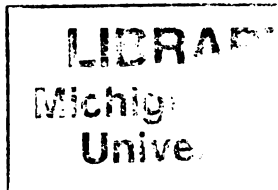


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**AN EVALUATION OF THE IMPACTS OF CHANGEABLE MESSAGE SIGNS
ON FREEWAY DIVERSION**

By

Bellandra Benefield Foster

A DISSERTATION

**Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

AN EVALUATION OF THE IMPACTS OF CHANGEABLE MESSAGE SIGNS ON FREEWAY DIVERSION

By

Bellandra Benefield Foster

The focus of this research is to evaluate the Changeable Message Sign (CMS) component of the Intelligent Transportation Systems (ITS) construction project completed within southeastern Michigan. The changeable message sign and detector loop infrastructure construction began in 1997. The construction and field testing phases are scheduled for completion in 1999 by the Michigan Department of Transportation contractor.

This research will explore three field sites within the ITS expansion area. The three sites were selected due to their configuration which allows a driver to make a choice to divert to a route other than their present route of travel. This diversion decision may be impacted by the changeable message sign display that exists along their travel path upstream from the decision point. Volume data for each site was obtained by analyzing the available loop detector measures of volume, speed and occupancy. Each site was analyzed on the basis of 'with' and 'without' CMS message activation. The 'without' condition includes site analyses during periods when either a blank or default message is displayed. The 'with' condition consists of periods when a specific informational type of driver information is displayed. Statistical significance of driver propensity to divert was analyzed based upon a comparison of traffic volume on the alternate routes.

A simulation analysis of each site was completed using the FRESIM component of the CORSIM simulation software to determine simulated driver delay, and compare actual and simulated traffic speeds.

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INTRODUCTION

This research project included the field site review, data collection, computer simulation and data analysis of the impact of the Michigan Department of Transportation (MDOT) Changeable Message Signs (CMS) on traffic flow at specific locations. Variable message signs comprise a portion of MDOT's 1996-1999 expansion of the Intelligent Transportation Systems (ITS) deployment in the southeastern Michigan area. The purpose of the ITS expansion is to assist the MDOT in managing freeway incidents, reducing congestion, and distributing traffic in response to planned and unplanned incidents.

This evaluation report describes the impact of CMS on delay, and the percentage of freeway traffic diverted as a result of the CMS displays. Driver diversion was analyzed at three freeway locations where CMS are present.

CHAPTER 1: RESEARCH PROJECT DESCRIPTION

Project Perspective

The investment of public funds can be justified on the basis of benefits and costs, and investment in freeway traffic management is no exception. The Michigan Department of Transportation (MDOT) has initiated the expansion of Intelligent Transportation System (ITS) deployment in Southeastern Michigan providing a unique opportunity to evaluate the net benefits of ITS deployment on a region wide basis.

This public ITS implementation project promises to improve the flow of traffic on most area freeways. The new system should increase MDOT's ability to respond to recurring and non-recurring congestion in the deployment area. However, the benefits and costs of the planned deployment are not known with certainty. While experience shows significant value in intelligent transportation systems technology, there is a need to quantify costs and benefits for public investment purposes. The MDOT Intelligent Transportation Systems deployment project provides a singular opportunity to evaluate the impact of a multifaceted region wide ITS deployment.

The MDOT deployment plan was one of the first ITS plans of its kind, and the deployment will result in one of the most comprehensive Intelligent Transportation Systems in the nation. This deployment offered a unique opportunity to collect before-and-after data to evaluate the effectiveness of ITS. It is unique in the sense that the plan is relatively comprehensive, it covers over 150 miles of urban freeway, and there was very little detection and traffic control technology deployed on the freeway system prior to this system expansion program. The conditions are ideal for a 'before' (generic or

blank display) and ‘after’ (priority message display) evaluation of the CMS -- something that has not been accomplished for any other major metropolitan area in the nation.

The Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS) expansion should assist MDOT in managing freeway incidents, reducing congestion, and distributing traffic in response to events and incidents. By quickly identifying, verifying, and responding to incidents, MDOT should see substantial reductions in system delay. Ideally, MDOT’s efforts will be coordinated with other agencies in the region for a more fully integrated management approach. The intent is to achieve greater throughput while also reducing the variability in flow and trip times.

The results of this project will enhance the ability of MDOT to assess the impacts resulting from deploying ITS Advanced Traveler Information technologies. In addition this study can make a significant contribution to our understanding of ITS deployment, locally and nationally.

Phase one of the ITS evaluation included a Congestion Assessment Study. A measure of corridor and system congestion was developed and approved by MDOT. The second phase of the ITS evaluation is designed to determine whether these measures are increased or decreased by the implementation. To establish the baseline conditions, volume data were collected from selected instrumented corridors during periods when message displays either contained a default message, or were blank. Nine months of historical data were obtained from the current MDOT loop detectors in the Detroit area.

Changeable message signs were deployed to communicate site-specific information to the motoring public. The evaluation was based on a comparison of data when priority, default, or blank CMS's were displayed, including driver diversion under each of these conditions. The purpose of this study was to evaluate the impact of providing information to the driver in terms of measures of effectiveness, which will assess freeway operations.

At the study locations used in this research, changeable message signs are used to provide traffic information, traffic warnings, regulations, routing, and traffic management information to highway users. They are designed to affect the behavior of motorists by providing real-time highway related information. As of July 1999, a total of 15,680 messages were available to the operator of the CMS located in the Michigan Department of Transportation traffic management center. These messages are listed by MDOT priority category as shown in Table 1.01. In addition to the five categories listed, a blank message board is also a display alternative.

Table 1.01 - MDOT Changeable Message Sign Display By Priority

1. Incident Management (accidents, freeway closures, etc.)
2. Traffic Management (incident and/or special event detours or road work)
3. Construction (e.g., Fines Doubled in Construction Zones)
4. Safety (e.g., State Troopers Wear Their Seat Belts, Do You?)
5. Non-MDOT, transportation related messages (e.g., Detroit Metro Airport Closed Due To Fog)

Messages within categories 3 through 5 scroll every 8 seconds. Message types 1 and 2 do not scroll. The Michigan Intelligent Transportation Systems Center (MITSC), which will control the CMS sites, refuses to post the following types of messages: advertising, promotions, telephone numbers, directing motorists to certain locations while diverting them from others to the detriment of commercial interests, non-traffic related messages, and others at the discretion of the MITSC directors. Messages containing the word 'congestion' will not be displayed due to motorist survey results, which revealed variations in driver perception of the meaning of this word.

The measures of effectiveness used in this research include reductions in delay, and percentage of diversion based upon message type displayed. The computer simulations for each analysis site include data which measure the delay consequences of incident induced or recurring congestion as a result of a drivers' decision to divert or not divert. Other measures of effectiveness which are available from the computer simulation include speed, fuel consumption, and air quality impacts. However, these measures were not used in this project.

Purpose of the Evaluation

This evaluation was designed to assess the benefits and costs of the CMS component of this ATMS/ATIS expansion program. The evaluation emphasized the benefits of incident management and traffic diversion, which are the most likely benefits from CMS. Some specific evaluation questions to be answered by the evaluation project include the following:

- What are the impacts of traffic diversion on delay? Specifically, what happens to delay and travel times when there is driver diversion under recurring and non-recurring congestion?
- How well is the CMS service operating? What are the impacts of a CMS message on driver route selection?

Problem Statement

The objective of this research project is to evaluate the impacts of a CMS providing motorist information during peak and non-peak hours on the freeway. The FRESIM traffic simulation program will be used to evaluate traffic conditions at each diversion site selected for evaluation. The study locations include three new CMS sites. The FRESIM simulation program assists the user in determining the value of various measures of effectiveness. The following measures will be utilized to evaluate the MOE's for each CMS analysis location.

- Vehicles In - Total number of vehicles which entered the upstream link and each of the downstream links since the beginning of the simulation.
- Vehicles Out - Total number of vehicles discharged from these links since the beginning of the simulation.
- Average Total Travel Time – Average vehicle minutes of travel time incurred by all vehicles that traversed the upstream link and one of the downstream links since the beginning of the simulation.
- Moving Time - Average travel time of the vehicles on the network while moving at a speed greater than zero.

- Delay Time in Units of Vehicle Seconds – Total time in which vehicles are slowed or stopped en-route through the network due to congestion delays. The difference between the Total Travel Time when allowed to travel at posted speed, and the Total Travel Time when congested traffic congestions result in delays.
- Density in Units of Vehicles/Lane Mile - Ratio of the average number of vehicles to the total lane-miles on each link.
- Speed in Units of Miles per Hour - Ratio of the Vehicle-Miles to Vehicle-Hours.

Methodology

The evaluation included monitoring detectors both upstream and downstream at three locations where CMS's are installed (diversion points). Analysis of speed and volume measures were performed under the following conditions:

- a. The system displays a message within priority category 4 or 5 as stated in Table 1.01.
- b. The system displays a message within priority categories 1, 2, or 3 as stated in Table 1.01.

Total freeway volume upstream from the nearest freeway diversion point downstream from the CMS, and the freeway volume on each of the alternative paths at the diversion point were compared. A simulation analysis of the freeway segment studied was conducted to conduct the incident impact analyses.

The following CMS locations were selected:

1. Eastbound I-96 east of Beck Road – City of Novi, Michigan
2. Eastbound I-696 at Manistee – City of Oak Park, Michigan
3. Westbound I-96 at Buchanan – City of Detroit, Michigan

Research Objectives

The objectives of this research were to:

1. Determine the impacts on driver diversion and speed due to the display of priority messages, versus generic message or blank display periods.
2. Based upon the computer simulation models developed for the selected sites, evaluate freeway incident impacts by varying the capacity of the freeway segments to simulate varying degrees of incident severity.

CHAPTER 2: LITERATURE REVIEW

Factors Influencing Driver Behavior in Making Route Choices

Driver travel behavior can be effected by two primary situations: 1) the traveler makes a one-time decision to change the planned travel route or travel time based upon the influence of an external event, such as traffic information and 2) a drivers' typical travel habits are modified over some time period due to changing circumstances in their environment. In the first situation, a message displayed on a changeable message sign could be used by the driver in selecting a route. The possible driver responses to the information displayed on a CMS would be to do nothing or to take an alternate route, depending on; the degree of congestion, the clarity, usefulness and reliability of the displayed information, and the individual driver tolerance to the prevailing traffic conditions.¹

The reaction of a driver is also determined by the individual's past experience in obtaining and utilizing traffic information. Many drivers may not use traffic recommendations due to one or more of the following reasons:²

- An acceptable alternative route is unavailable during the drivers' time of travel.
- The variable message sign information displayed is not relevant or reliable.
- The traffic usually clears within an acceptable length of time for the driver.
- Driver fear of getting lost if an alternative route is used.

Driver diversion behavior has been researched using the stated preference approach, the revealed/reported preference approach, or the field study approach.³ The primary goal of the stated preference approach is to analyze what drivers say they would do in response

to hypothetical traveling situations. The revealed preference approach analyzes driver behavior in real-life situations on the basis of reports from the respondents about previous actions or responses to typical driving situations. This research study is based upon the field study approach, which consists of the analysis of driver behavior through field observation of traffic, including observation of actual diversion behavior in response to specific messages.

Based upon a survey completed by Wohlschlaeger⁴, in order of importance, the survey results revealed that motorists prefer to travel a route which is more direct, faster and less congested than the alternate routes. Based upon studies completed by Huchingson and Dudek,⁵ using the stated preference approach, the median value of delay for drivers to make the decision to divert was 15-20 minutes for different locations within the United States. A study in Houston, Texas found the median value of delay for diversion to be only 5-6 minutes in the case where a service road is available as a convenient alternative route.⁶

The research completed by Khattak, Schofer, and Kopplemen provided a summary of factors that were found to influence driver diversion behavior. These factors included the following:⁷

- Level of Traffic Information
- Travel Time on the Preferred Route
- Travel Time on an Alternative Route
- Delay on the Preferred Route
- Congestion on the Preferred Route
- Congestion on the Alternative Route

- Familiarity with the Alternative Route
- Number of Traffic Stops on the Preferred and Alternative Routes⁸

Diversion behavior relative to an immediate warning message was studied by Firmin, Bonsall and Beaumont⁹ with the following results:

Driver Stated Reaction to Immediate Warning Message	
Divert at Next Opportunity	54%
Delay Diversion Until Problems Occur	14%
Would Not Divert – Continue to Proceed Ahead	32%

A 1997 survey completed by the Hanshin Japan Expressway Public Corporation¹⁰ included questions pertaining to drivers' desire for traffic information. One of the primary goals of the survey was to understand drivers' needs for traffic information.

The survey included a section for driver response to informational devices or media. In response to a listing of various methods of information transmittal, 50% of drivers considered AM/FM radio as the most desirable method. It is believed that this response is due to the simplicity and familiarity of AM/FM to drivers in receiving traffic information.

Research completed by Khattak, Schofer, and Koppleman,¹¹ indicated that drivers can successfully be diverted to alternate routes during special events through display of diversion messages. There was not enough evidence to indicate that drivers can be diverted during incidents. Field study results based upon research completed by Dudek

in San Antonio, Texas, revealed no statistical evidence that diversion increased due to the messages displayed under incident conditions.¹²

A model of driver response to delay was developed by Khattak, Schofer and Koppleman. The model predicts the increased propensity to divert based upon the following; number of alternative routes which the driver has formerly used, length of delay on preferred route, driver travel time, the drivers' risk taking behavior, and the driver's preferences about diverting. Other influential factors included driver gender and residential location.¹³ The model also indicated an increased likelihood of a driver to take an alternate route if they received delay information through traffic reports as opposed to visual observation of traffic delays.

Evidenced from prior research in various aspects of traffic information, there is a close relationship between the acquisition of traveler information and the quality of information. Based upon research completed in 1994 by the Peter Harris Research Group,¹⁴ a widely accepted hypothesis states that as the information quality improves, the more people are likely to use the information. A driver perceives quality of information in terms of clarity, usefulness and reliability of the displayed information.

Although the literature review revealed that one study found no statistical evidence to support the hypothesis that CMS message displays increase a driver's diversion probability, most studies resulted in the conclusion that driver's show an increased potential to divert based upon CMS message information.

Driver Changeable Message Sign Design Characteristics

Variable message signs have been used in highway applications in the United States for over 30 years. In the early 1970's, computer equipment to control the devices became relatively inexpensive, and many manufacturers began incorporating computer technology into their designs. This development was significant in providing unlimited message capability.¹⁵

In terms of the technology used, variable message signs can be classified into three categories:

1. Light reflecting
2. Light emitting
3. Hybrid

Light reflecting signs reflect light from an external light source such as the sun or automobile headlights. Light emitting signs generate their own light on or behind the viewing surface. Some manufacturers have combined the two technologies to produce hybrid displays which exhibit the qualities of both light reflecting and light emitting devices. In the case studies that are the focus of this research, the cms manufacturer is Voltron, Incorporated. The locations are equipped with hybrid type signs that combine light emitting and light reflecting technologies.

When a driver uses the information available on traffic reporting devices, such as a cms, benefits can occur in many ways. In addition to travel time savings, the intangible benefits include reduced anxiety, increased knowledge of travel options, increased reliability, and enhanced ability to avoid congestion and a reduction in the possibility of

getting lost.¹⁶ Based upon a research survey completed by Yim, Hall and Weissenberger, driver survey participants stated the most significant benefit received from traffic reports as the ability to make informed decisions. Other important benefits as reported by the driver included travel time savings, and a reduction in driver anxiety.

Changeable Message Sign Display Information

To be effective, a CMS must achieve the following:¹⁷

- Attract the motorists' attention
- Be legible and provide significant legibility distance.
- Cause minimal visual discomfort to the driver.
- Be effective under a variety of lighting conditions, including bright daylight, night, and low sun angles.
- Be effective under backlight and washout conditions – where backlight describes the condition where the sun is directly behind the sign and washout occurs when the sun is directly behind the driver.

When a driver simulation study was performed to evaluate different forms of variable route guidance messages at the TNO Institute for Perception in the Netherlands, the conclusions of the study included the following:¹⁸

1. The changeable message sign (CMS) format has a considerable influence on driver propensity to diverge from a 'normal' route. Of the CMS implementations reported, the combination of crossing out the critical destination of the main sign with an

indication of the reason that diverging is advised was the most effective message format.

2. More persuasive messages lead to less hesitation in driving behavior at the diversion point.

A case study was completed using drivers in Seattle, Washington. The purpose of the study was to investigate commuter behavior and decision making to develop functional requirements for an advanced driver information system. Results from the initial survey indicated that motorists could be clustered into four commuter groups, based upon variables that indicated how they modified their willingness to change departure time, route, or mode. The study defined the following motorist groups:¹⁹

- Route changers (20.6%) – motorists who were familiar with alternative routes and were willing to change routes before entering the major commuter freeway.
- Non-changers (23.4%) – motorists who were unwilling to change time, route, and mode.
- Route and time changers (40.1%) – motorists who were willing to change route and departure time.
- Before or ‘pretrip’ changers (15.9%) – motorists who were willing to make time, mode, or route changes before leaving home for their morning commute.

Approximately 1% of the route changers and non changer groups (11 of 1,588) indicated a willingness to adjust the time they left for work based on traffic information, as opposed to over 99% of the route and time changers and pretrip changer groups (2,010 of 2,018).

The survey subjects were asked to rank the various forms of information contained within the message display screen according to how helpful they felt the information would be in selecting a driving option. Ranking values were from one to five, with one being the most helpful. Time of delay estimates were clearly preferred across all commuter groups with a mean rank value of 1.97. Text messages ranked second with a mean value of 2.32 across all commuter groups except the non-changers. Pictures of actual traffic were ranked third with a mean of 2.86, and maps fourth with a mean of 3.17. Bar graphs shown on CMS's as a method of representing traffic conditions ranked a distant fifth with a mean of 4.51.²⁰

In a study completed by M. Brocken and M. Van der Vlist,²¹ the analysis of driving behavior at the diversion point in relationship with the inclination to diverge reveals that both are inter-related. The results of the study revealed that CMS configurations which contained all of the information drivers desired resulted in less hesitant behavior than in conditions when CMS's lacked the desired information. A high inclination to diverge appeared to be accompanied by early exiting and by maintaining a relatively high speed. According to the simulator results of this research, driver compliance rate to CMS display information is highest when the divergence is recommended based upon the message displayed. A route information system would provide CMS system evaluators with a better explanation of the variability in route choice behavior than would a route recommendation system. A route information system would include congestion and travel time information and route recommendations indicate specific alternate route(s).

In a study completed by Firmin, Bonsall and Beaumont,²² driver attitudes toward information from CMS's implemented in London were investigated through the

CLEOPATRA Project. The sign message texts for 22 signs within the study area were set by the Metropolitan Police Department. Two basic message types are used, immediate warning messages and advance warning messages. Common legends in the advance warning messages for the London CMS system include; the date and time of a roadway incident, incident location, cause for the incident and recommendation(s) for driver alternative action. Common legends for causes of the roadway incidents include the following wording:

- ACCIDENT
- CONGESTION
- ROADWORK

Commonly recommended legends for driver action or driver expectations include:

- DELAYS
- LONG DELAYS
- AVOID AREA
- CLOSED
- DIVERSION
- SLOW DOWN

Another facet of this study was a survey to determine driver interpretation and preference for the message board when there are no relevant messages.

The survey results of this study of reactions to a blank CMS were.²³

Driver Interpretation of Blank Variable Message Signs

No Problems Ahead	57%
No Information Available	35%
Other	8%

Information Preference When No Information Is Indicated

Blank VMS Sign	27%
A Message Stating 'No Information'	17%
A Message Displaying the Speed Limit	13%
A Message Displaying the Time of Day	12%
A Message Stating 'Light Traffic'	9%
Other	22%

The study concluded that drivers' preferences tend to be for up-to-date information and notification of alternative routes. Drivers would prefer to receive information specific to the route they are travelling and have signs used when no warning messages are available, rather than being left blank.

The results of a research study completed by the Ministry of Transportation in Ontario concluded the following as a result of a survey of 539 drivers on message display preferences.²⁴

- The most preferred term for stop-and-go traffic overall was 'Heavy Congestion'.

- Equal numbers of drivers preferred to be warned 2 to 3 kilometers or 4 to 5 kilometers in advance of traffic problems.
- To describe rush hour congestion, respondents preferred the terminology 'Rush Hour Conditions Next 5 Kilometers'.
- To describe normal free flowing traffic conditions, respondents preferred the terminology 'Normal Traffic Next 5 Kilometers'.
- Messages not relating to traffic conditions were clearly opposed by the majority of respondents.
- The greatest diversions were indicated when a message about lane closure, congestion or reduced speed was combined with an action directive such as 'Heavy Congestion Ahead....Use Collector Lanes'.

A 1997 survey completed by the Hanshin Japan Expressway Public Corporation²⁵ included questions pertaining to drivers' needs for traffic information. The questionnaire consisted of the following four parts:

1. Individual respondent attributes
2. Evaluation of the present information provided by the existing expressway information system
3. Travel behavior at the time of receipt of the questionnaire
4. Driver assessment of type(s) of information and device needs

The survey results revealed that 50% of drivers always or frequently pay attention to information pertaining to congestion. The results also revealed that more than 60% of drivers make use of the travel time information for their route choice, and about 40% of

drivers consider the information useful for reducing their irritation in congested traffic conditions. Of the 45% of survey respondents that stated congestion information is most desirable, the percentage of those who chose congestion **and** estimated travel time as most desirable information is over 85%.

Driver preferences for future investments pertaining to the vms signing were surveyed in the study completed by Firmin, Bonsall and Beaumont.²⁶ The driver responses resulted in the following:

Driver Preference for Future Sign Investment Funds	
Provide More Signs	37%
Update Information More Frequently	36%
Maintain and Improve Ordinary Signs	15%
Provide More Information on Signs	11%
Do Not Invest in Variable Message Signs	1%

Research completed by Khattak, Schofer and Koppleman²⁷ included driver expected length of delay, regular travel time on the usual route, and anticipated congestion level on the alternate route as three of the factors which influence en route diversion behavior.

Changeable Message Sign Location Planning

Based upon the review of a research document completed by Leo D. Klein of the HNTB Corporation,²⁸ the most desirable location for a CMS is overhead, so the sign is in

the motorists' direct line of sight. For interstate roadway systems, the signs should be placed about $\frac{3}{4}$ mile before the alternative route decision point.

A study completed by the Ministry of Transportation of Ontario defines the appropriate distance of a CMS from the gore of the downstream diversion point as follows:²⁹

(Safe Weaving Distance + Reaction Distance – Sight Distance)

Where:

Safe Weaving Distance = 1,000 meters (at Level of Service D)

Reaction Distance = 60 meters (2 seconds at 100 kilometers or 197 linear feet)

Sight Distance = 270 meters (886 linear feet)

Therefore:

Minimum Distance (CMS to Diversion Point) = $1000 + 60 - 270 = 790$ Meters

(2,592 linear feet)

In order to provide a factor of safety to this calculation, the changeable message signs are preferably located more than 900 meters before the diversion point. The Ministry of Ontario study provided a summary of placement guidelines for CMS sign locations on Highway 401. These guidelines are summarized as follows:³⁰

- Locate CMS 900 meters to 1,200 meters upstream of a diversion point.
- Locate CMS 300 meters upstream of any existing sign.
- Locate CMS such that all drivers entering the freeway have an opportunity to view a CMS before their first opportunity to utilize collector or expressway transfer roadways or other major diversion points.

- Desirable minimum spacing between CMS's is 3,000 meters and desirable maximum spacing is 5,000 meters.
- Locate CMS's over the collector lanes and adjacent to express lanes (if applicable) more than 150 meters apart along the freeway.

Based upon research completed by Upchurch, Thomas, Armstrong and Baaj, a CMS must be legible from a sufficient distance such that the driver, at a typical travel speed, has enough time to read the message. Based upon a review of previous research, a minimum exposure time of 6.0 seconds on a three line sign is recommended. As drivers approach an overhead sign, sign readability becomes restricted by the vertical cut-off angle of the windshield. The sign will become hidden from the motorist's view at a distance of about 150 feet. Based upon a 60 mile per hour travel speed, to be acceptable, a CMS sign with a three-line message should be legible from a minimum distance of 678 feet.³¹ Each of the CMS sign locations analyzed in this research contains three-line message displays, and they all meet this criterion.

CHAPTER 3: SITE REVIEW LOCATIONS AND DATA COLLECTION

Eastbound I-96 East of Beck Road

This analysis site is located along eastbound I-96 within the city of Novi, Michigan. The CMS at this site is the only one that is not positioned on an overhead structure. The CMS is located on a tower structure located on the south side of the freeway. Traveling eastbound, a driver would traverse the freeway detector loops and enter into the analysis site at 9,665 feet past the centerline of the Beck Road overpass. The changeable message sign tower is positioned on the right side of the freeway at the same milepoint as the detector loops. Based upon the message displayed on the CMS, the driver would make a decision to remain on I-96 which transitions to eastbound I-696, or divert to southbound I-275. This analysis site presents the possibility for the driver to reach a destination in downtown Detroit by using either I-696 and M-10 or I-275 and I-96.

The diversion analysis will be based upon the percentage of drivers who travel on I-696 versus the drivers who divert to southbound I-275. After passing the CMS, the driver would continue to travel 15,520 feet within the analysis zone to reach the exit detection loops on I-696. If the driver diverts to southbound I-275, the distance from the CMS to the diversion route exit loops is 9,500 feet. Based upon an analysis of volume data for five dates available in the months of November and December 1998, this site has a morning peak hour that occurs between 6:25 a.m. and 7:25 a.m.

Figure 3.01 shows the site area with approximate locations of the detector loops and CMS labeled.

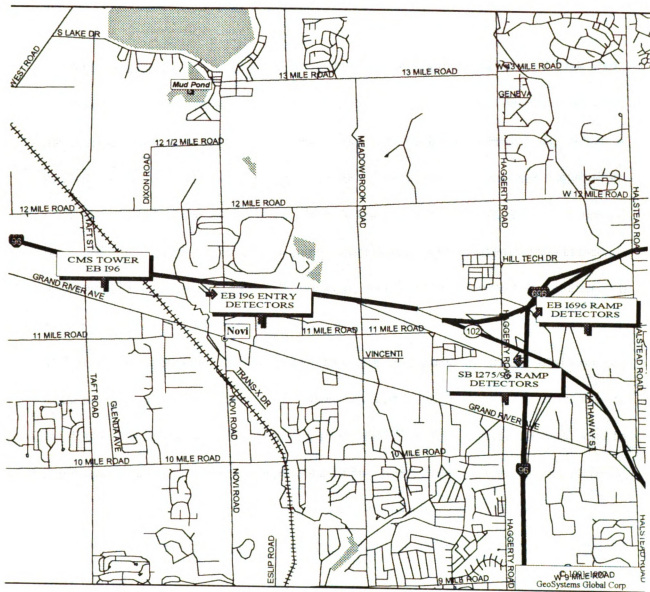


Figure 3.01 - Site Map for Eastbound I96, East of Beck Road – Novi, Michigan

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Eastbound I-696 at Manistee

This analysis site is located along eastbound I-696 within the city of Oak Park, Michigan. Traveling eastbound, a driver would traverse the freeway detector loops into the analysis zone at a point 5,540 feet east of the changeable message sign which is located on the Manistee Street bridge overpass. Based upon the message displayed on the CMS, the driver would make a decision to remain on I-696 or divert to northbound (or southbound) I-75. Based upon a combination of freeway and arterial route choices, a driver could reach a destination in the northeast section of the Detroit Metropolitan area by using either eastbound I-696 or northbound I-75.

The diversion analysis will be based upon the percentage of drivers who continue using I-696 compared with those who choose to divert to northbound I-75. After passing the CMS, the driver would continue to travel 14,370 feet within the analysis zone to reach the exit detection loops on eastbound I-696. If the driver chooses to divert to I-75, the distance from the CMS to the diversion route exit loops is 14,400 feet.

Figure 3.02 shows the site area with approximate locations of the detector loops and CMS labeled.

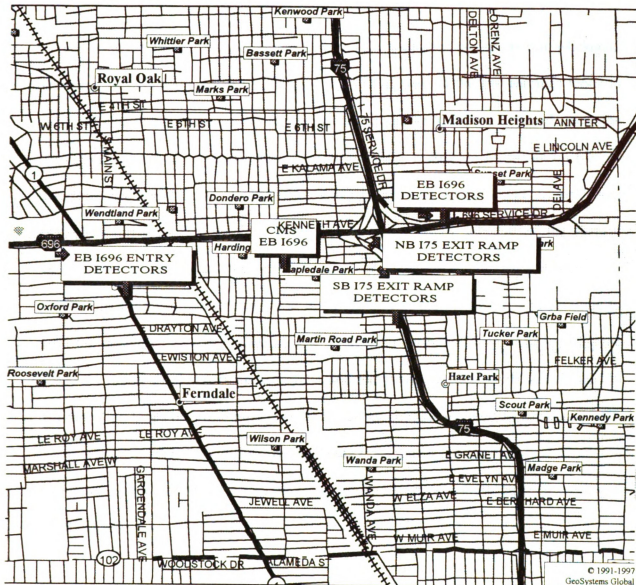


Figure 3.02 - Site Map for Eastbound I696 at Manistee – Oak Park, Michigan

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Westbound I-96 at Buchanan

This analysis site is located along westbound I-96 within the city of Detroit, Michigan. Traveling westbound, a driver would travel 2,890 feet west of the site entrance loops to the CMS that is located on the Buchanan Street bridge overpass. Based upon the message displayed on the CMS, the driver would make a decision to remain on I-96 or divert to eastbound I-94. Based upon a combination of freeway and arterial route choices, a driver could reach a destination in the western suburbs of the Detroit Metropolitan area by using either westbound I-96 or a combination of I-94 and M-10.

The diversion analysis will be based upon the percentage of drivers who continue to use I-96, compared with those who choose to divert to eastbound I-94. After passing the CMS, the driver would continue to travel 4,300 feet within the analysis zone to reach the exit detection loops on westbound I-96. If the driver chooses to divert to eastbound I-94, the distance from the CMS to the diversion route exit loops is 2,070 feet.

Figure 3.03 shows the site area with approximate locations of the detector loops and CMS labeled.

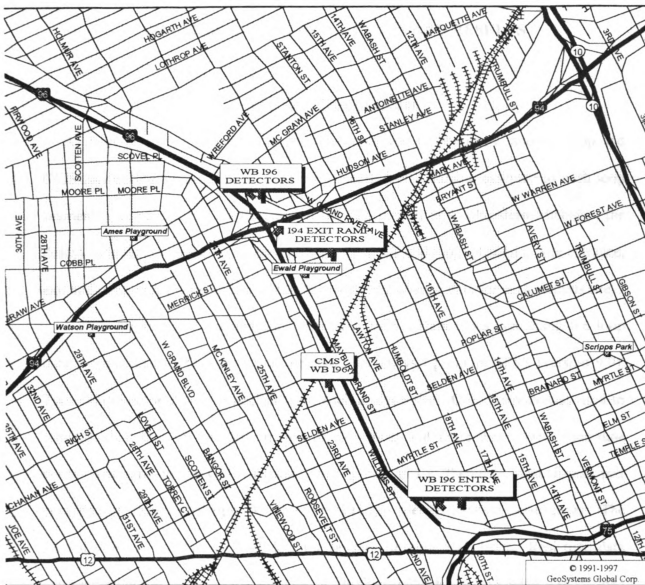


Figure 3.03 - Site Map for Westbound 196 at Buchanan – Detroit, MI

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CHAPTER 4: DATA DESCRIPTION AND RESULTS

Real Time Data Collection

As built plans for each analysis site were reviewed to obtain the specific loop and CMS hardware addresses. Each 'address' consisted of a number assigned to each loop segment. As part of the construction of the ITS project in southeastern Michigan, the design included assigning hardware addresses for CMS and loop locations. Site entrance, exit and ramp loops were used to obtain the required real-time data for each analysis site.

Data were available beginning in November 1998. Data tapes containing the loop data were formatted for use within the statistical analysis program SPSS (version 9.0). Two data directories were established for each analysis site. One directory was used to establish data files for the time period of November and December 1998. This time period was early in the CMS message development phase; therefore most display text consisted of default messages that were unrelated to specific incident occurrences. The second directory contained 1999 data for January through May 1999. Real time data were available for various dates in 1999. Data for Friday through Monday was avoided due to a higher potential for increased variances in traffic volumes.

Diversion Ratio Confidence Limits

The ratio of drivers who exited the analysis site via the mainline exit compared to the ramp exit were compared for the peak morning or afternoon volume period at each analysis site. The dates used for this analysis were:

- Wednesday, November 17, 1998
- Thursday, November 18, 1998
- Tuesday, December 8, 1998
- Wednesday, December 9, 1998
- Thursday, December 10, 1998

Each site was analyzed to determine the volume ratio between the mainline freeway and the exit ramp for the condition when there were no messages on the CMS. The analysis was completed for the higher of the peak morning or afternoon traffic volume period of 6 a.m. to 9 a.m. or 4 p.m. to 7 p.m.

Eastbound I-96 East of Beck Road

The diversion ratios for the eastbound I-96 at Beck site for the peak three-hour morning travel period are recorded in Table 4.01, and shown graphically in Figure 4.01:

Table 4.01 – EB I96 East of Beck A.M. Peak Period Diversion Ratios

Date	Time (a.m.)	Ratio	Mean Mainline Exit Volume	Mean Ramp Exit Volume	Mean Mainline Exit Speed (mph)
11/17/98	6:00-7:00	1.18	3354	2837	64.00
11/18/98	6:00-7:00	1.16	3378	2902	67.00
12/08/98	6:00-7:00	1.20	3514	2923	67.00
12/09/98	6:00-7:00	1.20	3417	2852	68.00
12/10/98	6:00-7:00	1.16	3361	2898	68.00
11/17/98	7:00-8:00	1.30	3947	3031	54.00
11/18/98	7:00-8:00	1.36	4203	3101	64.00
12/08/98	7:00-8:00	1.27	3871	3028	48.00
12/09/98	7:00-8:00	1.28	4021	3136	51.00
12/10/98	7:00-8:00	1.31	4136	3162	58.00
11/17/98	8:00-9:00	1.35	3506	2606	59.00
11/18/98	8:00-9:00	1.36	3438	2520	67.00
12/08/98	8:00-9:00	1.28	3582	2777	61.00
12/09/98	8:00-9:00	*1.08	2857	2653	*28.00
12/10/98	8:00-9:00	1.27	3502	2764	62.00

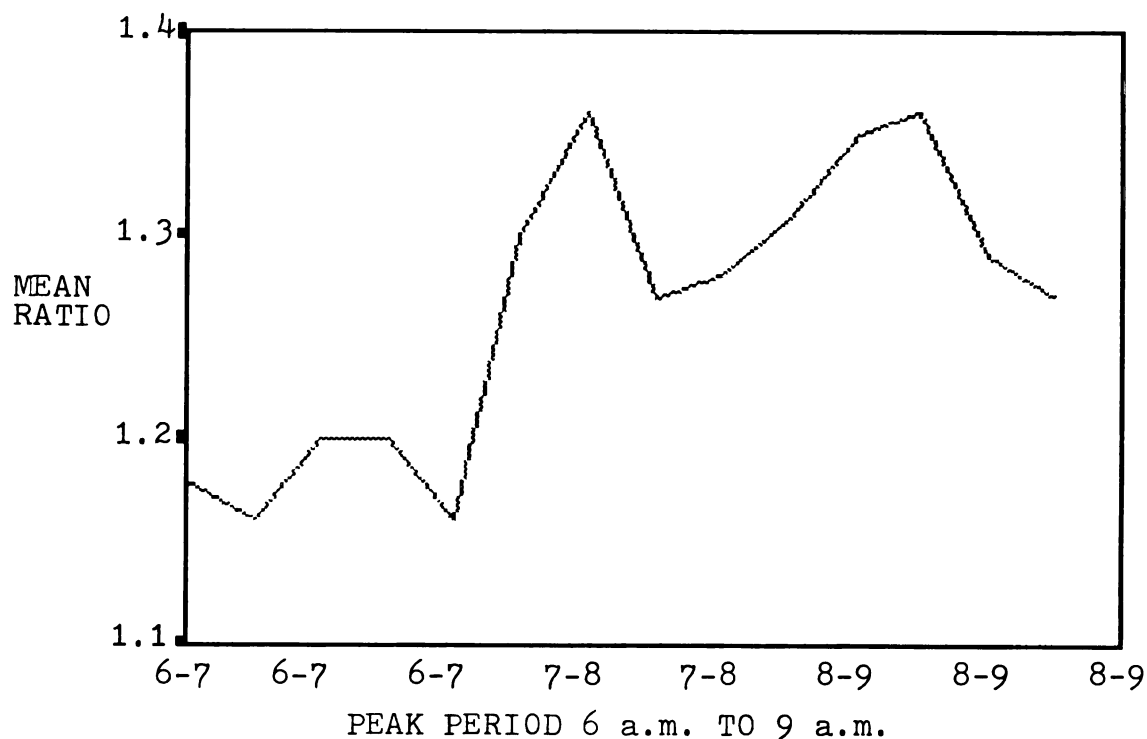


Figure 4.01 – EB I96 East of Beck Road - Ratio of I96 to I275 Traffic Volumes

*Based upon a review of the consistency of the information shown in Table 4.01, the data shown for the date of 12/09/98 for the time period of 8:00 to 9:00 a.m. will be rejected. The presumption is that either an incident occurred at this time or the data for this date and time period were not accurate due to an equipment malfunction.

The t statistic was used to determine confidence intervals since both volume populations are found to be normally distributed with equal population variances based on an analysis of a random sample of volumes over the two-month period. The t statistic was used to construct confidence intervals for the mean volume ratios for the peak traffic volume period of 6:00 a.m. to 7:00 a.m. and 7:00 a.m. to 9:00 a.m. Ratios found to be outside of the confidence limits for this time period will indicate that the ratio of the mainline volume to the ramp volume differs from the base conditions. The results for the 95%, 98% and 99% confidence levels are shown in Tables 4.02 and 4.03.

Table 4.02 - EB I96 East of Beck 6 a.m. to 7 a.m. Diversion Confidence Intervals

Significance Level	Confidence Interval
99%	1.139, 1.221
98%	1.147, 1.217
95%	1.155, 1.205

Table 4.03 - EB I96 East of Beck 7 a.m. to 9 a.m. Diversion Confidence Intervals

Significance Level	Confidence Interval
99%	1.268, 1.352
98%	1.273, 1.346
95%	1.282, 1.338

Accident occurrence data were available for the months of November and December (1998). The data is sorted by MDOT control section, state trunkline, and milepoint. The accident data were reviewed for dates and times where an accident occurred during the peak travel periods for each site. This review revealed two accidents that occurred along the eastbound I96 at Beck Road site. The accidents occurred on November 17, 1998 at 5:00 p.m. and December 7, 1998 at 6:00 p.m. These dates were included in the data that was retrieved to construct the confidence limits. Since both incidents occurred in the afternoon peak period rather than the morning peak period, diversion confidence limits were determined for the afternoon peak as well to determine whether the diversion ratio changed as a result of these accidents. The diversion ratio for the afternoon peak period is shown in Table 4.04.

Table 4.04 - EB I96 East of Beck P.M. Peak Period Diversion Ratios

Date	Time (p.m.)	Ratio	Mean Mainline Exit Volume	Mean Ramp Exit Volume	Mean Mainline Exit Speed (mph)
11/17/98	4:00-5:00	0.83	2007	2424	68.00
11/18/98	4:00-5:00	0.86	2239	2590	68.00
12/08/98	4:00-5:00	0.86	2142	2495	68.00
12/09/98	4:00-5:00	0.84	2144	2567	67.00
12/10/98	4:00-5:00	0.94	2458	2624	67.00
11/17/98	5:00-6:00	0.87	2121	2438	69.00
11/18/98	5:00-6:00	1.04	2162	2076	67.00
12/08/98	5:00-6:00	0.89	2144	2409	68.00
12/09/98	5:00-6:00	0.93	2302	2474	68.00
12/10/98	5:00-6:00	0.91	2262	2478	66.00
11/17/98	6:00-7:00	0.79	1693	2143	68.00
11/18/98	6:00-7:00	1.04	1781	1705	67.00
12/08/98	6:00-7:00	0.87	1678	1929	69.00
12/09/98	6:00-7:00	0.83	1649	1989	68.00
12/10/98	6:00-7:00	0.95	1759	1852	67.00

The t statistic was used to calculate the 95%, 98% and 99% confidence levels for the volume ratios between 5:00 p.m. and 6:00 p.m. and 6:00 p.m. and 7:00 p.m., excluding the days when accidents occurred. These limits are shown in Tables 4.05 and 4.06:

Table 4.05 – EB I96 East of Beck 5 p.m. to 6 p.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	0.74, 1.14
98%	0.79, 1.09
95%	0.84, 1.05

Table 4.06 – EB I96 East of Beck 6 p.m. to 7 p.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	0.69, 1.10
98%	0.72, 1.07
95%	0.77, 1.02

The analyses of the confidence limits for these dates were used to determine whether the accident occurrence had an impact on traffic conditions when no CMS message was available as a driver aide. Table 4.07 details the information pertaining to the accident occurrences on the dates in which the CMS did not display information to the motorist on the date and time of the accidents.

Table 4.07 Accident Occurrence With No CMS Message – EB I96 East of Beck Road

Date	Time	Location	Type	Injuries	# Vehicles Involved
11/17/98	5:00 p.m.	West of Haggerty	Sideswipe	0	2
12/7/98	6:00 p.m.	West of Grand River	Fixed Object	0	1

The driver diversion ratio was computed using the traffic volume data for the date of November 17, 1998 and December 7, 1998.

Table 4.08 Accident Data With No CMS Message - EB I96 East of Beck Road

Date	Accident Occurrence Time (p.m.)	Ratio	Mean Mainline Exit Volume	Mean Ramp Exit Volume	Mean Mainline Exit Speed (mph)
11/17/98	5:00	0.87	2121	2438	69
12/7/98	6:00	0.84	1484	1759	65

The diversion ratios of 0.84 and 0.87 are both within the confidence interval for their respective hour as shown in Tables 4.05 and 4.06. Therefore we cannot reject the hypothesis that the accident occurrence had no impact on the driver's decision to stay on the mainline freeway or divert to the ramp to southbound I-275 in the absence of advanced information provided by a CMS.

Eastbound I-696 at Manistee

The diversion ratios for the eastbound I-696 at Manistee Street site for the peak three hour morning travel period are recorded in Table 4.09, and shown graphically in Figure 4.02:

Table 4.09 – EB I696 at Manistee A.M. Peak Period Diversion Ratios

Date	Time (a.m.)	Ratio	Mean Mainline Exit Volume	Mean Ramp Exit Volume	Mean Mainline Exit Speed (mph)
11/17/98	6:00-7:00	1.87	3696	1979	67
11/18/98	6:00-7:00	1.88	3701	1967	68
12/08/98	6:00-7:00	1.88	3848	2050	67
12/09/98	6:00-7:00	1.89	3770	1992	68
12/10/98	6:00-7:00	1.88	3729	1982	69
11/17/98	7:00-8:00	2.26	5283	2336	64
11/18/98	7:00-8:00	2.42	5473	2266	64
12/08/98	7:00-8:00	2.29	5442	2377	64
12/09/98	7:00-8:00	2.30	5468	2380	64
12/10/98	7:00-8:00	2.38	5473	2297	64
11/17/98	8:00-9:00	2.08	4716	2264	62
11/18/98	8:00-9:00	2.00	4738	2372	64
12/08/98	8:00-9:00	*2.73	4760	1741	58
12/09/98	8:00-9:00	1.94	4134	2132	66
12/10/98	8:00-9:00	2.07	4807	2321	63

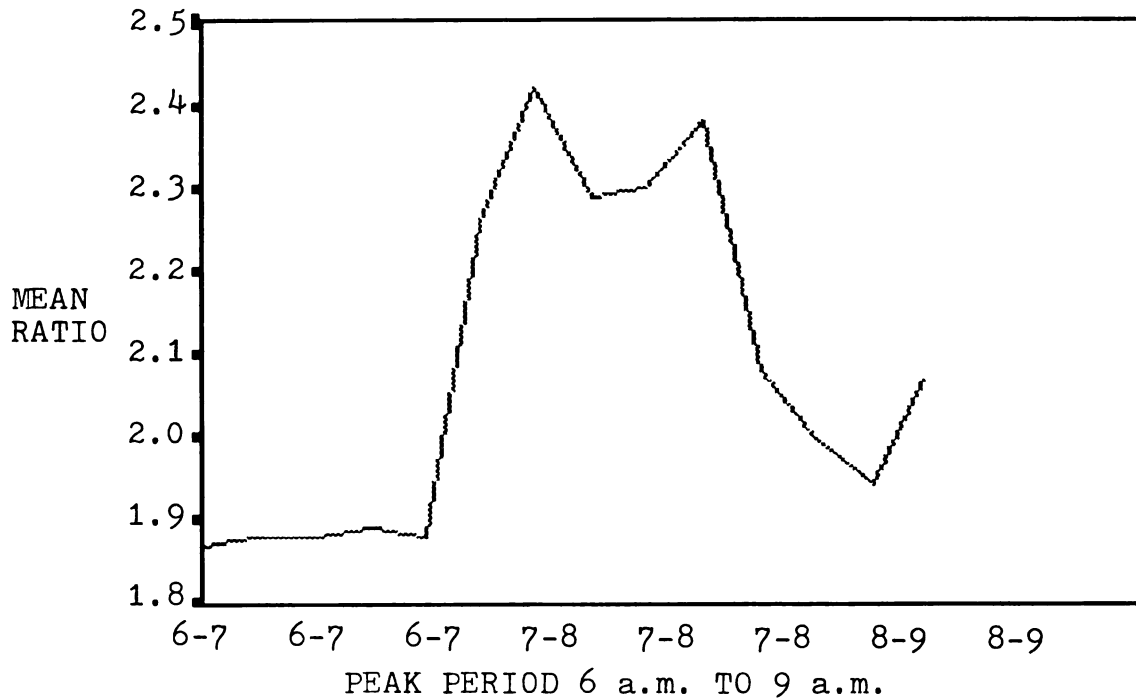


Figure 4.02 – EB I696 at Manistee – Ratio of I696 to I75 Traffic Volumes

*Based upon a review of the consistency of the information shown in Table 4.09, the data shown for the date of 12/08/98 for the time period of 8:00 to 9:00 a.m. will be rejected. The presumption is that either an incident occurred at this time or the data for this date and time period were not accurate due to an equipment malfunction.

As with the first site, the t statistic was used to calculate the 95%, 98% and 99% confidence levels. The results are shown in Tables 4.10-4.12 for the eastbound I96 at Manistee Street site:

Table 4.10 – EB I696 at Manistee 6 a.m. to 7 a.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	1.865, 1.895
98%	1.868, 1.892
95%	1.871, 1.889

Table 4.11 – EB I696 at Manistee 7 a.m. to 8 a.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	2.190, 2.470
98%	2.220, 2.450
95%	2.240, 2.420

Table 4.12 – EB I696 at Manistee 8 a.m. to 9 a.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	1.830, 2.210
98%	1.870, 2.170
95%	1.920, 2.130

The freeway incident data were reviewed for accidents that occurred at or beyond the exit limits of the site, possibly producing a traffic backup. Since there were no accidents reported for this site during the months of November and December (1998), an analysis of the statistical data based upon an accident occurrence with no CMS display could not be completed for this site.

Westbound I-96 at Buchanan

The diversion ratios for the westbound I-96 at Buchanan Street site for the peak three-hour afternoon travel period are recorded in Table 4.13 and shown graphically in Figure 4.03:

Table 4.13 – WB I96 at Buchanan P.M. Peak Period Diversion Ratios

Date	Time (p.m.)	Ratio	Mainline Exit Volume	Ramp Exit Volume	Mean Mainline Exit Speed (mph)
11/17/98	4:00-5:00	4.40	4981	1133	69
11/18/98	4:00-5:00	4.77	5075	1065	70
12/08/98	4:00-5:00	*7.40	5190	701	68
12/09/98	4:00-5:00	4.38	5416	1236	69
12/10/98	4:00-5:00	4.39	5243	1193	67
11/17/98	5:00-6:00	4.73	4581	968	67
11/18/98	5:00-6:00	4.68	4717	1008	68
12/08/98	5:00-6:00	*7.20	4910	682	65
12/09/98	5:00-6:00	4.48	4579	1023	67
12/10/98	5:00-6:00	4.36	4818	1105	66
11/17/98	6:00-7:00	3.24	2592	800	66
11/18/98	6:00-7:00	3.45	2452	710	69
12/08/98	6:00-7:00	*5.55	2625	473	68
12/09/98	6:00-7:00	3.25	2487	766	68
12/10/98	6:00-7:00	3.27	2495	763	68

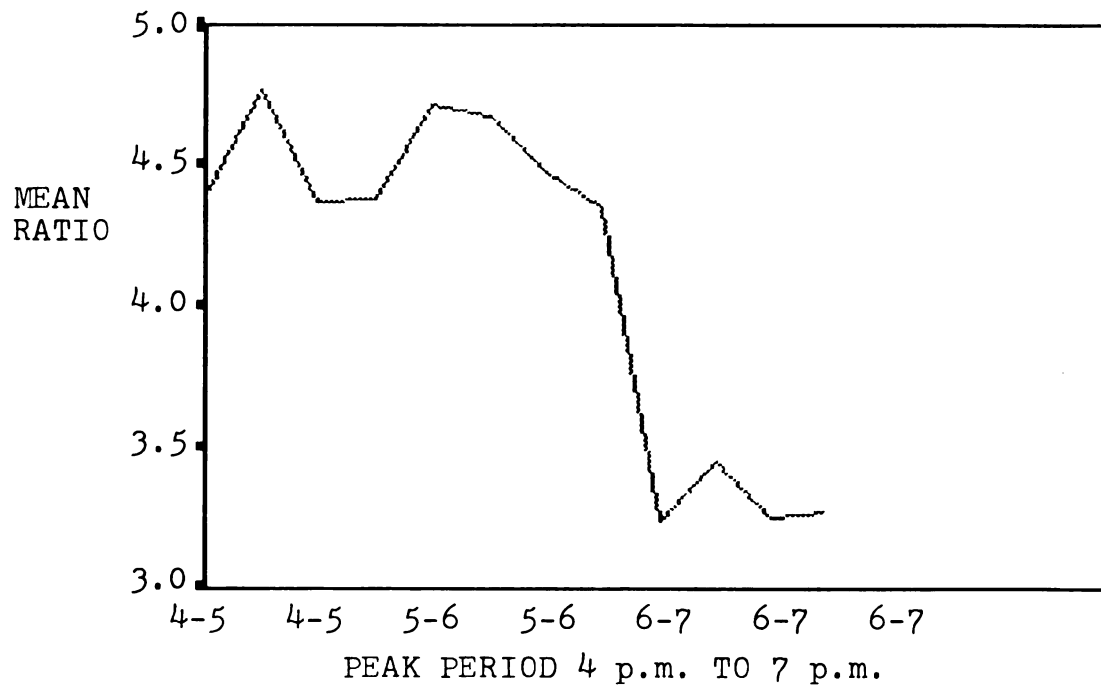


Figure 4.03 – WB I96 at Buchanan – Ratio of I96 to I94 Traffic Volumes

*Based upon a review of the consistency of the data shown in Table 4.13, ratio computations for the date of 12/08/98 for the time period of 4:00 p.m. to 7:00 p.m. will be rejected. The presumption is that either an incident occurred at this time or the data for this date and time period were not accurate due to an equipment malfunction.

Similar to the first two sites, the t statistic was used to calculate the 95%, 98% and 99% confidence levels. The results are shown in Tables 4.14 and 4.15 for the westbound I96 at Buchanan Site:

Table 4.14 - WB I96 at Buchanan 4 p.m. to 6 p.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	4.30, 4.74
98%	4.34, 4.70
95%	4.38, 4.67

Table 4.15 - WB I96 at Buchanan 6 p.m. to 7 p.m. Diversion Confidence Intervals

Significance Level	Diversion Confidence Interval
99%	3.01, 3.59
98%	3.08, 3.53
95%	3.14, 3.47

The freeway incident data were reviewed for accidents which occurred within or near the exit limits of the site, possibly producing a traffic backup. Since there were no accidents reported for this site during the months of November and December (1998), an

analysis of the statistical data based upon an accident occurrence with no CMS display could not be completed for this site.

Since there were insufficient data to determine the impact of an incident when no CMS was available to communicate with the motorist, it was not possible to create a base condition from the field data. Therefore, simulation was used to determine the impact of diversion on the average travel and delay time of motorists taking each of the two paths available at the diversion point.

The results of the simulation analysis can be used for two purposes. The first is to determine the extent of diversion required to have a measurable impact on the measures of effectiveness selected for the study. The second is to gain an appreciation for the negative impact of diverting traffic when there is no incident, or the incident is of short duration.

Simulation Analysis of Travel Time and Delay

An analysis was completed for each study site to determine the impact of changes in the volume ratio on driver delay. The FRESIM traffic simulation program was used to analyze the original traffic volumes, and the volumes when an additional 10% or more of the drivers who would normally continue to travel on the freeway, choose the ramp exit. Simulation analysis was also completed to determine the impact on delay, speed and travel times when 10% or more of the drivers who would normally divert to the ramp exit, chose to remain on the mainline freeway.

Based upon data retrieved for each site, the hour with the highest traffic volume was determined for each site. The data for this hour were used as input into the simulation

program to determine the values of the measures of effectiveness during normal conditions.

The morning peak hour for the eastbound I-696 at Manistee site was determined to be 6:45 a.m. to 7:45 a.m. when the total volume is 7752 vehicles per hour. The traffic volumes utilized in each of the three simulation cases for this site are shown in Table 4.16. Ten computer simulations were run for the existing and each of the 10% diversion analyses, with a different random seed for each case. The simulated results of the measures of effectiveness for the existing and diversion conditions during this peak travel period are as follows:

Eastbound I-96 at Manistee Street

The traffic volumes and simulation results for the existing condition and 10% diversion alternative in each direction are presented in Tables 4.16 to 4.19. Once again, ten runs were made using a different random number seed for each run.

Table 4.16 Simulation Volumes – EB I696 at Manistee Street

Diversion Case	Total Mainline Exit Volume	Total Ramp Exit Volume
Existing	5301	2451
10% Ramp	4771	2981
10% Freeway	5831	1921

Table 4.17 – Simulation Measures of Effectiveness – Existing Volumes

A.M. Peak (6:45 a.m.-7:45 a.m.) – EB I696 at Manistee Street

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-696 0.41 MILES	DELAY (VEH-MINS/ VEH-MILE) I-75 0.42 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-696	AVERAGE TRAVEL TIME (VEH-MINS) I-75
1	.10	.13	439.1	232.6
2	.11	.15	446.0	225.3
3	.11	.11	441.2	227.0
4	.12	.13	434.7	238.2
5	.11	.11	438.4	227.1
6	.11	.14	433.8	238.0
7	.12	.13	433.5	237.8
8	.11	.15	432.8	240.1
9	.10	.14	429.8	241.4
10	.10	.13	412.6	262.9
AVG.	.11	.13	434.2	237.04
Avg. Travel Time			23.64 seconds	28.66 seconds

Table 4.18 – Simulation Measures of Effectiveness –10% Diversion to Ramp

A.M. Peak (6:45 a.m.-7:45 a.m.) – EB I696 at Manistee Street

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-696 0.41 MILES	DELAY (VEH-MINS/ VEH-MILE) I-75 0.42 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-696	AVERAGE TRAVEL TIME (VEH-MINS) I-75
1	.10	.17	390.7	290.9
2	.11	.15	397.5	280.2
3	.12	.17	400.9	281.2
4	.11	.17	396.4	285.8

5	.11	.17	393.2	290.7
6	.10	.15	406.6	269.0
7	.12	.15	386.9	295.7
8	.10	.16	393.0	287.9
9	.10	.15	399.4	277.5
10	.13	.16	406.8	279.1
AVG.	.11	.16	397.14	273.80
Avg. Travel Time			24.34 seconds	27.41 seconds

Diverting an additional 10% of the traffic to the ramp to I-75 did not have significant impact on vehicle delay.

Table 4.19 - Simulation Measures of Effectiveness –10% Diversion to Mainline Freeway

A.M. Peak (6:45 a.m.-7:45 a.m.) - EB I696 at Manistee Street

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-696 0.41 MILES	DELAY (VEH-MINS/ VEH-MILE) I-75 0.42 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-696	AVERAGE TRAVEL TIME (VEH-MINS) I-75
1	.10	.10	471.8	187.5
2	.10	.13	468.7	193.9
3	.11	.10	473.7	187.4
4	.10	.13	459.7	200.8
5	.11	.10	477.5	180.2
6	.12	.12	486.1	176.0
7	.10	.12	470.6	189.0
8	.12	.12	482.4	178.6
9	.10	.11	483.2	174.4
10	.11	.13	480.3	178.2
AVG.	.11	.11	475.4	184.60
Avg. Travel Time			24.33 seconds	27.18 seconds

The delay and average travel time results reveal that a 10% diversion from either route to the alternative route has little impact on average travel times or delay on either route. This is primarily because the congestion formed on the weaving area link, regardless of which of the two exit paths, experiences delay.

Westbound I-96 at Buchanan Street

The afternoon peak hour for the westbound I-96 site was determined to be 4:35 p.m. to 5:35 p.m. The traffic volumes and simulation results for the existing condition and each of the diversion alternatives are presented in Tables 4.20 to 4.23.

Table 4.20 Simulation Volumes – WB I96 at Buchanan Street

Diversion Case	Total Mainline Exit Volume	Total Ramp Exit Volume
Existing	5446	1048
10% Ramp	4901	1593
10% Freeway	5991	503

Table 4.21 - Simulation Measures of Effectiveness – Existing Volumes

P.M. Peak (4:35 p.m.-5:35 p.m.) - WB I96 at Buchanan Street

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-96 0.67 MILES	DELAY (VEH-MINS/ VEH-MILE) I-94 0.27 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-96	AVERAGE TRAVEL TIME (VEH-MINS) I-94
1	.06	.12	736.6	72.8
2	.06	.11	750.2	66.6
3	.06	.12	768.7	59.5

4	.06	.14	755.3	66.3
5	.06	.13	752.6	67.5
6	.06	.16	747.8	69.6
7	.06	.16	728.5	77.3
8	.07	.14	767.0	60.1
9	.06	.12	760.8	62.3
10	.06	.12	729.5	77.1
AVG.	.06	.13	749.70	67.91
Avg. Travel Time			39.25 seconds	18.27 seconds

Table 4.22 - Simulation Measures of Effectiveness –10% Diversion to Ramp

P.M. Peak (4:35 p.m.-5:35 p.m.) - WB I96 at Buchanan Street

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-96 0.67 MILES	DELAY (VEH-MINS/ VEH-MILE) I-94 0.27 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-96	AVERAGE TRAVEL TIME (VEH-MINS) I-94
1	.06	.14	681.1	99.9
2	.06	.12	681.4	99.3
3	.06	.15	679.0	101.0
4	.06	.16	673.0	103.1
5	.06	.15	672.0	104.1
6	.05	.14	678.1	99.4
7	.06	.14	674.8	102.1
8	.06	.14	677.1	100.8
9	.05	.13	691.0	95.4
10	.06	.18	662.4	109.2
AVG.	.06	.145	676.99	101.43
Avg. Travel Time			39.24 seconds	18.35 seconds

Table 4.23 - Simulation Measures of Effectiveness –10% Diversion to Mainline Freeway

P.M. Peak (4:35 p.m.-5:35 p.m.) - WB I96 at Buchanan Street

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-96 0.67 MILES	DELAY (VEH-MINS/ VEH-MILE) I-94 0.27 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-96	AVERAGE TRAVEL TIME (VEH-MINS) I-94
1	.06	.12	825.5	31.8
2	.06	.12	810.0	38.5
3	.07	.13	834.4	30.0
4	.07	.18	817.1	38.9
5	.06	.11	838.4	26.9
6	.07	.14	831.6	31.7
7	.06	.12	829.1	31.6
8	.07	.11	819.0	37.5
9	.07	.15	843.4	28.9
10	.06	.15	827.1	32.2
AVG.	.065	.133	827.56	32.8
Avg. Travel Time			39.33 seconds	18.17 seconds

The results are similar to the first case, with the delay and average travel time changes from a 10% diversion from either route to the alternative route being quite small.

Eastbound I-96 East of Beck Road

The afternoon peak hour for the eastbound I-96 site was determined to be 6:25 a.m. to 7:25 a.m. when the average total traffic volume is 7408 vehicle per hour. The traffic volumes and simulation results for the existing condition and each of the diversion alternatives are presented in Tables 4.24 to 4.27.

Table 4.24 Simulation Volumes – EB I96 East of Beck

Diversion Case	Total Mainline Exit Volume	Total Ramp Exit Volume
Existing	4180	3228
10% Ramp	3762	3646
10% Freeway	4598	2810

Table 4.25 Simulation Measures of Effectiveness – Existing Volumes

A.M. Peak (6:25 a.m.-7:25 a.m.) – EB I96 East of Beck Road

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-696 1.71 MILES	DELAY (VEH-MINS/ VEH-MILE) I-275 0.95 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-696	AVERAGE TRAVEL TIME (VEH-MINS) I-275
1	.08	.07	1279.3	675.4
2	.08	.06	1377.3	636.9
3	.08	.06	1360.2	645.8
4	.09	.05	1348.5	659.1
5	.08	.06	1373.1	636.4
6	.09	.06	1333.9	665.2
7	.08	.05	1356.3	643.7
8	.08	.06	1370.5	643.7
9	.08	.05	1374.5	631.5
10	.08	.06	1309.4	673.9
AVG.	.08	.06	1348.3	651.2
Avg. Travel Time			100.12 seconds	62.72 seconds

Table 4.26 - Simulation Measures of Effectiveness – 10% Diversion to Ramp

A.M. Peak (6:25 a.m.-7:25 a.m.) – EB I96 East of Beck Road

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-696 1.71 MILES	DELAY (VEH-MINS/ VEH-MILE) I-275 0.95 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-696	AVERAGE TRAVEL TIME (VEH-MINS) I-275
1	.08	.06	1247.3	712.2
2	.08	.07	1222.3	735.7
3	.08	.06	1199.0	740.2
4	.07	.07	1244.6	721.0
5	.08	.06	1228.6	729.9
6	.08	.06	1187.9	758.0
7	.08	.06	1260.0	755.0
8	.07	.06	1151.9	774.5
9	.08	.06	1215.8	738.2
10	.08	.06	1227.2	731.8
AVG.	.08	.06	1218.46	739.7
Avg. Travel Time			97.35 seconds	65.27 seconds

Table 4.27 – Simulation Measures of Effectiveness–10% Diversion to Mainline Freeway

A.M. Peak (6:25 a.m.-7:25 a.m.) – EB I96 East of Beck Road

TRIAL	DELAY (VEH-MINS/ VEH-MILE) I-696 1.71 MILES	DELAY (VEH-MINS/ VEH-MILE) I-275 0.95 MILES	AVERAGE TRAVEL TIME (VEH-MINS) I-696	AVERAGE TRAVEL TIME (VEH-MINS) I-275
1	.09	.04	1502.4	555.4
2	.09	.06	1500.8	559.9
3	.12	.04	1541.8	541.3
4	.11	.04	1492.4	571.6

5	.10	.06	1463.8	582.9
6	.10	.05	1482.4	576.8
7	.08	.04	1468.8	571.1
8	.08	.04	1454.5	579.6
9	.10	.06	1506.7	556.8
10	.10	.05	1484.6	572.7
AVG.	.10	.05	1489.82	566.66
Avg. Travel Time			100.27 seconds	63.14 seconds

It is obvious from the results that a 10% diversion from either route to the alternate route has very little impact on average travel times or delay on either route. Thus, under normal conditions, the impact of a false alarm which results in a 10% diversion or less will be minimal, except for any excess travel time consumed in traversing a longer path to the drivers' ultimate destination.

Sensitivity of Delay to Diversion

This site was also simulated to determine the impacts on speed and delay as the percentage of diversion to the ramp and to the mainline increase. Various volumes were simulated to determine the point at which the network becomes congested, resulting in speeds less than 30 miles per hour at the diversion link 104-106 (See Figure 4.04). Based upon this simulation, the speeds on this link begin to show the impacts of congestion when the entry volume exceeds 4700 vehicles per hour. The link-node diagram shown below as Figure 4.04 displays the applicable network link (104-106).

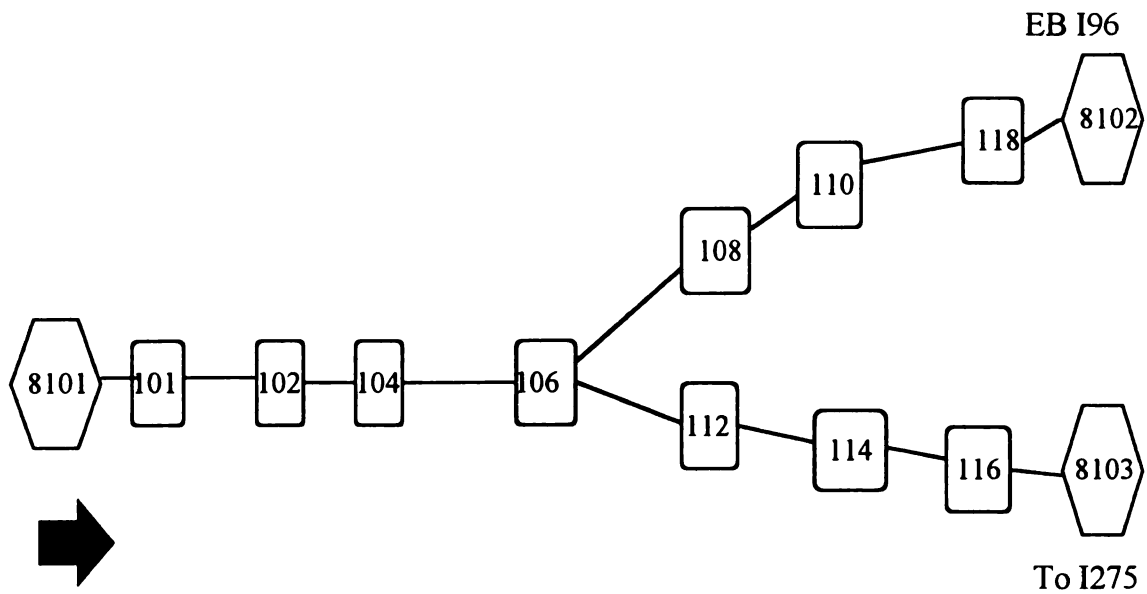


Figure 4.04 – EB I96 East of Beck – FRESIM Link-Node Diagram

The resultant speeds and delays on link (104-106) for various percentages of ramp diversion to the exit ramp ranging from 0 to 60 percent are shown in Figure 4.05. Figure 4.06 shows the impact on the same link when diversion is made to the mainline. The speed in miles per hour and delay in seconds per vehicle are shown on the y-axis. Figures 4.05 and 4.06 reveal that the freeway speeds (mph) and delay (sec/veh) along the weaving link are greatly impacted for those drivers attempting to continue their travel along the freeway mainline when there is a significant diversion to their route.

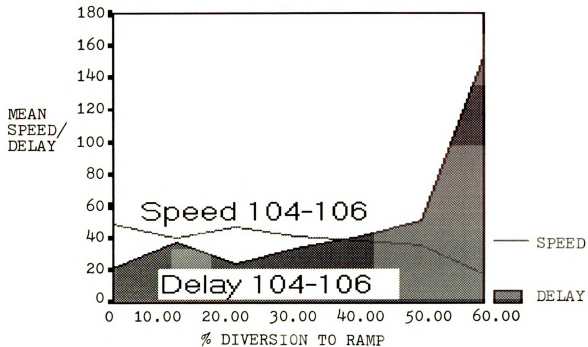


Figure 4.05 – EB I96 East of Beck – Speed and Delay on Weaving Link (104-106) Ramp

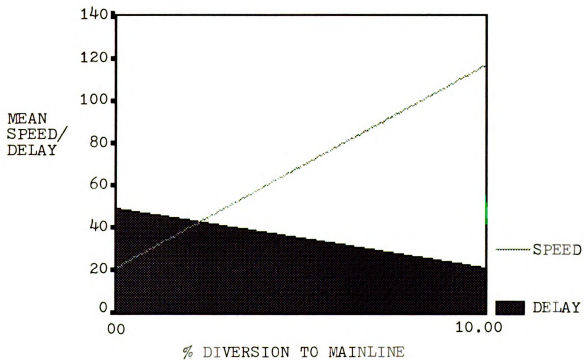


Figure 4.06 – EB I96 East of Beck – Speed and Delay on Weaving Link (104-106) Mainline

Figure 4.07 shows the resultant delay and speed on I-96 exit link (108-110) based upon an entry volume of 4700 vehicles, and ramp diversion percentages that vary from 0 to 60 percent. These results indicate that the congestion occurs on the link upstream from the diversion point where traffic is changing lanes to successfully exit the freeway. Once the traffic enters the exit ramp, the speed increases to the free flow speed of 65-70 miles per hour.

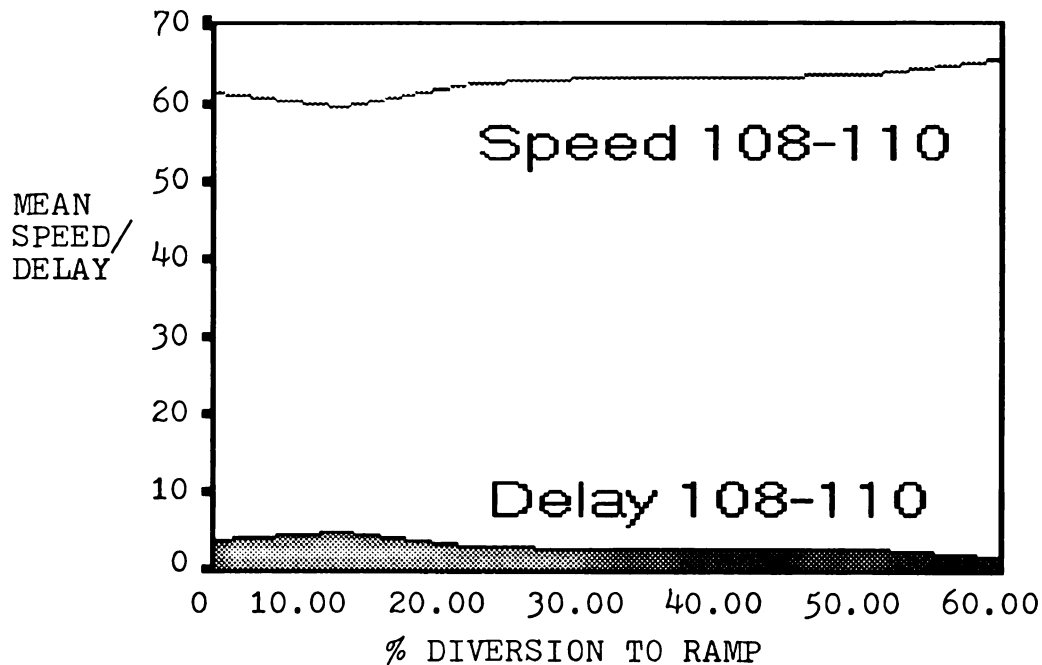


Figure 4.07– EB I96 East of Beck – Speed and Delay at Exit

Model Validation

A review of the actual speed data for link (108-110) for the morning peak hour of 6:25 a.m. to 7:25 a.m. shows that the average vehicle velocity was 64 miles per hour, as shown in Table 4.28.

Table 4.28 Actual Speed Data 6:25 a.m. to 7:25 a.m. – EB I96 East of Beck Road

Actual Average Mainline Exit Speed	Time of Day	Number Of Observations	Percent of Vehicles Traveling Greater than 65 MPH
64 MPH	6:25 am to 7:25 am	610	38.4%

To validate the FRESIM simulation model for this project, a comparison of the actual versus simulated mainline speeds for vehicles exiting the network was made using a volume of 7408 entering vehicles as shown in Table 4.24. The simulation was run for the site based on a mainline exit volume of 4180 vehicles and 3228 for the ramp exit volume. The results of the simulation revealed an average mainline exit speed of 61 miles per hour. The difference between the actual and simulated speeds is 4.67 percent. Thus, the model, as calibrated, appears to be a reasonably accurate reflection of the speeds measured in the field.

Analysis of Lane Closure Impact Due to Recurring or Non-Recurring Congestion

The I-96 at Beck Road location was simulated to determine the speed and delay impacts of a one-lane freeway or ramp closure based upon an entry volume of 4700 vehicles per hour. The impacts on weaving link (104-106), I-96 exit link (108-110) and ramp exit link (112-114) were analyzed to determine the network impact in terms of average speed and delay for vehicles in the network. The results shown in Table 4.29 reveal a 27.5 percent decrease in speeds along link 104-106 when one downstream I-96 lane is closed. Similarly, speeds along this link are decreased by 16 percent when one

ramp lane is closed. However, the impacts on the downstream links are different for the two cases, as would be expected. If one lane of I-96 is closed, the speed on this link (108-110) is reduced, while the speed on the I-275 ramp (112-114) remains high. The reverse occurs if the lane blockage is on the I-275 exit ramp. Table 4.29 also reveals the impact when an incident occurs which would cause a lane closure and diversion from the mainline to the ramp, or the ramp to the mainline.

Table 4.29 – EB I96 East of Beck Road Recurring/Non Recurring Congestion Analysis

Lane Treatment	Weaving Link 104-106 Speed	Weaving Link 104-106 Delay	I-96 Exit Link 108-110 Speed	I-96 Exit Link 108-110 Delay	Ramp Exit Link 112-114 Speed	Ramp Exit Link 112-114 Delay
	Miles/Hr	Sec/Veh	Miles/Hr	Sec/Veh	Miles/Hr	Sec/Veh
All Lanes Open	48.90	21.80	61.10	4.10	62.06	2.50
One I-96 Lane Blocked	35.44	50.40	19.35	69.10	62.72	2.30
One Ramp Lane Blocked	41.19	35.18	60.15	4.60	27.80	22.40
One I-96 Lane Blocked 10% Divert to Ramp	35.73	49.60	18.71	70.90	60.83	2.90
One I-96 Lane Blocked 20% Divert to Ramp	48.52	22.60	19.61	68.00	59.47	3.50
One I-96 Lane Blocked 30% Divert to Ramp	44.42	29.30	23.62	51.70	56.56	4.60
One Ramp Lane Blocked 10% Divert to I-96	26.38	85.10	57.90	5.80	44.72	10.10
One Ramp Lane Blocked 20% Divert to I-96	21.24	117.50	59.18	5.20	52.03	6.20
One Ramp Lane Blocked 30% Divert to I-96	21.26	117.5	58.16	5.70	49.04	7.90

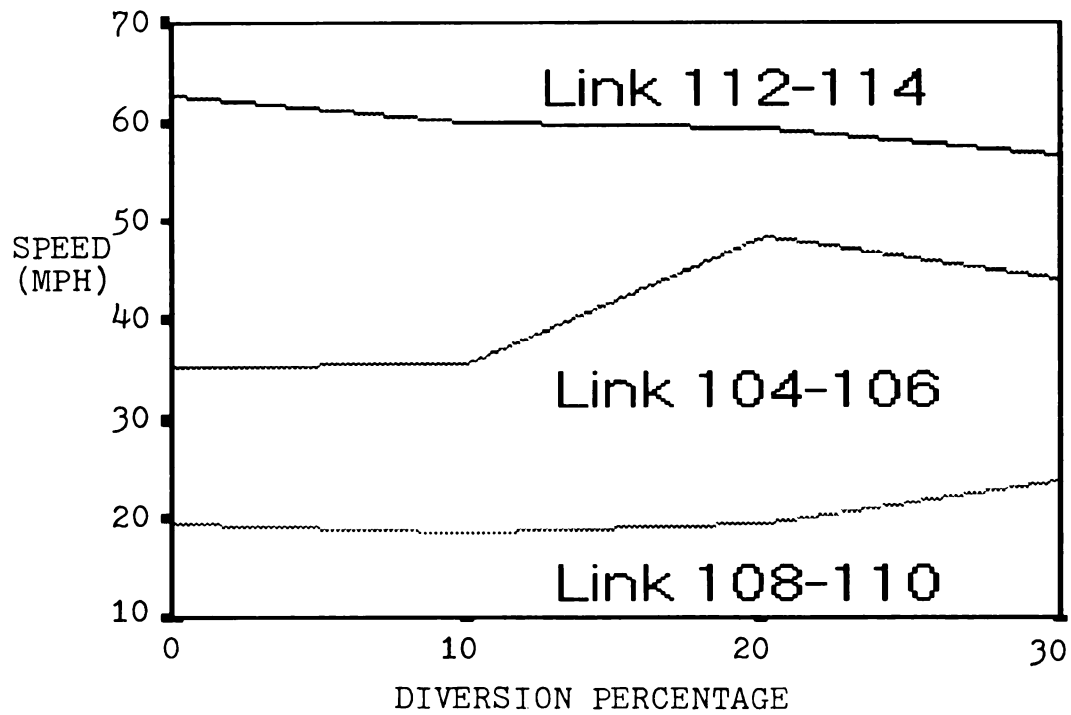


Figure 4.08–Link Speeds When One Lane of I96 is Closed/Ramp Diversion Increases

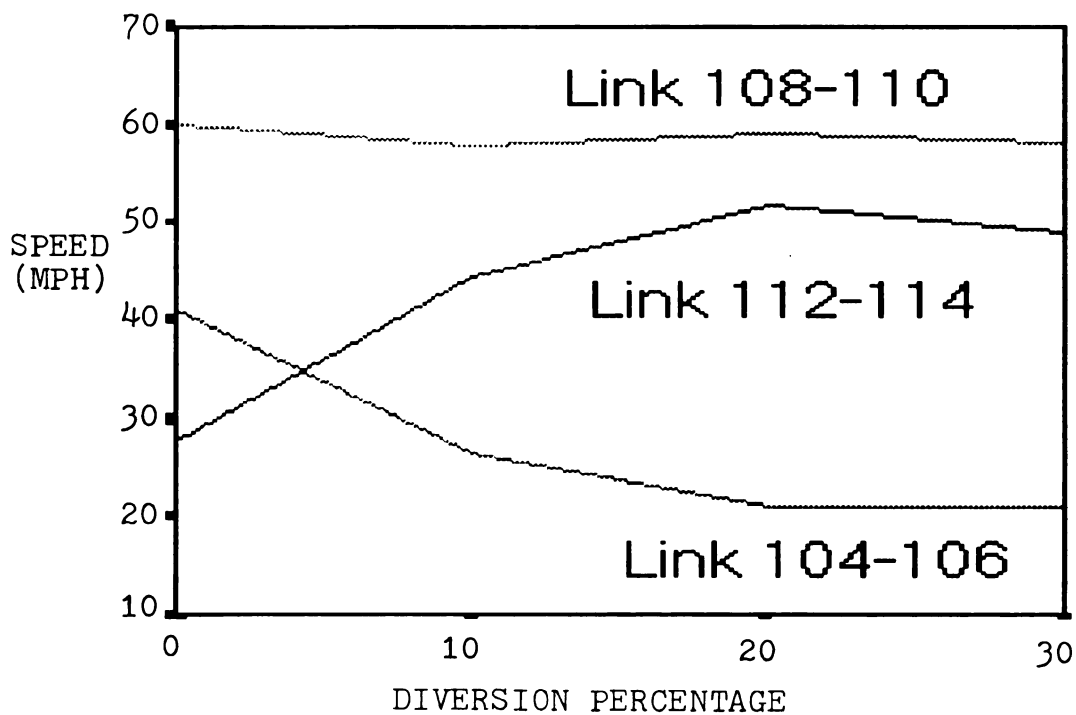


Figure 4.09–Link Speeds When One Ramp Lane is Closed/Mainline Diversion Increases

The results of this simulation, as shown in Table 4.29 and Figure 4.08, indicate an increase in the speed of traffic on links (104-106) and (108-110) can be achieved if the CMS successfully diverts traffic to the ramp when there is a lane closure on I-96. If 20 percent of the traffic can be diverted to the ramp, the speed on link (104-106) increases by more than 37 percent, from 35.4 to 48.5 miles per hour, with a 5 percent decrease in the speed of traffic on the ramp link (112-114).

If the message on the CMS results in a diversion of 30 percent, the increase in speed on link (104-106) decreases from the 20 percent diversion case due to the increased weaving required on this link, but the speed on link (108-110) is increased by about 30 percent from 19.4 to 23.6 miles per hour.

The results of this simulation, as shown in Table 4.29 and Figure 4.09, indicate an increase in the speed of traffic on links (112-114) can be achieved if the CMS successfully diverts traffic to the mainline when there is a lane closure on the ramp to I-275. If 10 percent of the traffic is diverted to the mainline, the speed on link (104-106) decreases by 35 percent, from 35.7 to 26.4 miles per hour due to the increased weaving, but there is a 61 percent increase in the speed of traffic on the ramp link (112-114) from 27.8 to 44.7 miles per hour. If 20 percent of the traffic can be diverted to the mainline, the speed on link (104-106) decreases even further to 48 percent, from 41.2 to 21.2 miles per hour, with an 87 percent increase in the speed of traffic on the ramp link (112-114) from 27.8 to 52.0 miles per hour.

An increase in diversion to 30 percent does not reduce speeds on the weaving link (104-106), but the speed on I-96 link (108-110) is decreased by about 3 percent from 60.2 to 58.2 miles per hour due to the heavier volume on this path.

Impact of Changeable Message Sign Display Messages on Traffic

The CMS message logs were obtained from the Michigan Department of Transportation for the period of November 1998 through June 1999. The message logs were reviewed for dates when messages were displayed at any one of the analysis sites. A thorough review of the message logs revealed two dates when data were available when a priority message was displayed to the motorists. These occurred at the westbound I-96 at Buchanan Street site on April 7, 1999, and on May 10, 1999 at the eastbound I-96 site east of Beck Road.

Westbound I-96 East of Buchanan

The message display for this site occurred on Wednesday April 7, 1999. Based upon the message log, a message was displayed at 12:57 p.m. regarding an accident on northbound Chrysler Freeway, which is a major north/south connector for travelers on westbound I-96. Since this message did not occur in the peak hour, it was necessary to determine the typical volume ratio for the two-hour period to be analyzed (12:55 p.m. to 2:55 p.m.). In addition to the date of the message, ten days within the month of April 1999 were used to determine traffic volumes. Data for the following dates were used for this analysis:

- Tuesday April 6, 1999
- Thursday April 8, 1999
- Tuesday April 13, 1999
- Wednesday April 14, 1999
- Thursday, April 15, 1999

- Wednesday, April 21, 1999
- Thursday, April 22, 1999 – Data measures were analyzed, but ratio was determined to be an outlier and was not used in the confidence limit determination.
- Tuesday, April 27, 1999
- Wednesday, April 28, 1999
- Thursday, April 29, 1999

An average of the traffic volumes for the ten days was computed to determine the average site speed, along with entrance, exit and ramp volumes. The number of one-minute (by lane) volume observations (N) is noted for each data set within this analysis. Based upon these numerical values, the volume ratios were determined, along with their statistical significance. Table 4.30 displays the information for April 7, 1999 at the site. The computed values of the comparison data are displayed in Table 4.31.

Table 4.30 - WB I96 at Buchanan Accident Message Display Analysis

Date of Message	Initial Display Time	Mainline Entrance Volume N=472	Mainline Exit Volume N=472	Ramp Exit Volume N=118	Volume Ratio	Mainline Exit Speed (mph)
4/7/99	12:57 pm	4936	3282	1682	1.95	69.00

Table 4.31 - WB I96 at Buchanan Accident Message Analysis – 12:55 p.m. to 2:55 p.m.

Date	Mean Mainline Entry Volume N=480	Mean Mainline Exit Volume N=480	Mean Ramp Exit Volume N=121	Ratio	Mean Mainline Exit Speed (mph) N=480
4/6/99	4945	3103	1636	1.90	66
4/8/99	4889	3316	1559	2.13	64
4/13/99	4983	3429	1562	2.20	69
4/14/99	5275	3669	1437	2.55	67
4/15/99	5378	3592	1357	2.64	68
4/21/99	5176	3534	1690	2.09	67
4/22/99	5373	3941	1116	*3.53	68
4/27/99	5070	3526	1564	2.25	69
4/28/99	5370	3592	1729	2.08	69
4/29/99	5241	3562	1415	2.52	68
Average	5147	3480	1550	2.23	67

The diversion ratio confidence intervals for the time period of 12:55 p.m. to 2:55 p.m. using the dates listed were computed as shown in Table 4.32. The ratio of 1.95 for the accident message display date of April 7, 1999 does not lie within these confidence intervals, indicating that the accident message display impacted the decision of motorists to divert from the freeway. This result is different from that found when the accidents that occurred in November and December (before the CMS were deployed) were analyzed. This indicates the message was effective in diverting traffic.

Table 4.32 – WB I96 at Buchanan Ratio Confidence Intervals

Significance Level	Diversion Confidence Interval
95%	2.04, 2.42
98%	2.00, 2.46
99%	1.96, 2.49

Eastbound I-96 East of Beck Road

The message display for this site occurred on Monday May 10, 1999. Based upon the message log, the accident message was displayed at 3:44 p.m. regarding an accident on the southbound I-275 freeway, which is a major southbound connector for travelers on eastbound I-96. The typical volume ratio for the two-hour period of 3:40 p.m. to 5:40 p.m. was analyzed. In addition to the date of the message, ten days in the month of May 1999 were used to determine traffic volumes. Data for the following dates were used for this analysis:

- Monday May 3, 1999
- Tuesday May 4, 1999
- Wednesday May 5, 1999
- Thursday May 6, 1999
- Tuesday May 11, 1999
- Wednesday May 12, 1999
- Thursday May 13, 1999
- Monday May 17, 1999
- Wednesday May 19, 1999
- Thursday May 20, 1999

The average traffic volumes for the ten days was computed to determine the site entrance, exit and ramp volumes. Based upon these numerical values, the volume ratios were determined, along with their statistical significance. Table 4.33 displays the

information for May 10, 1999 at the site. The computed values of the comparison data are displayed in Table 4.34.

Table 4.33 – EB I96 East of Beck Accident Message Display Analysis

Date of Message	Initial Display Time	Mainline Entrance Volume N=360	Mainline Exit Volume N=240	Ramp Exit Volume N=240	Volume Ratio	Mainline Exit Speed (mph)
5/10/99	3:44 pm	7262	4157	2445	1.70	69.00

Table 4.34 - EB I96 East of Beck Accident Message Analysis – 3:40 p.m. to 5:40 p.m.

Date	Mean Mainline Entry Volume N=480	Mean Mainline Exit Volume N=480	Mean Ramp Exit Volume N=121	Ratio	Mean Mainline Exit Speed (mph) N=480
5/3/99	7177	4062	2934	1.38	68
5/4/99	7653	4280	3211	1.33	68
5/5/99	7993	4365	3366	1.30	68
5/6/99	8200	4551	3406	1.34	68
5/11/99	8121	4767	3337	1.43	68
5/12/99	7907	4712	3595	1.31	68
5/13/99	8592	5002	3654	1.37	68
5/17/99	7867	4071	3419	1.19	68
5/19/99	8679	4786	3823	1.25	67
5/20/99	8502	4445	3709	1.20	68
Average	8069	4504	3445	1.31	68

The diversion ratio confidence intervals for the time period of 3:40 p.m. to 5:40 p.m. using the dates listed were computed as shown in Table 4.35. The diversion ratio of 1.70 for the accident message display date of May 10, 1999 is well outside of these confidence

intervals, indicating that the accident message display impacted the decision of motorists to divert.

Table 4.35 – EB I96 East of Beck Ratio Confidence Intervals

Significance Level	Diversion Confidence Interval
95%	1.25, 1.36
98%	1.24, 1.38
99%	1.23, 1.39

The computer simulation analysis of this case revealed a 2.77 percent difference in the travel time based upon a comparison of the average mainline and exit ramp volumes (4504, 3445) and the actual volumes of (4157, 2445) which occurred on the date of the message.

If the average ratio of the mainline traffic volume to ramp traffic volumes (1.31) existed on May 10, 1999 there would have been 2,858 vehicles on the ramp and 3,144 vehicles on I-96 during the incident. This means the CMS sign was successful in diverting 22% of the traffic from the I-275 ramp to I-96. The sensitivity analysis (Figure 4.09) showed that a 20 to 30 percent diversion, when there is a ramp lane closure, resulted in a 48% decrease in the speed of traffic on the weaving link (104-106) approaching the separation of traffic destined for I-275 and I-96.

The two accidents that occurred at this location on November 17, 1998 and December 7, 1998 before the CMS was operational, showed no diversion. The accident that occurred on May 10, 1999 recorded after the CMS was operational showed a diversion of

over 20%. If these results hold true, for other accidents and incidents, it appears that the CMS can have a significant impact on traffic volumes, and thus average speed and delay.

CHAPTER 5: RESEARCH SUMMARY AND CONCLUSIONS

This study was designed to evaluate the impacts on travel speed and delay due to the use of changeable message signs at locations where drivers could choose to divert from their typical route of travel. This analysis was completed by simulating selected locations on the Detroit Metropolitan Area freeway network when the freeways diverge to determine the impact of diverting traffic away from incidents.

A comparison of the volume ratios on alternative paths for normal traffic conditions and traffic conditions occurring within two hours after an incident when no CMS message was displayed to motorists was made. The volume ratios for each case was within the confidence intervals for the existing ratios, indicating that the accident occurrences had no statistically significant impact on the motorists' propensity to divert from their planned course of travel.

By using the FRESIM computer simulation model to determine travel time and delay based traffic diversion. It was determined that to have a significant impact on travel time, the CMS will have to cause a diversion of at least ten percent, and the impact is increased substantially if the diversion is twenty or thirty percent.

Diversion to the mainline and ramp were simulated for the weaving link and mainline exit link to show the potential impact on speed and delay as the percentage of the diversion increases to the ramp or mainline. Simulation analysis was also completed to compare speed and delay when a freeway lane closure or diversion is necessary due to recurring or non-recurring congestion. The results of this analysis revealed the potential for speed and delay variances when a driver diverts due to a lane closure.

The final analysis consisted of reviewing MDOT message logs to determine the dates and times of CMS messages displayed at the three sites included within this study. Confidence limits for the diversion ratios were developed using real time data for each site. The diversion ratio was computed for the date and time of the accident occurrence. In both cases the percent diversion was greater than 10%. The results suggested rejection of the null hypothesis that the accident message display did not impact the decision of motorists to divert from the freeway.

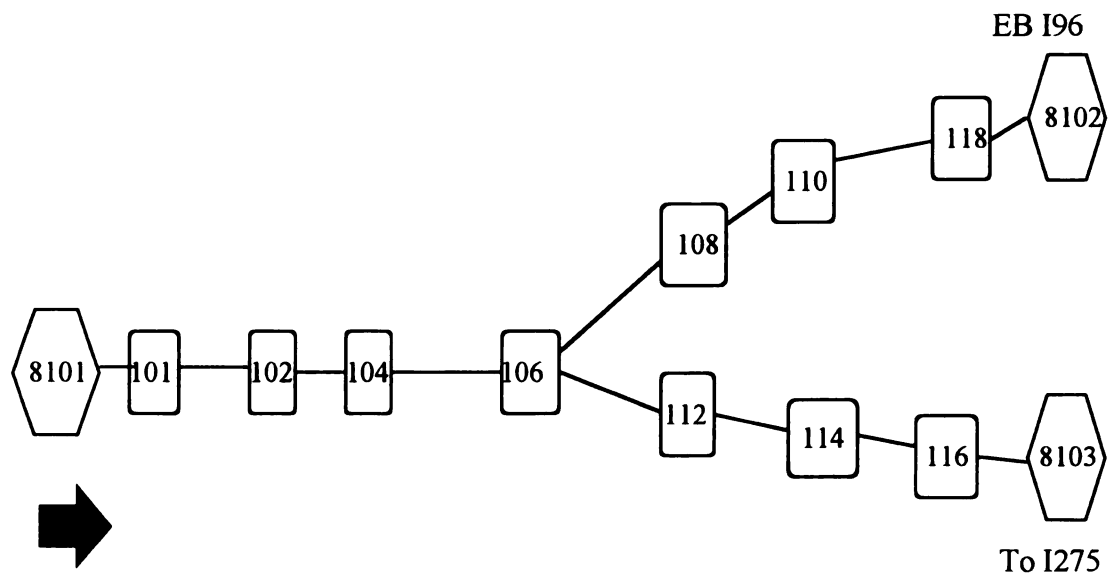
Although much of the data for 1998 was unavailable, beginning in 1999 data related to determination of the measures of effectiveness for each site was available. Unfortunately, only two incidents that required a priority message for display on the CMS occurred at the times the detector data were available. This limits the conclusions that can be justified by data.

This study may serve as a basis of determining changeable message sign impacts by comparing existing diversion volume ratios to those that occur as a result of incidents and changeable message sign information displayed to motorists.

APPENDICES

APPENDIX A

ITRAF 2.0										00	
Bellandra B. Foster EBI96/Beck										01	
1	0	25	21	8	09	99	Michigan State Univ.	80625	7781	7581	02
3600										03	
60										04	
										05	
8101	101	102	0	4							19
101	102	104	96620	4							19
106	108	110	61200	2							19
106	112	114	30091	2							19
108	110	118	29030	2							19
110	1188102	15000	2								19
112	114	116	20001	2							19
104	106	108	55440	2	93	5544103	5544				19
102	104	106	9510	4							19
114	1168103	20001	2								19
8101	101		118								20
101	102		11870								20
106	108		11870								20
106	112		11870								20
108	110		11870								20
110	118		11870								20
112	114		11870								20
104	106		11870				1000				20
102	104		11870								20
114	116		11870								20
8101	101	1024700									25
101	102	1044700									25
104	106	1082652	1122048								25
102	104	1064700									25
106	108	1102652									25
112	114	1162048									25
114	11681032048										25
108	110	1182652									25
110	11881022652										25
106	112	1142048									25
114	116	2									29
8101	1014700	15			1500	0200	1800	1800	30	3280	50
0											170
101	5280	10000									195
102	14942	10000									195
106	21437	10000									195
108	27557	10500									195
112	24446	9500									195
8101	0	10000									195
118	31960	11500									195
8102	33960	12500									195
8103	28446	8700									195
110	30460	11500									195
114	26446	9000									195
116	28446	8800									195
104	15893	10000									195
1											210



Eastbound I96 East of Beck Road FRESIM Link-Node Diagram

Loop Address Listing

Site Location

EB I-96 / BECK

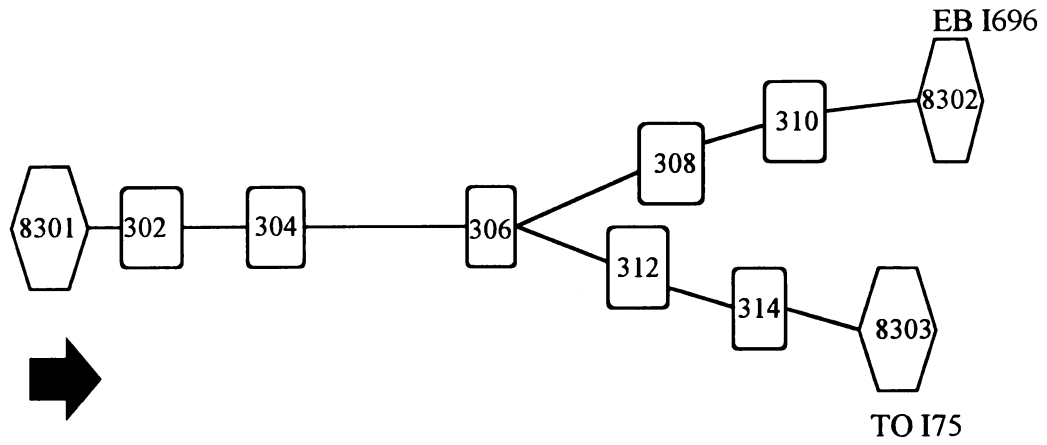
LOOP NUMBER	HwAddress
TO SB I-275/I96	
E1C	459009
E2C	459010
SB M-5 GRAND RIVER	
E3C	459011
E4C	459012
EXIT SITE EB I-96	
E1A	459779
E2A	459780
E1B	459779
E2B	459780
SITE ENTRY EB I-96	
E1A	459524
E1B	459524
E2A	459525
E2B	459525
E3A	459526
E3B	459526

date_time	activity_type	sign_hwaddr	mnemonic	activity_detail1
1:52:27 PM, 5/10/1999	36	0		Message Added To Library - 46657
1:53:25 PM, 5/10/1999	37	0		Message Library Edit - 46657
1:53:34 PM, 5/10/1999	37	0		Message Library Edit - 46657
1:54:22 PM, 5/10/1999	27	0	ACNS	Continuous Message Scheduled - 46657
2:03:37 PM, 5/10/1999	29	0		Global Message Deleted From Signs - 45831
2:05:38 PM, 5/10/1999	37	0		Message Library Edit - 45831
2:07:27 PM, 5/10/1999	27	0	GECN	Continuous Message Scheduled - 45831
2:45:25 PM, 5/10/1999	5	0		Sign Status
2:46:56 PM, 5/10/1999	8	6		Sign Mode Change - Force Self-Test
2:47:16 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
2:49:10 PM, 5/10/1999	8	6		Sign Mode Change - Force Blank
2:49:24 PM, 5/10/1999	24	6		Repair Mode - Clear SBC Flags
2:50:05 PM, 5/10/1999	8	6		Sign Mode Change - Force Immediate
2:51:31 PM, 5/10/1999	24	6		Repair Mode - Clear SBC Flags
2:51:46 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
3:08:13 PM, 5/10/1999	5	0		Sign Status
3:20:01 PM, 5/10/1999	5	0		Sign Status
3:22:48 PM, 5/10/1999	8	6		Sign Mode Change - Force Blank
3:22:59 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
3:25:26 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
3:26:52 PM, 5/10/1999	8	6		Sign Mode Change - Force Self Test
3:36:00 PM, 5/10/1999	8	6		Sign Mode Change - Force Blank
3:41:14 PM, 5/10/1999	5	0		Sign Status
3:44:16 PM, 5/10/1999	15	23	ACS2	Continuous Message Scheduled - 42726
3:44:31 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
3:46:54 PM, 5/10/1999	5	0		Sign Status
3:53:47 PM, 5/10/1999	27	0	ACNS	Continuous Message Scheduled - 46657
3:58:17 PM, 5/10/1999	27	0	FCNS	Continuous Message Scheduled - 46309
3:59:34 PM, 5/10/1999	5	0		Sign Status
4:01:37 PM, 5/10/1999	24	6		Repair Mode - Clear SBC Flags
4:01:43 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
4:02:13 PM, 5/10/1999	8	6		Sign Mode Change - Force Self-Test

date_time	activity_type	sign_hwaddr	mnemonic	activity_detail1
4:02:24 PM, 5/10/1999	8	6		Sign Mode Change - Force Time Sched
4:03:42 PM, 5/10/1999	8	6		Sign Mode Change - Force Time Sched
4:09:05 PM, 5/10/1999	5	0		Sign Status
5:11:17 PM, 5/10/1999	17	23		Single Message Deleted From Sign - 42726
5:25:32 PM, 5/10/1999	8	6		Sign Mode Change - Force Self-Test
5:25:48 PM, 5/10/1999	8	6		Sign Mode Change - Force Immediate
5:26:01 PM, 5/10/1999	8	6		Sign Mode Change - Force Time Sched
5:26:07 PM, 5/10/1999	24	6		Repair Mode - Clear SBC Flags
5:26:12 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
5:26:28 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
5:26:29 PM, 5/10/1999	24	6		Repair Mode - Reload Messages Into Sign
5:27:33 PM, 5/10/1999	5	0		Sign Status
5:30:25 PM, 5/10/1999	36	0		Message Added To Library - 46658
5:32:13 PM, 5/10/1999	36	0		Message Added To Library - 46659
5:33:19 PM, 5/10/1999	27	0	FCWF	Continuous Message Scheduled - 46659
5:52:12 PM, 5/10/1999	5	0		Sign Status
5:53:10 PM, 5/10/1999	27	0	GEAC	Continuous Message Scheduled - 44253
6:06:07 PM, 5/10/1999	5	0		Sign Status
6:06:24 PM, 5/10/1999	29	0		Global Message Deleted From Signs - 44253
6:11:30 PM, 5/10/1999	27	0	GEACC	Continuous Message Scheduled - 1047
6:21:06 PM, 5/10/1999	29	0		Global Message Deleted From Signs - 22330
6:27:37 PM, 5/10/1999	29	0		Global Message Deleted From Signs - 46659
6:53:45 PM, 5/10/1999	5	0		Sign Status
6:58:30 PM, 5/10/1999	17	15		Single Message Deleted From Sign - 104
6:58:43 PM, 5/10/1999	5	0		Sign Status
7:01:25 PM, 5/10/1999	5	0		Sign Status
7:03:21 PM, 5/10/1999	17	11		Single Message Deleted From Sign - 46566
7:07:19 PM, 5/10/1999	37	0		Message Library Edit - 46245
7:08:19 PM, 5/10/1999	37	0		Message Library Edit - 45845
7:25:56 PM, 5/10/1999	29	0		Global Message Deleted From Signs - 1047
7:40:48 PM, 5/10/1999	38	0		Deleted Message From Library - 1045
7:42:19 PM, 5/10/1999	37	0		Message Library Edit - 46416

APPENDIX B

ITRAF 2.0										00			
Bellandra B. Foster EBI696/Manistee										8	9	99Michigan State Univ.	1
1	0	10					80645	7781	8261	2			
3600										3			
60										4			
										5			
8301	302	304	0	5						19			
302	304	306	55390	5						19			
304	306	308	76560	4	93	7656				19			
306	312	314	12041	1						19			
308	3108302		10000	4						19			
312	3148303		10001	1						19			
306	308	310	11740	4						19			
8301	302		122							20			
302	304		12265							20			
304	306		12265			2600				20			
306	312-3		12255							20			
306	308+3		12265							20			
308	310		12265							20			
312	314		12255							20			
8301	302	304	100							25			
302	304	3068208								25			
304	306	3085301	3122451							25			
8301	3028208	20						27	24	26	20	03	50
8301	3021500	103000	203000	350708	45					1	53		
0											170		
302	5280	10000									195		
304	10819	10000									195		
306	18475	10000									195		
310	20649	10250									195		
8301	0	10000									195		
8302	22649	10300									195		
8303	22679	8500									195		
308	19649	10100									195		
312	19679	9300									195		
314	20679	9000									195		
1											210		



Eastbound I696 at Manistee FRESIM Link-Node Diagram

Loop Address Listing

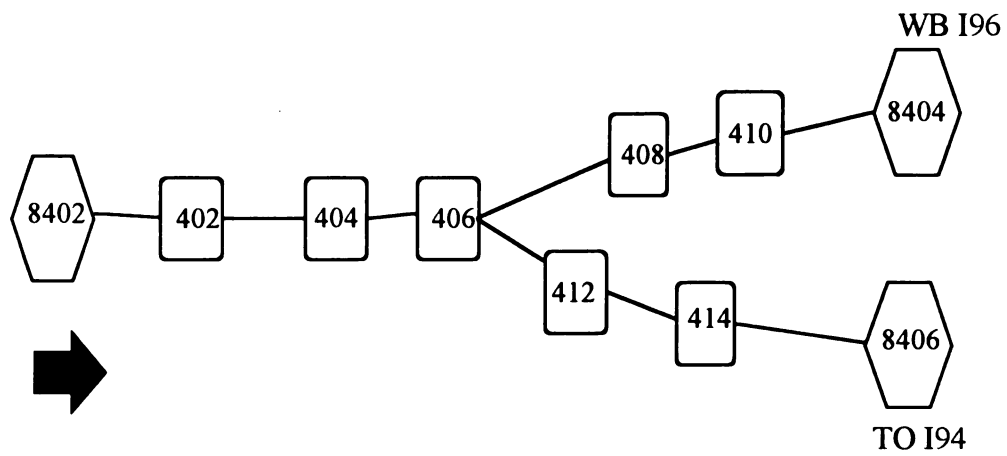
Site Location

EB I-696 / MANISTEE

LOOP NUMBER		HwAddress
TO NB/SB I-75		
E3C	NB I-75	131335
E1C	SB I-75	131333
E2C	SB I-75	131334
EXIT SITE EB I-696		
E1A		131329
E2A		131330
E3A		131331
E4A		131332
E1B		131329
E2B		131330
E3B		131331
E4B		131332
SITE ENTRY EB I-696		
E1A		131841
E2A		131842
E3A		131843
E4A		131844
E1B		131841
E2B		131842
E3B		131843
E4B		131844

APPENDIX C

ITRAF 2.0										00						
Bellandra B. Foster WBI96/Buchanan										8	9	99Michigan State Univ.	1			
1 0 10												81635	7781	8263	2	
3600															3	
60															4	
															5	
8402	402	404	0	5						1					19	
402	404	406	28880	5						9					19	
404	406	408	16600	4	93	1660				1	9				19	
406	412	414	04101	1						1					19	
408	4108404	10000	4							1					19	
412	4148406	10001	1							1					19	
406	408	410	26430	4						1					19	
8402	402		12265												20	
402	404		12265												20	
404	406		12265			1600									20	
406	412		12255												20	
406	408		12265												20	
408	410		12265												20	
412	414		12255												20	
8402	402	404	100												25	
404	406	4085446	4121048												25	
402	404	4065446													25	
8402	4025413	32										25	25	25	25	50
8402	4022413	052000	201000	35											1	53
0																170
402	5280	9900														195
406	9828	10300														195
408	12471	10700														195
412	10238	10000														195
8402	0	9700														195
8404	15471	10900														195
8406	13238	9200														195
410	13471	10800														195
414	11238	9650														195
404	8168	10000														195
1																210



Westbound I96 at Buchanan FRESIM Link-Node Diagram

Loop Address Listing

Site Location

WB I-96 / BUCHANAN

LOOP NUMBER	HwAddress
TO I-94	
W1C	658945
W2C	658946
EXIT SITE WB I-96	
W1A	658689
W2A	658690
W3A	658691
W4A	658692
W1B	658689
W2B	658690
W3B	658691
W4B	658692
SITE ENTRY WB I-96	
W1C FROM NB I-75	593153
W2C FROM NB I-75	593154
W3C FROM SB I-75	593155
W4C FROM SB I-75	593156

date time	activity_type	sign_hwaddr	mnemonic	activity_detail1
10:27:07 AM, 4/7/1999	27	0	FCN2	Time Scheduled Message Scheduled - 46565
10:33:19 AM, 4/7/1999	29	0		Global Message Deleted From Signs - 45973
10:33:32 AM, 4/7/1999	29	0		Global Message Deleted From Signs - 43680
10:40:00 AM, 4/7/1999	37	0		Message Library Edit - 46566
10:43:29 AM, 4/7/1999	36	0		Message Added To Library - 46567
10:44:20 AM, 4/7/1999	36	0		Message Added To Library - 46568
10:47:36 AM, 4/7/1999	27	0	RCWJ	Time Scheduled Message Scheduled - 46568
10:49:57 AM, 4/7/1999	27	0	RCWJ	Time Scheduled Message Scheduled - 46568
12:11:46 PM, 4/7/1999	36	0		Message Added To Library - 46569
12:12:45 PM, 4/7/1999	36	0		Message Added To Library - 46570
12:16:00 PM, 4/7/1999	15	8	FCSC	Continuous Message Scheduled - 46569
12:18:01 PM, 4/7/1999	38	0		Deleted Message From Library - 46567
12:55:19 PM, 4/7/1999	36	0		Message Added To Library - 46571
12:56:10 PM, 4/7/1999	37	0		Message Library Edit - 46571
12:57:08 PM, 4/7/1999	15	33	ACNC	Continuous Message Scheduled - 46571
12:58:58 PM, 4/7/1999	37	0		Message Library Edit - 46569
1:00:55 PM, 4/7/1999	17	11		Single Message Deleted From Sign - 46566
1:01:16 PM, 4/7/1999	17	11		Single Message Deleted From Sign - 46566
1:01:57 PM, 4/7/1999	15	11	FCSC	Continuous Message Scheduled - 46566
1:03:21 PM, 4/7/1999	37	0		Message Library Edit - 46566
1:06:23 PM, 4/7/1999	15	11	FCSC	Continuous Message Scheduled - 46566
1:52:01 PM, 4/7/1999	36	0		Message Added To Library - 46572
1:54:17 PM, 4/7/1999	27	0	FNCS	Continuous Message Scheduled - 46572
1:57:51 PM, 4/7/1999	27	0	FNCS	Continuous Message Scheduled - 46572
2:56:14 PM, 4/7/1999	5	0		Sign Status
3:09:46 PM, 4/7/1999	5	0		Sign Status
3:10:11 PM, 4/7/1999	5	0		Sign Status
3:10:45 PM, 4/7/1999	5	0		Sign Status
3:12:27 PM, 4/7/1999	5	0		Sign Status
3:14:10 PM, 4/7/1999	5	0		Sign Status
3:16:07 PM, 4/7/1999	5	0		Sign Status
3:20:11 PM, 4/7/1999	5	0		Sign Status

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⁴ Steven D. Wohlschlaeger, *Factors Affecting Motorist Route Choice and Diversion Potential*, Transportation Research Board, Paper Number 97-0968, 76th Annual Meeting, 1997, Washington, D.C., Abstract.

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⁹ P.E. Firmin, P.W. Bonsall, and H.C. Beaumont, *Drivers' Attitudes to Variable Message sign Information in London*, Institute for Transport Studies, University of Leeds, Leeds, United Kingdom, p. 6-7.

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