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Evaluation of the ADAPTIR System for
Work Zone Traffic Control

Kenneth R. Agent
University of Kentucky, ken.agent@uky.edu

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**EVALUATION OF THE ADAPTIR SYSTEM
FOR WORK ZONE TRAFFIC CONTROL**

by

Kenneth R. Agent
Research Engineer

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with

Kentucky Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U.S. Department of Transportation

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16. Abstract The ADAPTIR system (Automated Data Acquisition and Processing of Traffic Information in Real Time) uses variable message signs (VMS) equipped with radar units, along with a software program to interpret the data, to display appropriate warning and advisory messages to motorists approaching a work zone when certain speed and delay thresholds are met. The overall conclusion of the evaluation is that the ADAPTIR type system is an effective method to provide real time information to motorists approaching a work zone. The information relates to speed reductions, delay, and possible diversions. Drivers who traveled through the work zone when the VMS were in operation understood the messages and thought they were useful. However, there are limitations which must be considered. The accuracy of the messages is a function of the accuracy of the radar data, the number and location of the radar units, and the logic used to analyze the data. Care must be taken to assure that the radar units used have the capability to record very low speeds and that inappropriate speeds are not being recorded. If the lane closure is very long, additional radar units may need to be placed within the lane closure to increase the accuracy of the delay estimates. The logic must be analyzed to insure that motorists are being given appropriate messages.			
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EXECUTIVE SUMMARY

A traffic control system which acquires traffic data and provides real-time motorist information messages based on changing traffic conditions in a construction zone, without operator intervention, was evaluated. The ADAPTIR system (Automated Data Acquisition and Processing of Traffic Information in Real-time) uses variable message signs (VMS) equipped with radar units, along with a software program to interpret the data, to display appropriate warning and advisory messages to motorists approaching a work zone when certain speed and delay thresholds are met. The messages warn drivers when speeds are reduced ahead and when delays become excessive and advise the motorist of long delays when use of an alternate route should be considered.

The work zone was on Interstate 64 which is a four lane divided highway. The ADAPTIR system was used in one direction while a system using the same type of equipment and logic was developed and installed by the contractor in the opposing direction.

The evaluation involved an analysis of both systems performance and reliability and ability to collect accurate traffic speeds and estimate delays. Drivers were surveyed to determine their opinion of the information displayed.

The overall conclusion of the evaluation is that the ADAPTIR type system is an effective method to provide real time information to motorists approaching a work zone. The information relates to speed reductions, delay, and possible diversions. Drivers who traveled through the work zone when the VMS were in operation understood the messages and thought they were useful. However, there are limitations which must be considered. The accuracy of the messages is a function of the accuracy of the radar data, the number and location of the radar units, and the logic used to analyze the data. Care must be taken to assure that the radar units used have the capability to record very low speeds and that inappropriate speeds are not being recorded. If the lane closure is very long, additional radar units may need to be placed within the lane closure to increase the accuracy of the delay estimates. The logic must be analyzed to insure that motorists are being given appropriate messages.

Due to the cost of the system, it should only be used on high volume roadways where significant delays are anticipated. Logical alternate routes must be available if diversion messages are to be displayed. The length of time required to travel the alternate route must be considered when determining when to display an alternate route message. The terrain must be suitable for proper communication between the radar units and the central processing unit.

1.0 INTRODUCTION

Construction zones present numerous potential traffic conflicts. A method of acquiring traffic data and providing real-time motorist information messages based on changing traffic conditions, without operator intervention, could assist in reducing delay and crashes. One type of condition-responsive traffic control device system for work zones was evaluated. The ADAPTIR system (Automated Data Acquisition and Processing of Traffic Information in Real-time) was evaluated. This system was developed by the Scientex Corporation. The system measured traffic speeds at various locations on the approach to the work zone and used variable message signs to advise the motorists when certain thresholds of speed reduction and delays occurred.

The objective of the study was to evaluate the effectiveness of this type of system. Any problems with the operation of the system were documented, and the reliability of the system in conveying accurate information to the motorists was evaluated.

2.0 DESCRIPTION OF ADAPTIR SYSTEM

The ADAPTIR system uses variable message signs (VMS) equipped with radar units (Figure 1), along with a software program to interpret the data, to display appropriate warning and advisory messages to motorists approaching a work zone when certain speed and delay thresholds are met. The messages warn drivers when average speeds are reduced ahead, when delays become excessive, and advise the motorist of long delays when use of an alternate route should be considered.

The ADAPTIR system was used on Interstate 64 (I64) in Franklin County, Kentucky. At the work zone, I 64 is a rural, four lane divided highway. The speed limit is 65 mph. The speed limit was reduced from 65 mph to 55 mph through the work zone. The average daily traffic is about 34,000. The work consisted of pavement rehabilitation and resurfacing and bridge repair on an approximate five-mile section between two interchanges. The work was divided into four quadrants (two each direction) with the bridge over the Kentucky River dividing the quadrants. This bridge was located approximately in the middle of the work zone. The ADAPTIR system was used in the westbound direction. A system using the same type of equipment and logic was developed and installed by the contractor in the eastbound direction.

Both the ADAPTIR and contractor's systems used radar units to collect speeds at a series of four VMS leading to the work zone along with another radar unit on the arrow display at the lane closure. While the distances varied slightly, the first VMS was typically located about 4 to 5 miles from the lane closure with the lane closed about 2.5 miles. The ADAPTIR and contractor's systems were used in addition to the typical traffic control measures used for a lane closure on a multi-lane highway. Three types of messages were displayed. The messages dealt with a reduction in speed, a level of delay, and the display of an alternate route. Certain criteria were used in the development of the messages. Each warning consisted of two messages. Each message had three lines with a limit of eight characters for each line.

Average speeds were calculated at each VMS and the arrow display at set intervals (every two minutes westbound and every three minutes eastbound). When the average speed between two adjacent radar locations was reduced by 10 mph or more, a message was displayed on the VMS upstream from the location at which the radar found the reduced speed. The speed warning consisted of a sequence of the following two messages.

ROADWAY		REDUCE
ADVISORY		SPEED TO
XX AM OR PM	followed by	XX MPH

Photographs showing these messages are shown in Figures 2 and 3. The message was updated every two minutes for the ADAPTIR system used in the westbound direction and every three minutes for the contractor’s system in the eastbound direction. The “time stamp” gave a new time so motorists would realize the information was current. The speed was given in five mph increments with the speed rounded to the next lowest five mph interval from the average. If traffic was stopped at one location giving a zero speed, the upstream VMS gave a speed of five mph.

The delay from a specific VMS to the end of the work zone was calculated by comparing the time necessary to travel from that VMS at the posted speed limits compared to the time required to travel through the work zone at the speeds measured by the radar units. The speed limits used were 65 mph in advance of the lane closure and 55 mph through the lane closure and extending approximately to the first VMS. Slightly different methods were used by the two systems to determine speeds between signs. Either the speed determined at a specific sign was used as the speed to the next downstream sign or the average speeds between two adjacent signs were used as the speed between those signs. The speed at the arrow display was used as the speed through the lane closure portion of the work zone. A minimum speed was used through the work area (after the start of the lane closure) since no radar units were placed in this area. A minimum speed of 10 mph was used by ADAPTIR. The length of the work area (lane closure) varied slightly depending on where the work was being conducted. In any case, the work zone was a few miles in length and the speed at the arrow display (with the specified minimum) was used over this length. A delay message was displayed when the delay through the work zone reached a threshold of five minutes. The delay message consisted of a sequence of the following two messages. A photograph showing a delay message is shown in Figure 4.

ROADWAY		X MIN
ADVISORY		DELAY
XX AM OR PM	followed by	AHEAD

The final message related to an alternate route. It was displayed when the delay reached 15 minutes and this delay was maintained for a minimum time of 10 minutes for the ADAPTIR system and 9 minutes for the contractor’s system. The diversion message consisted of a sequence of the following two messages (Figures 5 and 6).

LONG		ALT RTE
DELAYS		FOLLOW
AHEAD	followed by	EXIT XX

The messages for speed reduction, delay, and diversion were displayed automatically based on the programmed logic. The speed message took precedence over the delay or diversion messages. However, one VMS could be displaying a speed message while another VMS could be displaying a delay or diversion message. Logic was used to ensure that the diversion message was not displayed unless the minimum delay existed at the VMS immediately upstream from the exit route. The diversion message was also not displayed on a VMS if it was positioned past the diversion route.

Each VMS was blank unless a speed or delay threshold was met. The exception was the VMS closest to the work zone which continuously displayed a message related to wide loads unless a speed or delay message was warranted which then replaced the wide load message.

This system provided information to motorists on the interstate. Additional VMS were placed on the diversion route to provide information when excessive delays occurred (Figures 7 and 8). The messages on these signs were input manually.

The system for each direction involved the purchase of four VMS in addition to the hardware and software to implement the system. The total cost, including signs, was about \$250,000 for one direction. The cost of the ADAPTIR system was approximately \$127,000.

3.0 PROCEDURE

The evaluation of the ADAPTIR system westbound and similar system eastbound at the Interstate 64 work site involved the following evaluation components.

Performance and Reliability: Maintenance problems were documented. A log of the sign messages which were displayed was reviewed to determine if they were proper relative to the programmed logic. Also, the speed and delay records were reviewed to determine if messages were always displayed when they should have been according to the programmed logic. The operation of the system was monitored when speeds close to zero were measured. Transportation Cabinet and contractor personnel were interviewed to determine problems which occurred.

Speed Measurements: Manual radar speed data were collected adjacent to the VMS and arrow display locations and compared to the speeds obtained by each system's radar. Also, the work zone was driven through on several days with the speed of the traffic flow recorded at each VMS and the arrow display and then compared to the speeds obtained by each system. The speed data logged in the systems were reviewed to determine the change in speeds when the speed advisory message was displayed. The accuracy of measuring very low speeds was evaluated.

Delay Estimates: The delay which was calculated through the work zone using the speeds logged in the systems was compared to the delay estimated by the system logic. The delay was also measured by driving through the work zone and compared to that estimated at the same time using system logic.

Diversion: The response of drivers to the alternate route message was evaluated by observing the number of vehicles exiting at the recommended exit. Simultaneous travel time runs were made on the interstate and along the alternate route to determine the difference in time during different levels of congestion.

Driver Opinion: The desired procedure was to interview drivers stopping in a rest area after they had driven through the work zone. The nearest rest areas were about two miles east and 23 miles west of the work zone. Therefore, the surveys were taken in the rest area located two miles east of the work zone. The surveys were taken after a time period when the VMS were in operation. Drivers were asked if they observed the messages on the VMS, if they understood the messages, and if the messages provided useful information.

4.0 RESULTS

4.1 Performance and Reliability

The reliability of the messages displayed to the motorists is a function of the accuracy of the radar data and the logic used to interpret the data. The major problem related to the accuracy of the radar data was the inability of the original radar used by the contractor (in the eastbound direction) to record very low speeds. The low speeds occurred along with long delays. When the low speeds were not recorded, the long delays which existed were not calculated and were not displayed. The contractor installed a new radar unit which detected the low speeds and this corrected the delay calculation as it related to the detection of low speeds. The original radar unit used by Scientex Corporation had no problem with detecting low speeds.

Care had to be taken to insure that the radar unit was positioned properly so inaccurate speeds would not be measured. A problem would occur if speed data for traffic on the opposite side of the interstate were included. The angle at which the radar was positioned had to be monitored. If speeds for the opposite direction were included, these speeds would generally be higher than that on the work zone side and would increase the average speed. The logic used in both systems included a method of rejecting outlying speed data points from the average. In a few instances the radar data was inaccurate because high winds changed the orientation of the radar. This resulted in low speed advisories being displayed inappropriately.

Both systems remained operational a high percentage of the time. There were occasional problems with such areas as lack of communication between the radar and the central processing unit, poor connections, lightning strikes, and low batteries, but no long term serious problems were noted. When the location of the work zone involved placing one of the radar units at a low

elevation compared to the central processing unit and between rock cuts, an additional antenna (repeater) had to be placed to allow the signal to be transmitted to the unit which was positioned at a low elevation. In an instance when communication could not be maintained with the radar on the arrow display, speeds from the previous sign were used in the analysis which reduced the accuracy of the delay calculations. A problem with an inaccurate time stamp displayed for eastbound traffic was found to be related to an occasional loss of communication and the resulting time necessary for the system to recalibrate to the correct time.

4.2 Speed Measurements

Manual speed data and moving speeds were compared to those measured by the radar units placed on the VMS and arrow display. There was good agreement between the manual and moving speeds and the average speeds obtained by the field radar equipment except at very low speeds for the eastbound direction with the first radar equipment used. The problems occurred in the eastbound direction when very low speeds (under approximately 20 mph) occurred. The radar did not record these low speeds and would measure higher speed in the opposite direction. As noted, this problem was eliminated with a change in the equipment and additional system logic. This problem was not found for the ADAPTIR system supplied by Scientex.

The system was designed to display a warning message to drivers when the traffic speed slowed by 10 mph or more prior to the next downstream radar location. The data were reviewed to determine if this occurred as programmed. The review showed that the speed message was displayed as designed and the appropriate speed was displayed.

4.3 Delay Estimate

The comparison between the delays calculated by both systems using the speed data with the delay data obtained by driving through the work site showed that, while substantial differences were found in some instances, both systems could generally determine when significant delays were occurring and display appropriate messages to the motorists. The contractor's system originally had a problem determining when large delays were occurring because of its problem with measuring the very low speeds, but after the radar units were changed, this system could determine when significant delays were occurring. There were typically longer delays in the westbound direction where the ADAPTIR system was used. These delays generally occurred between 4 and 6 pm.

The major source of differences in the delay calculated by the systems and the delay determined by driving through the work zone resulted from the lack of speed data within the lane closure which typically extended about 2.5 miles. There were five radar units between the first VMS and the arrow display. These radar units were placed within a range of 4 to 5 miles. Traffic would not typically back up beyond the second message board. The delay within the lane closure typically was a high percentage of the total delay. Alternate route message were displayed for westbound traffic in many instances when the delay determined by driving through

the work zone was substantially below the 15-minute diversion threshold. This occurred when the speed at the arrow display was very low but speeds increased within the lane closure. In the westbound direction, drive through data were taken in 15 cases in which the alternate route message was displayed. However, the actual delay was only greater than the 15-minute diversion threshold in three of these cases. Some of these instances was due to a problem with the diversion message being displayed when the system's calculated delays were under the 15-minute threshold. However, there were other instances when the actual delays was substantially below the 15-minute threshold but the calculated delay met the diversion criteria. The reason for this discrepancy was related to using the speed at the arrow display as the speed throughout the lane closure. When there was a substantial backup of traffic, the speeds were typically the lowest in the area of the arrow display with higher speeds in at least a portion of the lane closure section.

In a smaller number of instances, the actual delay was more than indicated on the signs due to slower speeds within the lane closure than at the arrow display; however, these were not situations where the delay was actually large enough for a diversion message but no message was displayed. The agreement between the measured delay and the calculated delay using the system logic was closer as the amount of delay decreased. There was closer agreement between these values for eastbound traffic which would be related to the generally smaller delays in that direction.

As described, the tendency was to display delays which were actually greater than that found by driving through the work zone. This occurred more often as delays increased. The major problem this could cause would be to recommend an alternate route when the time to take the alternate route is actually greater than staying on the interstate. While this situation occurred in a few instances, this did not cause a problem because drivers did not take the alternate route unless there was an obvious significant backup of traffic.

4.4 Diversion

Motorists did not typically respond to the diversion message and take the alternate route unless there was an incident which closed the road or caused a very major backup. An area of concern relating to the usefulness of the diversion message was the location of the various VMS relative to the exit to the alternative route. Situations occurred where the diversion message was displayed on an upstream VMS but only the delay message was displayed on the VMS immediately prior to the exit ramp for the diversion ramp. This situation could occur because the delay is calculated for each VMS and could be above the diversion threshold at the location of an upstream VMS but below this threshold when the motorist got to the exit ramp. The amount of delay at a VMS would be largest at the greatest distance from the start of the work area. The logic was changed such that no diversion message was displayed unless the delay threshold was met at the VMS immediately upstream from the exit ramp.

A comparison of the time to drive through the alternate route with the time to drive through the work zone between the interchanges for the diversion route showed that the diversion

message should not be displayed unless there was a very significant delay on the interstate. The 15-minute threshold used could have been increased.

4.5 Driver Opinion

Some drivers stopping at the rest area just east of the work zone were asked questions concerning messages displayed on the VMS leading to the lane closure. The surveys were conducted at times when it was determined that the VMS were in operation.

Interviews were conducted with 66 drivers who indicated they had traveled through the work zone at a time when it was known that the VMS were in operation. Of those, 59 (or 89 percent) indicated they had observed the VMS with 49 (74 percent) stating they observed a message on the VMS. The most common messages they noted were the speed and delay messages which were the messages on at the time. They were asked to rate, using a scale of 1 to 5, if they understood the messages and if the messages were useful. Of those responding, 77 percent thought the messages were very understandable and 76 percent thought they were very useful.

5.0 CONCLUSIONS

The overall conclusion of the evaluation is that the ADAPTIR system is an effective method to provide real time information to motorists approaching a work zone. Motorists indicated the information was understandable and useful. The information relates to speed reductions, delay, and possible diversions. However, there are limitations which must be considered. The accuracy of the messages is a function of the accuracy of the radar data, the number and location of the radar units, and the logic used to analyze the data. Care must be taken to assure that the radar has the capability to record very low speeds and that inappropriate speeds are not being recorded. If the lane closure is very long, additional radar units may need to be placed within the lane closure to increase the accuracy of the delay estimates.

The logic used to select the message must give consistent messages to the motorists. For example, the diversion message must not be displayed on one sign in advance of an exit but then not displayed on another sign as the motorist approaches the exit. This could occur if the estimated delay at an upstream sign in advance of the exit was above the diversion threshold but the delay was reduced to below that threshold at the sign immediately prior to the exit.

Due to the cost of the system, it should only be used on high volume roadways where significant delays are anticipated. Logical alternate routes must be available. The length of time required to travel the alternate route must be considered when determining when to display an alternate route message. The alternate route message should only be displayed when traveling through the work zone will result in a substantially longer travel time than using the alternate route. The terrain must be suitable for proper communication between the radar units and the central processing unit.

6.0 RECOMMENDATION

Since the conclusion of the evaluation was that the ADAPTIR type of system can effectively provide useful information to motorists driving through work zones, there is justification to use this type of system in the future. However, its use is limited to specific types of work zones. The typical use of this system would be on a high volume road with adequate alternate routes and terrain which would allow for good communication between the radar units and central processing unit. Every work zone has unique characteristics which must be considered when determining the logic for the messages displayed to the motorists. The system could be used to display speed and delay information even if alternate routes were not readily available.

The most practical method to implement use of this type of system for a specific location would involve having the contractors include a cost for operating the system in their bid. This would allow use of the latest technology with logic designed for the given work zone. This method of operation is preferred to purchase of a system by the Transportation Cabinet which would require maintenance, upgrading, and the need to change the logic to fit each new work zone.



Figure 1. Variable Message Sign Equipped with Radar Unit.



Figure 2. Message Showing Current Time.



Figure 3. Speed Advisory Message.



Figure 4. Delay Message.



Figure 5. Long Delay Message.



Figure 6. Alternate Route Message.



Figure 7. Message on Intersecting Route Advising of Delay on I 64.



Figure 8. Message on Intersecting Route Advising Use of Alternate Route.