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AUTOMATIC CAR IDENTIFICATION - AN EVALUATION

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16. Abstract

In response to a Federal Railroad Administration request, the Transportation Systems Center evaluated the Automatic Car Identification System (ACI) used on the nation's railroads. The ACI scanner was found to be adequate for reliable data output while the label was found to cause most problems with ACI data accuracy. System costs are discussed with several considerations which, depending on the application, can minimize system cost. A number of effective applications of ACI are cited. In addition several reasons why system implementation has not proceeded as planned are discussed. Finally, recommended Department of Transportation actions are included.

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INTRODUCTION

In September 1971, the Transportation Systems Center (TSC) was tasked by the Federal Railroad Administration to evaluate the automatic car identification system (ACI) and recommend possible courses of action to improve the system. Some of the problems being experienced by the railroads with respect to ACI include: unlabeled cars, unacceptably low reliability of scanner output, expense of equipment, and mixed feelings about the value of ACI. TSC reviewed all industry literature on the subject of ACI and its applications. In addition, each of the two ACI manufacturers was visited and the operation and design of each system was studied; technical documentation was also obtained. A number of railroads were contacted for their direct experience with ACI. Key installations in Chicago and Peoria, Illinois, were visited and evaluated.

Early in the TSC study, it became clear that there were three interrelated parts to the evaluation: the ACI hardware, the ACI label, and ACI applications and utilization. Each was investigated by TSC and is included in this report. The interrelationship among the three items is important. They cannot be treated separately. Both the label and the hardware contribute to system reliability; the label and the problem of unlabeled cars significantly influence system utilization.

This report also presents a brief history of the development of ACI for the railroads during the 1960's and the current status of freight car labeling and scanner installations on the nation's railroads. It presents the conclusions which resulted from the TSC study: namely, that ACI scanner hardware is adequate for reliable data output while the label causes most problems with ACI data accuracy; and that 100% labeled freight cars, improved label maintenance procedures, and widespread implementation of well planned ACI systems are required on railroads in order to realize maximum benefit from ACI.

Detailed narrative to support the conclusions is included in the report. Each section is summarized for the convenience of the reader. A description of the ACI system and results of several railroad sponsored tests are a part of the report. System costs are discussed with several considerations which, depending on the application, can minimize system cost. The report also presents numerous system applications and several reasons why system implementation has not proceeded as planned. Several recommended Department of Transportation actions are also included.

BACKGROUND

The knowledge of freight car location is an important aspect of a railroad's ability to efficiently and profitably operate its business. Freight cars with a variety of owners and a variety of destinations make up a train entering a given yard. The pile of waybills which the conductor presents to the yard attendant is often the only information available to the yard in conducting its operation. Advanced consists are provided by some railroads, but are often subject to error. Partially because of this lack of accurate information, freight car utilization is low; and car movements are inefficient, error prone, and costly. A checker at trackside or in a yard tower records the car owner initial and number for comparison with the list of waybills received from the conductor. Identification reports are often subject to human error and poor weather conditions, and require trains to slow down to less than 5 mph.

In the early 1960's, the Association of American Railroads (AAR) and various equipment manufacturers studied and reported on a concept to automatically identify passing freight cars. The AAR developed performance specifications which were issued in 1966. The specifications called for equipment able to:

- Identify cars passing at speeds up to 80 mph

- Automatically capture data

- Process data for direct input to computer

- Operate from -60°F to 125°F

Three companies (Abex, WABCO, Sylvania) which developed equipment against these specifications were invited to install their systems for competitive field testing in Pennsylvania and Chicago in 1967. Of the three, the Sylvania system most nearly met the AAR specifications, and was subsequently designated as the AAR automatic car identification (ACI) system to be adopted by the industry.

The AAR approved automatic car identification system consisted of color coded retroreflective labels mounted on all rolling stock and trackside optical scanners. Each scanner emits white light from a xenon source which is swept over each label by means of a rotating mirror. Light from the red-blue-white-black label is received by red and blue filters and photo detectors. The signals are digitized and formatted by a decoder located in a hut within 1000' - 1500' of the scanner, and then

transmitted to a central computer or teletype for use in accurately identifying in near real time the owner and number of each car in a train. The disadvantages of manual checking - slow train speeds, data losses as a result of poor weather and human error, and labor costs -- are eliminated.

Labeling of the freight car, caboose, and locomotive fleet began during 1967 and several railroads began installing automatic car identification (ACI) scanners, mostly for test and evaluation purposes. These early systems were subjected to the usual debugging problems experienced with new equipment. Scanner reliability was not good; decoder logic problems were experienced; and electro-magnetic interference from the diesel locomotive traction motors caused system malfunctions. These problems were solved by the manufacturer, but still system implementation was slow. Labeling deadlines were set and reset by the AAR in order to get all 1.8 million freight cars labeled. ACI Systems Corporation was formed in October 1970 to supply scanner systems of Computer Identics Corporation design. WABCO was licensed by Sylvania to manufacture Sylvania designed systems, but it (WABCO) became disenchanted with the market and dropped out in January 1971.

CURRENT STATUS

The AAR performed a study during July, 1971 to evaluate the performance of ACI. In its sample, 92% of the freight cars were labeled. The Canadian fleet is reported to be 98% labeled.

The scanner system hardware problems have been solved and all systems already installed have been retrofitted. Two vendors now produce ACI systems: Sylvania, which is now named GTE Information Systems; and ACI Systems Corporation, which sells systems manufactured by Computer Identics Corporation.

Automatic car identification systems have been installed on some 26 railroads. As of October 1, 1971, some 145 scanners had been installed. A list of these scanners, compiled from an AAR survey and *Railway System Controls*, is shown in Table 1. This list is not considered to be exhaustive as some railroads do not report equipment installations. Approximately 10 additional scanners have been installed by rapid transit systems in Chicogo and Boston. The General Managers Association (GMA) of the Chicago Terminal hopes to install more than 100 scanners in 1972. *Railroad System Controls* projects installation of at least 150 scanners during 1972 in addition to the GMA scanners.

TABLE I. STATUS OF ACI INSTALLATION DECEMBER 1971

Scanners Installed by Year						
1966	1967	1968	1969	1970	1971	Total
2	4	3	30	33	73	145

Scanners Installed by Railroad		
Railroad	Scanners	Locations
Santa Fe	11	1
Bessemer and Lake Erie	1	1
Burlington Northern	9	5
Canadian National	21	8
Chesapeake and Ohio/Baltimore and Ohio	6	2
Canadian Pacific	4	2
Rock Island	1	1
Rio Grande	6	1
Duluth, Missabe, and Iron Range	5	5
Detroit and Toledo Shore Line	2	1
Detroit, Toledo, and Ironton	10	9
Elgin, Joliet, and Eastern	1	1
Florida East Coast	2	2
Illinois Central	15	5
Kansas City Southern	1	1
Louisville and Nashville	5	5
Lake Superior and Ishpemig	2	2
Missouri-Kansas-Texas	2	1
Missouri Pacific	5	1
Norfolk and Western	9	1
Penn Central	2	2
Peoria and Pekin Union	9	1
Seaboard Coast Line	3	1
Soo Line	1	1
Southern Pacific	2	2
Southern	7	1
Union Pacific	3	3

Source: AAR Report on Automatic Car Identification October 1971
Railway System Controls January 1971, January 1972

CONCLUSIONS

a. The ACI system is of basically sound design for operation in the railroad environment. The scanner/decoder system has an accuracy greater than 99%. Little maintenance is required.

b. The retroreflective label represents the major problem with ACI systems. Label problems, particularly misapplication and poor maintenance, and unlabeled cars limit usable data accuracy to 85-90%. No industry wide maintenance instructions yet exist for labels. Many of the invalid label readings experienced to date have been due to faulty application of the labels and a lack of periodic cleaning and maintenance of labels.

c. Data enhancement, the correction of advance consist data with ACI data, improves the usefulness of ACI even with labeling accuracy problems that exist today.

d. ACI is an effective tool for improving railroad operations. It can automatically provide timely and accurate data for keeping track of rolling stock, verifying train make-ups and interchanges, and improving car utilization.

e. There is a reluctance on the part of many railroads to install ACI scanning systems. Benefits are difficult to measure and capital is often not available for ACI. Some railroads want to wait until key installation projects have proven their worth.

f. ACI scanner installation has not proceeded as originally expected. One contributing factor is that the railroads in general have not committed themselves to compliance with the AAR's recommendations and guidelines.

SYSTEM DESIGN

SUMMARY

THE ACI SYSTEM HAS A DEMONSTRATED READING ACCURACY IN EXCESS OF 99% (99.7% AVERAGE OF 490,000 LABELS READ IN 6 TESTS: 97% MINIMUM AVERAGE IN ONE TEST). SYSTEM PERFORMANCE (SINCE REDESIGN AFTER EARLY RELIABILITY PROBLEMS) INDICATES THAT FURTHER HARDWARE MODIFICATIONS TO INCREASE THE READING ACCURACY ARE NOT WARRANTED. THE ACI LABEL REPRESENTS THE MOST SIGNIFICANT PROBLEM WITH ACI. TWO TO THREE TIMES MORE ERRORS RESULT FROM LABEL PROBLEMS THAN FROM HARDWARE DIFFICULTIES. SOLVING THE LABEL PROBLEM CAN RESULT IN A VERY USABLE ACI SYSTEM.

An ACI system consists of four components: (Figure 1)

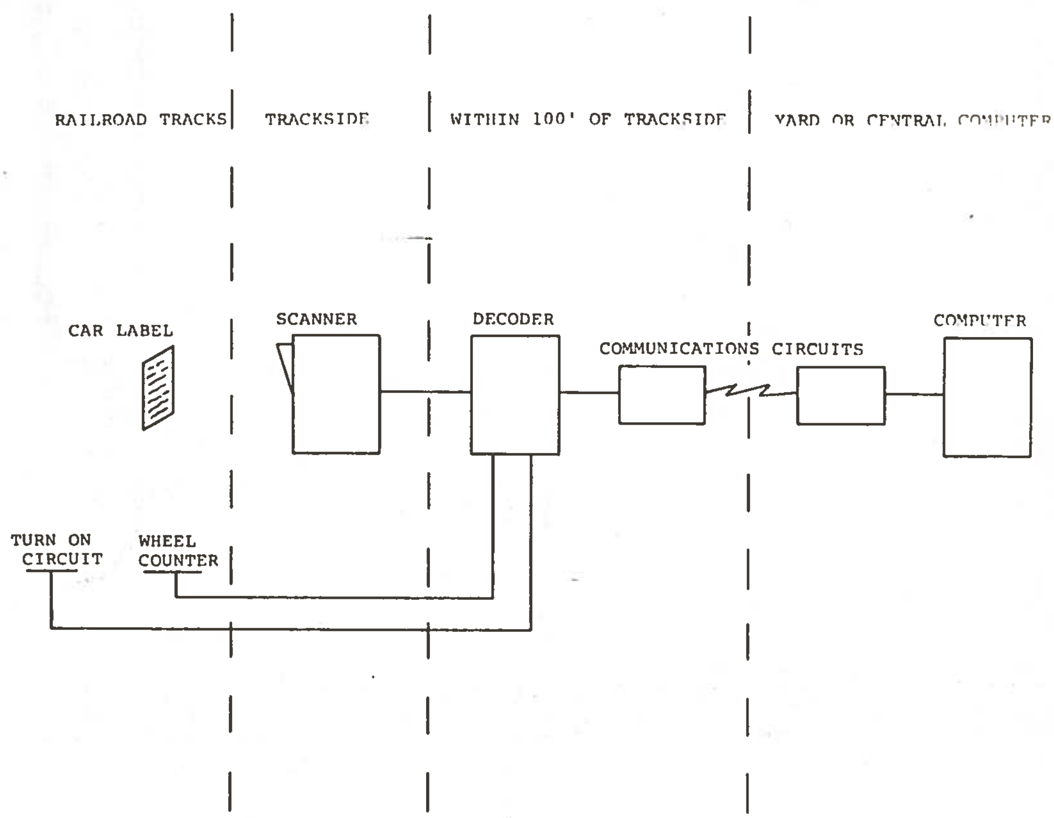

Figure 1. Automatic Car Identification System Diagram

a. red-blue-white-black colorcoded retroreflective labels mounted to the sides of rolling stock, locomotives, and piggyback trailers.

b. wheel detectors located on the track just before the location of the scanner and tied electrically to the scanner to note the existence of each car regardless of its label status

c. scanner hardware mounted on a pole near trackside to read labels of passing cars. Optical height is 9 feet with a depth of scan of 3 feet.

d. decoder located in an environmentally controlled hut within 1000 feet - 1500 feet of the scanner to convert the red and blue analog signals to a digital format suitable for transmission and computer input.

An ACI label, measuring approximately 10-1/2" X 22", consists of 13 Scotchlite label modules assembled vertically on a black background. These modules represent a start signal, equipment code, car initial (AAR owner code), car number, and a parity check signal.

The presence of a train is sensed by a turn-on device which causes the scanner lamp to be turned on. The wheel counter senses the presence of each car as it reaches the scanner. The scanner reads the label by means of a rotating mirror wheel which sends light from a xenon lamp to the label and receives the reflected light as the label is scanned vertically from bottom (start signal) to top (parity check). The reflected light is split with a dichroic mirror and then passes through red and blue filters to photo detectors. Both detectors are activated for white light; neither for black.

The analog red and blue signals are then transmitted to the decoder for amplification and conversion to digital signals. Additional formatting and parity calculations are performed before the signals are output to transmission lines for further data processing.

An ACI system is capable of reading labels on cars traveling at speeds up to 80 mph. While the label is 10-1/2" wide, only about 1/8" of label need be scanned for a valid reading. The mirror wheel spins such that one label may be scanned several times even at 80 mph. This offers a redundant capability of correcting erroneous readings. The wheel detector offers a key feature of the ACI system. It detects the presence of all cars in their order in the train regardless of the condition of the label (or the existence of a label). The feature of order is used to good advantage during data enhancement.

Technical problems were experienced with ACI systems during 1968-9, particularly in the reliability area. Extensive failure analysis and circuit design changes were made by the manufacturer. Since then, the 145 installed systems have performed well. GTE has stated that the ACI system exhibits a mean time between failure (MTBF) of 5000-8000 hours. While this figure has not been substantiated, no significant problems with system performance have been reported by the railroads.

The environmental operating characteristics of the systems are severe --- -50°F to 150°F (slightly different from original AAR specification) -- and "military specification" type environmental testing has been successfully performed on the system. Testing by Canadian Pacific in the winter of 1968-9 gave good system performance results under severe temperature conditions.

The system has been designed to require little preventive maintenance. The Xenon lamp must be replaced every 1200 hours and a timer has been provided to record hours of lamp operation. Most maintenance, preventive and corrective, is done on contract to the manufacturers. At least four railroads currently perform their own maintenance: Canadian National, Union Pacific, Southern Pacific, and Santa Fe. The manufacturers provide on-call 24 hours a day, 7 days a week maintenance plus periodic checks. Several maintenance aids have been provided. Built in test sets are standard on one manufacturer's system and available as an option on the other's. These test sets allow isolated testing to determine the point of malfunction in the decoder or scanner and to thoroughly check the entire operation during periodic checks of the system. A series of test labels is available to provide the inputs for these tests.

ACI ACCURACY TESTS

The system reading accuracy (ability to read good labels) is purported by the manufacturers to be in excess of 99%. Several railroads have conducted tests in ACI installations to determine scanning accuracy. The results of seven such tests over the period 1969-1971 were consolidated and are included in this report (Table 2).

The Duluth, Missabe, and Iron Range Railway (DMIR) has a 5 scanner installation near Duluth, Minnesota, for weigh-in-motion iron ore operations control. The DMIR conducted a test from April to July 1969 on 1500 cars which were individually checked for label correctness before the tests. The results showed a reading accuracy in excess of 99%. Another test during the same period read 9000 labeled cars and considering all errors had valid readings in excess of 99%.

The Missouri Pacific conducted tests - during 1969 with its 5 scanner set up at Dupo, Ill. About 95% of labeled cars were read correctly. The reading accuracy was slightly less than the previous tests noted above (97.6% vs 99+%).

The Canadian Pacific conducted a weigh-in motion test during the summer of 1970 in British Columbia with 4004 labeled cars. Overall accuracy during the test was 96.4%; only 0.85% of the errors were due to bad labels. Reading accuracy, thus, was 97.25%, the lowest of the seven tests. Certain system adjustment and software design changes were expected to increase overall accuracy to 98.5%, and reading to 99%+.

The AAR performed a test in Chicago in July 1971 and demonstrated overall valid reading accuracy of 93.82%. AAR analysis has shown that label problems account for most of the inaccuracy.

A Canadian National official reports an overall accuracy in 1971 tests with two scanners to be about 97%: 1% bad labels; 2% unknown.

TABLE 2. ACI TEST DATA

	5 Railroads 1969	DM&IR 1969	DM&IR 1969	Missouri Pacific 1969	Canadian Pacific 1969	AAR 1971	Canadian National 1971	TOTAL
#labels in sample[1]	120,189	57,653	238,603	13,803	4004	55,879	UNK	490,131 (col.1-6) (369942) (col.2-6)
#valid label readings[2]	UNK	57,589	238,555	12,976	3860	52,423	UNK	365,403 (col.2-6)
overall accuracy % 2÷1 3=1-2	UNK	99.89%	99.98%	94.008%	96.40%	93.82%	97.0%	98.77% (col.2-6)
#invalid readings 4	UNK	64	48	827	144	3456	UNK	4539 (col.2-6)
#bad labels 4÷1	UNK	0	0*	607	34	3190	UNK	3831 (col.2-6)
%bad labels 5=3-4	UNK	0%	0%	4.398%	0.85%	5.704%	1%	1.03% (col.2-6)

#reading errors
6=5÷1
	745	64	48*	220	110	266	UNK	1453 (col.1-6)

%reading error 100% -6	0.62%	0.11%	0.02%	1.594%	2.75%	0.476%	2%	0.3% (col.1-6)
%reading accuracy	99.38%	99.89%	99.98%	98.406%	97.25%	99.524%	98%	99.70% (col.1-6)
Source	AAR Data Sys. Div. report 1969 p.233	AAR DSD 1969 p.239	AAR DSD 1969 p.240	MoPac Dupo yards Apr. 1970 p.19	AAR DSD 1970 p.131	AAR test data	CN contact	

*only overall figures were given for this test. It was assumed that all errors were due to system reading error

From Data

Total labels read = greater than	490,131
Total overall accuracy 2÷1	98.77%
Min. overall accuracy	93.82%
Total reading accuracy 100%-(5÷1)	99.70%
Min. reading accuracy	97.25%

Conclusion

Bad labels are most significant ACI problem

LABELS

SUMMARY

FAR TOO MANY CARS (MORE THAN 5%) REMAIN UNLABELED IN THE UNITED STATES. OF THOSE CARS THAT ARE LABELED, SOME 2-5% CAUSE INVALID READINGS DUE TO DIRT, DAMAGE, AND MISAPPLICATION. NO INDUSTRY WIDE PROCEDURES OR GUIDELINES EXIST AT THIS TIME FOR LABEL MAINTENANCE. CONSEQUENTLY, THERE IS LITTLE MAINTENANCE OF LABELS. PROCEDURES EXIST FOR LABEL APPRICATION BUT APPARENTLY ARE NOT CAREFULLY FOLLOWED (1-2% OF ERRORS). UNLABELED CARS, DIRT, DAMAGE, AND MISAPPLICATION OF EXISTING LABELS ARE THE MOST SIGNIFICANT PROBLEMS WITH ACI. COMPLETION OF LABELING AND A VIGOROUS LABEL MAINTENANCE PROGRAM ARE NECESSARY FOR SUCCESSFUL ACI OPERATION.

The AAR test of ACI in July 1971 showed that 91.5% of freight cars in the sample were labeled. It is estimated that 95% of the fleet is labeled today; there is no forecast of when all cars will be labeled. The same AAR test indicated that of those 91.5% cars which were labeled, 6.2% did not read correctly. This gives only 85.3% usable data (8.5% unlabeled and 6.2% bad labels). AAR has been analyzing the data on those bad labels and indicates the following causes:

- excessive dirt 1.8%
- improper installation 2.3%
- missing or damaged 1.6%
- unknown cause .5%

In the 1969 Missouri Pacific test 50-65% of the cars were labeled. The most prevalent label problem (.912% of the 2.26% problems) was an incorrect validity check module on the label. Bad or missing label problems included misapplication (tilting, too low on car), physical damage, and incorrect modules. In one case, two adjacent cars had interchanged labels on one side - clearly a misapplication error.

In the Canadian Pacific (CP) 1970 tests, all cars were labeled. Only 0.85% had bad or missing labels. The Canadian National (CN) 1971 test resulted in 2% unlabeled cars and 1% bad labels. The other 2% invalid reads had an unknown cause. Both scanner errors and bad labels probably make up this 2%. It is interesting to note from these two tests that the Canadian railroads do not have as severe label problems in the U.S. railroads do. A higher percentage of cars are labeled and fewer bad labels occur on Canadian roads. These figures are indicative of the fact that the CN and CP take greater care in applying and maintaining labels than most U.S. roads.

A similar observation can be made about the Duluth, Missabe, and Iron Range (DM & IR). In its 1969 test, the DM & IR demonstrated 99.9% valid readings in some 238,000 readings of 9000 labeled cars. The lesson should be clear: if properly applied and maintained, ACI labels will give valid readings.

The 100% labeled iron ore fleet of the DM & IR contrasts with the rolling stock was observed in Chicago during the AAR test. Label problems alone accounted for 14.2% incorrect readings (8.5% unlabeled and 5.7% dirt-damage-misapplication). Only .5% of unknown cause might be attributable to scanner errors. Again it is clear that labeling the rest of the fleet and solving the maintenance/application problem will yield about 99% usable data from ACI.

Analysis of the label application procedures by TSC indicates the following. These is nothing inherently wrong with the material from which labels are made (i.e., 3M Scotchlite). If kept relatively clean, it can be expected in most cases to last five to ten years. However, no replacement cycle has been defined. Most labels for freight cars already in the fleet are made and applied by the railroads and are not subject to rigid quality control in either makeup or application of labels to freight cars. The AAR has published detailed procedures for making and applying labels. Apparently, however, the railroad personnel who do the work are not receiving or putting these procedures to work. Maintenance of labels is almost nonexistent. Simple cleaning of labels is rarely done. No industry wide procedures currently exist which describe the kinds and frequencies of performance of maintenance on labels although the AAR has such procedures in preparation.

All Scotchlite modules are covered with 3M Clear Coat #730, which is baked on at 280°F. The same coating may be applied to the entire label after modules are assembled, but this obviously can only be done in a controlled environment (280°F). Further, a fast air drying Scotchlite Edge Sealer #741 can be used to coat an entire label to extend its life.

This procedure of secondary coatings of the label (#730 and #741) can be used with new labels which are manufactured for a railroad; but only if a railroad has controlled label assembly facilities, can it use the coatings for new and replacement labels. 3M Bulletin #150 on Scotchlite maintenance should be consulted.

Two 3M Clear Coats (731 and #700) are available for the refurbishment and refinishing of existing labels. These Clear Coats are air dry coatings but must be dried for about 24 hours in a controlled environment. If not carefully controlled, the coatings may make label readability and longevity worse. For this reason, 3M does not recommend use of Clear Coat #731 and #700 unless a rigidly controlled environment is available.

Some railroads have noted the need for special, more rugged labels. For example, locomotives are washed at frequent intervals with harsh detergents which, in some cases, have required label replacement within nine months. Additionally, labels on some hopper cars which carry high temperature materials have been damaged or destroyed by spillage of these materials. The development of special labels for this type of application may be in order.

DATA ENHANCEMENT

SUMMARY

DATA ENHANCEMENT IMPROVES THE EFFECTIVENESS OF ACI BY CORRECTING ADVANCE CONSIST ERRORS WITH DATA FROM AN ACI LIST. IT REDUCES THE PRESENT IMPACT OF LABEL ERRORS AND WILL REDUCE THE EFFECT OF SCANNING SYSTEM ERRORS IN THE FUTURE. DATA ENHANCEMENT IS A NECESSARY STEP IN MAKING ACI USABLE FOR THE RAILROADS.

It has been pointed out that, due primarily to labeling problems only about 86% of ACI data from the AAR test was usable. Figures do not exist for the accuracy of manually prepared advanced consists. It seems likely, however, that due to reasons cited earlier - train speed, poor weather, human error - these lists are less accurate than most ACI lists. The prevalence of "lost" cars, misrouted cars, overbills, and no bills is indicative of the errors associated with manual identification. Normally, the errors on the ACI list are not the same as the errors on the manual consist. Further, the ACI output has two significant aspects: 1) every car is counted regardless of its label condition and 2) the exact order of the placement of cars in the train is noted. On the other hand, the advance consist has the owner, number, and destination for each car for which a waybill exists, again regardless of the car's label condition. The consist, however, may have errors in car order, number errors, and nobills/overbills.

In order to better utilize the ACI output and the advance consist, the concept of data enhancement was developed. The two train lists are matched and errors on one are corrected by data from the other. An 86% ACI output accuracy and 86% consist accuracy combine to give an overall train list accuracy in excess of 98%. Figure 2 is a plot showing the effect of data enhancement on data accuracy. For example, an unlabeled car appears on an ACI output (all zeros) between a Santa Fe car and a Burlington Northern car. The advance consist shows a Penn Central car between those two cars which cannot be found elsewhere on the ACI list. The Penn Central car is then assumed to be that unlabeled car and is input to the information center as such. By matchings of this type, unlabeled cars are identified, overbills are located and identified, clerical or reading errors can be corrected, and order errors on the consist and resulting train can be corrected.

Data enhancement can be performed manually as indicated above or, if a computer information system already exists on a railroad, can easily be done automatically. Regardless of how it is conducted, data enhancement is a powerful, and necessary tool in realizing useful results from ACI. It again points up the significance of the label problem. With an 86% consist and 86% ACI list (due to 8% unlabeled and 6% bad labeled cars), overall usable data accuracy is more than 98%. If all cars were labeled, the usable figure would rise to more than 99%. If most of the bad label problems were corrected and maintenance programs were established, usable data well in excess of 99% would result. On the other hand, eliminating all electronic error (a virtually impossible task for a reasonable price) would only raise the usable data percentage to near 99%.

It should be further noted that as advance consists become computer generated from a railroads information system with ACI as a primary input, consist accuracy will significantly improve. While bad label errors may carry through from consist to ACI list, electronic errors in a scanning system will be virtually eliminated by the use of data enhancement. This demonstrates the importance of solving the label problems which exist today.

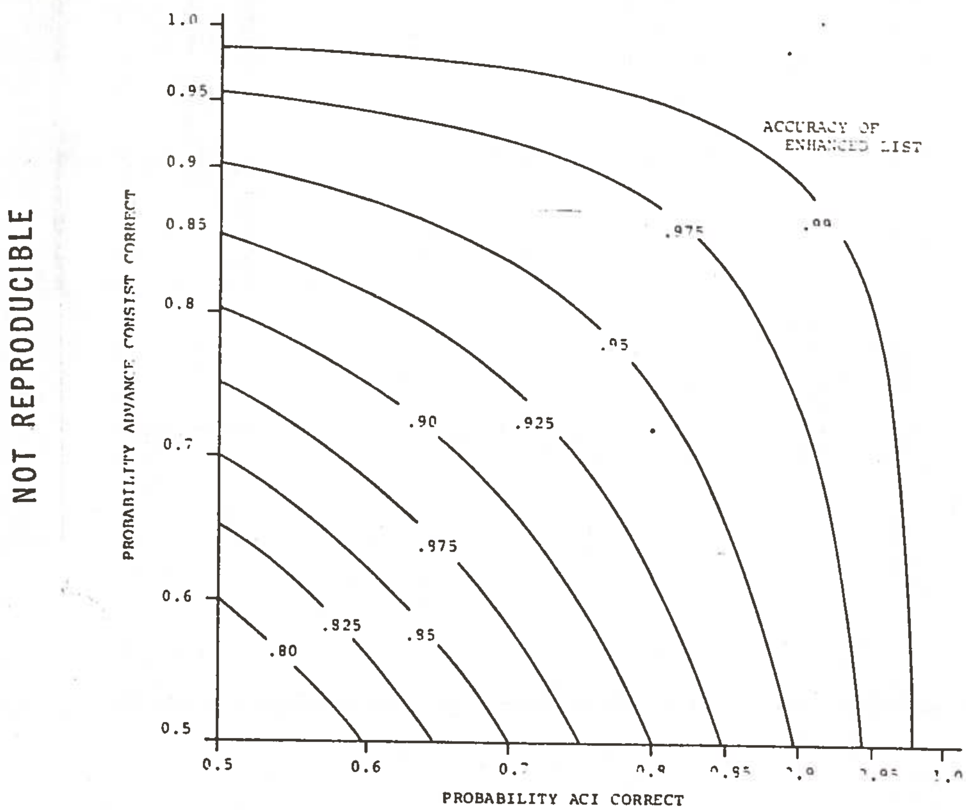

Figure 2. Enhanced Data List Probability

SYSTEM COST

SUMMARY

TOTAL COSTS AND SCANNER AVERAGE COST CAN BE MINIMIZED BY IMPLEMENTATION PLANNING, BY THE USE OF MULTISCANNER/DECODER OPERATION, AND BY PERFORMING AS MANY PROCESSING FUNCTIONS AS POSSIBLE ON A CENTRAL COMPUTER WHICH RECEIVES SCANNING SYSTEM OUTPUT. LEASING IS POPULAR BECAUSE OF THE CAPITAL STARVED FISCAL ENVIRONMENT IN THE RAILROADS. IN THE LONG RUN, PURCHASE IS MORE ECONOMICAL. AN EFFICIENT LABELING ACTIVITY ON A RAILROAD CAN MINIMIZE THE COST OF LABELING ITS FLEET. SYSTEM MAINTENANCE BY A RAILROAD MAY BE LESS EXPENSIVE THAN CONTRACT MAINTENANCE IF THE RAILROAD HAS AN APPROPRIATELY TRAINED LABOR FORCE AND PROPER LABOR AGREEMENTS.

TSC was asked to evaluate the costs of ACI system installations to determine if anything could be done to decrease the cost to the railroads. The two ACI manufacturers market systems which are competitively priced. It is difficult, however, to determine "average" costs because of the differences in system design. One manufacturer uses a programmable mini-computer as decoder while the other adds modules to the basic system to perform various functions. One manufacturer maintains published system price lists, while the other does not. A "typical" ACI system of one scanner, one decoder)with functions described below) costs about $24,000. This figure was determined by considering as nearly equivalent systems as possible and using all available data, as well as cooperation from both manufacturers. There is no attempt, however, to compare the costs or capabilities of the two systems. Each is an effective ACI system; it is up to individual railroads to choose the systems which most nearly meet their requirements.

While installation costs are included in the $24,000, site preparation and cabling are not. Site preparation costs average about $5,000 - $10,000. The GMA proposal to the FRA estimates about $7,000 per site for its 40 ACI sites.

GTE Information Systems reports that site preparation for a planned 9 scanner installation for the C&O/B&O in Chicago will cost (in a signed contract) about $3,000 per scanner including power but not communications requirements.

ACI System Corporation reports that a three scanner installation on the Indiana Harbor Belt Railroad cost about $3,000 per site preparation. However, trenching for cables and installation of track circuits were performed by the railroad. On a per scanner basis, the total site preparation for this installation was thus between $5,000 - $10,000.

The Canadian National Railway estimates site preparation to be upwards of $25,000. This was the case for example in a 5 scanner (plus minicomputer) installation at Edmonton. This cost includes communications, power, and certain administrative expenses. In the other examples cited above, communication costs and most costs to the railroads were not included.

Cabling costs from $1,00 to $2.00 per foot. This results in an additional ACI cost of $500 to $1,000 depending upon the location of the scanner relative to the decoder. This cost was included in the Canadian National example but not the C&O or Indiana Harbor Belt examples.

Several important factors which influence the ultimate cost of ACI site preparation are the availability of power, the availability of communications facilities, and the configuration (i.e., location) of the hardware to be installed. The tradeoffs of preparation and installation labor by contract or by the railroad itself should be considered. It may be that existing labor union contracts result in higher costs to the railroad than if the hardware manufacturer performs all the work. On the other hand, well trained railroad crews might save the railroad money in the preparation of ACI sites. The important point here is that the ACI project should be well planned from the beginning with the consideration of all alternatives to arrive at minimum cost. A compatible communication interface is part of an ACI system, although sometimes at additional cost. Communication lines and modems are normally leased. The cost of these communication systems depends on the data transmission rate required by the railroad. Generally, the higher the rate, the more expensive the system. With all low speed communication systems (about 150 baud or less), label storage with a memory buffer is necessary. Otherwise, train speed will be severely limited - to as little as 5 mph, and operating flexibility is decreased. For most applications, a buffer for 300-500 label storage is necessary. If medium to high speed transmission (600 baud or more) is provided and a buffered data processor receives the decoder outputs in real time, no buffer is required. Very often, the cost of communications can be minimized by using existing communications lines on the railroads. The type of lines and equipment available will thus dictate ACI design and cost.

If two or more scanners are to be used in one location (within 1,000 feet to 1,500 feet of the decoder hut), multi-scanner operation with one or more decoders may be possible and may result in a reduction in average cost per scanner. The ACI manufacturers have different design approaches to multiple scanner installations. One multiplexes up to 6 scanners per decoder, the other switches scanners among idle decoders. Trade-offs involving equipment redundancy and simultaneous train movements should be considered in planning the system configuration. Decoder failure has wider implications with multiple scanners. While this has not been a problem with multiple installations to date, it may be an important factor to consider in very remote installations and/or heavily traveled areas. Simultaneous movement of trains past several scanners feeding one decoder cannot be detected with the switched system. This may be a problem in system implementation planning. Prime considerations are the number and frequency of such movements. If the probability of simultaneous moves is low and if slight train delays are permissable, multiple scanner operation may be acceptable with the switched system. Reduction in average cost per scanner in multiple operations, in either case, can be significant.

It is good practice to perform as many functions of data processing as possible on a centralized computer system (central to the scanner -- not meant to imply the main computer of the railroad's operation) which receives ACI decoder outputs either in real time or after a train has past. For example, the carrier index feature provides conversion of the numberical code for each car owner to the alphabetic initial code for that owner. This feature, which costs $4,500-5,000 for additional memory buffers, is not necessary if further data processing is being performed and can easily be done by the central computer.

A typical ACI installation, whether stand alone or multiple operation, should include:

- scanner or scanners
- device to turn on ACI system
- wheel counter to detect presence of car
- message generator to provide date, time, scanner header data
- calendar clock to generate date, time
- buffer for 300-500 labels
- compatible communications interface

- TOFC formatting control

- train reverse detection.

The functions of TOFC formatting control and train reversal detection may be included in the ACI or in the central computer. All other data manipulation functions should be performed by the computer. Use of the buffer is determined as described above.

Many railroads lease scanning systems from the manufacturers in order to reduce capital outlays during a period. Leasing normally costs 3-5% of the purchase price per month including maintenance and parts. In periods of capital shortages such as exist today, leasing may well be necessary. This would also be available for situations in which ultimate scanner configuration is not defined. In the long run, purchase is more economical. As a minimum, lease arrangements with option to buy with charges prorated toward the purchase should be investigated.

Labels are not expensive in terms of cost to a railroad which is labeling its own fleet of cars. Materials for a label cost either $1.24 (label applied to car) or $2.62 (label plate or bracket included). Label assembly and application are not difficult -- several labels can be applied per hour. One manufacturer assembles labels at a rate of 20 per hour. Application consists of positioning and surface preparation before the plate is applied with 6 rivets or the label is applied directly to the car with the adhesive reverse side of the label.

The AAR Car Repair Billing Manual lists labor charges for initial application of a label to a previously unlabeled car. These rates are used in billing the owning railroad for labeling service rendered by another railroad. For applying labels to both sides of a car, charges are $15.13 for direct application and $18.35 with a plate. These labor charges do not appear to be in line with the difficulty of the job being performed. In other words, a railroad with an efficient labeling activity can make a profit by labeling cars owned by other railroads. This in fact has been done with much success by several railroads including the Burlington Northern, the Canadian National, and the Peoria and Pekin Union. This practice has undoubtedly acted as an incentive to the labeling of cars. The lesson to railroads should be clear: they should label their own cars at cost instead of paying another railroad to label them at Car Repair charges.

System maintenance contracts for 24 hour a day, 7 days a week maintenance cost 1% - 1 1/2% of purchase price per month. This cost includes spares and test equipment and does not apply when systems are leased. Decisions on maintenance should be carefully weighed. Depending on labor work rules and agreements, it may be less expensive for a railroad to buy spares and test equipment and perform its own maintenance. On the other hand, contract maintenance is fixed in cost and is not subject to renegotiated union contracts. Training and experience of railroad personnel must also be considered in determining the ultimate cost of contract versus railroad maintenance.

EFFECTIVENESS OF ACI

SUMMARY

ACI IS AN EFFECTIVE TOOL FOR RAILROAD USE IN KEEPING TRACK OF ROLLING STOCK AND IMPROVING CAR UTILIZATION. ACI DATA CAN BE USED TO IMPROVE THE EFFICIENCY OF YARD OPERATIONS BY REDUCING DELAYS, ELIMINATING ERRORS, AND VERIFYING AND PREPARING ADVANCED CONSISTS AND SWITCH LISTS. ACI CAN BE USED TO AUTOMATE WEIGHT-IN-MOTION OPERATIONS THUS REDUCING ADMINISTRATIVE COSTS. THE OVERALL EFFECT OF ACI, WHEN USED WITH RAILROAD INFORMATION SYSTEMS, IS AN IMPROVEMENT IN CAR UTILIZATION WHICH RESULTS FROM FASTER MORE ACCURATE CAR MOVEMENTS, AND ACCURATE AND TIMELY CAR LOCATION INFORMATION. THE ULTIMATE RESULT OF ACI IMPLEMENTATION IS FASTER AND MORE RELIABLE SERVICE TO SHIPPERS.

The concept of ACI is a sound one. Several well-planned installations to be described below have demonstrated significant benefits to railroad operations. ACI is best applied as an input to a railroad's information system (rather than in a stand alone configuration as has been the case with many installations which are for test and evaluation purposes only). The data from ACI are used to keep track of rolling stock on a rail system; to verify the makeup of trains and generate accurate, timely advance consists; to prepare switch lists; to verify humping activities in a yard; to verify car interchange with other railroad; and, as a result of all of the above, to improve freight car utilization and decrease administrative labor requirements. The strength of ACI is in the accurate and timely data it provides concerning the owner and number identifying each freight car.

In yards and terminals, ACI can make a significant contribution to improved operations. The main functions of a yard are to receive, classify, and then forward freight cars. Accurate identification of cars in order to verify these actions is obviously necessary. ACI provides the data used to verify the makeup of an arriving train; to verify the humping, switching, and classification activities; and to verify the makeup of a departing train. The latter verification also gives the yard the ability to supply an accurate advance consist to the destination of the train. All of these identifications are

performed automatically and allow administrative labor reductions. For some of these activities, ACI directly replaces a clerk. The savings are, thus, readily calculated and the task of selling ACI to the railroads, for this function, has been quite straightforward. The Peoria and Pekin Union Railway (P&PU) installed 9 scanners in its Peoria, Illinois, yard and immediately eliminated 12 clerks at a savings of about $10,000 per month.

Even if labor is not reduced by ACI, it can be more efficiently utilized. Accurate advance consists prepared from ACI allow a yard to plan in advance the activities it needs to perform. For example, if it knows that a 100 car train with cars for varying destinations will be arriving in about 2 hours (ACI provides the time of scan and location of scanners), then switch engines and crews can be ready, can have a prepared switch list, and can begin classification as soon as the train arrives. This improves operating efficiency, allows better manpower and motive power allocations, and can reduce delays experienced in yards. The GMA Project in Chicago, for example, is expected to reduce transit time through the Chicago terminal by at least 2 hours. This would equal a savings to the Chicago railroads of more than $2,500,000 each year. The Argentine yard in Kansas City has 11 scanners which contribute to a 50% throughtime reduction.

When ACI data are used in conjunction with an information system, car location information and eventually improved car utilization result. Fewer cars are lost or misrouted; fewer delays through a yard exist. Reliability and speed of service are improved. The GMA Project purports that it will improve car utilization by at least 3,975 cars per year. Thus better service can be offered to shippers.

In addition to the P&PU, GMA, and Argentine ACI installations, there are several other noteworthy yard ACI installations. The Calgary, Alberta yard of the Canadian Pacific is in the final phase of a 10 scanner implementation. One of the 10 scanners is located on the hump for use in automatic humping and classification. A local yard minicomputer controls the entire operation. The Missouri Pacific yard in Dupo, Illinois, has 5 scanners and a yard computer to capture in- and out-bound movements. The Burlington Northern ties 3 scanners into its computerized Pasco, Washington yard development.

Another important application of ACI is in the automation of weigh-in-motion scales used in mining operations. Scanners provide train makeup to the computer; tare weights (empty car weight) are retrieved from memory; the cars are scanned as they go over the scale and the weights are recorded with the cars' identification. Billing costs can be automatically produced from these data. The Duluth, Missabe, and Iron Range Railway

has a 5 scanner mining operation; the Penn Central and Illinois Central railroads each have a 2 scanner operation in midwestern coal mines. The Canadian Pacific has 1 scanner in a weigh-in-motion coal operation in British Columbia.

Another effective application of ACI is in monitoring the interchange between two railroads. The equipment can be jointly used thus saving each railroad money, and the scanner can be tied into a computer which will generate per diem charges since the time of scan and car identification are determined by ACI. The Canadian roads have such an operation in the Parsley Yard in Montreal. Two scanners and a minicomputer monitor the interchanges between the Canadian National and the Canadian Pacific. The two railroads are currently working on the development of joint use interchange procedures and documents. This cooperation will result in reduced administrative costs for the two roads. The GMA Project mentioned above will feature joint use equipment and will monitor, and help speed up interchanges among the 30 railroads in Chicago.

RELUCTANCE TO INSTALL ACI

SUMMARY

ACI IMPLEMENTATION HAS BEEN SLOWER THAN ORIGINALLY ANTICIPATED. MANY RAILROADS ARE RELUCTANT TO INSTALL ACI BECAUSE THE BENEFITS ARE HARD TO MEASURE AND BECAUSE ACI MUST COMPETE WITH OTHER HIGHER PRIORITY DEMANDS FOR CAPITAL. A NUMBER OF RAILROADS WANT TO WAIT FOR TOTAL FLEET LABELING AND THE RESULTS OF SEVERAL PROJECTS AND STUDIES BEFORE COMMITTING THEMSELVES TO INSTALLATION OF ACI. WHILE THE AAR HAS ISSUED ACI LABEL GUIDELINES AND RECOMMENDATIONS, TOO FEW RAILROADS HAVE MADE THE NECESSARY COMMITMENT TO INSTALL ACI.

Even though more than 92% of all freight cars are labeled, there is a reluctance on the part of many railroads to install ACI scanning and decoder systems. Several of the 26 railroads who have installed scanners did so only to evaluate its performance before making a commitment to operational implementation. For example, the Kansas City Southern, the Bessemer and Lake Erie, and the Soo have one scanner each for test; the Southern has four under test. It is appropriate to consider some of the reasons for the reluctance of many railroads to implement ACI.

The railroads find it difficult to measure the benefits of ACI. Increased car utilization, improved service to customers, and the relief of car shortages are "intangible" benefits which may affect later revenues and profits but which, the railroads say, have uncertain immediate value. It is extremely difficult to make general statements about the costs to shippers of unpredictable delivery times. ACI allows better yard planning and more efficient yard operations, but it is difficult to determine, in dollars, the before and after effects of ACI.

The costs incurred by a railroad in correcting erroneous data or in misrouting a car are difficult to measure. Cost saving, usually in labor, is the key element in justifying ACI; yet most benefits of ACI are beyond the reduction in labor savings.

Furthermore, many of the labor savings that the ACI system was expected to achieve were never realized. The explanation is

as follows: When ACI was conceived about 1960, there were a large number of clerks engaged in recording car numbers because very little car data was transmitted from yard to yard. ACI was supposed to replace these clerks. However, since 1960, the railroads have moved toward the adoption of information systems which capture car owner and number only once and which transmit that data from yard to yard as the car moves. These information systems have already greatly reduced the requirement for manual checking and concomitantly, the labor savings anticipated from ACI.

Because of the precarious fiscal balance of many railroads in the industry, there is reluctance to invest in new systems unless direct cost savings can be easily demonstrated. There is a shortage of capital and ACI must compete with other demands for funds. In most investment choice cases, the return on investment can be more easily calculated than that for ACI. The *potential* for new business or new revenue, for better service, and for improved equipment utilization does not sell in a cost oriented, cash poor environment. Consequently, funds are applied to buying new equipment, new track, etc. at the expense of ACI.

As a result of the hard to measure benefits of ACI, there is a "wait and see" attitude on the part of many railroads with respect to ACI implementation. Some believe that until 100% of the fleet is labeled, ACI will be of no value and that ACI implementation for their railroad will be deferred until all cars have been labeled. A concerted effort has been made to label the 1.8 million freight cars in the country. Deadlines for labeling have been imposed, and rules were instituted by which a railroad could label a car and charge its owner a fee for the service. This was a revenue source for some small roads and aided the acceptance of labeling. As pointed out earlier, all cars are not labeled, and without incentives to install ACI scanners, some railroads want to wait for 100% labeling. This waiting is self-defeating in that widespread implementation of ACI would tend to force the completion of the labeling. The important point is that ACI has been proven to be useful even with 85 - 90% useable data. The efforts to complete labeling and to implement scanners should proceed in parallel: the more scanners, the more cars that will be labeled; the more cars that are labeled, the more useful the ACI data.

Some railroads want to wait for the completion and results of certain studies and projects before proceeding with ACI implementation. For example, the General Managers Association in Chicago will install 109 scanners at 40 sites around the Chicago terminal. This project will significantly increase the number of installed scanners. The GMA has performed detailed calculations of the benefits to be derived which show reduced delay times, improved car utilization, and cost savings noted

earlier. The industry will be carefully watching this project to see if the railroads in Chicago reap the benefits purported due to ACI.

The AAR has just undertaken a study of the feasibility and design of a national freight car control system. The study will include an evaluation of ACI and its possible role in a future control system. Some railroads are saying that ACI implementation should be deferred until the study task force has made a judgement on ACI. It is important to note ACI is an input device capable of increasing their efficiency immediately even if a national control system is not implemented.

The following railroad departments are involved in ACI with different interests and responsibilities:

Operations - ACI user. Provides funding and clerical labor.

Communications & Signals - In charge of installation and maintenance of scanners, decoders, and communications equipment

Mechanical - In charge of label application and maintenance.

Data Systems - Operates computer, programs ACI data processing, performs data enhancement.

In each department, there are independent objectives, politics, and historic roles and relationships. However, it is the overall railroad operations that most benefit from ACI. While the Operations department may try to impress the importance of label maintenance upon the Mechanical department, Operations is not in a position to see that the maintenance really is performed. Further, if Mechanical activities must be oriented toward reducing costs, then label maintenance may be glossed over.

As pointed out earlier, less complex and less expensive ACI systems can be implemented if processing functions can be performed on a central computer. Railroads with few if any computer/communications facilities are reluctant to implement ACI because of the added expense for communications and computer facilities.

The Association of American Railroads has been the driving force behind ACI since the early days of its development. It defined and issued specifications for scanner/decoder performance, communication interface equipment, and even was a force in the

development of the IBM telecommunication system. The AAR has issued and revised detailed label application procedures and has in preparation label maintenance procedures. The AAR has performed the July 1971 ACI test and the October 1971 study of railroad commitment to ACI.

The AAR is a voluntary association of some 65 railroads which meets to discuss and perform research on problems of concern to all. The AAR set deadlines for label application and set Car Repair charges for label billing. The October 1971 AAR study of ACI recommends a continued industry commitment to ACI. This recommendation has been presented to and approved by the AAR Board of Directors. Unfortunately, too few railroads, for the reasons cited above, have made that commitment. The AAR, with DOT help, is likely to continue its ACI recommendation and guideline issuances. In addition, an education process should be undertaken to assure that each railroad is aware of the benefits to be derived from ACI.

RECOMMENDATIONS

It is recommended that the Department of Transportation issue a positive statement of Federal support to the implementation of ACI by the railroads. The statement could be simply the public issuance of this report or a part thereof.

It is recommended that the Department of Transportation assist the AAR wherever possible in publicizing the various applications and benefits which are expected of ACI, as well as publicizing the current problems, the possible solutions, and the importance of the individual railroad in the success of ACI. In particular, it is recommended that the importance of label maintenance be stressed at the appropriate levels of the railroad organization.

It is recommended that the Transportation Systems Center undertake the following research and development for the Federal Railroad Administration in support of the above recommendations:

a. Investigate the technique of threshold detection in ACI hardware to flag bad labels or deteriorating labels which require cleaning, replacement, or other maintenance.

b. Identify quantitatively the economic benefits of ACI, particularly the "intangible" benefits of costs to shippers, improved service, etc.

c. Analyze the entire label maintenance program and recommend (and/or demonstrate) maintenance improvements. Investigate improved information dissemination or personnel training which might result in improved label maintenance and label application techniques. Investigate possible label coatings which could be used during maintenance to extend label life. Investigate possible special purpose labels for extreme operational environmental conditions.