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Evaluation of Intellizone: A System for Providing Speed Advisories to Drivers Entering Work Zones

Principle Investigator
Name Horowitz, Alan
Affiliation Univ of Wisconsin, Milwaukee
Address PO Box 784
Milwaukee, WI 53201

Phone 414-229-6685
Fax
Email horowitz@uwm.edu

Vendor Name and Address
Quixote Transportation Safety
4021 Stirrup Creek Drive, Suite 100
Durham, NC 27713

Author(s) and Affiliation(s)
Alan J. Horowitz (Univ of Wisconsin, Milwaukee), Thomas Notbohm (WisDOT)

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Supplemental Notes

Abstract
Intellizone is a product for giving advanced warning to drivers of slowing traffic entering work zones. Intellizone consists of a series of microwave detectors and portable message signs, linked together by wireless communication. The study site was the northbound direction of US 41 in Green Bay, Wisconsin, which underwent lane closures. There were two sources of data for evaluating the effectiveness of Intellizone: the Intellizone detectors and a questionnaire administered to drivers who had just passed through the work zone. Drivers were generally satisfied with the speed advisory signs and most drivers felt that the signs were accurate.

Evaluation of Intellizone: A System for Providing Speed Advisories to Drivers Entering Work Zones

Alan J. Horowitz and Thomas Notbohm

November 5, 2003

1. TECHNOLOGY

Intellizone is a product of Highway Information Systems, which is a division of Quixote Transportation Safety (4021 Stirrup Creek Drive, Suite 100, Durham, NC 27713) for giving advanced warning to drivers of slowing traffic entering work zones. Intellizone consists of a series of microwave detectors and portable message signs, linked together by wireless communication. There can be as little as one detector associated with each sign. The detectors record speed, volume and occupancy each 30 seconds for each traffic lane, then the system computes a "decision speed" that is a volume-weighted average of speeds over all lanes over the previous 3 minutes. This decision speed is displayed in 10 mph ranges. The sign is blanked when the speeds are greater than 50 mph and the sign displays a "stopped traffic" warning when the speeds are less than 20 mph. Figure 1 is a photograph of a sign in operation. The speed advisory alternates with the constant phrase, "Actual Speeds Ahead". Intellizone can be customized for the work zone in terms of detector and sign placement, sign message, detector type, and formula for computing the "decision speed".

FIGURE 1 Two Alternate Messages Displayed by the Variable Message Sign, Located on the Median of US 41

2. STUDY SITE

The study site is the northbound direction of US 41 in Green Bay, Wisconsin. The northbound direction was selected because of anticipated heavy volumes due the combination of urban peak hour traffic and vacation traffic on Friday afternoons. US 41 is normally a 4-lane freeway, which was reduced to one lane in each direction during construction during the spring and summer of 2003. The work zone can also be approached from STH 172, an east-west highway that has an interchange with US 41 about ½ mile south of the work zone. The work zone terminates at the north end just ahead of the interchange with I-43. Figure 2 shows the placement of signs and detectors. Sign 3, which is located about 3.5 miles south of Sign 2, is not shown.

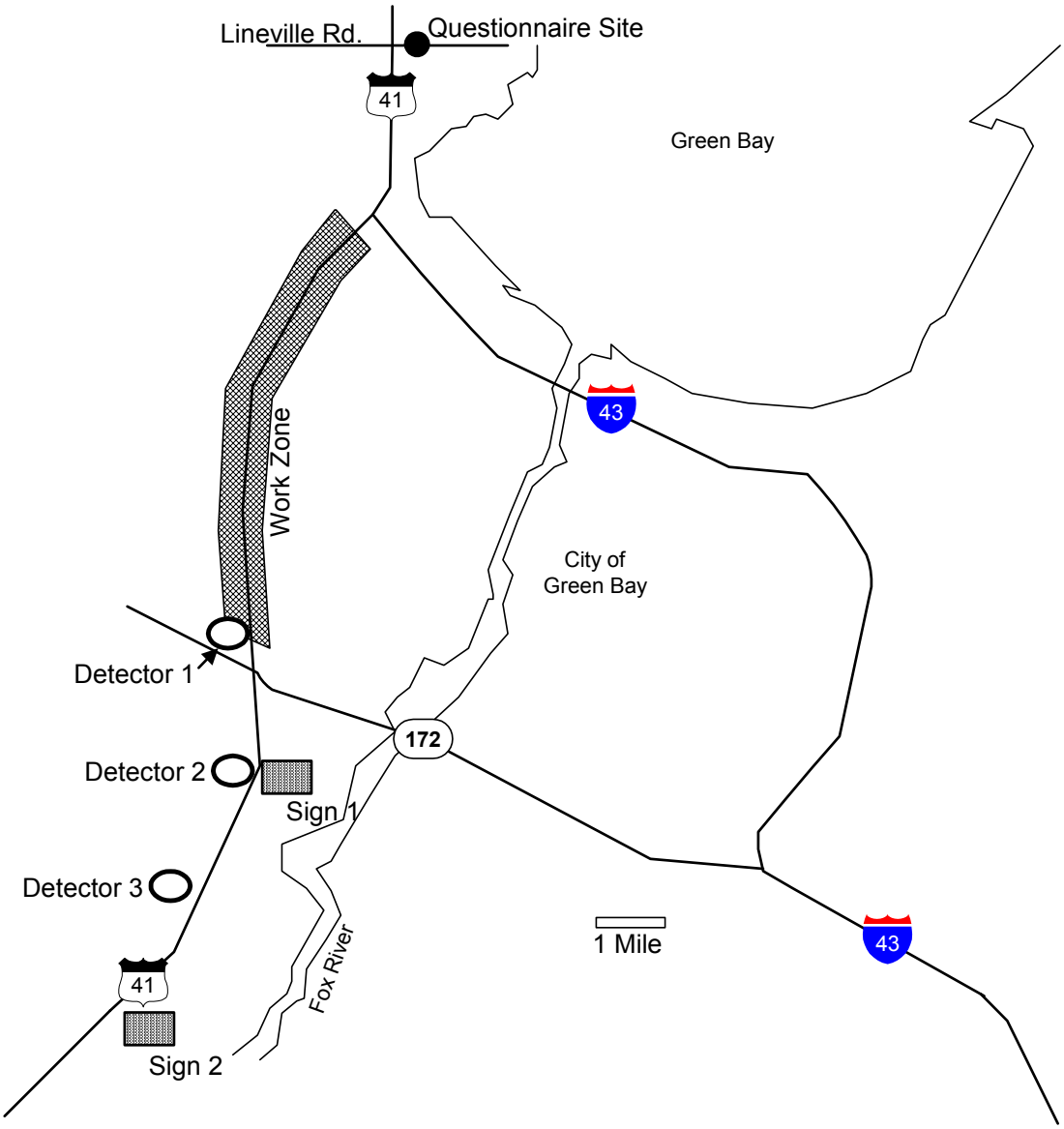

FIGURE 2 Location of Work Zone, Signs, Detectors and Questionnaire Site

Many vacation travelers who might normally use US 41 in Green Bay have the option of taking I-43, a parallel highway that bypasses Green Bay to the east and junctions with US 41 north of Green Bay.

3. DATA COLLECTION AND ANALYSIS

There were two sources of data for evaluating the effectiveness of Intellizone: the Intellizone detectors and a questionnaire administered to drivers who had just passed through the work zone. In addition, visual observations were continuously made of the queuing near the beginning of the work zone while the questionnaires were being administered.

Questionnaire Administration and Results

A questionnaire was administered to drivers exiting the freeway to stop at one of two gas stations located approximately 2 miles north of the work zone. The gas stations were located across the street from each other. These gas stations were chosen because they would likely attract a high percentage of long-distance travelers who originate their trip south of Green Bay. The questionnaire was read to drivers by the project staff. The questionnaire is reproduced in Appendix A.

Data was collected on three afternoons: May 23 (the Friday before the Memorial Day weekend); May 30 (the next Friday); and July 3 (the Thursday just ahead of the July 4th weekend). US 41 would normally have high volumes of traffic on those days. A total of 308 drivers were interviewed, all of whom stated that their trip started south of Green Bay. Of these drivers, 73% were male and the majority was between 26 and 45 years of age. There were a mix of trip purposes with 44% of drivers on a vacation or recreation trip and 40% of drivers on a work or business trip. 60% (186) of the drivers passed through the

work zone and another 16% (50) of drivers stated they would have ordinarily gone through the work zone but avoided it. Most of the respondents were alone (165). The mean automobile occupancy rate was 1.85.

Simple Tabulations from Questionnaire

Question 6 was directed to those 122 drivers who did not pass through the work zone.

6. Why did you not pass through the work zone?

☐ Would not have ordinarily gone through the work zone.
☐ Would have ordinarily gone through the work zone but planned ahead to avoid it.
☐ The trip was rerouted because the speed advisory signs said the speeds were low.
☐ The trip was rerouted because other en route information suggested avoiding the work zone.
☐ Other _____

Figure 3 shows the distribution of responses to question 6.

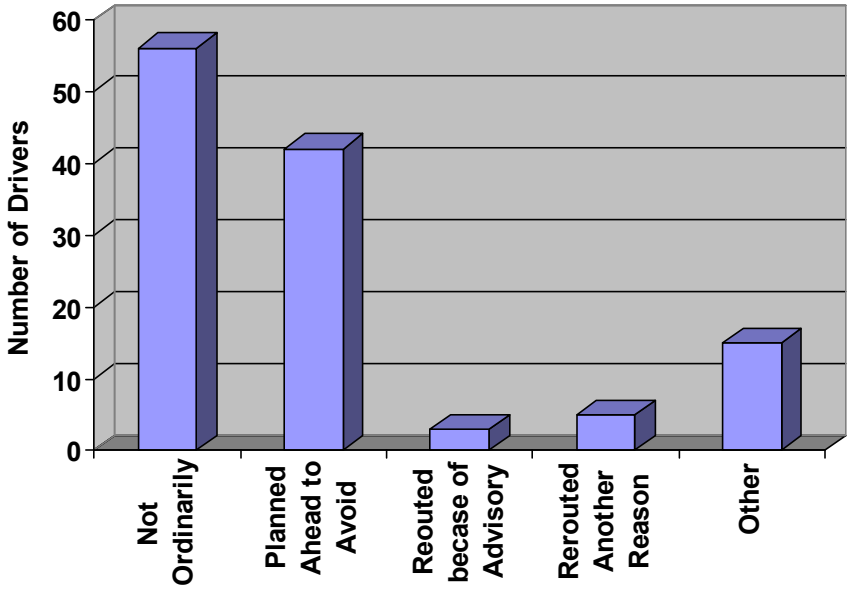

FIGURE 3 Reasons for Not Going through Work Zone

Prevalent "Other" reasons were "don't know" and "not on route". "Dangerous" was cited as an "other" reason by only one respondent. Only 3 drivers said they changed routes because of the speed advisory signs.

Question 7 was directed to those 186 drivers who passed through the work zone.

7. Why did you pass through the work zone?

☐ There was no choice. Explain _____
☐ The speed advisory signs indicated that any delays would be tolerable.
☐ Other information received indicated that any delays would be tolerable.
☐ Had no information about delays but assumed delays would be tolerable.
☐ It was a mistake.
☐ Other _____

Figure 4 shows the distribution of responses to question 7.

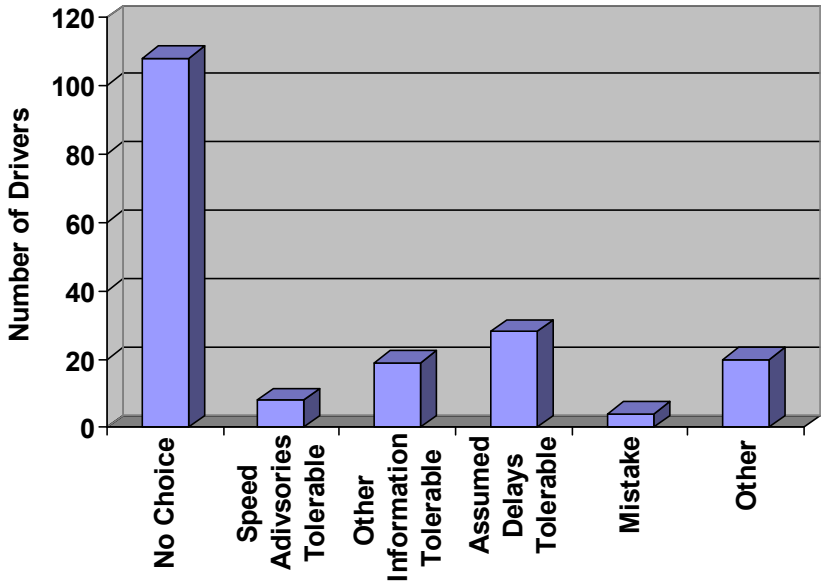

FIGURE 4 Reasons for Passing through the Work Zone

"Other" responses included "shorter route" and "usual route".

Question 8 was asked of all drivers, since some of the diverted drivers could have observed the speed advisory signs.

8. Rate the accuracy of the speeds displayed by the speed advisory sign approaching the work zone.

☐ Cannot rate the accuracy for some reason
☐ Very accurate
☐ Somewhat accurate
☐ Not accurate

Figure 5 shows the distribution of responses to question 8.

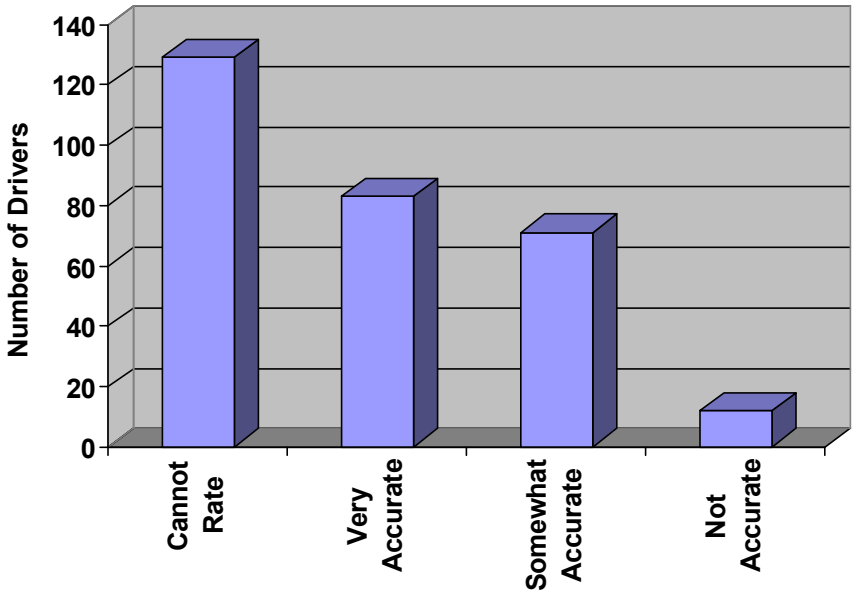

FIGURE 5 Perceived Accuracy of the Speed Advisory Signs

As expected, the vast majority of drivers who did not pass through the work zone indicated that they could not rate the accuracy. Only 12 drivers rated the signs as being not accurate.

Question 9 was also asked of all drivers, since some of the diverted drivers could have observed the speed advisory signs.

9. Rate your satisfaction with the speed advisory sign approaching the work zone.

☐ Cannot rate my level of satisfaction for some reason
☐ Very Satisfied
☐ Moderately Satisfied
☐ Neither Satisfied or Dissatisfied
☐ Moderately Dissatisfied
☐ Very Dissatisfied

Figure 6 shows the distribution of responses to question 9.

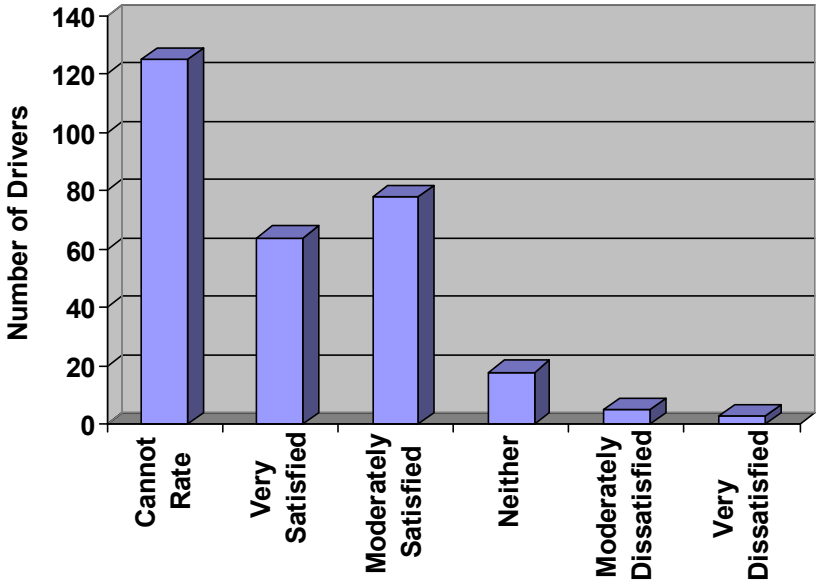

FIGURE 6 Level of Satisfaction with Speed Advisory Signs

Most drivers who could rate the signs indicated they were satisfied. Only 8 drivers indicated they were dissatisfied (moderately or very) with the signs.

Question 10 asked drivers how much delay they incurred by either driving through the work zone or avoiding it. Figure 7 shows the distribution of responses in minutes.

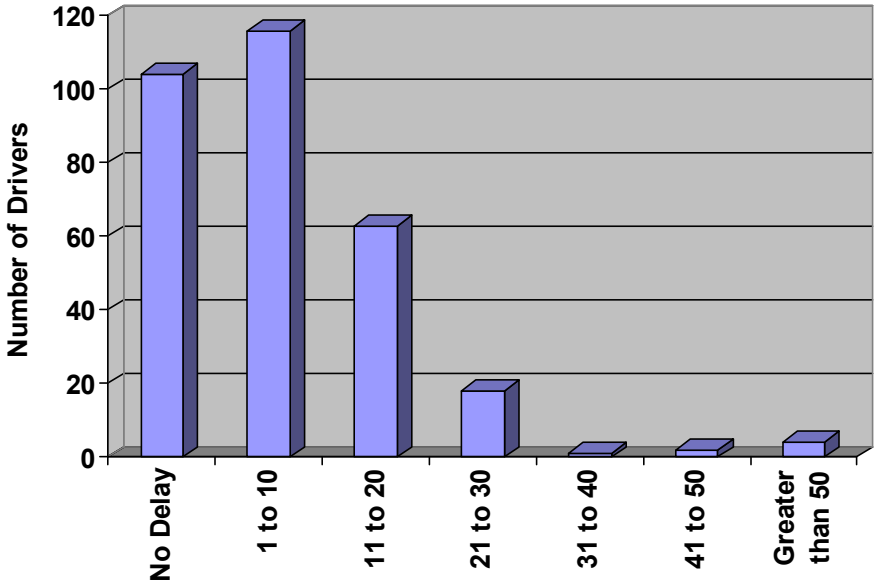

FIGURE 7 Distribution of Delays Due to Work Zone (Minutes)

Figure 7 indicates that delays were, for the most part, short. The average reported delay for the drivers was 8.9 minutes. Figure 8 compares the average reported delays by drivers passing through the work zone and drivers not passing through the work zone.

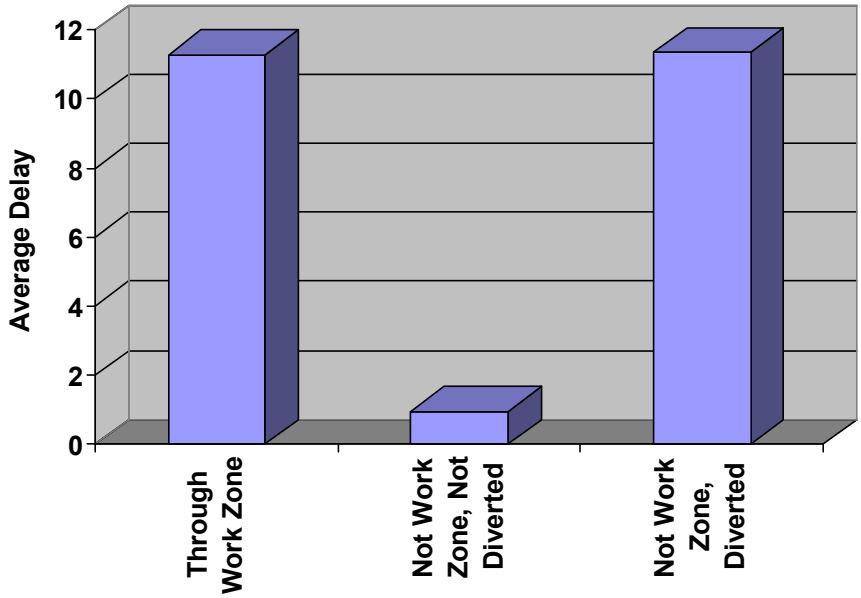

FIGURE 8 Average Delays of Drivers Through and Not Through Work Zone

In Figure 8 drivers not passing through the work zone are divided into those that were diverted and those that were not diverted. Interestingly, those drivers who said they were diverted reported almost exactly the same average delay (11.35 minutes) as those passing through the work zone (11.28 minutes). Drivers who would have normally taken another route incurred almost no delay on average (0.96 minutes). These results are consistent with the theory underlying user-optimal equilibrium traffic assignment[1] that is used by many traffic models to forecast the amount of diversion due to changes in highway geometry or traffic controls.

[1] User-optimal equilibrium traffic assignment is the most prevalent paradigm for forecasting the amount of traffic on highway networks. A property of such an assignment is that if there are two paths between an origin and destination and both paths are used, then the travel time on both paths would be equal.

Comparison of Driver Data with Detector Data

It may be hypothesized that there should be an inverse correlation between the speeds of vehicles and the amount of delay incurred by drivers. Figure 9 is a comparison between the reported delays for drivers passing through the work zone and the "decision" speed calculated by Intellizone, 8 minutes prior to the interview at the detector closest to the work zone. Any pattern to the data is difficult to discern. A graph between driver reported delay and the "decision" speed 12 minutes prior looks almost the same. Statistically, there is a slightly negative correlation coefficient between the two data items in Figure 9 (-0.14). The correlation coefficient has the correct sign. There are multiple possible explanations for this weak correlation: there was an equipment malfunction; drivers do not exactly know their delay; it is not possible to estimate the exact time the driver passed the detector; slowing occurred at a point that was not covered by a detector; or the "decision" speed is an average of two lanes, but the vehicle only occupies one of these lanes. A further exploration of this last explanation is presented in the next section. A case can be made that there was either an equipment malfunction or a problem with the aiming of the detector on July 3, as there were almost no vehicles reported to be in lane 2.

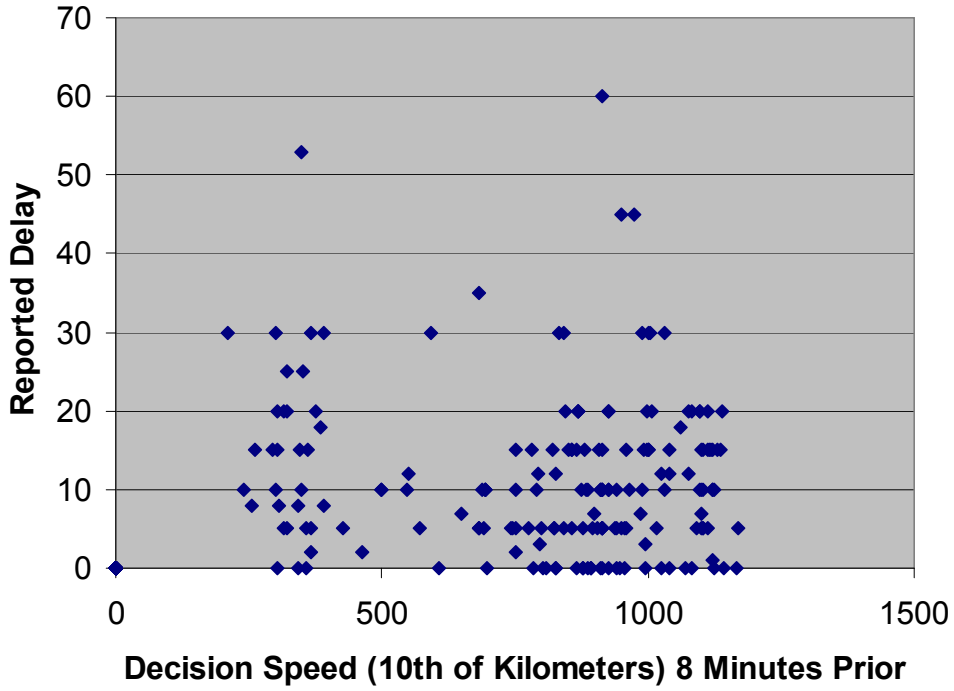

FIGURE 9 Relationship between Driver Reported Delay and Decision Speed

Analysis of Detector Data

Additional insights into driver behavior while approaching the work zone may be gained from analyzing Intellizone's detector data.

Figure 10 shows the relationship between the right and left lane speeds for individual minutes between 4 pm and 7 pm on May 23 for the detector closest to the work zone. The detector omitted some minutes, leaving 211 data points. The graph contains four points that are obviously incorrect, as they indicate unreasonably high speeds in one or both lanes.

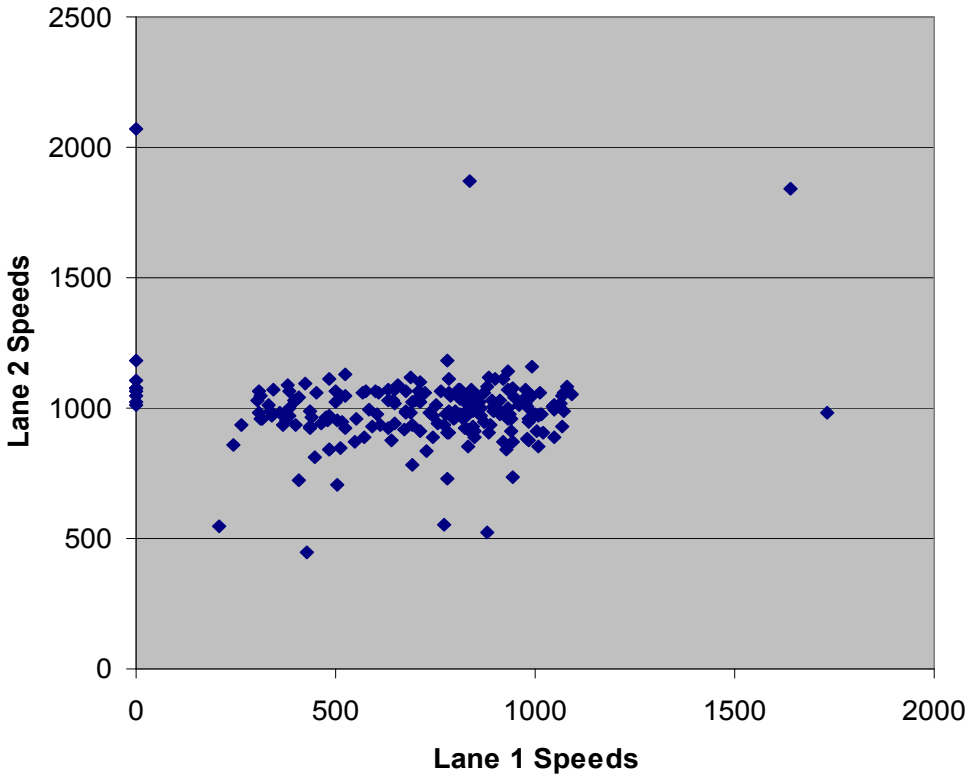

FIGURE 10 Relationship between Detector Speeds (10th of km/hr) at the Closest Detector to the Work Zone

Figure 10 reveals that there is no correlation between the two speeds. Except for four spurious data points, Lane 1 speeds vary between 0 and 110 km/hr, while Lane 2 speeds are almost constant around 100 km/hr. Field observations of the lane distribution reveal that drivers are forming long queues early in the lane (Lane 1) that remains open through the work zone and are allowing the closed lane (Lane 2) to run at close to free speeds until the need to merge at a point well passed the detector. Drivers bypassing the queue are incurring little delay, compared to those who are in the queue. Drivers bypassing the queue are not necessarily being inconsiderate, as the on-ramp from Highway 172 joins US 41 at a point that is typically closer to the work zone than the end of the queue.

The decision speed is volume weighted. The average volume in Lane 1 during this period at this detector was 1021 vehicles per hour and the average volume in Lane 2 was 1161 vehicles per hour, indicating that the volumes were reasonably balanced between lanes. Thus, with a weighting of about 50/50 the decision speed is often a compromise between two speeds that are in substantial disagreement with each other, so the decision speed is often not indicative of the actual speed for any of the vehicles. The decision speed is accurate only when both lane speeds are near free speed (in which case the sign is blanked) or when speeds are near zero (in which case the sign indicates that stopped vehicles are ahead).

Traffic Volumes as an Indicator of Total Diversion

The total amount of diversion away from the work zone was substantial. For example, on May 23 (the Friday before Memorial Day) an Intellizone detector measured a peak hour (2:45 to 3:45 pm) traffic volume of 2117 vph near the beginning of the work zone just ahead of the taper. Based on traffic counts from 2002, the peak hour on an average Friday in May should have been about 3300 vph.

Other Visual Observations

During questionnaire administration queues were observed to extend no farther than the Highway 172 bridge, a distance of less than 1 mile from the taper and well north (downstream) of the two other Intellizone detectors. The two most southern (upstream) signs (farthest away from the work zone) remained blank throughout the data collection periods.

There was recurring congestion near the middle of the work zone, due to traffic entering the freeway through temporary ramps. Delays were not severe, but traffic was often stopped. Because there were no detectors within the work zone itself, Intellizone could not alert drivers to the stoppage.

There was considerable speed variation just ahead of the taper when a distinct queue had not formed but the flow was unstable. The point at which speed was slowest did not always coincide with the location of the Intellizone detector.

Crash Experience

An interview with the Sheriff's captain responsible to traffic enforcement in Brown County revealed that there was only one incident during the whole construction period that could have significantly limited traffic flow in the northbound direction of US 41. This incident was caused by a SB truck dislodging several temporary barrier sections, which blocked the NB travel lane. The incident took about 4 hours to clear, but the NB lane was reopened quickly. All other crashes occurring in the work zone were property damage only and were quickly cleared.[2] The captain attributed this excellent safety record to the signing ahead of the work zone, the conspicuous presence of law enforcement officers just ahead of the taper and the large percentage of drivers who chose to avoid the work zone.

A check of the detector data for the date and time of the truck incident did not show any serious slowing of vehicles approaching the work zone, which was consistent with visual observations. The decision speed remained high throughout the incident at all three detectors.

3. CONCLUSIONS

Drivers are generally satisfied with the speed advisory signs and most drivers felt that the signs were accurate.

The signs did not cause an appreciable fraction of drivers to divert to alternate routes. The amount of diversion, overall, was already quite high due to extensive involvement of the local media and drivers' prior experience with this particular work zone.

Drivers diverting from the work zone, regardless of reason, reported the same amount of delay as drivers who did not divert.

The formula for calculating the "decision speed", which controlled the content of a sign's message, was an inaccurate estimation of the speeds of vehicles when there was appreciable queuing ahead of the work zone. The decision speed did not correlate well with the amount of delay reported by drivers passing through the work zone.

Given the excellent safety record for this work zone and the relatively small amount of recurring congestion, the two farthest upstream signs were not used. The two upstream signs would have been very helpful had there been a significant incident within the work zone during a time period in which the traffic volumes were near capacity.

4. RECOMMENDATIONS

Previously, the Midwest Smart Work Zone Deployment Initiative positively reviewed the Travel Time Prediction System (TIPS), another advisory system for drivers in advance of a work zone. Intellizone represents a good alternative to TIPS, but Intellizone lacks the sophisticated logic that enabled TIPS to estimate delays through the work zone instead of speeds at a single point. Intellizone has a potential cost advantage over TIPS because it can work with as little as one sign and one detector.

The formula for calculating "decision speed" in Intellizone needs revisiting, as it can lead to incorrect speed advisories for many drivers when the speeds in adjacent lanes are considerably different from each other.

There is a need to consider multiple detectors for a single sign. Additional detectors placed within the work zone or just ahead of the taper will increase the likelihood that the signs will display the slowest speed that is currently being experienced.

The decision on how many signs are required and where the signs are placed should be based on queue length estimates that anticipate that a certain percentage of drivers will voluntarily divert to alternate routes and on the probability that a serious incident might occur during a time period in which traffic volumes are near capacity.

[2] The truck crash was attributed to the truck following another vehicle too closely. When the lead vehicle stopped unexpectedly, the truck driver chose to hit the barrier rather than the lead vehicle.

APPENDIX A. SURVEY INSTRUMENT

Speed Advisory Sign Survey

Read to Respondent: I am working for the University of Wisconsin — Milwaukee and the Wisconsin Department of Transportation to gather opinions about some speed advisory signs that have been installed near a work zone in Green Bay. Can you take 4 minutes to answer a few questions? (If "no", then thank the person and end interview.) A speed advisory sign looks like this picture. (Show a picture of the sign.)

1. Did your trip originate south of Green Bay? ☐ yes ☐ no (If "no", then thank the person and end interview.)

2. What is the purpose of your trip? ☐ Vacation or recreation ☐ Work or business ☐ Other

3. Which road did you take to reach the Green Bay area?

☐ I-43 ☐ US 41 ☐ Highway 54 ☐ Highway 32 or 57 ☐ Other

4. Were you aware of the work zone on US 41 in Green Bay before making this trip? ☐ yes ☐ no

5. Did part of your trip include passing through the work zone on US 41 in Green Bay? ☐ yes ☐ no

(If the answer to 5 is no, otherwise ask question 7) 6. Why did you not pass through the work zone?

☐ Would not have ordinarily gone through the work zone.
☐ Would have ordinarily gone through the work zone but planned ahead to avoid it.
☐ The trip was rerouted because the speed advisory signs said the speeds were low.
☐ The trip was rerouted because other en route information suggested avoiding the work zone.
☐ Other _____

(If the answer to 5 is yes) 7. Why did you pass through the work zone?

☐ There was no choice. Explain _____
☐ The speed advisory signs indicated that any delays would be tolerable.
☐ Other information received indicated that any delays would be tolerable.
☐ Had no information about delays but assumed delays would be tolerable.
☐ It was a mistake.
☐ Other _____

8. Rate the accuracy of the speeds displayed by the speed advisory sign approaching the work zone.

☐ Cannot rate the accuracy for some reason
☐ Very accurate
☐ Somewhat accurate
☐ Not accurate

9. Rate your satisfaction with the speed advisory sign approaching the work zone.

☐ Cannot rate my level of satisfaction for some reason
☐ Very Satisfied
☐ Moderately Satisfied
☐ Neither Satisfied or Dissatisfied
☐ Moderately Dissatisfied
☐ Very Dissatisfied

10. Estimate how long your trip was delayed because of the work zone, either avoiding it or going through it.

_____ hours _____ minutes (formats: 1 ½ hours; 90 minutes; 1 hours 30 minutes)

11. (Gender) ☐ Female ☐ Male

12. About what is your age? ☐ 16-25 ☐ 26-45 ☐ 46-65 ☐ 66 or more

13. How many people, driver and passengers, are in your vehicle for this trip? _____