# Diversion from a Rural Work Zone Owing to a Traffic-Responsive Variable Message Signage System

**Alan J. Horowitz, Ian Weisser, and Thomas Notbohm**

Alan J. Horowitz, Professor, Center for Urban Transportation Studies, University of Wisconsin – Milwaukee, PO Box 784, Milwaukee, WI 53201, voice: 414-229-6685, fax: 414-229-6958, e-mail: horowitz@uwm.edu

Ian Weisser, Research Staff, Center for Urban Transportation Studies, University of Wisconsin – Milwaukee, PO Box 784, Milwaukee, WI 53201, voice: 414-229-5787, fax: 414-229-6958, e-mail: kweisser@uwm.edu

Thomas Notbohm, Traffic Operations Engineer, Wisconsin DOT Bureau of Highway Operations, P.O. Box 7986, Room 501, Madison, WI 53707-7986, voice: 608-266-0982, fax: 608-261-6295, e-mail: thomas.notbohm@dot.state.wi.us

Abstract: This paper reports the results of an experiment to determine the degree of alternative route selection from a rural freeway that can occur because of implementation of a traffic-responsive variable message signage system in a work zone. The message signs gave real-time estimates of travel time to the end of the work zone. Alternative route selection was measured through extensive volume counts on the freeway and on parallel arterial streets, both before and after implementation of the signage system. In addition, traffic volumes were measured at a variety of locations where alternative route selection was likely to occur and unlikely to occur. The analysis of peak period data found that alternative route selection rates were between 7% and 10% of the freeway traffic, depending upon the location and the day of week.

## INTRODUCTION

From a driver's perspective a work zone is primarily a bottleneck that has the potential to add long delay to a trip; such delay is now being recognized as a large hidden cost of highway repair and reconstruction. Stated preference studies have indicated that a substantial percentage of drivers would gladly choose an alternative route or divert while en route given reliable information about the amount of delay that might be incurred *(1,2,3)*. While there have been many psychometric studies *(e.g., 1,2,3,4,5,6)* of alternative route selection to messages on signs, there has not been a comparable effort to ascertain actual driver behavior through work zones under real-world conditions. Although very difficult to perform and usually bypassed for the sake of convenience *(6)*, such real-world tests are essential to validate psychometric studies, to understand the impacts of emerging information technologies on future work zones or other similar ATIS deployments and to refine mathematical models for simulating driver behavior near workzones so that benefits of such deployments may be anticipated.

Diversion from a work zone can have two distinct meanings: (1) the rerouting of traffic around the work zone on a temporary highway or alignment, as defined in section 6C.09 the MUTCD and (2) the voluntary rerouting of drivers on existing highways. To avoid confusing the two meanings, drivers' voluntary rerouting around a work zone, the subject of this paper, will be referred to here as "alternative route selection."

While field studies often lack information about drivers' motivations, they can give a much better sense of the overall level of alternative route selection than can be ascertained from stated preference or even revealed preference studies. In order to be useful, a field study needs to be carefully designed with experimental controls to allow comparisons of driver behavior though time and at different locations. Unfortunately, good opportunities and locations to perform such field studies are rare.

An opportunity to study such alternative route selection behavior presented itself during the summer of 2001 when the Midwest States Smart Work Zone Deployment Initiative (a consortium of 5 Midwest state DOTs) initiated an evaluation of a particular commercial ATIS product to warn drivers of impending delays. This product, the Travel Time Prediction System or TIPS, was deployed in and near a work zone on I-94 in Racine County, Wisconsin. See *(7)* for an earlier evaluation of TIPS. TIPS is just one of several products that can provide delay or speed advisories to drivers in work zones.

As part of the present evaluation of TIPS, there was a need to determine if sign messages activated in or near the work zone prompted any actions by drivers. This evaluation was accomplished by comparing before and after traffic volumes at several points on I-94 and on parallel highways. Although no field study is ideal, this particular work zone had many desirable attributes for observing alternative route selection behavior and for establishing sufficient experimental controls. The work zone was in a relatively isolated area, was otherwise devoid of real-time information for drivers, had a small set of identifiable alternative routes and had enough traffic to cause serious delays during peak periods.

**Hypotheses of Alternative Route Selection Analysis**

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

Measuring alternative route selection 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 alternative route selection, can only be monitored on some of the possible alternative routes. However, other methods of measuring alternative route selection that might have been more comprehensive were rejected as impractical or extremely expensive, especially considering the large sample sizes required to identify small effects. For example, questionnaires would have required stopping a large number of vehicles downstream of the work zone on many alternative routes and license plate matching techniques would have required the installation of video cameras at many locations over a two month period of time. Our floating car runs through the work zone and on a parallel road provided information on delay, but such data are considered to be correlated less to route selection decisions than are volumes. Our crash data would be only very indirectly related to route selection decisions.

The TIPS signs did not provide any guidance as to what might happen if an alternative route is chosen. Thus, we can further hypothesize that many drivers will choose not to divert even when it is to their advantage to do so, as indicated by previously mentioned psychometric studies. Some of these drivers would not possess enough local knowledge about alternative routes. Still others are uncertain about the travel time by an alternative route, skeptical about the information provided or optimistic that traffic will soon improve.

**THE WORK ZONE AND OPERATION AND CONFIGURATION OF THE SIGNAGE SYSTEM**

The work zone was slightly more than 12 miles long, starting just north of the Milwaukee-Racine county line and ending just south of the Racine-Kenosha county line. This is essentially a rural location where traffic advisory information is otherwise unavailable. The study was interested only in the southbound direction of traffic. The peak hours of traffic for this direction during the summer occurs on Sunday afternoons (between 2 pm and 5 pm), mainly due to a high volume of vacation travelers returning home from northern Wisconsin. Southbound traffic volumes were at their highest at the northern end of the work zone, reaching 4000 vph (over a 15-minute time interval) during peak hours, and were considerably smaller toward the southern end.

I-94 normally has three travel lanes and two shoulders before and through Racine County. The speed limit is normally 65 mph. During the 2001 road work, two lanes of traffic were provided in the before period on the right-most lane and right shoulder, and in the after period on the left-most lane and left shoulder. Capacity was further reduced because of small lateral clearances and rumble strips on the shoulders that had been filled with patching material, creating a mound resembling a low speed hump. The speed limit in the work zone was reduced to 55 mph. Lane closures were in effect for one month prior to the start of data collection in the before period. Delays, as estimated by TIPS, averaged from 0 minutes to 22 minutes over a 15 minute interval of time. Instantaneous delays of up to 32 minutes were estimated.

The signage system was configured by the Wisconsin Department of Transportation in an attempt to maximize the number of drivers who would benefit from the information and provide reasonable paths if drivers choose to divert. The signage system consisted of 5 microwave detectors and 4 signs, as indicated in Figure 1. TIPS also involved wireless communication hardware between the detectors and the base station and between the base station and signs. The base station consisted primarily of a desktop computer located in the resurfacing project’s office about 3 miles into the work zone. In addition, a telephone modem allowed remote monitoring of the condition of TIPS and manual override of the messages in times of emergency, equipment failure or a very serious incident. At no time during the operational test was a manual override necessary.

Detectors were located on I-94 at:

A. North of Airport Spur (ahead of work zone)
B. 1.8 miles from Airport detector, south of College (ahead of work zone)
C. 3.9 miles from Airport detector, north of Ryan (ahead of work zone)

D. 6.3 miles from Airport detector, just north of the Milwaukee-Racine county line and work zone
E. 10.1 miles from Airport detector, about 3 miles into work zone

Detectors were mounted on masts on trailers that were placed well away from the travel lanes.

Signs were located on I-94 ahead of the both the College and Ryan off ramps, on the north side of College just east of the I-94 on-ramp and on the south side of Ryan just west of the I-94 on-ramps. Signs were not placed at Rawson, a very logical location, because of construction activities near the interchange that might cause problems if there were a large number of diverted vehicles.

The portable message signs employed by TIPS were configured to cycle between two messages. One message indicated the estimated time to the end of the work zone (consistent with the finding in *(2)* that drivers prefer knowing the total travel time to a location) rounded to the nearest 4 minutes, as calculated by TIPS. The second message indicated the distance to the end of the work zone. The portable message signs were capable of displaying three lines of eight characters each. An example of the "time" message is:

```
36MIN TO
 END OF
WORKZONE
```

and an example of a distance message is:

```
WORKZONE
ENDS 15
 MILES
```

The TIPS signs did not provide information about alternative routes, which has been found by psychometric studies to encourage alternative route selection *(1,2,3)*. Alternative routes were marked with fixed signs for the benefit of those drivers choosing to divert.

Although it is not the purpose of this paper to report on the accuracy of TIPS, the equipment was judged to produce sufficiently good results to remain credible to repeat travelers. TIPS travel times were validated with floating car runs throughout all times in which volume data were taken. Floating car runs were also conducted on one alternative route (West Frontage Road).

Although not directly relevant to the objectives of this paper, the cost of the deployment is indicative of its comprehensiveness and its sophistication. The direct cost to lease, install, operate and maintain the TIPS hardware and software for four months of deployment was approximately $179,000. The vendor also contributed professional time and materials for this operational test.

## ALTERNATIVE ROUTE SELECTION ANALYSIS OF VOLUME DATA

### Alternative Routes

The Racine County 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 traffic controlled intersections, usually spaced about 1 mile apart. Most of these intersections were stop controlled, causing very little delay. 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 all 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 (population of about 100,000) that is reachable by the freeway and by Howell (STH 38), which can be accessed from the Ryan, College and Rawson interchanges. It was also possible for drivers to skip the queue ahead of the work zone on I-94 by exiting at Ryan and reentering the freeway at the 27$^{th}$ Street on-ramp located at the Milwaukee-Racine county line near the north end of the work zone.

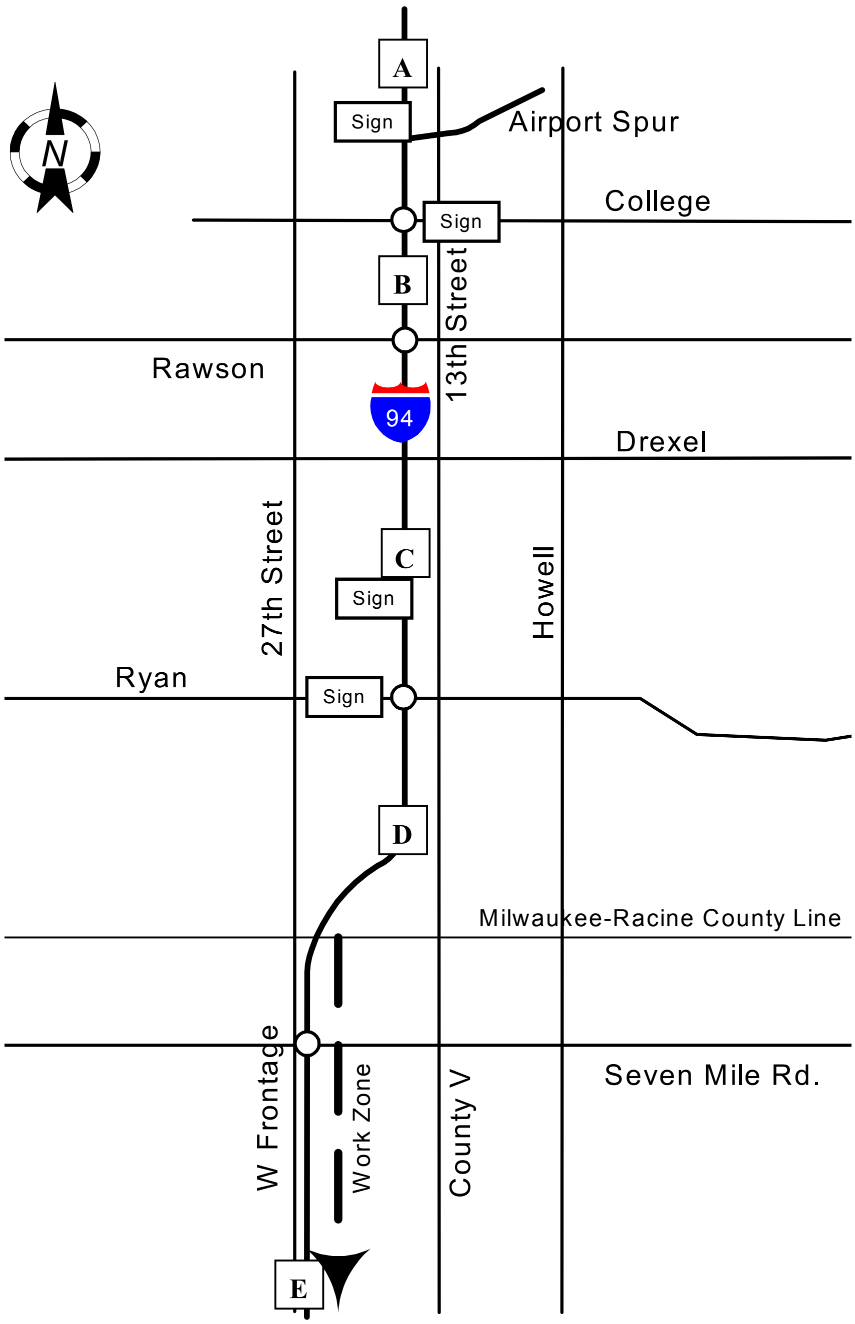


**FIGURE 1 TIPS Detector and Sign Configuration**

### 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 a shoulder, with no detectors, as a temporary travel lane; and the lane distribution was highly uneven because of the bumpy covering of the rumble strips. The same counting devices were used in both the before and after periods. Thus, any systematic errors in the counting devices would be insignificant when comparing after volumes to before volumes. The TIPS detectors and computers were fully operational during the before period, even though the signs were not deployed.

Tube counters measuring southbound traffic only were located at:

F. West Frontage Rd. just south of the Milwaukee-Racine county line
G. 27th St on ramp to I-94 at the Milwaukee-Racine county line (I-94 Ramp)
H. County V (13th St) just south of the Milwaukee-Racine county line
I. 27th Street just south of College
J. 27th Street just south of Ryan
K. Howell just north of the Milwaukee-Racine 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; see Figure 1.

The tube counters produced counts at 15-minute intervals, so the TIPS data, reported every 30 seconds, were aggregated to 15-minute intervals for consistency.

The Sunday special event mentioned earlier occurred each week and was located 1 mile into the work zone. Thus, the special event should not have a significant bearing on the results of the alternative route selection analysis.

The before and after periods were chosen so that traffic would have similar characteristics in both periods. Data was taken from June 11 through August 19. Count data for weekdays were from 3 pm to 7 pm. Count data for Sundays were from 2 pm to 6:45 pm. Although a scientific sample was not obtained, casual observations of license plates of vehicles within the work zone on Sundays indicated that the majority of southbound drivers originated outside of Wisconsin and would most likely be unfamiliar with local highways.

**Summary of Results**

*Queuing.* Queuing ahead of the work zone was observed to have occurred on all days. Queues of more than 2 miles in length were observed on Sundays.

*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 2. Two of the cutlines, College and Ryan, are ahead of the work zone by about 6 and 2 miles, respectively. The third cutline passes just outside of the work zone on its north end. While the Ryan and County Line cutlines share a detector at D, the County Line cutline is effectively south of the 27st Street on ramp (just north of the county line), as there are no off-ramps between D and Seven Mile Road, well south of the county line.

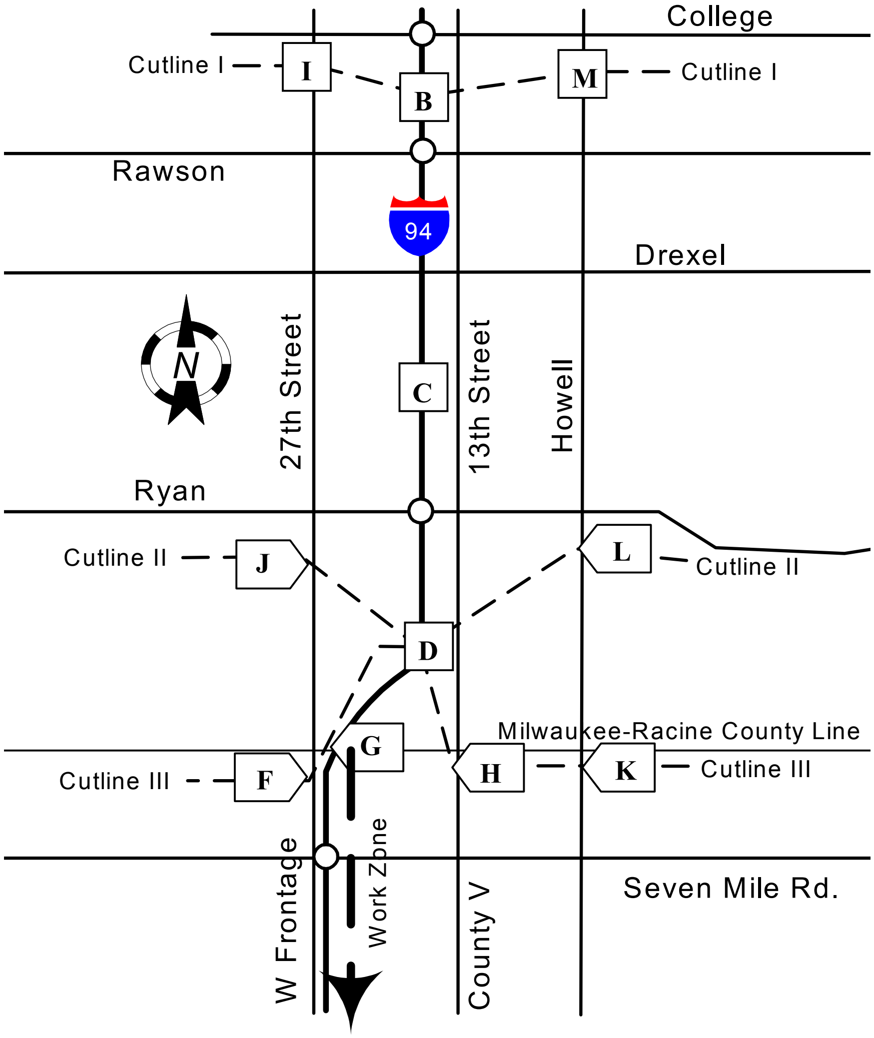


**FIGURE 2 Cutlines for Volume Counts**

*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 counts are summarized in Table 1 for weekdays and percentages of each cutline at a given detector is summarized in Table 2 for weekdays. Tables 3 and 4 give similar information for Sundays.

**TABLE 1 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 2 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 3 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 4 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 1 and 3 indicate that the before and after volumes, overall within the corridor, were very similar. Thus, it would be difficult to attribute any measured alternative route selection to traffic conditions by themselves. Tables 2 and 4 show the alternative route selection effects. It is seen that alternative route selection 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. The average count differences on I-94 at the College cutline were miniscule – just +3 vehicles on weekdays and -6 vehicles on Sunday. The College cutline is acting as a good control for the results seen at the other cutlines.

Alternative route selection was readily apparent at both the Ryan and County Line cutlines. Weekday and Sunday results were very consistent, showing between 5.0 and 6.7 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 partially 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.

A very large amount of data comprises Tables 1 and 3. Each average count in Table 1 was calculated from 128 15-minute samples. Each before average in Table 3 was calculated with 76 samples and each after average was calculated with 57 samples. Given these sample sizes, even small volume differences would be statistically significant. The alternative route selections seen in Tables 1 to 4 at Ryan and County Line are statistically significant at the 0.01 confidence level using the Chi square test (contingency table analysis).

The alternative route selection rates on Sundays were approximately the same as those on Thursdays and Fridays. Although Sunday's delays were greater, the level of alternative route selection knowledge among drivers is presumed to be less.

*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 alternative route selection 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 would have said if it had been operating.

Tables 5 and 6 summarize the cutline splits for I-94 only for these two sets of 15-minute intervals. Table 6, of course, is the more important of the two because it might demonstrate driver response to actual messages.

**TABLE 5 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 6 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 5 and 6 show similar patterns. Generally, higher splits on I-94 were associated with those periods with messages containing larger travel times. The data do not seem to 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 – precisely what TIPS is designed to do.

A further look at the data, particularly on Sunday at the County Line cutlines, shows an interesting effect that might be related to alternative route selection 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 for the "above" intervals than for the "below" intervals. A similar, but smaller, effect is seen at the Ryan cutline. A plausible 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 5 and 6 to Tables 2 and 4, because time intervals falling exactly on the median sign reading were excluded from Tables 5 and 6.

**Discussion of the Validity of the Before and After Comparison**

Before and after tests in real world settings cannot be fully controlled for all possible influences. However, this study was successfully able to keep almost constant all factors that traffic engineers commonly associate with drivers' routing decisions, including traffic volumes, trip purposes (by keeping all data collection in the summer and on the same days), weather, number of lanes, lateral clearances, special events, placement of TIPS equipment, other information sources and location. An ample amount of time was allowed ahead of data collection for drivers to become accustomed to the work zone. The only observed difference (besides the variable message signs) was the pair of lanes open to traffic. Minor incidents were balanced across the before and after periods. Investigators repeatedly drove through the work zone during all periods of data collection specifically to ascertain whether the traffic environment had changed significantly, and no such observations were made. The study did not collect information on vehicle destinations, which might have been revealed by a license plate survey, but there is no reason to believe that the distribution of destinations might have differed significantly between the before and after period. We are unaware of any influence that could explain, even partially, the differences in volumes except the deployment of the message signs. Nonetheless, additional operational tests would be required to be absolutely certain that an unknown or unmeasured influence could have biased the results.

### Discussion of Relevance for Assessment of Benefits of Travel Time Information

It is not the purpose of this paper to determine whether TIPS is cost effective, but the results presented in this paper, by themselves, could be used to calculate a ballpark estimate of the time-savings benefits of TIPS. A better estimate of benefits from only field data would also require floating car runs on more than one of the possible alternative routes and knowledge about volumes and delays outside of time periods of data collection. The most accurate and efficient method of assessing benefits would be traffic simulation (e.g., microscopic traffic simulations or dynamic traffic assignment models). Traffic simulation programs are quite good at estimating delays and travel times on alternative routes, but they are currently incapable of reliably estimating amounts of alternative route selection in work zone situations. The common assumption found in many of these models, that traffic conforms to a user-optimal equilibrium condition, will grossly overestimate the amount of alternative route selection. Thus, the alternative route selection results presented in this paper are essential to creating an accurate simulation and, therefore, an accurate determination of benefits. Such a simulation could calculate both the direct time-savings benefits to those drivers who choose alternative routes and the indirect time-savings benefits to those drivers who remain on the freeway.

## CONCLUSIONS

Many drivers are responsive to warnings that they might encounter excessive delays along their current route. However, a much larger percentage of drivers will not divert, even though it is to their advantage to do so. The reasons for many drivers failing to choose alternative routes might relate to the terse message given by the variable message signs and the lack of other sources of information, but the exact cause could not be fully ascertained from our data. Nonetheless, earlier psychometric studies suggest that the reasons probably relate to inadequate knowledge of route options or skepticism about the reported amount of delay – issues that should be taken into consideration in future designs of work zone information systems.

The before and after analysis supports the notion that the message signs are influencing drivers to change their routes. This study suggests that a 10% alternative route selection rate during peak periods is achievable when accurate, up-to-the-minute, information about delay through a work zone is provided and there is an attractive set of alternative routes.

By policy, the signs did not explicitly encourage drivers to use alternative routes. Psychometric studies would suggest that a higher alternative route selection rate could have been achieved had drivers been encouraged to do so.

## ACKNOWLEDGMENTS

The authors acknowledge the assistance of Alex Drakopoulos of Marquette University who participated in the design of the study and validated the TIPS messages. We also want to thank Prahlad Pant, a professor at the University of Cincinnati and the developer of TIPS, and the staff of the Wisconsin Department of Transportation for providing volume data. The study was funded by the Midwest States Smart Work Zone Deployment Initiative pooled-fund study.

The authors acknowledge the contributions of Pat McCoy in his role as director of the Mid-America Transportation Center at the University of Nebraska-Lincoln. Pat's energy and initiative were keys to the Midwest pooled-fund consortium's successful research of a variety of work zone technologies.

## REFERENCES

1. Polydoropoulou, A., Ben-Akiva, M., Khattak, A., Lauprete, G., "Modeling Revealed and Stated En-Route Travel Response to Advanced Traveler Information Systems," Transportation Research Record #1537, 1996.
2. Benson, B., "Motorist Attitudes about Content of Variable-Message Signs," Transportation Research Record #1550, 1996.

3. Peeta, S., Ramos, J., Pasupathy, R., "Content Of Variable Message Signs and On-Line Driver Behavior," Transportation Research Record #1725, 2000.
4. Ng, L., Barfield, W., Mannering, F., "Analysis of Private Drivers' Commuting Behavior and Commercial Drivers' Work-Related Travel Behavior," TRB 1998 CD ROM, Transportation Research Board, 1998.
5. Mehndiratta, S., Kemp, M., Lappin, J., Nierenberg, E., "Likely Users of Advanced Traveler Information Systems: Evidence from the Seattle Region," Transportation Research Record #1739, 2000.
6. Liu, Y., Mahmassani, H., "Dynamic Aspects of Departure Time and Route Decision Behavior Under Advanced Traveler Information Systems Modeling Framework and Experimental Results," TRB 1998 CD ROM, Transportation Research Board, 1998.
7. Zwahlen, H., Russ, A., "Evaluation of the Motoring Public's Acceptance of a Real-Time Travel Time Prediction System in a Freeway Construction Work Zone," TRB 2002 CD ROM, Transportation Research Board, 2002.