Effects of a Smart Work Zone on Motorist Route Decisions

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ABSTRACT

Traffic congestion and safety is an ongoing concern of many highway agencies when highway construction and maintenance work is necessary. An aging road infrastructure has resulted in the need for more maintenance activities, while at the same time traffic volumes continue to rise.

To manage traffic more effectively in and around work zones several agencies have begun using Smart Work Zone systems. This technology measures current traffic conditions approaching the work zone and uses portable roadside signing to advise drivers of reduced speeds ahead, expected delays, and the use of alternate routes. The purpose of the system is to reduce delays and queues, reduce driver frustration, and increase driver awareness of upcoming conditions.

A study was conducted of a Smart Work Zone deployment on Interstate 95 in North Carolina during the 2003 construction season to examine motorist's preference to use an alternate route when presented with real-time traffic information. When presented with advisory information drivers have the opportunity to make an informed choice to stay on the mainline or to use an alternate route. Use of the alternate route was affected by the type of information presented, with a greater response observed when specific information on the expected delay and an alternate route were provided, when compared to just the expected delay or a generic message. During periods of congestion at the alternate route exit more drivers chose to use the alternate route than when congestion was not present. The results are important as a measure of effectiveness for Smart Work Zone deployments and to facilitate modeling and quantification of benefits.

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Introduction

Smart Work Zones are being used as an innovative tool to manage traffic at locations where highway construction and repair work is causing congestion and safety concerns. Smart Work Zones provide real-time information to motorists of current conditions and in some applications provide alternate route suggestions. One of the purposes of a Smart Work Zone deployment is to reduce queue length, congestion and travel time for motorists by diverting some traffic from the mainline to alternate routes. Determining the reaction of motorists to real-time information is important as a measure of effectiveness for Smart Work Zone deployments and to facilitate modeling and quantification of benefits.

The objective of this research is to determine to what extent motorists will divert to an alternate route when provided with different levels of advisory messages. Advisory messages may provide several levels of detail depending on operating parameters and current conditions. In this study, the first level message considered was a general message that construction is occurring and that congestion and delays may be present, but no specifics as to the extent. The second level message included specific values for the amount of delay to be expected. The third level message provided specific values for the amount of delay to be expected and also suggested a specific alternate route. Visible congestion may also affect a driver's perception of the expected user delay and relevance of advisory messages, and therefore is also considered in determining driver response to messages.

Smart Work Zones as a Traffic Management Tool

The purpose of a Smart Work Zone system is to provide motorists with accurate and up to date information on current traffic conditions so they can make appropriate travel choices, given their own personal circumstances, preferences, and needs. In a work zone setting this is achieved through the use of portable trailer mounted equipment which includes non-intrusive traffic monitoring devices for obtaining data and portable changeable message signs for communicating information to drivers. Congestion and delay is alleviated at the work zone when motorists choose to use alternate routes that reduce their travel time and remove them from the work zone queue, thereby reducing travel time for motorists choosing to travel through the work zone. A typical Smart Work Zone system layout is illustrated in Figure 1.

The reaction of a motorist to a message sign providing traffic information is complex and may be affected by factors such as age, gender, trip purpose, network familiarity, education and trust in message content. Previous research into the use of variable message signs for freeway management applications has shown that drivers will respond differently depending on the content of the message provided. Messages that provide specific values for expected delay were more likely to result in a motorist choosing an alternate route than messages that did not provide specific values. Likewise, messages that provide guidance to a specific alternate route resulted in a motorist choosing to use an alternate route more often. For incident caused delays, identifying the location of the crash in the message also increased responsiveness of motorists. Driver responsiveness increased when at least two specific pieces of information were provided together and the greatest response was observed when three pieces of information, location, delay and alternate route, were provided(1). Other studies have also identified a link between message content and a motorist's willingness to use an alternate route(2, 3). Previous research has focused primarily on freeway management applications and there has been relatively little research into the response of drivers to travel information in a work zone setting. Research that has been done has not included messages that provide the motorist with both expected delay and alternate route guidance.

A field study in Wisconsin studied the response of drivers to real time information in a work zone setting in an area classified as rural, but with a number of alternate route options(4). The messages provided to motorists included the driving distance to the end of the work zone and the travel time to the end of the work zone. Alternate route advisories were not displayed on the variable message signs, but alternate routes were marked with static signing should motorists choose to use an alternate route. The results indicate that alternate route selection rates increased by seven to ten percent of the freeway traffic during peak periods, depending upon the location and the day of the week.

A similar project in Nebraska also studied the response of drivers to advisory information approaching a work zone. In this application delay advisories were provided when delays exceeded 5 minutes and when delays exceeded 30 minutes the message "CONSIDER ALT ROUTE" was also added, but no specific route was identified. Alternate route usage was eight percent when the signs were blank and increased to 11 percent of freeway traffic when an alternate route advisory was provided(5).

Site Configuration and Methodology

The field study was conducted in October, 2003 on Interstate 95 in Nash County, North Carolina near the city of Rocky Mount. A Smart Work Zone system had been deployed by International Road Dynamics and North Carolina Department of Transportation on this project since April 2003 and the operation of the system was not changed in any way for the study. Therefore, any local traffic was already familiar with the operation of the system and their reactions to messages included their previous experience with the system and perceptions of system accuracy and usefulness of information. However, more than 50 percent of vehicles traveling on Interstate 95 are not registered in North Carolina so there is an element of traffic with low system familiarity.

The project on which the Smart Work Zone system was deployed covered approximately 15 kilometres in both Southbound and Northbound directions, with an actual lane closure length of two to four kilometres at any time. Three sensor trailers were positioned upstream of the work area to monitor traffic conditions. Three message signs were positioned on I-95 upstream of the work area with at least one sign prior to the alternate route exit. Three additional message signs were positioned to provide route guidance to motorists on the alternate route. A typical road side message and public website are illustrated in Figure 2.

The information presented in this paper represents preliminary results from data collected at Exit 150 Southbound, which was the designated alternate route during the study period. The study location is in a rural area with an alternate route that normally experienced very low traffic volumes. This was ideal from a study and operational perspective in that there was minimal background traffic activity that might obscure the results and that capacity on the alternate route was sufficient to handle additional volumes of traffic.

Recording was conducted using a portable camera trailer that was already deployed as part of the Smart Work Zone system, as illustrated in Figure 3. To the motorist, there was no change in the look or configuration of the system that would affect driving behavior. Recordings were then analyzed to obtain the required information for the evaluation. Traffic counts were determined on one minute intervals for the quantity of cars and trucks on the mainline and the quantity of cars and trucks using the exit ramp to the diversion route. Traffic flow was also observed and periods of visible traffic congestion, characterized as slow moving or stop and go traffic, were noted. The point of observation was at the exit ramp to the alternate route, so is an indication of what motorists would see at the time of deciding whether to use the alternate route. Traffic congestion as observed from the portable camera trailer is shown in Figure 4. The Smart Work Zone system automatically records and archives video images from the camera and a log of all messages displayed on message signs. This information was used to correlate traffic volumes, traffic conditions, and sign messages for all time intervals.

Results of Analysis

To measure the effects of the Smart Work Zone on motorists using an alternate route, data was collected under three sign conditions. The three sign conditions considered and typical message wording were:

- Sign Condition 1: Generic message: “TRAFFIC SLOWING AHEAD / PREPARE TO MERGE” or “DRIVE WITH CAUTION / ROAD WORK AHEAD”
- Sign Condition 2: Delay message: “TRAFFIC STOPPED AHEAD / 10 MINUTE DELAY”
- Sign Condition 3: Delay message and route advisory: “TRAFFIC STOPPED AHEAD / 30 MINUTE DELAY / USE EXIT 150 AS ALT.”

Comparisons were made over several days under similar time and traffic conditions. Results from the mornings of Tuesday October 28th and Thursday October 30th are presented in Table 1. Line 1 shows that for a period of approximately one hour when only a generic message was posted, there were 25.7 cars and 8.6 trucks per hour on the exit ramp. For the same time period on October 28th when sign condition 2 or 3 were present, as shown in line 2, 73.7 cars and 11.6 trucks per hour used the exit ramp. The car volume on the exit ramp was almost three times higher when an advisory message of some type was present compared to a generic message. Truck volumes on the exit were only slightly higher under the advisory condition. Due to technical difficulties, the total traffic count for the mainline could not be obtained, so only the ramp volume counts can be compared. Traffic data recorded by the system indicated that congestion was not present at the decision making point and therefore traffic conditions are assumed to have no affect on driver choice.

Line 3 and 4 of Table 1 present a comparison of the reaction to the two types of advisory messages, one that only indicates delay (sign condition 2) and the other that indicates both delay and alternate route (sign condition 3). Usage of the exit by cars increased by 33 percent, while usage by trucks increased by 145 percent when the delay and alternate route were both provided. From these results it appears that longer delays and the designation of an alternate route affects both cars and trucks, but is of greater significance to trucks. When only delay times were posted, trucks were not as likely to alter travel plans. Under sign condition 3, the delay time indicated is greater than condition 2, as well as the alternate route advisory is added. Under condition 3 delays of 15 to 20 minutes were posted, while under condition 2 the posted delay was less than 15 minutes. It was not determined whether drivers were reacting to the increased delay time, the alternate route advisory, or a combination of both.

The results of observations on the afternoon of October 30th are presented in Figure 5. Each point on the graph represents the percentage of vehicles using the alternate route over a five minute interval starting at the time indicated. The traffic condition is indicated as either congested or uncongested by the line along the base of the graph. Traffic conditions were uncongested during the period from 12:02 to 14:30 and intermittently congested after 14:30. The sign status is indicated by the line along the top of the graph as either generic (condition 1) or advisory (condition 2 or 3). A generic message was posted prior to 14:30 while after 14:30 there were three short periods where an advisory message was provided.

Table 2 presents a breakdown of alternate route usage for variations of time, traffic, and sign message. Lines 1 to 3 are based on a generic warning being presented on the signs. Alternate route usage was lowest during the period of 12:00 to 14:30 when no congestion and no advisory was present (status 1) with an overall rate combining cars and trucks of 6.4 percent. After 14:30 intermittent periods of congestion and advisory sign messages began to occur. After 14:30 when congestion was not present (status 2) the alternate route was used by 10.9 percent of traffic. Although not categorized as "congested", it is reasonable to assume that conditions were closer to congested than during the period before 14:30 since intermittent congestion was occurring, so this period may represent an intermediate level of congestion. During periods where congestion was present, but only a generic message was provided (status 3), the alternate route usage jumped to 20.2 percent. From these results it appears that a motorist's decision to use an alternate route is affected by the presence of visible congestion at the decision point.

Lines 4 and 5 of Table 2 indicate the response of drivers to the two forms of message signs during uncongested conditions and provide a comparison to uncongested conditions with no advisory in line 1 and 2. It is noted that these results are based on a small sample size due to the intermittent periods when these conditions occurred. The sample size was further reduced by the use of a five minute buffer period in which data was not used after each change in sign status to allow for the time from when a motorist read the message to when they reached the exit. Exit usage was 9.3 percent during periods when a delay message was posted (status 4), an increase over usage prior to 14:30 when a generic message was displayed (status 1), but a decrease from usage after 14:30 when a generic message was displayed (status 2). When the alternate route message was displayed under uncongested conditions (status 5), exit usage increased to 25.5 percent.

The results of observations on the afternoon of October 28th, 2003 are presented in Figure 6. System operation was the same as for October 30th but there were periods of rainfall on October 30th which did not occur on October 28th. During the period from 12:00 to 14:00 the Smart Work Zone system displayed either a delay message or a delay and alternate route message. Congestion was only observed during a short period of time. Therefore this period provides a good contrast in operation to the period of generic messages over a similar time period on October 30th, as presented earlier.

There are two predominant conditions that existed during this time period, ignoring the short interval when congestion occurred. Analysis of exit ramp usage for October 30th is presented in lines 6 and 7 of Table 2. When the Smart Work Zone system displayed a delay message without providing an alternate route (status 6), 12.4 percent of cars, 8.2 percent of trucks and 11.4 percent of all vehicles used the alternate route. Comparing to results in line 1 and 2 in Table 2, there is an increase in ramp usage when a delay message is posted. When the Smart Work Zone displayed both the current delay and the suggested alternate route (status 7), 21.6 percent of cars, 27.3 percent of trucks, and 22.8 percent of vehicles overall used the exit ramp leading to the alternate route. This is a significant increase over the ramp usage when a generic message or a delay message was given under uncongested conditions. It is also of interest that in this case trucks were more likely to use the exit ramp. Lines 3 and 5 of Table 2 also showed trucks using the exit ramp more than cars, when congestion was present and when an alternate route advisory was given. For all other conditions cars used the exit at a greater rate than trucks. This may be an indication of the greater value placed on time by the trucking industry, and where it is clear that travel time is being impacted truckers are more eager to find a time saving alternative than car drivers.

Conclusion

The results of this study are useful as a measure of effectiveness for the deployment of Smart Work Zones. A primary purpose of Smart Work Zone is to reduce delay by appropriate diversion of traffic to alternate routes. By measuring diversion route usage, it was determined that the system was having the desired effect when the delay and alternate route messages were activated. Diversion route usage increased when a delay time and alternate route message was posted compared to no message or a message that only showed delay without identifying an alternate route. It was also observed that the visible presence of congestion at the decision point results in more drivers choosing to use an alternate route.

The results can be useful for an analysis of user delay reduction and the potential economic savings that could be realized through Smart Work Zone deployment. Estimates of delay time can be calculated based on the expected traffic flows and alternate route usage determined from this study and a monetary value assigned to delay reduction. The reaction of drivers to various control measures is also valuable input into traffic simulation models that may be used to analyze Smart Work Zone operations.

This study looked at a single deployment of a Smart Work Zone with specific conditions of traffic flow, closure type, driver familiarity and demographics, and available alternate routes. Traffic response will not be the same if these conditions are changed and further research is required to understand the effectiveness of Smart Work Zones in other settings. User delay reduction represents only one of the potential benefits of Smart Work Zone deployment and other benefits such as safety improvements and emissions reductions should also be considered.

References

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Tables

Table 1: Exit ramp traffic volume under varying sign messages

Status	Cars On Exit (Vehicles / hour)	Trucks on Exit (Vehicles / hour)	Vehicles on Exit (Vehicles / hour)
1. Oct. 30, 9:37 am to 10:33 am, no advisory	25.7	8.6	34.3
2. Oct. 28, 9:37 am to 10:33 am, delay and alternate route advisory	73.7	11.6	85.3
3. Oct. 28 am, delay advisory	75	11.8	86.8
4. Oct. 28 am, alternate route advisory	100.0	28.9	128.9

Table 2: Effects of message details and congestion on alternate route usage

Status	% Cars On Exit	% Trucks on Exit	% of all Vehicles on Exit
1. Oct. 30, Uncongested prior to 14:30, no advisory	6.6	5.5	6.4
2. Oct. 30, Uncongested after 14:30, no advisory	11.5	8.0	10.9
3. Oct. 30, Congested after 14:30, no advisory	19.7	22.4	20.2
4. Oct. 30, Uncongested after 14:30, delay advisory	10.8	4.3	9.3
5. Oct. 30, Uncongested after 2:30 pm, delay and alternate route advisory	21.1	50.0	25.5
6. Oct. 28, Uncongested, delay advisory	12.4	8.2	11.4
7. Oct. 28, Uncongested, Delay and alternate route advisory	21.6	27.3	22.8

Figures

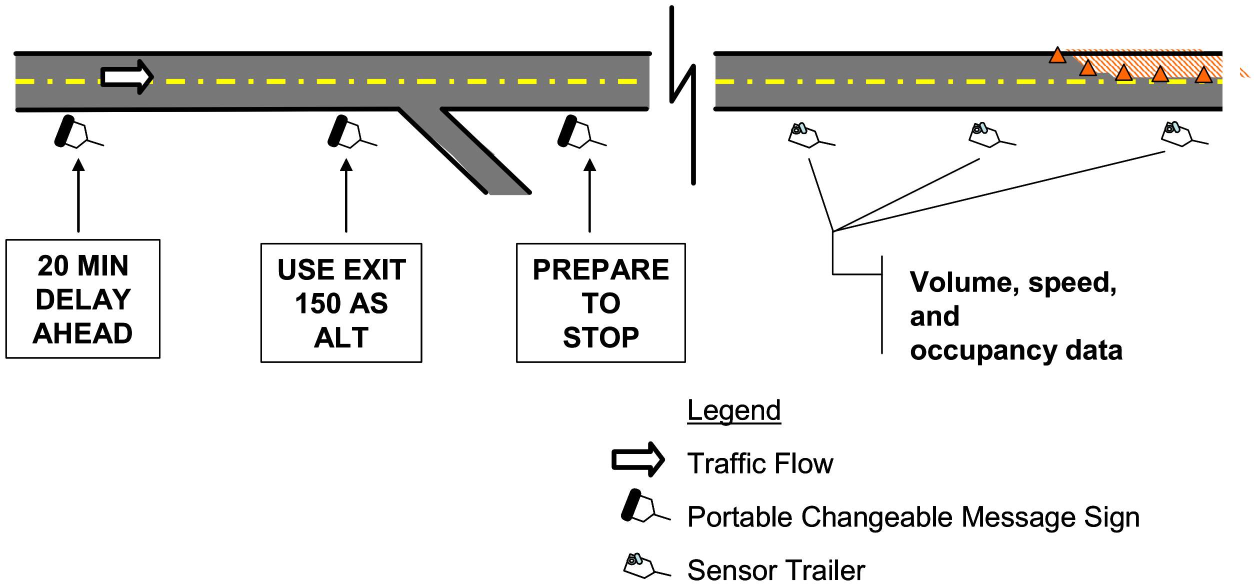

Figure 1: Typical Smart Work Zone system layout

Figure 2: Roadside and website display of Smart Work Zone information

Figure 3. Portable camera trailer deployed on Interstate 95

Figure 4. Traffic congestion as recorded by the portable camera trailer at Exit 150

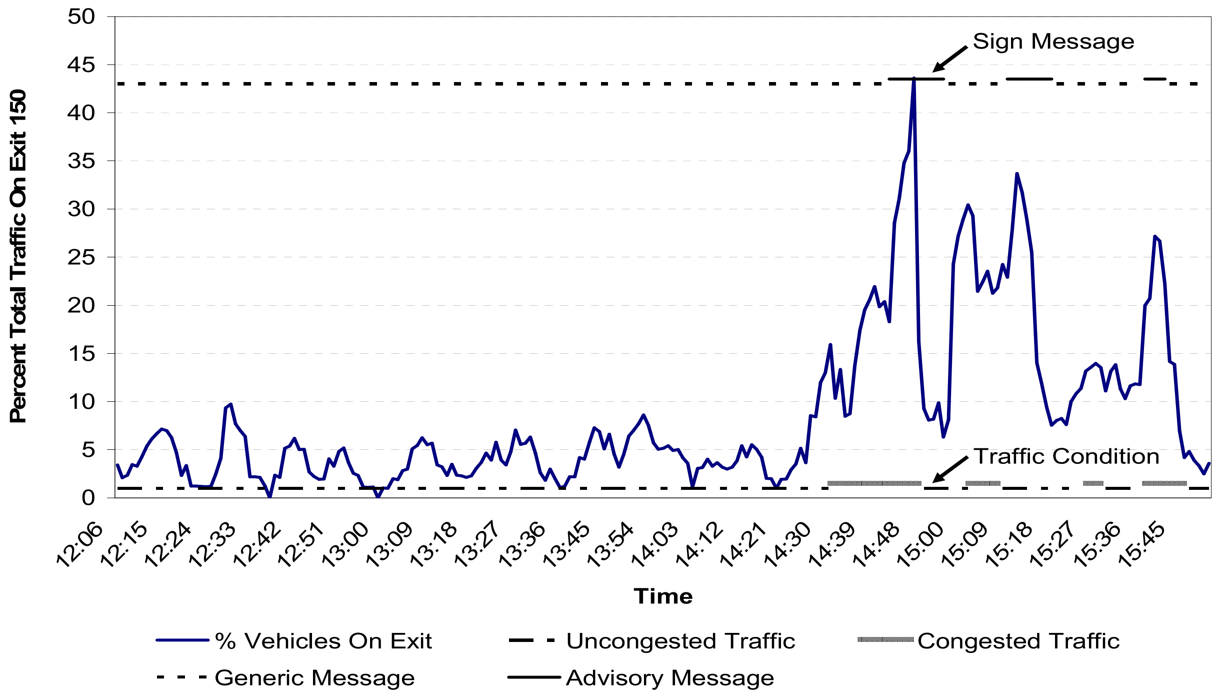

Figure 5: Percentage of total traffic using exit 150, October 30, 2003

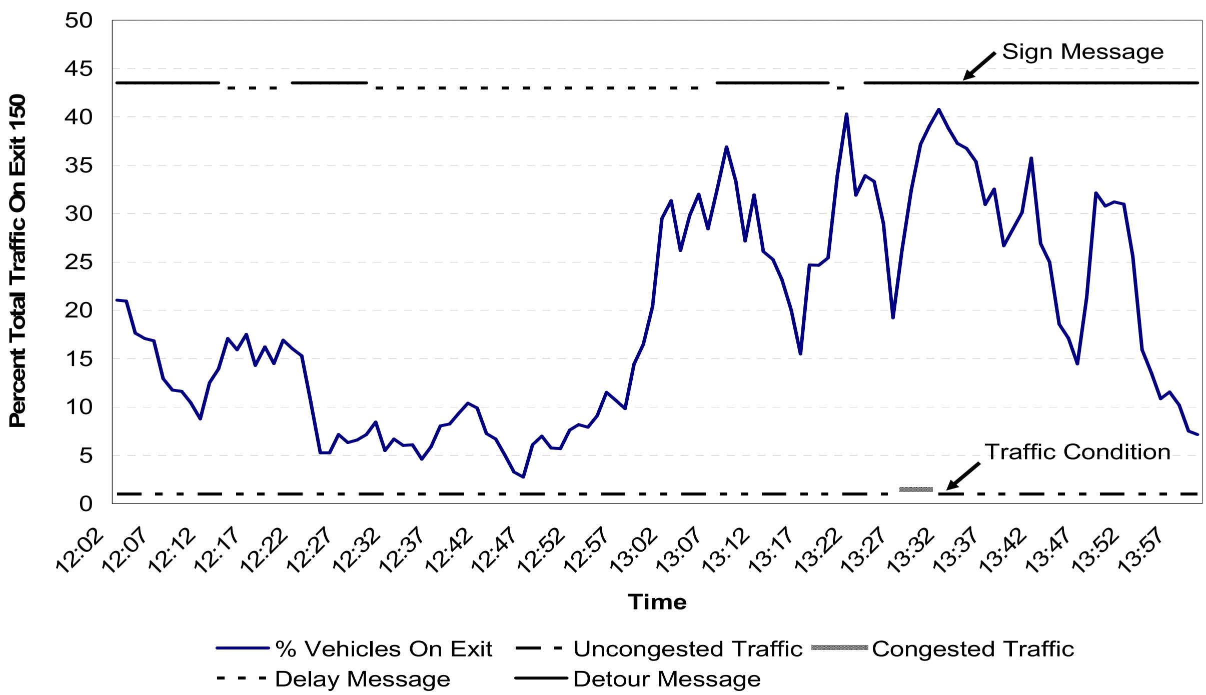

Figure 6: Percentage of total traffic using exit 150, October 28, 2003