

Final Report

**Implementation and Testing of the Travel Time Prediction System
(TIPS)**

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16. Abstract <p>The Travel Time Prediction System (TIPS) is a portable automated system for predicting and displaying travel time for motorists in advance of and through freeway construction work zones, on a real-time basis. It collects real-time traffic flow data using roadside non-contact sensors, processes the data in an on-site personal computer, calculates estimated travel time between different points on the freeway, and displays travel time information on several portable, electronic changeable message signs positioned at pre-determined locations along the freeway. TIPS was implemented and tested on I-75 work zone in northbound direction in Montgomery County, Dayton, Ohio during the freeway construction period of July 14, 2000 until November 4, 2000. The system operated for a minimum of 15 hours a day, from 5AM until 8PM, seven days a week. TIPS was configured to update the travel times on all CMSs at four-minute increments. The monitoring and operation of TIPS indicated that the system was highly reliable as initially put in place, with only minor adjustments being necessary to the initial hardware configuration. The hardware of the system including radios, micro-controllers, antennae, sensors and trailers performed reliably in all weather conditions (including severe thunderstorms). The TIPS software performed well during the period of deployment. In addition to providing real-time travel time information to motorists, TIPS also provided valuable assistance in the management of incidents on freeways. When an incident was reported by enforcement officers, an "ACCIDENT AHEAD" message was remotely displayed on each changeable message sign. The Ohio Department of Transportation (ODOT) hired Dr. Helmut Zwahlen, Russ Professor Emeritus at Ohio University, to conduct an independent evaluation of the Travel Time Prediction System (TIPS). He reported that about 88% of the actual times recorded for each sign, and for all the signs combined, were within a range of ± 4 minutes of the predicted time. Almost 97 % of surveyed motorists felt that a system to provide real-time travel information in advance of work zones is either outright helpful or maybe helpful.</p>			
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Executive Summary

Implementation and Testing of the Travel Time Prediction System (TIPS)

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The Travel Time Prediction System (TIPS) is a portable automated system for predicting and displaying travel time for motorists in advance of and through freeway construction work zones, on a real-time basis. It collects real-time traffic flow data using roadside non-contact sensors, processes the data in an on-site personal computer, calculates estimated travel time between different points on the freeway, and displays travel time information on several portable, electronic changeable message signs positioned at pre-determined locations along the freeway.

TIPS was implemented and tested on I-75 work zone in northbound direction in Montgomery County, Dayton, Ohio during the freeway construction period of July 14, 2000 until November 4, 2000. The system operated for a minimum of 15 hours a day, from 5AM until 8PM, seven days a week. TIPS also operated continuously twenty-four hours a day to facilitate night time construction and an additional lane closure during a weekend in September 2000. TIPS was configured to update the travel times on all CMSs at four-minute increments.

TIPS was monitored at all times when the system was in operation. The actual travel times through the work zone were frequently measured and compared to the travel times displayed by the system at the various CMS's. The monitoring and operation of TIPS indicated that the system was highly reliable as initially put in place, with only minor adjustments being necessary to the initial hardware configuration. The hardware of the system including radios, micro-controllers, antennae, sensors and trailers performed reliably in all weather conditions (including severe thunderstorms). The TIPS software performed well during the period of deployment. In addition to providing real-time travel time information to motorists, TIPS also provided valuable assistance in the management of incidents on freeways. When an incident was reported by enforcement officers, an "ACCIDENT AHEAD" message was remotely displayed on each changeable message sign.

The Ohio Department of Transportation (ODOT) hired Dr. Helmut Zwahlen, Russ Professor Emeritus at Ohio University, to conduct an independent evaluation of the Travel Time Prediction System (TIPS). He reported that about 88% of the actual times recorded for each sign, and for all the signs combined, were within a range of ± 4 minutes of the predicted time. Almost 97 % of surveyed motorists felt that a system to provide real-time travel information in advance of work zones is either outright helpful or maybe helpful. In summary, the results of the independent evaluation indicated that TIPS provides in general and most of the time useful and relatively accurate travel time predictions to the motoring public and appears to be perceived by the motoring public as helpful and useful.

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The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Implementation and Testing of the Travel Time Prediction System (TIPS)

1 INTRODUCTION

A freeway construction work zone creates conflicts between vehicular traffic and work activity. The closure of one or more lanes of a freeway section causes a bottleneck on the freeway and reduces the capacity in the work zone, which can lead to conditions that violate the expectations of the motorists. Such a work zone situation is a challenge to one of the main objectives of a traffic management system, that is, to maintain “the *safe* and *efficient* movement of traffic”. The advance warning area of a traffic control zone represents the area in which the motorists are informed as to what they can expect ahead. The information which is normally provided to the motorists include the type of construction activity, type of lane closure, extent of the work zone, and whether there are available alternate routes to avoid the construction all together. This information is given on static signs, or electronic portable changeable message signs (CMS) by way of static preprogrammed messages. This information is crucial in preparing the motorist to take appropriate action when they reach the work zone; however, these techniques do little to assist the motorist in areas where increased congestion leads to queuing up of vehicles for miles on the freeway. These drivers are generally not aware of what is going on ahead of them and how long it will take them to clear the work zone. This lack of real-time “*travel time*” information to motorists can lead to motorist frustration, accidents, or other avoidable incidents. This illustrates the need to accurately inform the motorists of the “*travel time*” through the work zone. The benefit of real-time “*travel time*” information is two fold. First, the motorist can make an informed decision on whether to stay on the freeway, or take an alternate route. Second, by knowing the time it will take to traverse the work zone before entering, the

anxiety and frustration felt while waiting indeterminately in traffic will be alleviated.

The Travel Time Prediction System (TIPS) was developed by Dr. Prahlad D. Pant of the University of Cincinnati. The Ohio Department of Transportation and the Federal Highway Administration provided funding for the research and development of TIPS. More details about TIPS can be found in References (1) and (2) and hence will not be repeated in this report. TIPS was designed to address the need for providing real-time travel time information to the motorists. TIPS can predict the travel time for the motorists from any one point on a freeway to any other. This system was designed with freeway work zones in mind, but has a much broader application for any freeway that suffers congestion, leading to travel times that fluctuate, and therefore pose an inconvenience, and potentially unsafe conditions, to motorists. TIPS is intended to provide real-time travel time information to the motorists both in advance of, and throughout the work zone, thereby reducing the motorist frustration and increasing safety on the highway. The ultimate benefit of the TIPS system is the reduction of congestion and travel times, by allowing motorists to take alternate routes. Thus the two main concerns of a traffic management system – safety and efficiency – are expected to improve.

TIPS combines the disciplines of traffic engineering and modeling, wireless communications, and computer science, in a portable, automated, and user-friendly system, which can be easily installed on-site. It is a comprehensive system that collects real-time traffic flow data using non-contact sensors, processes the data in an on-site personal computer, calculates the estimated travel time, and transmits the information to changeable message signs positioned at pre-determined locations along the freeway section, which in turn display the travel time information to the motorists.

The objective of this project was to implement and test the Travel Time Prediction System (TIPS) on northbound I-75 work zone in Montgomery County, Dayton, Ohio during the Summer and Fall of 2000. TIPS was operated a minimum of 15 hours per day- from 5:00 AM until 8:00 PM- seven days a week for about four months. The system was also run twenty-four hours a day upon

request from ODOT, to facilitate night time construction or other extraordinary events such as an accident in the work zone, or further overnight lane closures. The TIPS hardware and software were configured as necessary to meet site-specific objectives at the beginning of implementation. The key components to the implementation of TIPS were the purchase of additional trailers with solar panels and batteries, site survey, mobilization, equipment installation, and the operation, maintenance and monitoring of TIPS. Additionally, ODOT hired Dr. Helmut Zwahlen, Russ Professor Emeritus of Ohio University, to conduct an independent evaluation of TIPS at this site. The successful implementation and testing of TIPS at the Montgomery County site will allow ODOT to deploy one or more systems at construction projects in the future.

2. BACKGROUND AND SIGNIFICANCE OF WORK

TIPS was developed as an intelligent transportation systems (ITS) research project. It is a portable, automated, flexible, and user-friendly system. TIPS uses microwave radar detectors that provide contact closure signals, which in turn are used to compute volume and occupancy at 30-sec intervals. The traffic flow information is transmitted by 220 MHz radios to an on-site computer, which computes the travel time using a travel time prediction algorithm and model, and this information is transmitted to the changeable message signs (CMS's) by 220 MHz radios.

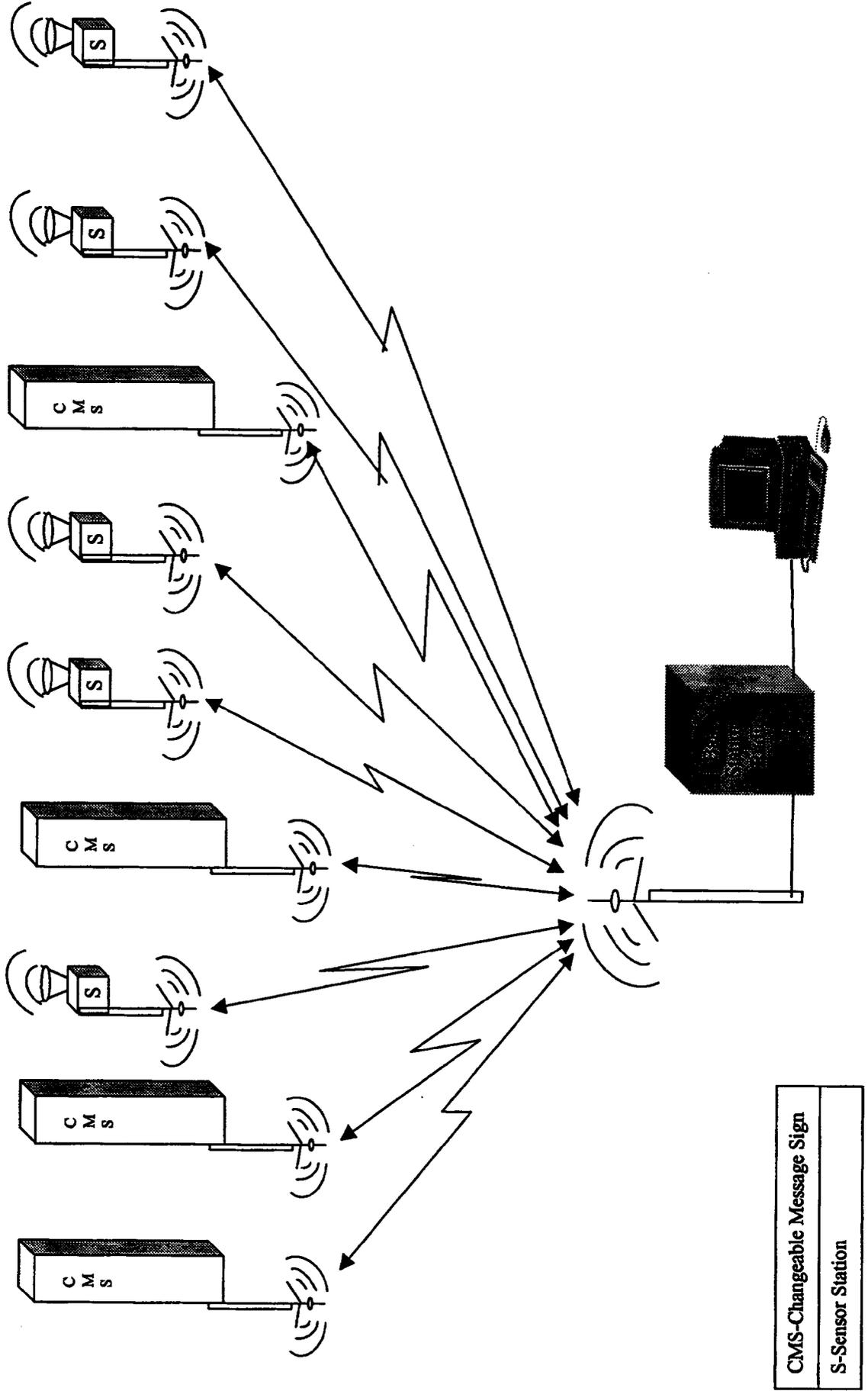
A more detailed list of the components of TIPS are as follows:

- Microwave radar sensors for vehicle detection on the freeway;
- Programmable microcontrollers for computing volume and occupancy for each lane;
- 220 MHz narrowband radio modems for transmitting volume and occupancy data from each sensor to the on-site PC;
- Intelligent traffic algorithm and travel time estimation model residing in the TIPS software (TIPS Version 2.1) in Windows NT environment;
- 220 MHz narrow-band radio modems for transmitting travel time information from the PC to portable changeable message signs;
- Changeable message signs for displaying travel time information to motorists;
- Mobile trailers equipped with solar panels and batteries that can be used for mounting sensors and radio modems.

A full-scale implementation of TIPS will provide further validation of the travel time prediction models and all other hardware and software components. Once the system is operational on a full-scale basis, the system can be reassessed for its effectiveness. The more the system is used, the better the scope for assessment, innovation and improvement. TIPS can also be used on any freeway

that experiences congestion on a regular basis, thereby making it a universal system rather than one for work zones only.

Figure 1. Basic TIPS Hardware Setup



3.0 IMPLEMENTATION AND TESTING

The scope of this project was to implement and test the Travel Time Prediction System (TIPS) on northbound I-75 work zone in Montgomery County, Dayton, Ohio during the freeway construction period of July 14, 2000 until November 4, 2000. During this implementation of TIPS, the hub of operations was located at the Lyons Road ODOT Outpost. The base station radio and personal computer were located at this location. Solar trailers and changeable message signs were located along the freeway at strategic locations in advance of, and in the construction work zone. This implementation provided ODOT with an additional example how research results can be implemented for the benefit of motorists in the State.

3.1 SOLAR TRAILER PURCHASE

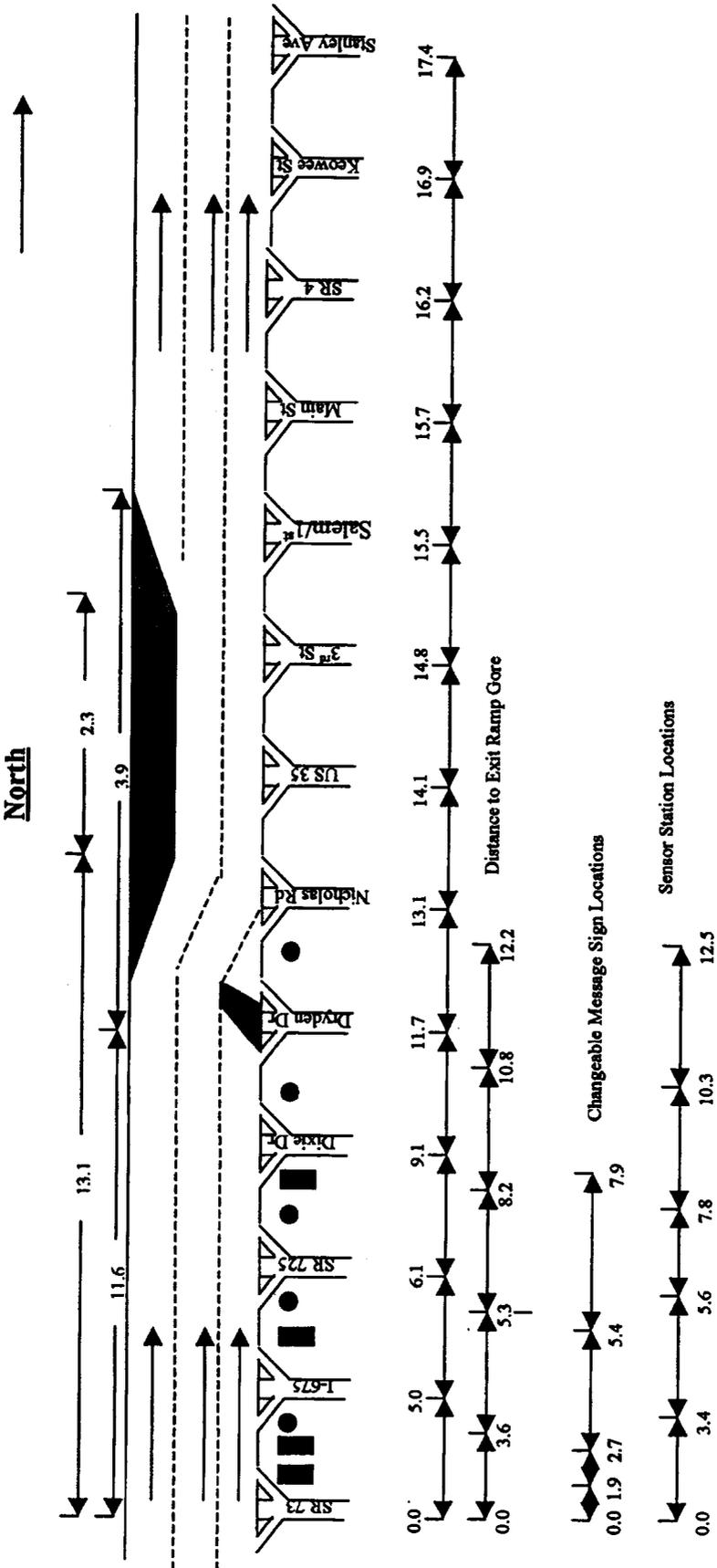
This project used the equipment that was purchased for the previous research project "A Portable Real-Time Traffic Control System for Freeway Work Zones" (Reference 1). A preliminary survey of the site showed that at least five sensors and four changeable message signs were required for this project. Four mobile trailers with solar panels and batteries that can also be used for mounting sensors and radio modems were purchased. These trailers consisted of a bank of three 80 watt solar panels which connected to a solar power controller, which in turn fed a bank of six 6 volt deep-cycle batteries that were connected in series and in parallel to give the output of three 12 volt batteries. The trailers also contained an eighteen-foot retractable mast for mounting the sensor and radio antenna.

An aluminum traffic control box and radio antenna mount were installed onto the four new trailers, two existing trailers, and five changeable message signs. Each aluminum box was used to house a radio and/or microcontroller. Necessary wiring was provided.

3.2 SITE SURVEY

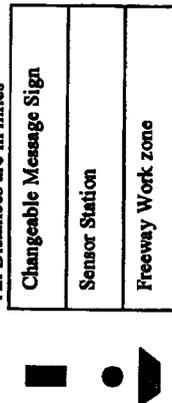
A thorough survey of the freeway work zone was performed. The site survey was carried out by monitoring traffic flow patterns in the field, with special attention paid to the traffic queues during peak hours. The taper, which was located just south of the Nicholas Road exit, brought the freeway down from three lanes to two lanes. The work zone extended to just north of the First St. exit where the taper ended and the freeway again became three lanes (see Fig. 2). It was observed that peak queuing times were between 7:00-8:30 AM and 4:00-5:30 PM weekdays. The increase in travel time was typically 12 to 16 minutes during these times, which is reflected in a queuing of motorists preceding the work zone of between one and one and a half miles. Occasionally, the traffic backed up about 3-3.5 miles during peak hours causing additional travel time of 22 to 26 minutes. Attention was paid to the best alternate routes for traffic. During the site survey and installation of the sensor trailers, the US 35 ramps were closed. The US 35 ramps subsequently opened during the operation and evaluation of the TIPS deployment, which impacted the traffic flow pattern. It was determined that if motorists were to take an alternate route to avoid an unwanted delay from increased congestion, they would most probably take I-675, SR 725, or Dixie Drive. Accordingly, three CMS's displaying real-time travel time information were placed before these exits. Additionally, a CMS that displayed a static message was also placed before I-675. These alternate routes were in advance of any significant congestion under normal circumstances, and also afforded the driver access to points north that would usually be accessed by staying on I-75. The locations of the changeable message signs were (Fig 2) as follows:

Figure 2. Schematic of Northbound I-75, Dayton, Ohio
(Not to Scale)



US 35 entry ramp was closed during the installation of sensors, but open during the data collection

**** All Distances are in miles



- Sign #1 was located 3.1 miles before I-675 (The sign was controlled remotely by the system personal computer and displayed the message “WORKZONE ENDS 14 MILES”)
- Sign #2 was located 2.3 miles before I-675 (This sign was system operated and cycled with two messages: the real-time travel time prediction of “XX MIN TO END OF WORKZONE” and “WORKZONE ENDS 13 MILES”)
- Sign #3 was located 0.7 miles before SR 725 (This sign was system operated and cycled with two messages: the real-time travel time prediction of “XX MIN TO END OF WORKZONE” and “WORKZONE ENDS 10 MILES”)
- Sign #4 was located 1.2 miles before Dixie Drive (This sign was system operated and cycled with two messages: the real-time travel time prediction of “XX MIN TO END OF WORKZONE” and “WORKZONE ENDS 8 MILES”)

Site survey for the installation of the sensors was carried out by paying specific attention to (a) areas that maintained free flow traffic under all conditions, (b) areas that started queuing motorists under severe congestion, (c) areas that started queuing motorists under moderate congestion, and (d) areas that experienced queuing under light congestion, (e) areas just after the highway taper. The locations for the five sensor stations were as follows (Fig 2):

- Sensor station #1 was located 9.7 miles in advance of the work zone (before I-675)
- Sensor station #2 was located 7.5 miles in advance of the work zone (before SR 725)
- Sensor station #3 was located 5.3 miles in advance of the work zone (before Dixie Drive)
- Sensor station #4 was located 2.8 miles in advance of the work zone (before Dryden Drive)
- Sensor station #5 was located 0.6 miles in advance of the work zone (before Nicholas Road)

3.3 MOBILIZATION

Before all equipment were transported to the site, it was important to test them one by one to make sure that they all functioned properly. Since most of the sensors purchased in the previous research project were operating with 120V electric power, they were converted to 12V DC operation. The mobilization process included a complete testing and configuration of all equipment to work with 220 MHz radio modems.

- All mobile radios were tested and necessary configurations were made to assure compatibility with the base station radio.
- Before the installation of sensor stations and CMSs at the site, an on-site testing of the two-way radio communications was performed at the Lyons Road ODOT Outpost in Dayton, Ohio to be certain that previously determined survey sites would support the required communication need of the system. A bucket truck with a fifty-foot mast carried a radio antenna and the base station radio, to simulate the fifty-foot antenna pole and base station radio configuration. A solar trailer was towed to the various locations that were intended to be used for sensor stations and changeable message signs. A computer with a communication software was used at each end to send and receive text messages from one end to the other.

3.4 INSTALLATION OF EQUIPMENT AT THE SITE

On July 10 and 11, 2000 five solar trailers were towed from their storage locations and placed at the previously defined locations along I-75 as detailed above. An additional sixth sensor trailer was stored at the Lyons Road ODOT Outpost in Dayton, Ohio. That same week four changeable message signs were towed and placed at their previously defined locations along I-75. An additional CMS was stored at the Lyons Road ODOT Outpost location. On July 12, 2000, the base station radio and personal computer were transported and installed at the

Lyons Road ODOT Outpost. A fifty-foot wooden pole, with radio antenna, was installed at the Outpost for use by the base station radio.

On July 12 and 13, 2000, the work crew installed the antennae, radios, microprocessors, and sensors on the solar trailers. The sensors were configured to detect full and accurate vehicular counts at each location.

TIPS began operating and displaying travel time messages at 12:51 PM on Friday, July 14, 2000. At this time three sensors stations were in operation and the travel time message was displayed on a changeable message sign that was located on northbound I-75 just south of SR 725. The full system began operation at 6:11 PM. All five sensor stations and three changeable signs were operating smoothly. The base station radio was receiving data from all five sensors and travel time information messages were being displayed on all changeable message signs.

Figure 3. I-75 Work Zone in City of Dayton, Ohio



Figure 4. Antenna Pole at ODOT Lyons Road Outpost



Figure 5. Personal Computer with TIPS Software

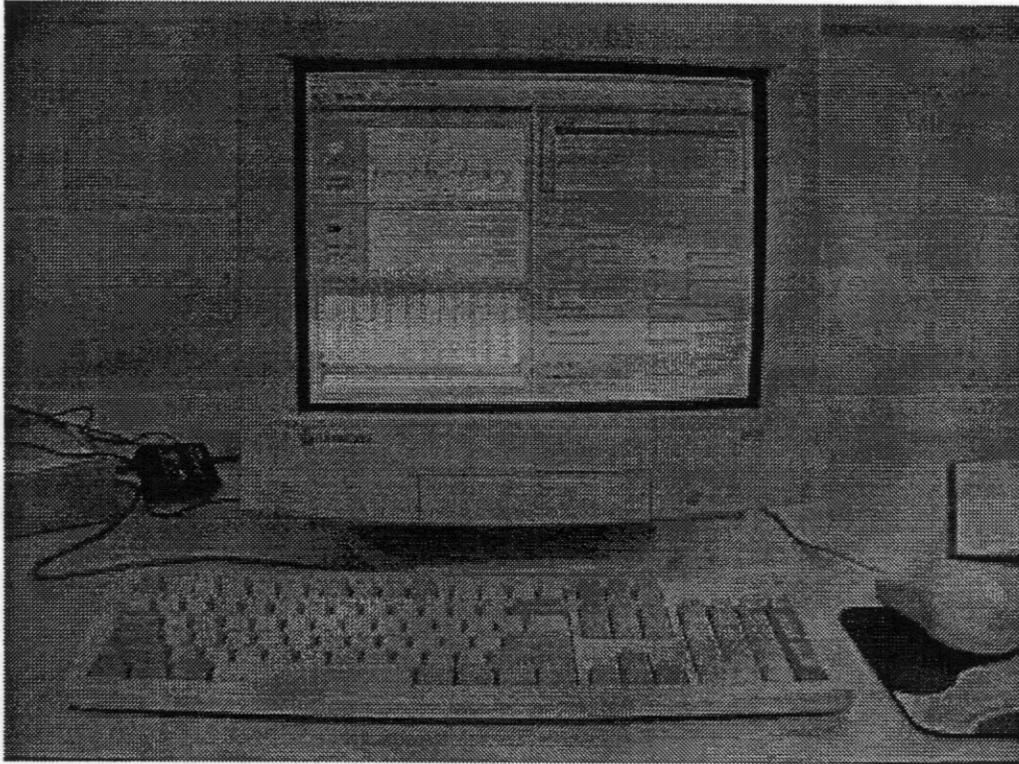


Figure 6. Trailer with Solar Panels, Sensor, and Radio

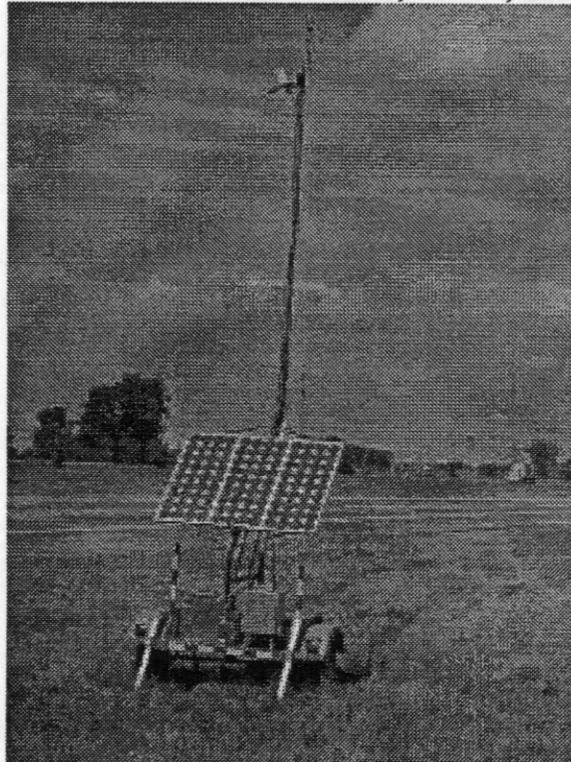


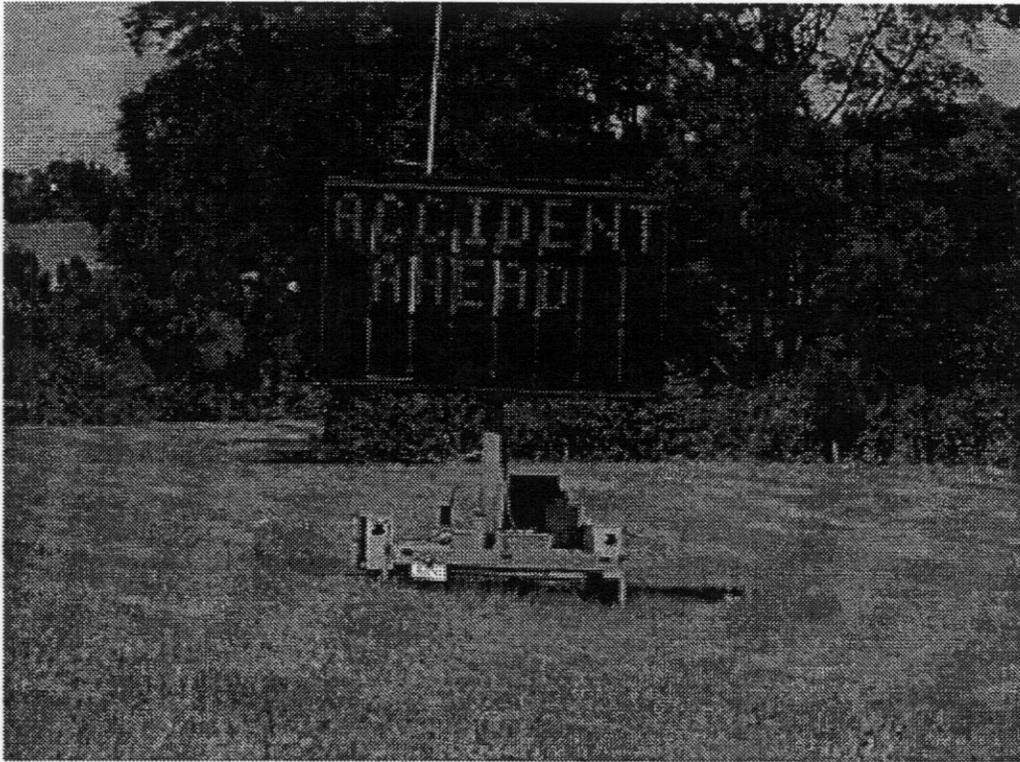
Figure 7. Cycle 1 of Real-Time Travel Time Message



Figure 8. Cycle 2 of Real-Time Travel Time Message



Figure 9. Real-Time “Accident Ahead” Message



3.5 OPERATION OF TIPS

As suggested by the Ohio Department of Transportation, the Travel Time Prediction System (TIPS) was run for 15 hours/day, 7 days/week. TIPS was operated from July 14, 2000 until November 4, 2000 (end of the construction season). The TIPS program was run a minimum of 15 hours a day, from 5AM until 8PM seven days a week during this time. TIPS was run continuously twenty-four hours a day upon request from ODOT on the weekend of Friday September 22, 2000 at 5AM until Monday September 25, 2000 at 8PM, to facilitate night time construction and an additional lane closure. TIPS was also kept running until 12AM on two occasions for other extraordinary events such as an accident in the work zone, which caused travel time delay to exist later than usual in the area preceding the construction zone.

TIPS was monitored at all times when the system was operating during this test deployment of the system for the northbound I-75 construction work zone in Dayton, Ohio. The actual travel time through the work zone was frequently measured and compared to the travel time displayed by the system at the various CMS's. The maintenance crew was "on-call" at all times of the system operation.

The monitoring and operation of TIPS indicated that the system was highly reliable as initially put in place, with only minor adjustments being necessary to the initial hardware configuration. The modifications were:

- The newly purchased solar trailers were originally outfitted with six 6-volt batteries wired in such a way to produce the output of three 12-volt batteries. It was determined that the power storage required by the system was best accomplished by eight 6-volt batteries wired to produce the output of four 12-volt batteries. The company executed the additional battery installation.
- The newly purchased solar trailers were originally outfitted with a bank of three 80 watt solar panels connected to a solar power controller, which supplied 20 amps of recharging current to the battery bank. It was determined that a solar controller which supplied 30 amps of recharging current was better

suited to the TIPS system power requirements. The company executed the controller change.

- The sensor station #5, located just south of Nicholas Rd, which was originally run utilizing the on-trailer radio antenna, was later outfitted with a 40 foot pole-mounted antenna for better radio communications.
- The antenna pole at sensor station #5 was originally set up with a ground wire from the top. After several lightning storms it was determined that this configuration actually put the RTMS sensor in great jeopardy. The sensor at station #5 was repaired three times because lightning strikes near the area caused a surge in the power sensor, damaging the unit. After the grounding wire was removed, the problem ceased.
- Each radio/micro-controller box was equipped with a fan controlled by a thermostat but the box was not insulated. On a few occasions after several consecutive days of temperatures in the 90's, it was observed that the microprocessor at sensor station #3, located just south of Dixie Drive, began to report unsuitable data, or report no data at all in the late afternoon that lasted about one to two hours. Suspecting that it could be a heat related problem, the aluminum box at this location was later insulated. However, this problem was not observed at other sensor stations. If it is a heat related problem, subsequent radio/micro-processor boxes should be insulated to provide the best protection against radiant heat.

3.51 PERFORMANCE OF HARDWARE AND SOFTWARE

The hardware and software performed well during the course of deployment in Dayton, Ohio when TIPS was operated from July 14, 2000 until November 4, 2000. The hardware of the system including radios, micro-controllers, antennae, sensors and trailers performed reliably in all weather conditions (including severe thunderstorms). The only weather related incidents were the previously-mentioned effects of lightning and related power surge on the

sensor at station #5, and the possible heat related problem experienced by the micro-controller at sensor station #3.

The TIPS software performed well during the period of deployment. The software was originally configured to calculate the travel times at five-minute increments. After repeatedly monitoring the actual travel times and comparing them to the predicted travel times, it was decided to update the travel times on all CMSs at four-minute increments. The new travel time increment was implemented on August 16, 2000.

3.52 INCIDENT MANAGEMENT

In addition to providing real-time travel time information to motorists, TIPS also provided valuable assistance in the management of incidents on freeways. The State Highway Patrol officers and the traffic enforcement officers of local municipalities were given the phone number of the TIPS monitoring center at ODOT Outpost. They reported any incidents in the construction work zone or the area preceding the work zone to the TIPS monitoring personnel who in turn immediately displayed "ACCIDENT AHEAD" message on the changeable message signs. The ability to remotely change the message displayed to the motorist was expected to relieve congestion and increase highway safety through the problem area by diverting traffic to alternate routes.

4 **INDEPENDENT EVALUATION OF TIPS**

The Ohio Department of Transportation (ODOT) hired Dr. Helmut Zwahlen, Russ Professor Emeritus at Ohio University, to conduct an independent evaluation of the Travel Time Prediction System (TIPS). This evaluation was performed primarily to (a) verify the accuracy of the travel times displayed on the CMSs and (b) to assess motorists' response to the messages displayed by TIPS. The data collection for the independent evaluation were performed on October 12-14, 2000. During this time, three cars with two persons in each car recorded the displayed and actual travel times for each changeable message sign from 5:00 AM until 8:00 PM each day. The surveyors also recorded the license plates of the cars on the freeway during this period. Later a questionnaire was mailed to more than 3100 owners of these cars, whose names and addresses were obtained by Dr. Zwahlen from the Bureau of Motor Vehicles. Readers are encouraged to read the report (Reference 3) on evaluation of TIPS deployment at this site. The result of the evaluation showed that 88% of the actual times recorded for each sign, and for all the signs combined, were within a range of ± 4 minutes of the predicted time. (Remember: TIPS was configured to display travel time at 4-minute increments). The result also showed that 97% of the surveyed motorists felt that a system to provide real-time travel time in advance of a work zone is either outright helpful or may be helpful. It was concluded that "the real-time TIPS system represents a definite improvement over any static non-real-time display system. It provides in general and most of the time useful and relatively accurate travel time predictions to the motoring public and appears to be perceived by the motoring public as helpful and useful". An abstract of the evaluation report is reproduced below:

ABSTRACT

"A real-time travel time prediction system (TIPS) was evaluated in a construction work zone. TIPS includes changeable message signs (CMSs) displaying the travel time and distance to the end of the work zone to motorists. The travel times displayed by these CMSs are computed by an intelligent traffic algorithm and

travel-time estimation model of the TIPS software, which takes input from microwave radar sensors that detect the vehicle traffic on each lane of the freeway. Besides the CMSs and the radar sensors, the TIPS system includes the computer and microcontroller computing the travel times, 220 MHz radios for transmitting data from the sensors to the computer and from the computer to the CMSs, and trailers with solar panels and batteries to power the radar sensors, CMSs, and radios. The evaluation included an accuracy analysis between the predicted and actual recorded travel times and a survey of the motoring public. Three crews driving independently of each other in the traffic stream recorded predicted and actual travel times at three CMSs to the end of the work zone for 12 hours each day for three consecutive days, resulting in 119 trial runs. The data recorder in each crew also recorded the license plate numbers of private non-commercial vehicles with Ohio license plates. A total of 3177 different license plate numbers were recorded and a questionnaire was sent to each one. A total of 660 completed surveys were returned and analyzed. Based on the regression analysis of actual times vs. predicted times, the system does on the average a reasonable job in predicting the travel times to the end of the work zone. About 88% of the actual times recorded for each sign, and for all the signs combined, were within a range of ± 4 minutes of the predicted time. However, a few differences (actual - predicted) as great as 18 minutes were observed. Survey responses indicated that the motoring public does perceive a certain inaccuracy in the travel times. However, almost 97 % of surveyed motorists felt that a system to provide real-time travel information in advance of work zones is either outright helpful or maybe helpful. In summary we may conclude that the real-time TIPS system represents a definite improvement over any static non-real-time display system. It provides in general and most of the time useful and relatively accurate travel time predictions to the motoring public and appears to be perceived by the motoring public as helpful and useful".

5 CONCLUSIONS & RECOMMENDATIONS

Traffic congestion in freeway work zones is generally a frustrating experience for motorists. An efficient traffic management system in freeway work zones becomes a top priority for public officials involved in the construction and rehabilitation of freeways. The Travel Time Prediction System (TIPS) would aid ODOT in this process and would be a useful tool due to the capability to provide real-time information to motorists about traffic conditions.

The implementation of the Travel Time Prediction System (TIPS) fulfilled the objective of informing the motorists of the estimated travel time to the end of the work zone. This information was potentially useful to the motorists in making driving and route decisions based on the travel time information displayed on the changeable message signs.

This successful implementation of TIPS serves to illustrate the capabilities and reliability of the system. TIPS has been useful in accurately predicting travel time through the work zone on northbound I-75 in Dayton, Ohio. TIPS was successfully used as an information system for motorists during additional lane closures resulting extended travel times when twenty-four hour construction was employed throughout the work zone. TIPS has been proven to be an accurate and flexible system to deliver *real-time* travel information to motorists. The full implementation of TIPS has provided motorists with the real-time travel time through the work zone, for the duration of the project.

This project, which is the implementation and testing of the TIPS system, was a success by any measure. The full-scale implementation of TIPS provided further validation of the travel time prediction model and all other hardware and software components. Based on the experience of the field tests, it was found that all components performed satisfactorily and the stated objectives of the project were achieved.

An independent evaluation of TIPS concluded that "the real-time TIPS system represents a definite improvement over any static non-real-time display

system. It provides in general and most of the time useful and relatively accurate travel time predictions to the motoring public and appears to be perceived by the motoring public as helpful and useful".

The researchers are confident that in the future, TIPS would be a valuable tool for providing real-time travel time information to motorists in freeway work zones. It is recommended that the Ohio Department of Transportation (ODOT) use the Travel Time Prediction System in future freeway work zones.

6 REFERENCES

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