

**Research Report
KTC-93-35**

**EVALUATION OF ELECTRONIC
TRUCK MONITORING**

by

Jerry G. Pigman
Research Engineer

and

Joseph D. Crabtree
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

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 University of Kentucky, the Kentucky Transportation Cabinet, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. The inclusion of manufacturer names or trade names are for identification purposes and are not considered as endorsements.

December 1993



DON C. KELLY, P.E.
SECRETARY OF TRANSPORTATION

COMMONWEALTH OF KENTUCKY
TRANSPORTATION CABINET
FRANKFORT, KENTUCKY 40622

BRERETON C. JONES
GOVERNOR

JERRY D. ANGLIN
DEPUTY SECRETARY
AND
COMMISSIONER OF HIGHWAYS

March 11, 1994

Mr. Paul Toussaint
Division Administrator
Federal Highway Administration
330 West Broadway
Frankfort, Kentucky 40602-0536

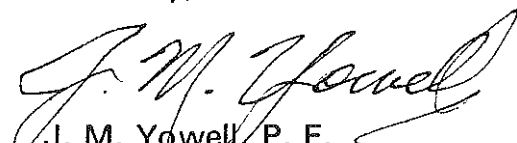
Dear Mr. Toussaint:

Subject: IMPLEMENTATION STATEMENT - Research Study, "Evaluation of Electronic Truck Monitoring", (KYHPR 91-135)

This study was an outgrowth of a previous study to analyze and document the monitoring systems in place for motor carrier operations in Kentucky. Through an evaluation process which considered various options for improving the efficiency of truck operations in Kentucky, a recommendation was made to implement a test of automatic vehicle identification (AVI) and mainline weigh-in-motion (WIM) equipment. The advantages and disadvantages of electronic monitoring equipment have been demonstrated through the field tests conducted as part of this study.

Successes and achievements associated with the project have been sufficient to justify continuation of the system operation. A preliminary evaluation of systemwide application of AVI showed the major cost element to be associated with equipping the state's truck population with transponders. Further evaluation of potential benefits for motor carriers will be undertaken to determine if they could reasonably bear the transponder cost. A recommended minimum level of activity for continued operation is to equip the Elizabethtown station with an automatic vehicle identification system and enroll additional carriers. Another option which will be considered within the Transportation Cabinet is to implement a pre-clearance concept involving weight/enforcement stations in Kentucky, Indiana, and Tennessee.

Sincerely,


J. M. Yowell, P. E.
State Highway Engineer

1. Report No. KTC-93-35		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Evaluation of Electronic Truck Monitoring				5. Report Date December 1993	
				6. Performing Organization Code	
7. Author(s) J.G. Pigman and J.D. Crabtree				8. Performing Organization Report No. KTC-93-35	
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, KY 40506-0043				10. Work Unit No. (TRIS)	
				11. Contract or Grant No. KYHPR-91-135	
				13. Type of Report and Period Covered Final Report	
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, KY 40622				14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the Federal Highway Administration, US Department of Transportation. Study Title: Evaluation of Electronic Truck Monitoring					
16. Abstract Automatic vehicle identification (AVI) and weigh-in-motion (WIM) equipment were installed at the northbound weigh/enforcement station on I-65 in Simpson County, Kentucky. The objectives were to determine the reliability and accuracy of the equipment and to determine the benefits/costs for the trucking industry and enforcement agencies. The test site for evaluation of the equipment became operational in July 1991 and the evaluation continued through June 1993. AVI equipment was provided by Amtech Corporation and WIM equipment by International Road Dynamics. Participating motor carriers were United Parcel Service and Averitt Express, with a total of 114 trucks equipped with transponders. The system operated the first year with the AVI and WIM systems serving only the function of verifying the passage of an equipped truck. During the second phase, the AVI/WIM system was moved to a position in advance of the station where equipped trucks could be identified and given a preclearance signal. Overall, it was determined that the electronic equipment could be used to collect data more accurately than through a manual process. However, it was also found that AVI and WIM equipment were not without problems, particularly when interfacing the two types of equipment. Benefits gained were increased levels of understanding of the reliability of AVI and WIM equipment. Improved relationships between motor carriers and enforcement personnel were seen as a benefit. A preliminary evaluation of systemwide application of AVI does not indicate it would be cost-effective unless greater benefits were gained by motor carriers.					
17. Key Words Automatic Vehicle Identification (AVI) Commercial Vehicle Operations (CVO) Preclearance Weigh Station IVHS Enforcement Transponder Truck			18. Distribution Statement Unlimited, with approval of the Kentucky Transportation Cabinet.		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 34	22. Price

TABLE OF CONTENTS

Executive Summary	iii
Acknowledgements	v
Introduction	1
Objectives	2
Initial System Design/Installation	2
Site Selection	2
Partnership Arrangements	2
AVI System Procurement	3
AVI Configuration	4
AVI/WIM Configuration	6
System Operation	8
Final System Design	10
Advance AVI/WIM Configuration	10
System Operation	12
Results	15
System Costs and Benefits	15
Evaluation Potential for Systemwide Applications	15
Summary and Recommendations	16
Appendix A: RFP for AVI System	18
Appendix B: System Activity Log	26

EXECUTIVE SUMMARY

Monitoring of trucking activity has been a continuing process for many years, with intensified interest in recent years. Advances in communication, computation, and other electronic technologies have begun to reshape the process of monitoring vehicles. An earlier by the Kentucky Transportation Center documented the monitoring systems in place for motor carrier operations in Kentucky. Results of that study were described in Research Report KTC-89-60, entitled "Integrated Truck Monitoring System". One recommendation of that study was to implement an operational test of automatic vehicle identification (AVI) to evaluate the impact on motor carrier monitoring activities. That recommendation resulted in a new study, which has the following objectives; 1) to determine the reliability and accuracy of the equipment under operational conditions, 2) to determine benefits/costs for the trucking industry and weigh/enforcement agencies through application of the equipment, and 3) to determine how AVI and mainline weigh-in-motion (WIM) equipment can be incorporated into an integrated truck monitoring system.

The test site for evaluation of AVI was the weigh/enforcement station on I-65 in Simpson County. A procurement process resulted in a contract being issued to Amtech Corporation for installation of AVI equipment. The equipment was installed adjacent to the station in June 1991 and approximately 114 trucks from United Parcel Service and Averitt Express were equipped with transponders. By arrangement with the Department of Vehicle Regulation, the transponder-equipped trucks were allowed to bypass the Simpson County station and the next northbound station at Elizabethtown. Soon after operation of the AVI system began, mainline WIM was installed by International Road Dynamics and interfaced with the AVI equipment. When an out-of control vehicle impacted the AVI reader-antenna, the system adjacent became inoperable and was moved to a position in advance of the exit ramp to the station. Operation of this AVI/WIM system began in September 1992 and was evaluated through June 1993.

The AVI system adjacent to the station was found to be fully operational 88 percent of the time as compared to 66 percent for the interfaced AVI/WIM system adjacent to the station. After moving the AVI/WIM system to a point in advance of the weigh station, the AVI system continued to perform adequately, but there was only sporadic operation of the combined AVI/WIM system. Despite the problems, it was determined that electronic equipment can be used to collect data consistently and more accurately than manual methods.

The primary benefit of the study was an increased level of understanding of the reliability of AVI and WIM equipment. The project also contributed to improved relationships between motor carriers and enforcement personnel, a prerequisite to expansion of electronic monitoring systems. One motor carrier estimated savings of \$24,000 per year in operating costs as a result of being permitted to bypass the weigh stations.

A preliminary evaluation of the potential for systemwide application of AVI showed that the major cost of such an effort would be to equip all trucks (those registered to operate in Kentucky) with transponders. It appears that this would only be feasible if motor carriers bore the costs of the transponders, which is reasonable to expect if they would experience benefits exceeding the transponder cost. Further evaluation of the magnitude of potential benefits is recommended.

ACKNOWLEDGEMENTS

This report was prepared in consultation with and under the guidance of the following members of the Study Advisory Committee:

Norris Beckley, Committee Chairman, Commissioner, Department of
Vehicle Regulation

Rob Bostrom, Department of Highways, Division of Planning

Jon Clark, Department of Administrative Services, Division of Automated
Services

David Herald, Department of Vehicle Regulation, Division of Motor Vehicle
Enforcement

Harold McCormick, United Parcel Service

David Roberts, Department of Vehicle Regulation, Division of Motor Vehicle
Enforcement

John Smith, Department of Vehicle Regulation, Division of Motor Vehicle
Enforcement

Kevin Sondrup, United Parcel Service

Leon Walden, Department of Highways, Division of Mass Transportation

Scott Wolf, Averitt Express

Significant contributions to the project by employees of the Department of Highways, Division of Planning should also be recognized. Specifically, the equipment installation and monitoring, which was coordinated by Rob Bostrom and Dan Inabnitt, was critical to the success of the project.

Others whose contributions to this study are acknowledged include the representatives of Amtech Corporation and International Road Dynamics.

An expression of appreciation is also extended to the following employees of the Kentucky Transportation Center for their contributions toward completion of this research report: David Cain, Carla Crossfield, Kurt Godshall, and Neil Tollner.

INTRODUCTION

As highways in Kentucky and across the nation become more congested, thus reducing mobility and efficiency of travel, there is a pressing need to provide additional transportation facilities or improve existing facilities. Severe constraints on construction of new highways have placed a strong emphasis on improving the performance of existing highways. In recent years, much attention has focused on applications of advanced technology to enhance mobility, safety, and efficiency of travel. This concept has come to be known as Intelligent Vehicle-Highway Systems (IVHS). Most IVHS applications incorporate advanced communications technologies that allow rapid transfer of information between the driver, the vehicle, and the highway infrastructure

The field of IVHS can be subdivided into many user services, which generally fall into the primary categories of Advanced Traveler Information Systems (ATIS), Advanced Traffic Management Systems (ATMS), Advanced Vehicle Control Systems (AVCS), Advanced Public Transportation Systems (APTS), Advanced Rural Transportation Systems (ARTS), and Commercial Vehicle Operations (CVO). Under the heading of CVO, the user services that have been identified in the draft National Program Plan for IVHS¹ are Commercial Vehicle Preclearance, Automated Roadside Safety Inspection, Commercial Vehicle Administrative Processes, On-Board Safety Monitoring, and Commercial Fleet Management. Potential benefits that may accrue from the application of advanced technologies to CVO include: 1) reduced delays due to weigh station preclearance and/or automation of the inspection process; 2) enhanced enforcement through more efficient allocation of enforcement agency resources; 3) improved safety of commercial vehicle operations; 4) reduced fuel consumption and emissions; 4) improved data collection for purposes of pavement management, highway design, and traffic management; and 5) reduced paperwork and administrative costs for commercial vehicle operators and state agencies.

Monitoring of trucking activity has been a continuing process in Kentucky and other states for decades. Interest has intensified in the past few years as a result of changes in the trucking industry. These changes have been brought about by deregulation, by maturation of the nation's trucking highway system, and by advances in communication, computation, and other electronic technologies that have begun to reshape the monitoring process. This study was an outgrowth of a previous study to analyze and document the monitoring systems in place for motor carrier operations in Kentucky. That study was completed by the Kentucky Transportation Center for the Kentucky Transportation Cabinet, and the results were documented in Research Report KTC-89-60, titled "Integrated Truck Monitoring System". In that report, it was noted that the application of electronic

¹The National Program Plan for Intelligent Vehicle-Highway Systems (IVHS) is being prepared by the Federal Highway Administration in cooperation with the Intelligent Vehicle-Highway Society of America (IVHS AMERICA). The first draft was distributed for review in October of 1993.

technologies offered potential for improvements that should be pursued through implementation of an operational test of automatic vehicle identification.

Considerable effort has been expended on monitoring trucking activity in Kentucky, with the state becoming a leader in its integration of on-the-road inspections through a centralized computer file in Frankfort. Automatic vehicle classification and weigh-in-motion technologies have been adopted for use in areas of planning and truck credentials certification. Automatic vehicle identification (AVI) appears to be the most promising new technology which can offer enhancements for monitoring motor carrier operations and improving the efficiency of truck movements through Kentucky.

OBJECTIVES

The initial objectives of the study were as follows: 1) to determine the reliability and accuracy of operation of state-of-the-art automatic vehicle identification equipment under operational conditions; 2) to determine trucking benefits/costs from mainline clearance of trucks at weigh/enforcement stations; 3) to estimate agency benefits/costs associated with application of automatic vehicle identification equipment; and 4) to determine how automatic vehicle identification and mainline weigh-in-motion equipment can be incorporated into an integrated truck monitoring system.

INITIAL SYSTEM DESIGN/INSTALLATION

SITE SELECTION

The weigh/enforcement station serving northbound traffic on Interstate 65 in Simpson County was selected for installation and evaluation of the automatic vehicle identification (AVI) equipment. Heavy volumes of truck traffic use I-65 in southern Kentucky near the Tennessee border, which was one of the criteria upon which the selection of a site was based. Average daily traffic on this section of I-65 is approximately 27,000, with trucks representing 29.3 percent of the traffic stream. The Simpson County station is also a state-of-the-art weigh/enforcement station which could be expected to remain essentially unaltered for several years and is suitable for installation of electronic equipment. In addition, the motor carriers being considered for participation in the mainline clearance operation were frequent users of I-65 and could anticipate operational savings if allowed to bypass the station.

PARTNERSHIP ARRANGEMENTS

The AVI project on I-65 in Simpson County involved the development of several partnerships which served as the cornerstone to the success or failure of

the project. Initially, the Kentucky Transportation Cabinet contracted with the Kentucky Transportation Center to prepare a work plan for demonstrating advanced technology applications using AVI on I-65. The Kentucky Transportation Center subcontracted with Amtech Corporation for the system design, installation and operation. The Transportation Center was responsible for overseeing the operation and evaluating the system. Motor carriers willing to equip their trucks with transponders were recruited and informed of the project expectations. A unique arrangement between two motor carriers (United Parcel Service and Averitt Express) and the Transportation Cabinet's Department of Vehicle Regulation demonstrated the benefits of a public-private partnership. The motor carriers were asked to make their participating trucks available for a safety inspection prior to enrolling them in the project. Division of Vehicle Enforcement personnel traveled to the carriers' terminals and performed the inspections during down times for the participating trucks. In return for their participation, the carriers were given the privilege to bypass the northbound weigh/enforcement station on I-65 in Simpson County. Through an arrangement with the Transportation Cabinet's Division of Vehicle Enforcement, participating motor carriers were also permitted to bypass the Elizabethtown weigh/enforcement station located on I-65 approximately 85 miles north of the Simpson County site. No AVI equipment was installed at the Elizabethtown site, so bypass privileges at that site were based totally on an honor system of allowing those who bypass the Simpson site to also bypass the Elizabethtown site. Information gained from the enforcement personnel at Elizabethtown indicated that the privilege of bypassing a second station did not create significant problems. For example, there were very few instances of non-transponder equipped trucks attempting to continue past without entering the weigh/enforcement station.

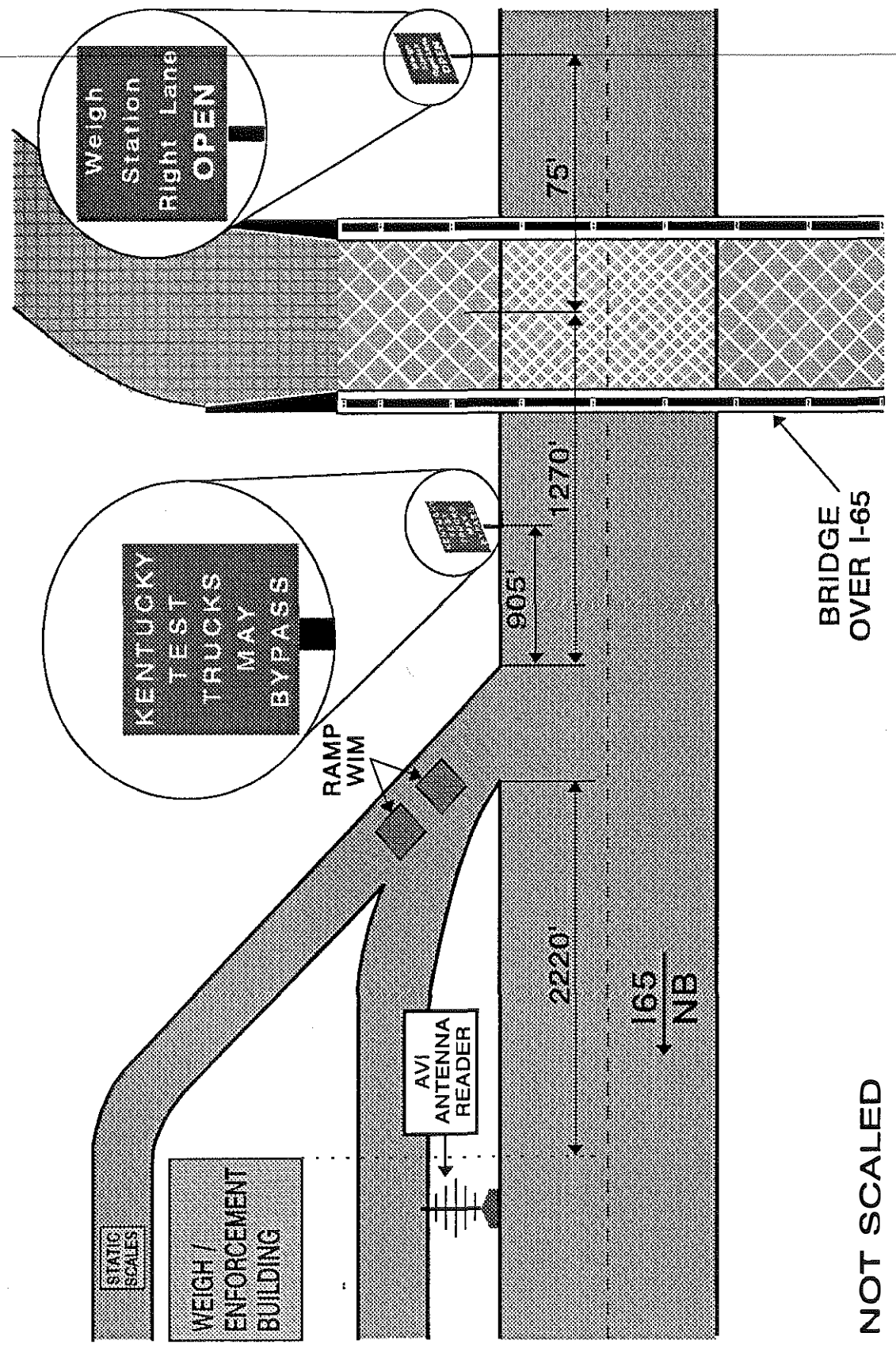
AVI SYSTEM PROCUREMENT

The procurement of the AVI system was initiated in the fall of 1990 with a letter to potential vendors soliciting cost information for their equipment. A meeting of the Study Advisory Committee was held in February 1991 to review cost information provided by the potential vendors. At that meeting, a decision was made to prepare a Request for Proposals (RFP) for an AVI system within the budget constraints of the research study. After review and approval by the Study Advisory Committee, the RFP was submitted to potential vendors on March 22, 1991. A copy of the RFP method of award, technical requirements, and evaluation criteria, as transmitted to potential vendors, is presented in Appendix A. The proposals were received on April 23, 1991, and the proposal evaluation process was completed on April 29, 1991. A contract was issued to Amtech Corporation in May 1991, and the AVI system was installed, tested, and operational by June 30, 1991.

AVI CONFIGURATION

The time and cost constraints of the project and the desire to quickly demonstrate AVI capabilities resulted in a decision to implement an AVI equipment demonstration project. The initial objective was to determine the reliability and accuracy of AVI equipment under operational conditions. To accomplish this objective, the most expedient and cost-effective approach was to install an AVI reader/antenna adjacent to the station and collect data for the transponder-equipped trucks. The AVI system consisted of a roadside reader/antenna connected by hardwire through conduit to a computer placed in the weigh station. Verification and processing of valid tag reads was accomplished through the control subsystem; which consisted of the automatic data processor, the weigh station computer, and a modem for interfacing with the Amtech Control Center (for remote diagnostics capabilities). Records of the passage of a transponder-equipped truck were stored on the weigh station computer with date and time of passage. An audible signal from the weigh station computer provided an indication that a tagged vehicle had passed the weigh station. A schematic showing the layout of the station with AVI installed adjacent to the weigh station is presented as Figure 1. In addition to the AVI antenna/reader, signs were installed which displayed the message "KY Test Trucks May Bypass". One of these signs was located approximately 900 feet in advance of the exit ramp to the weigh station and another approximately one mile in advance. As noted previously, bypass privileges were also given to transponder-equipped trucks at the Elizabethtown weigh/enforcement station. In order to inform drivers, two signs indicating "KY Test Trucks May Bypass" were installed at one-half mile and one and one-half miles in advance of the Elizabethtown station.

**Figure 1. AUTOMATIC VEHICLE IDENTIFICATION
ADJACENT TO WEIGH STATION**



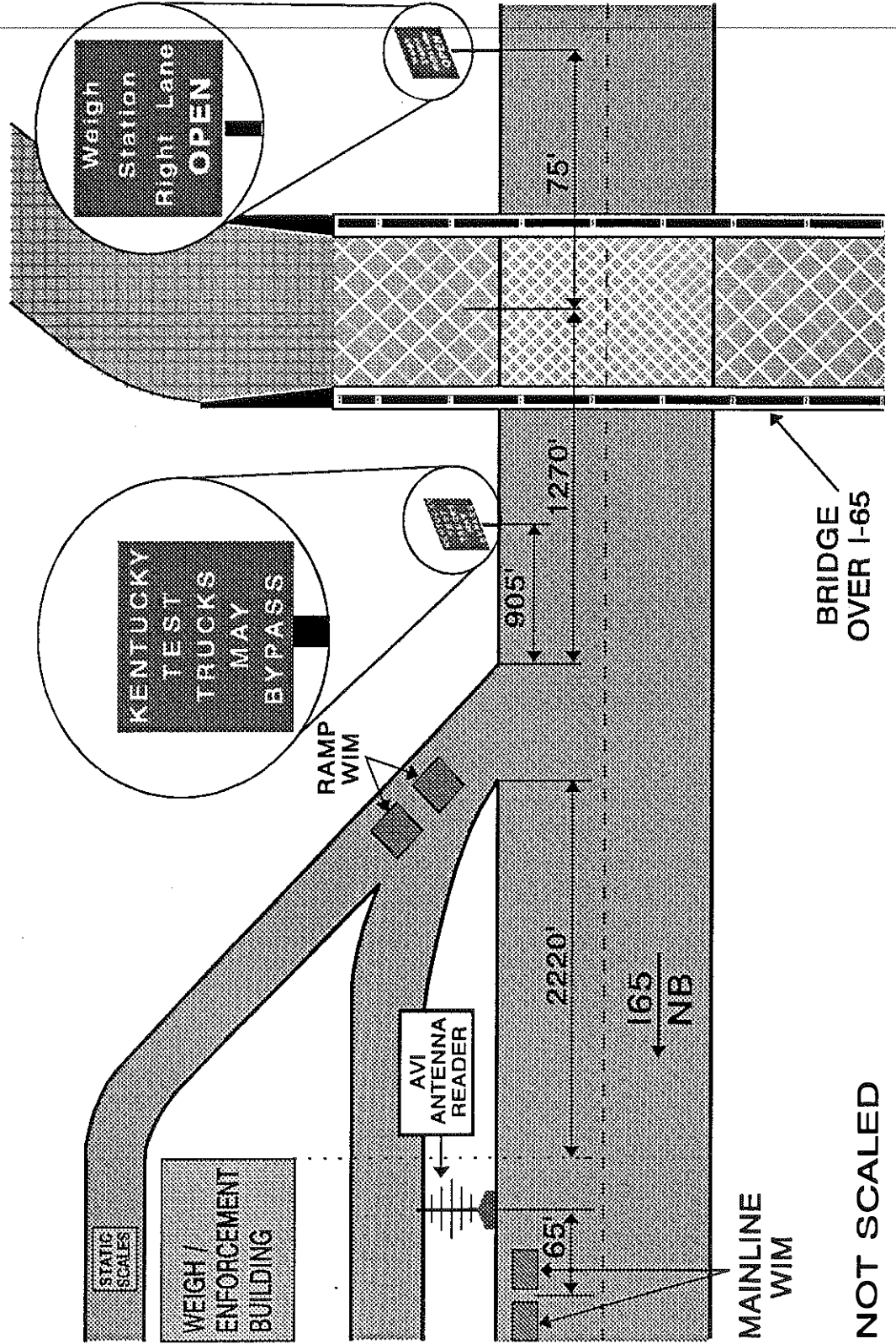
NOT SCALED

AVI/WIM CONFIGURATION

After approximately three months of operation as an AVI installation at the site in Simpson County, a decision was made to install a weigh-in-motion system on the mainline of I-65 near the AVI reader/antenna. This decision was the result of a desire on the part of the Kentucky Transportation Cabinet and the Transportation Center to evaluate a combined installation of mainline weigh-in-motion equipment and AVI equipment. By installing both types of equipment and developing an interface between the two systems, another level of technology was made available for application to motor carrier monitoring activities at weigh/enforcement stations. Amtech provided the software interface between existing AVI equipment and newly installed WIM equipment. The WIM equipment was provided by International Road Dynamics. The Transportation Cabinet installed piezoelectric cables, the equipment cabinet, conduit, and other connections necessary for operation of the system. The WIM piezoelectric cables were installed in the pavement just downstream from the AVI equipment. A schematic showing the layout of the site with AVI and WIM equipment adjacent to the weigh station building is presented in Figure 2. The configuration shown is identical to that shown in Figure 1 with the addition of WIM sensing loops and a control cabinet north of the AVI antenna.

Installation of WIM equipment and interfacing of the WIM equipment with the AVI equipment was completed on January 31, 1992.

Figure 2. AUTOMATIC VEHICLE IDENTIFICATION / WEIGH-IN-MOTION INSTALLATION ADJACENT TO WEIGH STATION



NOT SCALED

SYSTEM OPERATION

From July 1, 1991 to January 31, 1992, the system operated as an AVI installation, with the purpose of reading and recording data from the transponders of participating trucks. A summary of the system operation for this period is presented in Table 1. For the time period as a whole, which consisted of 215 days, the system was fully operational for 190 days, or 88 percent of the time. There were an additional six days during which the system was collecting and storing data, but the computer display was disabled. Thus, the data collection function had an uptime of about 91 percent. As shown in the table, there were several different causes for system downtime, but most failures were related to the reader's automatic data processor (ADP). Amtech investigated these failures and determined that variations in the weigh station's power supply were to blame. After installation of an uninterruptible power supply (U.P.S.) in October, the system operated for nearly four months with virtually no problems. Further details on system operation can be found in the system activity log in Appendix B.

Following the completion of the AVI/WIM interface on January 31, 1992, the system operated as a combined AVI/WIM system, generating and storing records with combined AVI and WIM data. This system configuration was in place until May 29, 1992 when the AVI reader antenna was impacted by an out-of-control vehicle. A summary of system operation during this time period is presented in Table 2. For the time period as a whole, the system was fully operational for 79 days out of a total of 119 days. This equates to 66 percent uptime. The AVI portion of the system had virtually no downtime, but the WIM equipment suffered two failures related to the WIM computer's hard drive. The first such occurrence was corrected by replacing the hard drive; in the second case the hard drive was reformatted. Again, further details on system operation can be found in the system activity log in Appendix B.

Table 1. Summary of AVI System Operation

Date	Description
July 1 - July 9, 1991	Operational
July 9 - July 11	Computer display disabled by lightning strike - Data collection unaffected
July 11 - August 2	Operational
August 2 - August 16	Down - Reader logic board
August 16 - August 22	Operational
August 22 - August 27	Down - Multiplex plug
August 27 - August 30	Operational
August 30 - September 1 ^a	Computer display down - ADP unit lost power - Data collection unaffected
September 1 ^a - October 1	Operational
October 1 - October 3	Computer display down - ADP unit failed - Data collection unaffected
October 3, 1991 - January 31, 1992	Operational

^aEstimated date of repair. Actual date was not recorded, but system was verified operational on 9/6/91.

Table 2. Summary of AVI/WIM System Operation

Date	Description
January 31 - February 19, 1992	Operational
February 19 - March 12	WIM disabled due to WIM computer hard drive failure - collection of AVI data continued
March 12 - April 17	Operational
April 17 - May 5	WIM disabled due to WIM computer hard drive failure - collection of AVI data continued
May 5 - May 29	Operational

FINAL SYSTEM DESIGN

ADVANCE AVI/WIM CONFIGURATION

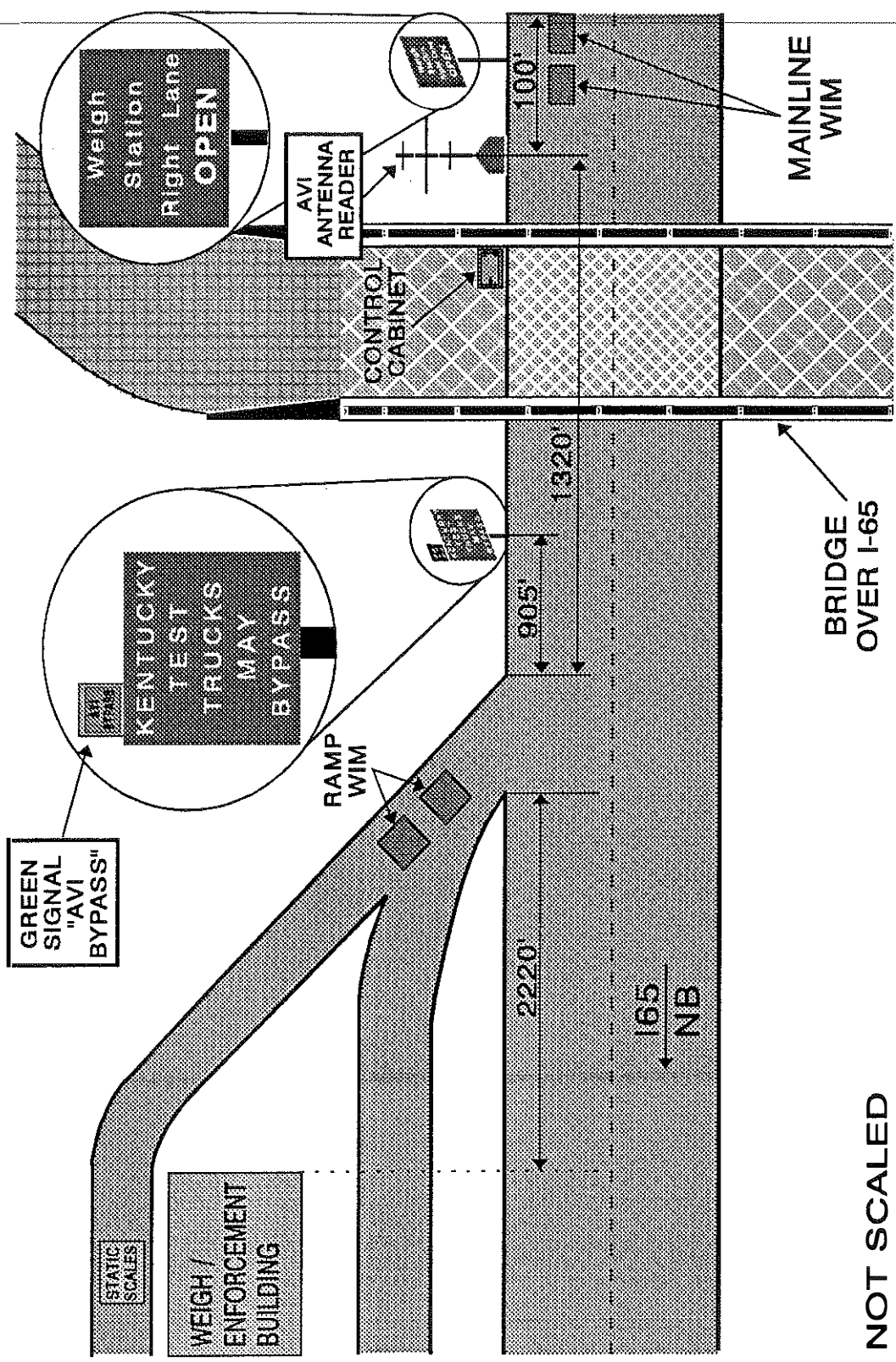
After the accident in May 1992, a new contract was issued to Amtech Corporation. This contract called for installation of a mainline preclearance system in advance of the weigh station. Again, Amtech subcontracted with International Road Dynamics to provide the WIM electronic equipment. Amtech provided and installed the AVI equipment and developed the software and interfaces. Piezoelectric cables and connecting conduit were provided and installed by Kentucky Transportation Cabinet personnel. The contract was issued in July 1992, and the installation was completed in September 1992.

The layout of the site with the mainline preclearance system installed is shown in Figure 3. As shown in the figure, mainline WIM equipment and an AVI reader were installed approximately one-quarter of a mile upstream of the exit ramp for the weigh station. The AVI reader was located downstream of the WIM sensors so that the transponder would be read as the truck exited the WIM sensors. A bridge passing over the Interstate provided an excellent, protected location (behind existing guardrail) for installing the AVI control cabinet and antenna. Also installed (in November 1992) was a roadside signal head which, when illuminated, would display the words "AVI BYPASS". The signal head was installed on the sign indicating "KY Test Trucks May Bypass", which was located 905 feet in advance of the weigh station exit ramp.

The system was programmed with the capability to gather weight and identification data for a transponder-equipped truck, compare the weight data to legal requirements, compare the identification data to a list of participating trucks, and activate the signal head if all checks were satisfactory. When weight data were unavailable due to problems with the WIM equipment or interface, the system could be instructed to function in a degraded mode by checking only the identification data and activating the signal head if the check was satisfactory.

Another capability which was tested, beginning in February of 1993, was the use of in-cab paging devices to communicate the preclearance message to the driver. Amtech installed a Motorola paging system in the weigh station building and interfaced that system to the preclearance system computer. Four Motorola pagers were installed in trucks for testing.

Figure 3. AUTOMATIC VEHICLE IDENTIFICATION / WEIGH-IN-MOTION INSTALLATION IN ADVANCE OF WEIGH STATION



NOT SCALED

SYSTEM OPERATION

Although installation of AVI and WIM equipment was completed in September 1992, problems associated with the WIM equipment and the AVI/WIM interface resulted in delays placing the equipment into operation. The AVI portion of the system became operational in November 1992, but the AVI/WIM interface was not operational until February 1993. From February through April, the AVI/WIM interface was operational on a sporadic basis. In May and June, the system was fully operational for a total of about five weeks, with "operational" being defined as both WIM and AVI data being collected for a transponder-equipped truck and transmitted to the weigh-station computer. A summary of system operation for September 1992 through June 1993 is presented in Table 3.

Table 3. Summary of Advance AVI/WIM System Operation

Date	Description
September 17 - November 11, 1992	System installed, but not operational
November 11, 1992 - February 18, 1993	AVI data collected, but WIM system not functional - hard disk problem
February 18 - February 24	Operational - combined AVI and WIM data collected
February 24 - 25	AVI data, but no WIM data
February 25 - March 9	System down
March 9 - March 15	AVI data, but no WIM data
March 15 - April 6	AVI data collection with sporadic recording of associated WIM data
April 6 - April 29	AVI data, but no WIM data
April 29 - May 20	Operational - combined AVI and WIM data collected
May 20 - May 27	System down
May 27 - June 9	Operational
June 9 - June 30	System down

Further details of system operation can be found in the system activity log in Appendix B.

The accuracy of the WIM equipment using piezoelectric cables as sensing devices was also evaluated as part of the project. During the WIM installation, comparisons of static axle weights and WIM axle weights were made using two test trucks. The test trucks had static gross weights of 77,000 and 81,900 pounds. A summary of the calibration test runs is presented in Table 4. Results indicated that the dynamic (WIM) weights ranged from 7.1 percent to 16.8 percent less than the static weight for a series of eight tests. It was found that the gross weight differences exceeded the acceptable tolerance of 10.0 percent in 3 of the 8 test runs. As noted previously, other problems were observed with the operation of the WIM electronics equipment. Specifically, the hard drive in the WIM computer continued to have problems throughout the test. Many of the problems resulted in downtime of the WIM system, which rendered the WIM/AVI interface nonfunctional.

Table 4. Summary of Calibration Test of IRD WIM Installation at I-65 Simpson County Site

		Truck #1 Weights (thousands of pounds)			
		Steering Axle	Drive Tandem	Trailer Tandem	Gross Weight
	Static Weights	12.1	30.4	34.5	77.0
Run #1	WIM Weights	10.4	27.7	33.3	71.5
	Difference from Static	-14%	-9%	-3%	-7.1%
Run #2	Wim Weights	11.4	28.4	31.5	71.3
	Difference from Static	-6%	-7%	-9%	-7.4%
Run #3	WIM Weights	10.9	28.3	31.8	71.0
	Difference from Static	-10%	-7%	-8%	-7.8%
Run #4	WIM Weights	11.0	27.5	31.6	70.1
	Difference from Static	-9%	-10%	-8%	-9.0%
		Truck #2 Weights (thousands of pounds)			
		Steering Axle	Drive Tandem	Trailer Tandem	Gross Weight
	Static Weights	13.0	29.2	39.7	81.9
Run #1	WIM Weights	10.9	23.5	33.7	68.1
	Difference from Static	-16%	-20%	-15%	-16.8%
Run #2	WIM Weights	11.3	26.9	35.2	73.4
	Difference from Static	-13%	-8%	-11%	-10.4%
Run #3	WIM Weights	10.9	25.1	32.5	68.5
	Difference from Static	-16%	-14%	-18%	-16.4%
Run #4	WIM Weights	11.7	25.3	33.6	70.6
	Difference from Static	-10%	-13%	-15%	-13.8%

RESULTS

SYSTEM COSTS AND BENEFITS

The cost of the initial AVI installation was \$49,700 and the supplier of the system was Amtech Corporation. Equipment for the project was provided through a lease arrangement with Amtech. The contract award was for a six-month period of operation and maintenance beginning July 1, 1991. After several problems were experienced with the operation of the system during the first few months, a six-month extension for system operation and maintenance was arranged through Amtech for an additional \$4,415. During the fall of 1991, an agreement was made with International Road Dynamics to provide a weigh-in-motion system in conjunction with the AVI system at the site on I-65. The only hardware cost associated with the installation of this system was \$3,000 for the piezoelectric cables, which were installed in the pavement by Transportation Cabinet employees. Traffic control and Transportation Cabinet personnel costs for installation of the cables were estimated to be \$5,000. After an accident at the AVI/WIM site adjacent to the weigh/enforcement station rendered the AVI system inoperable, another contract was issued to Amtech for installation of an AVI/WIM system in advance of the station. A contract for \$30,860 was issued to Amtech in late June 1992 for the new AVI/WIM system in advance of the station. As part of the contract, equipment was leased for another year; at a rate of \$4,415 per three-month period. Overall, the cost of system installation, operation, and maintenance for the two-year project was \$87,975.

The primary benefits of the AVI/WIM installation and operation have been to gain increased levels of understanding of the range and reliability of automatic vehicle identification equipment and weigh-in-motion equipment. As expected, there were operational problems with leading-edge technology systems such as AVI and WIM. Specifically, particular difficulties with implementing and maintaining the software interface between AVI and WIM were experienced. Reliability of the system was compromised by unusual weather conditions. There appeared to be significant susceptibility to lightning strikes, which resulted in system down times and operational problems. Specific benefits associated with the opportunity for trucks to bypass the weigh/enforcement stations were documented by United Parcel Service. Based on approximately 75 trucks being equipped with transponders and passing through the Simpson County station, it was estimated that annual time savings would result in an operating cost reduction of approximately \$24,000 per year for UPS.

EVALUATION POTENTIAL FOR SYSTEMWIDE APPLICATIONS

With advancements in technology and continuing requirements for data collection and reporting, the logical progression appears to be toward some form of electronic license plates or other means of carrying or transferring electronic data. A scenario that has been discussed, but not yet endorsed, is to equip all trucks operating in Kentucky with transponders to carry identification or other data in an electronic data format. It would then be possible, by placing a reader on the approach ramp to each weigh station, to eliminate the need for manual data entry of KYU numbers and vehicle unit numbers. This task is currently performed by clerks at the weigh/enforcement stations, at an estimated annual cost of

approximately \$700,000 per year. This estimate is based on 18 stations operating 24 hours per day and 248 work days per year, with the clerks earning \$6.50 per hour.

The cost to equip each of Kentucky's 18 weigh/enforcement stations with an AVI reader/antenna on the slow-speed ramp at the station building has been estimated to be \$450,000. This would include a computer in the weigh station and the interface between the reader/antenna and the weigh station computer. The estimate is based on a cost of \$25,000 per station. In order to eliminate the need for a clerk at the weigh station, all trucks registered to operate in Kentucky would have to be equipped with transponders². The estimated population of trucks registered to operate in Kentucky is 700,000. At a cost of \$25 per transponder, the total cost to place transponders on all 700,000 trucks would be \$17,500,000. This is obviously a significant cost which likely would have to be absorbed by the motor carrier industry. Therefore, before recommending a requirement that all trucks be equipped with transponders, the benefits and costs of such a requirement need to be fully evaluated.

Possible benefits to motor carriers from implementation of transponder technology include: 1) a reduction in paperwork requirements through electronic monitoring; 2) reduced potential for detainment at the weigh stations due to improper credentials; 3) increased safety resulting from electronic verification of motor carrier safety reports, and 4) the opportunity for registration through an electronic process. The potential also exists for motor carriers to use the transponder technology for their own purposes, such as tracking shipments, storing vehicle maintenance and inspection data, and electronically generating required reports. In addition, transponders could eliminate the need for multiple stickers, license plates, and identification numbers painted on the truck.

It is unknown whether these benefits are of sufficient magnitude now to justify the expense of equipping all trucks with transponders. However, it is certain that, as the technology continues to develop and more applications become available, the benefits will grow accordingly.

SUMMARY AND RECOMMENDATIONS

The evaluation of automatic vehicle identification and weigh-in-motion at the weigh station site on I-65 in Simpson County has proven to be an extremely useful experience in the application of advanced technology to motor carrier operations in Kentucky. There have been benefits gained by the participating motor carriers through the bypass opportunities afforded to them. The Transportation Cabinet enforcement personnel have gained a new level of knowledge about applications of electronic technology. In addition, specific applications of technology have been identified which show potential for increased operating efficiency. Relationships have been developed between the participating

²In actuality, there are some trucks registered to operate in Kentucky that never pass through weigh stations and would not need transponders. However, for the sake of this analysis, it is assumed that all trucks would need to be equipped with transponders.

motor carriers and the enforcement personnel which have allowed a better understanding of the operational characteristics of profit-oriented motor carriers and government regulatory/enforcement personnel.

The project has also served to provide a forum for experimentation and evaluation of relatively new electronic equipment and its applications to the motor carrier industry. Automatic vehicle identification equipment has been demonstrated and advantages and disadvantages have been identified as part of the field tests. It has been shown that electronic equipment can be used to collect data consistently and more accurately than data collected manually. However, it was also determined that AVI and WIM equipment are not without problems, particularly when interfacing the two types of equipment. Equipment malfunctions and other failures associated with weather were frequent enough to merit concern if wide-scale installations were put in place. In addition, there is a continuing concern with the accuracy levels which can be achieved with weigh-in-motion equipment.

Even with the problems as described, the successes and achievements associated with the project have been sufficient to justify continuation of the system operation. The recommended minimum level of activity for continued operation is to equip the Elizabethtown station (approximately 90 miles north of the Simpson station) with automatic vehicle identification equipment and enroll additional carriers. A reasonable goal could be to at least double the number of trucks equipped with transponders. The cost to install automatic vehicle identification at the Elizabethtown station and manage/evaluate the project for another year is estimated to cost in the range of \$125,000.

Another option which should be considered is to move toward an automated pre-clearance concept involving weigh stations in Kentucky, Indiana, and Tennessee. A logical expansion would be to equip one additional station in each of the states. This could involve the northbound station in Tennessee just south of the Kentucky border, the northbound Elizabethtown station in Kentucky, and the northbound station on I-65 in Indiana between Louisville and Indianapolis; in addition to the currently-equipped Simpson County station. Selection of this option would require development of a three-state partnership with an agreement to operate a decentralized system where each state would be independent with respect to credentials checking and weight verification. Increased motor carrier participation would also be an objective of this option. System components would be expected to cost in the range of \$75,000 for each mainline weigh-in-motion site and \$50,000 per site for automatic vehicle identification.

APPENDIX A
RFP FOR AVI SYSTEM



UNIVERSITY OF KENTUCKY

**REQUEST FOR PROPOSALS
for
Automatic Vehicle
Identification System**

PK-0025-0

UNIVERSITY OF KENTUCKY

DIVISION OF PURCHASES
REQUEST FOR PROPOSAL (RFP)

Proposal Number PK-0025-0	Date Issued 03/22/91
------------------------------	-------------------------

Schedule Name Automatic Vehicle Identification System
--

ATTENTION: This is Not an Order, Read All Instructions, Terms, and Conditions. Carefully.

Name of Purchasing Official Wm. P. Trammell / vlj	Area Code 606	Telephone 257-2851
--	------------------	-----------------------

IMPORTANT: Proposals Must Be Received By

Proposal Receiving Date 04/23/91	Time 4:30 p.m.	Location Division of Purchases
-------------------------------------	-------------------	-----------------------------------

VENDOR NAME AND ADDRESS

SUBMIT PROPOSAL TO:

DIVISION OF PURCHASES
University of Kentucky
Capital Construction Section
Room 322, Service Building
Lexington, Kentucky 40506

Gentlemen:

1. It is the intention of this Request for Proposal (RFP) to enter into competitive negotiation as authorized by KRS 45A.085.
2. Proposals for competitive negotiation shall not be subject to public inspection until negotiations between the purchasing agency and all offerors have been concluded and a contract awarded to the responsible offeror submitting the proposal determined in writing to be the most advantageous to the University, price and the evaluation factors set forth in the advertisement and solicitations for proposals considered.
3. An award of contract may be made upon the basis of the initial written proposals received without written or oral discussions.
4. Contracts resulting from this RFP must be governed by and in accordance with the laws of the Commonwealth of Kentucky.
5. The University reserves the right to request proposal amendments or modifications after the proposal receiving date.
6. The contents of the successful proposal shall become part of any contract awarded.

AUTHENTICATION OF PROPOSAL AND STATEMENT OF NON-COLLUSION AND NON-CONFLICT OF INTEREST

I hereby swear (or affirm) under the penalty for false swearing as provided by KRS 523.040:

1. That I am the offeror (if the offeror is an individual), a partner, (if the offeror is a partnership), or an officer or employee of the offering corporation having authority to sign on its behalf (if the offeror is a corporation);
2. That the attached proposal covering UNIVERSITY OF KENTUCKY RFP No. PK- 0025-0 has been arrived at by the offeror independently and has been submitted without collusion with, and without any agreement, understanding or planned common course of action with, any other vendor of materials, supplies, equipment or services described in the request for proposal, designed to limit independent bidding or competition;
3. That the contents of the proposal have not been communicated by the offeror or its employees or agents to any person not an employee or agent of the offeror or its surety on any bond furnished with the proposal and will not be communicated to any such person prior to the official award of contract;
4. That the offeror is legally entitled to enter into contracts with the Commonwealth of Kentucky and is not in violation of any prohibited conflict of interest, including those prohibited by the provisions of KRS 45A.330 to .340, and 164.390, and
5. That I have fully informed myself regarding the accuracy of the statements made above.

NOTICE

1. Any agreement or collusion among offerors or prospective offerors which restrains, tends to restrain, or is reasonably calculated to restrain competition by agreement to offer at a fixed price or to refrain from offering, or otherwise, is prohibited.
2. Any person who violates any provisions of KRS 45A.325 shall be guilty of a felony and shall be punished by a fine of not less than five thousand dollars nor more than ten thousand dollars, or be imprisoned not less than one year nor more than five years, or both such fine and imprisonment. Any firm, corporation, or association which violates any of the provisions of KRS 45A.325 shall, upon conviction, be fined not less than ten thousand dollars nor more than twenty thousand dollars.

SIGNATURE REQUIRED: This proposal cannot be considered valid unless the offeror signs it and prints or types his name, firm address, telephone number and date in the spaces provided. Offers signed by an agent are to be accompanied by evidence of his authority unless such evidence has been previously furnished to the issuing office.

University of Kentucky
Division of Purchases
Capital Construction Section
Room 322, Service Building
Lexington, Kentucky 40506-0005

IMPORTANT: SIGN OFFER BELOW

Firm _____

Address _____

City _____ State _____ Zip Code _____

Authorized Signature _____ Date _____

Print or Type Name _____

Title _____

Area Code No. _____ Telephone No. _____

REQUEST FOR PROPOSAL PK-0025-0

3.9 METHOD OF AWARD

3.9.1 The award of contract will be made by the University of Kentucky Division of Purchases after technical evaluation of proposals by the evaluation committee. The awards will be made to the qualified vendors submitting the proposal which is determined to have the lowest Evaluated Proposal Price.

3.9.2 The criteria to be used by the committee for evaluation of proposals and the maximum points obtainable are shown in Section 4.4. Each proposal will be evaluated independently by each committee member and the proposal will be given a score from 0 to the maximum shown for each criterion.

3.9.3 The score on each criterion will be summed to obtain the total evaluated score as determined by that committee member.

3.9.4 The Proposal Price will be the cost as quoted by the offeror in the Cost Proposal to supply the plan and specifications to meet the requirements of the RFP. The Evaluated Proposal Price (EPP) will be calculated by dividing the Proposal Price by the average total score awarded, then multiplying that quotient by the Maximum Possible Points. The Average Total Score is the average total score of all evaluators.

3.9.5 Formula

$$\text{EPP} = \frac{\text{Proposal Price} \times \text{Max. Points Possible}}{\text{Avg. Total Score}}$$

3.10 PROPOSAL SUBMISSION REQUIREMENTS AND PROPOSAL FORMAT

3.10.1 General

Each proposal must address the University of Kentucky Transportation Center needs as outlined in Section 4.0. Each proposal submitted must contain a Technical Proposal section and a separate and sealed Cost Proposal section. There are to be no cost figures included in the Technical Proposal. Each proposal may also have additional sections as specified herein.

3.10.2 Ten (10) copies of each technical proposal under sealed cover and two (2) copies of the cost proposal under separate sealed cover must be received by no later than 4:30 PM (local time) as stated by the Proposal Receiving Date on page 1 of the RFP. Any proposal received after this date and time may be rejected and returned unopened to the offeror.

3.10.3 Proposals should be either mailed or delivered to: Division of Purchases University of Kentucky 322 Peterson Service Building Lexington, Kentucky 40506-0005

4.0 TECHNICAL REQUIREMENTS

4.1 BACKGROUND

The Kentucky Transportation Center is currently performing a research study for the Kentucky Transportation Cabinet titled "Evaluation of Electronic Truck Monitoring". The objectives of the study are to evaluate state-of-the-art automatic vehicle identification (AVI) equipment under operational conditions and to determine how automatic identification and monitoring equipment can be incorporated into an integrated truck monitoring system. The study was initiated in July 1990 and is scheduled to continue through June 30, 1992.

Because of the research format in which this project is being performed, time and available funds are significant constraints. Therefore, it is requested that consideration be given to the most practical and cost-effective arrangements for achieving the objectives, including temporary installations and leasing arrangements.

Kentucky has in place at its weigh/enforcement stations a centralized computer system that serves as a link between a unique identification number displayed on a truck and a file containing information documenting the motor carrier's operating authority. However, it should be assumed that real-time access to the central file will not be necessary, and that any necessary linkage between the truck identification number and information to verify operating authority can be made through a file maintained on a personal computer at the weigh/enforcement station. Periodic and necessary updates of the local file may be accomplished by Transportation Cabinet personnel.

Kentucky utilizes a centralized computer system to monitor truck activity at its weigh stations on a 24 hour, seven day a week basis; data entry clerks at each location enter the company identifier (KYU number) and, if possible, the company unit number as each vehicle proceeds through the respective weigh stations. This entered information is then compared against a central file where the company's operating status is checked on a real-time basis; a response is received at the weigh station within three seconds of the observation entry if the company is delinquent for any reason. Delinquent vehicles are generally impounded until deficiencies are corrected. Examples of reasons for delinquency include non-payment of taxes, failure to file a tax return for the prior quarter, no liability insurance, and not having an active bond. All entered observations are recorded in a central database; reports are generated from this data base quarterly and as needed to assist auditors in reviewing tax returns. Approximately 700,000 KYU observations are recorded each month; unit numbers are now being successfully entered about 94 percent of the time.

4.2 OBJECTIVE

The objective of this procurement is to design, install, and maintain an automatic vehicle identification system at a single weigh/enforcement station on an interstate highway in Kentucky to permit electronic monitoring of transponder-equipped trucks.

4.3 GENERAL REQUIREMENTS

A system shall be designed and installed which will electronically monitor transponder-equipped trucks traveling on the mainline of an interstate, and enter and store in an ASCII file (or easily readable format), the vehicle identification into a local computer at the weigh/enforcement station. Detection of a transponder-equipped truck must generate one new record in the local computer database. Each record shall contain a unique truck identification number and the time (recorded to the nearest second) and date of passage. The capability to verify the operating status of participating trucks shall be accomplished in real time through a database maintained in the local computer. Passage of each transponder-equipped truck will be displayed on the local computer monitor and an audible signal sounded to verify the truck bypass. Fixed signs will be provided by the Kentucky Transportation Cabinet to relay a message that trucks participating in the automatic vehicle identification demonstration may automatically bypass the weigh/enforcement station.

It is anticipated that 100 or fewer transponder-equipped trucks will be involved in the test project. The contractor will be responsible for the provision and installation of all hardware and software to monitor only one direction of travel at a single weigh station. An exception will be the installation of transponders on participating trucks; which will be the responsibility of the Kentucky Transportation Center. The equipment shall be capable of detecting transponder-equipped trucks traveling in the right or outside lane on their approach to the weigh station at speeds up to 70 mph. The equipment shall be capable of operating throughout the year, without regard to weather or visibility conditions. The equipment shall not constitute a safety hazard due to its size or placement within the roadway right-of-way.

4.3.1 OPERATIONS AND MAINTENANCE REQUIREMENTS

The automatic vehicle identification is expected to be designed and placed into operation within 45 days after receipt of notification to proceed with work on the contract. The successful contractor is expected to maintain the equipment for a six-month, continuous period of operation, immediately following installation. Equipment not permanently affixed will become the property of the contractor at the end of the six-month demonstration.

REQUEST FOR PROPOSAL PK-0025-0

4.4 CRITERIA

- 4.4.1 The criteria below are the only criteria to be used in evaluating the technical requirements of the proposals. The criteria are arranged in the order they should be addressed within the technical proposal. The evaluation will be based upon the information provided in the proposal, additional information requested by the University for clarity or modification, and on an oral presentation if it is requested. Points awarded for each criterion up to the maximum will be based on how well each is met within a vendor's proposal.
- 4.4.2 In order to be considered technically responsive and eligible for consideration in the contract award process, scores awarded by the technical evaluation committee must exceed pre-established minimum thresholds.
- 4.4.3 The minimum total score, the sum of the minimum thresholds for the individual criteria, is 75.0. The maximum points for each criterion and minimum acceptable scores are shown in the following section.
- 4.4.4 Proposal Evaluation Criteria.

Technical requirements of the proposals will be evaluated based on the criteria described below. The contract will be awarded based on the process described in Section 3.9.

<u>Description</u>	<u>Maximum Points</u>	<u>Minimum Accept. Scores</u>
1. Responsiveness to the technical requirements of the RFP as described in Section 4.0.		
a. An understanding of the operational system as described in Section 4.0	15	11.25
b. The completeness and thoroughness of the respondent's proposed work plan.	25	18.75
2. Demonstration of technical competence and understanding as reflected in the proposal.		
a. Consistency of the qualifications of the contractor with the desired results of the outlined requirements.	15	11.25
b. Demonstration of prior accomplishments in the field of advanced technology as applicable to the proposed project.	15	11.25
3. Documentation of sufficient resources to accomplish the contract requirements satisfactorily and on schedule.	30	22.50
TOTAL	<u>100</u>	<u>75.00</u>

UNIVERSITY OF KENTUCKY
DIVISION OF PURCHASING SERVICES

Invitation No.: PK-0025-0 Date: April 1, 1991
For: Automatic Vehicle Identification System

ADDENDUM NO. 1

The following information is being provided in regard to
PK-0025-0 Automatic Vehicle Identification System.

1. The funding limit for this project is \$60,000.00 maximum.
2. There is a support structure & power available for detector installation that is suitable for this project.
3. The weigh station will be located either in Boone County, KY or Simpson County Kentucky.
4. It is estimated that approximately 100 truck tags will be required.
5. One (1) lane is to be detected.

Bidder must acknowledge receipt of this and any addenda either with bid or by separate letter. Acknowledgement must be received in the Office of Purchasing Services, Service Building, University of Kentucky no later than 4:30 P.M. on April 23, 1991. If by separate letter, the following information must be placed in the lower left hand corner of the envelope:

Invitation No: PK-0013-0

For: Long Distance Communication Services

Opening Date: September 18, 1990

By W. G. Trammell
Authorized Agent, Purchasing

Receipt Acknowledged _____
Firm

APPENDIX B
SYSTEM ACTIVITY LOG

ACTIVITY LOG

AVI Installation - I-65 Simpson County

"Evaluation of Electronic Truck Monitoring" KYHPR-91-135

The AVI system was installed during the last two weeks of June 1991 and the system became operational on July 1, 1991. A total of 114 trucks from United Parcel Service and Averitt Express were equipped with transponders and were monitored on the mainline rather than exiting the interstate and traveling through the weigh/enforcement station.

Following is a chronological summary of events occurring since the AVI system became operational.

- 7-10-91 Information was received from the Simpson County station indicating that a lightning strike on July 9 had rendered the system inoperable.

An Amtech representative was contacted and assurance was given that no data had been lost and there were no problems with the equipment other than the computer monitor.

- 7-11-91 Amtech representative John Everitt went to Simpson County to repair computer and the system was again operational.

- 7-11-91 Rhona Kasper from Amtech called to confirm that the system was operational and that John Everitt had instructed Capt. Roberts about the proper procedure to download the data from hard disk to floppy.

Amtech transmitted by fax to the Kentucky Transportation Center (KTC) the transponder reads to date.

- 7-18-91 Checked with Capt. Roberts to confirm system operation since the lightning strike on July 9.

- 8-7-91 Capt. Roberts notified KTC that the system was not operating and the last entry on the computer monitor was 8-2-91. He noted that there had been several instances where the computer would not record the transponder entries and would "catch up" later by scrolling several hours of data onto the screen at one time.

- 8-8-91 KTC representative traveled to station to attempt to determine the nature of the problem and to retrieve data from the computer. The computer display was not operating and trucks were not being recorded as they passed the reader on the mainline. The computer did not provide an audible signal when the transponder-equipped trucks passed on the mainline. It was confirmed that the last recorded UPS or Averitt truck had been recorded on 8-2-91.

Weigh/enforcement personnel noted a problem with other trucks following the UPS and Averitt trucks on the mainline. An estimate of 1-10 trucks daily following the transponder-equipped trucks was made.

- 8-16-91 KTC computer analyst traveled to station to install software to allow retrieval of data and processing by KTC. It was determined that a problem existed with incompatible floppy disks; attempting to use high density disks with a regular density drive.

Another problem was determined to be associated with tag reads not being displayed on the computer monitor. Initial investigation revealed a communications loss between the ADP and the reader. A reader logic board error was confirmed and a new board was installed by Lockheed technicians.

- 8-19-91 KTC technician traveled to the station to observe operation of the AVI system by visually comparing passage of the UPS and Averitt trucks with the Amtech equipment observations. During a six-hour period on August 19 and another six-hour period on August 20, there were 24 transponder-equipped trucks observed passing on the mainline and 24 "other" UPS or Averitt trucks without transponders passing through the weigh/enforcement station. There was also one UPS truck observed passing on the mainline that did not register on the computer monitor (was not recorded by Amtech equipment) and apparently was not equipped with a transponder.

- 8-20-91 A letter was received from Amtech outlining problems with the system and a plan was suggested to be more responsive; particularly during periods of after normal work hours.

- 8-23-91 Amtech representative called to inform KTC staff that the system was not operating and that repairs would be initiated.

- 8-27-91 Weigh station staff called KTC to confirm that system was not operating and that repairs had been attempted remotely through Amtech headquarters in Dallas.

- 8-28-91 KTC staff called Amtech and was informed that a technician had repaired or replaced a multiplex plug and the system was again operational.

- 8-30-91 Amtech representative called to inform KTC staff that ADP unit had lost power and repair would be attempted from remote center in Dallas. Concern was expressed related to the ADP four-plex unit; possibly it was being moved unintentionally by station personnel.

- 9-6-91 Weigh station was contacted by KTC staff and system was confirmed to be operational.

- 9-9-91 Weigh station was contacted by KTC staff and system was confirmed to be operational. Weigh station personnel noted a problem that appeared to be related to weekend operation when there were few or possibly no transponder-equipped trucks passing the reader. It was noted that pressing a "white reset button" would cause previously unrecorded "reads" to scroll onto the computer monitor.
- 9-11-91 KTC staff visited weigh station and retrieved data. The system was confirmed to be operational. It was again noted that the audible signal was not functioning properly and that a delay between the passage of a truck and the actuation of the audible signal was outside the visibility time window for weigh/enforcement personnel.
- 9-18-91 A call was made to Robert Combs (Amtech) to request a meeting of Amtech/Lockheed personnel and KTC to discuss the status of the project.
- 9-19-91 KTC staff visited weigh station to retrieve data and observed operation of the AVI system. During a 6-hour period, 12 UPS trucks were observed passing the weigh station on the mainline of I-65. It was noted that one UPS truck passed on the mainline and apparently was not equipped with a transponder. This was confirmed by the audible signal failing to register and the computer log of trucks passing the weigh station.
- 9-23-91 Robert Combs (Amtech) called KTC to suggest that it may be beneficial for KTC and Amtech to conduct extensive verification tests at the site to confirm operation of the system.
- 9-25-91 KTC staff visited weigh station to retrieve data and observe operation of the system. The system was operational and only the delay in the audible signal was observed as a problem.
- 9-30-91 Robert Combs (Amtech) called KTC to report that arrangements were being made to have Amtech and Lockheed representatives come to Kentucky to meet with KTC personnel to discuss the status of the system. The possibility of conducting verification tests immediately prior to the meeting was also discussed.
- 10-7-91 Robert Combs (Amtech) called KTC to report that the ADP unit on the reader had failed on 10-1-91 and been repaired on 10-3-91. He reported that there had been no loss of data and that only the computer monitor had failed to function.
- 10-16-91 Amtech representatives identified problems with the power supply at the weigh station and installed an uninterruptible power supply (U.P.S.) to protect the Amtech system from power variations. Their perception was that the equipment problems experienced to this point were due primarily to power variations.

- 1-31-92 Interfacing of AVI and WIM data accomplished by Amtech personnel, resulting in AVI and WIM records being combined into one file.
-
- 2-19-92 Kentucky Transportation Cabinet representative worked with Amtech representative to address problem with WIM computer (inability to boot up computer). Collection of AVI data contined, but with only sporadic inclusion of WIM data.
- 3-2-92 Dates apparently shifted by one day in AVI records (due to leap year error). Sporadic WIM records continued to have correct date.
- 3-03-92 Collection of AVI continued, but inclusion of WIM data ceased altogether.
- 3-12-92 Kentucky Transportation Cabinet representative replaced hard drive on WIM computer. Collection of combined AVI and WIM data resumed.
- 3-25-92 Kentucky Transportation Cabinet representative changed front axle thresholds in an attempt to reduce number of reads for vehicles not classified as trucks.
- 4-6-92 Dates in AVI records were adjusted to correct date.
- 4-9-92 KTC staff traveled to station to observe operation of the system and to retrieve data from the computer. The system appeared to be operating properly for the most part. However, no audible signal was provided when valid tags were read. Also, records were being generated in the MTAGIDQ.DAT file for many pickup truck/camper combinations (system was processing these as violations). A problem was observed with the system's ability to interpret two UPS trucks with short spacing between them.
- 4-21-92 Amtech representative Rick Cathrener was contacted and discussed operation of the system, discussing what should happen for various scenarios. This discussion included the problem of trucks following too closely, and the system's inability to "queue" trucks. Because the AVI equipment and the WIM equipment were installed independently, they were not positioned in the optimal locations for working together. The options presented by Amtech were to relocate the reader or to modify the program to allow queuing of trucks.
- Rick Cathrener stated that the audible signal for tag reads can be turned off and on by means of a switch on the alarm box. This switch may have been turned off during the observations on 4/9/92.
- 4-28-92 KTC representative traveled to station to observe operation of the system and to retrieve data from the computer. Noted that the beeper for valid tags was operational and the switch was turned on. Observed that the WIM equipment had not recorded any data since 4/17/92. Also observed that the times being recorded in the tag

records were incorrect (off by 12 minutes). In reviewing old data (for 4/17/92), noticed that the AVI time was 12 minutes behind WIM time. Observed three UPS trucks go past reader, with short spacing. Three audible indications (beeps) were noted, but only one record was generated (in VTAGIDQ.DAT).

- 5/5/92 Kentucky Transportation Cabinet representative reformatted hard drive on WIM computer. Collection of combined AVI and WIM data resumed.
- 5/14/92 KTC representative traveled to station to observe operation of the system and to retrieve data from the computer. System appeared to be operating normally.
- 5/27/92 KTC, Amtech, and IRD representatives met at the weigh station to observe/discuss operation of the system and the future of the project. The system was functioning normally, but the following problems were observed:
1. Many car/trailer combinations were being processed as violations.
 2. When a violation was processed, the audible signal didn't occur until the vehicle was out of sight. This apparently resulted from a five-second window in the programming, during which the system waits for a tag read to associate with the WIM record. Because the tag reader is upstream of the WIM sensors, this delay is unnecessary.
 3. When processing violations, the system could not handle multiple trucks with less than five seconds spacing between them. This appeared to be due to the same five-second search window discussed above. If a second WIM record is generated during this window, it apparently wipes out the first record in the buffer.
- (Note: There is also a five-second window after a tag read, during which the system looks for a WIM record to associate with the tag. This would explain the observation on 4/28/92, when the WIM equipment was not working, that three UPS tags were read in rapid succession but only one record was generated.)

In response to these problems, the IRD representative adjusted the WIM equipment, and was able to eliminate some (but not all) of the mis-classified car/trailer combinations. The Amtech representatives agreed to investigate reducing/eliminating the five-second window in processing violations.

- 5/29/92 The AVI reader/antenna was impacted by an out-of-control vehicle and rendered inoperable.
- 7/10/92 Contract was issued to Amtech Corporation to install AVI/WIM preclearance system.

- 9/17/92 Amtech representatives completed installation of AVI system and IRD representatives completed installation of mainline WIM system.
-
- 9/18/92 AVI/WIM installation was inoperative due to a power interruption.
- 10/23/92 At meeting of Study Advisory Committee to discuss status of system, Amtech indicated that power interruption problem had been resolved and that new software would be installed and the system would be operational within two weeks.
- 11/11/92 Amtech representatives were at site to install green light signal head and verify timing of signal for coordination with transponder-equipped trucks. Problems associated with the AVI system were corrected and the system became operational (AVI only). The installation of a roadside signal provided a means of displaying a bypass indication to the truck driver.
- 11/17/92 Bill Ische with Amtech called to inform KTC staff that representatives of Amtech and IRD would be at site within a week to make repairs to system. It was noted that there was a problem related to the WIM system's computer hard disk similar to the problem identified during the spring of 1992.
- 12/8/92 Amtech representatives were notified that the roadside signal head was displaying a green signal to all transponder-equipped trucks rather than just UPS and Averitt trucks participating in the project. The display problem was resolved on this date by Amtech.
- 12/18/92 After visits to the site by an IRD representative, it was concluded that failure of the WIM processor and hard disk had resulted in problems that could not be resolved without sending the unit back to Saskatchewan for repair. Preliminary plans were made to repair the system during the week of December 28th and return the unit to Kentucky during the first week of January 1993.
- 1/5/93 WIM electronics at the site were exchanged for extra IRD equipment available through the Transportation Cabinet. Cabinet employees traveled to the site and exchanged new WIM electronics equipment for defective equipment in place.
- 1/11/93 Amtech representatives called to discuss possible causes for failure of the AVI/WIM system interface to function. A possible explanation was the failure to attach a cable when the WIM electronics was reinstalled by Transportation Cabinet employees in the previous week. Reattaching the cable was accomplished by Capt. Smith at the I-65 station and results indicated this was not a solution to the problem as speculated.
- 1/14/93 A site visit was made by KTC staff to determine if on-site analysis could be beneficial in identifying the reasons for failures of the AVI and WIM equipment to operate without interruption. A check of the

Valid Tag History was made and it was determined that the file only contained tag read data for September 12-14, 1992. The absence of a Valid Tag History computer file confirmed that the AVI/WIM interface was not functioning and records were not being stored. However, information available indicated that the AVI tags were continuing to be read without the data input from the weigh-in-motion equipment.

- 1/25/93 Ken Diamond with IRD called to notify KTC staff that the WIM electronics system had been repaired and was being shipped to I-65, with expected installation during the week of February 8, 1993.
- 1/28/93 A Transportation Cabinet employee traveled to the site to work with Amtech representatives to analyze and repair the interface of the AVI and WIM systems.
- 1/29/93 Bill Ische with Amtech called to confirm that problems had been corrected to permit a proper interface of AVI and WIM equipment and the system should be operational again.
- 2/17/93 KTC staff met with Bill Ische from Amtech and Jae Lee from IRD to examine AVI/WIM system and make necessary modifications to insure proper operation. The IRD WIM electronics which had been returned to IRD for repairs were reinstalled in place of WIM electronics which had been installed at site by Kentucky Transportation Cabinet personnel in January 1993.

In addition, the AVI system was modified to accept the Motorola pager system. Software at the advance reader and at the weigh station was modified to incorporate the pager system which will be tested as a supplemental device or replacement for the roadside signal head. Four of the pagers were to be made available to install on UPS trucks and one would be used for testing by KTC personnel.

- 2/18/93 Bill Ische from Amtech called to confirm that the AVI/WIM system was operational again and that the in-cab Motorola pager device was operating properly.
- 2/25/93 Bill Ische from Amtech called to inform KTC staff that the system had apparently failed on 2/24/93. Amtech and IRD were communicating in an attempt to determine if the problem could be diagnosed and corrected without a visit to the site.
- 3/3/93 Jae Lee from IRD called to confirm that the equipment had failed sometime on the 24th or 25th of February. There was speculation between IRD and Amtech that the failure was associated with a power surge or lightning strike at the site.

Dan Inabnitt from the Transportation Cabinet had called IRD and reported that the system could not be dialed remotely from Frankfort on 3/2/93. Jae Lee indicated that an IRD representative would be

sent to the site for additional testing and analysis on March 8, 1993.

3/9/93 AVI functionality restored without WIM interface.

5/6/93 Ken Diamond from IRD called KTC to report that the WIM electronics had been replaced again approximately two weeks earlier; which allowed the system to begin operation again. It was noted that the interface with Amtech AVI equipment had been accomplished and was operating without problems on April 29, 1993.

Data retrieved from computer at weigh station indicated that continuous data had begun to be generated on April 29th for interfaced AVI and WIM equipment.

6/18/93 Bill Ische from Amtech called KTC to report that the AVI system was apparently malfunctioning, as evidenced by their inability to establish a communication link between the Amtech Control Center and the I-65 site. This was confirmed by KTC's inability to connect remotely with the weigh station computer and download the data collected since the last download on June 8, 1993.