# Smart Work Zone Deployment Initiative
# Summer 2001
# Travel Time Prediction System (TIPS)

## Wisconsin Evaluation

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# Smart Work Zone Deployment Initiative Wisconsin Evaluations
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## ABSTRACT

The present report is an evaluation of the Travel Time Prediction System (TIPS), a portable automated system for predicting and displaying travel time for motorists in advance of and through work zones, on a real-time basis. TIPS collects real-time traffic flow data using roadside sensors, computes estimated travel time between different points on the freeway and the end of the work zone, and displays this information on several Changeable Message Signs (CMS).

The system was deployed along the Southbound direction of Interstate 94 (I-94) in Milwaukee and Racine County, Wisconsin, in advance of a construction zone that required three lanes of traffic to be tapered to two. Four CMS were installed, at locations where drivers would have an opportunity to exit (or not enter) the freeway, if displayed travel times were excessive. Two were placed facing Southbound I-94 drivers and two on surface arterials, before ramps connecting to I-94. The evaluation measured the system's ability to accurately predict travel times to the end of the construction zone, using data for the two CMS that were installed on I-94. The system's impact on trip diversions when higher travel times were displayed was also evaluated.

Travel time accuracy was evaluated based on a comparison of Actual and TIPS-estimated travel times. Actual travel time data was collected by two-person teams, who drove through the construction zone continuously during hours of higher traffic volumes on selected Thursdays, Fridays and Sundays in June, July and August of 2001. TIPS information was provided in electronic form and also collected from CMS deployed in the field. A total of 210 travel time runs, performed on I-94, were available for analysis.

A comparison of Actual and TIPS travel times indicated that the evaluated system generally followed increases and decreases in Actual travel time. It predicted travel times quite accurately, on average, but a rather wide range of Actual travel times corresponded to each individual TIPS travel time estimate. Although the differences between Actual and predicted travel times were between two and three minutes, on average, the percentage of Actual travel times within +/-4 minutes of system-predicted times was 46% and 66% for the two evaluated CMS. Predicted travel times were within 30% of Actual travel times for 85% and 86% of the analyzed observations.

Two restrictions were imposed on the evaluated system, namely: i) displayed travel times should be multiples of four minutes; and, ii) travel times should be displayed for at least three minutes. Based on available information, the restrictions were found to have minimal impact on the accuracy of travel time predictions provided to motorists.

The evaluated system performed reliably throughout the data collection hours, with the exception of one day when an apparent communications problem did not allow predicted travel times to be conveyed to the CMS.

A comparison of crash statistics between the before and the after TIPS CMS installation periods did not identify statistically significant safety performance changes in the work zone downstream of the CMS. However, the injury crash frequency for the TIPS work zone was less after TIPS began operation than for a similar construction zone in the opposite direction of travel, which was used as a control site for the safety evaluation. But because the analysis periods were short - 69 days both before and after TIPS operation - results should not be viewed as conclusive.

Modest trip diversion changes were identified, during the period TIPS was operational, when displayed travel times exceeded their median value.

# Table of Contents

LIST OF TABLES

## LIST OF FIGURES

**APPENDIX A**
**EVALUATION CORRIDOR INFORMATION**

**APPENDIX B**
**TRAVEL TIME RESULTS**

**APPENDIX B**
**TRAVEL TIME RESULTS**
**(continued)**

**APPENDIX C**
**EVALUATION CORRIDOR PHOTOGRAPHS**

**APPENDIX D**
**DATA COLLECTION MATERIALS**

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## TECHNOLOGY

The Travel Time Prediction System (TIPS) is a portable automated system for predicting and displaying travel time for motorists in advance of and through work zones, on a real-time basis. It collects real-time traffic flow data using roadside non-contact sensors (microwave radar sensors), processes the data in an on-site personal computer, computes estimated travel time between different points on the freeway and the end of the work zone, and displays this information on several portable, electronic changeable message signs (CMS) positioned at pre-determined locations along the freeway or adjacent arterials. Provision of real time travel time information allows motorists to make decisions about driving through the freeway work zone or taking an alternate route.

According to the developer, the system has a communications range of 20 miles, its sensors can detect traffic flow in each lane (for up to eight lanes), and it provides travel time predictions with an accuracy of +/- 3 min. Communications between system detectors, the on-site personal computer and the CMS are through radios using the 220MHz frequencies that have been allocated to FHWA (no special FCC permission to use these frequencies is required). The system is powered by batteries charged through solar panels.

System objectives are to: i) provide reliable travel time information; ii) reduce travel time–motorists are expected to use less congested alternate routes, once expected travel times through a work zone become excessive; iii) reduce mainline and corridor travel time by encouraging motorists to use alternate routes; and, iv) reduce mainline risk of rear-end collisions–mainline traffic volumes are expected to be lower due to diverted traffic, resulting in smoother traffic flow that will reduce the risk of such collisions.

Information about this technology is available through Prahlad D. Pant, Ph. D., President, PDP Associates, Inc., 2367 Springdale Road, Cincinnati, Ohio, 45231, Phone 513 226 6009. Web: www.pdpassociates.com, E-mail: pant@pptips.com

## BACKGROUND

The TIPS system was installed to provide travel time predictions for an Interstate 94 (I-94) construction zone in Wisconsin, in the summer and early fall months of 2001. Construction involved replacing pavement in both directions of I-94 along the entire length of Racine county; TIPS system components were installed in advance and along the northern-most portion of the southbound direction only. The evaluation presented herein is based on a comparison of travel time data collected through travel time runs, with travel times predicted through the TIPS system. In addition, estimates of the effect of TIPS-displayed information on the number of freeway trips diverted from the construction zone are presented.

## STUDY SITE

The present evaluation took place on I-94, in Milwaukee and Racine Counties, between the Layton Avenue Interchange on the north, and County Trunk Highway KR in the south. Aerial photographs of the northern end of the corridor, the construction zone taper, and a typical section of the Racine County construction zone can be found in Figures A1 through A5 in Appendix A. Throughout the length of this corridor, both directions of I-94 have three 12-foot through lanes of asphalt pavement, and 10-foot concrete shoulders on either side (Picture C1, Appendix C). Rumble strip sets, constructed into the shoulders were present at regular intervals. The northern part of the corridor (Milwaukee County) is within an urban area, and the southern end of the evaluation corridor (Racine County) is rural, with development concentrated in the vicinity of freeway exits. Weekday Average Daily Traffic was 79,263 vpd in 1999 at a location approximately 1.5 miles south of the Racine-Milwaukee County line. Traffic was peaking at 90,355 vpd on Fridays, followed by Thursdays at 82,355 vpd. Peak traffic months were June through August (these coincided with the evaluation time period), and peak travel days were Fridays. Traffic peaked at 100,849 vpd on August Fridays. Sundays were the next highest travel days in August at 95,063 vpd, Thursdays were the next highest travel days in June and July. Traffic was almost evenly divided in both directions, with the peak direction carrying 50.1% of the ADT (detailed traffic information is presented in Appendix A pp.A6-A9).

### Construction Zone Description

The construction zone extended from approximately 2,000 feet south of Oakwood Road in Milwaukee County (Figure A1), to the south end of Racine County at County Trunk Highway KR, located at the Racine County border, with a total length of approximately 12.5 miles. Construction was scheduled in two phases: the left half of the moving lanes (median lane and half of the middle lane) was replaced in both directions of travel during construction phase one, and the right half of the moving lanes (half of the middle lane and the right lane) was replaced during construction phase two.

The southbound I-94 construction taper was located near the southern-most end of Milwaukee County, approximately at the middle of the short freeway segment following a South-West direction (Figure A2 detail in Figure A3). During the first phase of the project, the left-most southbound lane (median lane) was closed in advance of the construction zone; only the right two lanes were open to through traffic. Traffic was shifted to the right lane and the right shoulder, approximately at the Milwaukee County/Racine County border. The concrete rumble strips on the shoulders were temporarily patched over with asphalt (Picture C2), in order to provide a smoother ride for drivers driving on this temporary travel lane. During construction phase two, a similar strategy was adopted to shift traffic to the left shoulder and the newly repaved median lane. A detail of the taper during the second construction phase is presented in Picture C3.

A typical construction phase one zone section can be seen in Picture C4. The left half of the traveled way has been ground, and the right half is used as:

a (narrow paved) left shoulder (where the construction barrels are placed),
a through traffic lane
part of the temporary right travel lane.

The remainder of the temporary right travel lane is on the right shoulder, which also serves as a narrow paved right shoulder. The rumble strips have been temporarily patched over with asphalt. The space to the left of the construction barrels was often used by disabled vehicles and vehicles involved in minor crashes. A narrow gravel shoulder is available on the right-hand side-Picture C4. A similar travel lane shift was implemented during the second construction phase, during which vehicles were driving on the left half of the available space. Construction phase two started in mid-July 2001.

**Alternate routes**

A number of alternate routes were available to southbound I-94 motorists who wanted to avoid driving through the construction zone:

1. The WisDOT-designated alternate route followed an alignment west of I-94 (Figures A1 and A2): 27th Street (also designated as US 41 and State Trunk Highway 241), is a divided arterial ranging from 4 to 6 lanes. Five intersections between College Avenue and the Milwaukee/Racine County border (a six-mile segment) are signalized.
   At the Milwaukee/Racine County line the alternate route makes a 90-degree turn to the right (Picture C5) and after a few hundred feet a similar turn to the left to continue in a southbound direction on the West Frontage Road (WFR), a two-lane highway running parallel to I-94. WFR has gravel shoulders and is stop-controlled at I-94 off-ramps and surface streets. A typical view of the WFR is presented in Picture C6, at the intersection with 7-Mile Road. The WFR veers west of the freeway in the vicinity of State Trunk Highway 20, the only signalized intersection south of the Milwaukee/Racine county line. Following this intersection, WFR parallels once again I-94 through a series of two 90-degree turns. WFR follows a similar deviation at 58th Street, and becomes parallel to I-94 south of STH 11. The end of this alternate route was considered to be County Trunk Highway KR, at the Racine/Kenosha County line.
   The speed limit in the six-lane portion of the alignment is 40 mph; south of Ryan Road it is 45 mph. WFR has a speed limit of 55 mph where it parallels I-94. The speed limit is 35 mph in the vicinity of STH 20 and an advisory speed limit of 15 mph is posted on all 90-degree turns.
   Alternate I-94 route signs leading to this alignment were posted on I-94 north of the College Avenue and the Ryan Road exit ramps.
2. CTH V (13th Street) parallels I-94 on the east. It is a two lane highway with gravel shoulders and is stop-controlled at intersections with east-west highways (Picture C7). The south end of CTH V is STH 20. It is accessible through the College Avenue, Rawson Avenue and Ryan Road I-94 exits.
3. STH 38 (CTH H, Howell Avenue) also parallels I-94 on the east. Its south end is CTH K. It is accessible through the Airport Spur, College Avenue, Rawson Avenue and Ryan Road I-94 exits.

**Evaluation description**

The purpose of the evaluated TIPS system installation was to provide predictions of the travel time required for motorists to traverse the construction zone. The goals of the present evaluation were to: i) assess the accuracy of TIPS system-generated travel time prediction; ii) assess any safety impacts that TIPS-displayed information may have had on crashes, and, iii) to assess the effect the provided information had on inducing drivers to use alternate routes.

The evaluated system produced travel time estimates for each Changeable Message Sign (CMS) every 30 seconds. These estimates were subsequently processed through an algorithm and conveyed to the appropriate CMS to be displayed to motorists. The accuracy of TIPS-system-generated predictions [item i) above] was separately assessed using the 30-second travel time estimates and travel times displayed on system CMS.

The evaluation was divided into two phases. Evaluation phase one took place during construction phase one, when traffic was using the right lane and right shoulder; evaluation phase two took place during construction phase two, when traffic was using the left shoulder and the newly constructed median lane. Both evaluation phases were shorter than the respective construction phases.

***Evaluation Phase One.***
Evaluation phase one started four weeks after the start of construction phase one. During this evaluation phase, TIPS detectors and computing facilities were installed. Although travel time predictions were continuously calculated, this information was not displayed to the motorists; however, the information was stored in electronic files. The evaluators collected Actual travel time information using vehicles that were driven continuously through the construction zone for approximately four hours during peak traffic hours on peak traffic days. Traffic volume information was simultaneously collected using road tubes[1], the TIPS system detectors, and loop detectors embedded in the pavement. Road tubes were used to monitor alternate route traffic (the 27th Street-West Frontage Road alignment west of I-94, County Trunk Highway V and State Trunk Highway 38, east of I-94). TIPS system detectors and pavement-embedded detectors were used to monitor freeway traffic.

***Evaluation Phase Two.***
Data collection during evaluation phase two was identical to that during the phase one, with the addition that four Changeable Message Signs (CMS) were used to continuously display predicted travel time information to southbound motorists. Two CMS were placed on the freeway, and two on arterial streets near southbound I-94 ramps. The exact placement of the CMS is presented in the paragraph addressing TIPS equipment placement.

***Evaluation method***.
A certain number of southbound drivers, especially those traveling to destinations near the city of Racine, Wisconsin[2] would have chosen to divert to alternative routes as a result of the I-94 construction, in anticipation of increased delays through the construction zone. It was expected that construction-induced diversion would have stabilized within the first few weeks of construction work. Evaluation phase one was scheduled to start after this initial driver adjustment period. One of the goals of the present evaluation was to estimate the number of any **additional** diverted trips due to providing drivers with the estimated travel time through the construction

[1] This effort was supervised by WisDOT crews.

[2] Racine, a city of approximately 86,000 population with a Primary Metropolitan Statistical Area of 175,034 is located approximately 18 miles south of Milwaukee, and 6 miles east of I-94.

zone during evaluation phase two. The number of additional diverted trips could be calculated by comparing traffic volumes during the two evaluation phases.

Given the short construction period, evaluators had to strike a balance between collecting adequate field travel time data, and allowing enough time for trip diversions due to construction activity to stabilize prior to collecting field data. It was desirable to provide adequate time for drivers to get used to construction phase one conditions and construction phase two conditions so the analysis would be based on stabilized traffic conditions. In addition, the traffic diversion part of the analysis required data collection both with TIPS travel time information present and absent. The above-described evaluation arrangement satisfied all driver adjustment period concerns: evaluation phase one started four weeks after the start of construction phase one and evaluation phase two started two weeks after the initiation of construction phase two. Travel time information was collected in the field ***both*** when ***no*** predicted travel time information was available to motorists, ***and*** when TIPS-based travel time information ***was*** provided to the drivers. Because TIPS hardware and software was operational during both evaluation phases, and "raw" calculated predicted travel times were collected in electronic files at each 30-second interval, system accuracy evaluation could be performed for both evaluation phases. In addition, an adequate number of travel time runs was available, since travel time run data was gathered during both evaluation phases. System accuracy evaluation using travel times displayed on CMS was based on data gathered during evaluation phase two, when CMS signs were placed in the field.

The original evaluation plan included performing travel time runs on the officially designated route to the west of I-94 (the 27$^{th}$ Street- West Frontage Road alignment). The data would be used to assess travel time threshold values that would induce more drivers to choose the alternate alignment when I-94 travel times became exceedingly long. However, use of this alternate route was minimal, and travel times on that route remained unchanged, even when I-94 was congested.

**TIPS Equipment Placement**

The evaluated system consisted of five microwave detectors, placed at various locations along the southbound travel direction, that relayed traffic information wirelessly to a computer (Picture C8) located in a construction trailer off of State Trunk Highway (STH) 20 in Racine County (Picture C9). The computer, in turn, communicated wirelessly with four trailer-mounted Changeable Message Signs (CMS) that displayed predicted travel times through the work zone. The changeable message sign trailer and microwave detector trailer located to the right of the right shoulder at the gore of exit 318 are depicted in Picture C10. This location is identified in Figure A1 (see "TIPS SIGN #1" label).

TIPS detectors were placed along I-94, at the following locations (Figures A1 and A2):

A. Milepoint 318.00 Exit 318 (General Mitchell Airport) in the exit gore area.
B. Milepoint 319.90 just south of the Rawson Avenue bridge, next to the right-hand shoulder (1.90 miles South of Detector A).
C. Milepoint 321.98 just south of Puetz Road, next to the right-hand shoulder, behind a guardrail (3.98 miles South of Detector A).
D. Milepoint 324.32 within the construction taper area, located behind the arrow board, on the left shoulder during construction phase 1, and on the right shoulder during

construction phase 2 (Picture C3) (6.32 miles South of Detector A).

E. Milepoint 328.30 at the Weigh Station off-ramp gore (10.3 miles South of Detector A, about 3 miles into the work zone). The exact location is identified in Figure A5.

A total of four CMS signs were placed in the field after the end of construction phase one. Their locations are identified in Figures A1 and A2:

Sign #1 at the exit gore of the General Mitchell Exit (Exit 318), facing Southbound I-94 traffic (Picture C10).

Sign #2 on the right shoulder of College Avenue, facing Westbound traffic, East of I-94 (Picture C11).

Sign #3 on the right shoulder 0.15-mile South of Puetz Road (Exit 321) and 0.85-mile North of Ryan Road (Exit 322), facing Southbound I-94 traffic (Picture C12).

Sign #4 on the right shoulder of Ryan Road, facing Eastbound traffic, just before the I-94 Southbound ramp (Picture C13).

## TRAVEL TIME DATA COLLECTION

### *Actual Travel Time Data*

Nineteen Marquette University students, were recruited to collect travel time data. All individuals were given a Powerpoint® presentation about the nature of the project, the particular tasks they were to perform for the data collection effort, their travel routes, the equipment and forms they were to use, and field work safety. Presentation materials can be found in Appendix D.

Travel time information was collected on I-94 between Layton Avenue on the north and County Trunk Highway KR on the south; data was also collected on the officially designated alternate route described above (the 27$^{th}$ Street – West Frontage Road alignment), between College Avenue and CTH KR. Two-member teams, a driver and a data recorder collected data recording materials from the Engineering Building at Marquette University, at their designated times on data collection dates, then drove to the north end of their assigned data collection route (either I-94 or the alternate route) and started collecting data while continuing their southbound travel, using a laptop computer running a special data collection spreadsheet.

Once teams reached the south end of their respective routes, they were to use CTH KR to turn around and start traveling in the opposite direction, until reaching the north end of their designated routes, to start a southbound run once again. All teams used I-94 for their northbound travel. Teams would continuously record for approximately four hours, during peak traffic conditions. Upon completion of their recording assignment, teams would return to Marquette University to hand-in the recording equipment. A list of data collection dates is presented in Table 1 below. The first team was timed to arrive at the start of the study corridor at approximately 2:45 pm, and the last team would leave the corridor at approximately 7:00 pm on Thursdays and Fridays. The first teams working on Sundays would start recording at 1:45 pm, and the last teams would finish recording at 6:30 pm. Fifteen minutes of travel to and from the north end of the study corridor were included on either end of the time periods mentioned above.

Each team was supplied with a laptop computer equipped with a voltage inverter that provided power for the laptop computer through the vehicle cigarette lighter adaptor. A specially written Quattro® Pro spreadsheet macro would automatically insert a time stamp any time the data

recorder hit the "Enter" key. The data recorder was supplied with a clipboard furnished with data collection forms and a pencil with eraser. Locations where time stamps were to be recorded (checkpoints) were listed on the spreadsheet, and a hard copy of these locations was also provided. Data recorders were also equipped with a map and a set of detailed notes where all checkpoints were identified. Two separate sets of maps and notes were available, one for data collection on I-94 and one for data collection on the alternate route (Appendix D); each team would be equipped with the appropriate set, depending on their assigned route for a given date. Instructions were provided to data recorders on how to connect the hardware, start the data recording program, correct mistakes, or skip over missed checkpoints (see Appendix 3). Data recorders were equipped with tape recorders and instructed to record conditions related to any delays they encountered; also any unusual traffic conditions. During evaluation phase two, data recorders were asked to use forms similar to the ones on pages D43-D44 and fill in (in pencil) the message displayed on TIPS CMS, as well as the time they recorded this information.

Table 1. Evaluation Dates and Number of Travel Time Runs (TTR)

| **Evaluation Phase One** | | | **Evaluation Phase Two** | | |
|---|---|---|---|---|---|
| **Date** | **Number of TTR** | | **Date** | **Number of TTR** | |
| | **Sign #1** | **Sign #3** | | **Sign #1** | **Sign #3** |
| Thursday June 14 | 6 | 7 | Thursday July 26 | 8 | 8 |
| Friday June 15 | 3 | 4 | Friday July 27 | 15 | 15 |
| Sunday June 17 | 13 | 13 | Sunday July 29 | 11 | 12 |
| Thursday June 21 | 13 | 13 | Thursday August 2 | 7 | 7 |
| Friday June 22 | 19 | 19 | Friday August 3 | 14 | 15 |
| Sunday June 24 | 9 | 9 | Sunday August 5 | 5 | 4 |
| Thursday June 28 | 12 | 11 | Thursday August 9 | 4 | 5 |
| Friday June 29 | 3 | 3 | Friday August 10 | 10 | 10 |
| Sunday July 1 | 12 | 11 | Sunday August 12 | 6 | 6 |
| Thursday July 5 | 8 | 8 | Thursday August 16 | 8 | 8 |
| Friday July 6 | 17 | 17 | Friday August 17 | 10 | 9 |
| Sunday July 8 | 16 | 15 | Sunday August 19 | 7 | 7 |
| Total Phase One | 131 | 130 | Total Phase Two | 105 | 106 |
| Total Sign #1 = 236<br>Total Sign #3 = 236 | | | | | |

The teams were instructed to use a (provided) stopwatch, pencils and forms if the laptop

equipment malfunctioned. All laptop clocks were synchronized to Standard Central Time before each data recording date. A digital camera was used by the PI to record conditions during some data recording dates. The camera's clock was also synchronized to Standard Central Time.

At the end of each data collection day, information was transferred from the laptop computers to a central database where individual spreadsheets were appended into the project database and readied for analysis using the Statistical Package for Social Sciences (SPSS) computer program. Data recorders' names were preserved with each dataset. Quality control checks were run each day in order to identify obvious problems, such as missing data or unreasonable speeds between checkpoints.

A project web site was used to communicate with project participants regarding their assigned dates and times. Details of all materials available to data recorders are presented in Appendix D.

***TIPS Travel Time Data***

TIPS specifications required that predicted travel times be presented in four-minute increments (for example, if the minimum travel time to be displayed by a given CMS was 16 minutes, this CMS would only display travel time values of 16, 20, 24, 28, etc. minutes). In addition, a particular travel time value would have to be displayed for a minimum of three minutes before it could be changed.

The TIPS system vendor provided two types of electronic files containing TIPS-produced travel time estimates, for the same days and hours for which field data was collected. "Type A" TIPS files contained 30-second "raw" travel time estimates. This information was further processed by TIPS to produce the travel time information intended for display at a particular CMS, and stored in "Type B" TIPS files. Information in "Type A" files represented an instantaneous travel time estimate; information in "Type B" TIPS files conformed with the specifications described in the previous paragraph. Motorists viewed (through CMS) travel time information contained in Type B files when communications between the TIPS computer and field CMS were functioning properly. Type B file and CMS information could be different when communications between the TIPS computer and CMS signs did not function properly (this situation occurred during one data collection date and is described in detail under travel time results).

Type A files were available for both evaluation phases; type B files were available for evaluation phase two only. Files were forwarded to evaluators, typically during the week following each field data collection effort.

As mentioned above, no CMS were deployed in the field during evaluation phase one; during evaluation phase two, travel time information was displayed to motorists through CMS.

Type A TIPS files conformed to one of three formats shown in Table 2, depending on the date on which data was collected. Between June 14 and July 6, 2001, three travel time predictions were provided, corresponding to the locations where CMS signs #1, #2 and #3 would be placed during evaluation phase two. Sets of three lines of data were provided for each 30-second interval. Numeric values following the colon indicated travel times rounded to the closest four-minute travel time increment.

Table 2. Type A TIPS file formats

**Format for June 14, 2001.**

```
=== At Thursday, June 14, 2001

=== At 15/00/12 ,
            TravelTime of 1th sign is : 24
            TravelTime of 2th sign is : 20
            TravelTime of 3th sign is : 20
```

**Format for June 15 through July 6, 2001.**

```
=== At Sunday, June 17, 2001 11:27:03 ,   Starting =================

=== At 11/27/15 ,
            TravelTime of 1th sign is : 24 (  22.50)
            TravelTime of 2th sign is : 20 (  20.27)
            TravelTime of 3th sign is : 20 (  18.20)
```

**Format for July 8 through August 19, 2001.**

```
=== At Thursday, August 09, 2001 15:07:29 ,   Starting =================

=== At 15/07/39 ,
            TravelTime of 1th sign is : 24 (  23.04)
            TravelTime of 2th sign is : 24 (  23.04)
            TravelTime of 3th sign is : 20 (  18.48)
            TravelTime of 4th sign is : 20 (  18.48)
```

Starting with June 15 data, additional travel time information was provided (value within parentheses). Parenthesized values represented the exact travel times predicted by TIPS ("TIPS Time" in what follows). [These values, rounded to the closest 4-minute value are the ones reported immediately after the colon in each data line].

Starting with July 8, 2001, type A TIPS files contained travel time information corresponding to where CMS #4 would be placed.

Type B files conformed to the format shown in Table 3. The capital letter at the beginning of each line corresponds to a particular pre-programmed CMS message; a listing of the preprogrammed CMS messages for the evaluated corridor is shown in Table 4. Each data line in Table 3 provided information about the message intended to be displayed at each CMS (the location of each CMS is listed above, under the TIPS equipment placement section of the report).

Each record informing that a message was sent to a CMS at a given time/date is followed by a record confirming that the message was received by the CMS and the time/date this communication occurred. For example, the first two lines of Table 3 indicate that message "H" (28 MIN TO END OF WORKZONE) was sent to sign #3 (for sign location see Figure A2 on page A2) at 13:45 on July 29, 2001; this communication was confirmed by sign #3 at 13:45 on

Table 3. Type B TIPS file format

```
H is sent to sign 3 13:45 07/29/2001
H is confirmed by sign 3 13:45 07/29/2001.
I is sent to sign 3 13:50 07/29/2001
I is confirmed by sign 3 13:50 07/29/2001.
H is sent to sign 3 13:54 07/29/2001
H is confirmed by sign 3 13:54 07/29/2001.
I is sent to sign 1 13:54 07/29/2001
I is confirmed by sign 1 13:54 07/29/2001.
I is sent to sign 2 13:54 07/29/2001
I is confirmed by sign 2 13:54 07/29/2001.
H is sent to sign 4 13:58 07/29/2001
H is confirmed by sign 4 13:58 07/29/2001.
J is sent to sign 1 14:08 07/29/2001
J is confirmed by sign 1 14:08 07/29/2001.
```

Table 4. Type B file codes

| | | |
|---|---|---|
| A | - | Blank Message Board |
| B | - | ACCIDENT AHEAD |
| C | - | WORK ZONE AHEAD |
| D | - | LONG DELAY AHEAD |
| E | - | 16 MIN TO END OF WORKZONE |
| F | - | 20 MIN TO END OF WORKZONE |
| G | - | 24 MIN TO END OF WORKZONE |
| H | - | 28 MIN TO END OF WORKZONE |
| I | - | 32 MIN TO END OF WORKZONE . |
| J | - | 36 MIN TO END OF WORKZONE |
| K | - | 40 MIN TO END OF WORKZONE |
| L | - | 44 MIN TO END OF WORKZONE |
| M | - | 48 MIN TO END OF WORKZONE |
| N | - | 52 MINTO END OF WORKZONE |
| O | - | 56MIN TO END OF WORKZONE |
| P | - | 60 MINTO END OF WORKZONE |
| Q | - | 64 MIN TO END OF WORKZONE |
| R | - | 68 MIN TO END OF WORKZONE |
| S | - | 72 MIN TO END OF WORKZONE |
| T | - | 76 MIN TO END OF WORKZONE |
| U | - | FREEWAY CLOSED 7 MI ROAD |
| V | - | FREEWAY CLOSED AT HWY G |
| W | - | FREEWAY CLOSED AT HWY K |
| X | - | FREEWAY CLOSED AT HWY C |
| Y | - | FREEWAY CLOSED AT HWY 11 |
| Z | - | FREEWAY CLOSED AT KR |

the same date. Type B files were provided for all **evaluation phase two** dates for the hours during which travel time data collection took place. No such information was available for evaluation phase one.

## TRAVEL TIME DATA ANALYSIS

Field travel time data was collected mostly for the two CMS signs located on I-94 (sign #1 and sign #3). Very limited data was collected for CMS #2. Travel time collected in the field ("Actual" travel time data in what follows) was merged with TIPS file information, in order to create a file whose records contained: i) the time a team passed the location of a CMS; ii) TIPS data; and, iii) the date the data was collected. All travel times were recorded in hour:minute:second format. A total of 236 such travel time records were available for CMS #1, and an equal number for CMS #3.

The system vendor requested that two days be excluded from the evaluation, because of incidents that had an important effect on travel times during those days. Sunday, June 17 was excluded because of a semi-truck incident. Actual travel times were 62, 51, 44, 39 and 34 minutes respectively during the first five runs on that day. June 21 was excluded because of an incident that occurred close to the end of the travel time run data collection effort. Actual travel times ranged from 26 to 38 minutes during that incident.

Although the system is capable of producing travel time estimates, and can communicate with CMS in the field, at least every 30 seconds, it would not be practical to display travel time predictions that change very frequently, because drivers approaching a CMS could become confused about which information to consider valid, and/or may doubt whether system information is valid at all.

In order to avoid the problem of continuously changing displayed travel times, TIPS travel time information is presented in multiples of four-minute increments (a CMS can display travel times of 16, 20, 24 etc. minutes, but would not display a travel time of 21 minutes, for example). In addition, a given travel time value must be displayed for three minutes before it can be changed. Thus, travel time information updates were not too frequent and drivers approaching a TIPS CMS were not likely to see the displayed travel time change many times. These requirements were established and were already incorporated in the TIPS algorithm before the system was installed in Wisconsin.

The thrust of the present evaluation is centered around a previously established criterion: it was desired to consider the frequency with which TIPS travel time predictions were within +/- 4 minutes of Actual travel times. It should be kept in mind that this criterion was not based on typical statistical procedures, but was derived based on engineering judgment.

Two observations stem from this discussion: i) there is an inherent error that was intentionally included (for practical reasons) in displayed travel times; and, ii) a statistically-derived 95 percent confidence interval for how well predicted travel time matches Actual travel time is not the appropriate method to test system performance against the stated criterion.

Assessment of the ability of the evaluated system to provide travel time estimates within four minutes of Actual travel times is provided in the present report by: i) visual presentations of Actual and predicted travel times for each evaluated day; and, ii) by histograms and tabulated differences between Actual and TIPS travel times.

The analysis also uses traditional statistical methods to investigate the relationship between Actual and TIPS travel times, and evaluate the accuracy of TIPS predictions: i) a paired T-Test comparison is performed between Actual and TIPS times to assess the difference between each Actual and the corresponding TIPS time; ii) a table is provided, presenting differences between Actual and TIPS travel times for each displayed TIPS time, in order to assess whether the magnitude of the differences varies across TIPS times; iii) box-and-whiskers plots are used to present the distribution of Actual versus TIPS time; iv) a scattergram of Actual versus TIPS times is used to visually demonstrate the scatter of Actual time for each value of TIPS time; and, finally, iv) two regression models using TIPS time to predict Actual time are calibrated in order to evaluate TIPS predictive ability by statistical means.

It was desired to assess the impact that the imposed restrictions on displayed travel times had on TIPS travel time prediction accuracy. For this reason, two separate comparisons with Actual travel times were undertaken. Actual travel times were compared to: a) TIPS-generated "raw" travel time estimates (30-second data); and, b) travel time information displayed on TIPS signs, recorded during travel time runs. The evaluation based on "raw" travel time estimates provides the opportunity to assess the impact of policies imposed on CMS messages (for example the 4-minute time step and the requirement that displays remain unchanged for at least three minutes). The second evaluation, based on CMS information viewable by drivers, is of use to the practitioner, who is interested in the reliability of information displayed to drivers approaching the work zone.

## TRAVEL TIME RESULTS-RAW DATA

Raw travel time predictions (information from Type A TIPS files) was compared to Actual travel times measured in the field. The results are presented below.

### *Compliance with +/- 4 Minute Criterion*

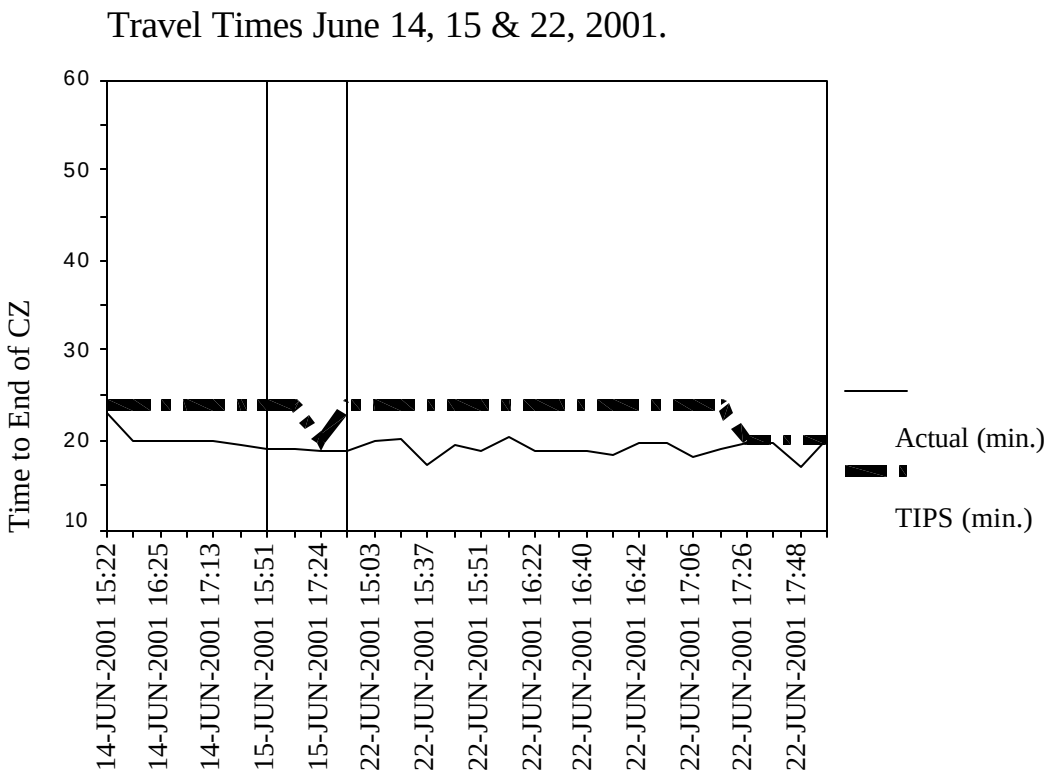
Figure 1 presents Actual (continuous line) and TIPS travel time data (broken line) for June 14, 15, and 22 for CMS #1. It should be noted that the data represent measurements at discrete time instances–lines are provided for easier visualization. Time intervals between observations are not of equal duration-they represent intervals between the times that teams passed a TIPS sign. Vertical lines are placed within the Graph to separate data collection days. Each line corresponds to the first observation of the day. Complete series of similar Graphs for CMS #1 and CMS #3 are presented in Figures B1 and B2 pp. B-1 through B-8 in Appendix B.

Travel times were typically higher on Sundays (June 24, July 8 and 29, August 5, 12 and 19), and remained near minimum levels during Thursdays and Fridays, with minor exceptions.

In general, TIPS data match Actual data patterns well. An especially good match is evident for June 24 when higher travel times were present, and June 28 and 29 for CMS #3 only, when travel times were at minimal levels. The July 5 data indicate that, although TIPS data matched

Actual travel time data patterns, travel times were consistently overpredicted. Underpredictions occurred in some instances of higher Actual travel times, for example, on July 1 and July 29 (CMS displays malfunctioned on the latter date, but electronic data were available). There are some instances under non-congested conditions, when TIPS overpredicted (for example, June 14, 15, 22, August 9 and 10), but differences between Actual and TIPS travel times are very close to the four-minute permissible range.

Figure 1. Actual and TIPS Travel Times




The last Graphs for each CMS in Figures B1 and B2 present information about the two days that were excluded from further analysis due to serious incidents. June 17 (Sunday) Actual data indicate travel times up to 65 minutes for CMS #1 and 62 minutes for CMS #3. TIPS travel times appear to eventually follow Actual data on that day. TIPS followed Actual travel times very well during the June 21 incident, toward the end of the field data collection effort, when delays were not as severe as in the previous instance.

Figures 2 and 3 present histograms of Actual minus TIPS travel times, in minutes, for CMS #1 and #3, respectively. The same information is presented in tabular form in Tables B1 and B2 in Appendix B pp. B-9 and B-10. Time intervals in Figures 2 and 3 and Tables B1 and B2 are defined in the following manner: differences greater than three and less than, or equal to four

Figure 2. Actual Minus TIPS Travel Time CMS #1

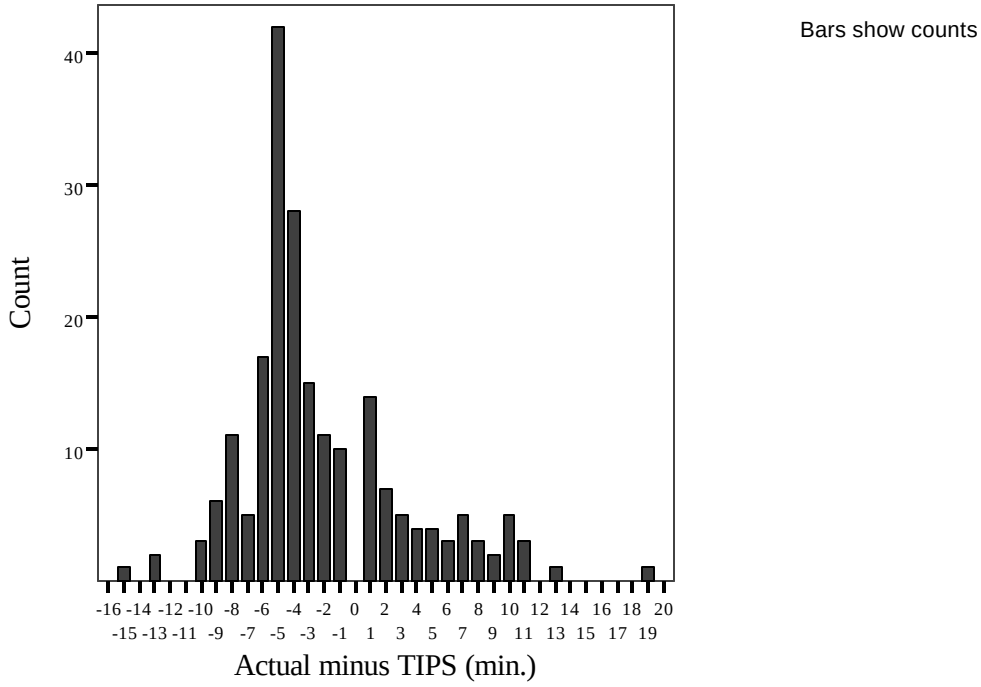
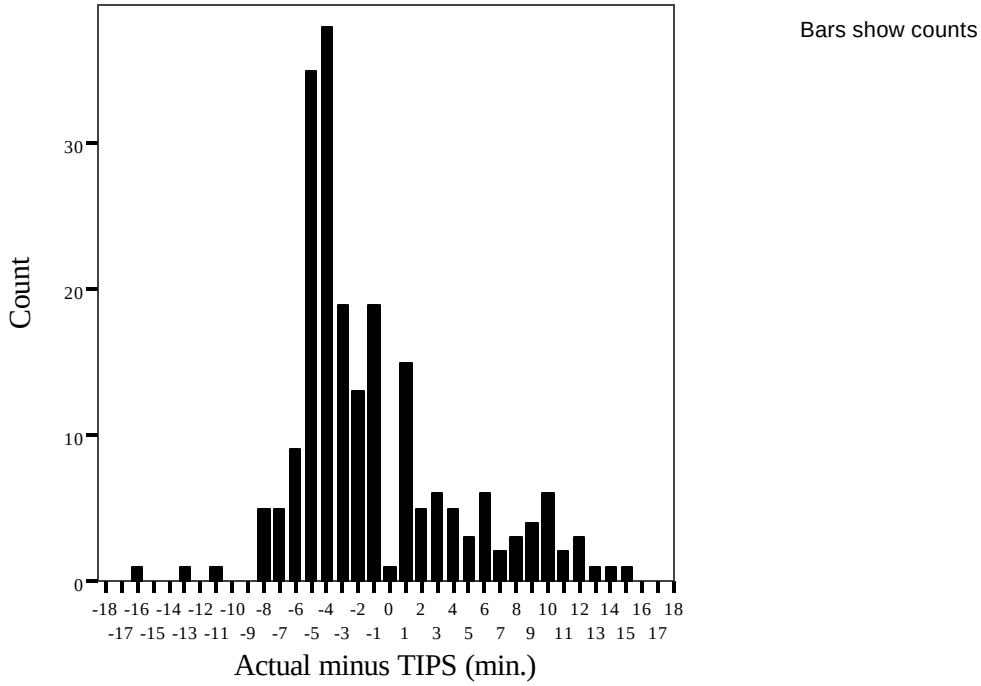



Figure 3. Actual Minus TIPS Travel Time CMS #3



minutes are coded into category "4"; differences of less than minus three minutes and greater than, or equal to minus four minutes are coded into category "- 4." All other categories are coded similarly, except for the value zero, which represents differences of exactly zero minutes (zero is not included in either of the intervals "1" or "- 1"). This type of coding was necessary in order to establish the number of observations within +/- 4 minutes, and other similarly defined ranges.

The percentage of TIPS predictions within +/- 4 minutes was 45.2% for CMS #1 and 57.7% for CMS #3. Predictions exceeding Actual travel times by more than four minutes constituted 41.8% and 27.1% of the observations for CMS #1 and CMS #3 respectively, and those lower than Actual travel times by more than four minutes were 13.0% and 15.2% of the observations, respectively. (67.3% and 75.8% of the differences were within +/- 5 minutes, respectively.)

***Statistical Comparisons***

A paired-samples T-Test comparison, performed for the difference of Actual - TIPS travel time, is summarized below. The **average** difference was -2.1 minutes for CMS #1 and -1.0 minutes for CMS #3. These differences were statistically significantly different from zero at the 0.05 level of significance. Overall, differences between Actual and TIPS travel times were small for all practical purposes and enough observations were available to result in narrow confidence intervals.

CMS #1: Actual – TIPS = 25.6 – 27.7 = - 2.1 minutes, 95% C.I. –2.8 to –1.4 minutes (n = 209)
CMS #3: Actual – TIPS = 21.9 – 22.9 = - 1.0 minutes, 95% C.I. –1.7 to –0.4 minutes (n = 209)

An examination of whether Actual minus TIPS travel time differences vary with increasing TIPS travel time was undertaken next. Because of the importance of this issue to the present evaluation, information is presented in a variety of tables and figures in order to provide a comprehensive coverage. Although some information is common among figures and tables in order to provide a common basis for comparisons, a different type of information is presented with each new figure or table.

Tables B3 and B4 pp. B11 and B12, provide information similar to Tables B1 and B2 for **each** TIPS travel time value. The tables provide the opportunity to evaluate system performance based on criteria other than the stated +/- 4 minute interval, for example, a criterion requiring TIPS travel times to be within a fixed percentage of Actual travel times. If, for example, TIPS predictions were required to be within 30% of Actual travel times, the data indicates that 88% of the predictions would have satisfied the criterion.

Figure 4 graphically presents the relationship between TIPS and the corresponding Actual travel times for CMS #3, through box-and-whiskers graphics. The thick horizontal line within each box represents the median[3] Actual travel time that corresponds to a given TIPS travel time. The upper edge of each box is the 75$^{th}$ percentile value (75% of Actual travel times are below this value), and the lower edge of each box is the 25$^{th}$ percentile value. Thus, the box contains 50%

[3] Median value: the number of observations exceeding this value is equal to the number of observations below that value. Thus, the median is the 50$^{th}$ percentile of Actual travel times.

of the Actual travel time data. The whiskers define the minimum and the maximum Actual travel time values. Any values that are between 1.5 and 3.0 box lengths from the upper or lower edge of the box are defined as "outliers" and are represented by empty circles. Values in excess of 3.0 box lengths from the same box edges are defined as "extreme" values, and are represented by asterisks. In summary, box plots provide five distribution points: minimum value, the 25$^{th}$, 50$^{th}$ and 75$^{th}$ percentile values, and the maximum value. In addition, information is provided on outlier and extreme values. This information can be used to judge whether the distribution is symmetric (median in the middle of the box, whiskers of equal lengths for a symmetric distribution) and whether the distribution is spread-out or centered around the median.

Figure 4. Boxplot TIPS and Actual Travel Times CMS #3

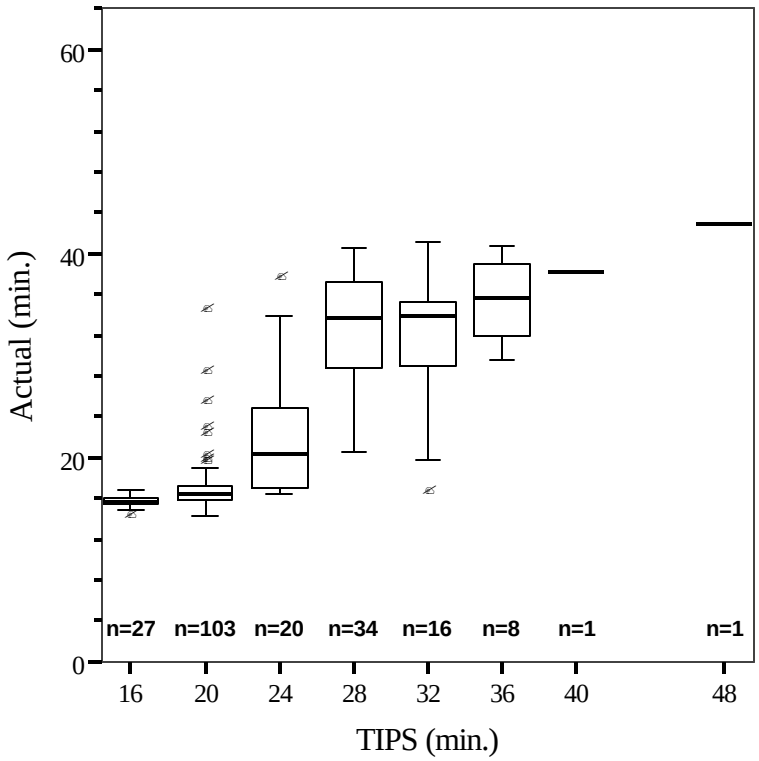


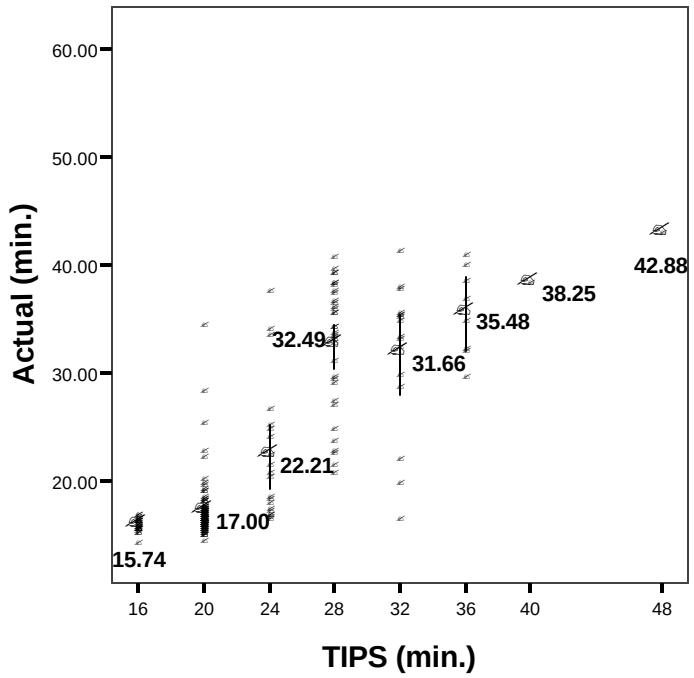

Figure 4 indicates that Actual travel times were within the required four-minute interval when TIPS indicated a travel time of 16 minutes. The same was true when TIPS indicated a travel time of 20 minutes, for most observations. However, the median value was approximately 17 minutes in that case, and most Actual travel times were below 20 minutes, the TIPS travel time. Three (out of 103) Actual travel times exceed the upper limit of 24 minutes. (They are shown as extreme values, because the "box" containing 50% of the observations around the mean has a very narrow range. What is important for this category is not that these three are shown as "extreme" values, but, rather, that the majority of Actual times is consistently below the TIPS time.) It is helpful to consult Table B4 here. It shows a heavy concentration of Actual times four and five minutes below TIPS times.

For TIPS indications of 24 minutes, approximately 50% of Actual travel times were below the lower limit of 20 minutes (24 - 4 minutes) and some observations were above the upper limit of 28 (24 + 4) minutes. For TIPS indications of 28 minutes, more than 50% of Actual travel times were above the upper limit of 32 minutes, and some observations were below the lower limit of 24 minutes.

More than 50% of Actual travel times were within the four-minute for TIPS indications of 32 minutes, and the same was true for TIPS indications of 36 minutes, however the number of observations in each of these two groups was small ( 16 and 8 observations respectively). Only one observation was available for each of TIPS indications of 40 and 48 minutes. Actual travel times were 38 and 43 minutes respectively. Box-and-whisker diagrams for both evaluated CMS are included in Appendix B (Figures B3 and B4).

Figure 5 is a scatter plot of Actual travel times in relation to TIPS travel times for CMS #3. (Note that the number of cases within each TIPS travel time category can be read off of Figure 4). Average Actual travel times were provided for each value of TIPS travel time. Most average Actual travel times were very close to the respective TIPS travel times: 0.3 minutes for TIPS time of 16 minutes, 3.0, 1.8, 4.5, 0.3 and 0.5 minutes for TIPS times of 20, 24, 28, 32 and 36 minutes, respectively. However, the scatter of Actual travel times is quite broad within each TIPS travel time category. (Darker areas of the scatter plot indicate higher concentrations of observations and correspond to the box-and-whiskers information in Figure 4). Information for both evaluated CMS is presented in Appendix B, in Figures B5 and B6. Data for CMS #1 were very similar: the differences ranged between 0.3 to 4.5 minutes as well and there was a rather wide scatter of observations around the means.

Figure 5. Scatter Plot of Actual Versus TIPS Travel Times for CMS #3



A linear regression model was postulated, using TIPS predictions for CMS #3 to estimate Actual travel time. The model is presented graphically in Figure B8, page B18; supporting statistics are presented at the bottom of the same page. The R-square value was 0.681. Both the coefficient of the independent variable (TIPS time) and the constant are statistically significantly different from zero at the 0.05 level of significance. Similar findings apply to the model calibrated for CMS #1. The calibrated regression model for CMS #3 is shown in Equation (1) below.

*Actual Travel Time* = -5.920 + 1.213 (*TIPS time*) Equation (1)

The calibrated regression equation for CMS #1 is given in Equation (2). The $R^2$ value for that model was 0.643.

*Actual Travel Time* = -8.555 + 1.233(*TIPS time*) Equation (2)

Ideally, for a perfect Actual travel time prediction, the constant term would be zero, the independent variable coefficient would be equal to one, and the standard error of the mean would be zero. Standard errors for both regression lines were very large compared to the desired criterion of +/- four minutes (5.1 and 4.7 minutes for CMS #3 and #1 respectively) and are due to the wide scatter of data points around the respective regression lines. The 95% confidence intervals for Actual travel times, located approximately two standard errors from on either side of the regression line are indicated on the respective figures.

## TRAVEL TIME RESULTS-CMS DATA

### *Compliance with +/- 4 Minute Criterion*

Travel time information displayed on TIPS Changeable Message Signs (CMS) was compared to Actual travel times measured in the field. The results are presented below. The order of presentation is the same as in the previous section. For detailed statistics interpretations, the reader is referred to the previous section. The term "SIGN" is used in the following text and in Appendix B figures and tables to represent travel time information recorded by data recording teams from CMS operating in the field. It should be kept in mind that only data for evaluation phase two was available for this analysis. The number of data points indicated in Appendix B are lower than those available for the previous analysis because: i) some CMS indications did not include travel times (for example an indication "WORK ZONE AHEAD" would not be included in travel time statistics); and, ii) some field-collected CMS information was incomplete and could not be matched to Actual travel time information.

Figures B9 and B10 pp. B19- B26 indicate that, during Thursdays and Fridays, when travel times were at or near minimum levels, TIPS CMS indicated higher than Actual travel times. This discrepancy was within the +/- 4-minute allowable accuracy most of the time for CMS #1 and CMS #3. One instance of much larger overpredictions occurred on Friday, August 17, for both CMS.

Travel time predictions during the typically more congested evaluation phase two Sundays (July 29, and August 5, 12 and 19) were mostly lower than Actual travel times. No definitive conclusions can be drawn for these dates, given the very limited number of data points available for analysis, and the special situation that occurred on July 29, described below.

The following times when no travel time information was provided on the CMS were noted:

On Thursday, July 26, 2001, CMS #3 was recorded to be blank during three travel time runs, at 14:54, 15:10, and 16:00. The message "WORK ZONE AHEAD" was reported at 15:45. CMS #1 did display travel time information during the same travel time runs.

On Sunday, July 29, 2001, CMS #1 was unintelligible during all travel time runs that occurred between 14:02 and 16:29. During the same day, CMS #3 displayed a travel time of 20 minutes throughout the data collection period (see Figure B10, page B23). Because of these problems at CMS #1 and #3, data for this date was excluded from all statistical tabulations and figures following Figure B10.[4]

Travel time runs during which data collection teams did not record both the time they went by a CMS and the travel time displayed at a CMS are noted under each graph in Figures B9 and B10. Actual travel times are shown, but no SIGN travel time is reported for these instances.

Figures B11 and B12 on pages B27 and B28, respectively, present histograms of Actual minus SIGN travel times, in minutes, for CMS #1 and #3, respectively. The same information is presented in tabular form in Tables B5 and B6.

The percentage of TIPS predictions within +/- 4 minutes was 46.4% for CMS #1 and 65.5% for CMS #3. Predictions exceeding Actual travel times by more than four minutes constituted 41.7% and 23.0% of the observations for CMS #1 and CMS #3 respectively, and those lower than Actual travel times by more than four minutes were 11.9% and 11.5% of the observations, respectively. (63.1% and 76.9% of the differences were within +/- 5 minutes, respectively.)

***Statistical Comparisons***

A paired-samples T-Test comparison, performed for the difference of Actual - SIGN travel time, is summarized below. The **average** difference was -3.1 minutes for CMS #1 and -2.1 minutes for CMS #3. These differences were statistically significantly different from zero at the 0.05 level of significance. Overall, differences between Actual and SIGN travel times were small for all practical purposes and enough observations were available to result in narrow confidence intervals.

CMS #1: Actual – SIGN = 24.9 – 28.0 = -3.1 minutes, 95% C.I. -4.4 to -1.9 minutes (n = 86)
CMS #3: Actual – SIGN = 21.0 – 23.2= -2.1 minutes, 95% C.I. -3.2 to -1.1 minutes (n = 88)

An examination of whether Actual minus TIPS travel time differences vary with increasing SIGN travel time was undertaken next.

Tables B7 and B8 pp. B31 and B32, provide the measured differences between Actual and SIGN times for **each** SIGN travel time value. The tables indicate that 85% and 86% of displayed SIGN

[4] The TIPS Type B file for this day indicates that the system produced travel time predictions, but these predictions were not conveyed to the CMS in the field. Records indicating that various travel times were sent to individual CMS and records indicating that these messages were confirmed by the respective CMS were present in the file.

travel times were within 30% of Actual travel times for CMS #1 and #3, respectively.

Figures B13 and B14 graphically present the relationship between SIGN and the corresponding Actual travel times for CMS #1 and #3 respectively, through box-and-whiskers graphs.[5] For smaller SIGN values, the distribution of Actual travel times is compact, with few outliers, but most values are lower than CMS-displayed travel times. Two trends are evident as SIGN values increase: the scatter of Actual travel times increases, and the number of observations (for congested conditions) decreases. No useful conclusions can be based on the two-to-six observations present for most SIGN values greater than or equal to 32 minutes.

Figures B15 and B16 are scatter plots of Actual travel times in relation to SIGN travel times for CMS #1 and #3, respectively. (Note that the number of cases within each TIPS travel time category can be read off of Figures B13 and B14). Average Actual travel times are provided for each value of SIGN travel time. Average Actual travel time values have small differences from the respective SIGN travel times: the differences range between zero and five minutes for the majority of SIGN values for both CMS #1 and CMS #3. However, the scatter of Actual travel times is quite broad within each SIGN travel time category and some notably larger differences exist for each CMS.

Linear regression models were postulated, using SIGN as the independent variable to predict Actual travel times for CMS #1 and CMS #3. The constant terms were not statistically significantly different than zero at the 0.05 level of significance. The models are presented graphically in Figures B17 and B18; supporting statistics are presented at the bottom of the respective pages. The calibrated regression models for CMS #1 and #3 are shown in Equations (3) and (4) below.

$$\textit{Actual Travel Time} = -5.076 + 1.070\ (\textit{SIGN time}) \qquad \text{Equation (3)}$$

$$\textit{Actual Travel Time} = -3.689 + 1.067\ (\textit{SIGN time}) \qquad \text{Equation (4)}$$

The standard errors of the means are relatively large, compared to the stated criterion of +/- four minutes (5.89 and 4.83 minutes for CMS #1 and #3 respectively). It is expected that Actual travel times will be contained within two standard errors of the mean from the regression line approximately 95.5% of the time (these boundaries are indicated approximately by the lines on either side of the regression lines in Figures B17 and B18).

Conclusions follow the diversion and safety analyses and discussions.

**SAFETY ANALYSIS**

Construction zone crash data was obtained from WisDOT. It was desired to compare crash experience between the period before TIPS deployment and the period after TIPS CMS were operational in the field. However, because traffic volumes peaked in August (after CMS were deployed in the field) it was also desirable to provide some type of traffic volume control for any

[5] For detailed explanations about how to interpret box-and-whisker graphs, refer to the previous section.

safety comparisons. Traffic volume control was provided by comparing Southbound to Northbound crash experience: Daily directional traffic was almost evenly split—see Appendix A p. A7-(thus traffic volume increases through both crash analysis periods would influence crash experience in the two directions of traffic identically), and symmetric construction zones were present in the two directions of traffic (construction zone layout for Northbound traffic was a mirror image of the one described for Southbound traffic earlier in this report; construction zone layout changes occurred nearly simultaneously with their Southbound counterparts).

Two periods of equal lengths were analyzed: May 7 through (and including) July 15, 2001 (the "Before" period) and July 16, through September 23, 2001 (the "After" period). These periods overlapped with construction period one and construction period two and have equal durations (69 days each). The periods start on a Monday and end on a Sunday (they contain equal numbers of each day of the week). Although travel time collection ended on Sunday, August 19, TIPS CMS were operational throughout the evaluated safety analysis after period.

Table 5 presents a summary of crash frequencies for each direction of travel during the before and the after safety analysis periods. A noticeable increase in Northbound crashes can be seen in the after period, however, the chi-square statistic for Table 5, indicates that this is not statistically significant for a one-sided test.

## SAFETY RESULTS

Table 5. Construction Zone Crashes May 5-July 15 and July 16-Sept. 23, 2001

| | Before | After | Total |
|---|---|---|---|
| Northbound | 39 | 55 | 94 |
| Southbound | 31 | 34 | 65 |
| Total | 70 | 89 | 159 |
| Fisher's exact one-sided significance p = 0.270 (two-sided significance 0.516) | | | |

Crash analyses for the influence of light (day, night) and road conditions (dry, wet) did not indicate any statistically significant differences. It was interesting that crash severity was statistically significantly different between the two directions of travel, however results should be viewed with caution, given the very small numbers of analyzed crashes. Table 6 provides a summary of findings for injury crashes (property damage only crashes can be found by subtracting injury crashes from Table 5 cells—they did not differ significantly between the two directions of travel). One fatal crash occurred in the Northbound direction in the after period. Table 6 indicates that the comparatively high number of Northbound injury crashes in the after period was statistically significantly different at the 0.05 level of significance. The reasons for this occurrence are not evident from the analyzed information. The data is not sufficient to support any definitive conclusions at this point. TIPS CMS operation did not appear to impact Southbound safety performance, but when compared with Northbound the data is not inconsistent with TIPS providing the potential to improve safety at the work zone.

Table 6. Construction Zone Injury Crashes May 5-July 15 and July 16-Sept. 23, 2001

| | Before | After | Total |
|---|---|---|---|
| Northbound | 9 | 22 | 31 |
| Southbound | 9 | 6 | 15 |
| Total | 18 | 28 | 46 |
| Fisher's exact one-sided significance p = 0.046 (two-sided significance 0.058) | | | |

Given the short analysis periods, and the inherent instability of traffic conditions within construction zones, findings should not be viewed as conclusive. It would be desirable to compile similar statistics from a large number of construction sites where the system is deployed, before definitive conclusions can be stated.

## DIVERSION ANALYSIS OF VOLUME DATA

### Objective of Diversion Analysis

TIPS provides travel time estimates upstream of the work zone so drivers can choose alternative routes. Presumably drivers would divert in greater numbers when they have information that their current route will take a long time.

A major benefit of TIPS would be a reduction in volume through the work zone, resulting in less congestion and delay for vehicles remaining on the mainline freeway, while allowing many other drivers to reach their destinations faster on alternative routes. In this manner, the capacity of the whole traffic system could be better used.

TIPS was configured to help drivers in their diversion decisions. Portable changeable message signs were placed upstream of the College and Ryan off-ramps to allow informed decisions about leaving the freeway. Similar message signs were also placed on College and Ryan, upstream of the southbound on-ramps, to allow informed decisions about entering the freeway. Exact sign placement is addressed above in the "TIPS Equipment Placement" section.

Measuring diversion is difficult because of the large variety of destinations for drivers approaching the work zone and the large number of possible routes to reach those destinations. Traffic volumes, the principal means of measuring diversion, can only be monitored on some of the possible diversion routes.

Many drivers will choose not to divert even when it is to their advantage to do so. Some of these drivers do not possess enough local knowledge about alternative routes. Others are uncertain about the travel time by an alternative route. Still others are skeptical about the information provided or are optimistic that traffic will soon improve. TIPS did not provide any guidance as to what might happen if an alternative is chosen.

The work zone had one particularly attractive alternative route that should have been known to all regular drivers. There is a frontage road that runs the full length of the work zone on the freeway's west side, immediately adjacent to and clearly visible from the southbound travel lanes. The frontage road is a two-lane road with a rural cross-section over most of its length. Traffic speeds are close to 55 mph between most of the intersections, usually spaced about 1

mile apart. There are a few places where the frontage road jogs, perhaps giving the impression that it is discontinuous. Recurring congestion occurred along a short segment of the frontage road on Sunday afternoons due to a special event. Except for times and places with incidents, traffic was otherwise light on this road throughout the test periods.

Other alternative routes involve destinations north of the southern end of the work zones. One such destination is the city of Racine that is reachable by the freeway and by Howell (same as STH 38), which can be accessed from the Ryan, College, and Rawson interchanges.

**Location of Detectors and Tubes**

Volume counts were obtained by either the TIPS detectors on the freeway mainline or by tube counters along surface arterials and at one on-ramp. Loop detectors already present on the freeway mainline could not be used because a substantial amount of traffic used the shoulder, with no detectors, as a temporary travel lane; and the lane distribution was highly uneven. The same counting devices were used in both the before and after periods.

TIPS detectors were located on I-94 at:

A. North of Airport (ahead of work zone)
B. 1.9 miles from Airport detector, south of College (ahead of work zone)
C. 4.0 miles from Airport detector, north of Ryan (ahead of work zone)
D. 6.3 miles from Airport detector, just north of county line and work zone
E. 10.3 miles from Airport detector, about 3 miles into work zone

Tube counters measuring southbound traffic only were located at:

F. West Frontage Rd. just south of County Line
G. 27th St on ramp to I-94 County Line (I-94 Ramp)
H. County V (13th St) just south of County Line
I. 27th Street just south of College
J. 27th Street just south of Ryan
K. Howell just north of County Line
L. Howell just south of Ryan
M. Howell just south of College

Howell in Milwaukee County becomes STH 38 in Racine County and 27$^{th}$ Street in Milwaukee County becomes the West Frontage Rd. in Racine County.

The tube counters produced counts at 15-minute intervals, so the TIPS data were aggregated to 15-minute intervals for consistency.

The Sunday special event mentioned earlier occurred each week and was located 3 miles into the work zone. Thus, the special event should not have a significant bearing on the results of the diversion analysis.

Count data for weekdays were from 3 pm to 7 pm. Count data for Sundays were from 2 pm to 6:45 pm.

## DIVERSION RESULTS

***Cutlines.***

Volumes were organized into three cutlines for analysis.

I (College): B, I, M
II (Ryan): D, J, L
III (County Line): D, F, G, H, K
Not Used: A, C, E

A map of the cutlines is shown in Figure 6. Two of the cutlines, College and Ryan, are ahead of the work zone by about 6 and 2 miles, respectively. The County Line cutline appears to pass just outside of the work zone on its north end. Because of the inclusion of the 27th Street on-ramp in this cutline and the fact that there are no off-ramps between detector D and Seven Mile Rd. (approximately one mile into the work zone), the cutline is effectively south of the county line and within the work zone.

***Distribution Across Cutlines.***

Volume data were available for 4 Thursdays, Fridays and Sundays during the before period and for 4 Thursdays and Fridays and 3 Sundays in the after period. Thursdays and Fridays were analyzed together as "weekday" with Sunday kept separate. Average volumes are summarized in Table 7 for weekdays and percentages of each cutline at a given detector is summarized in Table 8 for weekdays. Sunday data are presented in Tables 9 and 10.

Table 7. Average Weekday 15-Minute Counts

| | Cutline | | | | | |
|---|---|---|---|---|---|---|
| | I College | | II Ryan | | III County Line | |
| | Before | After | Before | After | Before | After |
| I-94 | 717 | 720 | 665 | 612 | 665 | 612 |
| 27th Street or W Frontage Road | 381 | 370 | 112 | 157 | 22 | 26 |
| Howell | 267 | 269 | 249 | 281 | 155 | 182 |
| CTH V | | | | | 37 | 49 |
| On Ramp to I-94 @ 27th Street | | | | | 40 | 26 |
| Total | 1365 | 1359 | 1026 | 1050 | 919 | 895 |

Table 8. Weekday Splits Across Cutlines

| | Cutline | | | | | |
|---|---|---|---|---|---|---|
| | I College | | II Ryan | | III County Line | |
| | Before | After | Before | After | Before | After |
| I-94 | 52.5% | 53.0% | 64.8% | 58.3% | 72.4% | 68.4% |
| 27th Street or W Frontage Road | 27.9% | 27.2% | 10.9% | 15.0% | 2.3% | 2.9% |
| Howell | 19.6% | 19.8% | 24.3% | 26.8% | 16.8% | 20.3% |
| CTH V | | | | | 4.1% | 5.5% |
| On Ramp to I-94 @ 27th Street | | | | | 4.3% | 2.9% |
| I-94 + 27th Street on Ramp | | | | | 76.7% | 71.3% |

Table 9. Average Sunday 15-Minute Counts

| | Cutline | | | | | |
|---|---|---|---|---|---|---|
| | I College | | II Ryan | | III County Line | |
| | Before | After | Before | After | Before | After |
| I-94 | 789 | 783 | 740 | 693 | 740 | 693 |
| 27th Street or W Frontage Road | 328 | 321 | 113 | 149 | 39 | 64 |
| Howell | 141 | 146 | 192 | 210 | 124 | 151 |
| CTH V | | | | | 53 | 72 |
| On Ramp to I-94 @ 27th Street | | | | | 38 | 31 |
| Total | 1258 | 1250 | 1045 | 1052 | 994 | 1011 |

Table 10. Sunday Splits Across Cutlines

| | Cutline | | | | | |
|---|---|---|---|---|---|---|
| | I College | | II Ryan | | III County Line | |
| | Before | After | Before | After | Before | After |
| I-94 | 62.8% | 62.6% | 70.9% | 65.9% | 74.4% | 68.5% |
| 27th Street or W Frontage Road | 26.1% | 25.7% | 10.8% | 14.2% | 3.9% | 6.3% |
| Howell | 11.2% | 11.7% | 18.3% | 20.0% | 12.4% | 14.9% |
| CTH V | | | | | 5.3% | 7.1% |
| On Ramp to I-94 @ 27th Street | | | | | 3.9% | 3.1% |
| I-94 + 27th Street on Ramp | | | | | 78.3% | 71.6% |

Tables 7 and 8 indicate that the before and after volumes, overall, were very similar. Thus, it would be difficult to attribute any measured diversion to traffic conditions by themselves. Tables 8 and 10 show the diversion effects. It is seen that diversion did not occur as far upstream as the College cutline, which was just downstream from the first TIPS sign and the very next off-ramp beyond the TIPS sign. However, diversion was apparent at both the Ryan and County Line cutlines. Weekday and Sunday results were very consistent showing between 5.0 and 6.9 percent of all drivers in the corridor switching between I-94 and an alternative route. These percentages correspond to between 7.0 and 10.0 percent of I-94 drivers choosing an alternative route. All alternative routes (except the on-ramp) gained traffic. The on-ramp was monitored to determine whether drivers were skipping the queue by exiting at Ryan and re-entering once within the work zone. This behavior was not observed.

***Effect of Message on Volumes.***

It is also possible to relate the volumes to the messages displayed on the TIPS signs. All 15-minute intervals in the after period were categorized into whether the displayed travel time exceeded the median displayed travel time or whether the displayed time was less than the median. No distinction was necessary between the signs at College and the signs at Ryan, as their messages almost always differed by exactly 4 minutes. It can be hypothesized that diversion would be greater when the signs displayed a relatively high travel time.

As a control, it is also possible to similarly categorize all 15-minute intervals in the before period based on what the sign should have said, a "phantom message", if it had been operating.

Tables 11 and 12 summarize the cutline splits for I-94 only for these two sets of 15-minute intervals. Table 12, of course, is the more important of the two because it might demonstrate driver response to actual messages.

Table 11. I-94 Cutline Splits During the Before Period both Above and Below the Phantom Median Sign Message

| | Cutline | | | | | |
|---|---|---|---|---|---|---|
| | I College | | II Ryan | | III County Line | |
| | Below | Above | Below | Above | Below | Above |
| Weekdays | 51.6% | 53.4% | 64.1% | 65.6% | 71.7% | 73.2% |
| Sunday | 61.9% | 63.5% | 68.4% | 72.4% | 70.2% | 76.0% |

Table 12. I-94 Cutline Splits During the After Period both Above and Below the Actual Median Sign Message

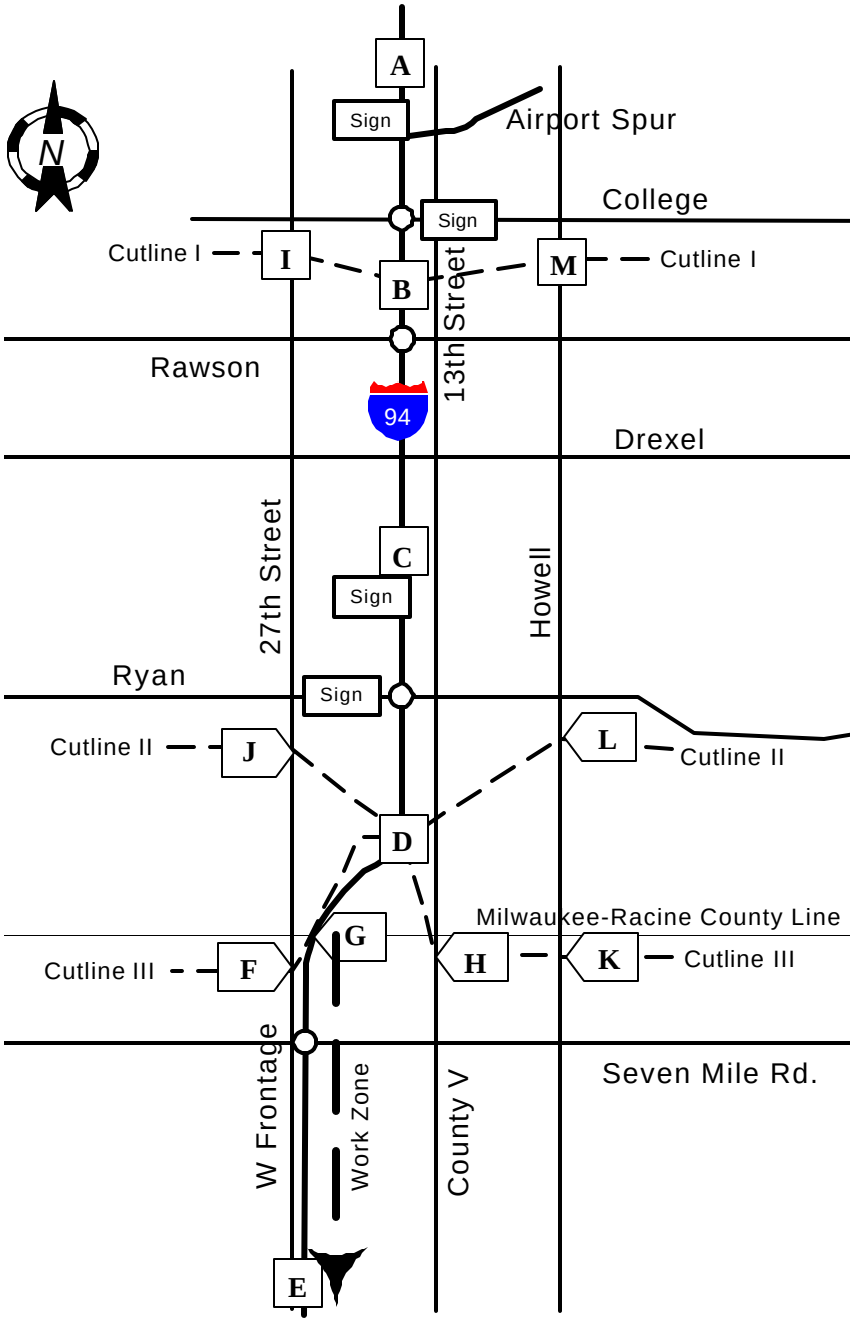
| | Cutline | | | | | |
|---|---|---|---|---|---|---|
| | I College | | II Ryan | | III County Line | |
| | Below | Above | Below | Above | Below | Above |
| Weekdays | 52.8% | 53.2% | 56.8% | 59.6% | 67.7% | 69.1% |
| Sunday | 62.5% | 62.8% | 66.1% | 66.0% | 69.0% | 68.1% |

Tables 11 and 12 show similar patterns. Generally, higher splits on I-94 were associated with those periods with messages containing larger travel times. The data do not convincingly support the hypothesis that larger travel time estimates are convincing drivers to divert. Instead the data seem to suggest that high traffic volumes cause TIPS to display long travel times – essentially what TIPS is designed to do.

A further look at the data, particularly on Sunday at the County Line cutline, shows an interesting effect that might be related to diversion decisions (shaded cells). In the before period, the "above" percentage is nearly 6% higher than the "below" percentage, as would be expected from the physical operation of TIPS. In the after period there is a slightly lower percentage in for the "above" intervals than the "below" intervals. A logical explanation to these percentages is that TIPS is somewhat mitigating the effects of the higher volumes by displaying large travel times and having drivers react.

It is not possible to compare Tables 11 and 12 to Tables 8 and 10, because time intervals falling exactly on the median sign reading were excluded from Tables 11 and 12.

Figure 6. Cutlines for Volume Counts



**DISCUSSION**

It is true that the demonstrated closeness of statistical averages between Actual and Predicted travel times is not sufficient to prove that the system is successful, given the presence of a wide scatter of Actual travel times around predicted travel times, whether "raw" or CMS-displayed information is used for comparisons. The question arises, however, whether the requirement that predictions be within +/- 4 minutes is an appropriate one to judge system performance. The criterion appears counter-intuitive in part, because it requires the evaluated system to demonstrate increasingly more accurate performance, as travel times increase (presumably due to increasing congestion levels): during free-flow conditions, when travel times were minimal, the criterion of +/- 4 minutes represented between 20-25% of the travel time for the two evaluated CMS (minimum travel time of 20 and 16 minutes for CMS #1 and #3, respectively). When travel times increased to 40 minutes, the same criterion required predictions to be within 10% of Actual travel times. A travel time of 40 minutes displayed at CMS #3 (located approximately 14 miles from the end of the work zone), corresponded to average speeds of approximately 21 mph in the evaluated corridor. Given the level of congestion this speed indicates, and the possibility of unstable flow and rather unstable travel times, drivers may be satisfied with a travel time estimate that is within a much wider range.

During travel time runs it was noted that heavy vehicles often slowed down in overpasses within the work zone, possibly because temporary Jersey barriers were placed very close to the edge of travel lanes (often less than 3 feet—see Picture C14) at these locations.[6] This barrier placement was necessary while half of the bridge deck was being replaced. Queues would typically form behind the slower-moving vehicles at STH 11, STH 20 and CTH K. When traffic volumes increased on Sundays, and especially in August, the impact of these queues became significant enough to occasionally induce forced-flow unstable conditions along the entire length of the work zone.

Given that the last TIPS detector was located approximately three miles into the construction zone, more than nine miles from its south end, TIPS could not detect the slower speeds around overpasses. In situations when this impact became so severe that the entire construction zone would be affected, the shock wave of dramatically reduced speeds would reach the south-most TIPS detector with some delay, perhaps as long as 6-8 minutes. Severe short-term or longer duration speed reductions due to frequent incidents (e.g., mechanical problems) were similarly either completely undetected or detected after some delay. This was not a TIPS system shortcoming, but a consequence of the chosen system setup, which, in turn, was dictated by budgetary constraints.

It is very likely that TIPS accuracy (observations in compliance with the +/- 4 minute criterion) would have been much higher in the absence of speed variations south of the south-most TIPS detector. Alternatively, had additional TIPS detectors been placed at intervals within the construction zone (for example at the above-described bottlenecks on overpasses), TIPS predictions could have accounted for conditions that could not be detected under the evaluated

[6] Heavy vehicles typically avoided using the temporary travel lane placed on the shoulder. This was probably due to the bumpy ride on the patched-over rumble strips. Under low traffic volumes, smaller vehicles could pass heavier vehicles using the temporary travel lane, but under heavier volumes this was not possible.

system setup.

If additional detectors were used within the work zone, additional Changeable Message Signs (CMS) could have also been used within the work zone, ahead of exits connecting to alternate routes. These CMS would have informed drivers how travel time conditions had changed at intermediate points along their travel through the work zone.

## CONCLUSIONS

### *Travel Time Analysis*

Two comparisons with actual travel times were performed to assess the accuracy of travel time predictions produced by the evaluated system (TIPS). The first comparison used "raw" travel time predictions, produced every 30 seconds. Raw travel time predictions were processed by TIPS in order to "smooth" predicted travel times and comply with two requirements: i) travel time predictions should be displayed on Changeable Message Sign (CMS) to motorists in 4-minute increments; and, ii) CMS information should not change before it is displayed for at least three minutes. The second comparison was based on information displayed on CMS, in the field. Data for the first comparison was gathered both in evaluation phase one and evaluation phase two, since it was independent of the presence of CMS in the field. The second comparison depended on information from CMS and was necessarily limited to evaluation phase two, when CMS were deployed in the field.

The two analyses provided the opportunity to quantify the effect that the above-listed two requirements had on the accuracy of the evaluated system.

***Comparison of Actual with "Raw" TIPS Data.*** Estimated travel times produced by the evaluated system generally followed Actual travel time patterns through the two evaluation periods. The requirement that TIPS travel times be within +/- 4 minutes of Actual travel times was satisfied for 45% of the observations for CMS #1 and 58% of the observations for CMS #3. TIPS travel times within +/-5 minutes of Actual travel times were 67% and 76% respectively.

Differences between **average** Actual and TIPS travel times were statistically significant, but very small for all practical purposes (approximately 2 minutes for CMS #1 and 1 minute for CMS #3). **Average** travel time **differences** for each of the six separate TIPS travel times that were prevalent in the database (16, 20, 24, 28, 32, and 36 minutes), were also small, ranging from 0.3 to 4.5 minutes for both CMS. Linear regression models using TIPS travel time estimates to predict Actual travel times had a relatively good fit, explaining approximately 64% and 68% of the variation in Actual travel times for CMS #1 and #3 respectively. However, standard errors of the means were rather large, compared to the guideline of +/- 4 minutes (5.13 and 4.7 minutes respectively, leading to 95% confidence intervals approximately +/- 10 and +/- 9 minutes respectively).

Although **average** Actual travel times were close to travel times predicted by the evaluated system (averages over a number of observations were quite accurate), Actual travel times were rather widely scattered. Thus, individual travel time predictions, did not closely match all Actual travel times. Travel time predictions at discrete points in time were not within the +/- 4 minute interval for 55% and 42% of the Actual travel times for CMS #1 and #3, respectively.

***Comparison of Actual with CMS Data.*** CMS travel time compliance with Actual travel times was similar to that for raw travel time predictions: 46.4% and 65.5% of CMS #1 and CMS #3 travel times were within +/-4 minutes of Actual travel times, respectively (63.1% and 76.9% were within +/-5 minutes, respectively).

Differences between **average** Actual and CMS travel times were statistically significant, but small for all practical purposes (3 and 2 minutes for CMS #1 and CMS #3, respectively). **Average** travel time **differences** for each of the CMS-displayed travel times ranged mostly between zero and five minutes, but some larger differences existed. Regression models using CMS travel times to predict Actual travel times explained 49% and 59% of the variation in Actual travel times for CMS #1 and CMS #3, respectively. The models had rather large standard errors of the means (5.9 and 4.8 minutes respectively), indicating a rather wide scatter of Actual travel times around predicted travel times.

On average, CMS travel times were very close to Actual travel times, but individual observations were rather widely scattered, thus travel time predictions at individual points were not within the +/-4 minute interval for 51% and 41% of the Actual travel times for CMS #1 and CMS #3, respectively.

***Raw and CMS Data Conclusions.*** The analysis of Raw TIPS data is based on almost two-and-a-half times as many data points as the analysis of CMS data, due to the availability of data throughout evaluation periods one and two. Thus, this data set provides more statistically sound information than the analysis of CMS data. There are no striking differences between conclusions based on the two datasets: percentages of travel time predictions within +/- 4 minutes and average differences between predicted and Actual travel times are within similar ranges. The largest measured differences between the two data sets is among the R-square values of the linear regression models used to explain the variation in Actual travel times, using predicted travel times: raw data models have $R^2$ values of 0.64 and 0.68 compared to 0.49 and 0.59 for models based on CMS data. Standard errors of the means, however, are very similar between models for the same CMS, indicating similar scatters of Actual travel times around a given predicted travel time.

Based on the available information, it appears that the smoothing applied on raw travel time predictions, and the application of the restriction not to change a CMS indications for at least three minutes, did not have a significant impact on the accuracy of the evaluated system.

It would be desirable to have more data points representing congested conditions, since it is under such conditions that the evaluated system is of most use. Only three days (Sundays), during which higher travel times were present, were included in the analysis of CMS data.

***System Reliability***

The evaluated system was operational during data collection hours, with the exception of one day, July 29, 2001, when CMS #1 was unintelligible, and CMS #3 displayed a travel time of 20 minutes throughout the data collection hours (actual travel times ranged between 35 and 41 minutes that day). Although the TIPS algorithm was functional (see pages B3 and B7 for CMS #1 and #3, respectively), information was not communicated to the CMS (see pages B19 and

B23 for CMS #1 and #3, respectively).

***Safety Analysis***

A comparison of crash statistics between the before and the after TIPS CMS installation periods did not identify statistically significant safety performance changes in the work zone downstream of the CMS. However, the injury crash frequency for the TIPS work zone was less after TIPS began operation than for a similar construction zone in the opposite direction of travel, which was used as a control site for the safety evaluation. But because the analysis periods were short - 69 days both before and after TIPS operation - results should not be viewed as conclusive.

***Diversion Analysis***

Many drivers are responsive to warnings that they might encounter excessive delays along their current route. A large percentage of drivers will not divert because of a lack of knowledge about diversion options.

The before and after analysis supports the notion that TIPS is influencing drivers to change their routes.

## RECOMMENDATIONS

The evaluated system demonstrated an ability to follow travel time changes. Although its measured performance using the +/- 4 minute criterion may not be impressive, it should be kept in mind that this criterion was arbitrary and may need to be modified, especially for higher travel time values.

An agency using the evaluated system may decide to modify this rather rigid requirement, that was established based on practical considerations. Perhaps a requirement for TIPS travel time predictions to be within a certain percentage of the Actual travel time would be a reasonable performance criterion: four minutes constituted 25% of the Actual travel time in the evaluated corridor, when travel times were at minimal levels, but only 6% of the maximum Actual travel times. Thus, using a rigid criterion requires the evaluated system to provide increasingly better accuracy as travel times increase, which is counter-intuitive. For example, TIPS predictions were within 30% of the Actual travel times 88%-91% of the time on the evaluated corridor.

Future TIPS deployments would benefit from additional detectors installed along the entire length of a construction zone, especially near potential bottlenecks (such as the ones on bridge decks, in the evaluated corridor). These detectors would sense slower speeds due to recurrent congestion and incidents within the work zone considerably sooner than the evaluated system detector arrangement. (TIPS does not claim to be an incident detection system; however, detection of very low speeds within the work zone could be used to post messages such as "LONG DELAY AHEAD.") Use of additional detectors would make deployment of additional CMS throughout the work zone possible, providing the opportunity to communicate travel times to drivers at more points along their travel through the work zone.

The finding that the evaluated system induced drivers to use alternate routes during higher displayed travel times provides a good reason to deploy the evaluated system. Diverted trips provide a relief for traffic remaining in the work zone.

**ACKNOWLEDGMENTS**

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# APPENDIX A

# EVALUATION CORRIDOR INFORMATION

Figure A1. I-94 Corridor and Alternative Routes - North End

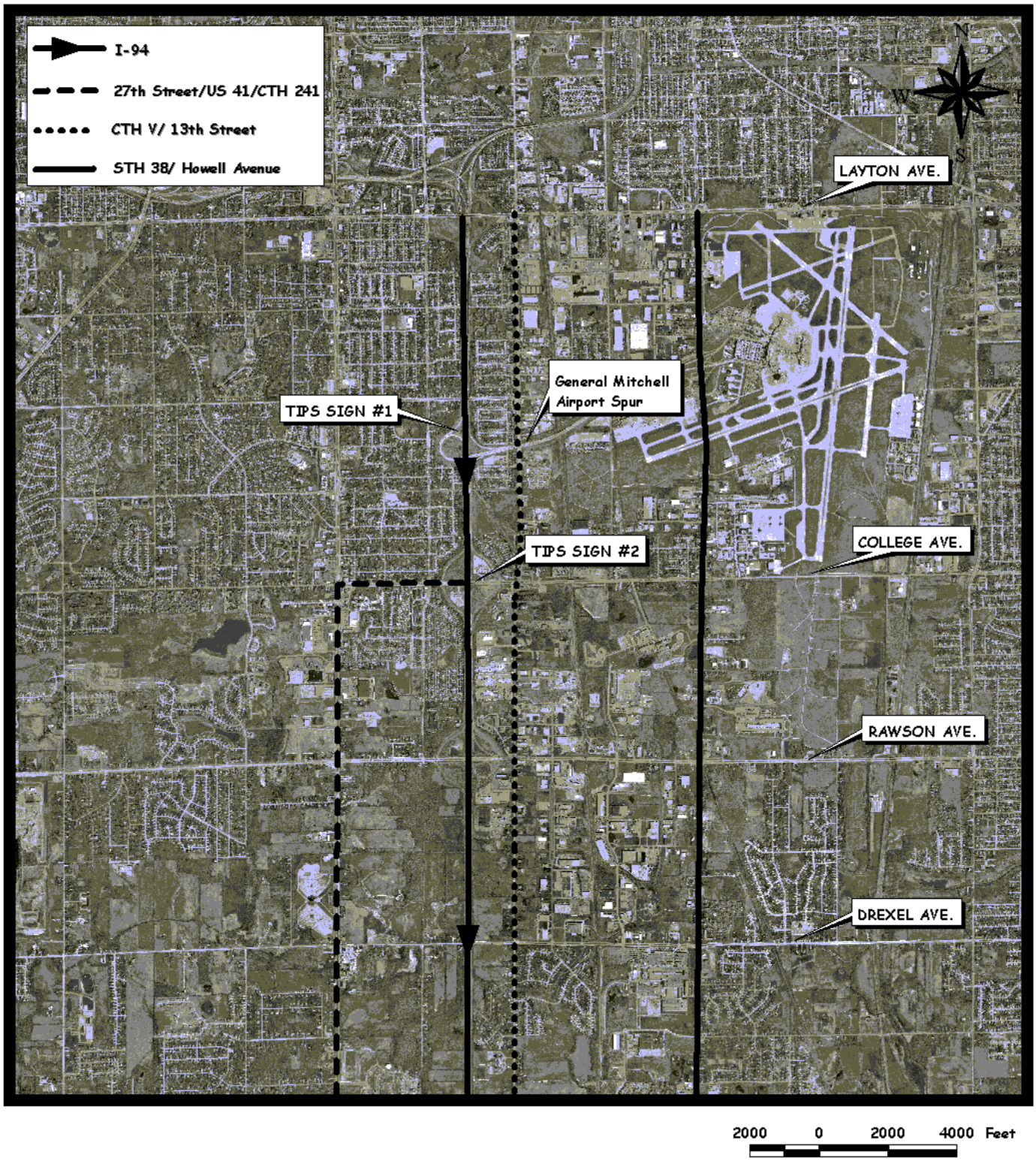


Figure A2. I-94 Corridor and Alternative Routes, Milwaukee - Racine County Line

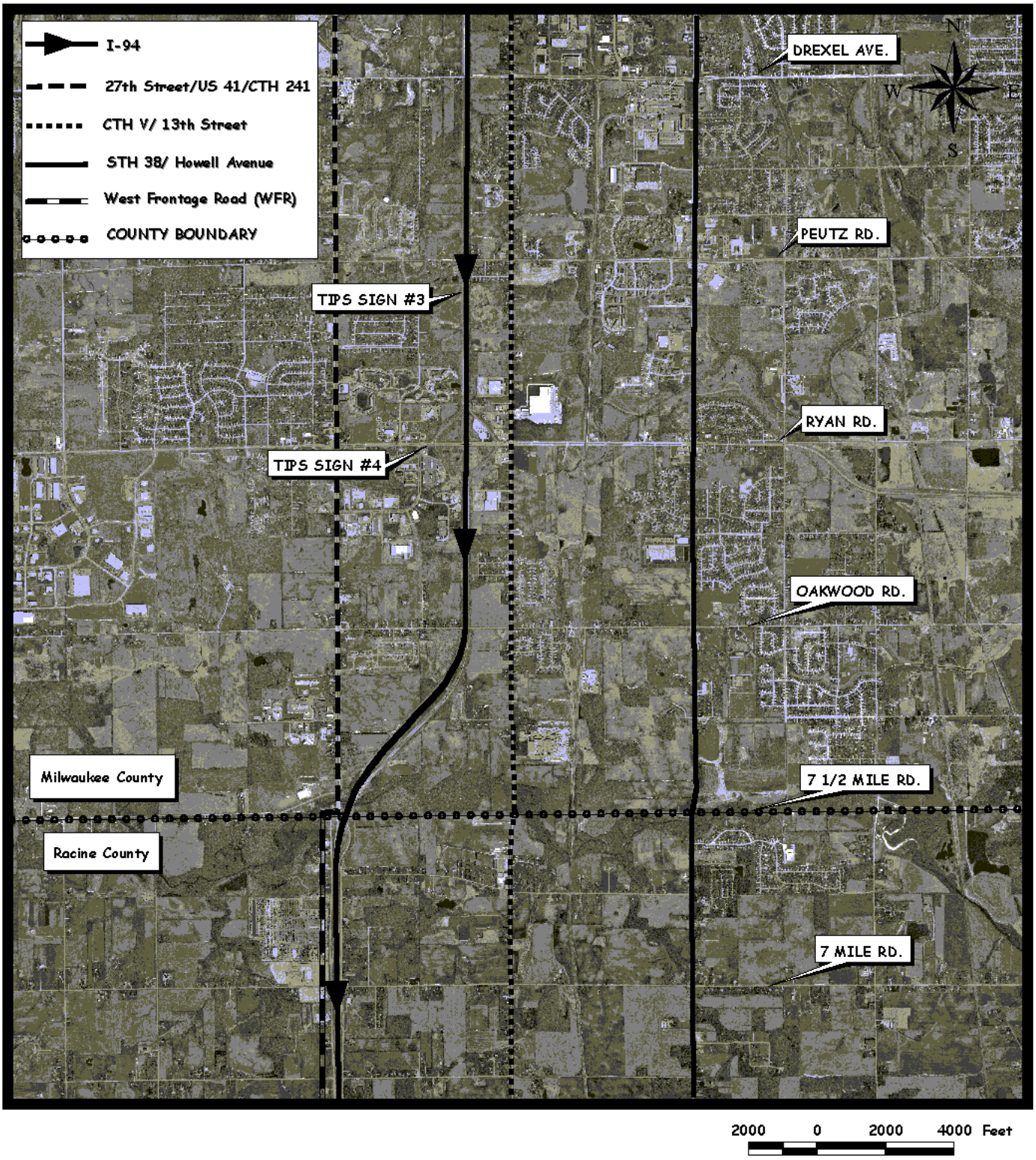


Figure A3. I-94 Corridor Construction Zone, Taper Detail

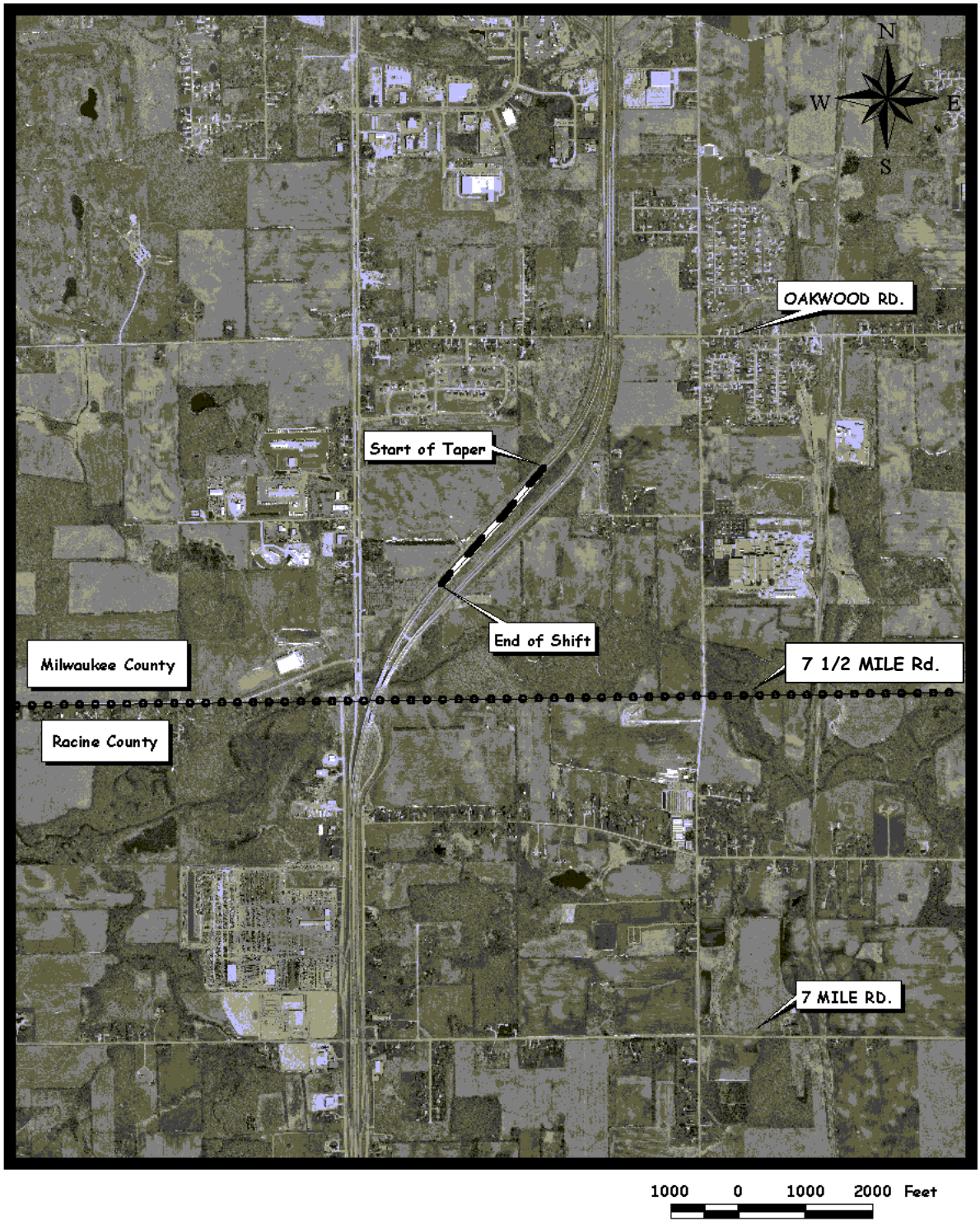


Figure A4. I-94 Construction Zone, Racine County. Typical On- and Off- Ramps

Figure A5. I-94 Construction Zone, Racine County. Detector E Location

Location: KILBOURNVILLE Station: 51-0001

County: RACINE Route: I-94

This station was installed in March of 1963 on I-94, approximately 1.5 miles south of the Racine-Milwaukee County line. In l971, a third lane was added to the roadway. From 1951-1964, the recorder was located south of Ryan Road in Milwaukee County.

This site has six lanes and is functionally classified as "Rural Interstate".

ANNUAL AVERAGE DAILY TRAFFIC

| | Weekday | Saturday | Sunday | Day | | Weekday | Saturday | Sunday | Day |
|---|---|---|---|---|---|---|---|---|---|
| 1976 | 37,508 | 39,990 | 43,550 | 38,737 | 1991 | 64,644 | 64,298 | 65,346 | 64,688 |
| 1977 | 38,987 | 41,745 | 45,084 | 40,240 | 1992 | 67,020 | 68,636 | 68,669 | 67,330 |
| 1978 | 41,230 | 43,938 | 46,414 | 42,354 | 1993 | 70,334 | 69,730 | 68,239 | 69,956 |
| 1979 | 40,740 | 41,050 | 43,203 | 41,146 | 1994 | 69,417 | 68,871 | 69,475 | 71,072 |
| 1980 | 39,979 | 40,358 | 42,803 | 40,444 | 1995 | 72,322 | 72,590 | 71,187 | 73,999 |
| 1981 | 40,655 | 41,325 | 44,060 | 41,251 | 1996 | 74,132 | 74,179 | 71,598 | 75,617 |
| 1982 | 41,470 | 41,413 | 44,613 | 41,920 | 1997 | 76,662 | 75,255 | 73,144 | 77,540 |
| 1983 | 43,952 | 43,532 | 46,186 | 44,189 | 1998 | 79,073 | 79,014 | 76,357 | 80,512 |
| 1984 | 45,915 | 46,282 | 48,530 | 46,354 | 1999 | 79,263 | 77,571 | 74,779 | 79,965 |
| 1985 | 48,770 | 48,867 | 50,292 | 48,996 | 2000 | | | | |
| 1986 | 50,310 | 50,630 | 51,621 | 50,540 | 2001 | | | | |
| 1987 | 51,685 | 51,467 | 52,581 | 51,762 | 2002 | | | | |
| 1988 | 55,870 | 54,949 | 56,532 | 55,835 | 2003 | | | | |
| 1989 | 60,379 | 59,600 | 59,619 | 60,159 | 2004 | | | | |
| 1990 | 62,744 | 62,205 | 62,608 | 62,647 | 2005 | | | | |

WEEKLY TRAFFIC DATA

| | 1997 | 1998 | 1999 |
|---|---|---|---|
| | Avg. Per Day | Avg. Per Day | Avg. Per Day |
| Sunday | 73,144 | 76,357 | 74,779 |
| Monday | 74,827 | 76,677 | 76,516 |
| Tuesday | 74,796 | 77,897 | 77,340 |
| Wednesday | 77,773 | 80,147 | 81,130 |
| Thursday | 79,254 | 81,570 | 82,066 |
| Friday | 87,730 | 91,921 | 90,355 |
| Saturday | 75,255 | 79,014 | 77,571 |
| AVERAGE | 77,540 | 80,512 | 79,965 |

Wisconsin Department of Transportation
Day of Week Summary Statistics
At Continuous Counter Sites

1999 Traffic Year

Site ID : 510001
Location: I-94 - 1.5 MI S OF MLWKE CNTY - KILBOURNVILLE

County: RACINE

Axle Factor Group : 28
Seasonal Factor Group: 3

Growth Factor Group : 3
FHWA Functional Class: 1

| Calendar Month | MADW | | | | | | | MADT | MTR | MAWDT | MTR | MAWET | MTR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sun | Mon | Tue | Wed | Thu | Fri | Sat | | | | | | |
| December | 67,043 | 76,372 | 77,810 | 81,546 | 76,494 | 80,622 | 75,602 | 76,498 | 0.96 | 78,055 | 0.98 | 71,322 | 0.94 |
| January | 49,575 | 65,497 | 67,393 | 67,755 | 71,943 | 75,687 | 51,599 | 64,207 | 0.80 | 68,147 | 0.86 | 50,587 | 0.66 |
| February | 67,103 | 71,569 | 72,779 | 74,931 | 76,903 | 84,925 | 71,342 | 74,222 | 0.93 | 74,045 | 0.93 | 69,222 | 0.91 |
| March | 70,367 | 74,127 | 71,494 | 79,740 | 80,211 | 87,595 | 72,673 | 76,601 | 0.96 | 76,393 | 0.96 | 71,520 | 0.94 |
| April | 75,220 | 74,474 | 77,821 | 80,055 | 81,934 | 89,005 | 75,514 | 79,146 | 0.99 | 78,571 | 0.99 | 75,367 | 0.99 |
| May | 77,738 | 76,164 | 76,522 | 79,807 | 81,920 | 91,416 | 78,328 | 80,271 | 1.00 | 78,603 | 0.99 | 78,033 | 1.02 |
| June | 84,134 | 83,303 | 82,992 | 85,607 | 86,706 | 96,942 | 86,542 | 86,604 | 1.08 | 84,652 | 1.07 | 85,338 | 1.12 |
| July | 85,714 | 82,642 | 83,701 | 85,950 | 90,102 | 100,152 | 89,118 | 88,197 | 1.10 | 85,599 | 1.08 | 87,416 | 1.15 |
| August | 95,063 | 84,461 | 83,930 | 88,647 | 89,711 | 100,849 | 91,954 | 90,659 | 1.13 | 86,687 | 1.09 | 93,508 | 1.23 |
| September | 77,008 | 77,047 | 76,336 | 79,895 | 82,011 | 93,327 | 81,115 | 80,963 | 1.01 | 78,822 | 0.99 | 79,061 | 1.04 |
| October | 75,010 | 76,524 | 77,694 | 81,592 | 84,874 | 95,536 | 79,905 | 81,591 | 1.02 | 80,171 | 1.01 | 77,457 | 1.02 |
| November | 73,371 | 76,007 | 79,607 | 88,036 | 81,982 | 88,203 | 77,165 | 80,624 | 1.01 | 81,408 | 1.03 | 75,268 | 0.99 |
| AADW | 74,779 | 76,516 | 77,340 | 81,130 | 82,066 | 90,355 | 77,571 | | | | | | |

| AADT 79,965 | AAWDT 79,263 | AAWET 76,175 | POS DIR TRAFFIC 49.9% | ARITH. MEAN DAILY TRAFFIC 80,000 | CV% 12.9 |
|---|---|---|---|---|---|

Note 1: MAWDT Includes Monday-Thursday. MAWET Includes Saturday-Sunday.

Wisconsin Department of Transportation
Percent Annual Average Hourly Traffic Volume
At Continuous Counter Sites

Site ID : 510001
Location: I-94 - 1.5 MI S OF MLWKE CNTY - KILBOURNVILLE

County: RACINE

Axle Factor Group : 28
Seasonal Factor Group: 3

Growth Factor Group : 3
FHWA Functional Class: 1

1999 Traffic Year

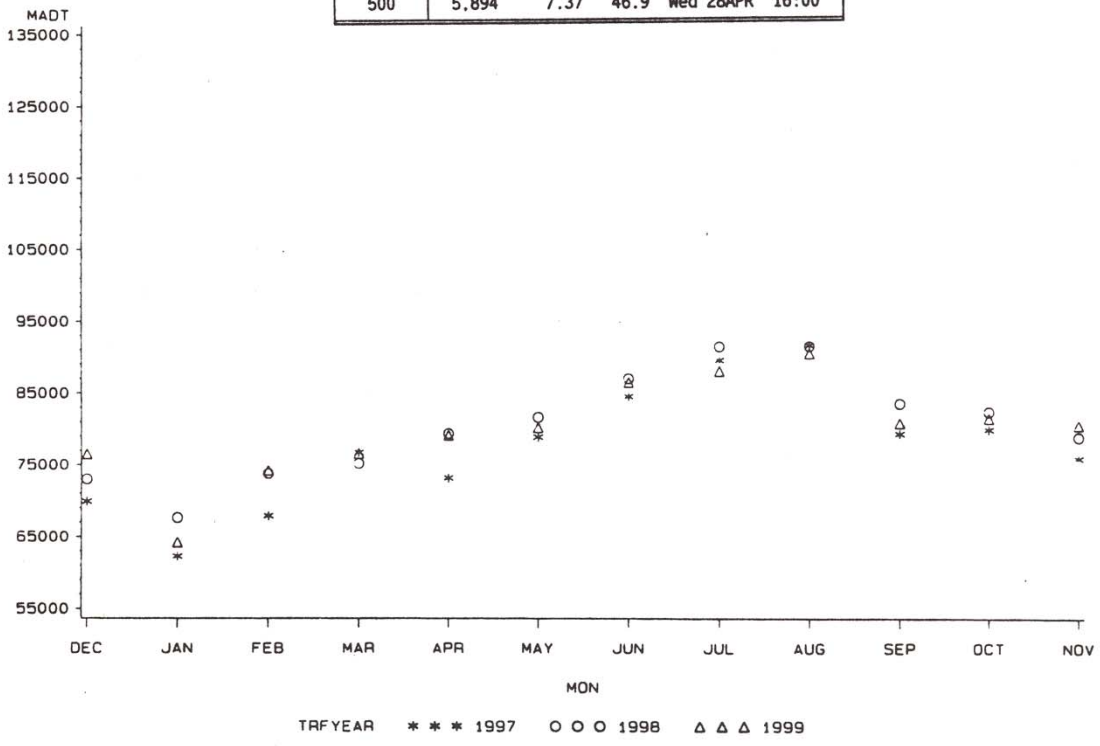
| | SUNDAY | | MONDAY | | TUESDAY | | WEDNESDAY | | THURSDAY | | FRIDAY | | SATURDAY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEG | % POS | NEG | % POS | NEG | % POS | NEG | % POS | NEG | % POS | NEG | % POS | NEG | % POS |
| AADW | 35,612 | 39,167 | 37,431 | 39,084 | 38,594 | 38,746 | 40,734 | 40,396 | 41,582 | 40,483 | 47,269 | 43,085 | 39,493 | 38,078 |
| 00:00 | 1.75 | 1.67 | 1.26 | 1.12 | 1.13 | 1.19 | 1.18 | 1.21 | 1.21 | 1.25 | 1.15 | 1.21 | 1.72 | 1.90 |
| 01:00 | 1.07 | 1.08 | 0.92 | 0.72 | 0.88 | 0.88 | 0.91 | 0.86 | 0.93 | 0.92 | 0.88 | 0.92 | 1.20 | 1.24 |
| 02:00 | 0.79 | 0.99 | 0.77 | 0.62 | 0.80 | 0.80 | 0.88 | 0.79 | 0.90 | 0.82 | 0.84 | 0.82 | 0.95 | 1.09 |
| 03:00 | 0.59 | 0.61 | 0.78 | 0.79 | 0.87 | 0.91 | 0.93 | 0.88 | 0.91 | 0.92 | 0.86 | 0.88 | 0.84 | 0.86 |
| 04:00 | 0.61 | 0.55 | 1.33 | 1.37 | 1.42 | 1.38 | 1.50 | 1.33 | 1.44 | 1.35 | 1.30 | 1.28 | 1.06 | 0.95 |
| 05:00 | 0.86 | 0.78 | 3.16 | 2.88 | 3.29 | 2.81 | 3.19 | 2.65 | 3.11 | 2.60 | 2.74 | 2.38 | 1.73 | 1.50 |
| 06:00 | 1.49 | 1.19 | 6.18 | 5.26 | 6.21 | 5.39 | 6.00 | 5.04 | 5.72 | 4.92 | 4.90 | 4.40 | 2.66 | 2.29 |
| 07:00 | 2.19 | 1.92 | 6.79 | 6.49 | 6.75 | 6.72 | 6.63 | 6.37 | 6.21 | 6.32 | 5.31 | 5.64 | 3.59 | 3.38 |
| 08:00 | 3.24 | 2.95 | 5.36 | 5.65 | 5.40 | 5.89 | 5.53 | 5.59 | 5.18 | 5.62 | 4.51 | 5.09 | 4.57 | 4.69 |
| 09:00 | 4.43 | 4.56 | 5.11 | 5.57 | 5.04 | 5.57 | 5.20 | 5.49 | 4.94 | 5.54 | 4.54 | 5.28 | 5.35 | 6.09 |
| 10:00 | 5.75 | 5.93 | 5.31 | 5.58 | 5.09 | 5.27 | 5.22 | 5.29 | 5.15 | 5.35 | 4.88 | 5.34 | 6.02 | 6.94 |
| 11:00 | 6.80 | 6.95 | 5.41 | 5.59 | 5.18 | 5.27 | 5.24 | 5.45 | 5.32 | 5.47 | 5.25 | 5.58 | 6.57 | 7.17 |
| 12:00 | 7.26 | 7.73 | 5.55 | 5.79 | 5.29 | 5.32 | 5.26 | 5.75 | 5.37 | 5.59 | 5.57 | 5.87 | 6.66 | 7.40 |
| 13:00 | 7.25 | 7.86 | 5.61 | 5.91 | 5.51 | 5.64 | 5.40 | 5.82 | 5.65 | 5.82 | 6.09 | 6.06 | 6.61 | 7.12 |
| 14:00 | 7.26 | 7.90 | 6.16 | 6.12 | 6.14 | 5.93 | 6.10 | 6.14 | 6.24 | 6.10 | 6.59 | 6.38 | 6.59 | 6.87 |
| 15:00 | 7.35 | 8.01 | 6.84 | 6.65 | 6.89 | 6.63 | 6.88 | 6.80 | 6.81 | 6.67 | 6.94 | 6.68 | 6.58 | 6.78 |
| 16:00 | 7.70 | 8.13 | 7.38 | 7.07 | 7.41 | 7.13 | 7.39 | 7.18 | 7.15 | 7.10 | 7.24 | 6.98 | 6.95 | 6.57 |
| 17:00 | 7.42 | 7.51 | 7.10 | 7.01 | 7.11 | 7.07 | 6.90 | 7.00 | 6.82 | 6.94 | 6.90 | 6.82 | 6.57 | 6.04 |
| 18:00 | 6.72 | 6.35 | 5.23 | 5.38 | 5.35 | 5.56 | 5.33 | 5.60 | 5.42 | 5.79 | 6.05 | 6.12 | 5.87 | 4.98 |
| 19:00 | 5.77 | 5.38 | 3.72 | 3.94 | 3.73 | 3.89 | 3.82 | 3.90 | 4.10 | 4.02 | 4.99 | 4.48 | 4.58 | 3.89 |
| 20:00 | 4.83 | 4.46 | 3.17 | 3.29 | 3.21 | 3.30 | 3.31 | 3.28 | 3.58 | 3.42 | 4.15 | 3.49 | 3.94 | 3.43 |
| 21:00 | 3.86 | 3.49 | 2.85 | 3.03 | 3.01 | 3.14 | 2.99 | 3.20 | 3.25 | 3.13 | 3.55 | 3.26 | 3.73 | 3.24 |
| 22:00 | 3.03 | 2.37 | 2.35 | 2.39 | 2.57 | 2.55 | 2.50 | 2.60 | 2.76 | 2.52 | 2.83 | 2.81 | 3.22 | 3.10 |
| 23:00 | 1.96 | 1.61 | 1.65 | 1.77 | 1.69 | 1.75 | 1.68 | 1.76 | 1.81 | 1.80 | 1.94 | 2.22 | 2.43 | 2.47 |
| NDAYS | 51 | | 50 | | 49 | | 50 | | 51 | | 51 | | 51 | |

Site ID : 510001
Location: I-94 - 1.5 MI S OF MLWKE CNTY - KILBOURNVILLE County: RACINE

Axle Factor Group : 28
Seasonal Factor Group: 3

Growth Factor Group : 3
FHWA Functional Class: 1

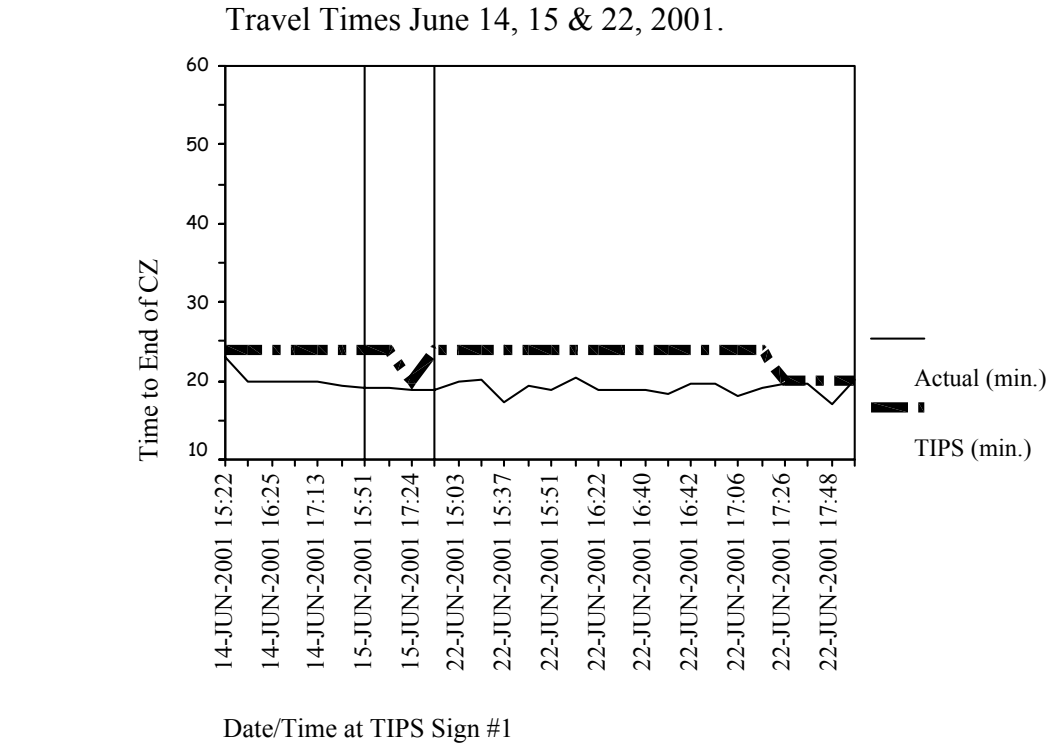
| Annual Highest Hour | Volume | %AADT | +Dir% | Begin Date | Time |
|---|---|---|---|---|---|
| 1 | 7,747 | 9.69 | 51.9 | Sun 08AUG | 17:00 |
| 2 | 7,707 | 9.64 | 53.8 | Sun 08AUG | 16:00 |
| 3 | 7,493 | 9.37 | 52.8 | Sun 08AUG | 14:00 |
| 4 | 7,489 | 9.37 | 50.0 | Thu 25NOV | 11:00 |
| 5 | 7,380 | 9.23 | 53.7 | Sun 15AUG | 16:00 |
| 6 | 7,302 | 9.13 | 53.4 | Sun 08AUG | 15:00 |
| 7 | 7,234 | 9.05 | 58.7 | Sun 15AUG | 15:00 |
| 8 | 7,201 | 9.01 | 45.9 | Fri 08OCT | 16:00 |
| 9 | 7,162 | 8.96 | 50.9 | Fri 29OCT | 16:00 |
| 10 | 7,140 | 8.93 | 52.2 | Sun 08AUG | 13:00 |
| 11 | 7,132 | 8.92 | 53.8 | Sun 28NOV | 15:00 |
| 12 | 7,121 | 8.91 | 41.4 | Fri 02JUL | 16:00 |
| 13 | 7,113 | 8.90 | 56.5 | Sun 15AUG | 13:00 |
| 14 | 7,104 | 8.88 | 42.3 | Fri 20AUG | 15:00 |
| 15 | 7,098 | 8.88 | 45.8 | Wed 24NOV | 16:00 |
| 16 | 7,096 | 8.87 | 49.3 | Wed 24NOV | 17:00 |
| 17 | 7,077 | 8.85 | 54.2 | Sun 28NOV | 14:00 |
| 18 | 7,051 | 8.82 | 45.8 | Fri 05NOV | 16:00 |
| 19 | 7,051 | 8.82 | 50.5 | Sun 08AUG | 12:00 |
| 20 | 7,047 | 8.81 | 56.7 | Sun 22AUG | 13:00 |
| 21 | 7,046 | 8.81 | 45.7 | Wed 24NOV | 15:00 |
| 22 | 7,023 | 8.78 | 55.5 | Sun 22AUG | 15:00 |
| 23 | 7,013 | 8.77 | 44.9 | Fri 03SEP | 16:00 |
| 24 | 7,010 | 8.77 | 48.2 | Sat 14AUG | 14:00 |
| 25 | 6,998 | 8.75 | 40.2 | Fri 02JUL | 14:00 |
| 26 | 6,992 | 8.74 | 54.4 | Sun 15AUG | 17:00 |
| 27 | 6,986 | 8.74 | 49.5 | Sun 08AUG | 11:00 |
| 28 | 6,985 | 8.74 | 57.6 | Sun 15AUG | 12:00 |
| 29 | 6,981 | 8.73 | 43.1 | Fri 08OCT | 15:00 |
| 30 | 6,969 | 8.72 | 53.8 | Sun 15AUG | 14:00 |
| 40 | 6,843 | 8.56 | 55.1 | Sun 22AUG | 16:00 |
| 50 | 6,797 | 8.50 | 53.4 | Sun 18JUL | 13:00 |
| 60 | 6,744 | 8.43 | 48.0 | Sat 14AUG | 12:00 |
| 70 | 6,709 | 8.39 | 52.0 | Fri 29OCT | 17:00 |
| 80 | 6,685 | 8.36 | 47.2 | Fri 23APR | 16:00 |
| 90 | 6,629 | 8.29 | 52.3 | Sun 08AUG | 18:00 |
| 100 | 6,610 | 8.27 | 52.3 | Sun 22AUG | 11:00 |
| 200 | 6,339 | 7.93 | 50.8 | Thu 11NOV | 16:00 |
| 300 | 6,156 | 7.70 | 47.4 | Fri 16JUL | 13:00 |
| 400 | 6,001 | 7.50 | 50.0 | Sun 09MAY | 18:00 |
| 500 | 5,894 | 7.37 | 46.9 | Wed 28APR | 16:00 |



# APPENDIX B.1

# TRAVEL TIME RESULTS

**Figure B1. Actual and TIPS Travel Time CMS #1**



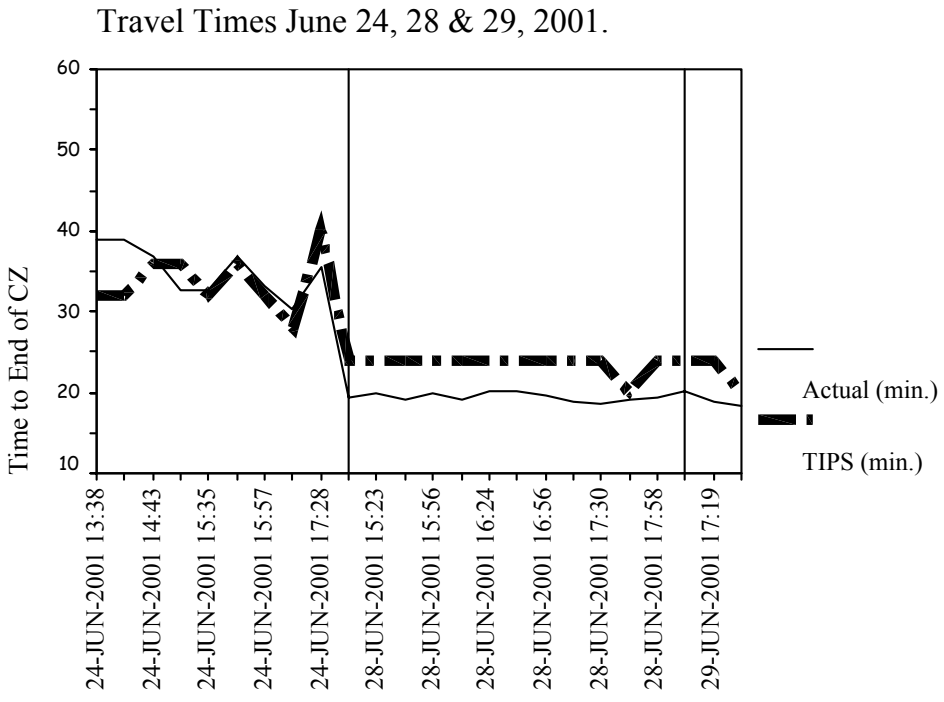
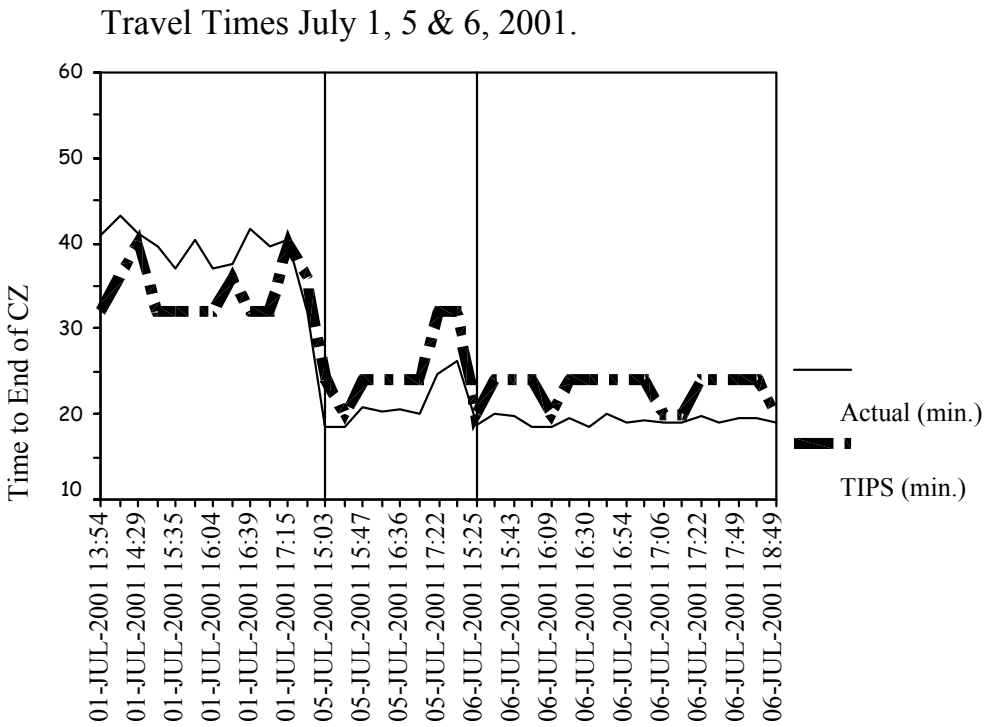



**Figure B1. Actual and TIPS Travel Time CMS #1 (Continued)**



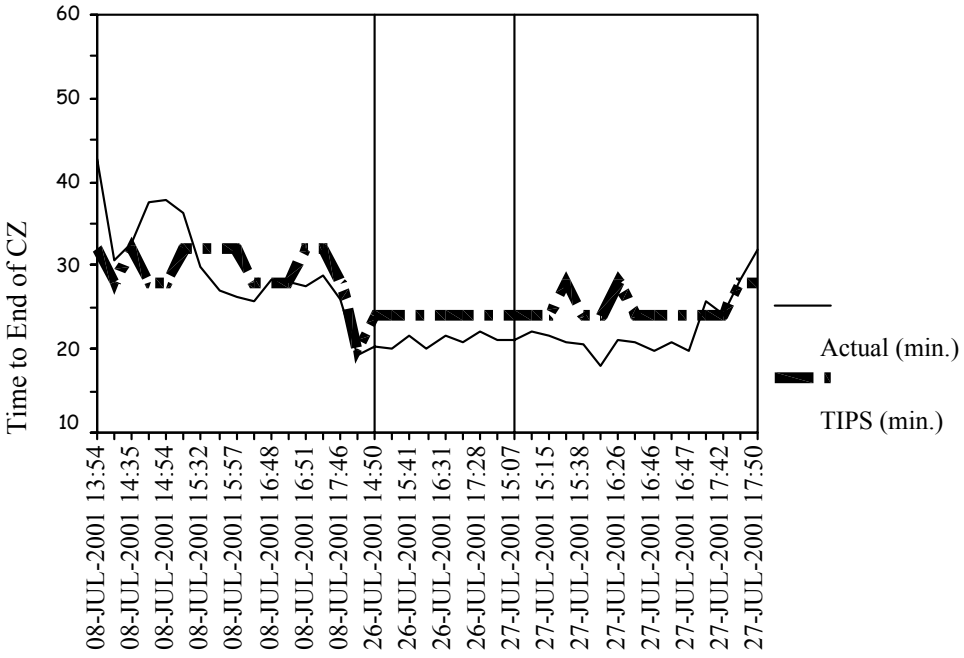
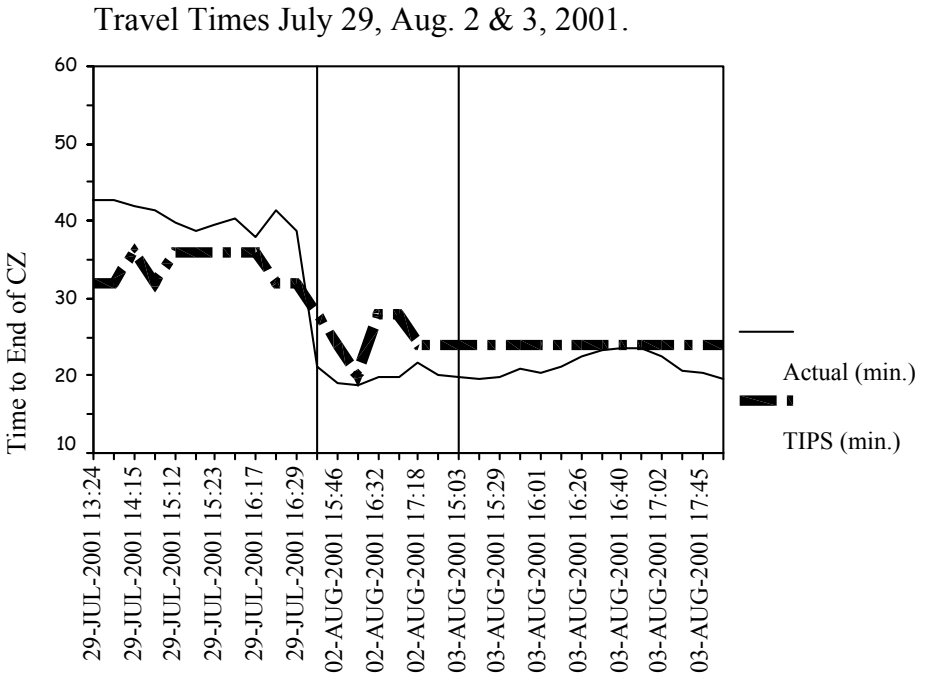



**Figure B1. Actual and TIPS Travel Time CMS #1 (Continued)**



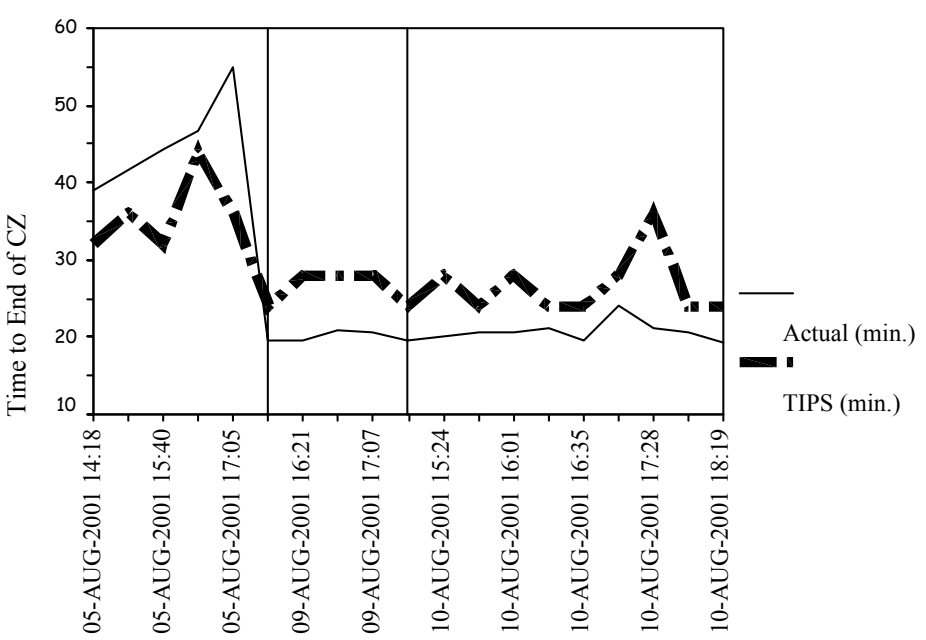
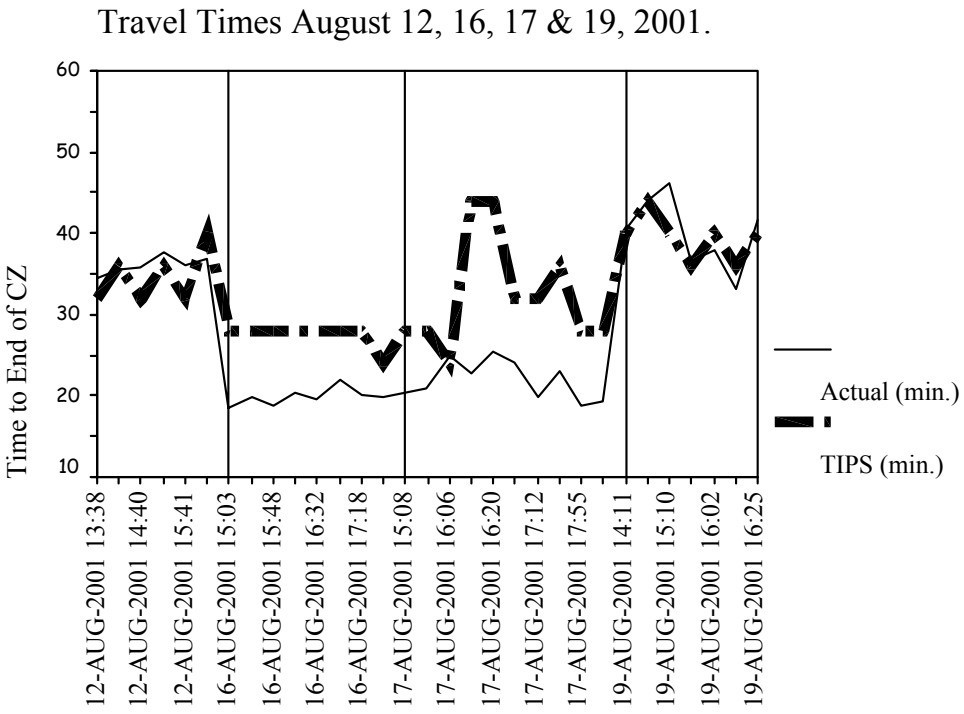



**Figure B1. Actual and TIPS Travel Time CMS #1 (Continued)**



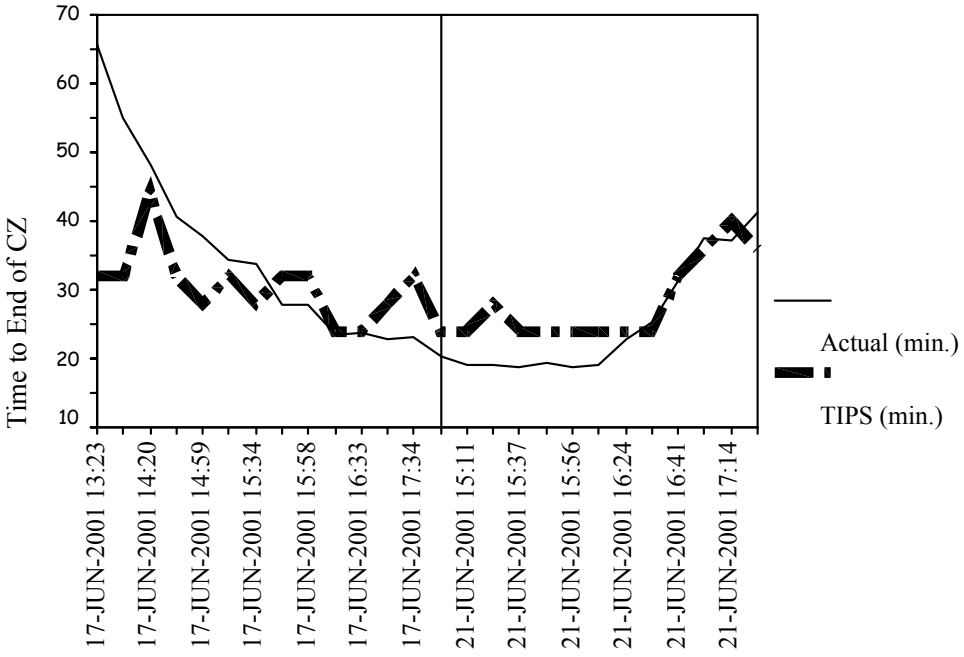
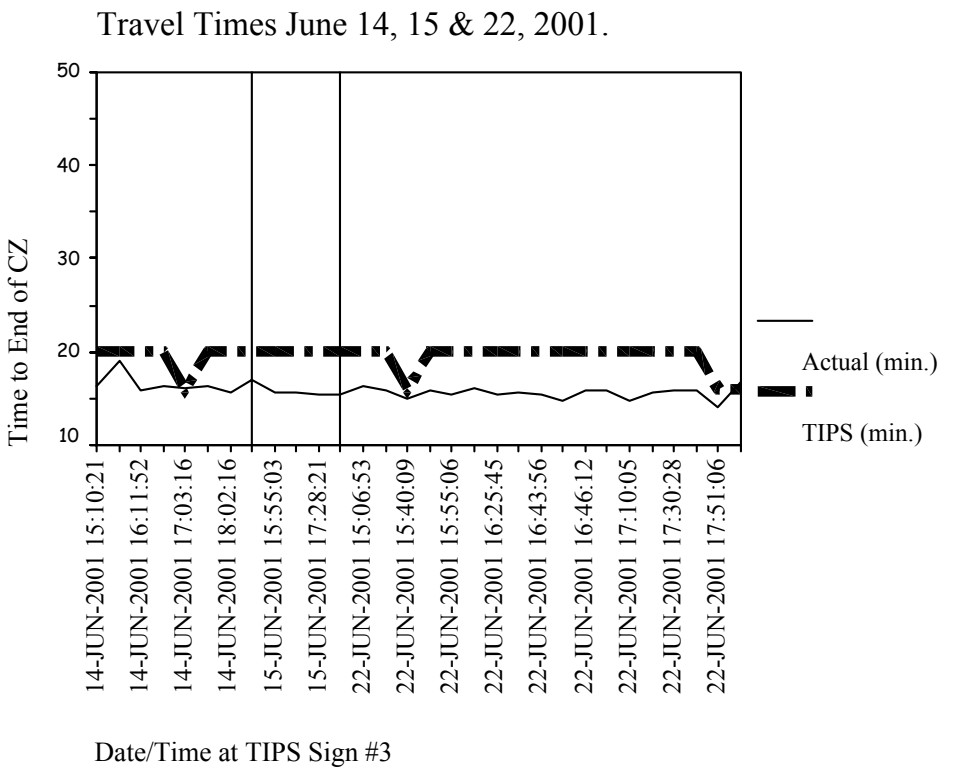



**Figure B2. Actual and TIPS Travel Time CMS #3**



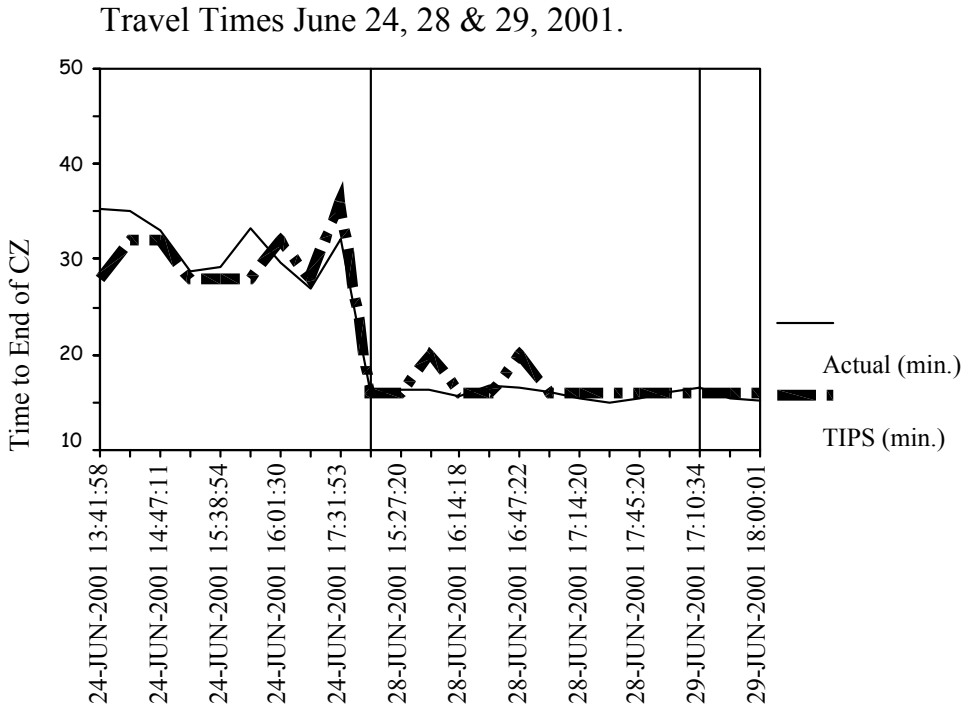
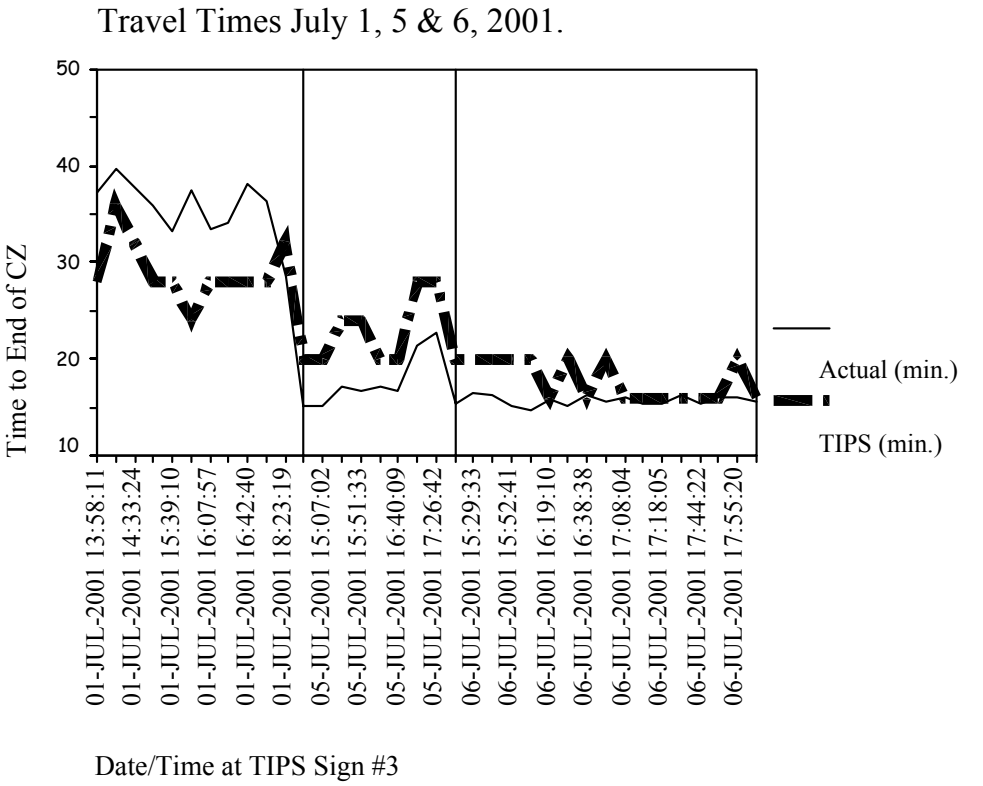



**Figure B2. Actual and TIPS Travel Time CMS #3 (Continued)**



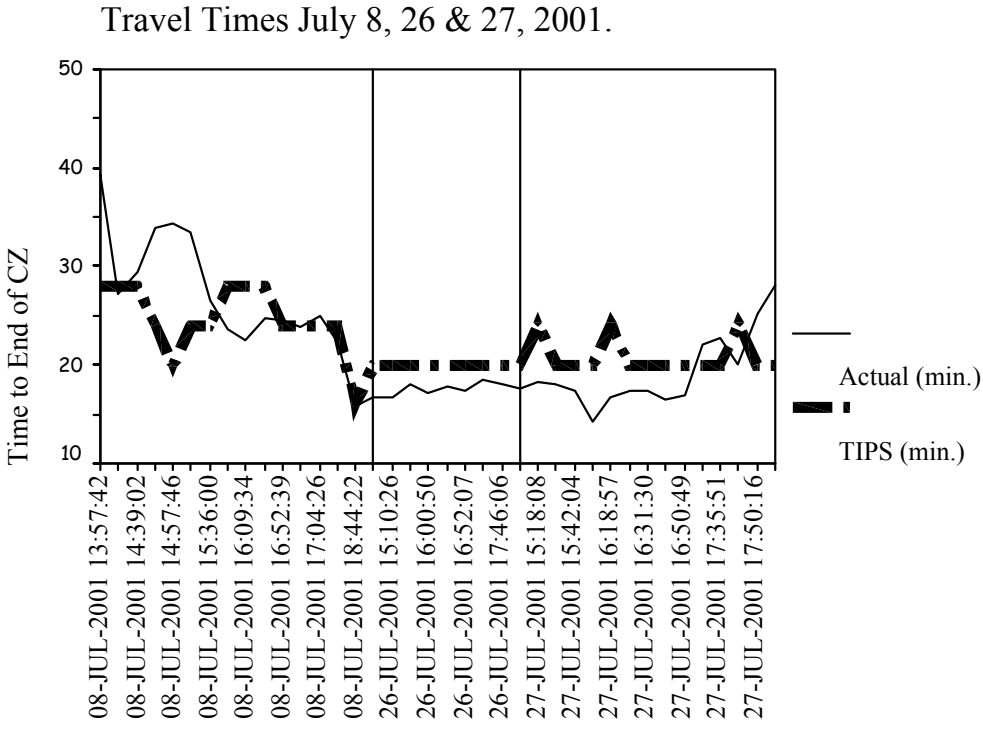
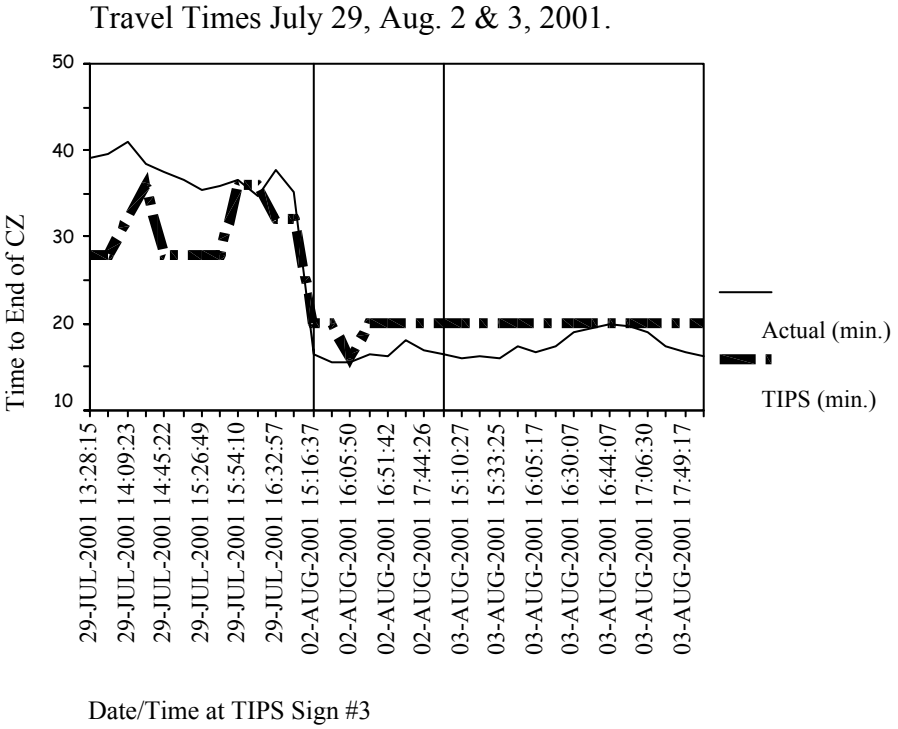
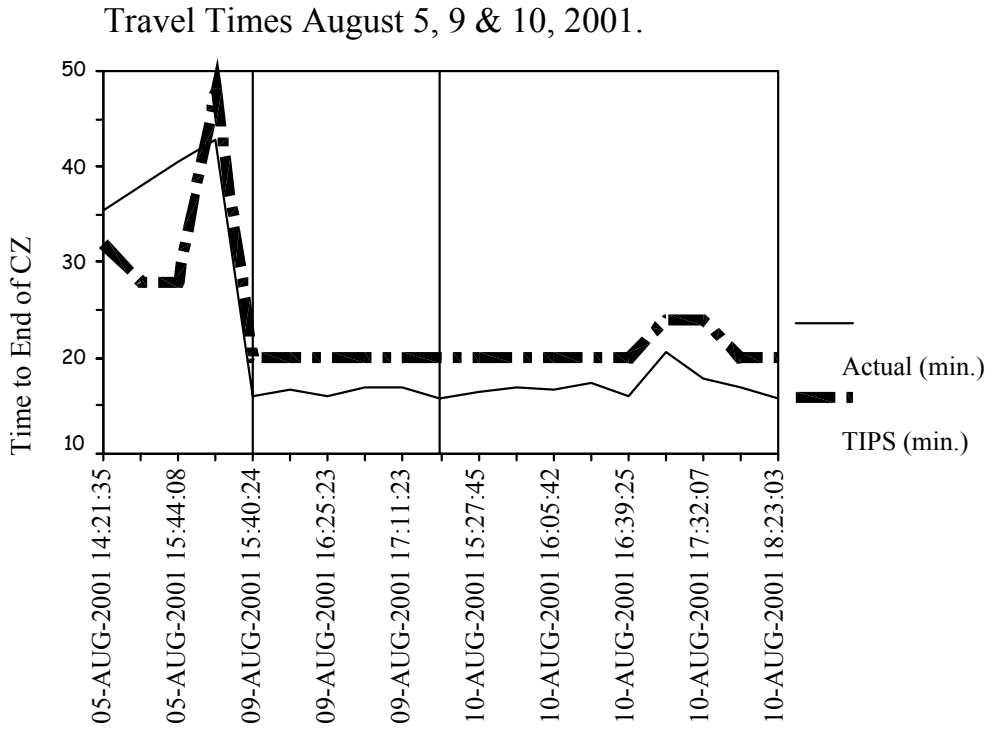
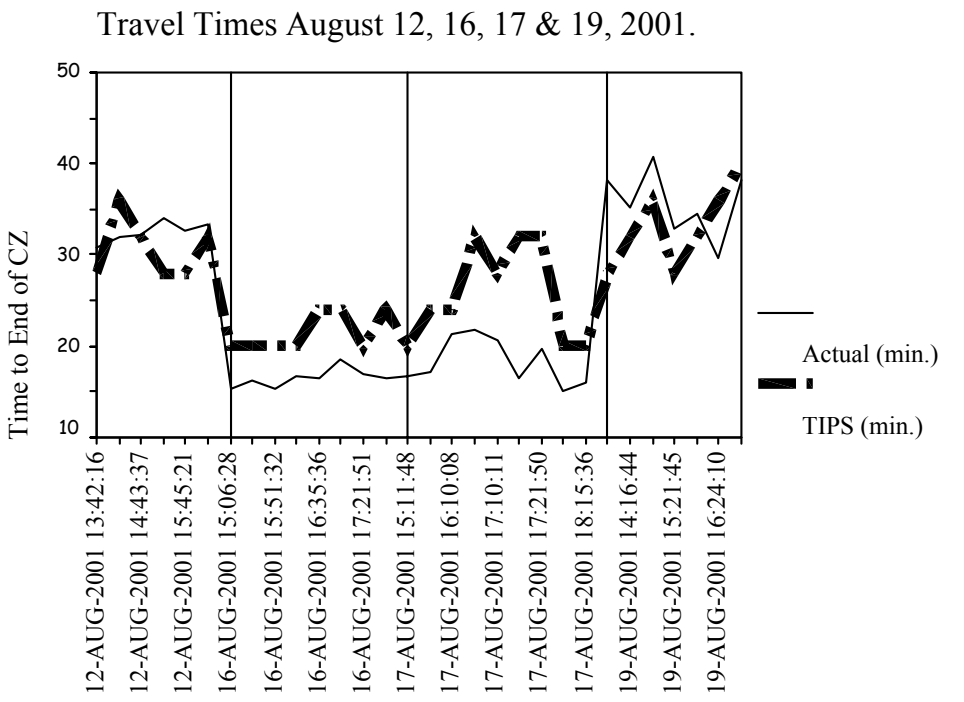



**Figure B2. Actual and TIPS Travel Time CMS #3 (Continued)**



**FigureB2. Actual and TIPS Travel Time CMS #3 (Continued)**



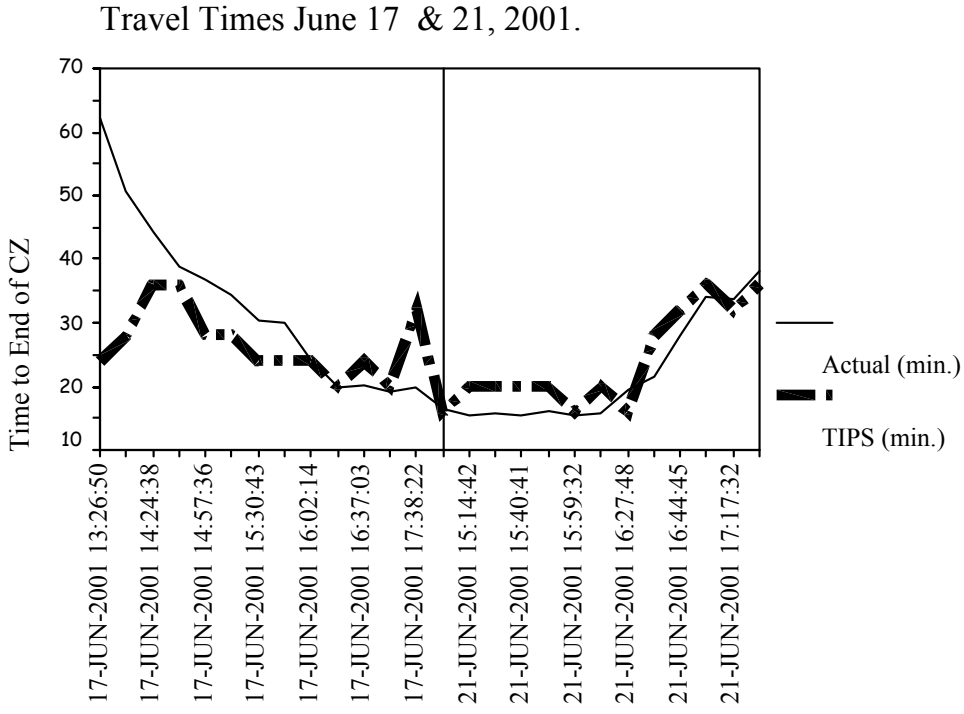



**Table B1. Actual Minus TIPS Travel Time (min.) CMS #1**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | -15 | 1 | .5 | .5 | .5 |
| | -13 | 2 | 1.0 | 1.0 | 1.4 |
| | -10 | 3 | 1.4 | 1.4 | 2.9 |
| | -9 | 6 | 2.9 | 2.9 | 5.8 |
| | -8 | 11 | 5.2 | 5.3 | 11.1 |
| | -7 | 5 | 2.4 | 2.4 | 13.5 |
| | -6 | 17 | 8.1 | 8.2 | 21.6 |
| | -5 | 42 | 20.0 | 20.2 | 41.8 |
| | -4 | 28 | 13.3 | 13.5 | 55.3 |
| | -3 | 15 | 7.1 | 7.2 | 62.5 |
| | -2 | 11 | 5.2 | 5.3 | 67.8 |
| | -1 | 10 | 4.8 | 4.8 | 72.6 |
| | 1 | 14 | 6.7 | 6.7 | 79.3 |
| | 2 | 7 | 3.3 | 3.4 | 82.7 |
| | 3 | 5 | 2.4 | 2.4 | 85.1 |
| | 4 | 4 | 1.9 | 1.9 | 87.0 |
| | 5 | 4 | 1.9 | 1.9 | 88.9 |
| | 6 | 3 | 1.4 | 1.4 | 90.4 |
| | 7 | 5 | 2.4 | 2.4 | 92.8 |
| | 8 | 3 | 1.4 | 1.4 | 94.2 |
| | 9 | 2 | 1.0 | 1.0 | 95.2 |
| | 10 | 5 | 2.4 | 2.4 | 97.6 |
| | 11 | 3 | 1.4 | 1.4 | 99.0 |
| | 13 | 1 | .5 | .5 | 99.5 |
| | 19 | 1 | .5 | .5 | 100.0 |
| | Total | 208 | 99.0 | 100.0 | |
| Missing | System | 2 | 1.0 | | |
| Total | | 210 | 100.0 | | |

**Table B2. Actual Minus TIPS Travel Time (min.) CMS #3**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | -16 | 1 | .5 | .5 | .5 |
| | -13 | 1 | .5 | .5 | 1.0 |
| | -11 | 1 | .5 | .5 | 1.4 |
| | -8 | 5 | 2.4 | 2.4 | 3.8 |
| | -7 | 5 | 2.4 | 2.4 | 6.2 |
| | -6 | 9 | 4.3 | 4.3 | 10.5 |
| | -5 | 35 | 16.7 | 16.7 | 27.1 |
| | -4 | 38 | 18.1 | 18.1 | 45.2 |
| | -3 | 19 | 9.0 | 9.0 | 54.3 |
| | -2 | 13 | 6.2 | 6.2 | 60.5 |
| | -1 | 19 | 9.0 | 9.0 | 69.5 |
| | 0 | 1 | .5 | .5 | 70.0 |
| | 1 | 15 | 7.1 | 7.1 | 77.1 |
| | 2 | 5 | 2.4 | 2.4 | 79.5 |
| | 3 | 6 | 2.9 | 2.9 | 82.4 |
| | 4 | 5 | 2.4 | 2.4 | 84.8 |
| | 5 | 3 | 1.4 | 1.4 | 86.2 |
| | 6 | 6 | 2.9 | 2.9 | 89.0 |
| | 7 | 2 | 1.0 | 1.0 | 90.0 |
| | 8 | 3 | 1.4 | 1.4 | 91.4 |
| | 9 | 4 | 1.9 | 1.9 | 93.3 |
| | 10 | 6 | 2.9 | 2.9 | 96.2 |
| | 11 | 2 | 1.0 | 1.0 | 97.1 |
| | 12 | 3 | 1.4 | 1.4 | 98.6 |
| | 13 | 1 | .5 | .5 | 99.0 |
| | 14 | 1 | .5 | .5 | 99.5 |
| | 15 | 1 | .5 | .5 | 100.0 |
| | Total | 210 | 100.0 | 100.0 | |

**Table B3. Actual Minus TIPS Travel Time (min.) CMS #1**

| | | TIPS time CMS #1 | | | | | | | Group Total |
|---|---|---|---|---|---|---|---|---|---|
| | | 20.00 | 24.00 | 28.00 | 32.00 | 36.00 | 40.00 | 44.00 | |
| Actual minus TIPS (min.) | -15 | | | | | 1 | | | 1 |
| | -13 | | | | 1 | 1 | | | 2 |
| | -10 | | | 3 | | | | | 3 |
| | -9 | | | 6 | | | | | 6 |
| | -8 | | | 9 | 2 | | | | 11 |
| | -7 | | 2 | 3 | | | | | 5 |
| | -6 | | 15 | | 2 | | | | 17 |
| | -5 | | 38 | | 2 | 1 | 1 | | 42 |
| | -4 | | 24 | 1 | 1 | 1 | 1 | | 28 |
| | -3 | 1 | 9 | 2 | 1 | 1 | 1 | | 15 |
| | -2 | 7 | 4 | | | | | | 11 |
| | -1 | 6 | 3 | | | 1 | | | 10 |
| | 1 | 1 | 2 | 3 | 2 | 3 | 2 | 1 | 14 |
| | 2 | | 1 | | 1 | 3 | 2 | | 7 |
| | 3 | | | 2 | 1 | 1 | | 1 | 5 |
| | 4 | | | 1 | 1 | 2 | | | 4 |
| | 5 | | | | 3 | 1 | | | 4 |
| | 6 | | | | 1 | 2 | | | 3 |
| | 7 | | | | 4 | | 1 | | 5 |
| | 8 | | | | 2 | 1 | | | 3 |
| | 9 | | | | 2 | | | | 2 |
| | 10 | | | 2 | 3 | | | | 5 |
| | 11 | | | | 3 | | | | 3 |
| | 13 | | | | 1 | | | | 1 |
| | 19 | | | | | 1 | | | 1 |
| Group Total | | 15 | 98 | 32 | 33 | 20 | 8 | 2 | 208 |

**Table B4. Actual Minus TIPS Travel Time (min.) CMS #3**

| | | TIPS time CMS #3 | | | | | | | | Group Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 16.00 | 20.00 | 24.00 | 28.00 | 32.00 | 36.00 | 40.00 | 48.00 | |
| Actual minus TIPS (min.) | -16 | | | | | 1 | | | | 1 |
| | -13 | | | | | 1 | | | | 1 |
| | -11 | | | | | 1 | | | | 1 |
| | -8 | | | 4 | 1 | | | | | 5 |
| | -7 | | | 3 | 1 | | 1 | | | 5 |
| | -6 | | 4 | 2 | 2 | | | | 1 | 9 |
| | -5 | | 33 | | 1 | | 1 | | | 35 |
| | -4 | | 33 | 2 | 1 | 1 | 1 | | | 38 |
| | -3 | | 17 | 1 | | 1 | | | | 19 |
| | -2 | 3 | 6 | 1 | 1 | | 1 | 1 | | 13 |
| | -1 | 13 | 4 | 1 | 1 | | | | | 19 |
| | 0 | 1 | | | | | | | | 1 |
| | 1 | 10 | 1 | 1 | 1 | 1 | 1 | | | 15 |
| | 2 | | | 1 | 2 | 2 | | | | 5 |
| | 3 | | 2 | 1 | 1 | 1 | 1 | | | 6 |
| | 4 | | | | | 4 | 1 | | | 5 |
| | 5 | | | | 2 | | 1 | | | 3 |
| | 6 | | 1 | | 3 | 2 | | | | 6 |
| | 7 | | | | 2 | | | | | 2 |
| | 8 | | | | 3 | | | | | 3 |
| | 9 | | 1 | | 3 | | | | | 4 |
| | 10 | | | 2 | 3 | 1 | | | | 6 |
| | 11 | | | | 2 | | | | | 2 |
| | 12 | | | | 3 | | | | | 3 |
| | 13 | | | | 1 | | | | | 1 |
| | 14 | | | 1 | | | | | | 1 |
| | 15 | | 1 | | | | | | | 1 |
| Group Total | | 27 | 103 | 20 | 34 | 16 | 8 | 1 | 1 | 210 |

**Figure B3. Boxplot TIPS and Actual Travel Times CMS #1**

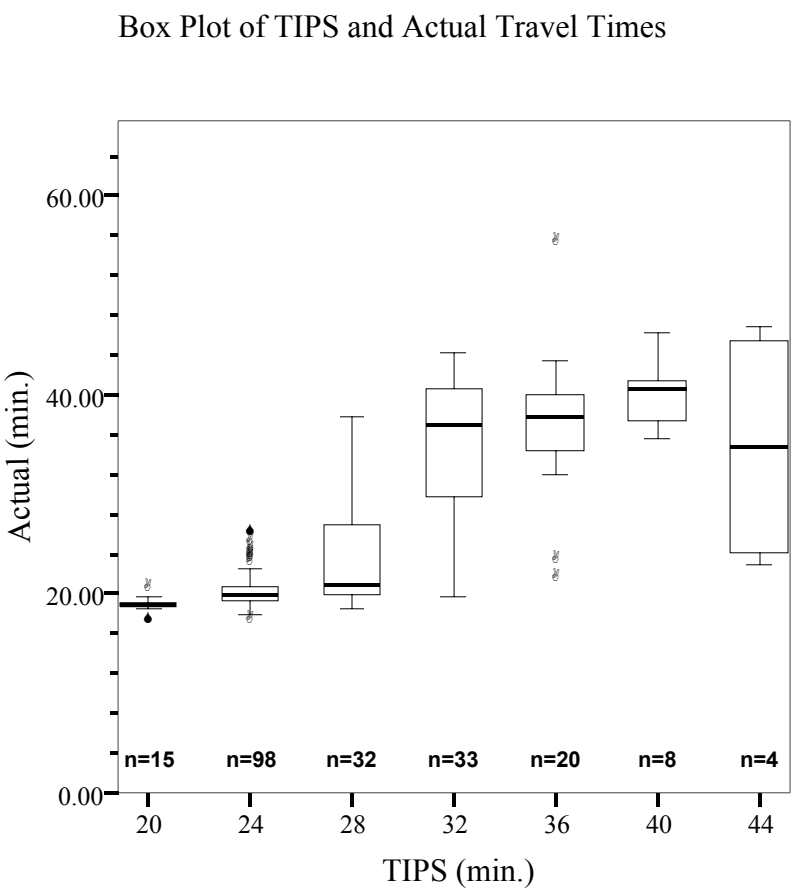


**Figure B4. Boxplot TIPS and Actual Travel Times CMS #3**

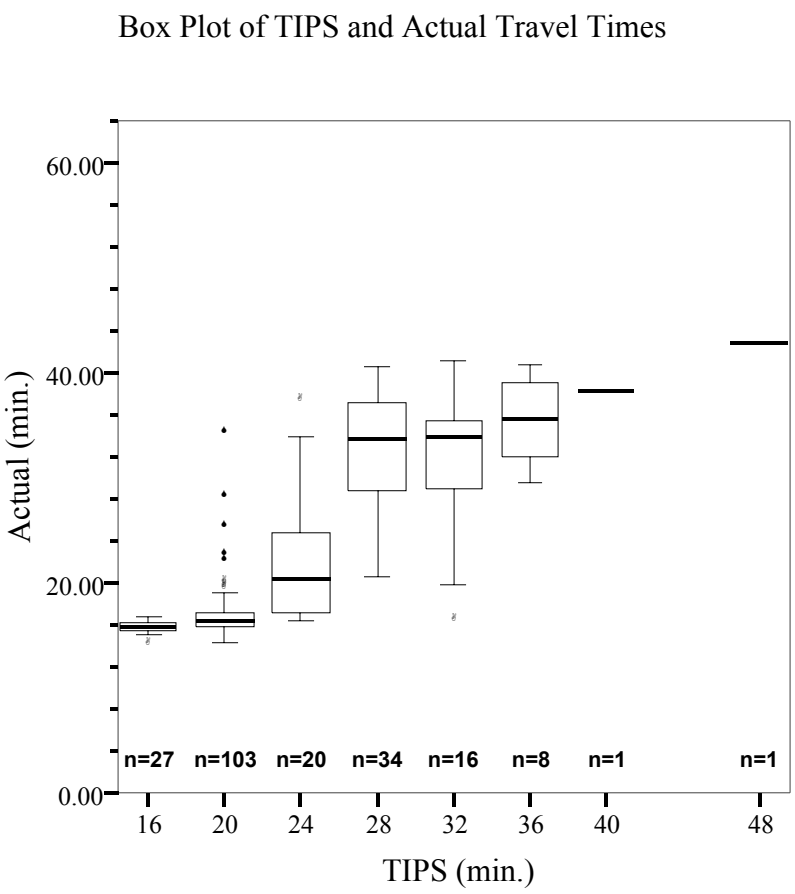


**Figure B5. Actual Versus TIPS Travel Time Scatter Plot CMS #1**

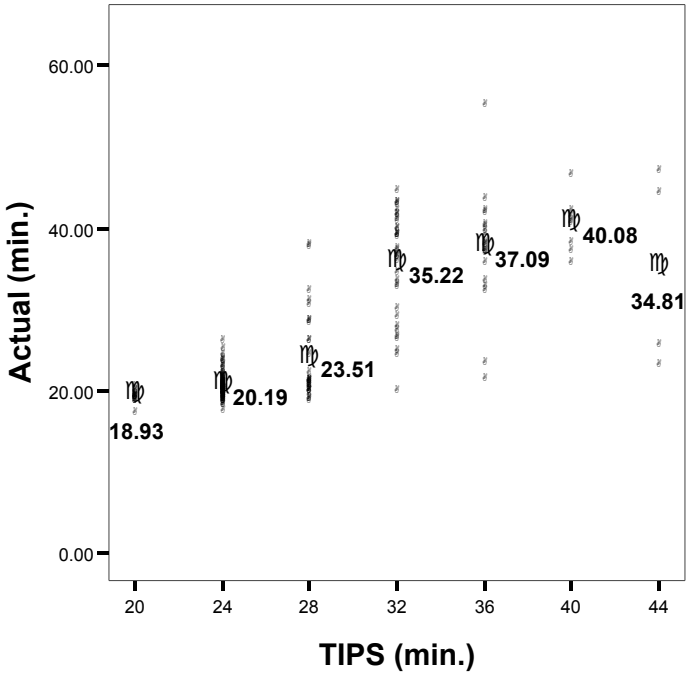


**Figure B6. Actual Versus TIPS Travel Time Scatter Plot CMS #3**

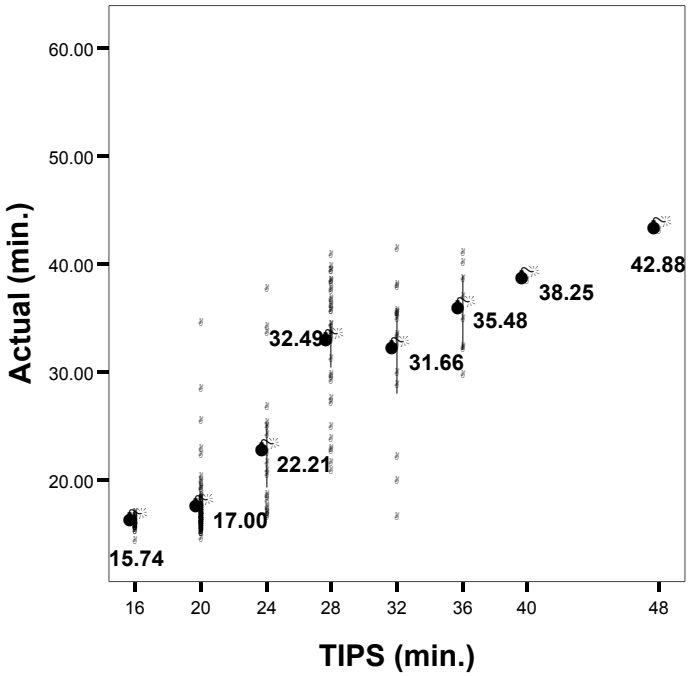
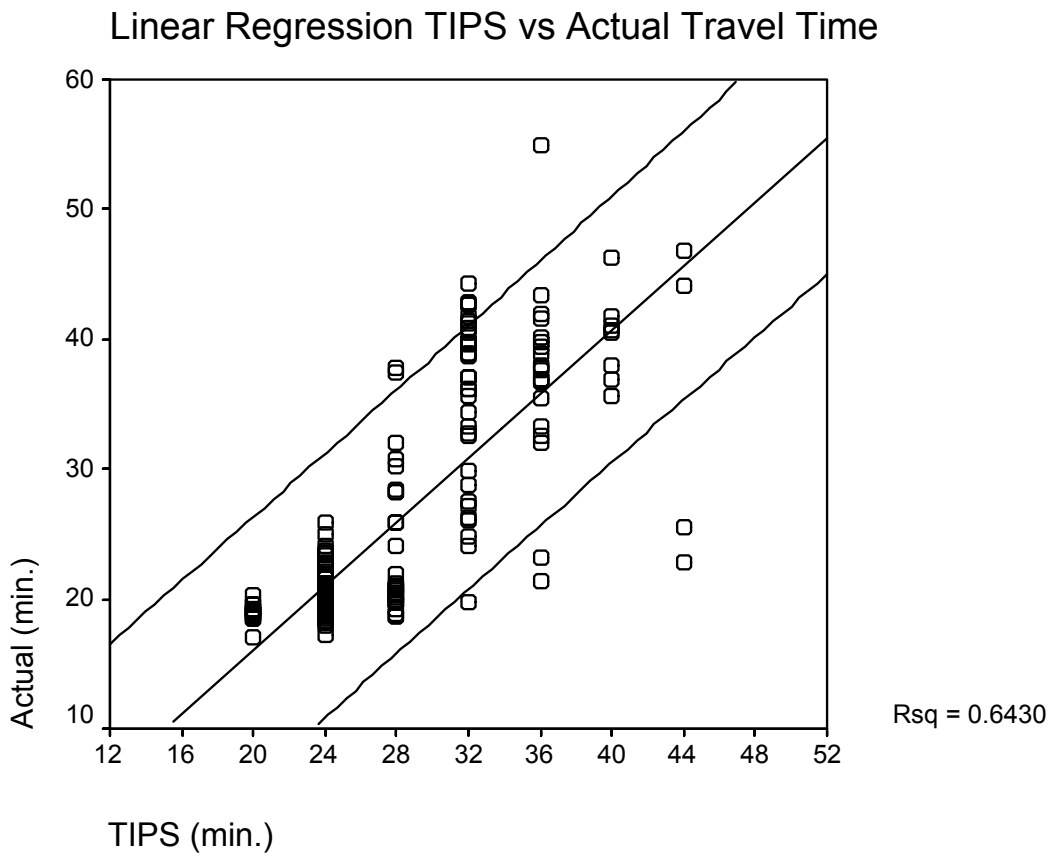
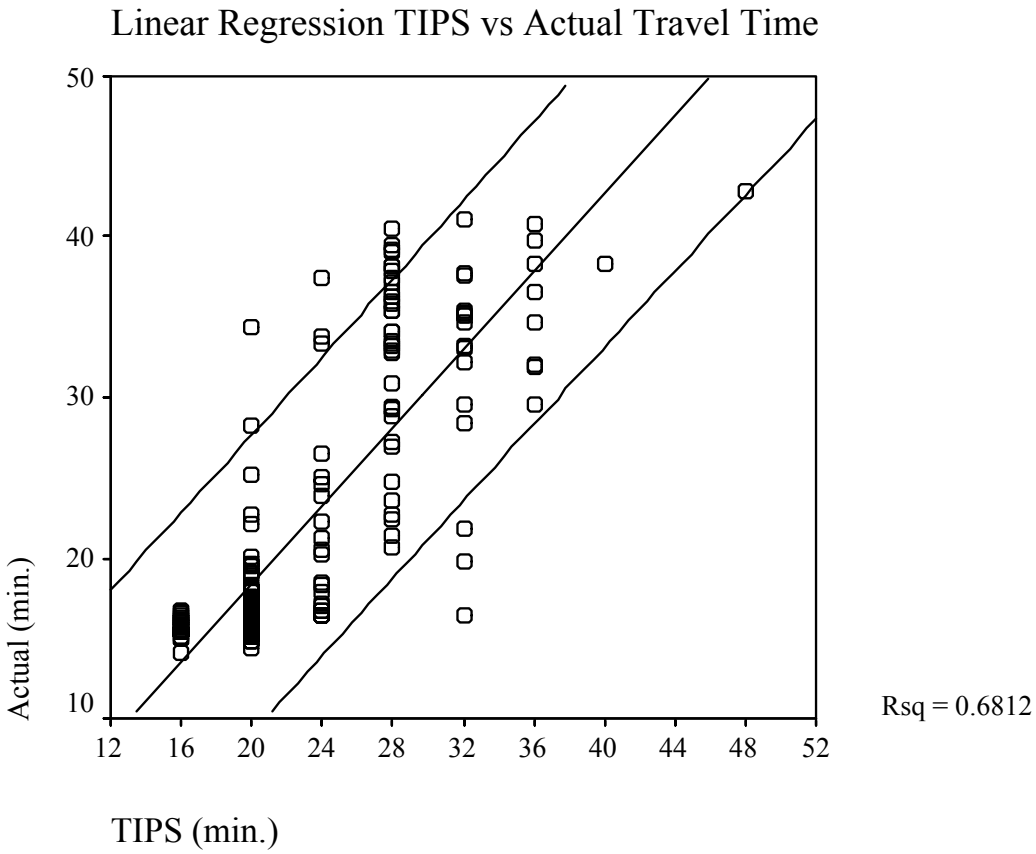


**Figure B7. Linear Regression Model CMS #1**



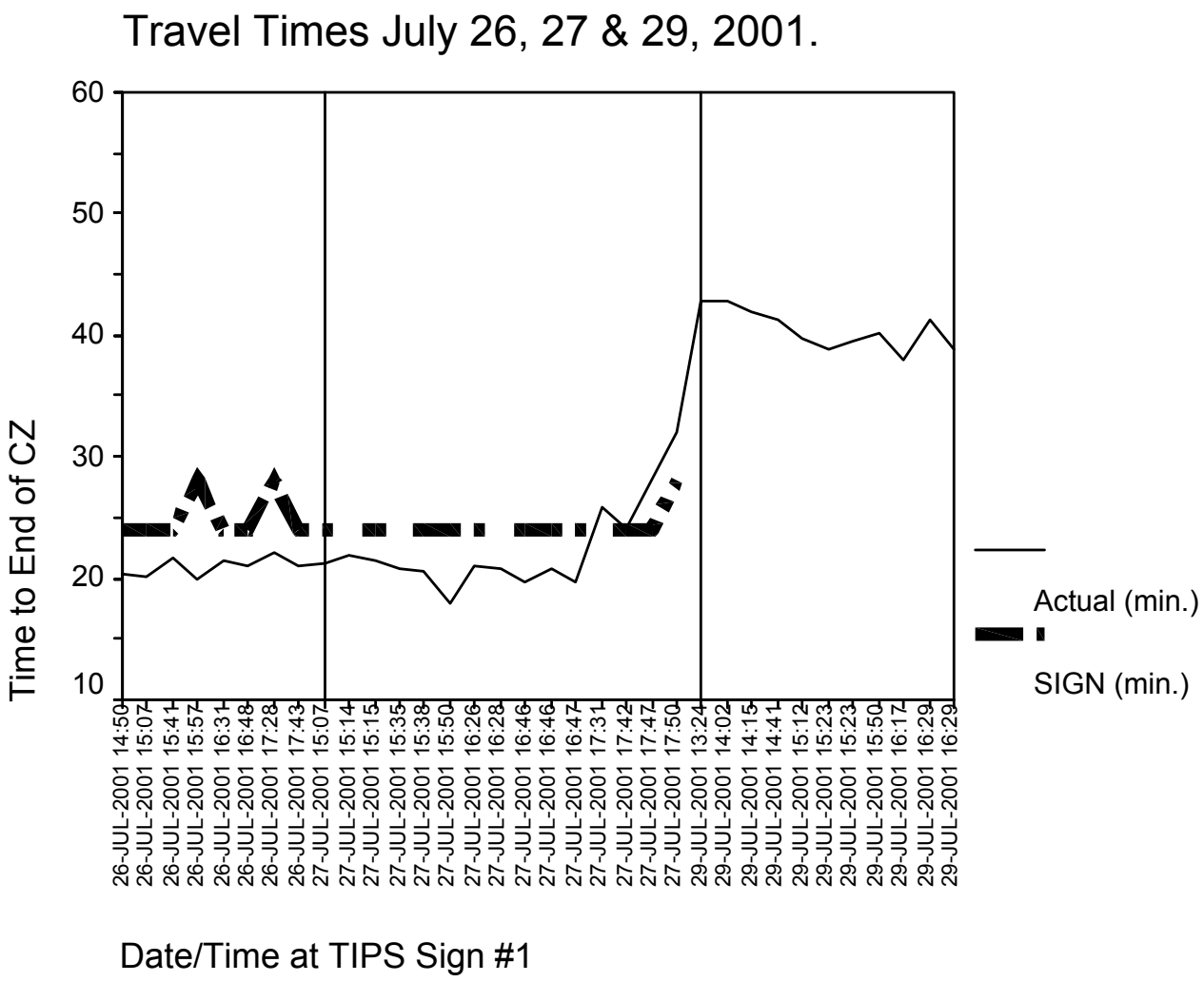

```
Multiple R           .80190
R Square             .64305
Adjusted R Square    .64133
Standard Error      5.13289

            Analysis of Variance:

                DF   Sum of Squares      Mean Square

Regression       1        9872.4254        9872.4254
Residuals      208        5480.0866          26.3466

F =     374.71388       Signif F =  .0000

-------------------- Variables in the Equation --------------------

Variable                   B        SE B       Beta          T  Sig T

TIPS                1.232898     .063691    .801904     19.358  .0000
(Constant)         -8.555075    1.800335                -4.752  .0000
```

**Figure B8. Linear Regression Model CMS #3**




```
Multiple R           .82535
R Square             .68120
Adjusted R Square    .67966
Standard Error      4.70462

            Analysis of Variance:

                DF   Sum of Squares      Mean Square

Regression       1        9837.0274        9837.0274
Residuals      208        4603.7580          22.1335

F =     444.44162       Signif F =  .0000

-------------------- Variables in the Equation --------------------

Variable                   B        SE B       Beta         T  Sig T

TIPS                1.213469     .057560    .825347    21.082  .0000
(Constant)         -5.919832    1.358316               -4.358  .0000
```

**Figure B9. Actual and SIGN Travel Time CMS #1**



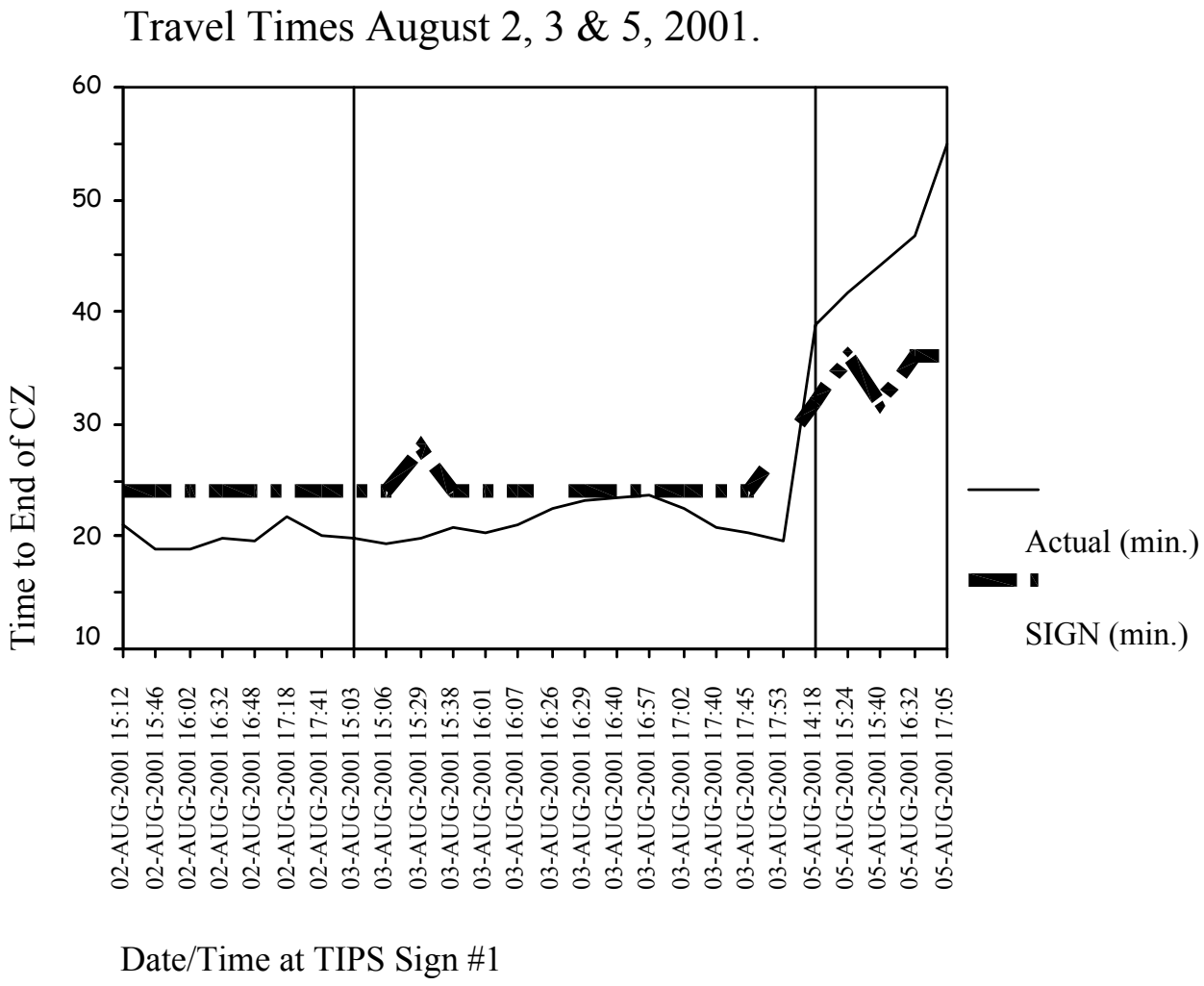

July 27:

Incomplete SIGN information at: 15:14:24, 15:35:18, 16:28:03 and 17:31:52

July 29:

CMS unintelligible

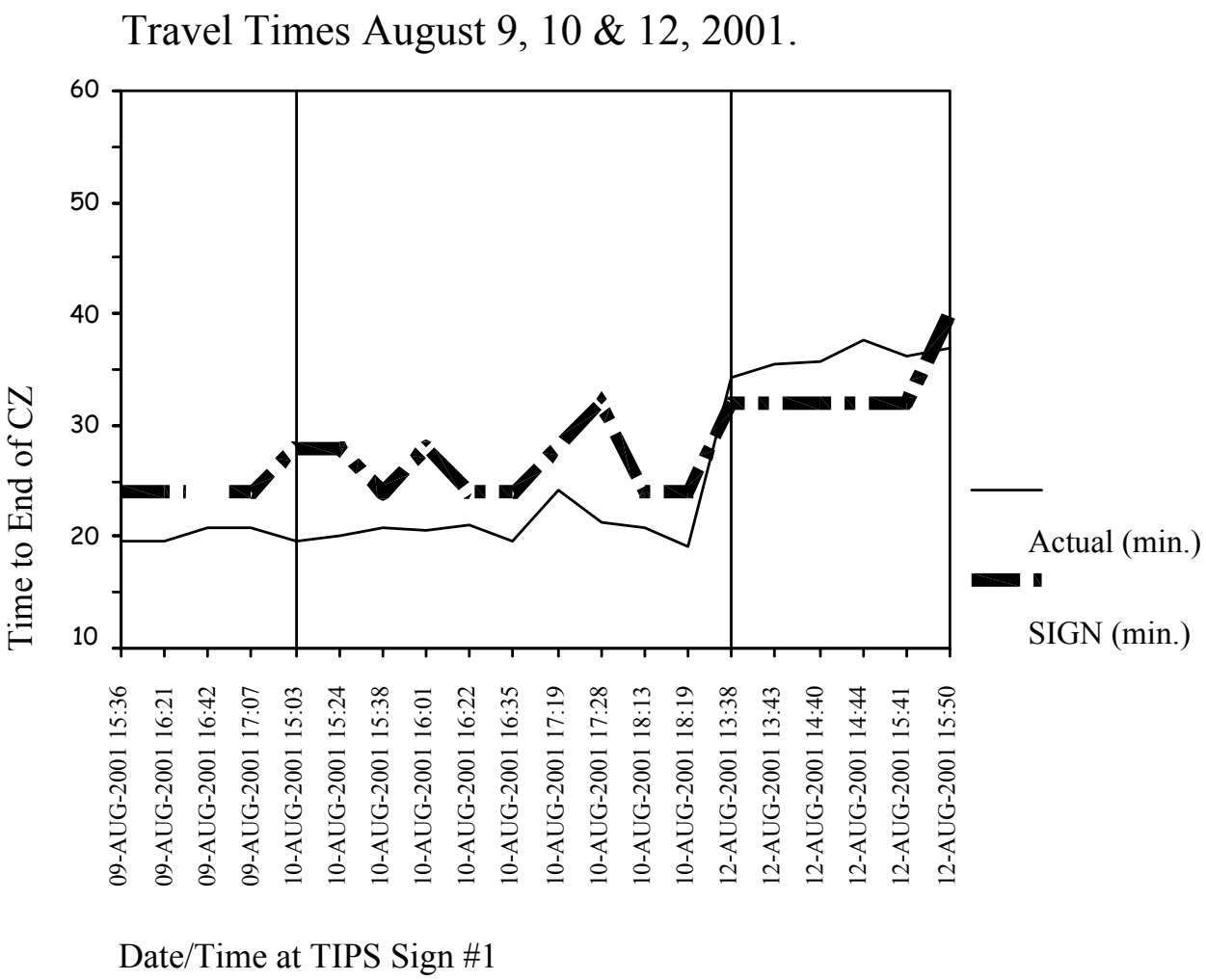
**Figure B9. Actual and SIGN Travel Time CMS #1 (continued)**




August 3:

Incomplete SIGN information at: 16:26:27 and 17:53:51

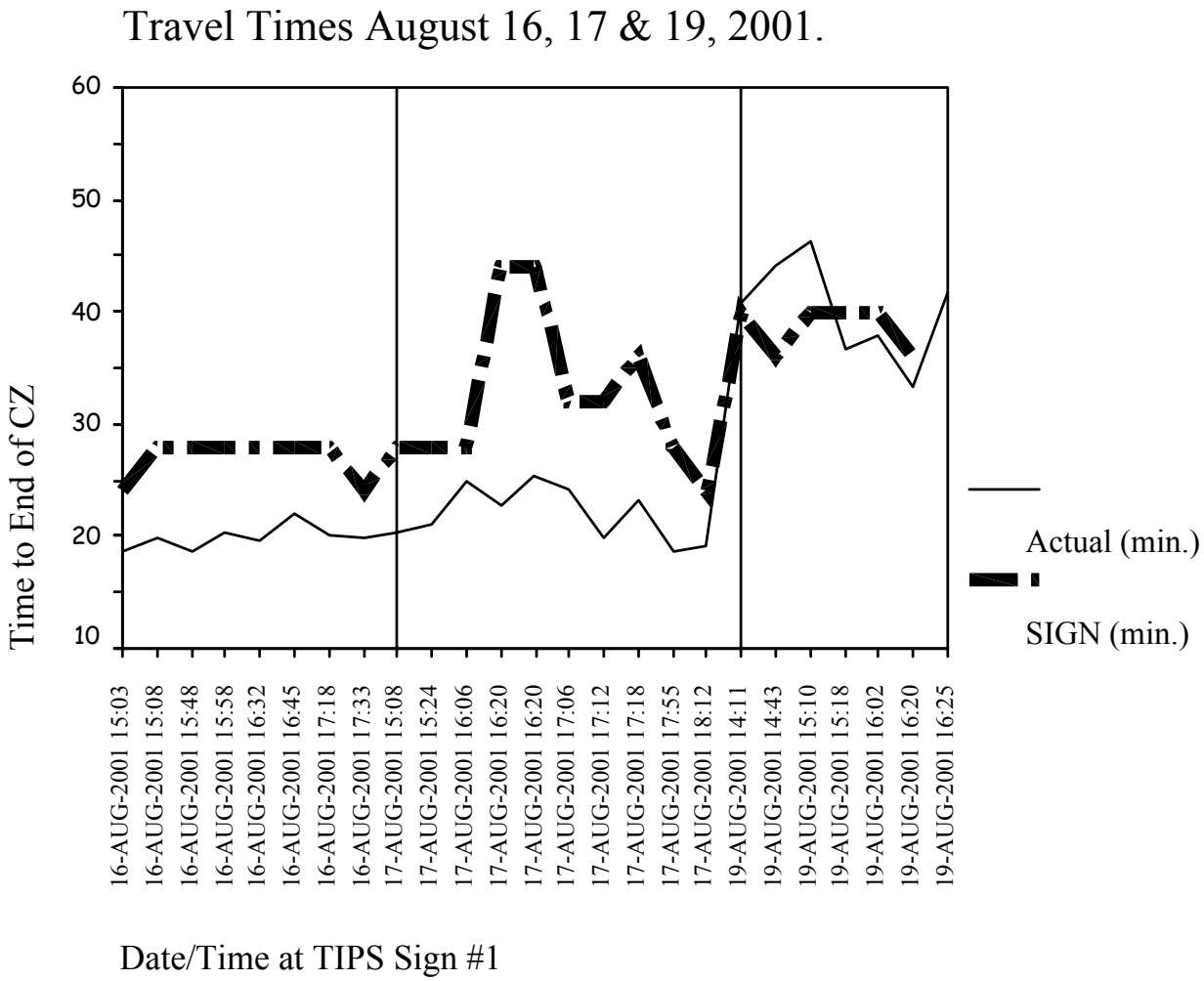
**Figure B9. Actual and SIGN Travel Time CMS #1 (continued)**




August 9:

Incomplete SIGN information at: 16:42:27

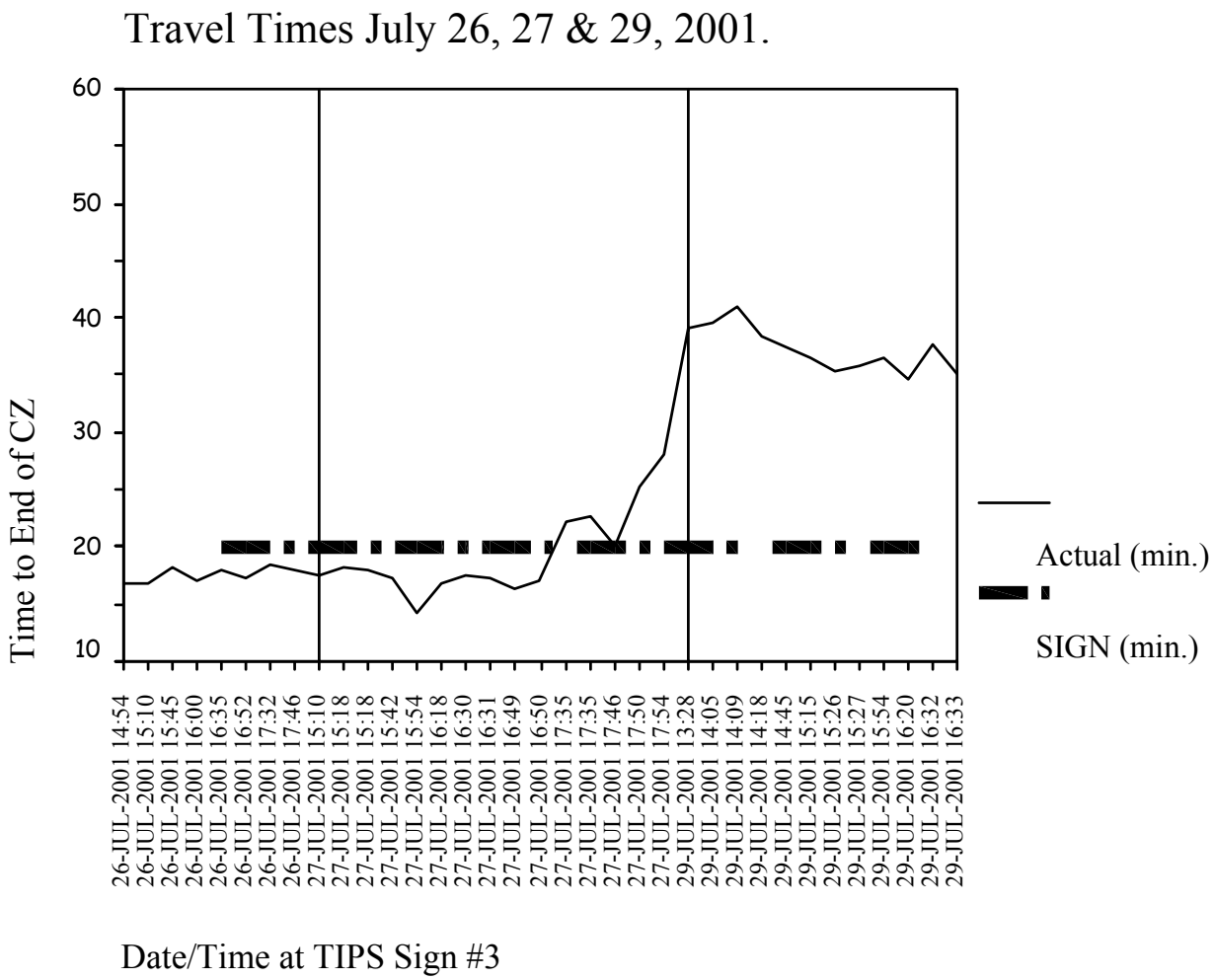
**Figure B9. Actual and SIGN Travel Time CMS #1 (continued)**




August 19:

Incomplete SIGN information at: 16:25:10

**Figure B10. Actual and SIGN Travel Time CMS #3**




July 26:

Blank Message Board 14:54:37
Blank Message Board 15:10:26
WORK ZONE AHEAD 15:45:03
Blank Message Board 16:00:50

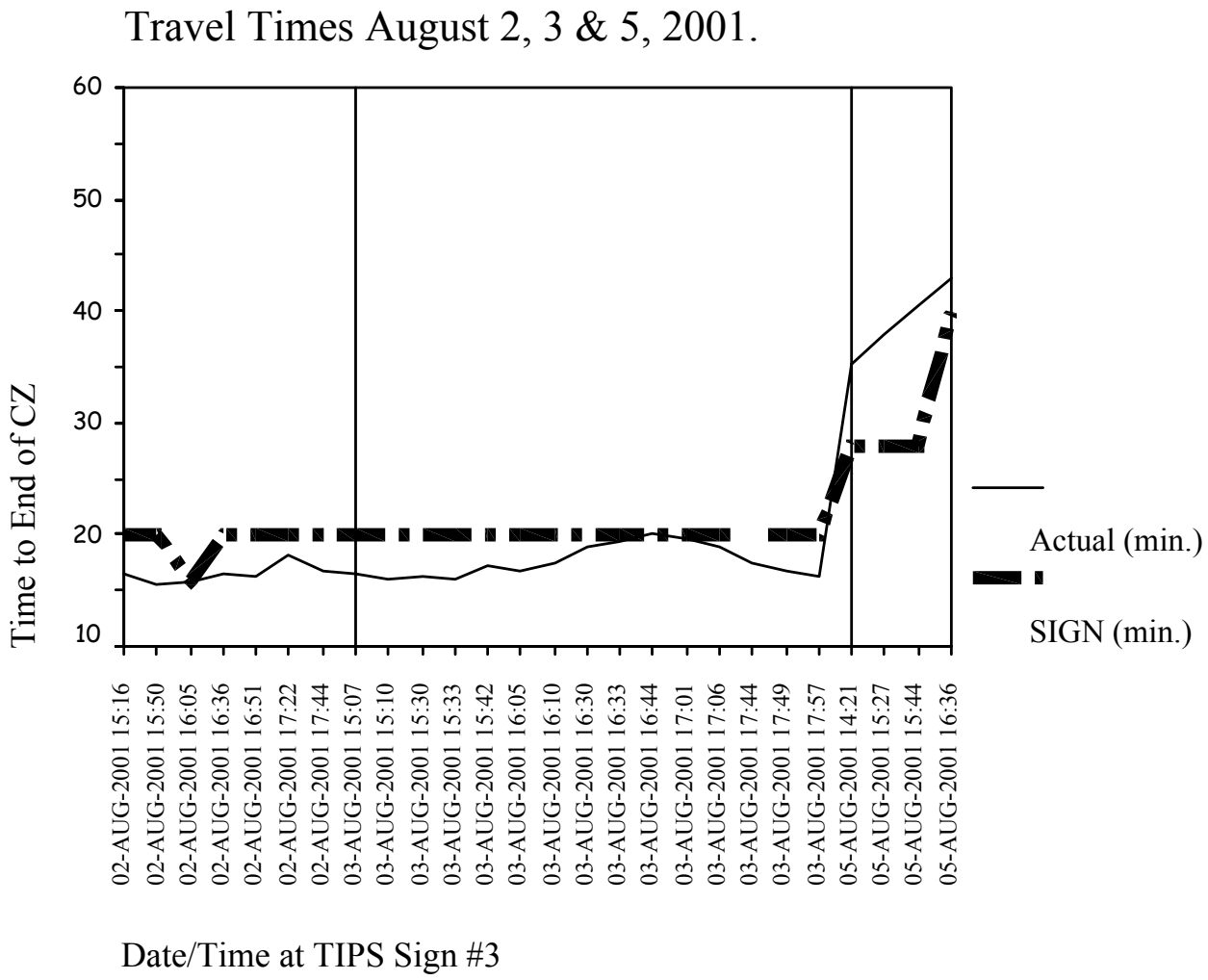
July 27:

Incomplete SIGN information at: 17:35:34

July 29:

Incomplete SIGN information at: 14:18:46
Incomplete SIGN information at: 15:27:34
Incomplete SIGN information at: 16:33:32

**Figure B10. Actual and SIGN Travel Time CMS #3 (continued)**




August 3:

Incomplete SIGN information at: 17:44:08

**Figure B10. Actual and SIGN Travel Time CMS #3 (continued)**

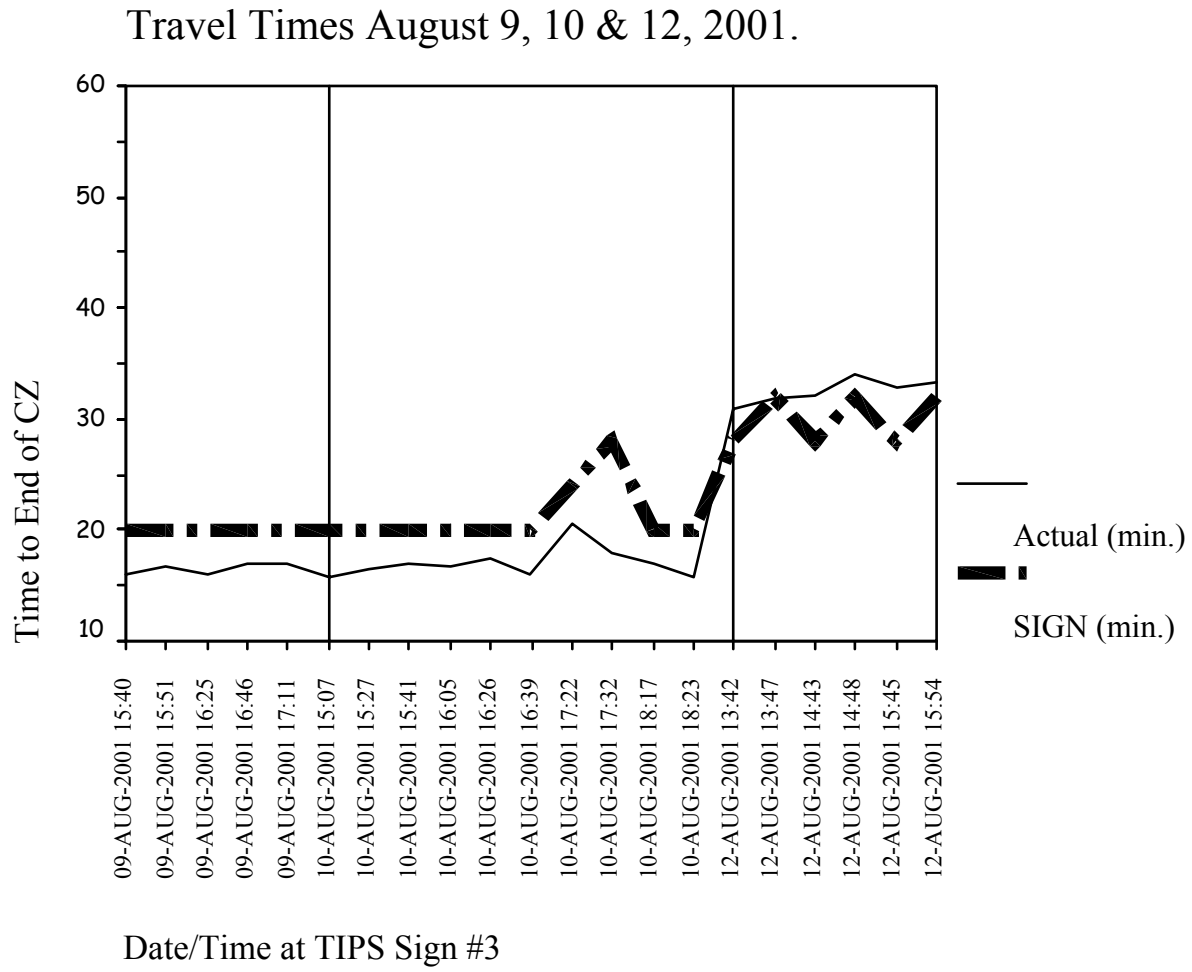
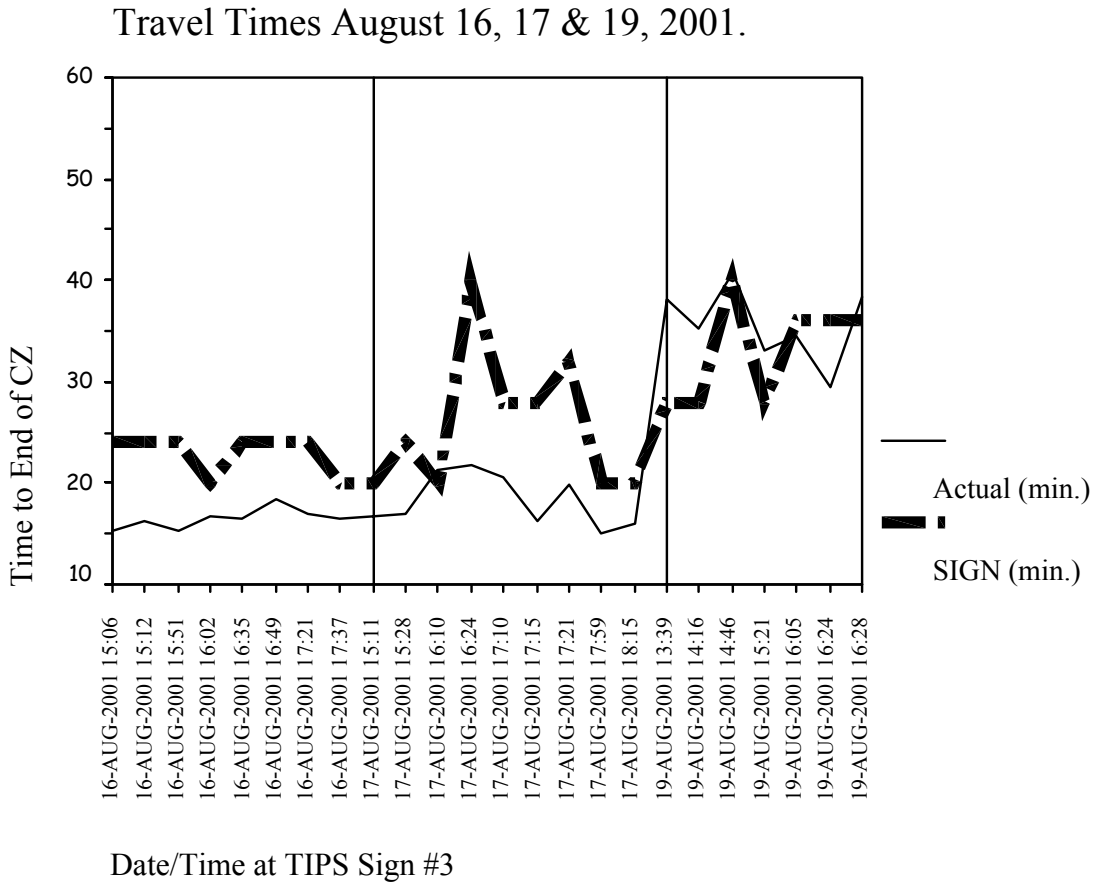


**Figure B10. Actual and SIGN Travel Time CMS #3 (continued)**



# APPENDIX C

# EVALUATION CORRIDOR PHOTOGRAPHS

Picture C1. Southbound Traffic I-94 View From Ryan Road Overpass
(Courtesy of Prahlad Pant)


Picture C2. I-94 Southbound Racine County. Construction Phase One: Left Half of Travel Lanes Removed, Right Shoulder Rumble Strips Patched Over with Asphalt

Picture C3. I-94 Southbound Racine County. Construction Phase Two. Construction Zone Taper Detail: TIPS Detector Visible Behind Arrow Board.

Picture C4. I-94 Southbound Racine County. Construction Phase One. Narrow Gravel Right Shoulder Visible

Picture C5. I-94 Southbound Alternate Route Milwaukee-Racine County Border. Detail of connection between 27th Street and West Frontage Road


Picture C6. I-94 Southbound Alternate Route. Typical Cross-Section of West Frontage Road at 7-mile Road

Picture C7. Alternate Route CTH V Typical Cross-Section


Picture C8. TIPS Computer

Picture C9. I-94 Construction Trailer. The TIPS Antenna is Visible in the Foreground

Picture C10. I-94 Southbound, General Mitchell Airport (GMIA) Exit. CMS #1 and Detector A Visible North of the GMIA Overpass

Picture C11 CMS #2 College Avenue Facing Westbound Traffic


Picture C12. I-94 Southbound, South of Puetz Road, North of Ryan Road CMS #3 and Detector C Visible

Picture C13. CMS #4 Ryan Road Facing Eastbound Traffic


Picture C14. Narrow Left Shoulder on Overpass

# APPENDIX D

# DATA COLLECTION MATERIALS

**DETAILS ABOUT CHECK POINTS**
**Traveling southbound on 27th Str. and northbound on I-94**

- Crossing **roadways are identified** with small green signs on structures, in Milwaukee County. No signs are mounted on structures within Racine County: check points must be identified using information on signs located before the actual check point location. Notice that a sign identifying the location of the next check point may be placed before you reach the current check point.
- **When to record time stamps:** Hit "Enter" when you cross the middle of an intersection (after you have stopped for a red signal), when you cross over the middle of a roadway under the freeway, or the middle of a bridge over the freeway. Exit **gore** is the tip that the right edge lane line forms with the left edge line of a freeway exit ramp.
- When recording to the **tape recorder**:
  1. Let the tape recorder run a couple of seconds before speaking.
  2. Keep comments **short** and **understandable**. You will need to transcribe what you recorded–minimize the time you will need to do that.
  3. Record your **location** (mile points are marked on the median in Milwaukee County, for example 392.4- written vertically on green signs mounted on light posts) **and time**. Use exit numbers in Racine County-estimate how far from an exit you are.
- **Queues**: Traffic moving at 10mph or less. Record **when** you join the queue and at **what milepoint**. Record **when** queue dissipates and **where** you are when this happens.

**Abbreviations:**

NB Northbound = heading north.
SB Southbound = heading south.
E. = East.
W. = West.
N. = North.
S. = South.
CTH = County Trunk Highway.
STH = State Trunk Highway.
US = US highway.
I-94 = Interstate 94.
Str. = Street.
Ave. = Avenue.

**Please be aware that:**

27th Str. is also US 41 and STH 241.
When traveling S. on I-94 you are on EB I-94 (this is also SB US 41 in Racine County).
When traveling N. on I-94 you are on WB I-94 (this is also NB US 41 in Racine County).

**Getting to the Travel Time Run Site**

Exit the Parking Structure to 17th Str. (one-way southbound).

Turn Right on Clybourn (1st signal south of Wisconsin Ave.)

Turn left on 25th Str. (See signs to East I-94, mounted on light posts on Clybourn).

Make a **sharp** left **immediately after** the bridge over the freeway (I-94). This is the ramp to southbound (east) I-94.

Ramp lane merges into the right-most lane of I-94. Stay in that lane.

Follow the right-hand ramp **to 43, 94, 41 South--Chicago**, after passing the 13th Str. Exit 310 A.

Move one lane to the left at the end of the ramp and continue south (east) on I-94. Speed limit is 50 mph. It later changes to 55 mph.

Speed limit goes back down to 50 mph in advance of a curve to the right after Howard Ave 3900 S. Change lanes to the middle lane.

Stay on I-94 (to Chicago and Mitchell Airport) past the point where I-894 westbound (also named I-43 south) peels off to the right to go to Beloit.

**Record** the presence of any freeway **queue: time and location.** Record time, your direction of travel, and location when queue dissipated.

Sign: Exit 319 College Ave. 1/4 mile.

Speed limit 55 mph.

Go to the next page.

**Check points traveling Southbound on 27th Street**

***Numbers correspond to check point numbers on your spreadsheet***

**Exit freeway to WB College Ave. (CTH ZZ), Exit 319.**

Notice any TIPS message ("TRAVEL TIME TO END OF CONSTRUCTION ZONE ... MINUTES") and record it on the tape recorder. Record location, direction of travel and time. **This is very important!**

1. First signal at 20th Str. Enter your first check point.–get ready!

2. Left turn on 27th Str. (STH 241 or US 41, signed as Alt 94) (second signal after interchange). Approximately 20 minutes after leaving Marquette.

Notice any TIPS message ("TRAVEL TIME TO END OF CONSTRUCTION ZONE ... MINUTES") and record it on the tape recorder. Record location, direction of travel and time. **This is very important!**

3. Sycamore Str./Sycamore Ave. (signal)

4. Rawson Ave. (CTH BB) 7100 S. (signal). Right lane ends south of BB.

5. Drexel Ave. 7900 S. (signal)

6. Ryan Rd. (STH 100) 9500 S. (signal)

**Attention!!! Approximately 1.7 miles S. of Ryan Rd:**

- I-94 becomes visible at the extension of 27th.
- Watch for Changeable Message Sign (CMS) visible on median displaying messages: "TRAFFIC PATTERNS CHANGED" "STAY ALERT" "TRUCKS ENTERING AND EXITING HIGHWAY" etc.

- "Alternate 94" blue freeway sign on right shoulder points straight-ahead. **Slow down–you are about to make a right turn.**

3 signs will come into view suddenly on the right-hand shoulder (see picture below):

- "Racine Co." small green sign mounted on light post.
- "West Frontage Road" white rectangular sign with black arrow pointing to the right.
- "Alternate 94" blue freeway shield sign points to the right.

**Frontage road starts at a 90 deg. right turn** right there. **Turn right!**

7. **Leaving 27th Str. and starting on the West Frontage Road.**


8. 7-Mile Rd. STOP
Undivided highway.

9. CTH G Exit 327. STOP
Over I-94.

10. CTH K E-W Exit 329. STOP
Undivided highway.

11. STH 20 Exit 333. SIGNAL **Stay on right-hand lane** to continue straight.
Divided highway.

**Attention!!!**
Continue straight across the intersection.
You will need to make a 90 degree turn to the left, to avoid the Grand View Business park at the extension of the frontage road. Notice white rectangular sign pointing to West Frontage Road on the right side of the roadway. Get in the left lane (see picture below). A 90 degree right turn follows shortly, and the frontage road continues south.

Picture: **West Frontage Road S of CTH 20, facing south: Grand View Business Park.**

**Attention!!!** After approximately 1.5 miles:
58th Rd. Three sets of rumble strips as you approach this stop sign.
Undivided highway.
W. Frontage Rd. (Sylvania Ave.) makes **a right turn and then a left turn** to continue south.



12. STH 11 Exit 335 STOP
Divided highway.

13. CTH KR Exit 337. STOP. Signs to "Dragaway." Camera mounted on top of pole, west side of structure.

This is the **south end of your travel time run.** (Racine-Kenosha County Line)
Turn left at STOP sign, go **under freeway**, **turn left** at next STOP sign **on East Frontage road**. Heading North, to start I-94 northbound run.

**Check points traveling northbound (WB) on I-94.**

**Use** East Frontage Road **ramp to get back on I-94 northbound immediately north of KR**.

14. I-94 on-ramp.

15. STH 11 Exit 335.
Divided highway.
Small silver silos on right-hand side ( E of I-94).

16. CTH 20 Exit 333.
Divided highway.
Post-mounted camera on bridge.
Sheriff substation.
Crash investigation site.

17. CTH K E-W Exit 329.
Undivided highway.
Post-mounted camera on structure.

18. CTH G E-W Exit 327.
Over I-94.
Post-mounted camera on bridge.

19. 7-Mile Rd Exit 326.
Two-lane undivided highway.
AMOCO gas station right-hand side (E of I-94).

20. Exit to 27th Str. is closed with barricades.
Time stamp when passing exit gore.

**Entering Milwaukee County.**
**End of construction zone.** Three through lanes.
Bridges are marked with crossing highway name.
Mileposts every 1/10th of a mile mounted on light posts in the median.
Decreasing milepoints northbound.

21. Oakwood Rd. 10300 S.

22. Ryan Rd. (STH 100) 9500 S. Exit 322.

23. Puetz Rd. 8700 S.
Milepost 321.9 (on median).

24. Drexel Ave. 7900 S.
Milepost 320.9 (on median).

25. Rawson Ave. (CTH BB) Exit 320.
Milepost 319.9 (on median).

26. College Ave (CTH ZZ) Exit 319.
Mark exit gore. (When you **begin** traveling on the exit ramp).

**North end of run. Prepare for next SB run.**

Go to top of ramp, turn left to travel westbound to 27th Str. (STH 241).

Go back to Control Point **1**, page 3.

**DETAILS ABOUT CHECK POINTS**
**TRAVELING ON I-94**

- **Crossing roadways are identified** with small green signs on structures, in Milwaukee County. No signs are mounted on structures within Racine County: check points must be identified using information on signs located before the actual check point location. Notice that a sign identifying the location of the next check point may be placed before you reach the current check point.
- **When to record time stamps:** Hit "Enter" when you cross the middle of an intersection (after you have stopped for a red signal), when you cross over the middle of a roadway under the freeway, or the middle of a bridge over the freeway. Exit **gore** is the tip that the right edge lane line forms with the left edge line of a freeway exit ramp.
- When recording to the tape recorder:

1. Let the **tape recorder** run a couple of seconds before speaking.
2. Keep comments **short** and **understandable**. You will need to transcribe what you recorded–minimize the time you will need to do that.
3. Record your **location** (mile points are marked on the median in Milwaukee County, for example 392.4- written vertically on green signs mounted on light posts) **direction of travel and time**. Use exit numbers in Racine County-estimate how far from an exit you are.

- **Queues**: Traffic moving at 10 mph or less. Record **when** you join the queue and at **what milepoint**. Record **when** queue dissipates and **where** you are when this happens.

**Abbreviations:**

NB Northbound = heading north.
SB Southbound = heading south.
E. = East.
W. = West.
N. = North.
S. = South.
CTH = County Trunk Highway.
STH = State Trunk Highway.
US = US highway.
I-94 = Interstate 94.
Str. = Street.
Ave. = Avenue.

**Please be aware that:**

27th Str. is also US 41 and STH 241.
When traveling S. on I-94 you are on EB I-94 (this is also SB US 41 in Racine County).
When traveling N. on I-94 you are on WB I-94 (this is also NB US 41 in Racine County).

**Getting to the Travel Time Run Site**

Exit the Parking Structure to 17th Str. (one-way southbound).

Turn Right on Clybourn (1st signal south of Wisconsin Ave.)

Turn left on 25th Str. (See signs to East I-94, mounted on light posts on Clybourn).

Make a **sharp** left **immediately after** the bridge over the freeway (I-94). This is the ramp to southbound (east) I-94.

Ramp lane merges into the right-most lane of I-94. Stay in that lane.

Follow the right-hand ramp **to 43, 94, 41 South--Chicago**, after passing the 13th Str. Exit 310 A.

Move one lane to the left at the end of the ramp and continue south (east) on I-94. Speed limit is 50 mph. It later changes to 55 mph.

Speed limit goes back down to 50 mph in advance of a curve to the right after Howard Ave 3900 S. Change lanes to the middle lane.

Stay on I-94 (to Chicago and Mitchell Airport) past the point where I-894 westbound (also named I-43 south) peels off to the right to go to Beloit.

**Record** the presence of any freeway **queue: time and location.** Record time, your direction of travel, and location when queue dissipated.

Place first time stamp on your spreadsheet, as you pass the junction to 894 on your first run. Exit 317 Layton Ave. coming up. Second time stamp will be the **on-ramp tip of the gore area.**

It should take approximately 14 minutes to get here when the freeway is not congested.

Speed limit 55 mph.

Go to the next page item **5**.

**Check points traveling southbound (EB) on I-94**

***Numbers correspond to check point numbers on your spreadsheet***

1. Enter first time stamp while traveling westbound on Layton Ave.-get ready.

2. Left turn on 20th (first signal after interchange)

3. Left turn at first median opening to get on SB on-ramp.

4. Mark on-ramp gore tip.

5. General Mitchell International Airport Exit 318
Milepost 318.0 (posted on median light post)
Right lane will become exit only for Exit 318 to Mitchell International Airport. Move one lane to the left.

Notice any TIPS message ("TRAVEL TIME TO END OF CONSTRUCTION ZONE ... MINUTES") and record it on the tape recorder. Record location, direction of travel and time. **This is very important!**

6. College Ave. (CTH ZZ) Exit 319
Over I-94.

7. Rawson Ave. (CTH BB) Exit 320
Over I-94.

8. Drexel Ave. 7900 S.
Over I-94

9. Puetz Rd. 8700 S.
Over I -94

Notice any TIPS message ("TRAVEL TIME TO END OF CONSTRUCTION ZONE ... MINUTES") and record it on the tape recorder. Record location, direction of travel and time. **This is very important!**

10. Ryan Rd. (STH 100) 9500 S. Exit 322
Over I-94

11. Oakwood Rd. 10300 S.
Under I-94

I-94 curves to the right.
Racine Co. Sign 11100 S (small green sign)
I-94 curves to the left. **This is where the on-ramp from 27th SB (US 41 SB) connects.**
No signs on bridges in Racine County.
Watch for signs **before** a check point. Be alert when the check point is coming up.

12. 27th SB not easy to see-joins at acute angle as I-94 curves to the left

13. 7-Mile Rd. Exit 326
Under I-94

14. CTH G Exit 327
bridge over I-94.
Post-mounted camera on bridge.

15. CTH K Exit 329
Under I-94

16. STH 20 Exit 333
Under I-94. Divided highway.
Sheriff Substation
Crash Investigation Site

17. STH 11 Exit 335. (**Attention! you cross STH 11 before the exit–record check point properly)**
Under I-94.
Divided highway.

18. CTH KR **Exit 337. Get off the freeway.**
**Time stamp when passing exit gore.**

19. **Time stamp when crossing KR STOP sign.**

STOP sign is the Racine-Kenosha County Line. **South end of travel time run.**
Turn left at STOP sign, go under freeway, turn left at next STOP sign on East Frontage road.
Heading North, to start I-94 northbound run.

**Use** East Frontage Road **on-ramp to I-94 immediately north of KR**.

**Check points traveling northbound (WB) on I-94.**

20. **I-94 on-ramp immediately north of KR**.

21. STH 11 Exit 335.
Under I-94.
Divided highway.
Silver silos on right-hand side (E of I-94).

22. CTH 20 Exit 333.
Under I-94.
Divided highway.
Post-mounted camera on bridge.
Sheriff substation.
Crash investigation site.

23. CTH K E-W Exit 329
Under I-94.
Undivided highway.
Post-mounted camera on structure.

24. CTH G E-W Exit 327
Over I-94.
Post-mounted camera on bridge.

25. 7-Mile Rd Exit 326.
Under I-94.
Undivided highway.
AMOCO gas station right-hand side (E of I-94).

26. Exit to 27th Str. is closed with barricades.
**Time stamp when passing exit gore.**

Entering Milwaukee County.
End of construction zone. Three through lanes.
Bridges are marked with crossing highway name.
Mileposts every 1/10th of a mile mounted on light posts in the median.
Decreasing milepoints northbound.

27. Oakwood Rd. 10300 S.
Under I-94.

28. Ryan Rd. (STH 100) 9500 S. Exit 322
Over I-94.

29. Puetz Rd. 8700 S.
Over I-94.
Milepost 321.9 (on median).

30. Drexel Ave. 7900 S.
Over I-94.
Milepost 320.9 (on median).

31. Rawson Ave. (CTH BB) Exit 320.
Over I-94.
Milepost 319.9 (on median).

32. College Ave (CTH ZZ) Exit 319.
Over I-94.
Milepost 318.9 (on median).

33. General Mitchell International Airport (STH 119) Exit 318.
Over I-94. Name not marked on structure.
Milepost 318.2 (on median).

34. Layton Ave. (CTH Y) Exit 317. **Get off freeway, to WB Layton Ave.** Use loop ramp past the Layton Avenue structure, which crosses over I-94.
**Time stamp when passing under the Layton bridge.**

**North end of travel time run. Prepare for next SB run. Go to item 1 page 3.**

**Special instructions for first run on I-94:**

Start Quattro Pro, open "timer94.wb3."

Left-click on the button "Run 1" when you are about where I-894 separates from I-94.
This will place a time stamp next to the first check point, used only to test that the program is running ok.

Use the down arrow to skip to check point #4 (Layton Avenue I-94 on-ramp gore).
This ramp is after the Layton Avenue bridge over I-94.
Hit Enter as you pass by the tip of the gore. Continue hitting "Enter" as you pass check points.

When ready for Run 2, left-click on the "Run 2" button to place the test check point. This time you will be marking check points 2 and 3 as you cross them, hitting "Enter."

**Difficult to locate check point:**

Check point #12 (27th Street/US41 on-ramp) is difficult to locate.
Watch for a curve to the right, after you cross Oakwood.
A "Racine County" small green rectangular sign is on the right shoulder, just before you enter the next curve (to the left). The on-ramp joins I-94 exactly as you make the left turn, and it should be over your right shoulder.

# TRICKY CHECKPOINTS AT THE BEGINNING OF YOUR RUNS

TRAVELING southbound on I-94 **first run of the day:**
**Do not exit here** LAYTON AVENUE (EXIT 317)
The exit is AFTER the Layton Ave. bridge. **Not a checkpoint!**

TRAVELING southbound on I-94
**Check point #4 Layton Avenue on-ramp gore**
(follows the Layton Avenue exit shown above)
**Mark the tip that the two white lines form**, seen between the passenger car and the pickup truck.

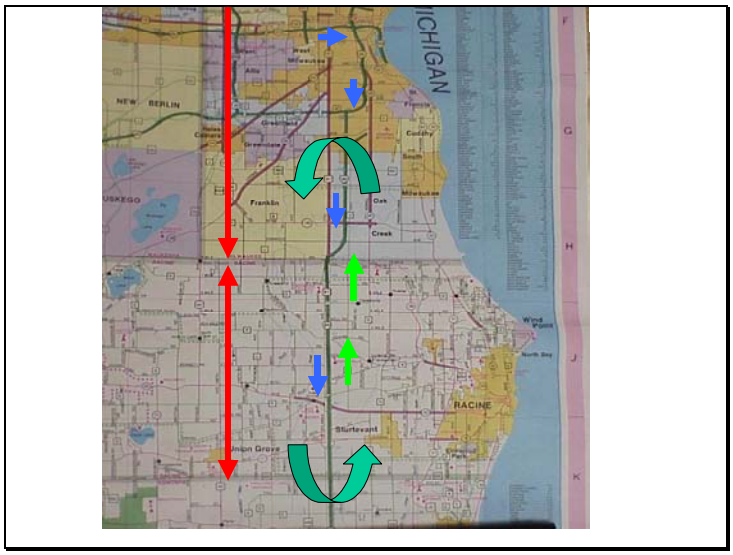
Traveling southbound on I-94. Sign reads: “Exit 315, Gen Mitchell Int’l Airport, Exit Only”
Attention: **this is not checkpoint #5**
The proper location for checkpoint #5 is shown in the next picture.


**I-94 southbound: checkpoint #5:** the sign reads:
“City of Cudahy, Milwaukee Area Tech College, South Campus, Exit 319”
There is no sign on the bridge itself. **Bridge beams are red-brown color.**

**I-94 southbound: checkpoint #12:** After Oakwood, you have entered a gentle curve to the right, and now you are exiting a gentle curve to the left. You are already in the construction zone, and you went over a bridge that is being reconstructed. Leaving the bridge, you will see the yellow merge sign behind the guardrail—this is the merge with 27th Street southbound traffic.


**I-94 southbound: checkpoint #12:** A little past the yellow diamond merge sign you will see the on-ramp. **Mark the tip where the two white lines meet. This is an important point for the study.**

Slide 1



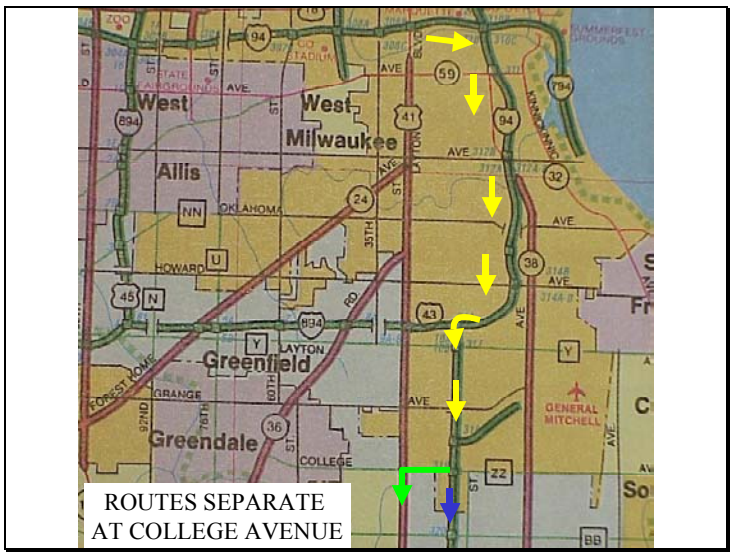

Slide 2

Slide 3


Slide 4

Slide 5


Slide 6



Slide 7


Slide 8

Slide 9

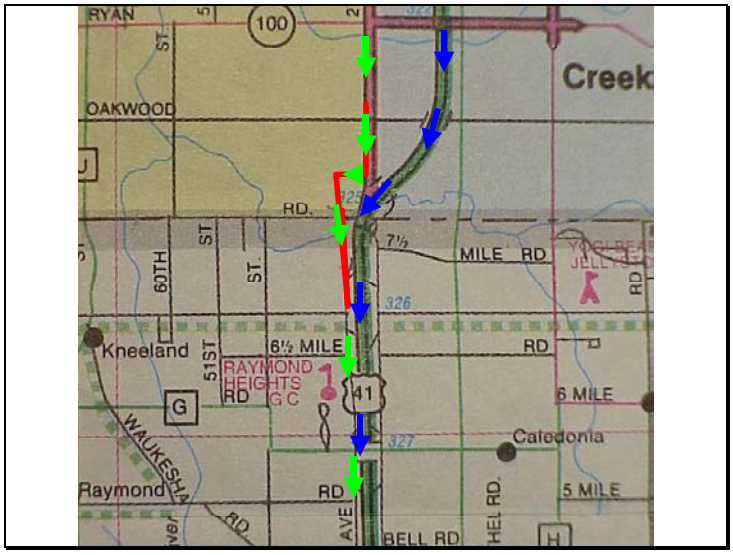

Slide 10

Slide 11


Slide 12

Slide 13

Slide 14



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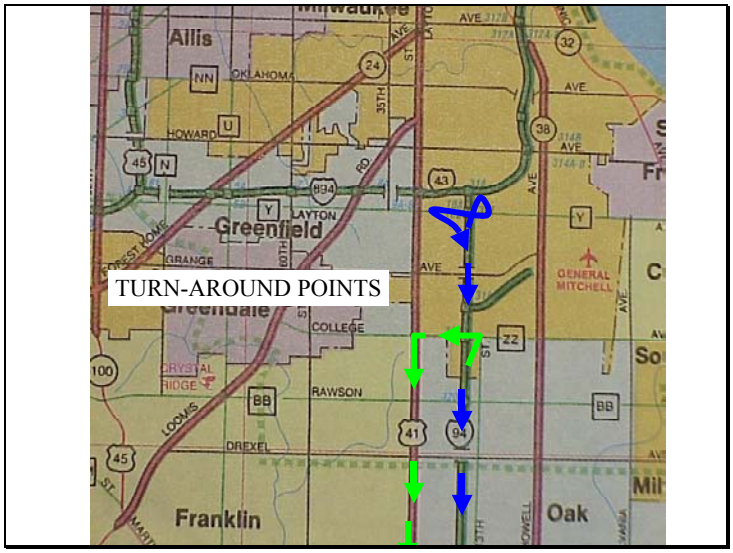
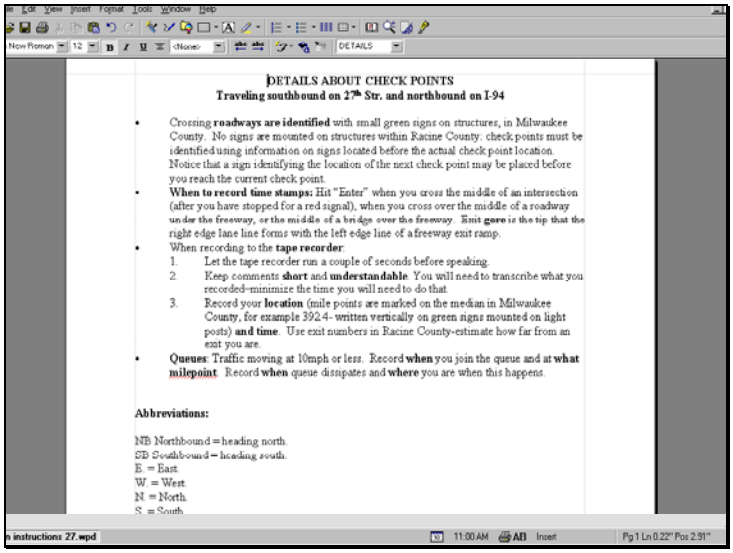
Slide 37

Slide 38



Slide 39


Slide 40



DETAILS ABOUT CHECK POINTS

**Traveling southbound on 27th Str. and northbound on I-94**

- Crossing **roadways are identified** with small green signs on structures, in Milwaukee County. No signs are mounted on structures within Racine County. check points must be identified using information on signs located before the actual check point location. Notice that a sign identifying the location of the next check point may be placed before you reach the current check point.
- **When to record time stamps:** Hit "Enter" when you cross the middle of an intersection (after you have stopped for a red signal), when you cross over the middle of a roadway under the freeway, or the middle of a bridge over the freeway. **Exit gore** is the tip that the right edge lane line forms with the left edge line of a freeway exit ramp.
- When recording to the **tape recorder**:
  1. Let the tape recorder run a couple of seconds before speaking.
  2. Keep comments **short** and **understandable**. You will need to transcribe what you recorded–minimize the time you will need to do that.
  3. Record your **location** (mile points are marked on the median in Milwaukee County, for example 392.4- written vertically on green signs mounted on light posts) **and time**. Use exit numbers in Racine County-estimate how far from an exit you are.
- **Queues**: Traffic moving at 10mph or less. Record **when** you join the queue and at **what milepoint**. Record **when** queue dissipates and **where** you are when this happens.

**Abbreviations:**

NB Northbound = heading north.
SB Southbound = heading south.
E. = East.
W. = West.
N. = North.
S. = South.

Slide 41

## DETAILS ABOUT CHECK POINTS

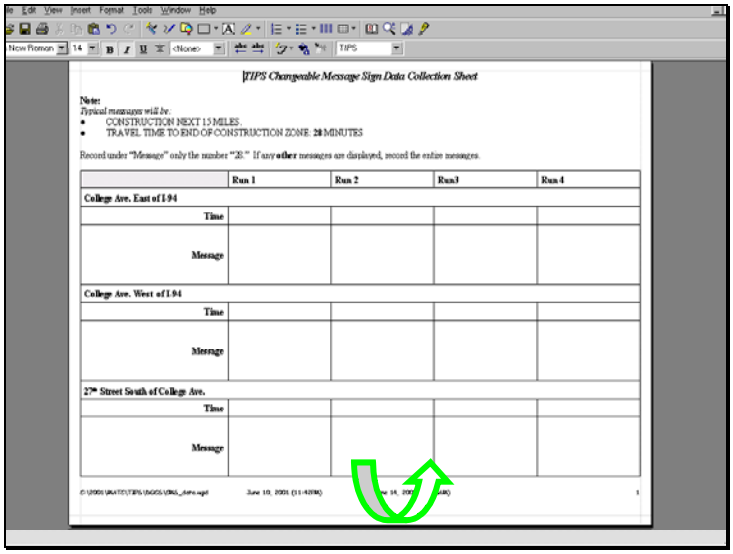
- Crossing **roadways are identified**
- **When to record time stamps**
- Recording to the **tape recorder**. **location and time**
- **Queues**: **when, what milepoint**.
- **Abbreviations**
- **Please be aware that...**

Slide 42

## Getting to the Travel Time Run Site

- 17th Str. (one-way southbound).
- Right on Clybourn (1st signal S. of Wisc.)
- Turn left on 25th Str.
- Make a **sharp** left **immediately after** the bridge over the freeway (I-94).
- Follow the right-hand ramp **to 43, 94, 41 South--Chicago**, after passing the 13th Str. Exit 310 A.

Slide 43



*TIPS Changeable Message Sign Data Collection Sheet*

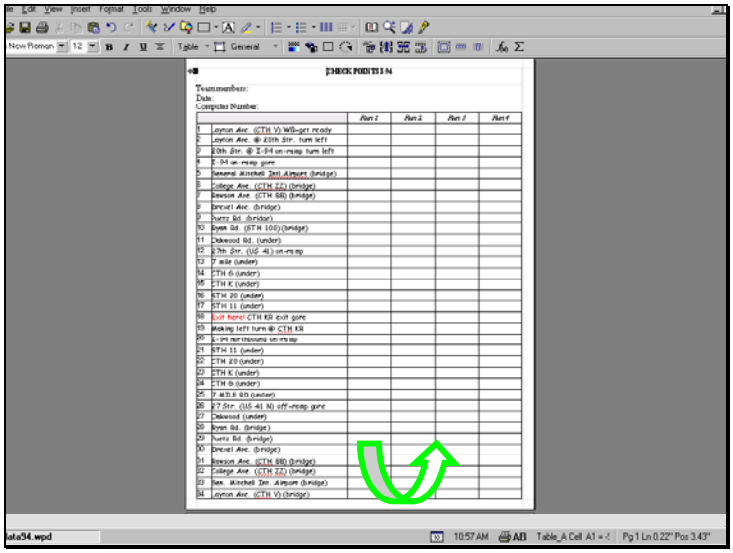
**Note:**
*Typical messages will be:*

- CONSTRUCTION NEXT 15 MILES.
- TRAVEL TIME TO END OF CONSTRUCTION ZONE: **20** MINUTES

Record under "Message" only the number "20." If any **other** messages are displayed, record the entire messages.

| | Run 1 | Run 2 | Run3 | Run 4 |
|---|---|---|---|---|
| **College Ave. East of I-94** | | | | |
| **Time** | | | | |
| **Message** | | | | |
| **College Ave. West of I-94** | | | | |
| **Time** | | | | |
| **Message** | | | | |
| **27th Street South of College Ave.** | | | | |
| **Time** | | | | |
| **Message** | | | | |

Slide 44

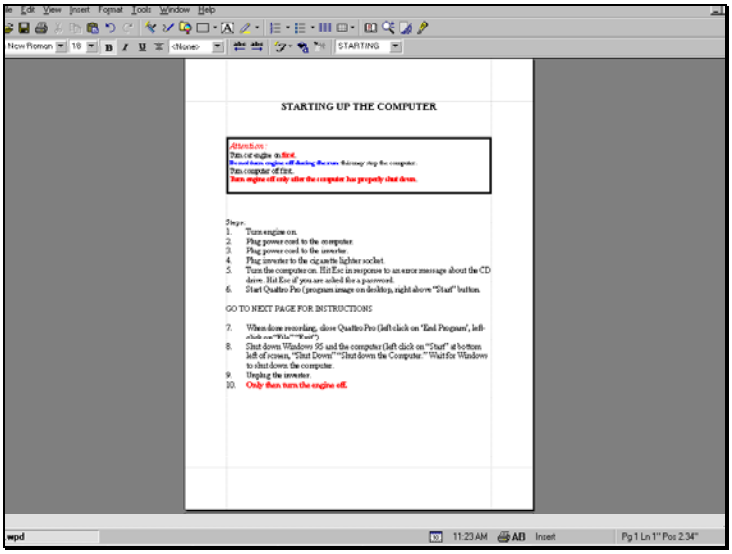


**CHECK POINTS I-94**

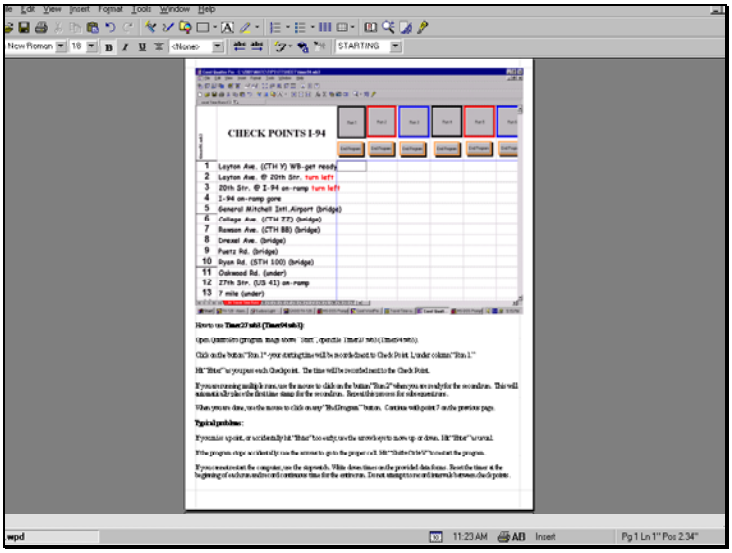
Team members:
Date:
Computer Number:

| | | Run 1 | Run 2 | Run 3 | Run 4 |
|---|---|---|---|---|---|
| 1 | Layton Ave. (CTH V) WB–get ready | | | | |
| 2 | Layton Ave. @ 20th Str. turn left | | | | |
| 3 | 20th Str. @ I-94 on-ramp turn left | | | | |
| 4 | I- 94 on-ramp gone | | | | |
| 5 | General Mitchell Intl. Airport (bridge) | | | | |
| 6 | College Ave. (CTH ZZ) (bridge) | | | | |
| 7 | Dawson Ave. (CTH BB) (bridge) | | | | |
| 8 | Drexel Ave. (bridge) | | | | |
| 9 | Yuetz Rd. (bridge) | | | | |
| 10 | Ryan Rd. (STH 100)(bridge) | | | | |
| 11 | Oakwood Rd. (under) | | | | |
| 12 | 27th Str. (US 41) on-ramp | | | | |
| 13 | 7 mile (under) | | | | |
| 14 | CTH O (under) | | | | |
| 15 | CTH K (under) | | | | |
| 16 | STH 20 (under) | | | | |
| 17 | STH 11 (under) | | | | |
| 18 | Exit here! CTH KR exit gone | | | | |
| 19 | Making left turn @ CTH KR | | | | |
| 20 | I- 94 northbound on-ramp | | | | |
| 21 | STH 11 (under) | | | | |
| 22 | CTH 20 (under) | | | | |
| 23 | CTH K (under) | | | | |
| 24 | CTH O (under) | | | | |
| 25 | 7 MILE RD (under) | | | | |
| 26 | 27 Str. (US 41 N) off-ramp gone | | | | |
| 27 | Oakwood (under) | | | | |
| 28 | Ryan Rd. (bridge) | | | | |
| 29 | Yuetz Rd. (bridge) | | | | |
| 30 | Drexel Ave. (bridge) | | | | |
| 31 | Dawson Ave. (CTH BB) (bridge) | | | | |
| 32 | College Ave. (CTH ZZ) (bridge) | | | | |
| 33 | Gen. Mitchell Int. Airport (bridge) | | | | |
| 34 | Layton Ave. (CTH V) (bridge) | | | | |

Slide 45




Slide 46



## *TIPS Changeable Message Sign Data Collection Sheet*

**Note:**
***Typical messages will be:***

- CONSTRUCTION NEXT 15 MILES.
- TRAVEL TIME TO END OF CONSTRUCTION ZONE: **28** MINUTES

Record under "Message" only the number "28." If any **other** messages are displayed, record the entire messages.

| | **Run 1** | **Run 2** | **Run3** | **Run 4** |
|---|---|---|---|---|
| **College Ave. East of I-94** | | | | |
| **Time** | | | | |
| **Message** | | | | |
| **College Ave. West of I-94** | | | | |
| **Time** | | | | |
| **Message** | | | | |
| **27th Street South of College Ave.** | | | | |
| **Time** | | | | |
| **Message** | | | | |

*TIPS Changeable Message Sign Data Collection Sheet*

**Note:**
***Typical messages will be:***

- CONSTRUCTION NEXT 15 MILES.
- TRAVEL TIME TO END OF CONSTRUCTION ZONE: **28** MINUTES

Record under "Message" only the number "28." If any **other** messages are displayed, record the entire messages.

| | **Run 5** | **Run 6** | **Run 7** | **Run 8** |
|---|---|---|---|---|
| **College Ave. East of I-94** | | | | |
| **Time** | | | | |
| **Message** | | | | |
| **College Ave. West of I-94** | | | | |
| **Time** | | | | |
| **Message** | | | | |
| **27th Street South of College Ave.** | | | | |
| **Time** | | | | |
| **Message** | | | | |

## *TIPS Changeable Message Sign Data Collection Sheet, signs located on I-94*

**Instructions:**

- **Fill in the time that you went by the sign board (this is very important!)** make sure your watch is synchronized with (414) 844-1414.

- **Fill-in the number of minutes** in the "XX MIN TO END OF WORKZONE" line, if such a message is displayed.
- **Circle all displayed messages** among the listed ones.
- If a message is ***not included in the list***, ***write the complete message in the appropriate space.***

| **Run 1** | | |
|---|---|---|
| | **SIGN AT GENERAL MITCHELL INTERNATIONAL AIRPORT EXIT** | **SIGN NEAR RYAN ROAD EXIT** |
| **Time** | **Fill-in ☞** | **Fill-in ☞** |
| **Message** | **Fill in ☞**_____MIN TO END OF WORKZONE<br>WORKZONE ENDS 19 MILES<br>FREEWAY CLOSED 7MI ROAD<br>FREEWAY CLOSED AT HWY G<br>FREEWAY CLOSED AT HWY K<br>FREEWAY CLOSED AT HWY C<br>FREEWAY CLOSED AT HWY11<br>FREEWAY CLOSED AT KR<br>ACCIDENT AHEAD<br>WORK ZONE AHEAD<br>LONG DELAY AHEAD<br>Other (write message): | **Fill in ☞**_____MIN TO END OF WORKZONE<br>WORKZONE ENDS 15 MILES<br>FREEWAY CLOSED 7MI ROAD<br>FREEWAY CLOSED AT HWY G<br>FREEWAY CLOSED AT HWY K<br>FREEWAY CLOSED AT HWY C<br>FREEWAY CLOSED AT HWY11<br>FREEWAY CLOSED AT KR<br>ACCIDENT AHEAD<br>WORK ZONE AHEAD<br>LONG DELAY AHEAD<br>Other (write message): |

| **Run 2** | | |
|---|---|---|
| | **SIGN AT GENERAL MITCHELL INTERNATIONAL AIRPORT EXIT** | **SIGN NEAR RYAN ROAD EXIT** |
| **Time** | **Fill-in ☞** | **Fill-in ☞** |
| **Message** | **Fill in ☞**_____MIN TO END OF WORKZONE<br>WORKZONE ENDS 19 MILES<br>FREEWAY CLOSED 7MI ROAD<br>FREEWAY CLOSED AT HWY G<br>FREEWAY CLOSED AT HWY K<br>FREEWAY CLOSED AT HWY C<br>FREEWAY CLOSED AT HWY11<br>FREEWAY CLOSED AT KR<br>ACCIDENT AHEAD<br>WORK ZONE AHEAD<br>LONG DELAY AHEAD<br>Other (write message): | **Fill in ☞**_____MIN TO END OF WORKZONE<br>WORKZONE ENDS 15 MILES<br>FREEWAY CLOSED 7MI ROAD<br>FREEWAY CLOSED AT HWY G<br>FREEWAY CLOSED AT HWY K<br>FREEWAY CLOSED AT HWY C<br>FREEWAY CLOSED AT HWY11<br>FREEWAY CLOSED AT KR<br>ACCIDENT AHEAD<br>WORK ZONE AHEAD<br>LONG DELAY AHEAD<br>Other (write message): |

| Run 3 | | |
|---|---|---|
| | **SIGN AT GENERAL MITCHELL INTERNATIONAL AIRPORT EXIT** | **SIGN NEAR RYAN ROAD EXIT** |
| **Time** | **Fill-in ☞** | **Fill-in ☞** |
| **Message** | **Fill in ☞**_____MIN TO END OF WORKZONE<br>WORKZONE ENDS 19 MILES<br>FREEWAY CLOSED 7MI ROAD<br>FREEWAY CLOSED AT HWY G<br>FREEWAY CLOSED AT HWY K<br>FREEWAY CLOSED AT HWY C<br>FREEWAY CLOSED AT HWY11<br>FREEWAY CLOSED AT KR<br>ACCIDENT AHEAD<br>WORK ZONE AHEAD<br>LONG DELAY AHEAD<br>Other (write message): | **Fill in ☞**_____MIN TO END OF WORKZONE<br>WORKZONE ENDS 15 MILES<br>FREEWAY CLOSED 7MI ROAD<br>FREEWAY CLOSED AT HWY G<br>FREEWAY CLOSED AT HWY K<br>FREEWAY CLOSED AT HWY C<br>FREEWAY CLOSED AT HWY11<br>FREEWAY CLOSED AT KR<br>ACCIDENT AHEAD<br>WORK ZONE AHEAD<br>LONG DELAY AHEAD<br>Other (write message): |

*CHECK POINTS 27th Street (STH 241)*

**Team members:**
**Date:**
**Computer Number:**

| | | *Run 1* | *Run 2* | *Run 3* | *Run 4* |
|---|---|---|---|---|---|
| **1** | **College Ave. (CTH ZZ) get ready** | | | | |
| **2** | **27th (STH 241) & College** | | | | |
| **3** | **Sycamore (signal)** | | | | |
| **4** | **Rawson--County BB (signal)** | | | | |
| **5** | **Drexel (signal) 7900 S.** | | | | |
| **6** | **Ryan (signal) 9500 S.** | | | | |
| **7** | **Leaving 27th!!!->W. Frontage Rd.** | | | | |
| **8** | **7 mile STOP sign** | | | | |
| **9** | **CTH G STOP sign** | | | | |
| **10** | **CTH K STOP sign** | | | | |
| **11** | **STH 20 SIGNAL-go straight** | | | | |
| **12** | **STH 11 STOP sign past RR xing** | | | | |
| **13** | **CTH KR STOP sign County Line Rd. South end of run. Make 90 deg. left** | | | | |
| **14** | **I-94 northbound on-ramp** | | | | |
| **15** | **STH 11 (under)** | | | | |
| **16** | **STH 20 (under)** | | | | |
| **17** | **CTH K (under)** | | | | |
| **18** | **CTH G (over)** | | | | |
| **19** | **7 MILE RD (under)** | | | | |
| **20** | **27 Str. (US 41 N) off ramp gore** | | | | |
| **21** | **Oakwood (under)** | | | | |
| **22** | **Ryan (over)** | | | | |
| **23** | **Puetz (over)** | | | | |
| **24** | **Drexel (over)** | | | | |
| **25** | **Rawson (over)** | | | | |
| **26** | **College Ave. (CTH ZZ) exit gore** | | | | |

| | |
|---|---|
| **1** | **College Ave. (CTH ZZ) get ready** |
| **2** | **27th (STH 241) & College** |
| **3** | **Sycamore (signal)** |
| **4** | **Rawson--County BB (signal)** |
| **5** | **Drexel (signal) 7900 S.** |
| **6** | **Ryan (signal) 9500 S.** |
| **7** | **Leaving 27th!!!->W. Frontage Rd.** |
| **8** | **7 mile STOP sign** |
| **9** | **CTH G STOP sign** |
| **10** | **CTH K STOP sign** |
| **11** | **STH 20 SIGNAL-go straight** |
| **12** | **STH 11 STOP sign past RR xing** |
| **13** | **CTH KR STOP sign County Line Rd. South end of run. Make 90 deg. left** |
| **14** | **I-94 northbound on-ramp** |
| **15** | **STH 11 (under)** |
| **16** | **STH 20 (under)** |
| **17** | **CTH K (under)** |
| **18** | **CTH G (over)** |
| **19** | **7 MILE RD (under)** |
| **20** | **27 Str. (US 41 N) off ramp gore** |
| **21** | **Oakwood (under)** |
| **22** | **Ryan (over)** |
| **23** | **Puetz (over)** |
| **24** | **Drexel (over)** |
| **25** | **Rawson (over)** |
| **26** | **College Ave. (CTH ZZ) exit gore** |

**CHECK POINTS I-94**

Team members:
Date:
Computer Number:

| | | *Run 1* | *Run 2* | *Run 3* | *Run 4* |
|---|---|---|---|---|---|
| 1 | Layton Ave. (CTH Y) WB-get ready | | | | |
| 2 | Layton Ave. @ 20th Str. turn left | | | | |
| 3 | 20th Str. @ I-94 on-ramp turn left | | | | |
| 4 | I-94 on-ramp gore | | | | |
| 5 | General Mitchell Intl.Airport (bridge) | | | | |
| 6 | College Ave. (CTH ZZ) (bridge) | | | | |
| 7 | Rawson Ave. (CTH BB) (bridge) | | | | |
| 8 | Drexel Ave. (bridge) | | | | |
| 9 | Puetz Rd. (bridge) | | | | |
| 10 | Ryan Rd. (STH 100) (bridge) | | | | |
| 11 | Oakwood Rd. (under) | | | | |
| 12 | 27th Str. (US 41) on-ramp | | | | |
| 13 | 7 mile (under) | | | | |
| 14 | CTH G (over) | | | | |
| 15 | CTH K (under) | | | | |
| 16 | STH 20 (under) | | | | |
| 17 | STH 11 (under) | | | | |
| 18 | Exit here! CTH KR exit gore | | | | |
| 19 | Making left turn @ CTH KR | | | | |
| 20 | I-94 northbound on-ramp | | | | |
| 21 | STH 11 (under) | | | | |
| 22 | CTH 20 (under) | | | | |
| 23 | CTH K (under) | | | | |
| 24 | CTH G (over) | | | | |
| 25 | 7 MILE RD (under) | | | | |
| 26 | 27 Str. (US 41 N) off-ramp gore | | | | |
| 27 | Oakwood (under) | | | | |
| 28 | Ryan Rd. (bridge) | | | | |
| 29 | Puetz Rd. (bridge) | | | | |
| 30 | Drexel Ave. (bridge) | | | | |
| 31 | Rawson Ave. (CTH BB) (bridge) | | | | |
| 32 | College Ave. (CTH ZZ) (bridge) | | | | |
| 33 | Gen. Mitchell Int. Airport (bridge) | | | | |
| 34 | Layton Ave. (CTH Y) (bridge) | | | | |

## CHECK POINTS I-94

| | | *Run 5* | *Run 6* | *Run 7* | *Run 8* |
|---|---|---|---|---|---|
| 1 | Layton Ave. (CTH Y) WB-get ready | | | | |
| 2 | Layton Ave. @ 20th Str. turn left | | | | |
| 3 | 20th Str. @ I-94 on-ramp turn left | | | | |
| 4 | I-94 on-ramp gore | | | | |
| 5 | General Mitchell Intl.Airport (bridge) | | | | |
| 6 | College Ave. (CTH ZZ) (bridge) | | | | |
| 7 | Rawson Ave. (CTH BB) (bridge) | | | | |
| 8 | Drexel Ave. (bridge) | | | | |
| 9 | Puetz Rd. (bridge) | | | | |
| 10 | Ryan Rd. (STH 100) (bridge) | | | | |
| 11 | Oakwood Rd. (under) | | | | |
| 12 | 27th Str. (US 41) on-ramp | | | | |
| 13 | 7 mile (under) | | | | |
| 14 | CTH G (over) | | | | |
| 15 | CTH K (under) | | | | |
| 16 | STH 20 (under) | | | | |
| 17 | STH 11 (under) | | | | |
| 18 | Exit here! CTH KR exit gore | | | | |
| 19 | Making left turn @ CTH KR | | | | |
| 20 | I-94 northbound on-ramp | | | | |
| 21 | STH 11 (under) | | | | |
| 22 | CTH 20 (under) | | | | |
| 23 | CTH K (under) | | | | |
| 24 | CTH G (over) | | | | |
| 25 | 7 MILE RD (under) | | | | |
| 26 | 27 Str. (US 41 N) off-ramp gore | | | | |
| 27 | Oakwood (under) | | | | |
| 28 | Ryan Rd. (bridge) | | | | |
| 29 | Puetz Rd. (bridge) | | | | |
| 30 | Drexel Ave. (bridge) | | | | |
| 31 | Rawson Ave. (CTH BB) (bridge) | | | | |
| 32 | College Ave. (CTH ZZ) (bridge) | | | | |
| 33 | Gen. Mitchell Int. Airport (bridge) | | | | |
| 34 | Layton Ave. (CTH Y) (bridge) | | | | |

# STARTING UP THE COMPUTER

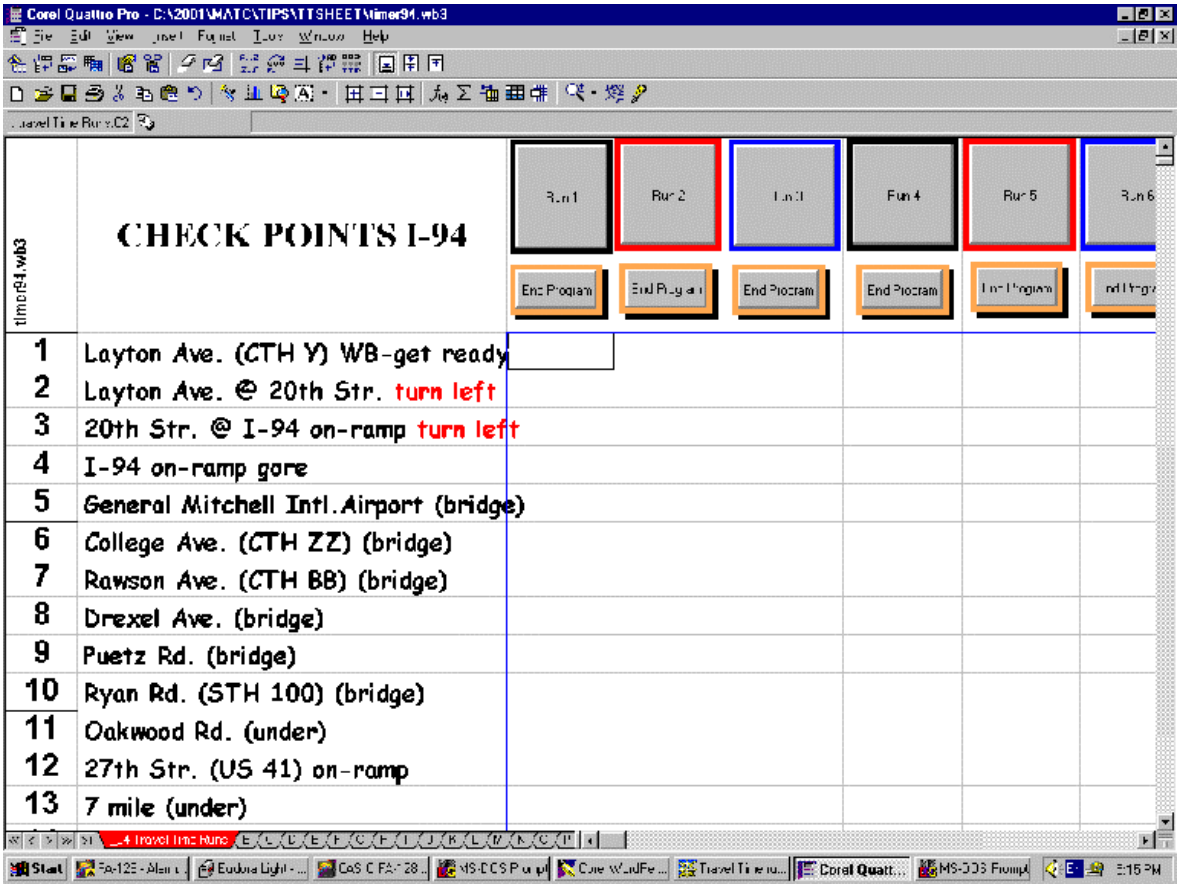
***Attention:***
Turn car engine on **first**.
**Do not turn engine off during the run**–this may stop the computer.
Turn computer off first.
**Turn engine off only after the computer has properly shut down**.

Steps:

1. Turn engine on.
2. Plug power cord to the computer.
3. Plug power cord to the inverter.
4. Plug inverter to the cigarette lighter socket.
5. Turn the computer on. Hit Esc in response to an error message about the CD drive. Hit Esc if you are asked for a password.
6. Start Quattro Pro (program image on desktop, right above "Start" button.

GO TO NEXT PAGE FOR INSTRUCTIONS

1. When done recording, close Quattro Pro (left click on 'End Program', left-click on "File" "Exit").
2. Shut down Windows 95 and the computer (left click on "Start" at bottom left of screen, "Shut Down" "Shut down the Computer." Wait for Windows to shut down the computer.
3. Unplug the inverter.
4. **Only then turn the engine off.**




How to use **Timer27.wb3 (Timer94.wb3)**:

Open QuattroPro (program image above “Start”, open file Timer27.wb3 (Timer94.wb3).

Click on the button “Run 1" -your starting time will be recorded next to Check Point 1, under column “Run 1.”

Hit “Enter” as you pass each Checkpoint. The time will be recorded next to the Check Point.

If you are running multiple runs, use the mouse to click on the button “Run 2" when you are ready for the second run. This will automatically place the first time stamp for the second run. Repeat this process for subsequent runs.

When you are done, use the mouse to click on any “End Program” button. Continue with point 7 on the previous page.

**Typical problems:**

If you miss a point, or accidentally hit “Enter” too early, use the arrow keys to move up or down. Hit “Enter” as usual.

If the program stops accidentally, use the arrows to go to the proper cell. Hit “Shift+Ctrl+V” to restart the program.

If you cannot restart the computer, use the stopwatch. Write down times on the provided data forms. Reset the timer at the beginning of each run and record continuous time for the entire run. Do not attempt to record intervals between check points.