RESPONSE OF NORTH CAROLINA MOTORISTS TO A SMART WORK ZONE SYSTEM

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ABSTRACT

An evaluation is made of the response of motorists to the deployment of an intelligent transportation system (ITS) at several highway construction projects in North Carolina. The primary objective of the Smart Work Zone system is to improve safety and mobility for motorists by providing them with real-time information regarding traffic conditions and alternate route options. A survey was conducted of local residents to determine their perceptions and acceptance of the Smart Work Zone.

The ITS system measures current traffic conditions at strategic points to advise drivers of expected delays ahead and direct them to alternate routes using portable changeable message signs and provides current delay information on a website. Under periods of heavy delay the system will encourage drivers to use specified detour routes, reducing traffic demands at the work zone.

Surveys were mailed to 1468 residents in the vicinity of the construction projects and over 20 percent were completed and returned. Survey results were broken down based on the frequency with which motorists travelled through the work zone area. Results indicate that overall, motorists were aware that the system was providing more up-to-date information than at other work zone sites and perceived the information as always accurate or sometimes accurate in over 95 percent of cases. The majority of motorists were unaware that a website existed to obtain current travel conditions, but those that were aware made moderate use of the website. Over 95 percent of motorists supported the future use of these types of systems in North Carolina.

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INTRODUCTION

Work zones are a necessary part of maintaining and upgrading the highway transportation infrastructure. They are also a cause of increased congestion, reduced safety, and traveler dissatisfaction. Ever increasing traffic demands coupled with an aging infrastructure in need of more attention to maintain adequate service levels are only making the problem worse. Work zones are responsible for an estimated 24 percent of nonrecurring congestion on the United States highway system. Work zone fatalities have been increasing steadily for the last few years, with 1,181 fatalities resulting from crashes in work zones in 2002 *(1)*. According to an FHWA report on roadways and transportation, American drivers indicated that work zones were the second leading cause of driver dissatisfaction, second only to poor traffic flow *(2)*. If a transportation agency takes a customer oriented view towards providing a safe and efficient transportation system then addressing sources of dissatisfaction should be a priority. One of the new approaches being used by transportation agencies to address safety and mobility issues in work zones is the application of intelligent transportation systems (ITS) technology in work zones. Commonly referred to as Smart Work Zones, ITS technology in work zones is a tool that can be used to better manage traffic in and around work zones to improve safety and mobility. The purpose of this study is to examine how one agency is trying to address the frustration of motorists with work zones and determine the success of their efforts based on the reaction of local residents.

North Carolina Department of Transportation (NCDOT) has used Smart Work Zones on several projects to provide real-time information to motorists informing them of expected delays and alternate route options. In this study, a survey of local residents was conducted to determine their perceptions and acceptance of a Smart Work Zone system. The local residents are an important group in assessing system performance as they are both users of the system and also provide funding for the systems through tax revenue. The two projects that are the subject of this study took place on Interstate 95 in North Carolina on sections of rural freeway.

Limited information is currently available on motorist attitudes and reaction to a Smart Work Zone. A survey was conducted of motorists in Ohio that traveled through a Smart Work Zone *(3)*. When asked about the perceived accuracy of the system, 41.7 percent said the system was sometimes accurate and 28.0 percent said the system was always accurate. A system that could advise motorists of delay in advance with enough opportunity to use alternate routes was indicated as helpful by 85.6 percent of respondents. The route studied in Ohio started on the outskirts of Dayton and ended in the downtown area.

NORTH CAROLINA I-95 REHABILITATION AND SMART WORK ZONE PROJECT

Interstate 95 is a key north-south trade and travel corridor running the entire length of the eastern seaboard. Interstate 95 carries a large portion of through traffic back and forth between the heavily populated regions of north-eastern USA and Florida. Two rehabilitation projects took place on Interstate 95 in 2003, one between milepost 101 and 107 in the vicinity of Smithfield and the other between milepost 145 and 154 in the vicinity of Rocky Mount.

Interstate 95 in North Carolina presents some challenges in regards to work zone traffic management. With an AADT of 35,000 to 40,000 on most sections, closure of one of the two lanes for road work results in congestion and queuing. While work zones at any location result in increased safety concerns, Interstate 95 in North Carolina has some characteristics that compound the safety problem. Approximately 57 percent of all drivers on Interstate 95 reside outside of North Carolina, compared to only 5 percent of drivers on all North Carolina highways residing outside of North Carolina. Driver familiarity can be a factor in work zone safety and mobility and in this case a large portion of drivers will be unfamiliar with the work taking place and the traffic control measures being used. The fatal crash rate on Interstate 95 is 1.05 fatal crashes per 100 million vehicle miles traveled, 62 percent higher than the state-wide crash rate on rural Interstates of 0.65 fatal crashes per 100 million vehicle miles traveled *(4)*.

To manage traffic during these projects, NCDOT contracted for the use of a Travel Messenger system supplied by International Road Dynamics Inc. Travel Messenger is a real time information system designed to alert drivers to expected delays and direct them to an alternate route when appropriate. Roadside information signs divert traffic to an alternate route to alleviate congestion on the mainline route when excessive traffic delays begin to occur. The signs also keep drivers who have stayed on the mainline informed of the expected delays in order to relieve anxiety and road rage. A roadside message sign providing delay information is illustrated in Figure 1.

Trailer mounted non-intrusive traffic sensors deployed at three locations in the area leading up to the construction site monitor traffic conditions on an on-going basis. As traffic approaches exits leading to detour

routes, a portable changeable message sign (PCMS) is activated based on current conditions to divert traffic to the detour route and to inform drivers of the number of minutes of delay to be expected. The typical components and layout of a Smart Work Zone system are illustrated in Figure 2. On this project, 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.

Three levels of messages were provided to motorists, depending on the traffic conditions. Messages were displayed on three lines and up to three frames in sequence. Generic messages informing motorists of a work zone ahead, such as "Traffic Slowing Ahead / Prepare To Merge" and "Real Time Traffic Info / No Delay Exits 150-141", were displayed when no delays were detected. When short delays were detected, but not long enough to warrant the use of the alternate route, the current delay estimate was displayed with a message such as "Traffic Stopped Ahead / 15 Minute Delay". When delay time reached the point where the alternate route would offer a shorter travel time, the amount of delay and the suggested alternate route were displayed using a message such as "Traffic Stopped Ahead / 20 Minute Delay / Use Exit 141 As Alt.".

The Travel Messenger system also provides information remotely via a website to traffic managers and the general public, as illustrated in Figure 3. A public website provides information to travelers prior to departure so they can plan to avoid the area during periods of heavy traffic. By encouraging drivers to use alternate routes or change the timing of their travel plans, demand and congestion is decreased. Information provided to traffic managers allows them to monitor the traffic flow and respond to incidents or periods of excessive congestion.

SURVEY OF MOTORIST RESPONSE TO A SMART WORK ZONE

Real time information systems in work zones are a relatively new tool being used by NCDOT to manage traffic during construction projects. As part of a larger evaluation of the impacts of using real-time information systems in work zones, the objective of this study was to determine the views of local motorists regarding the accuracy, usefulness and future use of this type of technology. Other aspects of the evaluation will look at effects on motorist delay, safety, and the views of the trucking industry and out-of-state traffic.

In the vicinity of the two construction projects are the communities of Smithfield and Rocky Mount. 1486 local residents were selected to participate in the survey, with the only criteria being residence in one of the two communities. Frequency of travel was determined from survey responses. No further separation of respondents was made, such as age, gender, experience, or other factors.

Survey participants received a mail-out survey within two months after the conclusion of the construction projects. The survey package included a cover letter on NCDOT letterhead from the Director of Construction asking for the recipient's participation in the survey, a brief description of the system and its use during the 2003 construction season and a one page survey with 11 multiple choice response questions. A postage paid return envelope addressed to NCDOT was also included. Surveys were completed and returned by 333 recipients, a response rate of 22.7 percent.

ANALYSIS OF SURVEY RESULTS

The survey contained two types of questions. Some questions were used to determine characteristics of the motorist such as the frequency of their travel through the work zone, their access to the internet, and their awareness of a travel information website. Other questions were used to determine perceptions, response, and opinions regarding the travel information system. Responses to survey questions one to five are presented in Table 1.

Question 1 determined the frequency of travel of survey respondents through the area of the work zone. Interstate 95 is not a regular commuter route for many of the residents of this area, as only 11.7 percent of respondents indicated using the route several or many times per week. The majority of respondents indicated traveling the route either several times per month (29.8 percent) or once per month or less (47.9 percent). Surveys returned from residents who never traveled through the area of the work zone were 10.5 percent of the total surveys returned. In addition to providing some indication of local travel patterns, responses to question 1 will be used in breaking down responses to other questions according to frequency of travel. Through the remainder of the discussion, respondents will be categorized based on the frequency of travel as frequent, occasional, and infrequent.

Question 2 asked motorists if they remembered seeing the changeable message signs as they travelled through the work zone. For this question, respondents who had indicated never traveling through the work

zone were excluded. In 90.9 percent of responses it was indicated that the motorist remembered seeing the signs. The percentage of respondents recalling seeing the signs was similar for frequent (94.9 percent) and occasional (96.0 percent) travellers, but dropped off slightly for infrequent (86.7 percent) travellers.

The purpose of question 3 was to determine if motorists realized that they were observing a real-time information system as opposed to pre-programmed messages that they might see at other construction sites. Responses to question 3 are illustrated in Figure 4. For this question, those respondents who indicated never travelling through the work zone and those indicating not remembering seeing the signs were excluded, leaving 262 responses for analysis. This same subset was also used for analyzing responses to questions 4 through 9. When the whole subset was considered, 80.9 percent indicated that they realized this was a real-time information system. Frequent motorists (91.7 percent) were more likely to recognize that the system was based on current traffic information than occasional (79.6 percent) and infrequent (78.9 percent) motorists.

Question 4 dealt with the perceived accuracy of the system. Responses to question 4 are illustrated in Figure 5. The system was classified as always accurate by 42.6 percent of respondents, sometimes accurate by 54.4 percent of respondents, and seldom accurate by 3.0 percent of respondents. The frequent users perceived the system as being more accurate than the occasional and infrequent users. Of the frequent users, who would have more experience with the system on which to base their judgment, 51.4 percent indicated the system was always accurate, 48.6 percent sometimes accurate and no respondents indicated seldom or never accurate.

Question 5 addressed the influence of the system on route choice. Responses to question 5 are presented in Figure 6. Frequent travelers were highly likely to be influenced by the system, with 40.5 percent indicating they were often influenced and another 45.9 percent indicating they were sometimes influenced, which combined includes 86.4 percent of frequent travelers. This is noticeably higher than the occasional (70.3 percent) and infrequent (60.2 percent) travelers who indicated being influenced sometimes or often. Considering the results of question 3, 4 and 5 together, the results suggest that as motorists realized the system was providing real-time information to them and gained trust in the accuracy of the information, the system had a greater influence on the travel choices.

Responses to survey questions 6 to 11 are presented in Table 2. Question 6 asked motorists if they were able to read and understand the messages presented by the system. The question was general in nature and did not refer to any specific message that may have been displayed. Responses to question 6 are illustrated in Figure 4. In all categories the ability to read and understand the message was near 100 percent, with the lowest response being 98.5 percent.

In addition to the roadside message signs, a travel information website was also available where motorists could check the current status of traffic at the work zone. Responses to question 7 indicated that 75.4 percent of motorists had convenient access to the internet. This information was used in breaking down the responses to question 8 and 9.

When asked in question 8 if they were aware a website existed to obtain travel information only 15.7 percent of respondents indicated they were aware of the travel information website. An unexpected result was that more respondents without internet access (26.2 percent) indicated they were aware of the website than respondents with internet access (12.4 percent).

The subject of question 9 was the amount of use that respondents made of the travel information website. Responses to question 9 are illustrated in Figure 6. It was indicated by 93.1 percent of respondents that they never used the website. When those without convenient internet access were removed from consideration, the percentage never using the website only decreased slightly to 92.7 percent.

Until motorists are aware that the website information is actually available and they have a way to access that information, they can not really be considered as potential users. When only potential users, those who were aware of the travel information website's existence and had convenient internet access, are considered the rate of usage shifts considerably. The percentage of respondents never using the website decreased from over 90 percent of all respondents to 52.0 percent when only potential users are considered. In the group of potential users, 4.0 percent used the website often, 16.0 percent sometimes and 28.0 percent seldom checked the website.

Question 10 is a more general question regarding the alteration of trip planning by changing departure time. The response is not necessarily directly related to the presence of the information system, although the website could influence the decision making process. When a traffic disruption is known to exist, such as a lane closure in a work zone, some motorists will choose to change their travel plans to avoid periods of expected delay. The amount of travel time shifting will affect traffic demand at the work zone and change the amount of delay experienced by motorists. Estimates of expected delay that take into account travel time

shifting may be more accurate; therefore it is useful to have an indication of how much travel time shifting occurs.

Any motorist that travelled through the work zone could have shifted travel time without actually having seen the roadside signs. Therefore question 10 is based on all respondents except those that never travelled through the work zone. Travel time shifting was used often (7.2 percent) and sometimes (16.6 percent) by 23.8 percent of motorists. Time shifting often or sometimes was only indicated by 15.4 percent of frequent travellers, which is less than the amount of time shifting by occasional (26.8 percent) and infrequent (24.0 percent) users. It may be that the frequent travelers represent more work related trips with less flexibility while the occasional and infrequent trips are more personal with greater flexibility in timing.

The final question was a summary question to determine, all things considered, whether respondents felt that NCDOT should continue deploying real-time information systems. Responses to question 11 are illustrated in Figure 4. Since this was a policy question all survey responses were considered including those who had never travelled through the work zone. NCDOT should continue to use systems of this type according to 95.3 percent of survey respondents. The frequent travelers, who had the most exposure to the system, were 100 percent in favor of NCDOT deploying more systems of this type. Support was slightly less but still very high for other motorist groups as well, with 96.8 percent of occasional and 92.9 percent of infrequent users supporting future use. Also of interest was the effect of perceived system performance on support for future use. Respondents who felt the system was sometimes accurate or always accurate indicated more than 96 percent support for future use of the system. When system accuracy was perceived as seldom accurate support for future deployment dropped to 77.8 percent. Referring back to question 4, it was only 3.4 percent of respondents that felt the system was seldom accurate.

BENEFITS OF SMART WORK ZONE DEPLOYMENT

A variety of potential costs and benefits that may result from a transportation project have been identified *(5, 6, 7, 8)*. A listing of benefits and costs that may be relevant for a Smart Work Zone project is given in Table 3, categorized into Agency, User and Society. Some of the items listed may actually cross the category boundaries, and may be either a benefit or a cost depending on the specifics of the application. Some evaluation approaches have attempted to monetize most or all of the benefits and costs of a project, while others treat many of the factors in a subjective and qualitative manner.

A comprehensive assessment of costs benefits was not completed for the case study projects. However the survey results provide some relevant information for the assessment of a Smart Work Zone. One of the benefits apparent from the survey is the good will towards NCDOT generated by the project. The support for future deployment of Smart Work Zone systems was over 95 percent. Survey respondents were also given an opportunity to provide written comments regarding the project and the majority were positive in nature.

The resident engineers responsible for each of the case study projects were provided the opportunity to provide feedback on the use of Smart Work Zones. A potential negative effect of a Smart Work Zone is congestion caused on alternate routes due to the increased volume of traffic but this was not an issue on this project. One occurrence of congestion on the alternate route did occur when I-95 southbound was completely closed due to an incident. In this case, the Smart Work Zone was found to be very useful as an incident management tool to mitigate the effects of the crash and resulting traffic congestion *(9)*.

More than 65 percent of respondents indicated that the sign messages “sometimes” or “often” affected their travel route decisions. This indicates that this approach can be used as a traffic management tool to reduce travel time and travel time delay. A field investigation of alternate route usage at one of the sites indicated that 5 to 15 percent of traffic reacted to an alternate route advisory and modified their travel plans (Bushman, 2004).

DISCUSSION AND CONCLUSIONS

In its continuing efforts to provide a quality transportation infrastructure while maintaining safety and mobility, NCDOT has deployed Smart Work Zones on a number of recent construction projects. Overall, the reaction of local residents to the efforts of NCDOT was highly positive with more than 95 percent supporting future projects of this type. Perceptions of system accuracy and the usefulness of the information to influence travel decisions were positive, especially for frequent travelers through the work zone. All responses from frequent travelers indicated that the system was either sometimes accurate or always accurate. The travel information website which provided motorists with the opportunity to check conditions prior to beginning a trip appears to be under utilized with more than 93 percent of respondents never using it. Based on the survey responses, the

lack of website usage appears to be primarily due to a lack of awareness and accessibility. Motorists who were aware of the website and had access to the internet made moderate use of this service.

The results presented here cover one sector or road users, the local residents in the vicinity of the work zone. Two other sectors not covered here, commercial trucking and out of State drivers, will be addressed as part of a larger evaluation of the use of Smart Work Zones.

A wide range of potential benefits and costs that could result from the deployment of a Smart Work Zone have been identified. The results of this study contribute to the analysis of costs and benefits. The development of an approach for a more comprehensive analysis of Smart Work Zone project is recommended. This analysis approach should include both a qualitative analysis of effects and a quantitative economic analysis of significant costs and benefits. Since Smart Work Zones are a relatively new approach to traffic management, the analysis will rely on available past research but may also require other techniques such as modeling and simulation where historical information is insufficient.

ACKNOWLEDEMENTS

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LIST OF TABLES AND FIGURES

TABLE 1 Survey Results: Questions 1 to 5

1. During the period of April to October 2003 work zones were located on I-95 near Smithfield and Rocky Mount. Which of the following best describes how often you drove through the area of one of these work zones? *(332)*	**Several or many times per week**	**Several times per month**	**Once per month or less**	**Never**
	11.7 %	29.8 %	47.9 %	10.5 %
2. Do you remember seeing the changeable message signs which provided information about expected delays and alternate routes? *(296)*			**Yes**	**No**
			90.9 %	9.1 %
2.a. Travel Frequency: Several or many times per week (39)			94.9 %	5.1 %
2.b. Travel Frequency: Several times per month (99)			96.0 %	4.0 %
2.c. Travel Frequency: Once per month or less (158)			86.7 %	13.3 %
3. Did you know or perceive that the sign messages were based on current traffic condition information rather than pre-programmed messages? *(262)*			**Yes**	**No**
			80.9 %	19.1 %
3.a. Travel Frequency: Several or many times per week (36)			91.7 %	8.3 %
3.b. Travel Frequency: Several times per month (93)			79.6 %	20.4 %
3.c. Travel Frequency: Once per month or less (133)			78.9 %	21.1 %
4. Based on your driving experience through these work zones, do you feel the delay information presented on the signs was accurate and reliable? *(264)*	**Always accurate**	**Sometimes accurate**	**Seldom accurate**	**Never accurate**
	42.6 %	54.4 %	3.0 %	0.0 %
4.a. Travel Frequency: Several or many times per week (37)	51.4 %	48.6%	0.0 %	0.0 %
4.b. Travel Frequency: Several times per month (94)	30.9 %	66.0 %	3.2 %	0.0 %
4.c. Travel Frequency: Once per month or less (132)	48.5 %	47.7 %	3.8 %	0.0 %
5. When a delay advisory was shown on the changeable message signs, did this information influence your decision whether to choose an alternate route to avoid the area of the work zone? *(264)*	**Often**	**Sometimes**	**Seldom**	**Never**
	26.1 %	41.7 %	17.4 %	14.8 %
5.a. Travel Frequency: Several or many times per week (37)	40.5 %	45.9 %	13.5 %	0.0 %
5.b. Travel Frequency: Several times per month (94)	27.7 %	43.6 %	17.0 %	11.7 %
5.c. Travel Frequency: Once per month or less (133)	21.1 %	39.1 %	18.8 %	21.1 %

* Number in brackets indicates number of survey responses meeting criteria

TABLE 2 Survey Results: Questions 6 to 11

6. Were you able to read the messages on the signs and understand their meaning? *(268)*			**Yes**	**No**
			98.9 %	1.1 %
6.a. Travel Frequency: Several or many times per week (37)			100.0 %	0.0 %
6.b. Travel Frequency: Several times per month (94)			98.9 %	1.1 %
6.c. Travel Frequency: Once per month or less (137)			98.5 %	1.5 %
7. Do you have convenient access to the internet, such as at home or in your workplace? *(268)*			**Yes**	**No**
			75.4 %	24.6 %
8. Were you aware a website was available where information on current traffic conditions and delays on these specific projects could be obtained? *(267)*			**Yes**	**No**
			15.7 %	84.3 %
8.a. Internet access (202)			12.4 %	87.6 %
8.b. No Internet access (65)			26.2 %	73.8 %
9. How often did you check this website before making a trip through the area of the work zone? *(259)*	**Often**	**Sometimes**	**Seldom**	**Never**
	0.4 %	1.5 %	5.0 %	93.1 %
9.a. Internet access (193)	0.5 %	2.1 %	4.7 %	92.7 %
9.b. Access and aware of website (25)	4.0 %	16.0 %	28.0 %	52.0 %
10. Did you ever alter the start of your travel by more than one hour in an attempt to avoid delays on I-95? *(290)*	**Often**	**Sometimes**	**Seldom**	**Never**
	7.2 %	16.6 %	16.6 %	59.7 %
10.a. Travel Frequency: Several or many times per week (39)	5.1 %	10.3 %	20.5 %	64.1 %
10.b. Travel Frequency: Several times per month (97)	6.2 %	20.6 %	20.6 %	59.7 %
10.c. Travel Frequency: Once per month or less (154)	8.4 %	15.6 %	13.0 %	63.0 %
11. Do you think NCDOT should continue to deploy more of these kinds of systems in the future to keep travellers informed of current conditions? *(317)*			**Yes**	**No**
			95.3	4.7
11.a. Travel Frequency: Several or many times per week (38)			100.0 %	0.0 %
11.b. Travel Frequency: Several times per month (95)			96.8 %	3.2 %
11.c. Travel Frequency: Once per month or less (155)			92.9 %	7.1 %
11.d. Travel Frequency: Never or no response (28)			96.4 %	3.6 %
11.d. Travel Frequency: Never (27)			96.3 %	3.7 %
11.e. Information always accurate (109)			96.3 %	3.7 %
11.f. Information sometimes accurate (140)			97.1 %	2.9 %
11.g. Information seldom accurate (9)			77.8 %	22.2 %

* Number in brackets indicates number of survey responses meeting criteria

Table 3 Potential Benefits and Costs Associated With a Smart Work Zone Deployment

Agency	User	Society
Construction efficiency	Travel time delay	Air pollution
Construction schedule flexibility	Travel time variability	Noise pollution
Public relations	Vehicle operating costs	Alternate route congestion
Incident management / mitigation	Driver aggressiveness reduction	Business/economy impact
Benefits to other agencies	Fatal crash reduction	
Worker safety	Injury and property crash reduction	
Project management		
Data collection		
Right of way requirements		
Future innovation		

FIGURE 1 Roadside Message Sign Providing Delay Information

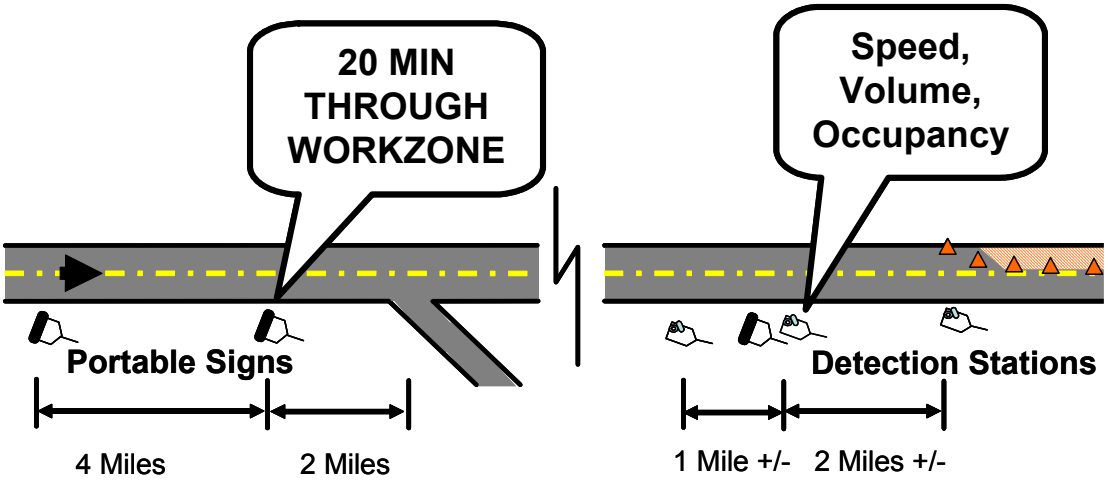

FIGURE 2 Typical Smart Work Zone System Layout

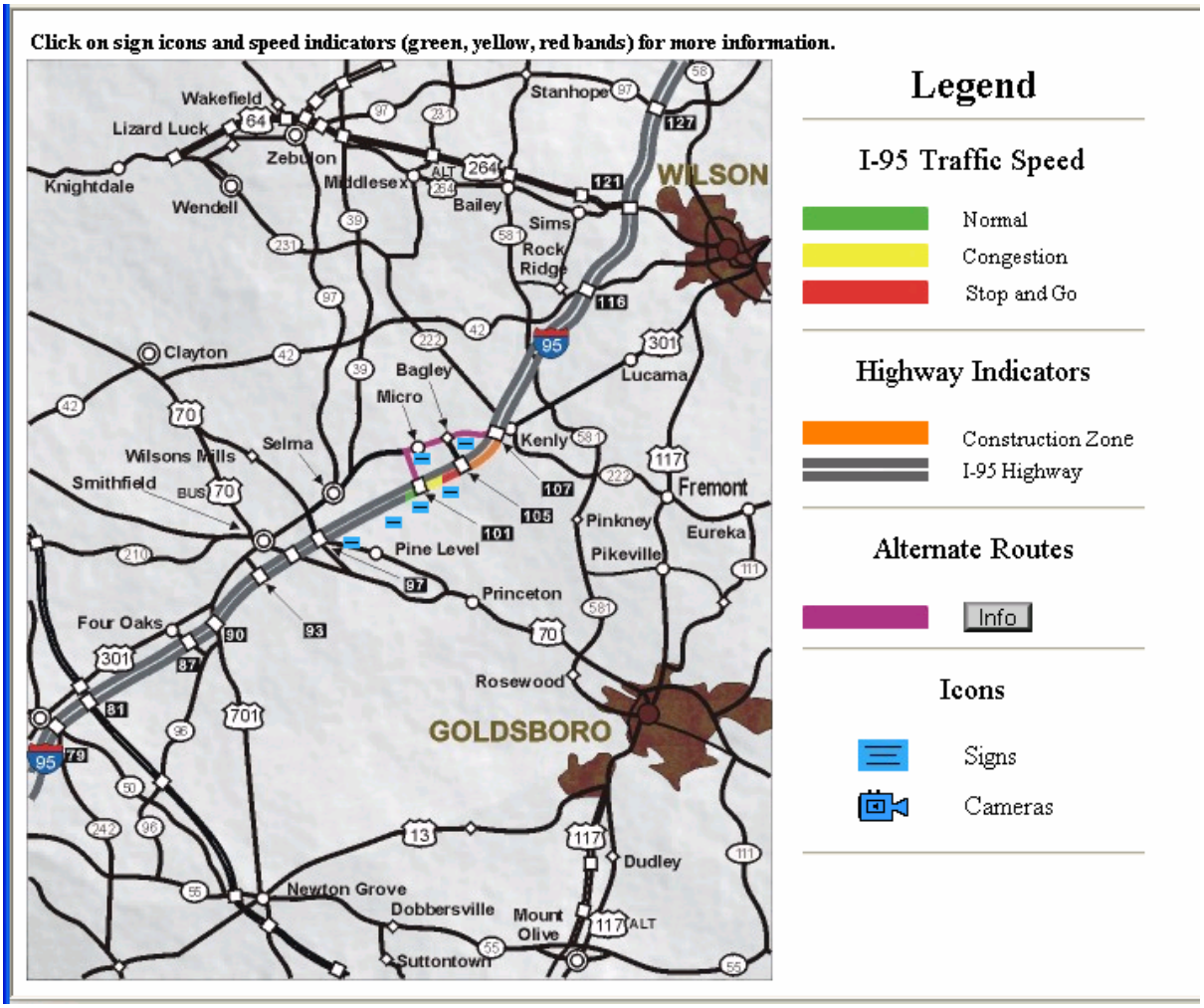

FIGURE 3 Typical Smart Work Zone Travel Information Webpage

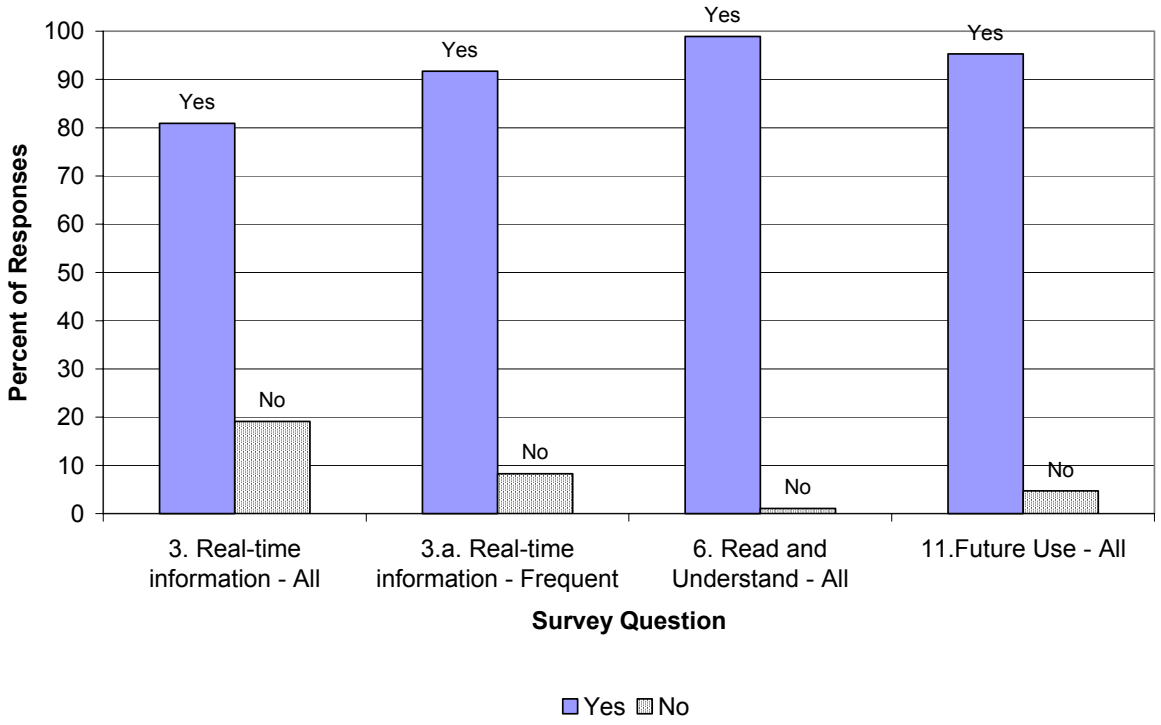

FIGURE 4 Response to Survey Question 3 (Awareness that real time information was being provided), Question 6 (Ability to read and understand sign), and Question 11 (In favor of future deployments)

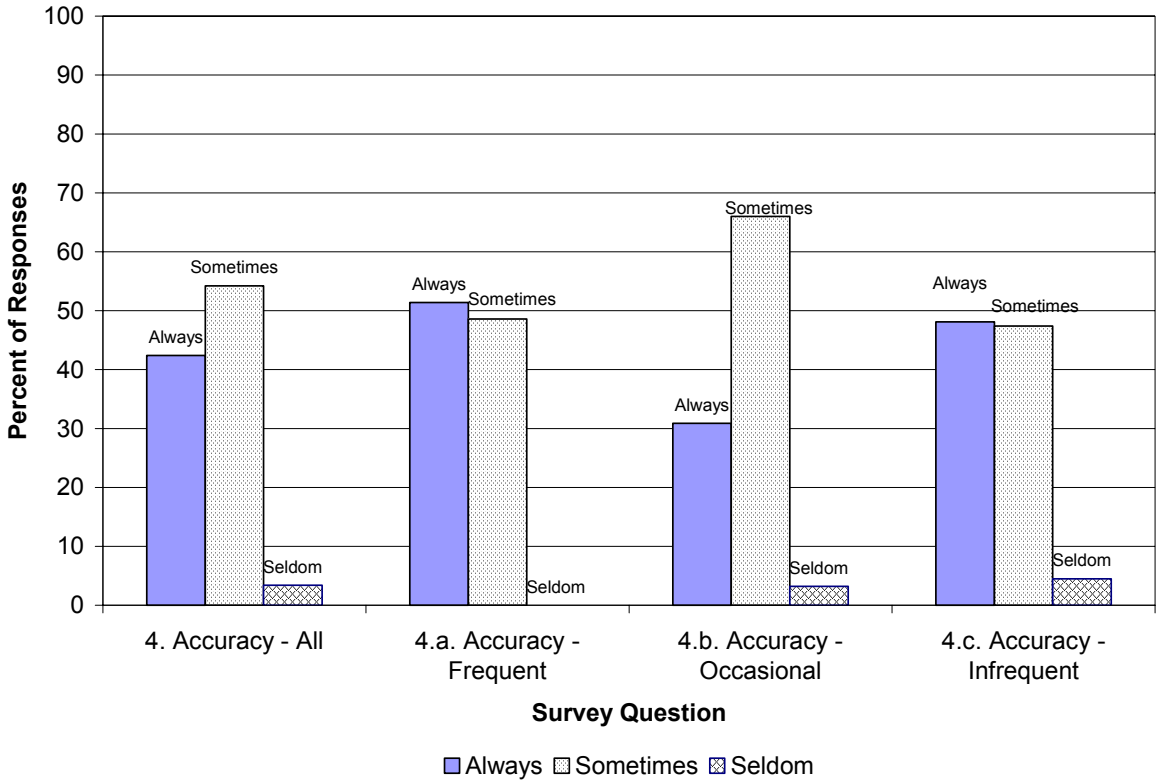

FIGURE 5 Response to Survey Question 4 (Perception of system accuracy broken down be frequency of travel)

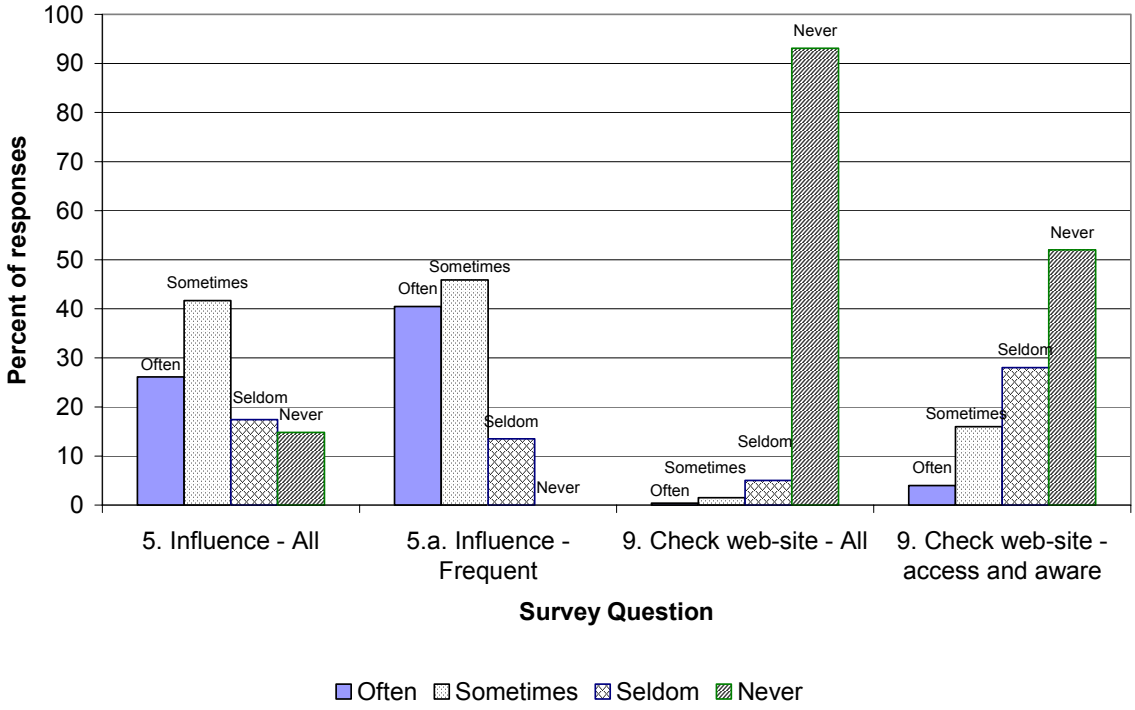

FIGURE 6 Response to Survey Questions 5 (Influence of delay message on route choice) and Question 9 (Use of website)