Thur
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3 30pm	n/a	n/a	n/a	104 0	105.3	n/a	n/a	n/a	102.3	n/a	n/a	102.5
3:45pm	n/a	n/a	n/a	76.2	102.7	n/a	n/a	119.0	101.4	n/a	n/a	n/a
4 00pm	n/a	n/a	n/a	98 4	99 4	n/a	n/a	100.3	103.1	n/a	n/a	n/a
4 15pm	n/a	n/a	n/a	58 3	94.5	n/a	n/a	n/a	100.4	n/a	n/a	n/a
4:30pm	n/a	n/a	n/a	104 7	88 2	n/a	n/a	89.0	103.9	n/a	n/a	117.1
4 45pm	n/a	n/a	n/a	116 1	81.3	n/a	n/a	94.2	109.5	n/a	n/a	104.1
5 00pm	n/a	n/a	n/a	247 9	85.7	n/a	n/a	113.0	108.7	n/a	n/a	95.4
5 15pm	n/a	n/a	n/a	138.6	88 9	n/a	n/a	n/a	97.4	n/a	n/a	45.7
5 30pm	n/a	n/a	n/a	94 8	83 4	n/a	n/a	106.5	110.3	n/a	n/a	52.0
5 45pm	n/a	n/a	n/a	91 0	67 6	n/a	n/a	82.1	105.5	n/a	n/a	109.4
6 00pm	n/a	n/a	n/a	106.1	n/a	n/a	n/a	62.5	106.3	n/a	n/a	103.0
6:15pm	n/a	n/a	n/a	57.0	n/a	n/a	n/a	93.1	108.7	n/a	n/a	61 0

	7/28	Fri	7/31	Mon	8/1	Tue	8/2	Wed	8/3	Thur	8/4	Fri
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3 30pm	n/a	n/a	n/a	90.7	96.9	105.2	n/a	n/a	99.4	n/a	n/a	n/a
3 45pm	n/a	98.3	n/a	108.4	88.6	n/a	n/a	n/a	98.2	n/a	n/a	80.0
4 00pm	n/a	54.3	n/a	101.5	97 4	93.2	n/a	n/a	96.6	n/a	n/a	113.9
4:15pm	n/a	76.6	n/a	112.4	98 7	100 7	n/a	n/a	96.6	n/a	n/a	84.7
4.30pm	n/a	61.6	n/a	121.7	98.7	103 4	n/a	n/a	99.8	n/a	n/a	97.7
4:45pm	n/a	90.7	n/a	142.5	104.3	157.0	n/a	n/a	99.8	n/a	n/a	52.9
5 00pm	n/a	72.6	n/a	92.0	100.3	96 7	n/a	n/a	96.6	n/a	n/a	66.5
5.15pm	n/a	66.5	n/a	n/a	96.6	107.6	n/a	n/a	95.8	n/a	n/a	66.7
5:30pm	n/a	120.8	n/a	n/a	95 9	104.0	n/a	n/a	99.8	n/a	n/a	70.1
5:45pm	n/a	102.9	n/a	n/a	105.5	93.7	n/a	n/a	90.2	n/a	n/a	65.0
6:00pm	n/a	138.0	n/a	n/a	102.7	75 7	n/a	n/a	98.2	n/a	n/a	157.4
6:15pm	n/a	107.6	n/a	n/a	104.0	121.6	n/a	n/a	96.6	n/a	n/a	83.4

I-66 EB - from RT243 to I-495 -- link 14004
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start Time	Calculated Avg Speed	7/12 Wed		7/13 Thur		7/14 Fri		7/17 Mon		7/18 Tue		7/19 Wed	
		UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	96.5	n/a	n/a	n/a	n/a	53.1	n/a	96.6	175.2	n/a	115.0	n/a	n/a
3:45pm	93.1	91.0	102.2	92.9	n/a	70.9	98.3	93.4	164.0	n/a	89.0	n/a	105.7
4:00pm	97.3	93.9	102.0	93.4	n/a	102.3	116.7	101.5	116.8	n/a	103.7	n/a	111.1
4:15pm	96.6	96.6	79.2	102.5	n/a	95.0	93.5	91.4	98.6	n/a	111.9	n/a	117.0
4:30pm	96.5	97.7	91.9	95.8	n/a	95.4	n/a	99.0	84.2	n/a	126.6	n/a	106.0
4:45pm	95.7	91.8	85.7	87.0	n/a	n/a	n/a	103.5	89.5	n/a	n/a	n/a	111.8
5:00pm	94.6	90.5	103.9	95.0	112.3	93.4	n/a	99.3	109.5	n/a	n/a	n/a	n/a
5:15pm	92.9	70.1	127.2	74.1	95.2	91.8	n/a	100.4	112.6	n/a	n/a	n/a	n/a
5:30pm	93.8	89.4	104.3	92.5	89.7	96.6	120.0	110.0	100.8	n/a	n/a	n/a	95.0
5:45pm	96.8	95.8	111.8	92.2	90.0	97.2	109.0	103.1	105.1	n/a	110.7	n/a	n/a
6:00pm	97.5	87.8	115.4	98.2	100.0	91.8	n/a	100.6	n/a	n/a	106.0	n/a	n/a
6:15pm	97.4	95.0	104.8	96.1	103.6	93.9	n/a	99.8	113.9	n/a	107.5	n/a	n/a

	7/20 Thur		7/21 Fri		7/24 Mon		7/25 Tue		7/26 Wed		7/27 Thur	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	95.0	n/a	n/a	109.0	n/a	101.8	n/a	n/a	101.0	n/a	n/a	n/a
3:45pm	91.1	n/a	n/a	267.0	n/a	107.9	n/a	n/a	105.5	n/a	n/a	n/a
4:00pm	96.2	n/a	n/a	100.5	n/a	103.3	n/a	n/a	99.3	n/a	n/a	n/a
4:15pm	95.0	n/a	n/a	n/a	n/a	133.1	n/a	n/a	103.1	n/a	n/a	n/a
4:30pm	88.6	n/a	n/a	117.2	n/a	95.3	n/a	n/a	105.5	n/a	n/a	104.0
4:45pm	88.2	n/a	n/a	81.8	n/a	95.7	n/a	n/a	111.1	n/a	n/a	96.1
5:00pm	91.8	n/a	n/a	131.2	n/a	91.0	n/a	n/a	103.9	n/a	n/a	97.0
5:15pm	89.4	n/a	n/a	158.7	n/a	78.9	n/a	n/a	99.8	n/a	n/a	112.4
5:30pm	88.6	n/a	n/a	103.7	n/a	75.3	n/a	n/a	103.1	n/a	n/a	n/a
5:45pm	104.3	n/a	n/a	77.8	n/a	31.3	n/a	n/a	101.0	n/a	n/a	125.8
6:00pm	92.9	n/a	n/a	92.2	n/a	72.1	n/a	n/a	105.5	n/a	n/a	266.0
6:15pm	103.1	n/a	n/a	116.0	n/a	72.0	n/a	n/a	100.4	n/a	n/a	84.3

	7/28 Fri		7/31 Mon		8/1 Tue		8/2 Wed		8/3 Thur		8/4 Fri	
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	n/a	n/a	n/a	123.5	n/a	113.2	n/a	n/a	93.9	n/a	n/a	n/a
3:45pm	n/a	107.6	n/a	97.1	n/a	n/a	n/a	n/a	91.8	n/a	n/a	104.7
4:00pm	n/a	89.9	n/a	102.1	n/a	84.6	n/a	n/a	94.2	n/a	n/a	111.3
4:15pm	n/a	122.5	n/a	104.0	n/a	89.3	n/a	n/a	94.5	n/a	n/a	n/a
4:30pm	n/a	88.3	n/a	97.4	n/a	94.0	n/a	n/a	98.2	n/a	n/a	107.4
4:45pm	n/a	119.4	n/a	98.7	n/a	103.0	n/a	n/a	91.8	n/a	n/a	n/a
5:00pm	n/a	79.3	n/a	97.7	n/a	94.1	n/a	n/a	93.9	n/a	n/a	124.0
5:15pm	n/a	n/a	n/a	n/a	n/a	100.5	n/a	n/a	104.7	n/a	n/a	77.7
5:30pm	n/a	102.0	n/a	96.7	n/a	131.5	n/a	n/a	87.8	n/a	n/a	60.5
5:45pm	n/a	94.5	n/a	n/a	n/a	100.4	n/a	n/a	96.6	n/a	n/a	56.7
6:00pm	n/a	109.1	n/a	n/a	n/a	100.0	n/a	n/a	94.5	n/a	n/a	81.2
6:15pm	n/a	n/a	n/a	n/a	n/a	45.8	n/a	n/a	90.2	n/a	n/a	102.5

c-13

I-495 NB - from I-66 to RT7 -- link 19116
Calculated Average Speed. Daily Average Speed (UMD) and TIC Calculated Speed (TIC) - ALL SPEED IN (KPH)

Start	Calculated	7/12	Wed	7/13	Thur	7/14	Fri	7/17	Mon	7/18	Tue	7/19	Wed
Time	Avg Speed	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	95.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3:45pm	92.0	91.8	n/a	n/a	n/a	83.7	61.0	n/a	n/a	n/a	n/a	n/a	n/a
4:00pm	90.6	90.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	103.0
4:15pm	96.1	95.7	n/a	n/a	n/a	96.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:30pm	97.5	91.3	n/a	n/a	n/a	87.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:45pm	97.8	99.8	n/a	n/a	n/a	106.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:00pm	99.6	100.6	n/a	n/a	n/a	95.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:15pm	95.8	99.8	n/a	n/a	n/a	90.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:30pm	94.3	81.6	n/a	n/a	n/a	88.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:45pm	96.8	95.0	n/a	n/a	n/a	93.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:00pm	98.1	91.8	n/a	n/a	n/a	95.8	n/a	n/a	n/a	n/a	n/a	n/a	111.0
6:15pm	96.3	97.4	n/a	n/a	n/a	95.0	n/a	n/a	100.	n/a	n/a	n/a	n/a

	7/20	Thur	7/21	Fri	7/24	Mon	7/25	Tue	7/26	Wed	7/27	Thur
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	59.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3:45pm	95.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:00pm	92.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:15pm	98.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:30pm	98.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4:45pm	97.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	55.0
5:00pm	101.0	n/a	n/a	n/a	n/a	66.0	n/a	n/a	n/a	n/a	n/a	n/a
5:15pm	93.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:30pm	98.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5:45pm	97.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:00pm	101.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6:15pm	99.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	7/28	Fri	7/31	Mon	8/1	Tue	8/2	Wed	8/3	Thur	8/4	Fri
	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC	UMD	TIC
3:30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	99.3	n/a	n/a	n/a
3:45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	93.9	n/a	n/a	n/a
4:00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	86.2	n/a	n/a	n/a
4:15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	92.3	n/a	n/a	n/a
4:30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	110.3	n/a	n/a	n/a
4:45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	91.0	n/a	n/a	n/a
5:00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	91.8	n/a	n/a	n/a
5:15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	98.2	n/a	n/a	n/a
5:30pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	90.2	n/a	n/a	n/a
5:45pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	99.8	n/a	n/a	n/a
6:00pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	102.3	n/a	n/a	n/a
6:15pm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	92.6	n/a	n/a	93.7

APPENDIX D

Speed (Travel Time) Field Tests (UMD) and Outputs From the Operational Test Selected Comparison Days

Differences in Travel Time Speeds VS UMD   07/13/95

KPH

| | 56.35 |
| 48.3 |
| 40.25 |
| 32.2 |
| 24.15 |
| 16.1 |
| 8.05 |
| 0 |
| -8.05 |
| -16.1 |
| -24.15 |
| -32.2 |
| -40.25 |
| -48.3 |

7:00   7:15   7:30   7:45   8:00   8:15   8:30   8:45   9:00

time

—— TIC
■ ERA
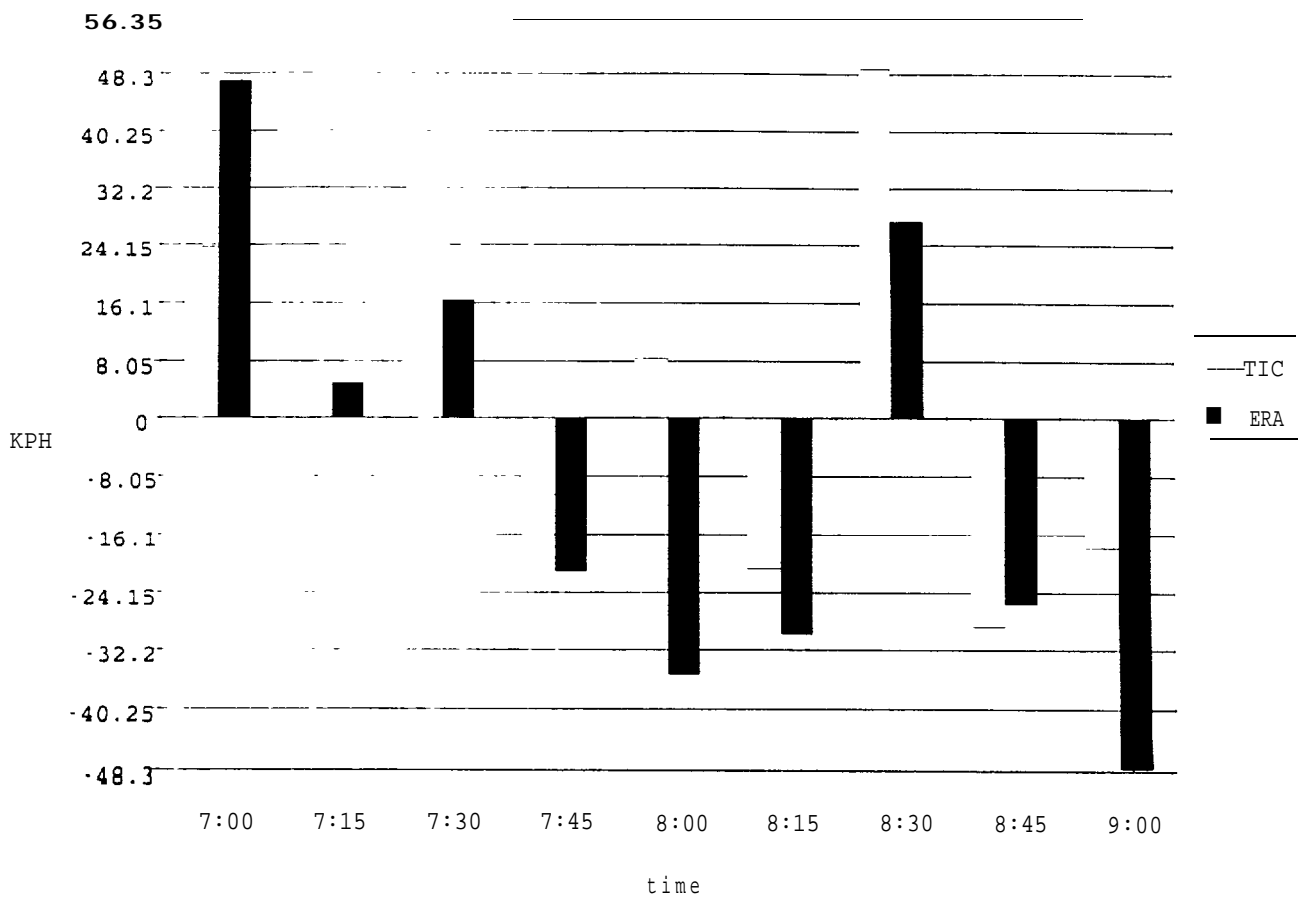
Actual Test Vehicle Speeds   07/13/95 link 14003
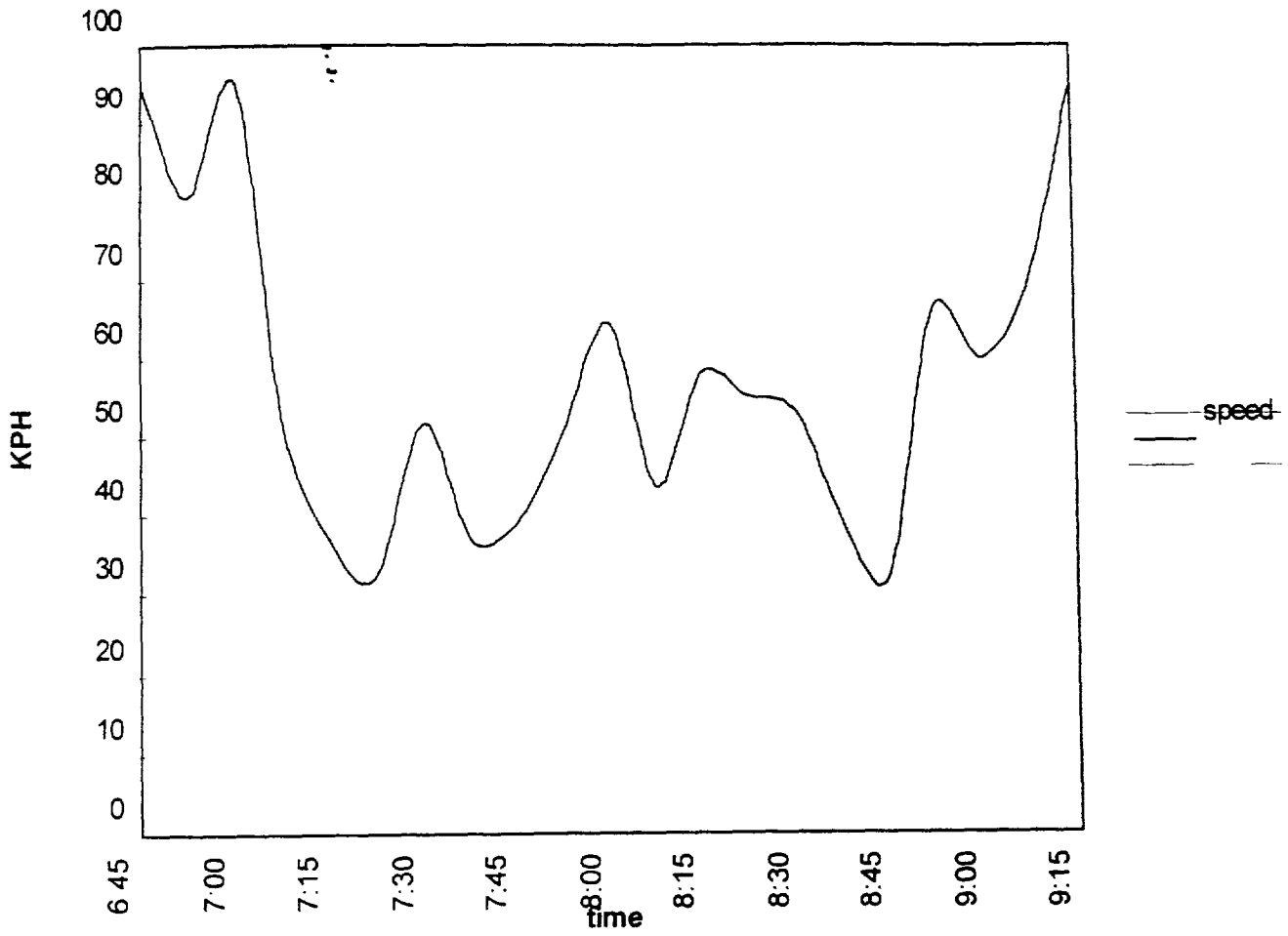
APPENDIX E

Arterial Link Speed Data for 7/11 thru 8/3

(for Comparison to the One Day Sample: 7/27/95)

Speed data for VA RT29

RT29 EB - from Nutley to Cedar -- link 110 14

TIC Calculated Speed (TIC) and Daily Average Speed (UMD) -- ALL Speeds in (KPH)

	7/11	7/12	7/13	7/18	7/19	7/20	7/25	7/26	727	7/27	8/1	8/2	8/3
	Tue	Wed	Thur	Tue	Wed	Thur	Tue	Wed	Thur	Thur	Tue	Wed	Thur
	TIC	TIC	TIC	TIC	TIC	TIC	TIC	TIC	UMD	TIC	TIC	TIC	TIC
6 30	n/a	n/a			n/a			n/a	63.6	n/a			n/a
6 45	n/a	n/a			n/a			n/a	61.7	n/a			n/a
7 00	n/a	n/a	55 3		n/a			n/a	66.3	n/a		52	n/a
7·15	n/a	n/a			n/a			n/a	55.2	n/a			n/a
7 30	n/a	n/a			n/a	52	51	n/a	47.5	n/a			n/a
7 45	n/a	d a	50 5		n/a			n/a	45.1	n/a			n/a
8.00	n/a	d a		6 4 7	n/a		27	n/a	48.8	n/a	69.5		n/a
8.15	n/a	d a			n/a			n/a	64.1	n/a			n/a
8:30	n/a	n/a	33		N a			n/a	54.9	n/a			n/a
8.45	n/a	d a			n/a	49		n/a	51.5	n/a	22		n/a
9.00	n/a	n/a			n/a	42	76 5	n/a	AR 8	n/a	31 7		n/a

RT29 EB - from Cedar to Prosperity -- link 11015

TIC Calculated Speed (TIC) and Daily Average Speed (UMD) -- ALL SPEEDS IN (KPH)

	7/11	7/12	7/13	7/18	7 19	7/20	7/25	7/26	7/27	7/27	8/1	8/2	8/3
	Tue	Wed	Thur	Tue	Wed	Thur	Tue	Wed	Thru	Thur	Tue	Wed	Thur
	TIC	TIC	TIC	TIC	TIC	TIC	TIC	TIC	UMD	TIC	TIC	TIC	TIC
6 30	n/a	n/a						n/a	50.1	n/a			n/a
6.45	n/a	n/a						n/a	70.2	n/a			n/a
7 00	n/a	n/a			0			n/a	71.3	n/a			n/a
7 15	n/a	n/a						n/a	50.1	n/a			n/a
7·30	n/a	n/a						n/a	48.0	n/a		82.5	n/a
7·45	n/a	n/a	84.2					n/a	25.8	n/a	5.2	71.5	n/a
8·00	n/a	n/a						n/a	10.9	n/a			n/a
8 15	n/a	n/a						n/a	17.7	n/a	64		n/a
8.30	n/a	n/a		21				n/a	39.0	n/a			n/a
8.45	n/a	n/a					36	n/a	48.9	n/a			n/a
9:00	n/a	n/a				51		n/a	60.0	n/a		12 0	n/a

RT29 WB - from Prosperity to Cedar -- link 11115

TIC Calculated Speed (TIC) and Daily Average Speed (UMD) -- ALL SPEEDS IN (KPH)

	7/11 Tue TIC	7/12 Wed TIC	7/13 Thur TIC	7/18 Tue TIC	7/19 Wed TIC	7/20 Thur TIC	7/25 Tue TIC	7/26 Wed TIC	7/27 Thur UMD	7/27 Thur TIC	8/1 Tue TIC	8/2 Wed TIC	8/3 Thur TIC
6 30	n/a	n/a				n/a		n/a	58.5	n/a			n/a
6 45	n/a	n/a				n/a		n/a	62 6	n/a			n/a
7 00	n/a	n/a			0	n/a		n/a	65 4	n/a			n/a
7 15	n/a	n/a				n/a		n/a	59 6	n/a			n/a
7 30	n/a	n/a				n/a		n/a	52.7	n/a		104	n/a
7.45	n/a	n/a	52 5			n/a		n/a	45 9	n/a	7		n/a
8.00	n/a	n/a				n/a		n/a	54.3	n/a			n/a
8 15	n/a	n/a				n/a	91	n/a	59.9	n/a	79.5		n/a
8 30	n/a	n/a				n/a		n/a	62.8	n/a	161		n/a
8.45	n/a	n/a				n/a		n/a	56.0	n/a	56.5	32	n/a
9 00	n/a	n/a	91	86		n/a		nla	52 7	n/a	23 3		n/a

RT29 WB - from Cedar to Nutley -- link 11114

TIC Calculated Speed (TIC) and Daily Average Speed (UMD) -- ALL SPEEDS IN (KPH)

	7/11 Tue TIC	7/12 Wed TIC	7/13 Thur TIC	7/18 Tue TIC	7/19 Wed TIC	7/20 Thur TIC	7/25 Tue TIC	7/26 Wed TIC	7/27 Thur UMD	7/27 Thur TIC	8/1 Tue TIC	8/2 Wed TIC	8/3 Thur TIC
6 30	n/a	n/a			n/a			n/a	68.9	n/a			n/a
6 45	n/a	n/a			n/a			n/a	69.4	n/a			n/a
7 00	n/a	n/a			n/a			n/a	65 2	n/a			n/a
7 15	n/a	n/a			n/a			n/a	59 7	n/a			n/a
7 30	n/a	n/a			n/a			n/a	63.6	n/a	79		n/a
7 45	n/a	n/a			n/a		48 5	n/a	58.0	n/a	83		n/a
8 00	n/a	n/a			n/a	84		n/a	66.0	n/a			n/a
8·15	n/a	n/a	61	91.5	n/a			n/a	58.8	n/a		62	n/a
8.30	n/a	n/a	49.1		n/a			n/a	58.9	n/a	131	49	n/a
8 45	n/a	n/a			n/a	43.7	42	n/a	67.3	n/a			n/a
9.00	n/a	n/a			n/a	35.9	79.6	n/a	58.8	n/a		9	n/a

APPENDIX F

Remote Users Questionnaire

Returned questionnaires from the remote users.

CAPITAL IVHS Questionnaire
(Cellular telephone based Operational Test/Wide Area surveillance)

Name/Agency_____ _____

1. **How did you use the information from the cellular based surveillance system?**
   a) To identify incidents_____ . **b) To verify incidents**_____.
   c) To alert patrol_____ . **d) To modify/activate VMS/HAR**
   e) To verify system status_____ **f) To determine system status**_____
   g) Other (please discuss) _____ _____ . .

2. **How frequently did you use the system?**
   a) Several times per day _✓_____ **b) Daily**____
   c) Weekly _____ **d) Only for incidents** _____
   e) Other (please specify) _____ _____

3. **If you did not use the information frequently why?**
   a) Did not yet know its reliability_____
   b) Existing system determines statues and detects incidents _____
   c) Output is too difficult to interpret. _____
   d) The system is too difficult to use.
   e) Other (please specify) . _____

4. **What difficulty, if any, did you experience in understanding the data format?**

5. **What suggestions do you have for changing the data format?**

6. **How useful was the data for your activities?**

   OUR Vehicles ARE going FAIRLAKES + NUTLEY ST AND long before they appear on the system.

7. **What could be changed to make the data more useful to you?**

8. **What changes could be made in you operation (TMC) to make this data more useful?**

9. **What the information accurate enough for your use?**

10. **Was the system easy to learn how to operate? Why or why not?**

11. **What problems did you have with the system?**

District of Columbia

Bowie

College Park

Frederick

Frederick County

Gaithersburg

Greenbelt

Montgomery   County

Prince George's County

Centreville

Takoma Park

Arlington County

Fairfax

Fairfax County

Falls Church

Loudon   County

Prince William County

April 8, 1996

Everett C. Carter
Professor
Department of Civil Engineering
University of Maryland At College Pa
College Park, MD 20742-3021

Dear Dr. Carter:

This is in response to your April 2, 1996 letter requesting our thoughts on possible uses for data that may be collected as part of a permanent CAPITAL IVHS system. Some of the possible uses for incident data and travel time speed data that could be obtained from such a system are listed below.

Congestion Management System (CMS)

For the CMS we evaluate on an annual basis the locations and extent of congestion in the region. For limited access highway system (Freeways & Expressways) we have relied on the aerial survey which provides us with densities which is used to estimate average speeds on the links. Because of cost limitations our surveys are limited to peak period coverage on a three year cycle. If the CAPITAL IVHS system could provide average speeds it could be a direct measurement instead of an estimation and speeds probably might be available on a 24 hour basis.

For arterial highways we have been relying on the demand model forecasts to provide us with average speeds. This is supplemented by periodic travel time/speed measurements on a limited number of facilities. There is a great need for speed/travel time data on arterial highways in order to perform an assessment of existing conditions. This letter assumes the CAPITAL ITS project could provide the information on the arterial system in addition to the freeway system.

At present, we do not include any estimates of non-recurring congestion. The annual report could indeed be enhanced if we can provide an assessment of the impact of non-recurring congestion.   Maryland and Virginia are implementing Incident management programs which would have air quality implications if indeed the delay from incidents are reduced. The data when available could enable us to

2

quantify the benefits of incident management program.

Demand Model

MWCOG is in the midst of a model improvement program which will improve the way demand modelling is done in the region. In order to validate the model, volume and speed data will be required on many of the facilities in the region. In addition the demand is periodically validated to meet Federal requirements. Speed data from the cellular system could satisfy some of the needs.

I hope this information is useful to you. Please call me if you have any additional questions.

Sincerely

Daivamani Sivasailam
Department of Transportation Planning

APPENDIX G
Example of Police Logs: Incidents

99
87

VA STATE POLICE
24G4

INCIDENT REPORT
DATE: 8/4/95   TIME: 1625

TYPE OF INCIDENT: 10-46 | | 10-50 |X| OTHER

INCIDENT LOCATION 1-395| | 1-495| | 1-66 |X| 1-95| | N S E (W)

AT (location): Rte 123

NUMBER of LANES BLOCKED: | 2| ALL? | | (Specify)

No. of VEHICLES INVOLVED | 6| AUTO |✓| TRUCK| | TRACTOR TRL: |_|

Did TMS find INCIDENT? (YES) / (NO)   (if no, indicate how incident was located)

NOTIFICATIONS GIVEN TO:

VSP:| |METRO:|X|SHADOW|X| Va TOC:| |DISTRICT Ofc:|_|Md TOC: |_|

OTHERS NOTIFIED: ~~9988~~ 9987

TIME HELP ARRIVED: 1630   WHO? 9987

SIGNS AVAILABLE. YES / NO   USED: 1,2, 5, 6, 15, 16
Display messages used below Use (*) for flashing line. Use "CANNED" msg. number)

| Accident I-66W |
| at Route 123 |
| * | USE Caution |

Not visible

Estimated BACKUP: 1   INCIDENT CLEARED AT: 1736
OPERATOR (S) on DUTY: HD   Supervisor's Signature: Q

G-1

CASE NUMBER	DATE	TIME	DISPATCH	ARRIVAL	CLERK	STREET		INTERSECT STREET	TYPE	DAY OF HALL
9404500108	902149	1455	1511	1551	140100000	I4			ONINMON30PCN-H&R-PROP DMG ACC	0066000508I/4M 06
9407000144	801099	1842	1857	1929	120100000	I66/NUTLEY	ST	I66	INFRI300NOTHER TRAFFIC CMPLT	0066002899999006
9409300024	040399	1904	1905	1909	160300000	RT66/NUTLEY	XX	RT495	INSUN49ABOTHER	0066002899999006
9409500061	504059	0957	0995	71029	190200000	I-66/123	XX		INTUE49ABOTHER	0066024382507 06
9409900050	409940	0350	00480	0206	120300000	I66/RT	XXW	PRI LEE JACKSON MEMORIAH	INFRI300NSAT2IAADWI-ALCOHOL	0123306599999006
9410000219	410949	0226	02260	0420	120100000	I66/RT 29	RT29	INSUN49ABOTHER	0066029810OF 06
9410200106	412949	1500	1500	0326	180200000	I66/RT 123	XX	RDINTUE49ABOTHER	0066002899999006
9410500102	415949	0150	01500	0420	130200000	LEE JACKSON	XX	I66	INTUE49ABOTHER	0066002899999006
9410700017	417949	0230	02330	0352	180200000	I66 AT 123	RD	I	INSUN49ABOTHER	0066002899999006
9411800011	428949	0220	02200	308	170200000	I66/RT 50	XX	6	INTHU48APOTH MISC SERVICES	0049506659999006
9413700010	517949	1521	1521	82120	131020000	COMPTON	RD	I66--ON COMPTON	RDINTHU2GHLABANDONED AUTO/VEH	0495006H2M 06
9413800045	518949	0905	0905	20430	130100000	I66/RT 29 W	PRI	PRI	CEINTUE49ABOTHER	0495006659999006
9413900006	519949	1001	1001	0915	170200000	I66	XXW	LEE JACKSON MEM ON W	XXINMED49ABOTHER	0495006659999006
9414000066	519949	0280	102810	322	130100000	I66/ RT 29W	PRI	CEINTHU49ABOTHER	0066002899999006
9414000062	520949	1620	16200	1638	A180100000	FAIRFAX COUNTY	PM	I66--ON WB	66INFRI300PCN-H&R-PROP DMG ACC	0066000508I/4M 06
9414000125	520949	1808	18081	904	170200000	I66	XX	SULLY	HYINFRI300PBN-H&R-PERS INJ ACC	0066002899999006
9414100078	523949	1391	1391	1225	170200000	I66	XXW	SULLY	RDINMON30PCN-H&R-PROP DMG ACC	0066002899999006
9414400029	524940	0716	0716	0745	160200000	I66	XX	NUTLEY	STINTUE30PCN-H&R-PROP DMG ACC	0066024382507 06
9414400006	790524949	1019	1021	1053	180100000	CHAIN BRIDGE	RD	I66EB	XXINTUE30PCN-H&R-PROP DMG ACC	0123306599999006
9414500109	6052494	1459	1154	659	1201000000	I66	XX	LEE	HYINTUE30PCN-H&R-PROP DMG ACC	0066029810OF 06
9414500127	5b5259	4165	1654	727	120200000	I66	XX	SULLY	RDINWED30PCN-H&R-PROP DMG ACC	0066002899999006
9414500012	805259	1656	1656	710	A000000000	9495 S		I66	INWED30PCN-H&R-PROP DMG ACC	0066002899999006
9414500117	05259	4171	1714		120200000	I66	XX	SULLY	RDINWED30PCN-H&R-PROP DMG ACC	0064500668 25M 06
9414500158	405259	4194	1950	2044	150200000	STRINGFELLOW	RD	I66	INWED30PCN-H&R-PROP DMG ACC	0495006682I/10M06
9414600824	05189	40802	080	803	170200000	I495S	XX	I66E	XXINTHU30PAN-H&R-FATAL ACC	0495006659999006
9414700129	5052779	4153	4154	719	170200000	LEE JCKSN	HY	I66	XXINFRI30PCN-H&R-PROP DMG ACC	0050006659M 25M 06
9415000095	5094	191	1919	622	160500000	I495	XXS	I66	XXINMON30PCN-H&R-PROP DMG ACC	0495006659999006
9415100113	5194	151	1514	517	160500000	I495		I66	INTUE30PCN-H&R-PROP DMG ACC	0495006659999006
9415100117	05194	151	1514		A000000000	I66 E		PRI I495	INTUE30PBN-H&R-PROP DMG ACC	0495006H2M 06
9415100119	5194	214	1514	619	160400000	I495		I66	XXINTUE30CHITLRUN-PROP DMG	9999006659N.2M 01
9415100184	5194	214	1414	142	170200000	FAIR OAKS MALL	XX	I66	INTUE300CHITLRUN-PROP DMG	9999006659N.2M 01
9400100034	01949	31203	1301	8343	801000000	FAIRFAX COUNTY	PM	I66--ON WB	66INSAT48AIPUBLIC RELATIONS/LIAISON 9999006659N.2M 01

G-2