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TRANSIT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Transit Administration

Training for On-Board Bus Electronics

A Synthesis of Transit Practice

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of vice configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at anytime. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end-users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

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NOTICE

The project that is the subject of this report was a part of the Transit Cooperative Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the project concerned is appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Special Notice

The Transportation Research Board, the Transit Development Corporation, the National Research Council, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project report.

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PREFACE

A vast storehouse of information exists on many subjects of concern to the transit industry. This information has resulted from research and from the successful application of solutions to problems by individuals or organizations. There is a continuing need to provide a systematic means for compiling this information and making it available to the entire transit community in a usable format. The Transit Cooperative Research Program includes a synthesis series designed to search for and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in subject areas of concern to the transit industry.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to senior managers charged with procuring, implementing, operating, and maintaining on-board electrical and electronic (E/E) equipment and systems. The purpose is to document training practices at a sampling of transit agencies concerning the application and repair of advanced on-board electronics so that key personnel have the knowledge needed to make informed decisions. Synthesis results indicated that senior managers with a commitment to provide employee training are behind the successful implementation of advanced electronic technology. The objectives of the synthesis were to examine the level of E/E training being provided by transit agencies to highlight innovative and effective training approaches and, based on findings from the conclusions, to provide agencies with the opportunity to improve their training programs. Because maintenance is an area that is often overlooked, this synthesis gives it the greatest focus.

Administrators, practitioners, and researchers are continually faced with issues or problems on which there is much information, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered or not readily available in the literature, and, as a consequence, in seeking solutions, full information on what has been learned about an issue or problem is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the issue or problem. In an effort to correct this situation, the Transit Cooperative Research Program (TCRP) Synthesis Project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit issues and problems and synthesizing available information. The synthesis reports from this endeavor constitute a TCRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to a specific problem or closely related issues.

This document from the Transportation Research Board integrates information from a search of available literature with survey responses obtained from key staff at 25 transit agencies across the country. Telephone follow-up calls were made to respondents. Telephone interviews were held with other agencies, training institutions, and equipment suppliers with E/E training experience. Site visits to collect case study information were made to Dallas Area Rapid Transit (DART) and New Jersey Transit (NJT) because of their noteworthy training programs administered in different labor environments.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, available information was assembled from numerous sources, including a number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

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This study was managed by Donna L. Vlasak, Senior Program Officer, who worked with the consultant, the Topic Panel, and the J-7 project committee in the development and review of the report. Assistance in Topic Panel selection and project scope development was provided by Jon Williams, Manager, Synthesis Studies. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Christopher W. Jenks, Manager, Transit Cooperative Research Program, assisted TCRP staff in project review.

Information on current practice was provided by many transit agencies. Their cooperation and assistance was most helpful.

TRAINING FOR ON-BOARD BUS ELECTRONICS

SUMMARY

This synthesis of current practice documents the procedures and resources used by transit agencies to provide employee training on advanced on-board electrical and electronic (E/E) equipment and systems. The study is intended for senior managers charged with procuring, implementing, operating, and maintaining on-board E/E equipment, with the primary focus given to maintenance training. The topic of advanced on-board electronics cuts across multiple agency departments, making it essential that a wide range of management personnel have the knowledge needed to make informed decisions. To determine if key agency personnel have that knowledge, a series of tests is included in Appendix D. Test questions were compiled from information obtained through the study.

Data used to document training practices were obtained through a literature search, a survey questionnaire, and site visits made to New Jersey Transit (NJT) and Dallas Area Rapid Transit (DART). The survey responses represent the experiences of 25 transit agencies with a combined fleet of over 14,400 buses maintained by over 5,500 mechanics. Site visits were made to NJT and DART because of their noteworthy training programs administered in different labor environments. Whereas DART only employs mechanics with degrees from accredited vocational schools and community colleges, NJT must hire all maintenance personnel as entry-level cleaners before advancing them to mechanical positions. Both agencies provide extensive E/E training to all mechanics and tie job and wage advancement to the successful completion of that training.

The proliferation of on-board E/E equipment is changing the way agencies provide bus service and the manner in which passengers use that service. Benefits offered by this technology were not imaginable just a few years ago when buses were a great deal simpler. Electronics affect virtually every area of the bus from engines, transmissions, and brakes to passenger information and comfort systems such as Automatic Vehicle Location, heating and air conditioning, destination signs, and fare collection. Developments in 42-volt electrical systems, electronic dashboards, and hybrid-electric and fuel cell propulsion systems will add even greater benefits. Although the proliferation of electronics has greatly enhanced the capabilities and benefits of such systems, it has also introduced a new level of complexity. Unless a new level of skill and knowledge is acquired to address this complexity, the full range of benefits made possible by this technology will not be realized. Furthermore, agencies risk wasting significant amounts of money on equipment that does not function as intended and risk embarrassment if they are not prepared to join with other transportation modes to help create a comprehensive intelligent transportation system (ITS).

When it comes to improving the understanding of E/E technologies, the study finds that the quality of training is essential. Without the appropriate level of professionalism, training can easily become an exercise in futility. To be effective, E/E training programs are developed and taught by skilled professionals who understand proven educational principles as well as bus transportation. Agencies with successful training programs use lesson plans with stated objectives and a list of required training materials, a mix of classroom and

hands-on instruction, tests and procedures to ensure that skills have been imparted and that the training was useful, and other essential elements. Supplemental training programs offered by equipment suppliers, professional organizations, and educational institutions are also used to enhance an agency's in-house programs. Additionally, many agencies include training as a requirement of new vehicle and equipment procurements as an effective way in which to use capital funding to provide E/E training.

According to the survey results, senior managers could benefit from having an improved understanding of E/E technologies for several important reasons. Improved knowledge in these matters allows them to comprehend the full level of resources and funding needed to support agency-wide training, to provide effective project oversight and long-range planning assistance, and to participate in nationwide efforts to promote the use of standardization. Survey results indicate several areas where upper management could play a significant role in developing and promoting industry-wide acceptance of standards, such as those pertaining to

- On-board data communication protocols,
- A single operator interface (e.g., a keypad) to control multiple on-board E/E systems by operators, and
- A central data point for diagnosing multiple on-board E/E systems.

The study finds that senior managers could also benefit from having a better understanding of the "maintenance free" concept. Although sophisticated E/E equipment does not require maintenance in the form of periodic adjustments, the equipment *can* malfunction over time and therefore requires the services of skilled technicians. One survey respondent in particular expressed great frustration that the agency's general manager continually denied requests for the additional training needed to repair E/E equipment because the vendor said the equipment was "maintenance free." Improved knowledge of E/E technologies also benefits senior management in that the equipment can provide them with new sources of data to help them manage their operations and vehicles more efficiently.

The study also reveals that bus operators and their supervisors could benefit from additional E/E training. In addition to operating the equipment properly to maximize its full potential and minimize potential distractions while driving, having a more thorough understanding of the equipment's functionality and related terminology can assist maintenance personnel with fault diagnosis. Most agencies use the train-the-trainer approach, where agency instructors who have received training from manufacturers then provide similar training to bus operators. Some agencies videotape the manufacturer-provided training to assist with their own training programs. Additionally, training aids that include fully functional equipment contained in a classroom display (e.g., training mock-ups) are used to facilitate operator training. Manuals that document procedures were found to be useful in that they provide a convenient reference for operators who need to periodically renew their understanding of the equipment they operate.

Survey results indicate that maintenance personnel seek additional training to enhance their E/E knowledge and skills. Much of the equipment they are required to work on is extremely sophisticated. In many cases the equipment is an offshoot of aerospace technology and requires the use of personal computers and other electronic tools to diagnose, repair, calibrate, and program. Although supplemental training is available from outside sources, the complexity of the equipment is such that it requires a comprehensive training approach. Although agencies such as NJT and DART, the two case studies used in this synthesis, have the necessary resources to develop a professional in-house program and combine it with outside training to impart needed skills, many agencies do not.

E/E training assistance is available through several sources including industry publications, knowledgeable agency staff members, existing in-house training programs, equipment manufacturers and suppliers, and courses offered by the FTA, National Transit Institute, and others. FTA's Outreach Training Program specifically targets agencies needing assistance with applying ITS standards when implementing E/E technologies, whereas FTA's Peer-to-Peer Program provides agencies with short-term assistance to address specific ITS issues. In addition to material that specifically addresses E/E subjects, there are several organizations and publications that provide information on the overall subject of education and training. For example, the Instructional Systems Development Model used by educators is a five-part process that strives to ensure that the instruction provided actually meets students' needs. A separate listing of reference material on training sources for both E/E and educational-related subjects is provided at the conclusion of this report.

Based on the findings, the study indicates that transit management and the entire transit community should accelerate their efforts to improve training programs for all employees who interact with E/E equipment. The study also indicates that management and industry leaders should adopt standards in three areas: (1) on-board data communication; (2) a single operator interface (e.g., a keypad) to initialize multiple on-board systems such as fare collection, destination signs, Advanced Vehicle Location, etc.; and (3) a central location for obtaining diagnostic and other essential on-board data.

In particular, it is indicated that a concept to establish training centers for maintenance personnel on a statewide level should be adopted nationally. These centers would use the instructors, curriculum, and extensive training aids already in place at several agencies throughout the country with comprehensive E/E training programs. In addition to eliminating the duplication of vast resources required by each agency, the use of regional training centers would ensure that maintenance personnel from agencies throughout the country would receive, in a systematic and standardized manner, the advanced skills needed to repair advanced E/E equipment.

CHAPTER ONE

INTRODUCTION

BACKGROUND

With the worldwide expenditures for automotive electronics forecasted to rise nearly 7% annually to $98 billion in 2005 (*1*), electronics is fast becoming the new buzzword in public transportation. Next to "alternative fuels," no two words used in connection with buses generate as much emotion among industry professionals as "new electronics" (*2*). This heightened emotion stems from the many exciting possibilities and immense challenges presented by a technology that affects virtually every on-board bus system. Without question, the application of electronics is rapidly changing the way transit agencies operate buses and how passengers use them to travel.

The need to keep pace with advances in electronics through training cannot be overstated. Lack of a skilled work force to procure, implement, operate, maintain, and manage the data generated from this equipment will greatly undermine the potential benefits made possible by this increasingly complex technology. These are the very advantages that bus transit needs if it is to complement other forms of transportation, especially the passenger automobile.

A decade ago, bus electrical systems were simple and the application of solid-state electronics extremely limited. A major attraction of the diesel engine over gasoline for bus applications was its ability to sustain the combustion process without the need for electrical assistance. Whereas gasoline engines need an electric "spark" to ignite the air/fuel mixture for combustion, a diesel engine relies on its own internal heat and the characteristics of the fuel itself to provide the ignition source.

As a result of the simplified electrical systems, training was directed to the numerous mechanical, pneumatic, and hydraulic systems that once dominated bus technology. Until recently, electrical repairs were primarily confined to tracing the interruption of battery power in the vast number of hard-wired circuits that circumnavigated the bus from one end to the other. The diagnostic tool of choice was a simple and relatively crude instrument called the "test lamp." Its pointed metal end is physically inserted through the wire's protective insulation to illuminate a small lamp within the tool to determine if battery current is present in the underlying conductor. This diagnostic procedure is simple and requires little skill.

INCREASED COMPLEXITY REQUIRES NEW SKILLS

Today, the diesel engine continues to be self-igniting, but requires sophisticated electronics to monitor a host of operating conditions and to precisely control fuel delivery for optimum efficiency and minimal exhaust emissions. Furthermore, engines powered by natural gas require electronic ignition systems similar to those found in gasoline engines, while hybrid and fuel cell propulsion technologies have adopted even more complex uses of electronics. Beyond the propulsion system, electronics have become an integral part of virtually every bus system, including the transmission, brakes, climate control, vehicle location, fare collection, passenger counters, destination signs, lighting, and stop annunciators. Additionally, the traditional "hard-wired" electrical system with electromechanical relays to control on/off-type functions has been replaced with an electronically controlled multiplexing system.

In the next generation electrical system, buses and other vehicles will move to a 42-volt system that will greatly affect maintenance personnel (*3*). Being hailed by some as the "second electrical revolution for vehicles," the move to a 42-volt electrical system is expected within the next 5 years (*4*). Electronic dashboards where operator controls, instruments, and displays function electronically and generate even more data will only add to the complexity. The enhanced skills needed to maintain and repair these advanced E/E technologies have resulted in a scarcity of qualified technicians, causing many of the leading vehicle and equipment manufacturers to place a greater emphasis on training. According to a leading engine manufacturer, "the skill set is quite different today . . . it's not wrenches and grease anymore, it's computers and high-tech analysis" (*5*).

The high-technology analysis inherent with sophisticated on-board electronics brings with it a new set of skills for technicians; skills that were not required with mechanical-based systems. Using traditional tools such as a mechanic's test lamp to diagnose sophisticated electrical and electronic (E/E) systems can cause extensive and expensive damage. The test lamp has been replaced with multipurpose electronic tools such as multi-meters, laptop computers, vendor-specific electronic diagnostic tools, and a range of software programs. Although the tools more accurately measure E/E conditions, they require a new set of skills to operate.

Unlike other technologies, the introduction of advanced electronics brings with it a requirement for specific skills that cannot be avoided. For example, transit agencies that "send out" certain work such as the rebuilding of engines and transmissions to outside vendors no longer have that option when troubles arise with advanced E/E systems, such as multiplexing and Automatic Vehicle Location (AVL). The many components that make up these systems are distributed throughout the vehicle, making them impractical to remove and send out. Although the repair of this equipment could be contracted to a vendor who works on site, there are too many components affected by electronics for an agency not to have the skills needed to diagnose and repair this equipment.

As with other forms of transportation, bus personnel will need to acquire the necessary skills to deal with the onslaught of advanced E/E equipment. Because the application of electronics is relatively new and somewhat unique to buses, these skills must be acquired through training. In the larger automobile and heavy-duty trucking industries, where annual vehicle sales average approximately 15 million and 200,000 units, respectively, the organizational framework in which to provide training is well established. In 1988, for example, auto manufacturers and the repair industry became concerned over the increasingly complex nature of vehicle electronics. In response, several organizations, the Society of Automotive Engineers (SAE), California Air Resources Board, and the U.S. Environmental Protection Agency, pooled their resources and developed standardized procedures and equipment to diagnose E/E faults. Auto manufacturers then developed training courses on E/E subjects to instruct dealer personnel.

With approximately 5,000 units sold annually, bus transit could never match the level of effort put forth by the auto industry. However, bus equipment is equally sophisticated, and without a national infrastructure to provide adequate E/E training the burden falls squarely on the shoulders of transit management.

Electronic "Mistakes" Easy to Mask

Survey results indicated that the proliferation of electronics has made it essential that a wide range of agency departments improve their understanding of E/E equipment and systems. Without this understanding, it becomes much easier for those directly responsible for E/E equipment to conceal any mistakes resulting from their lack of understanding. For example, if equipment fails to deliver intended results because the specifications were inadequate, it would be easier for the person(s) responsible for the specifications to blame the vendor if other agency personnel were not knowledgeable enough to determine who was deficient.

The same could apply to untrained mechanics who simply replace electronic components until they stumble upon the defective one. Unless management comprehends the technology and has procedures in place to determine if the equipment was actually defective, many non-defective parts might be scrapped. One agency participating in this study admitted that a trainer decided to test a stack of expensive relays marked "defective" only to find that more than 90% were in good working order. According to leading manufacturers of bus electrical charging systems, nearly 50% of all alternators sent in for repairs are in perfect working order (*6*).

Unfortunately, the amount of money and time spent improperly applying sophisticated E/E technology will never be known. What is known, however, is that transit agencies need adequate training to implement and repair highly advanced E/E equipment. Although some agencies were quick to understand the complexity involved and moved to provide the needed training, others did not. As a result, those with trained personnel have implemented the technology with positive results, whereas some agencies with untrained staff have suffered the consequences.

TCRP Report 43: A Starting Point for Understanding

Successful implementations of advanced E/E equipment are frequently praised in trade journals and industry forums; however, the many failures are rarely discussed. Some of these shortcomings are presented in the 1999 TCRP study, *Understanding and Applying Advanced On-Board Bus Electronics* (*TCRP Report 43*) (*7*). Alongside the many successes, the negative encounters such as project delays, vendors going out of business and leaving behind unsupported equipment, agencies procuring E/E equipment before it has been proven in revenue service, legal disputes, bad press, protracted procurements that made the equipment obsolete before it arrived, and other such experiences, are presented. The faulty implementations are not intended to undermine the technology. Instead, they illustrate what could go wrong if agencies are not prepared with trained personnel.

In addition to highlighting the successes and failures of applying advanced on-board electronics, *TCRP Report 43* recognized the need for E/E training and is highly recommended as a companion to this study. Whereas this study focuses on the ingredients needed for establishing an E/E training program, *TCRP Report 43* provides a basic level of understanding concerning the actual subject of E/E and its application to transit buses.

TCRP Report 43 serves as a useful starting point for understanding E/E applications because it puts into perspective the many facets of this complex subject. It describes how electronics have improved the functionality of specific components, and goes on to describe how individual components can be integrated into larger systems to provide even greater benefits. The report concludes with a set of guidelines designed to assist transit agencies

- Decide if a given technology is appropriate for their operation.
- Plan procurement strategies for advanced electronic equipment and systems.
- Take more complete advantage of the technology's capabilities.
- Manage the data generated from the equipment.

"Maintenance Free" Is Not "Failure Free"

The need for E/E training was made clear when this synthesis was first announced over the Transportation Research Board website created to exchange information between bus maintenance personnel (*8*). Within minutes of being posted a maintenance manager from an agency with a small bus fleet called to relate a frustrating scenario. The maintenance manager admitted that, while the technicians at this particular agency were extremely proficient at troubleshooting mechanical problems, they were not able to do the same with electronics. As a result, many on-board E/E systems were inoperable because mechanics, and the manager himself, did not have the expertise needed to repair them. In this particular case, the general manager failed to recognize the maintenance department's inability to repair this equipment and refused requests for additional training, having been told by the vendors that electronic systems are "maintenance free."

It is true that solid-state electronics such as integrated circuits have no moving parts and do not require periodic maintenance for adjustments and lubrication as did some of the electro-mechanical components they replaced. However, although electronics have proven highly reliable they can malfunction over time. Whether installed in a transit bus or a luxury automobile, electronic components can fail periodically and require unique skills to diagnose and repair. The failure may be related to a defective component or a wire connection to that component. A new E/E product rushed to market before being fully proven in revenue service may also contribute to failures. Regardless, it is unrealistic to expect that electronic components will operate without failure(s) over the life of a transit bus, especially when that vehicle is subjected to shock, vibration, temperature extremes, and other hostile environmental conditions.

Not All Training Is Equal

The survey results and site visits make it apparent that not all training is created, or delivered, equally. Two agencies can devote the same of amount of time training for their employees but end up imparting different knowledge and skills. When it comes to complex E/E systems the quality of the training is especially critical and must be part of a larger overall program to improve the essential skills of agency personnel. To be effective, the study finds that training programs must be based on proven educational principals.

Several education-related publications, listed separately in the Training Sources section of this study, are provided to assist transit agencies

- Develop effective training programs,
- Improve work performance,
- Develop learning objectives,
- Determine the skills that need to be learned,
- Determine if what was learned in the classroom was transferred to the workplace, and
- Determine the effect training had on the organization.

Many of the education-related publications listed in the Training Sources section of this study refer to the application of an Instructional Systems Development model when establishing training programs. The model consists of five parts: analysis, design, development, implementation, and evaluation. The step-by-step process strives to ensure that the instruction given results in being the correct solution to a particular problem. Application of the Instructional Systems Development model ensures that the courses and objectives are derived from demonstrated needs, and the only material covered is that which meets the students' needs.

OBJECTIVES

This synthesis documents the training practices at a sampling of transit agencies with regard to the application and repair of advanced on-board electronics. The objectives of the synthesis are to

- Examine the level of E/E training being provided by transit agencies;
- Highlight innovative and effective approaches;
- Identify outside sources for training;
- Identify the essential areas of knowledge that must be understood by upper management, operations, and maintenance staff;
- Allow agencies to improve their training programs as a result of the information presented here; and
- Draw conclusions based on the findings.

METHODOLOGY

Information presented in this synthesis was obtained through

- A search of available literature;
- Survey questionnaire responses obtained from 25 transit agencies;
- Telephone follow-ups made to agencies responding to the survey;
- Telephone interviews with other agencies, training institutions, suppliers, and others with E/E training experience; and
- Site visits made to Dallas Area Rapid Transit (DART) and New Jersey Transit (NJT).

Respondents to the questionnaire represent 25 transit agencies with a combined fleet size of 14,474 buses and 5,503 mechanics (not including hostlers, cleaners, parts personnel, administrators, etc.). The responses are summarized and included within relevant sections of the synthesis.

Pertinent information obtained from the site visits to NJT and DART is also included within relevant synthesis sections. These agencies were selected as site visit locations because their comprehensive E/E training programs were conducted in different labor environments. DART's policy is to recruit maintenance personnel with existing experience and provide training to enhance that experience. In NJT's case, union policy dictates that all new maintenance employees must be recruited as entry-level cleaners and service line workers, which places a different set of demands on its training program.

In meeting the synthesis objective of identifying knowledge areas that need to be understood by key agency personnel, a series of basic tests have been developed and are included in Appendix D of this study. The tests can be used to determine if key staff actually have a fundamental understanding of E/E technology or if additional training is required. A test is not included for bus operators, because of the varying equipment and procedures involved from agency to agency. Questions used in the tests were assembled from information obtained through the literature search and from actual exams used by agencies to test their employees.

ORGANIZATION

Information synthesized from the study has been organized into several chapters and appendixes. Following the Summary and Introduction chapters, the synthesis presents a chapter on E/E training as it relates to management and its role in creating an environment where effective training can take place (chapter 2). Maintenance training is highlighted in chapter 3, receiving the majority of the attention with an emphasis on

- Training programs and methods (e.g., frequency, sources, testing, and training aids),
- The use of procurement specifications to obtain training,
- Human resources (e.g., staffing, labor issues, hiring, and advancement),
- Financial resources (e.g., cost allocations and budgets), and
- Knowledge areas (e.g., E/E principals and troubleshooting).

A chapter on operations training (chapter 4) follows, which highlights many of the same subject groups as maintenance, with a focus on the unique training requirements for bus operators. The final chapter draws conclusions based on the synthesis findings.

Following the References, a separate listing of resources is provided where agencies can find additional information on E/E-related subjects, as well as information on the subject of providing education in general. A copy of the survey questionnaire is included as Appendix A and a listing of the survey respondents is found in Appendix B. A copy of NJT's troubleshooting guide for bus operators is included as Appendix C. A series of tests to determine basic E/E skill levels are included as Appendix D, with answers to those questions found in Appendix E. Appendix F contains the specification language issued by the Delaware Transit Corporation on its requirements for training and documentation to be provided by manufacturers, as part of new bus procurements.

CHAPTER TWO

MANAGEMENT TRAINING

According to survey respondents, senior managers play a pivotal role in determining whether agency personnel receive the necessary knowledge and skills because of their influence over funding and their philosophy toward the overall training function. Management can either value the importance of a trained work force and commit the necessary resources to training or it can deal with the negative consequences of an untrained staff. Because it is difficult to find employees qualified to work on those E/E technologies unique to transit, training them becomes essential.

The difficulty in finding qualified people to handle the complexities inherent with advanced technology was exemplified by a group of industry professionals who were asked by *Bus Ride Magazine* to comment on what they saw as the biggest challenges facing transit today. One operations director stated that finding qualified people to service constantly changing on-board technology was *the* most critical challenge (*9*).

Behind the successful implementation of advanced electronic technology are top managers with a commitment to providing employee training. At one transit agency that has one of the country's most successful AVL implementations, the executive director understands the importance that training plays in achieving success with E/E implementations, stating that

> Training is the most important aspect of the successful use of advanced electronic systems within transit agencies. Upper management has to be well briefed and understand the benefits of such systems, and staff must understand the benefits and the fact that [this technology is] a tool for success and enhanced service levels to the customer. Our overall goals are effectiveness and efficiency resulting in an increase in passengers. The advanced systems being utilized today and coming tomorrow will save time, lives and money (personal communication, G.E. Cook, Ann Arbor Transportation Authority, August 2001).

As this executive director notes, both senior management and staff need to understand complex E/E technologies if they are to be applied successfully. However, it is often difficult for those without a technical background to grasp the intricacies involved with advanced technologies. This difficulty sometimes causes management to oversimplify the technologies and not devote the time needed to fully understand them. As revealed in the survey results, failure on the part of management to become knowledgeable about advanced E/E applications can have negative consequences because staff is allowed to procure equipment without the necessary oversight and long-range planning. The expense and potential risk involved with this technology makes it incumbent upon top decision makers to become more knowledgeable about a technology that will only grow more prevalent and complex over time.

WHERE MANAGERS GET TRAINING

According to survey results, except for the 20% who reported that management receives no training at all, there was no common method cited by which managers receive information on E/E equipment. Popular responses included trade group meetings, publications, trade shows, and seminars. Only 20% of those responding to the survey listed their own in-house training department as a source for management training. Of those agencies with in-house E/E training for managers, all reported that the training could be improved.

Twenty percent of the survey respondents reported that managers receive information from vendors and suppliers. In an attempt to simplify their products, however, suppliers often omit deficiencies inherent with the equipment, choosing instead to highlight only the benefits. In doing so, managers do not typically receive a well-rounded and objective explanation of the technology from suppliers and are often shielded from any inherent product inadequacies.

The need for improving management's understanding of advanced electronics was evident from the survey results. Sixty-five percent reported that management would benefit from receiving additional training, which would include an improved awareness of the

- Extensive training needed for staff;
- Extra costs associated with procuring, operating, and maintaining E/E equipment;
- True capabilities and limitations of the equipment involved; and
- Knowledge needed to develop long-range planning strategies.

With regards to their staff being trained on the implementation, operation, and maintenance of advanced on-board electronic equipment, 62% of the agencies responded that their training programs are adequate, 24% say that they are inadequate, and 14% are uncertain. Concerning the level of funding provided by the agency for E/E training, 50% reported that it is adequate, 41% say it is inadequate, and 9% are uncertain.

SURVEY RESPONDENTS FAVOR E/E EQUIPMENT

The survey asked management to rate the effectiveness of specific on-board E/E equipment in improving the quality of service provided to passengers and improving the efficiency of their agency's operation. The equipment's effectiveness was rated on a scale of one to five, with five being the highest score possible. Table 1 provides the average rating for each E/E item.

TABLE 1
MANAGEMENT'S RANKING OF THE EFFECTIVENESS OF E/E EQUIPMENT

E/E Equipment	Ranking
Engines, transmissions, brakes	4.0
Radios	3.9
Fare collection	3.9
Destination signs	4.4
Next-stop annunciators	4.2
Automatic vehicle location	3.9
Automatic passenger counters	3.7
Others—multiplexing	4.0

Note = Ranking is on a scale of 1 to 5, with 5 the highest possible score.

The average ranking of four (of a possible five) for all E/E equipment combined indicated a strong feeling by management that the equipment is useful to their operation. However, several suggestions were made by managers for improving the effectiveness of this equipment including

- Initiating a joint effort between agencies and manufacturers to develop equipment that meets the agency's needs,
- Improving reliability,
- Adopting a standardized approach to integrating on-board equipment,
- Making the equipment easier to use,
- Holding suppliers responsible for meeting specifications/contract terms,
- Using equipment to its full potential, and
- Developing good supplier/agency support and cooperation.

Although the comments received were diverse, a call for standardizing the integration of on-board E/E equipment was the most frequent response concerning the changes needed to improve the equipment's effectiveness.

MANAGEMENT'S ROLE

Survey results indicated that the role of management is seen primarily as one of authorizing and supporting specific training programs. Other survey comments encouraged a broader role for management.

- Providing funding to ensure adequate training.
- Supporting industrywide efforts to develop a standardized approach for the integration of on-board electronic systems to improve interchangeability and reliability.
- Supporting agencywide efforts to keep advanced E/E equipment operational.
- Supporting the use of advanced E/E equipment as an integral part of mass transit service improvements.

These survey responses serve as an ideal guide to define management's role in supporting both agencywide and industrywide efforts to bring about a smooth and orderly implementation of advanced E/E technologies.

Adopt Standards

Developing standards to ensure the interoperability of E/E equipment and improving the effectiveness of that equipment is considered an essential role for management. Despite the importance placed on standardization by the survey results, bus transit has been slow to adopt a standardized approach to several facets of E/E implementation. One area where survey respondents reported inadequate standardization is in the application of on-board data communications (i.e., the electronic "language" used by E/E equipment to share the data that are essential to equipment integration). Although many embrace the SAE J1708 family of standards for in-vehicle data communications and integration of so-called Information Level equipment (e.g., AVL, fare collection, and passenger information systems) as recommended by the FTA, others disagree, claiming that more suitable alternatives exist. By obtaining a better understanding of on-board data communications, management can take a more active role in this area and provide the leadership needed to unite the entire industry around acceptable standards.

Other areas where survey respondents indicated a lack of standardization included the multiple keypad entries that bus operators must make when initializing each on-board system, including fare collection, destination signs, the radio/AVL system, and next-stop annunciators. The use of a single operator interface, which requires a standard data communications network to integrate, would allow operators to make one keypad entry to initialize all systems.

The study also indicates that management could play a key role in the development of a standardized approach for centralized on-board data access where mechanics could perform diagnostic tests and obtain data from one location.

Currently, separate tools called "readers" are needed to access data from each on-board system (i.e., engine, transmission, anti-lock brakes, air conditioning, multiplex electrical system, etc.). The automobile industry standardized centralized vehicle data access more than 10 years ago. Regardless of the car make or model, auto mechanics from large dealerships to small repair shops can access vital data with a standardized tool. This approach was made possible, in part, by standardizing on-board data communications.

Keep Equipment Operational

Supporting agencywide efforts to keep advanced E/E equipment operational was identified by the survey as another essential role for management. Prepared with the necessary knowledge, management could provide the leadership needed to help coordinate activities across many agency departments. An informed management team could also help create the atmosphere of collaboration needed to make all elements of the technology work smoothly.

Champion E/E Applications

Management's role in championing the application of advanced E/E equipment as an integral part of mass transit service improvements was also viewed as essential by survey respondents. Equipment that improves an agency's efficiency, and the level of services and amenities provided to passengers, is critical if bus transit is to complement the advancements made in other modes of surface transportation.

"The Penske Way"

Roger Penske, who controls a transportation conglomerate with revenues of $10 billion annually, provides a good example of the importance management places on training in the private sector. Mr. Penske took control of the Detroit Diesel Corporation in 1988, and the company market share grew from 3.5 to 27% in 12 years. According to Mr. Penske, who has since sold his interests in the company, "we're setting up training centers in each of our [car dealership] regions because we think there's real money to be made by training people" (*10*).

Instead of setting aside a prescribed number of training hours for each employee, dealership personnel are given proficiency tests, which are then used to determine the actual amount of training required. Training is provided in regions, and auto manufacturers are called in to participate. The regional approach eliminates the need to provide training at each dealership location, thereby making more efficient use of available resources.

TRAINING SOURCES

Several sources exist that can assist management in becoming more knowledgeable about the technologies associated with intelligent transportation systems (ITS) and advanced on-board electronics. In addition to the references cited in the following sections, a separate section of this study provides a listing of websites and publications on training sources, making it convenient to locate sources for information on E/E and related subjects.

Initial Resources

A starting point for management to obtain knowledge would be to tap that which already exists among the agency's own staff. Another place to start is *TCRP Report 43*, which serves as a primer to the many facets of the technologies and programs involved (*7*). Various websites contain a wealth of information on ITS and emerging standards. The website for the ITS Joint Program Office (JPO) (*11*) provides information on and links to several training opportunities, including those offered by the Institute of Transportation Engineers, the National Transit Institute, and the FTA. ITS America's website (*12*) and the Transit Standards Consortium (TSC) website (*13*) also provide information on E/E technologies and training.

Of the many publications available through the ITS JPO, "Building Professional Capacity in ITS: Assessment of ITS Training and Education Needs—The Transit Perspective" identifies the level of professional development needed for the successful deployment of new ITS technologies (*11*). Research focuses on professional capacity building categorized by position or role, project type, and stage of deployment.

FTA Outreach Training

Based on the recommendations by the JPO and others, the FTA is collaborating with the SAE, TSC, and others to provide training as part of the U.S. Department of Transportation's (USDOT) comprehensive ITS standards Outreach and Education program. The project's objective is to provide training on the application and use of specific ITS standards. Use of these standards for both on-vehicle and off-vehicle applications is essential to creating an overall architecture that allows data generated from all elements of ITS (e.g., transit, highways, and public works) to exchange that data in a uniform and compatible manner.

Without the interoperability made possible through standards, ITS simply will not function. All elements of ITS need to communicate in a language understood by all parties if land-based transportation is to truly function as an integrated "system." Understanding this, the Transportation Equity Act for the 21st Century (TEA-21), the reauthorization of the federal surface transportation program, supports the development of standards and ties federal funding for ITS projects to those standards. If transit fails to develop standards within a specified period, the USDOT can step in and establish provisional standards.

The FTA offers several programs to help agencies understand the application of ITS standards to transit. FTA's ITS Technical Assistance Program is specifically targeted to assist those agencies that find themselves behind in their efforts to become integrated with other ITS participants. Funds are available to assist agencies with their understanding of ITS implementation policies by providing them with on-site training. The policy that applies to transit is the FTA National ITS Architecture Policy for Transit Projects, which recommends the use of standards when integrating ITS technologies. Several agencies have taken advantage of this service to obtain a better understanding of the recommended standards.

FTA's technical assistance also includes the Peer-to-Peer Program, which supports the deployment of ITS through a free technical assistance program where agencies can enlist short-term help to address specific ITS issues. The Peer-to-Peer Program is open to any public organization or transit agency involved in planning, evaluating, or operating an ITS technology.

Only 17% of survey respondents reported having participated in some type of FTA-sponsored training, indicating that transit agencies are not taking full advantage of these opportunities. Additional information on any of FTA's technical assistance programs regarding ITS implementation is available through FTA regional offices.

The FTA is also planning to offer several courses tailored for a broad range of transit managers. These courses will target board members, senior staff, financial officers, directors, risk managers, and senior planners and assist them in understanding the capabilities of electronic systems, while alerting them to initial and long-term risks of integrating those systems with and without ITS standards. These courses will also explain the current mandate for ITS standards for USDOT funding and identify the management value of the information provided by these systems.

Courses designed for project managers, fleet and maintenance managers, management information system managers, fare collection managers, and route planners will address the capabilities of open-architecture, ITS compliant in-vehicle systems for optimum performance, expansion, and ease of replacement. Other courses will assist managers responsible for equipment and vehicle procurement in preparing specifications that will ensure a fully compliant ITS vehicle using open-architecture data communication networks. Additional courses will include instructions on how to incorporate newer ITS standards into older "legacy" systems using smart bus technologies made possible by in-vehicle standards. A future course on maintaining these so-called "smart bus" technologies will also be offered. Information on these courses is also available through the FTA regional offices.

KNOWLEDGE AREAS

The proliferation of advanced electronics into virtually every bus system requires that senior management be expected to understand the basics about many E/E technologies. The costs and potential risks associated with this equipment, coupled with the equipment's ability to provide data to improve management control, dictate that managers improve their understanding of the technologies and issues involved. Furthermore, the accelerated rate at which the technologies are being introduced requires management to become involved in long-range planning where equipment obsolescence is accounted for and transitions to new technologies are made as efficiently as possible.

Based on the review of literature and survey results, the knowledge areas listed in the next two sections are those with which general managers and senior management should be familiar.

Technology

- Definition of smart bus technologies, including the capabilities and limitations of each technology. These include electronically controlled drivetrain systems, passenger information systems, vehicle location, fare collection, and other advanced on-board systems.
- Benefits offered by integrating that equipment into larger systems.
- How data flows between E/E systems on board the bus, between the bus and the transit agency, between one transit agency and another, and between other ITS modes.
- Funding and staffing requirements for applying advanced E/E systems.
- Environmental issues (e.g., SAE J1455) that equipment must meet when installed on board a bus.
- Various methods used for on-board data storage and transferring data on and off the vehicle (e.g., wireless networks, floppy discs, and physical cable connection).
- Differences and limitations of both open (i.e., available to the public) and proprietary (i.e., restricted to licensed vendors) data communication.
- How on-board data communications are integrating components on three bus levels: drivetrain (e.g., engine

and transmission), electrical control (e.g., multiplexing), and information (e.g., AVL and radio).
- How the three bus levels may merge in the future.
- Familiarization with various approaches to on-board data communications such as SAE J1708, SAE J1939, LonWorks, Controller Area Network, DeviceNet, etc.
- Familiarization with other emerging data communication options such as TCP/IP, USB, Firewire, Bluetooth, and advanced wireless protocols.

ITS Integration

- USDOT programs that involve the application of advanced E/E technologies, such as ITS and the Advanced Public Transportation Systems Program, which applies specifically to transit.
- USDOT programs that encourage the use of data communication's standards to ensure interoperability between ITS elements. These programs include the National ITS Architecture, National Transportation Communications for ITS Protocols, Transit Communications Interface profiles, and Vehicle Area Network.
- How the use of ITS standards reduces risk, provides for long-term funding and planning, and protects technology investments.
- Familiarization with the concept where local and regional agencies share data through the use of standard data communication standards (e.g., the "511" telephone number to obtain national traveler information).
- How to obtain technical assistance from FTA on ITS implementation.

A test to assist agencies determine if management has a basic understanding of these knowledge areas is included in Appendix D; Appendix E provides the answers. Test questions were compiled from information obtained through the literature search.

CHAPTER THREE

MAINTENANCE TRAINING

According to T. Wireman in *World Class Maintenance Management*, maintenance organizations will never be cost-effective without high-quality training programs for maintenance (*14*). Unfortunately, maintenance training is often deferred in times of budgetary crisis. This philosophy needs to be changed if maintenance is to be managed successfully (*14*).

The approach of deferring the needs of maintenance is not unusual. It is consistent with how transit and other industries often view the maintenance function. Despite the comprehensive skills needed to diagnose and repair increasingly complex E/E equipment, maintenance unfortunately continues to be viewed by many as a second-tier activity. Because maintenance is often overlooked, this synthesis will give it the greatest focus.

There are several examples of transit agencies with noteworthy maintenance training programs that include E/E training as part of the curriculum. This synthesis has selected two, DART and NJT, because both have comprehensive maintenance training programs staffed by qualified professionals who understand the intricacies of education, as well as maintenance. Other similarities between the training approach of the two agencies include the use of

- Detailed lesson plans with stated objectives and detailed instructions to facilitators that include required training materials,
- Both classroom and hands-on instruction for students,
- A test to determine if the students actually acquired the necessary skills,
- A career path that ties successful completion of training courses to promotion and salary increases, and
- Procurement specifications that require bus manufacturers to supply training and training materials.

A major difference between the two agencies is the way in which they hire maintenance employees. Although both provide training to every mechanic, they do so from different labor environments. DART's labor agreement allows it to hire individuals with accredited degrees. NJT hires all nonsalaried maintenance personnel as entry-level bus cleaners and service line workers despite any other skills they may have.

In DART's case, hiring mechanics with a degree from a community or technical college ensures them that the mechanic has basic reading and writing skills, understands fundamental technical and electrical principles, and has made an investment in tools. Proof of accreditation for higher education institutions is verified from publications issued by the American Association of Collegiate Registrars and Admissions Officers (*15*) and the American Council on Education (*16*).

The dedication to training at both agencies is obvious. DART's training manager displays a quotation from management expert and noted author Tom Peters that reads, "We find the best return on investment comes from training . . . your rewards go for the lifetime of the employee rather than just the lifetime of the equipment." NJT's training manager displays a similar poster that includes training as part of NJT's mission statement.

TRAINING PROGRAMS AND METHODS

E/E training is just one element of an agency's overall maintenance training program. Survey results indicated that separating E/E training from the larger training function is difficult because the two are so intertwined. For example, training on engines typically includes electrical theory and electronics because they play such critical roles in the way a modern engine operates.

Agencies responding to the survey use a variety of approaches to provide maintenance personnel with E/E training. Some teach E/E theory and application as a standalone course, whereas others include it within courses such as those pertaining to engines or air conditioning. In other cases, the subject is taught by outside organizations such as vendors, private technical schools, and local community colleges. DART offers dedicated courses on E/E subjects, whereas NJT includes E/E training as part of its overall maintenance training program. Both supplement their programs with vendor training.

NJT and DART continually update their training programs to include new E/E technologies. New technology training is included as part of the procurement for new buses and E/E equipment as well. Training curriculums are then updated with new technology material. If either agency experiences a particular problem associated with E/E equipment, special training classes are initiated to address the problem.

There is no single approach to providing E/E training for maintenance personnel that is appropriate for all agencies to follow. The varied approaches identified in this study are offered as examples to assist agencies evaluate existing approaches to E/E training.

Frequency and Amount

Providing the right amount, quality, and level of training requires a delicate balance. For example, 10 h of well-designed training is better than 1 week of training that is poorly organized. In addition, training needs to be tailored to the audience to be effective. Another consideration is the amount of overall time needed for the training—too much and valuable time is wasted, too little and not enough knowledge is conveyed. Among the biggest concerns is that agencies will spend time and money training employees only to have them use that training to obtain higher-paying jobs elsewhere. Both NJT and DART are well aware of this risk, but also realize that the alternative is an unskilled work force. The approach at both agencies is to create a working environment designed to retain employees. Part of that approach is to have employees consider the agency's benefits package, along with wages, to determine the true value of their salaries.

Among the agencies surveyed, the number of hours of E/E training provided to maintenance employees annually ranges from 0 to 96 h, with 20 to 40 h of annual training as the mean. Because skill levels and hiring practices vary greatly among agencies, there was no meaningful conclusion derived from the data concerning the amount of E/E training that should be provided to maintenance personnel. In many cases the actual amount of time provided just for E/E training was difficult to calculate because so much of the training (e.g., air conditioning and engines) has an E/E element to it.

Regarding its in-house E/E training program, DART, which has 16 different job title classifications for maintenance personnel, requires that electronics mechanics take 12 different courses to achieve the highest educational level in that specialty. Of the 12 courses, 9 are directly related to E/E subjects. For a DART electronics mechanic to reach the highest job classification requires 90 h of training devoted exclusively to E/E subjects.

NJT does not offer dedicated E/E courses (unless required on a special basis), but instead includes E/E training as part of its regular maintenance training curriculum. NJT's Advanced Level Repairman Training (Repairman "A") program, which includes 256 h of training, devotes approximately 80 h of that training to E/E-related subjects. Although NJT and DART have different approaches to performing E/E repairs (i.e., DART uses dedicated specialists, whereas NJT requires all "A-level" mechanics to make the repairs), they do provide similar amounts of E/E training for each mechanic (i.e., 80–90 h).

Agencies also supplement their training programs with training provided by manufacturers as part of new bus procurements. In a recent procurement, NJT, which employs 850 mechanics, specified 1,328 h of total mechanics training, of which 112 h is applied specifically to E/E training. During a recent procurement for a new bus order to DART, which employs 240 mechanics, the agency specified that the bus manufacturer deliver 120 h of total training for bus mechanics, 32 h of which is devoted to E/E subjects. Both NJT and DART require that bus manufacturers provide a training curriculum that the agency must approve in advance. Using another example, the Delaware Transit Corporation, which employs 38 mechanics, specified that a new bus manufacturer provide a minimum of 40 h of E/E training for bus mechanics.

Examples of the training hours provided here are based on an 8-h workday. However, it is important to note that approximately 6 h of actual "contact" training is provided because of lunch and other daily breaks. Milwaukee County Transit limits maintenance training to only 4 h per day because of its concern that a person's attention span diminishes during the course of a full day's training. In a related note, educators find that training is most effective when that training is provided during the employee's normal shift. Providing training during the day to an employee that normally works at night disrupts the worker's sleep pattern, which in turn affects the learning process.

In-House Versus Supplied Training

All agencies surveyed furnish some type of E/E training to their maintenance employees, with nearly 80% of the respondents using a combination of in-house programs and outside programs offered by vendors, local community colleges, and private organizations that specialize in automotive technical training. The remaining 20% rely solely on their in-house programs.

As part of its in-house training program, Long Beach Transit offers an 8-week Mechanic Mentor Apprentice Program that exposes high school and college students to real-world jobs and a potential career in transit. Long Beach mechanics serve as volunteer teachers/mentors for the students. The program was developed in cooperation with union officials and local community colleges. Students receive classroom training on Mondays, spending the rest of the week working on vehicles under the direct supervision of the mentors.

DART and NJT both supplement their in-house training program with vendor-provided training. Because they place a great deal of emphasis on the professionalism and effectiveness of their own training programs, each agency qualifies the outside training before it is given to their employees.

As with nearly 90% of the survey respondents, both DART and NJT specify training as part of their new vehicle procurements. The vendor-provided training included with new bus procurements not only supplies expert supplemental training, it also serves to use capital funding for training purposes. Relying solely on in-house training can be inefficient because it does not utilize the vast resources and talent available from those who actually manufacture or supply the equipment. (Additional information on the requirements for specifying training with new bus procurements is provided below.)

NJT and DART offer their in-house training programs (which include E/E training) to other agencies on a reasonable, daily-fee basis, which can be important to those without the necessary training resources. Because the training is tailored specifically to transit bus applications, this type of outside training can be extremely beneficial to smaller agencies looking for qualified training programs for their maintenance staff.

Other Sources for Outside Training

In addition to NJT and DART, the San Mateo County Transit District in Northern California offers technical training to other transit agencies. Other sources for outside maintenance training include the bus manufacturer and component supplier. Every major vendor of advanced E/E equipment should offer training. If not, transit agencies should question the reason. Local community colleges, cited by several respondents including NJT and DART, are also used for E/E training. Several agencies report that they establish a relationship with these colleges to help tailor their courses for transit applications and offer employment opportunities to students upon graduation.

As mentioned in chapter 2, FTA's Outreach Training program will offer E/E-related courses for maintenance managers as well as mechanics. Two private organizations often cited in the survey results that offer E/E training for maintenance personnel are Universal Technical Institute's Custom Training Department, headquartered in Phoenix, Arizona, and the Nashville Auto Diesel College in Nashville, Tennessee.

Publications and Training Aids

Publications

Most bus and component manufacturers offer printed training material on their products, which agencies can use as training resources. Although many publications are available on specific E/E products, a series of manuals published by Delco–Remy, a division of General Motors, are used extensively by both case study agencies to assist maintenance personnel in understanding the basics of electricity and electronics. Among the technical publications offered by Delco–Remy are

- *Fundamentals of Electricity and Magnetism,*
- *Fundamentals of Semiconductors,*
- *Charging, Ignition and Cranking Systems: Periodic Maintenance and Circuit Checks,* and
- *Diagnostic Procedures for Heavy-Duty Electrical Systems.*

Training Aids

Both case study agencies also specify the inclusion of training aids and mock-ups (i.e., working classroom displays of actual on-board equipment) as part of their new bus procurements. For DART, one bus manufacturer provided a specially equipped training bus with see-through (e.g., Plexiglas) floors, cut-away panels for easy access and viewing, and labeling of all major E/E components (see Figures 1–3). More importantly, DART and NJT specify that bus manufacturers provide fully functional training mock-ups for individual bus systems, such as multiplexing, brakes, fare collection, fire suppression, and other systems. The mock-ups, where all working components of a particular system are mounted on a board or confined to one area, replicate how the components function when installed on a vehicle. Trainers use the mock-ups to describe the functionality of equipment, and then "bug" each system with defects to test the mechanic's troubleshooting abilities. Although an entire bus equipped solely for training may not be appropriate for all agencies, mock-ups are useful to train and test employees.

FIGURE 1 Training bus equipped with Plexiglas panels and other learning aids (source: DART).

FIGURE 2 Plexiglas floor on training bus allows students to see components from inside the vehicle (source: DART).

FIGURE 3 Test gauges allow for on-board systems diagnostics and training (source: DART).

FIGURE 4 Multiplexing systems training mock-up.

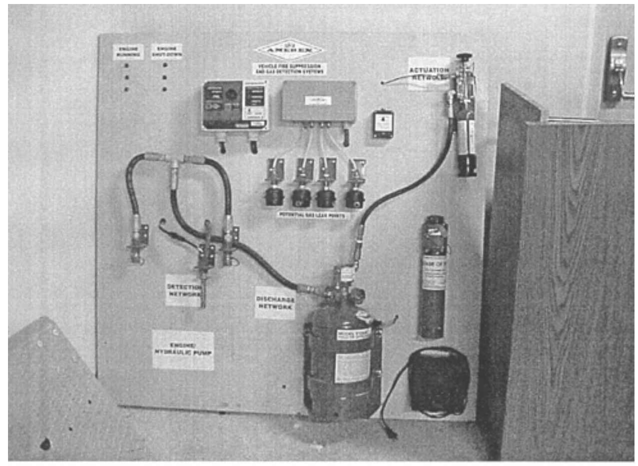

FIGURE 5 Fire suppression training mock-up.

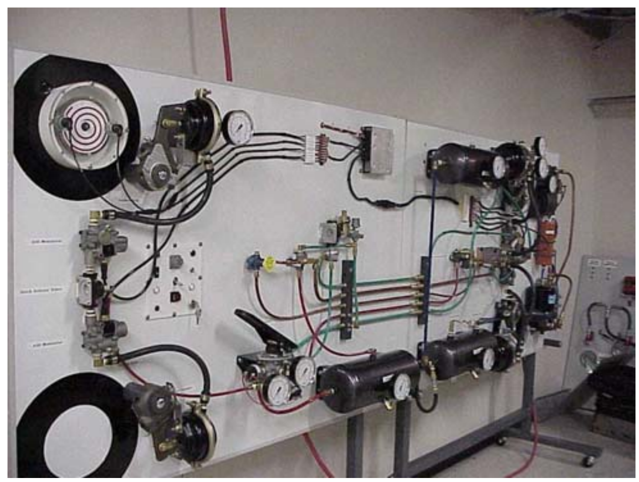

FIGURE 6 Brake system training mock-up.

FIGURE 7 Door module allows training and diagnostic functions to be conducted in a classroom setting (source: DART).

Figure 4 shows a multiplexing system mock-up, Figure 5 a fire suppression mock-up, Figure 6 a brake system mock-up, and Figure 7 shows a door system mock-up. Each of these mock-ups was provided by a bus manufacturer as part of DART's procurement process and is used by the agency to train and test their maintenance employees.

To train its employees on how to program a multiplexed bus electrical system, the Orange County Transportation Authority uses a portable display board. In addition to diagnostics, students use the mock-up, which includes a laptop personal computer (PC), to write programs and load those programs into the multiplex system to help them understand how a combination of different inputs can cause different outputs. The Orange County Transportation Authority's portable mock-up board is shown in Figure 8.

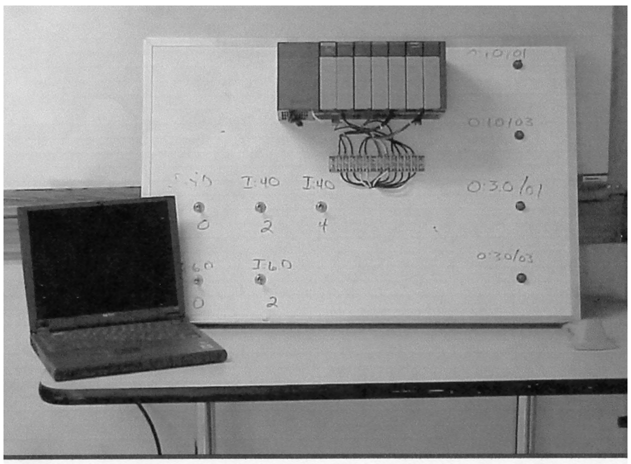

FIGURE 8 OCTA's portable mock-up board is used to help students understand multiplexing.

Interactive Training

DART, NJT, and other agencies report that they use an interactive, self-study training program available through a major engine supplier that allows mechanics to use a computer and related software programs to learn about computer usage, basic electrical theory, and the manufacturer's own electronic engine control system. The self-study program allows mechanics to work at their own pace and work outside the formal classroom setting when needed to review information and procedures. When a student completes a training module, the computer disk is returned to the instructor who can review each mechanic's progress. Figure 9 shows a bank of PCs used by DART to conduct interactive training.

The interactive training program assumes that the mechanic *knows* little or nothing about using computers or basic E/E principles, an approach that several agencies report using to make certain that mechanics fully comprehend the subject. As a result, the first training modules teach basic computer skills, which includes the use of Windows and rudimentary directory structures. An intermediate set of training modules provides a basic understanding of E/E theory and troubleshooting, whereas the remaining modules go in-depth on troubleshooting specific engines. Tests are included with each training module.

FIGURE 9 Bank of PCs used by DART maintenance employees to run interactive training programs.

Tools

All of the agencies surveyed report that they provide tools to maintenance personnel for E/E repairs including

- Multi-meters;
- Laptops and PCs loaded with the latest diagnostic software;
- Product-specific diagnostic tools with the latest software for engines, transmissions, etc.;
- Oscilloscopes;
- Battery and charging system test equipment;
- Soldering tools;
- Power supplies; and
- Equipment to create EPROM (Electronically Programmable Read-Only Memory) devices, which are used to program destination signs and other E/E equipment.

Of all agencies responding to the survey, not one listed the traditional "test lamp" as an E/E tool. The test lamp has been replaced by the following three tools, available either individually or incorporated into a so-called multi-meter.

- Voltmeter—used to measure electrical pressure in a circuit; measurements are given in "volts."
- Ammeter—used to measure the amount of current flow; measurements are given in "amps."
- Ohmmeter—used to measure the resistance in a circuit; measurements are given in "ohms."

In addition to the multi-meter, agencies report that the laptop PC has become an essential tool for use with on-board E/E equipment. Component suppliers offer PC software and/or specific tools for programming and diagnosing major electronically controlled equipment including engines; transmissions; brakes; heating, ventilation, and air conditioning (HVAC); doors; multiplexing; and passenger information systems such as destination signs, next-stop annunciators, and radio/AVL systems.

PC-based tools are typically used to diagnose faults to a replaceable subcomponent level (e.g., a control unit, sensor, or relay). Once the fault is identified, mechanics are trained to simply replace the defective part. Depending on which part was found to be defective, agencies can scrap it, return it for a core credit, or send it out to be repaired. Long Beach Transit in California uses a different approach. The agency contracted with a firm to provide training on rebuilding the circuit boards found in many electronic subcomponents, and constructed a special "clean room" electronics shop to repair these boards. Long Beach, however, is the exception. Most agencies diagnose down to the subcomponent level and replace the defective part.

PCs Used to Extract Data

In addition to diagnostics and programming functions, laptops and PCs are used to extract data concerning the performance characteristics of various on-board E/E systems. Engine data, for example, include information pertaining to fuel economy, brake applications, coolant temperature plotted over time, idle time, idle fuel consumption, and other information. Some agencies use a full-size PC mounted on a rolling cart to perform the same functions as a laptop. Figure 10 shows a PC connected to a fully functional drivetrain mock-up used at DART to extract data and diagnose faults. The same tool can be connected to a bus using longer cables. Because maintenance personnel are required to use PCs, software programs, and multi-meters in addition to traditional mechanical tools is an indication of the advanced skills needed to correct E/E-related faults.

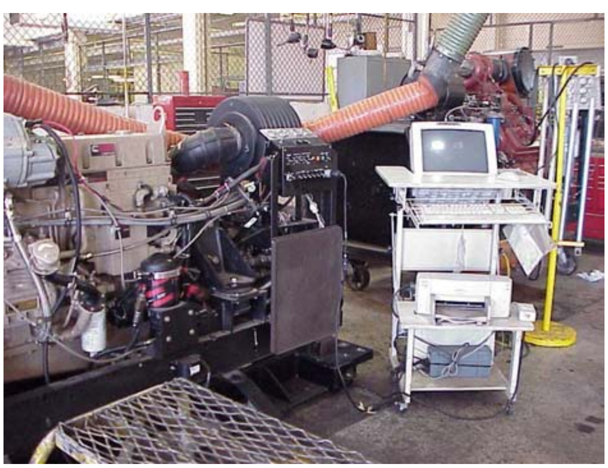

FIGURE 10 Portable PC is used to extract drivetrain data at DART.

PCs Used to Program Multiplexing

The use of a PC-based tool is essential to reprogramming on-board multiplexing systems that control bus electrical functions. For example, when an agency wants the bus headlamps to turn on automatically when the operator activates the wipers, the multiplexing system is programmed with a PC to do so instead of adding more wires and relays. The programming can be done by the agency, if qualified, or by the bus manufacturer (typically for a fee). Of those responding to the survey with multiplexed systems, 80% make the programming changes themselves. The remaining 20% rely on the bus manufacturer to program changes or do not make changes.

Diagnostic Tools Are Getting Smaller

Another major engine supplier offers a pocket-sized device that provides quick and easy access to a host of engine-related data. The device is an example of a growing trend toward smaller data processing tools that mechanics will soon have at their disposal in plentiful supply to help diagnose E/E faults and extract data.

The tool uses an off-the-shelf, hand-held personal digital assistant that snaps into the device. A cable then interfaces with the vehicle's on-board diagnostic connector to provide real-time engine data. Mechanics use this extremely portable tool to diagnose engine faults, clear fault codes, and export data. Similar tools are available, or will be available shortly, for multiplexing and other on-board E/E systems.

Central Data Access Sought to Reduce Multiple Tools

Each major on-board system controlled by electronics typically requires a specific diagnostic tool and software package, prompting agencies to inventory, calibrate, maintain, and train employees on a variety of special tools. In February 2000, the Metropolitan Transit Agency of New York City met to review their concerns over the number of special E/E tools needed, and determine why all on-board diagnostic data could not be accessed from one central location using a standardized link. The TCRP Project C-12 Electrical Interface Working Group revising the E/E section of the American Public Transportation Association's (APTA) *Standard Bus Procurement Guidelines* responded to these concerns with a new E/E section entitled "Central Data Access." Conceptual in nature, the section is an attempt to move bus transit diagnostics to the point where data generated from several on-board systems can be accessible from one location.

Bus Manufacturer Introduces Central Data Concept

Using an open communication protocol (i.e., one published and available to the public), a leading bus manufacturer has incorporated a new on-board system that monitors virtually every E/E system from a central computer and screen (*17*). Loaded with diagnostic software from the major subsystem suppliers (e.g., engine, transmission, multiplexing, and HVAC), maintenance personnel monitor the operation of those systems from one on-board computer screen without having to use a separate laptop or diagnostic reader. In the near future, other bus manufacturers are expected to offer similar single-point data access tools for diagnosing multiple on-board systems.

TRAINING AND DOCUMENTATION SPECIFIED THROUGH PROCUREMENTS

As mentioned previously, the majority of agencies surveyed specified training as part of their new bus procurements. Use of capital funding for training purposes assists agencies in providing the knowledge, tools, and documentation needed to keep advanced E/E bus systems operational. Unfortunately, bus transit does not have a representative training specification that agencies can include with their own procurements. Several agencies recommended producing one as part of APTA's *Standard Bus Procurement Guidelines*. Regardless, several specifications, including those from DART and NJT, were reviewed as part of this study. The salient features of the training deliverables contained in the specifications reviewed in this study are summarized here.

An actual example of the specification language used by the Delaware Transit Corporation to define requirements for training and documentation when procuring new buses is included in Appendix F. Agencies can use the material presented in Appendix F, along with the summary of training specification language provided below, to evaluate their own procurement specifications for training and documentation.

Training

- Indicate the location of training (e.g., at the agency or within a 50-mile radius).
- Identify expenses to be provided by the contractor if training is beyond a specified mileage range (e.g., travel and per-diem for classes held beyond a 50-mile range).
- Identify the number of hours per class, the number of classes required, and the maximum number of students allowed in each class for each subject.
- Provide a clear indication of the areas to be covered by the training (e.g., troubleshooting and repair of all on-board E/E equipment and use of laptop computers and software for troubleshooting).
- Identify the timing for each training course (e.g., within 60 days before delivery of the first bus for mechanics or within 60 days after delivery of first bus for operators).
- Distinguish between Running Repair training (e.g., preventative maintenance inspections, daily diagnosis, or troubleshooting to replacement level of component) and Overhaul Training (e.g., skills needed to rebuild electronic control units or circuit boards).
- Include both hands-on and classroom procedures for training and testing.
- Indicate that agency management must evaluate and approve the training before it is given to staff.
- Insist that training aids and material reflect the same equipment as specified on the bus (e.g., that it is not generic).
- Provide mock-up training modules for any equipment/component that requires theoretical discussion and insist that the equipment become the property of the procuring agency.
- Provide special tools (e.g., defined as any tool not found in catalogs offered by major equipment providers), especially diagnostic and programming tools and related software, for electronically controlled systems including engines, transmissions, anti-lock braking systems (ABS), HVAC, destination signs, multiplexing, etc.
- Provide laptop computers and related software programs that are preloaded, configured, and tested.
- Insist that training to be available for all work shifts.

Documentation

- Indicate the number of copies for all training material to be provided and specify the requirements and formatting of any electronic copies.
- Indicate the requirements for all instructional material (e.g., lesson plans and handouts to be in same format as agency's).
- Provide training videos for specific subjects (e.g., electrical system components and troubleshooting or multiplex wiring system).
- Indicate the requirements for updating the training material (e.g., service bulletins, post-production retrofits, correct errors and omissions found by agency).
- Provide wiring and electrical system schematics and diagrams.

HUMAN RESOURCES

Testing and Career Advancement

Testing is essential if an agency wants to ensure that its staff is qualified to diagnose and repair E/E equipment and that its training program is effective. Of those responding to the survey, 50% report that they use testing to promote maintenance personnel, another 25% base promotions on seniority, and the remainder use a combination of testing and seniority, hire employees directly into specified positions, or could not be classified. When it comes to hiring maintenance employees, 44% of those responding require a degree, proof of previous experience, testing, or a combination of these qualifications.

DART's Approach

In DART's case, employees are required to pass a written test before being hired. Once hired, employees must begin participating in DART's comprehensive Maintenance Training Program. At the conclusion of each course employees are given written and practical tests. If employees fail to pass the written test by scoring less than 80%, or fail to pass the practical test with a score of less than 90%, they are given 6 months in which to take a second test on their own time. If an employee fails the second test he/she must remain at the current job classification until the course is offered again, which must also be taken and passed on the employee's own time. Employees who fail to achieve a passing grade on the New Employee Orientation course, which they must take within 6 months of being hired, are automatically dismissed.

DART has started a new procedure, allowing maintenance employees to choose courses much like a college program. Upon completion of two mandatory courses (New Employee Orientation and Coach Service Readiness), employees can choose to pursue careers in one of 16 job classifications. In the Electronics Mechanic Career Plan, for example, employees must take two mandatory courses before choosing from among 10 E/E-specific courses that include electronic preventive maintenance inspections, radio troubleshooting and diagnosis, and understanding and programming multiplex systems. Each career plan also includes the number of classes that must be taken within a given time period to advance from one job-level classification to the next.

DART maintains a database of all maintenance training, which employees are free to access. Employees can also use the database to keep track of the courses they have taken, those they have passed, and to find out when other courses are available. DART also uses the database to determine those employees who have not taken and passed courses on a regular basis and meets with them to determine the reason. Because the completion of classes is tied to pay increases, employees are generally diligent about pursuing the training courses on their own.

As with DART's entire training program, procedures for testing are clearly indicated in a training handbook. Employees who are absent for more than 10% of a given training class are not eligible to take the test needed for advancement. Written procedures are also provided for those who wish to appeal test results.

DART uses an educational process called "item analysis," which examines students' responses to each test question to ensure that their tests are valid and match the stated objectives of the material taught (*18*). The process examines the difficulty and discriminating factors of each test question. To determine a question's difficulty factor, DART analyzes the percentage of correct answers for that question. An acceptable difficulty factor is one where the number of correct answers to a question falls within the range of 40 to 60%.

DART also uses item analysis to evaluate the discrimination factor, which compares correct answers for a specific question to the average of correct answers for all test questions. If a particular question stands out, DART evaluates it to determine if it is too vague, too tricky, emphasizes trivial details, or if the instructor did not address the particular subject adequately. The question is then reworded and reevaluated after the next test is administered.

NJT's Approach

NJT, which hires all maintenance personnel as cleaners and general service workers, also uses a proficiency test to determine mechanical competence before hiring. As with DART, the test is the property of the agency and not available for this study. NJT also uses written and practical tests to advance their employees. Because NJT maintenance employees are brought in at an entry-level position, the training is progressive (i.e., courses must be taken in a specified sequence, except for specialty and refresher training). After passing the initial 4-day course on Serviceperson Training, the next step for advancement is Entry Level Repairman, where approximately one-third of the 34-day training program is devoted to understanding basic electrical principles. Maintenance personnel then progress into a 32-day Advanced Level Repairman training program, followed by a program on Foreman Training. Employees must pass tests at each stage before advancing to the next.

NJT also offers specialty and refresher courses. Except for a limited number of E/E and communications specialists, the agency does have separate job classifications. However, once at a particular level (e.g., Advanced Level Repairman) mechanics tend to take jobs in areas in which they have a particular interest (e.g., transmission overhaul or brakes).

Labor Issues

For training to be successful, the survey results indicated that both management and labor need to work together to define how each will benefit. The DART and NJT case studies are good examples of successful labor–management relationships. Both agencies have worked closely with unions to develop their training programs, and both have a manual with written procedures that defines in very clear terms exactly how workers are promoted, the review process involved, and how disputes are handled. According to DART's senior training manager, everything must be clearly spelled out between management and labor if training is to be effective (personal communication, R.M. Bennett, DART, August 2001). Promotion based on employee testing was the big hurdle for both agencies, but each worked with their respective labor union to convince them that a highly skilled work force was beneficial to both.

Sixty-four percent of survey respondents claimed that they did not have any labor issues associated with the hiring, testing, or promotion of technicians with E/E skills. Of those reporting labor issues, most responses dealt with having to promote workers based on seniority only, implying that longevity did not always produce someone who was best qualified to diagnose and repair E/E equipment.

Job Classification

Whether agencies have specialists that work exclusively, or near exclusively, on E/E repairs varies from agency to agency depending on their management philosophy. Those without a specialist classification require all mechanics to have the skills needed to work on E/E equipment. They prefer an arrangement where any mechanic can be called upon to diagnose and repair E/E-related faults when needed. For those with E/E specialists, the philosophy is that it is more beneficial to the agency and its employees to train a limited number of workers who already have experience and interest in a particular field.

Of the agencies responding to the survey, 76% have E/E specialists, one agency subcontracts its E/E repairs, and the rest do not use a "specialist" classification. Although NJT and DART both have E/E specialists, they provide basic E/E training to all maintenance personnel because so much of the bus operation is affected by E/E applications.

The information in Table 2 is based on the survey responses and provides an indication of the varied approaches taken by agencies toward E/E job classifications. It includes the number of buses; number of mechanics; number of E/E specialists, if applicable; whether those specialists work in other areas (e.g., brake relining) when needed; and if they are paid a higher wage. For those agencies with E/E specialists, 55% use them for work in other areas when needed. Only 20% of agencies with specialists pay them at a higher wage scale compared with other mechanics that do not specialize in E/E repairs.

FINANCIAL RESOURCES

The amount spent on training annually by agencies that responded to the survey varied greatly. Table 3 lists the number

TABLE 2
COMPARISON OF AGENCIES WITH AND WITHOUT E/E SPECIALISTS

No. of Buses	No. of Mechanics	No. of E/E Specialists	Do E/E Specialists Work in Other Areas?	Are E/E Specialists Paid a Higher Wage?
1,950	850	16	No	Yes
1,900	1,400	75	No	Yes
1,371	268	12	Yes	No
1,256	346	68	No	No
925	361	45	Yes	Yes
842	240	8	No	No
770	270	29	Yes	No
700	297	0	N/A	N/A
524	228	0	N/A	N/A
524	255	5	Yes	No
510	142	8	No	No
387	110	10	Yes	Yes
340	110	20	Yes	No
330	60	50	Yes	No
276	38	6	Yes	No
264	54	0	N/A	N/A
231	82	3	Yes	No
228	44	1	No	No
220	100	5	No	No
210	70	2	Yes	Yes
197	47	0	N/A	N/A
155	45	0	N/A	N/A
148	44	4	No	No
123	25	0	N/A	N/A
93	17	3	No	No

Note: N/A = not available.

TABLE 3
COMPARISON OF MAINTENANCE TRAINING BUDGETS

No. of Buses	No. of Mechanics	Annual Maintenance Training Budget ($)	Annual E/E Training Budget ($)	Affect of On-Board E/E Equipment on Maintenance Budget
1,371	268	3,500,000	375,000	N/A
1,256	346	1,700,000	100,000 (est.)	Increase downtime and failure rate
842	240	400,000	N/A	N/A
700	297	50,000	N/A	N/A
510	142	450,000	55,000	2 to 3% offset by ease of diagnostics
387	110	125,000	17,500	20% (parts expensive)
340	110	100,000	N/A	Increase, uncertain
330	60	130,000	25,000	12%
276	38	60,000	N/A	25%
264	54	100,000	N/A	N/A
228	44	75,000	N/A	100%
197	47	5,300	0	Minimal increase
155	45	10,000	0	N/A
148	44	25,000	1,000	15% increase
123	25	14,500	N/A	N/A

Note: N/A = not available.

of buses, number of mechanics, training budgets, and the affect that on-board E/E equipment has had on agency budgets. The largest agency responding to the survey spends an average of $1,400 per mechanic annually on E/E training, whereas the smallest agency spends an average of less than $25 annually per mechanic. Considering that the level of E/E complexity of buses is nearly equal for both agencies, the funds provided for training differed greatly.

KNOWLEDGE AREAS

Bus maintenance personnel require a great deal of knowledge when it comes to on-board E/E technologies. In addition to diagnosing and repairing the equipment, they often participate in writing specifications and assisting bus operators with their questions. E/E knowledge areas *(in addition to* those related to technology reported in chapter 2 for management) that bus maintenance personnel should be familiar with include

- Fundamentals of electricity (e.g., current, voltage, and resistance);
- Ohm's Law (the relationship between current, voltage, and resistance);
- Electrical circuits (e.g., series, parallel, and series–parallel);
- Building and testing electrical circuits;
- Multiplexing—operation, diagnostics, and repair;
- Fundamentals of electronics (e.g., diodes, transistors, and integrated circuits);
- Procedures and tools for testing and diagnosing E/E components (e.g., PCs, voltmeter, ammeter, multimeters, and carbon pile);
- Troubleshooting and repairing starting and charging circuits;
- Ability to read wiring schematics, diagrams, and related symbols;
- Troubleshooting and repairing DC motors (both brush and brushless);
- Welding and other vehicle repair activities that may affect on-board E/E equipment;
- Understanding diagnostic codes, troubleshooting, and repairing all electronically controlled equipment including engines, transmissions, braking systems, air conditioning systems, destination signs, and fareboxes; and
- Understanding mobile two-way radio communications technology, including the diagnosing and repairing of radio equipment.

A test to assist maintenance managers determine if they and the mechanics working for them have a basic understanding of these knowledge areas is included in Appendix D; Appendix E includes the answers. Test questions were compiled from the literature search and actual tests used by transit agencies that participated in this study.

In addition to the knowledge areas listed previously, the study indicates that maintenance managers need to prepare themselves for the E/E equipment that will become a part of bus technology in the near future. One such technology is 42-volt electrical systems, which are expected within the next 5 years. The move to a 42-volt system is both dramatic and far-reaching, affecting virtually every area of vehicle supply, assembly, component design, and manufacture (*19*). Technology advances expected from the switch to 42 volts include electrically operated power steering, brake and suspension systems, more efficient water pumps, improved pneumatic and hydraulic systems, preheated exhaust catalysts, and fully electric air conditioning systems.

The 42-volt systems are also expected to result in the use of an integrated starter–alternator unit needed to cope with the ever-increasing electrical loads produced from on-board equipment. The integrated starter–alternator will also allow the engine to be shut down during idle and immediately restarted when needed to reduce fuel consumption and exhaust emissions. This completely new approach for generating power and starting, which will require dual voltage capability for a transitional period, will introduce added complexity and require yet another set of E/E skills for mechanics to learn.

Other new E/E technologies that maintenance managers need to prepare themselves for include hybrid-electric and fuel cell propulsion systems, where electric power and related control systems are used to power the bus, and electronic dashboards, where controls, instruments, and displays are fully electronic.

CHAPTER FOUR

OPERATIONS TRAINING

SAFETY IS JOB NO. 1

According to NJT's *Professional Operator Workbook*, which is used by more than 3,000 bus operators, the primary responsibility of an operator is safety—ensuring the safety of passengers, the general public, the bus, the facilities, and co-workers (*20*). The introduction of advanced on-board E/E equipment, especially that related to information and communications systems, has added significantly to operators' responsibilities. The steady growth of telematics, the term used to describe a host of in-vehicle electronic devices that require interaction from the operator (e.g., radio, navigation, fare collection, and destination signs), has brought with it an increased need for training. This training is not only required to ensure the proper operation of the equipment, but to minimize any potential distractions that operating this equipment might cause.

Telematics and Potential Distractions

Although there are no known studies on the relationship between the increased use of in-vehicle telematics and potential distractions to transit bus operators, there are several studies related to telematic distractions in automobiles. Major automobile manufacturers are currently studying the subject through the use of driver simulators, whereas several universities have issued reports on their findings.

A study conducted by the University of North Carolina's Highway Safety Research Center reviewed accidents involving 32,000 vehicles that occurred from 1995 through 1999 (*21*). The study found that 8.3% of those accidents were the result of the driver being distracted by telematics. Of those accidents, 11.4% happened while the driver was making audio system adjustments, 3% while making climate control adjustments, and 1.5% while using a cell phone. In another study conducted by Response Insurance, cell phone use accounted for a higher percentage of accidents and near-accidents. According to that study, 13% of cell phone users said that using the phone caused, or almost caused, an accident (*21*).

Although applications are different between cars and buses, and the percentages for telematic distractions are relatively low, interaction with on-board E/E equipment has the potential to cause distractions. According to a researcher at General Motors, the human element is the most important and the most difficult element to deal with regarding telematics. Although providing drivers with information can enhance safety (e.g., traffic conditions, weather, and detours), there is the potential for distraction by providing information in a less-than-ideal way. According to the General Motors researcher (*21*)

> To understand the best way to provide any particular information—or whether to provide it at all—one really has to understand how the driver is carrying out the driver tasks minute by minute . . . The most difficult part of telematics is understanding the driver's needs—or cognitive workload—and understanding how to provide the information that the driver wants or needs in a way that does not distract him or her from driving.

Driver-distraction testing is also being conducted by the National Highway Traffic Safety Administration through a $40 million simulator facility and by closed-course and open-road driving tests. Until transit-specific studies are undertaken, agencies can mitigate potential distractions caused by on-board electronic equipment by providing operators with adequate training. As discussed later in this chapter, improved operator training with regard to on-board E/E equipment also assists maintenance personnel with fault diagnosis. Several agencies have instituted programs and procedures to improve the communication between bus operators and maintenance.

Multiple Keypads Increase Training Requirements

The increasing amount of on-board E/E equipment, such as destination signs, AVL, fare collection, and radios, requires the operator to interact with several control panels or "keypads" located throughout the operator's workstation. Not only do these keypads take up valuable space, they require operators to memorize different programming routines for each system and vehicle.

The most recent version of APTA's *Standard Bus Procurement Guidelines* contains a revised section on Electrical, Electronic and Data Communication Systems (Section 5.5) that uses as a baseline a single human machine interface (HMI) networked with other components. Although this approach is actually some time away from implementation, the intent is to get the industry moving in this direction. Using a single HMI to access multiple systems has become commonplace in modern automobiles. Survey results indicate that agencies would like to apply the HMI concept to transit buses as well.

TRAINING PROCEDURES

Use of Detailed Manuals

Until such time when several on-board systems are integrated into a single HMI (or a limited number of HMIs) as has been accomplished with the automobile, operator training is focused on providing detailed instructions on each bus system. Because the amount of information needed for operating these systems can be extensive, detailed manuals become an essential part of an agency's training program. The manuals produced by NJT serve as good examples. Not only do they assist NJT with its operator-training program, they also document the operator's responsibilities and serve as a reference and refresher when needed.

Detailed NJT bus operator manuals, available for each bus type, use a step-by-step approach to describe various bus functions and troubleshooting procedures. Each manual begins with a technical comparison of each bus model and includes 40 different categories such as length, width, engine type, cost, and whether they are equipped with transmission retarders, ABS, daytime running lights, and other features.

The manuals go on to provide detailed information on the operations of every major on-board system including HVAC, emergency alarm, automatic fire suppression, destination signs, and ABS. Of particular interest is NJT's troubleshooting section. Concise, step-by-step instructions are provided to assist bus operators in remedying malfunctions and ensuring that the basic steps have been taken before additional help is requested. The troubleshooting section prepared by NJT for an MCI D4000 commuter bus is included as Appendix C. It addresses several E/E areas, including the troubleshooting of the multiplex system, lighting, destination signs, wheelchair lift, and other equipment.

Providing instructions on operating on-board E/E equipment is just one part of NJT's overall operator training program, which includes sophisticated driving simulators to provide real-life training and job screening before prospective employees actually get behind the wheel. The state of New Jersey licenses NJT as a recognized driving school. The vast resources available to NJT, combined with their dedication and professionalism, allows them to provide the type of training needed to operate a modern transit bus fully equipped with sophisticated technical and electronic equipment.

Procedures at Other Agencies

The amount of operator training provided annually for E/E equipment by agencies responding to the survey varied greatly, from 15 min to 50 h, with the majority falling in the 5- to 10-h range. The amount of training provided depends on the type of on-board equipment the agencies have. AVL training is the most extensive for operators, requiring approximately 4 h. Typical AVL training is recommended before, during, and approximately 6 months after implementation to ensure that operators understand the procedures involved. Agencies also recommend that follow-up training be conducted periodically because of the complexities involved and because agency policies and procedures change over time. Providing on-going training is also beneficial in that it allows operators to pass on suggestions concerning ways to use the equipment more efficiently after they gain more experience with it.

The majority of survey respondents have the bus manufacturer or product vendor train agency trainers, who in turn provide the operator with training on E/E equipment. The "train the trainer" approach is common for AVL, as well as for other E/E equipment training because of the number of operators involved.

Virtually all survey respondents cite hands-on training, where operators work with actual E/E equipment, as the primary method used to provide training. Long Beach Transit uses film-editing equipment to produce in-house videos to assist with their operator-training program. Most agencies report limiting class size to 10 to 15 individuals.

LYNX (Orlando, Florida), Metro Transit (Minneapolis, Minnesota), and Connecticut Transit provide mock-up equipment such as a fareboxes, radios, and destination signs in the operator's room, which provides the operator with the opportunity to practice with the equipment as needed. Others agencies place informational videos on advanced on-board E/E equipment in the operator's room for them to view in their free time.

A popular training aid used for AVL equipment is the so-called "bus in a box." All of the components typically found in the bus are contained in a tabletop mock-up, which allows operators to become familiar with the equipment in a classroom environment. Figure 11 shows a classroom display of an AVL mock-up consisting of an operator's handset, speaker, display terminal, covert microphone and activation device, radio, and vehicle logic unit.

When asked to rate the effectiveness of their own in-house training program for operators on a scale of 1 to 5 (with 1 = low and 5 = high), survey respondents gave themselves an average score of 4.1, indicating a large measure of satisfaction with their programs. Survey respondents also gave vendors an average score of 4.1 for their training programs, and rated training aids such as the bus-in-a-box and other training mock-ups slightly higher at 4.5.

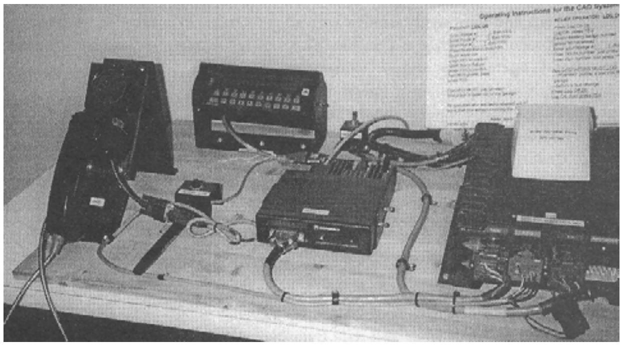

FIGURE 11 Classroom "bus in a box" display of AVL system (source: Ann Arbor Transportation Authority).

HUMAN RESOURCES

Labor Issues

Most agencies did not address the question dealing with labor issues associated with bus operators and the use of on-board E/E equipment. Those agencies that reported labor issues, however, cited the following

- Union does not allow the operator to diagnose faults.
- Union demands hard copies of any video surveillance photos if an operator is involved in a violation of rules.
- Wage adjustments are requested when an operator becomes qualified on E/E equipment.
- Union resisted agency demands that students be tested as a way of validating the training, but eventually withdrew its opposition.

Operator Feedback to Maintenance

As noted earlier in this chapter, obtaining accurate feedback from operators on the condition of the vehicles they drive assists maintenance with diagnosing problems. Operators spend extended periods of time in a bus and, if properly trained, can provide valuable information to maintenance.

All survey respondents listed the Operator's Bus Condition Report, also known as a "defect card," as a way of obtaining feedback from operators on E/E equipment. By law, operators are required to conduct a pre-trip inspection before boarding passengers and the defect card is typically used to communicate any deficiencies found. The card must be completed, signed, and returned by the operator after each run. Maintenance then reviews the cards and schedules needed repairs.

NJT uses an automated approach to communicate defects noted by the operator to the maintenance department. Operators use a pen or pencil to darken squares on a specially produced defect card to indicate up to 20 pre-printed (or most commonly occurring) defects. If the pre-printed defects listed are not sufficient to describe the problem, a darkened square is used to indicate that written comments are included elsewhere on the card. The operator can also darken the appropriate squares to indicate bus and operator numbers. Cards are then run through a machine that identifies the defect(s) marked by the operator and automatically issues a repair order. Pierce Transit in Tacoma, Washington, uses a similar system for automatically generating a work order from what are called "electronic defect cards."

To encourage operators to provide feedback, the Central New York Regional Transportation Authority (CENTRO) in Syracuse, New York, has their maintenance department send a written response to the operator explaining how the reported problem was addressed (*22*). Maintenance personnel are also able to spend time riding with operators to get a better understanding of a problem. The team approach between operators and maintenance helps CENTRO to efficiently identify and repair faults. The Santa Cruz Metropolitan Transit District requires maintenance personnel to interview operators when they submit their defect cards to obtain first-hand information concerning the reported defects.

Nearly 90% of the respondents reported that providing operator feedback to maintenance on E/E and other faults is effective. However, because operators were not interviewed as part of the survey, their opinions concerning the effectiveness may not be the same. Despite the high approval rate of existing approaches, 50% of agencies responding to the survey had suggestions for improving the process of informing maintenance personnel of defects. A summary of the comments received included

- Improving communication between operators and maintenance,
- Providing more technical training to operators,
- Having operators and maintenance personnel use the same terminology to describe faults, and
- Holding operators accountable for completing the defect card in full.

Survey respondents also indicated that radio dispatchers need better training to work with operators when troubleshooting faults. Because dispatchers communicate directly with operators and are often required to make decisions concerning the need for road assistance calls, detailed technical training on E/E equipment can prove valuable in working with operators to determine the exact nature of the fault and whether road assistance is required.

Houston Metro holds quarterly meetings with operators that specifically address issues related to on-board E/E equipment, whereas the Ann Arbor Transportation Authority uses an operator committee to discuss E/E and other issues with maintenance. Both agencies reported that they have benefited from these meeting because they provide operators with a better technical understanding of the vehicles they operate and familiarity with related terminology. They also report that the meetings foster a cooperative working relationship between operators and mechanics.

When a bus operator has a specific question regarding the functionality of on-board E/E equipment, 35% of survey respondents reported maintenance as one of the departments where the question gets directed. Only one agency directs operator questions to an "electronics person," while the remainder direct questions to the street supervisor, dispatcher, or operations trainer. Nearly 85% report that the procedures in place to address specific E/E questions by the operator are adequate, although 50% report that additional training and/or improved communication would enhance the process.

OPERATIONS MANAGEMENT TRAINING

Of those agencies responding to the survey, 85% provide on-board E/E equipment training to bus operations managers and supervisors. Nearly 80% reported that existing procedures to provide this training were adequate. However, nearly all (more than 93%) indicate that additional training—and time—was needed to improve the operations manager's understanding of the technology. When asked if it would be beneficial to have the operations management and supervisors become more knowledgeable in E/E equipment and maintenance, more than 86% answered yes. Reasons for improving the operations management's knowledge include

- Providing a better overall view of the equipment to operators,
- Being better able to assist maintenance,
- Answering operator questions immediately and advising them correctly,
- Understanding the needs of operators better,
- Having street supervisors provide the assistance needed to reduce road calls, and
- Allowing operators to make full use of technology.

KNOWLEDGE AREAS

As mentioned previously, having a better understanding of the equipment allows operators to use that equipment more efficiently and helps them to communicate more effectively with maintenance. Determining how knowledgeable operators and their managers should be about advanced on-board E/E equipment is an area that each agency must address individually. Given that the operator's primary responsibility is to operate the bus safely, having a technical understanding of how the equipment functions certainly becomes secondary. However, safety is often linked to the correct operation of the equipment. In addition, having a basic understanding of how the equipment functions and the terminology involved helps to keep the equipment working properly.

Take anti-lock brakes for example. Agencies such as NJT want operators to know that electronic sensors constantly monitor wheel movement and that under braking the system automatically releases brake pressure to any wheel that stops moving before the vehicle does. Having this understanding gives the operator the confidence to apply continuous, heavy pressure on the brake pedal during a panic stop, while steering around the trouble spot, knowing that traction with the road surface is being maintained automatically by ABS.

NJT also wants the operator to understand that if the ABS malfunction light should illuminate, the service brakes work in the same manner as buses without ABS. As a result, the operator is instructed to let up slightly on the brakes if wheels lock and report the malfunction on the daily defect card. Having a basic understanding of the technology allows NJT operators to react correctly—and safely—when a malfunction occurs. An understanding of the terminology involved allows the operator to describe the malfunction in a manner understood by maintenance.

Knowledge areas needed for bus operators are somewhat difficult to summarize because of the variety of equipment used by agencies and their differing philosophies. Some agencies report that bus operators should be given only the information needed to operate the equipment, and that giving them too much information is counterproductive. Others agencies, such as NJT, Houston Metro, and the Ann Arbor Transportation Authority, believe in making operators more knowledgeable about the equipment they operate.

In addition to the example of ABS, other essential E/E-controlled systems that agencies may want their bus operators to have a greater technical understanding of (depending on their management philosophy) are reviewed here.

- Engine
  - General operation, including electronic controls and integration with transmission and ABS.
  - Traction control feature (if equipped) and conditions/procedures for switching on/off.
  - Location of rear-start switch, battery disconnect switch, voltmeter (if installed) for proper battery voltage, and other engine-related E/E equipment.

- Understanding of warning lamps and gauges, and related procedures when lamps illuminate and gauge levels exceed the maximum.
- Understanding of automatic engine protection and shutdown, conditions that can cause the engine to shutdown or reduce power, use of related gauges to help verify fault, and procedures to override the engine protection system.
- Understanding of the data that can be retrieved from the drivetrain system (e.g., vehicle speed characteristics, idle time, fuel economy, and brake applications).

- Transmission
  - General transmission operation, including electronic controls and integration with engine, retarder, and ABS.
  - Retarder feature (if equipped) and conditions/procedures for switching on/off.
  - Warning lamps and related procedures when lamps illuminate.
  - Procedures for placing bus in and out of gear (e.g., fast idle off and service brakes on).

- Electrical System
  - Multiplexing characteristics and features.
  - Lights and other equipment that may be in “sleep mode” after master control switch has been off for some time.
  - Procedures for resetting the system.
  - Procedures when malfunction lights illuminate.
  - Any special features that may be programmed into the system (e.g., headlamps automatically go on when wipers activated).

- Fire Suppression
  - Operating features of the system, location of all components, and familiarization with the control panel.
  - Procedures for engine shutdown and override.
  - Manual activation procedures.

- Destination Sign
  - Familiarization with control panel (e.g., keypad).
  - Programming procedures.
  - Emergency alarm procedures.

- HVAC
  - Operating features of the system, location of all components, and familiarization with the control panel.
  - Procedures for air conditioning and heating.
  - Procedures for auxiliary heat (if equipped).

- AVL/Radio

(Note: Each system has its own unique set of requirements, which are best presented by the AVL/radio supplier. Typically, the supplier trains an agency trainer, who in turn trains the operators.)

  - Understanding and location of all system components, including the handset and mobile data terminal.
  - Procedures for using on-board equipment including communicating with voice and text messages, priority communication, and standard communication modes.
  - Log on/off procedures.
  - Use of covert microphone, alarms, and other emergency procedures.
  - Understanding of operator-initiated and dispatcher-initiated functions.

- Wheelchair Lift
  - Procedures for setting the engine, transmission, and brake.
  - Operating lift controls.
  - Procedures for securing the wheelchair inside the bus.
  - Operating the lift manually when the power system fails.

- Fare Collection
  - Sign-on procedures (i.e., employee identification number).
  - Understanding fare-related terminology and reader abbreviations.
  - Initialization procedures (i.e., run number, line number, etc.).
  - Procedures for end of trip, end of run, relief, break, etc.
  - Procedures for sign-off.

- Stop Announcement/Microphone
  - Activating the power.
  - Procedures for delivering inside and outside messages.
  - Procedures for delivering automatic messages and manual announcements.

CHAPTER FIVE

CONCLUSIONS

Several conclusions can be drawn from this study, the most significant being that the proliferation of on-board bus electronics has brought with it the need for teaching a new set of skills to those who manage, procure, operate, and maintain this complex equipment. Without these skills transit agencies face the prospect of wasting large sums of money on equipment that does not function properly and lagging behind in nationwide efforts to link all land-based transportation into one intelligent system.

The substantial benefits—and risks—associated with electrical and electronic (E/E) technology demand that agencies and the transit industry as a whole focus completely on training. More than setting aside time and processing employees through a series of "training courses," the training itself must be effective at addressing specific agency needs. A discussion about protons and electrons is useful when it comes to understanding electrical theory; however, this knowledge alone does little good if technicians cannot apply it when repairing defective equipment. Ensuring that E/E training programs provide the necessary knowledge and skills requires a consolidated effort by agency management and the entire transit community. The risks associated with not applying E/E technologies correctly are too critical to dispense training in a haphazard manner. Although the cost of providing effective training may be high, the price of not providing it will certainly be higher.

Other conclusions drawn from this study are grouped here by category.

- **Training in General**
  - The level of complexity inherent with on-board E/E bus equipment is the same for all agencies regardless of fleet size and resources.
  - Agencies with fewer resources may have a more difficult time establishing effective training programs.
  - Effective training is based on proven educational platforms developed and taught by professionals with the ability to
    - Design training curriculums that achieve specific job performance outcomes (i.e., enhance workers' current capabilities with the additional knowledge and skills that address specific deficiencies in the workplace).
    - Produce lesson plans with stated objectives and required training materials.
    - Incorporate the appropriate mix of classroom and hands-on activities.
    - Establish the criteria for successful completion of the training (e.g., pass written and hands-on tests with minimum passing score).
    - Validate test questions to ensure that they are appropriate.
    - Keep records of those attending courses and make certain that training is administered to those who need it.
    - Provide refresher training as needed.
  - Many training sources exist to supplement in-house programs. They include programs and materials provided by equipment manufacturers and suppliers, the FTA, Intelligent Transportation Society of America, Institute of Transportation Engineers, National Transit Institute, Transit Standards Consortium, community colleges, private training institutions, and other transit agencies. (A listing of training sources is included in a separate section following the References).
  - Validating outside training programs before they are given to agency personnel ensures that course objectives meet specific agency needs.
  - Including training, manuals, training aids, special tools, and other materials as part of new bus and equipment procurements uses capital funding to impart needed E/E skills to employees. The extra costs involved with providing this material, however, will affect the number of buses that can be procured under a fixed budget.
  - A knowledgeable work force allows personnel from different departments to work together to obtain E/E equipment that benefits the agency as a whole.

- **Management Training**
  - The role of senior management is primarily seen as one of obtaining the necessary funding and support for E/E training.
  - An improved understanding of E/E technologies allows senior management to fully comprehend E/E funding requirements, promote agencywide training, take an active role in developing nationwide standards, provide useful project oversight, and assist with long-range planning.
  - Areas where management could play a greater role with regard to the implementation of standards include
    - On-board data communication for so-called "Information Level" components [e.g., automatic

vehicle location (AVL), fare collection, automatic passenger counters, radios].
- ➢ Use of single operator interface (e.g., keypad) to control multiple on-board E/E systems.
- ➢ Use of a central location to diagnose on-board E/E faults and obtain data from bus systems.

- **Maintenance Training**
  - Although solid-state electronic components are said to be "maintenance free," they malfunction periodically and require skilled technicians and special tools to diagnose and repair.
  - Many of the tools needed by mechanics include PCs, electronic multi-meters, and a new series of pocket-sized electronic tools, all of which require specialized skills to operate correctly.
  - Agencies are inconsistent in their allocation of maintenance training funding, with amounts ranging from $1,400 per mechanic annually at the largest agency surveyed to less than $25 per mechanic annually for the smallest agency.
  - Linking maintenance training to job and pay advancement serves as an incentive for improving knowledge and skill levels.
  - Future technologies such as 42-volt electrical systems, electronic dashboards, and electric propulsion systems will add more complexity to buses and require maintenance personnel to acquire yet another set of E/E skills.
  - Maintenance training should assume that technicians know little or nothing about E/E theory; instruction should start at the beginning to ensure that basic knowledge areas are fully understood before moving on.
  - Interactive computer training is available and useful for allowing maintenance and other agency personnel to become familiar with computers and to learn about E/E subjects and products at their own pace.
  - Working closely with labor unions in the development of training programs is essential, especially when using tests for hiring and advancement purposes.

- **Bus Operations Training**
  - Training bus operators, their managers, and dispatchers to understand the basic functionality of E/E equipment and related terminology helps to ensure that E/E equipment will be operated properly. This understanding also assists maintenance with fault diagnosis.
  - Proper operation of advanced on-board E/E equipment by bus operators is essential given the potential distractions that interacting with this equipment may cause.
  - Detailed bus operator manuals assist with training because they document responsibilities and serve as a convenient refresher when needed.
  - The "training-the-trainer" approach, where manufacturers and suppliers train agency instructors who in turn train operators, is a common approach given the large number of operators that require training when new equipment is introduced to the fleet.
  - To facilitate operator training on AVL and similar equipment, the "bus-in-the-box" mock-up, where all on-board components are assembled on a working display, is a helpful tool for learning.

Based on the conclusions drawn from this study, four primary findings are offered.

1. **Reexamining Existing Training Programs**—Agencies should reexamine their existing training programs to ensure that the new skills needed as a result of complex E/E technologies are firmly in place. To assist agencies determine if additional training is required, a series of tests developed from information collected in this study are included in Appendix D. The ultimate responsibility for providing training falls on senior management. Their role in obtaining the necessary funding and resources is critical to the successful implementation of E/E technologies.

2. **Becoming More Knowledgeable**—Senior management and the entire transit community should improve their collective understanding of E/E technologies to facilitate the efficient and cost-effective implementation of these technologies. Agency management can take advantage of the many sources identified in this study, including *TCRP Report 43*, discussions with knowledgeable staff members, participation in existing in-house training programs, and by taking courses offered by the FTA, National Transit Institute, and other organizations. In particular, FTA's Outreach Training Program for managers is suggested, along with other FTA-sponsored training programs.

Training for bus operators and their supervisors can be accomplished through an enhancement of existing in-house programs supplemented by "train-the-trainer" instruction provided by bus manufacturers and equipment suppliers. Training for bus maintenance personnel is later addressed as a separate recommendation.

3. **Adopting Standardized Approach to Equipment Integration**—The transit bus industry should use its collective understanding of E/E technologies to adopt a standardized approach to equipment integration. Areas where the standardized approach to equipment integration is needed include

- An on-board data communications solution to sharing data between "Information Level" equipment such as AVL, automatic passenger counters, and fare collection that promote the open exchange of data and limit proprietary approaches. *(Note: Some, but not all, agencies accept SAE J1708 as a suitable approach to on-board data communications for their operations.)*
- A single operator interface, which would allow bus operators to make one keypad entry to initialize multiple on-board systems such as fare collection, destination signs, radio/AVL, etc.
- A single data port for accessing diagnostic and other data from multiple on-board systems.

4. **Establishing Regional Maintenance Training Centers**—The need for improved E/E maintenance training was clearly indicated by the material examined in this study. However, obtaining the knowledge and skills needed to effectively diagnose and repair sophisticated E/E equipment requires the level of professional training exhibited by New Jersey Transit and Dallas Area Rapid Transit, the two case study examples used in this synthesis. Most agencies simply do not have the resources needed to achieve this level of training. Furthermore, the skills needed by maintenance are extremely comprehensive, which is not surprising given that much of it was developed for aerospace applications.

Given these conditions, it is suggested that serious consideration be given to a proposal to establish training centers for bus maintenance. Although the original proposal encompassed all maintenance training activities, this suggestion applies specifically to E/E-related training. (If needed, the training could then be expanded to include other areas of bus maintenance as well.)

This suggestion involves establishing a series of regional E/E maintenance training centers throughout the country. These centers would use the resources of transit agencies that already have extensive training programs and aids in place. Depending on the agencies qualified to administer this training, the centers could be established using the existing FTA regional structure.

Using this approach, each agency would continue to provide agency-specific training. However, the bulk of E/E training for maintenance personnel would be held at regional centers located at selected transit agencies. These regional transit centers would be fully equipped with qualified instructors, training mock-ups, interactive video equipment, and other training materials. To support the additional requirements imposed on these centers, agencies could pay a fee to attend and/or other sources could provide additional assistance. The regional training approach would ensure that training is administered professionally and that it would eliminate the duplication of vast resources required at each agency.

As part of the Survey Questionnaire, agencies were asked to provide suggestions that they felt would be useful to their peers concerning E/E training. Many of these suggestions apply to the implementation of E/E technologies. However, because technology implementation affects training, the suggestions are included here to assist other agencies understand the issues involved. These suggestions serve as examples of "lessons learned" to assist other agencies determine where to place their training emphasis, and the steps bus transit as a whole could take to improve the implementation of E/E technologies. The frank suggestions provided here (almost) word for word also substantiate the synthesis findings.

Implementation Suggestions

- Start small. Choose projects one at a time to build intelligent transportation system applications; do not try to do everything at once.
- Use proven technologies. Do your homework and check equipment supplier references; do not attempt to be a pioneer in a specific technology.
- Learn from the experiences of others before embarking on your own programs that involve E/E technologies. Work with other agencies to determine what equipment is effective and what is not.
- Ensure that equipment purchased can be upgraded or will meet foreseeable needs throughout the life of the vehicle.
- Keep a close watch over the manufacturers and the installation of E/E systems; validate contract compliance and double-check everything.
- The bus industry should start a nationwide information-sharing program on E/E applications.
- Be prepared for confusion on the part of technicians and bus operators when introducing E/E equipment.
- Understand how individual E/E equipment affects the overall picture.
- Double the time originally estimated for procuring, installing, and de-bugging E/E equipment. Also, plan for a 10 to 15% increase in the cost of spare parts.
- Set implementation goals based on benchmarks and best practices.
- When planning for equipment, look far enough ahead of the constantly changing electronics industry.
- Clearing the "bureaucratic clutter" allows systems integration to take place in a timely manner.
- Fully test equipment before placing it in service.
- Only purchase equipment that you need for managing the operation (not the latest gizmos).
- Learn how to make full use of the equipment's capabilities.

Procurement Specification Suggestions

- Include training requirements when writing specifcations for new bus procurements.
- Include E/E training, tools, and training support equipment when writing procurement specifications.
- Include training requirements as part of the American Public Transportation Association's Standard Bus Procurement Guidelines.
- Take advantage of the technical support offered by component manufacturers when writing technical specifications for new equipment procurements.

General Training Suggestions

- Assign a full-time staff person—or contract—to plan, implement, develop, and deliver new technology training.
- Train all agency personnel involved with E/E equipment to provide agencywide input and oversight on specific projects.
- Involve the younger employees with computer and electronic knowledge who have an interest in the E/E technologies and are eager to learn more.
- When training people on E/E equipment, try not to overcomplicate the subject.
- Take advantage of the many training programs and materials available from outside sources.
- Evaluate all outside training before it is given to agency personnel.
- Include training time in annual manpower plans.
- Have upper management take a more active role in promoting training and developing industrywide standards.

Maintenance Training Suggestions

- Ensure that maintenance personnel have basic E/E theory and troubleshooting skills before requiring them to repair E/E equipment.
- Use of laptop PCs and related software programs, when used by someone who is properly trained, definitely helps shop personnel keep vehicles operating at peak performance.
- Consider the advantages and disadvantages of having either a dedicated group of specialists to make E/E repairs or requiring all mechanics to make the repairs when structuring your maintenance organization.

Funding

- Be prepared to spend money on E/E equipment and related training.
- Provide sufficient funding for a solid E/E training program.

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TRAINING SOURCES

The following listing provides a convenient reference of organizations, books, and reports available on electrical and electronic (E/E) subjects and training.

Organizations

U.S. Department of Transportation (USDOT)
The USDOT Intelligent Transportation System (ITS) website, http://www.its.dot.gov, provides information on, and links to, a variety of ITS-related activities and training programs.

Federal Transit Administration (FTA)
The FTA website, http://www.fta.dot.gov, has an education link to the Peer-to-Peer and Technical Assistance programs designed to assist agencies implement ITS technologies. (Links to these sites are also available through the USDOT ITS website.)

The Peer-to-Peer Program provides short-term assistance in the form of industry experts willing to address specific ITS issues. The Technical Assistance program also uses industry experts who travel to transit agencies to evaluate planned or on-going ITS projects and provide assistance. The assistance is directed toward helping agencies understand and apply the FTA National ITS Architecture Policy for Transit Projects. The policy recommends the use of standards when implementing ITS technologies, allowing data generated by the technologies to flow in an open manner between the bus, the local transit agency, regional agencies and organizations, and, ultimately, the entire ITS national community.

Requests for technical assistance should be directed to the regional FTA office.

American Public Transportation Association (APTA)
The APTA website, http://www.apta.com, offers several education and training programs. APTA is also working with TRB to develop Bus Transit System Standards (TCRP C-14). Under the guidance of transit industry working groups, the project will identify and prioritize the standards and recommended practices most needed by the bus transit industry. The C-14 project begins with a fast-tracked effort to develop standards using the Society of Automotive Engineers (SAE) process. In its early stages, the C-14 project may adopt standards and recommend practices relating to E/E activities.

Intelligent Transportation Society of America (ITS America)
The mission of ITS America is to foster public/private partnerships to increase the safety and efficiency of surface transportation through the application of advanced technologies. Their website, http://www.itsa.org, contains information on research, planning, standards development, deployment, and marketing of ITS programs, products, and services.

Transit Standards Consortium (TSC)
The mission of TSC is to provide a transit industry forum for comprehensive and integrated research, development, testing, training, and maintenance of transit standards to improve cost-effectiveness, customer service, and employee satisfaction. Much of the work in standards is directed toward data communications standards for transit applications. Their website, http://tsconsortium.org, contains information on, and links to, several topics related to E/E activities, including education and outreach, along with cooperative activities with SAE.

Society of Automotive Engineers (SAE)
The SAE website, http://www.sae.org, is a one-stop resource for technical information and expertise used in designing, building, maintaining, and operating all forms of self-propelled vehicles including trucks and buses. SAE technical committees have established several standards and recommended practices used in bus applications. SAE also publishes technical papers and books, and offers a wide range of training programs. SAE is working with the transit community to develop a new series of standards for buses (see APTA entry).

National Transit Institute (NTI)
NTI was established at Rutgers University through the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 to support the national training and development needs of the transit industry. The purpose of NTI is to develop and implement a national program of training for federal, state, and local employees, and to provide a national clearinghouse of training and development material. Information on training opportunities is available at the NTI website, http://www.fta.dot.gov/library/program/NTI.HTM.

American Society for Training and Development (ASTD)
ASTD is a professional association consisting of 150 chapters that provides information, research, analysis, and practical information on workplace learning and performance issues. ASTD provides a variety of practical tools and publications that showcase the latest professional training trends and techniques being used worldwide. The ASTD website is located at http://www.astd.org.

Publications

Schiavone, J., *TCRP Report 43: Understanding and Applying Advanced On-Board Bus Electronics*, Transportation

Research Board, National Research Council, Washington, D.C., 1999.

Provides a general understanding of advanced on-board equipment, including the data communication networks that exchange data between this equipment.

Wireman, T., *World Class Maintenance Management*, Industrial Press, Inc., New York, N.Y., 1990.

Reviews the management controls that must be in place to improve maintenance efficiency and reduce costs. An entire chapter is dedicated to maintenance training.

Accredited Institutions of Post-Secondary Education Programs Candidates, American Council on Education, Washington, D.C., 2000.

Provides a directory of accredited institutions, professionally accredited programs, and candidates for accreditation.

Mehrens, W.A. and I.J. Lehmann, *Measurement and Evaluation in Education and Psychology*, Holt, Rinehart & Winston, Inc., Orlando, Fla., 1984.

Includes a series of procedures that can be used to evaluate the effectiveness of training programs.

Kirkpatrick, D.L., *Evaluating Training Programs*, 2nd Ed., Berett–Koehler Publishers, Inc., San Francisco, Calif., 1998.

Includes procedures to determine if learning actually took place, if what was learned was transferred to the workplace, and the effect of the training on the organization that sponsored the training.

Mager, R.F., *Analyzing Performance Problems, Preparing Instructional Objectives, Measuring Instructional Results, How to Turn Learners On…Without Turning Them Off, Goal Analysis, Making Instruction Work,* The Center for Effective Performance, Atlanta, Ga., 1997. http://cepworldwide.com.

The six books by Robert Mager, a highly respected member of the training and development community, simplify the critical elements of designing effective instruction and improving performance. The first step in this process is to determine if a need exists for instruction, then develops learning objectives from the work in which the student will be expected to function. The next step involves determining which objectives the study already can do, then develops training that fills the gap between what students can already do and what they need to do.

ACRONYMS AND ABBREVIATIONS

AATA	Ann Arbor Transportation Authority
ABS	anti-lock brake system
APTA	American Public Transportation Association
APTS	Advanced Public Transportation System
AVL	automatic vehicle location
CENTRO	Central New York Regional Transportation Authority
CNG	compressed natural gas
DART	Dallas Area Rapid Transit
DC	direct current
DDC	Detroit Diesel Corporation
DOT	Department of Transportation
E/E	electrical/electronic
EPROM	electronically programmable read only memory
FTA	Federal Transit Administration
GIS	Geographic Information System
GPS	global positioning system
HVAC	heating, ventilation, and air conditioning
IC	integrated circuit
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System
JPO	Joint Program Office
LED	light-emitting diode
LYNX	Central Florida Regional Transportation Authority
NHTSA	National Highway Traffic Safety Administration
NJT	New Jersey Transit
NTCIP	National Transportation Communications for ITS Protocols
NTI	National Transit Institute
NYCTA	New York City Transit Authority
RF	radio frequency
SAE	Society of Automotive Engineers
TCIP	Transit Communications Interface Profiles
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century
TRB	Transportation Research Board
TSC	Transit Standards Consortium
VAN	Vehicle Area Network
VLU	vehicle logic unit

APPENDIX A

Survey Questionnaire

Transit Cooperative Research Program
Project J-7, Topic SF-9

"Employee Electronic System Training for Transit Bus"

GENERAL INFORMATION

Name/Title of Respondent____ Date ______________

Note: Please direct questions to the appropriate staff in your agency

Transit Agency Name____

Location (City, State/Province)____

Contact Phone # ____ FAX___________________

E-Mail Address ____

Mailing Address (office)

____

____

Purpose: Bus transit has entered a new era of electronic technology that brings with it a new set of capabilities and challenges. Without proper employee training, many of the advantages offered by advanced on-board electronic equipment will not be realized. The complexity of this new technology and the need to provide adequate training cannot be overstated.

The goal of this project is to document electrical and electronic (E/E) training offered by transit agencies, and to identify innovative approaches to E/E training that may assist others.

The areas covered by this survey include Maintenance, Bus Operator and Management/Supervisory training. To ensure accuracy, please direct questions to the appropriate staff. All survey responses will be confidential, and survey results will be presented only in aggregate format.

Thank you for taking the time to assist us in documenting this important topic.

1. Does your transit agency contract out for:
   Bus Operations? ______ YES _______ NO
   If YES, contractor's name ________________________________
   Bus Maintenance? ______ YES ______ NO
   If YES, contractor's name ________________________________

2. How many fixed-route buses do you have in your fleet? _______

   List the number, or percentage, of those buses equipped with electronically controlled:

   ______ Engines ______Transmissions _______ Anti-Lock Braking
   ______ Radios ______ Multiplexing _______ Passenger Counters
   ______ Dest. Signs ______ Fare Collection _______ Vehicle Location
   ______ Next-Stop Annunciators ______ Fire Suppression
   ______ Climate Control List Others ________________________________

3. During the next five years, indicate the number or percentage of additional buses your agency plans to have equipped with electronically controlled (estimate):

   ______ Engines ______ Transmissions _______ Anti-Lock Braking
   ______ Radios ______ Multiplexing _______ Passenger Counters
   ______ Dest. Signs ______ Fare Collection _______ Vehicle Location
   ______ Next-Stop Annunciators ______ Fire Suppression
   ______ Climate Control List Others ________________________________

MAINTENANCE

4. How many mechanics does your agency have servicing your fixed-route fleet (not including hostlers, cleaners, parts personnel, administrators, etc.)? ______________

5. Does your transit agency have all mechanics work on general electrical repairs (wiring repairs, etc.)?
   ______YES _______ NO, only electrical/electronic specialists

6. Does your agency have all mechanics work on electronic repairs (dest. sign, farebox, radio, etc.)?
   ______ YES _______ NO, only electrical/electronic specialists

7. If you answered YES to Nos. 5 or 6, how many E/E specialists do you have? ___________

   Do these specialists work on mechanical repairs when needed? ______ YES _______ NO
   Are the E/E specialists paid to a higher wage scale? ______ YES ______ NO
   Are mechanics required to have, or provided with, special tools? _______ YES ______ NO
   If YES to above, list special tools (i.e., multi-meters, etc.)________________________________

8. List any special E/E tools and E/E diagnostic equipment provided by your agency:
   ____

   ____

9. If buses are equipped with multiplexing, does your agency program the multiplexed system?
   ______ YES ______ NO ______ Not Applicable

10. Does your agency provide electronic or electrical training to maintenance personnel?
    ______ YES ______ NO

    If YES, how is it provided? ______ In-House ______ Out-Sourced ______ Combination

Describe your E/E training program (include any innovative approaches) ___________________________________

____

____

11. Does your agency specify electrical/electronic training as part of its bus procurements?
______ YES ______ NO

12. On average, how many hours of total electrical/electronic training is provided annually to your agency's maintenance staff? _________

13. Please use the chart below to rate the effectiveness of E/E maintenance training programs in improving the ability of technicians to diagnose, repair and maintain on-board E/E equipment.

E/E Training Program	**Effectiveness** (1 = Low, 5 = High, N/A = non-applicable) (Please circle one)
Transit Agency Provided	1 2 3 4 5 N/A
FTA Provided	1 2 3 4 5 N/A
University/School Provided (Identify the university/school)	1 2 3 4 5 N/A
OEM/Supplier Provided (Identify the vendor)	1 2 3 4 5 N/A
OEM/Supplier Provided (Identify the vendor)	1 2 3 4 5 N/A
OEM/Supplier Provided (Identify the vendor)	1 2 3 4 5 N/A
Other (List)	1 2 3 4 5 N/A
Other (List)	1 2 3 4 5 N/A

14. Does your agency have a test to determine E/E skill levels? ______ YES ______ NO

15. How are E/E technicians promoted? ____

____

16. What qualifications does your agency look for when hiring E/E technicians? __________________________

____

17. Are there any labor issues associated with E/E technicians (i.e., hiring, testing, promoting, tools, etc.)?
______ YES ______ NO
If YES, describe them____

18. What is your annual budget for your agency's total maintenance training program? $_____________

19. What is your annual budget for E/E maintenance training only? $____________

20. What affect has advanced on-board electronic equipment had on your overall maintenance budget? (list any increases in percentages) ____

BUS OPERATORS

21. On average, how many hours of training is provided annually per operator for electronically controlled equipment? ___________ What is your agency's annual budget for this training? $______________

22. Describe how bus operator training is provided when new on-board electronic equipment is introduced to the fleet:
____
____

23. List any special tools, training aids, or innovative approaches used by your agency to provide operator training on electronically controlled equipment: ____
____
____

24. List any labor issues associated with bus operators and the use of on-board electronic equipment:
____
____

25. Use the chart below to rate the effectiveness of bus operator training on electronic on-board equipment provided by your agency and outside sources (include publications and training aids if applicable).

E/E Training Program	**Effectiveness** (1 = Low, 5 = High, N/A = non-applicable) (Please circle one)
Transit Agency Provided	1 2 3 4 5 N/A
OEM/Supplier Provided (Identify the vendor)	1 2 3 4 5 N/A
OEM/Supplier Provided (Identify the vendor)	1 2 3 4 5 N/A
OEM/Supplier Provided (Identify the vendor))	1 2 3 4 5 N/A
Specific Training Aid (List)	1 2 3 4 5 N/A
Specific Training Aid (List)	1 2 3 4 5 N/A
Other (List)	1 2 3 4 5 N/A
Other (List)	1 2 3 4 5 N/A

26. Describe how bus operators provide feedback on electronic equipment malfunctions to maintenance personnel:
____
____

27. Is this procedure effective? ______ YES ______ NO

What should be done to improve this process? ____
____

MANAGEMENT/SUPERVISORY TRAINING

Maintenance Managers

28. Describe how maintenance managers and supervisors receive training on on-board electronic equipment:

____

____

Are the procedures described above adequate? _______ YES _______ NO

29. What should be done to improve their level of understanding?

____

____

Bus Operations Managers

30. Do operations managers and supervisors receive training on on-board electronic equipment?
_____ YES _____ NO

If YES, who receives the training and how is it administered: _______________________

____

Are the procedures described above adequate? _______ YES _______ NO
What should be done to improve management's understanding of this technology?_______________

____

31. When a bus operator asks a question about the functionality of an electronic component or system, who at your agency answers that question? _______________________________
Are the procedures in place to answer bus operators' questions adequate? ______ YES _____ NO
What should be done to improve these procedures to keep operators better informed? ______________

____

32. What should be done to improve operations managers' and supervisors' understanding of advanced electronics?

____

____

33. Would there be a benefit in having Bus Operations management and supervisors more knowledgeable in electronic and electrical equipment use and maintenance? ________ YES ______ NO
If YES, explain: _______________________________________

____

General Manager/Upper Management

34. Describe how the general manager and upper management receive training on on-board electronic equipment:

____

____

Are the procedures described above adequate to allocate funds and make informed decisions concerning the implementation of advanced electronics?

_______ ADEQUATE   ______ COULD BE BETTER

What should be done to improve management's understanding of this technology?_____________________________

____

35. Would there be a benefit in having general managers and upper management more knowledgeable in electronic and electrical equipment use and maintenance? ______ YES _______ NO
If YES, explain:____

____

36. What should management's role be in promoting the understanding of advanced on-board electronic equipment throughout the entire agency?____

37. Overall, do you feel that your staff is adequately trained regarding the implementation, operation, and maintenance of advanced on-board electronic equipment?

______ YES   ______ NO   ______ UNCERTAIN

38. Do you feel that the current funding level provided by your agency for electronic training is adequate?

______ YES   ______ NO

39. Use the chart below to rate the effectiveness of specific on-board electronic equipment in improving the quality of service provided to passengers, and improving the efficiency of your agency's operation.

E/E Equipment	**Effectiveness** (1 = Low, 5 = High, N/A = non-applicable) (Please circle one)
Engines, Transmissions, Brakes	1 2 3 4 5 N/A
Radios	1 2 3 4 5 N/A
Fare Collection	1 2 3 4 5 N/A
Destination Signs	1 2 3 4 5 N/A
Next-Stop Annunciators	1 2 3 4 5 N/A
Automatic Vehicle Location	1 2 3 4 5 N/A
Automatic Passenger Counters	1 2 3 4 5 N/A
Other (List)	1 2 3 4 5 N/A
Other (List)	1 2 3 4 5 N/A

40. What should be done to improve the effectiveness of this equipment?

____

____

____

____

GENERAL QUESTIONS

41. What are the lessons your agency has leaned in applying advanced on-board electronics?

____

____

____

____

42. Based on your experiences, what suggestions would you give to other agencies as they begin to implement advanced electronics?____

____

____

43. Feel free to include any other information that you feel may improve the level of understanding and training concerning the implementation, operation, and maintenance of on-board bus electronics:

____

____

____

____

____

PLEASE RETURN THE COMPLETED QUESTIONNAIRE TO:

John J. Schiavone
32 State Street
Guilford, CT 06437

Phone & FAX: (203) 453-2728

APPENDIX B

Survey Respondents

Ann Arbor Transportation Authority, Michigan

Capital District Transportation Authority, New York

Central Florida Regional Transportation Authority (LYNX), Florida

Chicago Transit Authority, Illinois

City of Phoenix Transit System, Arizona

Coast Mountain Bus Company, Burnaby, BC, Canada

Connecticut Transit, Connecticut

Dallas Area Rapid Transit (DART), Texas

Fort Worth Transportation Authority, Texas

Golden Gate Transit, California

Greater Cleveland Regional Transit Authority, Ohio

Long Beach Transit, California

Madison Metro Transit System, Wisconsin

Metropolitan Atlanta Rapid Transit Authority, Georgia

Metropolitan Transit Authority of Harris County, Texas

Metro Transit, Minnesota

Milwaukee County Transit System, Wisconsin

New Jersey Transit Corporation, New Jersey

OMNITRANS, California

Orange County Transportation Authority, California

Pierce Transit, Washington

Sacramento Regional Transit District, California

San Mateo County Transit District, California

Santa Clara Valley Transportation Authority, California

Santa Cruz Metropolitan Transit District, California

APPENDIX C

Troubleshooting Guide for Bus Operators

NJ TRANSIT BUS OPERATIONS INC.
OPERATIONAL TRAINING
TROUBLE SHOOTING GUIDE MCI D4000 COMMUTER BUS

If you encounter a problem in any area, check the items listed and adjust any item that is not in the correct position. **If problem cannot be resolved, call the Control Center.** Report all defects on Operator's Bus Condition Report.

ENGINE

Won't start

1. Master Control in RUN position.
2. Transmission in neutral (**N**).
3. Proper voltage (check voltmeters in luggage compartment).
4. Two battery disconnect switches in on position.
5. Rear engine start switches in normal positions.
6. Try to start from rear. (Parking brake must be on.)
7. Wait 15 seconds for bus to come out of sleep mode.

Won't accelerate

1. Parking brake off.
2. Fast idle off when putting into gear.
3. Bus in gear (service brake must be applied when putting in gear). Shift back to **N** with foot on brake, and then back to **D**.
4. Wheelchair Master in **OFF** position.
5. Guarded lift switch in lift compartment **OFF**.
6. Lift doors closed and locked.
7. Kneel in raised position. Kneel telltale must be out.

Engine Protection System

This system is designed to shut the engine down in 30 seconds if the engine fire detection system, oil pressure sensor, coolant temperature sensor, or low coolant level sensor detect a problem. The **STOP ENG** telltale will illuminate and the Engine Protection System will be activated. There will also be a decrease in engine power. If more than 30 seconds is needed to reach a safe area, activate the ENGINE OVERRULE switch located to the left of the operator. Lift the guarded cover, press the spring loaded switch **to the ON position and then release;** this will give an additional 30 seconds of operation. Each on and off of the overrule switch will again set the 30 second engine shutdown timer. Press the switch before the 30 second countdown reaches zero. **CONTINUED OPERATION OF THE ENGINE, EVEN FOR A SHORT TIME, COULD RESULT IN FIRE OR ENGINE DAMAGE. USE THE OVERRULE ONLY TO MOVE TO A SAFE AREA.**

If necessary to restart the bus after the Engine Protection System has shut the engine down, rotate the Master Control to the **ENGINE STOP** position, wait 10 seconds. Turn Master Control to the **RUN** position, Press ENGINE OVERRULE switch to the **ON** position and release. Restart engine in normal manner. If the problem still exists, the engine will again shut down in 30 seconds. Use only to move to a safe area.

AUTOMATIC FIRE SUPPRESSION SYSTEM

When the automatic fire suppression systems detects a fire in the engine compartment, an audible alarm will sound, and a light will illuminate on the Fire Suppression Control Panel. **The engine will shut down in 30 seconds** if no operator action is taken.

If more than 30 seconds is needed to reach a safe area, activate the ENGINE OVERRULE switch located to the left of the operator. Lift the guarded cover, press the spring loaded switch **to the ON position and then release;** this will give an additional 30 seconds of operation. Each on and off of the overrule switch will again set the 30 second engine shutdown timer. Press the switch before the 30 second countdown reaches zero.

This switch is used to delay engine shutdown to allow movement to a safe area only. Fire extinguisher chemical will discharge, the switch only delays engine shutdown.

BRAKES

Inoperative or insufficient

1. Air pressure over 80 PSI.
2. Heat fade from excessive pressure. Downshift to lower gear on hills to prevent heat fade..
3. Brakes dry?
   To dry, apply brakes lightly while driving for short distance at low speed until brakes dry.

Parking brake will not release

1. Full hard service brake application required to release parking brake.
2. Air pressure over 80 PSI.
3. Dash lift key in **OFF** position.
4. Guarded switch in lift compartment in **OFF** position.
5. Both lift doors closed.
6. Lift door emergency air dump in proper position
7. Kneel in raised position. Kneel telltale should be out.
8. Try releasing and applying the parking brake several times.
9. Try applying and releasing service brake several times.

If emergency and bus must be moved only to safe area, hold parking brake override (located to the left rear of driver) down and move bus. Releasing will apply spring brakes suddenly. Advise passengers to brace themselves.

ABS dash telltale light remains on

1. Should go out after 1st movement over 7 mph.
2. If light remains on, indicates ABS function is lost. Drive as with buses not equipped with ABS. Notify Control Center if ABS light remains on.

TROUBLE SHOOTING GUIDE MCI D4000 COMMUTER BUS (Cont'd)

TRANSMISSION

Will not go in gear- Indicated by blinking trans display

1. 60 pounds of pressure on service brake must be applied when putting in gear. Shift back to **N** with foot on brake and then back to **D**.
2. Fast idle **OFF** before putting in gear? Turn off.
3. Try turning bus off and restarting.

Transmission display shows countdown when brakes are applied.

The display could show a countdown from "6" to "4" when brakes are applied. This is a normal display when Jake Brake is activated and is no cause for concern.

CHECK TRANS LIGHT

Do not shift! Once bus is shifted to neutral, if fault remains, you will not be able to shift back to drive. If light comes on, call Control Center and follow their instructions. Do not shift to neutral until reaching a safe area. If possible, complete your trip. NEVER LEAVE THE OPERATOR'S SEAT WITH THE BUS IN GEAR. Turning off the engine and restarting may reset transmission. Try only if told to do so by Control Center.

LIGHTS

Interior lights won't illuminate

1. Battery power on.
2. Interior light switch in NORMAL position and Master Control in LIGHTS or CL LPS position.
3. If Master Control is in off position, 3 position interior light switch must be in **ON** position for interior lights to work.
4. Are two battery switches in on position?

Lights come on unexpectedly

Bus is equipped with Pre Trip Assist feature. If both turn signal buttons are depressed at same time, all exterior lights will come on for two minutes. Depress one turn signal button to stop "pre trip assist mode."

Lights go off when bus is not running.

Bus is equipped with a "Sleep Mode" system. Most lights left on after Master Control is turned off, will automatically shut off after 20 to 30 minutes. Turn Master Control on or activate entrance door switch to put lights back on. Hazard flashers and clearance lights are not in the "Sleep Mode" system.

DESTINATION SIGN

Won't display information

1. Master Control on to power sign?
2. Proper destination sign code entered?.

Interior display shows "EXCEEDING RANGE" and/or beeping sound

1. Proper code entered? Enter correct code.
2. Press PR, Press "000", Press "ENTER"

AIR CONDITION AND HEATING

No or insufficient AC

1. Engine running.
2. HVAC switch in **ON** position.
3. Air pressure over 95 pounds.
4. Driver's heat off. Push T handle control down.
5. GEN STOP telltale light off.
6. Roof hatch open. Close if open.
7. Temperature control set. Set to cool setting.
8. Try closing passenger & operator outside air intakes.

No or insufficient Heat

1. Engine running.
2. HVAC switch in **ON** position.
3. Blowers may not operate until 120 degrees F coolant temperature is reached.
4. Temperature control set. Set to warm setting.
5. Press Auxiliary Heat spring loaded switch. Wait 20 minutes for Pro Heat to heat coolant.
6. GEN STOP telltale light off.
7. Roof hatch open. Close if open.
8. Adequate coolant level.
9. Driver's heat on. Pull T handle control up.
10. Try closing passenger & operator outside air intakes.
11. Turn off P/R BLOWERS if still too cold.

DOORS, ENTRANCE

Won't close or open

1. Air pressure above 100 PSI.
2. After start up, allow air to continuing building a full minute after air gauge reads 120 psi. Door air chambers are last to fill.
3. Air dump valve in proper position.
4. Master Control in RUN position.
5. Battery power on.

CAUTION: No one should stand near doors when the Master Control is used, door air dump is used, battery power is disconnected or restored. Depending on the position of the door handle and various switches, door could open or close unexpectedly.

KNEELER NOT WORKING

1. Parking brake must be on and entrance door closed for kneeler to operate.
2. Air pressure must be over 100 pounds.

ELECTRICAL FUNCTION NOT WORKING

Check that 2 switches in battery compartment are in on position.

Any unusual electrical problems, turn switch off and wait 20 seconds for system to reset. Sometimes, it may be necessary to turn main battery power off for 20 seconds for multiplex system to reset.

Network Failure telltale light indicates failure in multiplex system. Try turning off main battery power for 20 seconds for system to reset. If Network Failure telltale still remains on, engine should not be run without authorization from Control Center.

NJ TRANSIT BUS OPERATIONS
OPERATIONAL TRAINING
MCI "D" SERIES COMMUTER BUS
TROUBLESHOOTING GUIDE FOR RICON LIFT

If you encounter a problem in any area, check the items listed and adjust any item that is not in the correct position. **If problem cannot be resolved, call the Control Center.** Report all defects on Operator's Bus Condition Report (BCR).

Upper wheelchair lift door will not open

1. Lift must be just below coach floor level for door to open or close.
2. If malfunction, use air dump located in lift compartment to dump upper wheelchair door air and manually open door.

The light on top of the control unit should be on. If not:

1. Parking brake on, engine running, transmission in neutral, fast idle on.
2. Is WHEELCHAIR key on dash in **ON** position?
3. Is lift compartment guarded switch in **ON** position?.

Outer barrier will not come down, or to the up position

1. Lift on level ground. Reposition bus if necessary.
2. As you look at bus, ground sensor on left side bottom depressed?
3. If necessary, pull out and twist knob to lower and raise barrier.
4. If barrier is lowered manually, **IT MUST BE RAISED MANUALLY**.

Lift will not operate

1. Parking brake on, engine running, transmission in Neutral, HIGH fast idle.
2. Is WHEELCHAIR key on dash in **ON** position?
3. Is lift compartment guarded switch in **ON** position?
4. Safety belt <u>must be buckled</u> for lift to raise or lower.
5. Weight over 660 pounds on lift. Request guide enter bus by entrance door.
6. Adequate backup pump oil level. Check pump in forward baggage compartment with lift on ground. Oil level should be at black mark.

Will not stow

1. Push **red** button and **IN** rocker switch on control panel at the same time.
2. Grab rails stored correctly. Left side (as you look at bus) must be folded down first.
3. Outer barrier up. If necessary, pull out and twist knob to raise barrier.

Dash WHEELCHAIR key turned to OFF position, but Wheelchair dash telltale light is still on

1. After dash key is turned to OFF position, a full hard application of service brake is required to turn off. Apply full service brake application.
2. Guarded lift power switch located in lift compartment must be off.
3. Both upper lift door and lift cassette door must be properly closed.

Cannot raise seat for mobility device securement

4. Put slight pressure on bottom seat pad by release handle, while pulling release handle.

APPENDIX D

Tests to Determine Basic Electrical and Electronic Skill Levels

MANAGEMENT TEST

1) Explain the relationship between the following ITS programs: NTCIP, TCIP, and VAN.

____

____

____

____

____

____

2) TEA-21, the Transportation Equity Act for the 21st Century, remains silent when it comes to developing standards for ITS data communication.

a) True

a) False

3) SAE J1708 is an on-board communications network that can transmit data between:

a) Drivetrain level components

a) Information level components such as the AVL and next-stop annunciation system

a) All of the above

a) None of the above

4) Proponents of SAE J1708 for transmitting on-board Information Level data defend its low baud rate of 9600 bits per second by bring up the fact that J1708 is:

a) faster than J1939 and LonWorks

a) fast enough for on-board use and faster than the baud rates used for off-board radio transmission

a) faster than CAN-based networks

a) all of the above

5) An open communications network is one where:

a) Information broadcast on the network is open for all devices to *send*

a) Information broadcast on the network is open for all devices to *receive*

a) Information broadcast on the network is open for all devices to *send and receive*

a) Information concerning communications protocols are open to the *public*

6) Data can be exchanged between different on-board communications networks by use of a:

a) Gateway

a) Diode

a) Central Data Exchange Network Rectifier (CD-ENR)

a) Pro Link™

7) Data stored in the on-board drivetrain system can reveal information about the operator's interaction with the brake pedal.

a) True

a) False

8) In a multiplexed system, the on/off control of existing on-board electrical devices such as lights, windshield wipers, and door interlocks can be changed by:

a) Reprogramming the system with a laptop computer or similar device

b) Moving the dip switches in proper sequence on the CPU

c) Replacing the Multiplex Relay Module (MRM)

d) All of the above

9) Which of the following technologies are <u>NOT</u> used to improve the accuracy of GPS-based AVL systems:

a) Dead Reckoning

b) Differential GPS

c) Selective Availability

d) Signposts

10) With regard to AVL, GIS refers to the:

a) On-board control unit

b) On-board display unit

c) Communications network that connects the bus to the base station

d) The underlying basemap that contains the network of municipal streets, highways, and other roads

11) Infrared sensors can be used in an APC system to count passengers.

a) True

b) False

12) In transit communications, the term "refarming" applies to:

a) adopting a standard approach to radio signal transmissions

b) narrower radio frequency bands

c) eliminating RFI (radio frequency interference)

d) using older signpost AVL with newer GPS systems

MAINTENANCE TEST

1) In electricity, unlike charges:

a) attract

b) repel

c) remain neutral

d) explode

2) Ohm's law expresses the relationship between:

a) current, voltage, and resistance in a circuit

b) series, parallel, and series-parallel circuits

c) conductors, magnetism, and electromagnetism

d) electromagnetic induction and radio suppression

3) In Ohm's law, ohms equals:

a) volts divided by amperes

b) amperes divided by volts

c) amperes times volts

d) battery voltage minus battery amperes

4) The basic unit of resistance is the:

a) ohm

b) current

c) electron

d) proton

5) Excessive resistance in a circuit can be caused by:

a) poor connections

b) corrosion

c) partially broken wires

d) all of the above

6) When a switch is open:

a) power or ground does NOT flow through it

b) power or ground DOES flow through it

c) the switch is in need of repair or replacement

d) the switch is subjected to possible water intrusion

7) A diode is an electrical device that:

a) does not allow current to flow at all

b) allows DC current to flow

c) allows AC current to flow

d) accelerates the flow of current

8) In an electrical circuit, an ammeter can be used to measure:

a) ohms

b) current

c) ams

d) voltage

9) To measure current through a component, the meter is placed in:

a) series with the component

b) parallel with the component

c) both of the above

d) none of the above

10) To measure voltage across a component, the meter is placed in:

a) series with the component

b) parallel with the component

c) both of the above

d) none of the above

11) Which symbol of the multi-meter screen is used to indicate that the input is too large:

a) Ø

b) ¥

c) OL

d) OC

12) One millampere of current flow equals:

a) 0.1A

b) 0.01A

c) 0.001A

d) 0.0001A

13) In a series circuit, if the voltage remains constant while the resistance is doubled the current will:

a) double

b) decrease by one-half

c) increase by one-half

d) short circuit

14) In a circuit with a 10 ohm and a 15 ohm resistor connected in parallel, the total resistance of the circuit is:

a) 6 ohms

b) 12 ohms

c) 18 ohms

d) 25 ohms

15) Cold cranking amps are a measure of the:

a) alternator output

b) alternator field current

c) battery's ability to maintain electrical current discharge

d) engine's ability to start when ambient temperatures fall below zero-degrees F

16) If the positive terminal of 12V battery #A is connected to the negative terminal of 12V battery #B and battery #A is properly grounded, batteries #A and #B will:

a) short circuit and possibly explode

b) be wired for 24V

c) be wired for 6V

d) none of the above

17) Assuming that the voltage regulator and the alternator are not damaged, no voltage at the voltage regulator "POS" terminal will cause the charging system to:

a) charge normally

b) overcharge

c) undercharge

d) not charge at all

18) In a multiplexed electrical system, there are no traditional hard-wired connections

a) True

b) False

19) In a multiplexed electrical system, LEDs are typically used to:

a) indicate circuit integrity and aid in diagnostics

b) link all system-wide modules

c) provide power to circuits over 12 volts

d) replace electro-magnetic relays

20) With the introduction of SAE J1939 for drivetrain integration, a SAE J1708/1587 network is no longer needed.

a) True

b) False

21) The SAE J2496 cabling standard:

a) carries both clean power and data

b) carries clean power only

c) carries data only

d) defines the cable interface between anti-lock braking and other drivetrain components

22) SAE J1455 defines:

a) the environment in which E/E equipment must be capable of surviving

b) the previous generation of drivetrain data communication

c) the communication standard for multiplexing

d) the Recommended Practice (RP) for installing multiplex systems

23) The use of a CDPD service allows data to be transmitted between the bus and agency similar to a:

a) cell phone

b) GPS device

c) analog scanner

d) Common Digital Peripheral Device

24) LEDs are NOT used to illuminate:

a) headlights

b) dash warning indicator lights

c) running lights

d) brake lights

APPENDIX E

Test Answers

MANAGEMENT TEST

1) Explain the relationship between the following ITS programs: NTCIP, TCIP, and VAN.

The NTCIP (National Transportation Communications for ITS Protocols) is an important part of the National ITS Architecture. Its mission is to develop standard communication interfaces to allow dissimilar ITS elements (e.g., transit, highways, etc.) to communicate with one another. NTCIP converts data used by dissimilar ITS elements in a format understood by all.

TCIP (Transit Communications Interface Profiles) is the transit portion of the NTCIP program. It ensures that data generated by transit vehicles and agencies are compatible with NTCIP and the entire ITS community.

VAN (Vehicle Area Network) is the program that applies specifically to in-vehicle data communication.

Each program is designed to make data generated by the many ITS participants understood by all. For example, an ITS architecture of understood protocols allows traffic signals to give priority to fire emergency vehicles over transit buses when needed. This benefit is only possible if vehicle location and other vehicle data can be communicated to and understood by all transportation agencies involved.

2) TEA-21, the Transportation Equity Act for the 21st Century, remains silent when it comes to developing standards for ITS data communication.

a) True
b) False (USDOT is allowed to impose standards if standards are not adopted voluntarily)

3) SAE J1708 is an on-board communications network that can transmit data between:

a) Drivetrain level components
b) Information level components such as the AVL and next-stop annunciation system
c) All of the above
d) None of the above

4) Proponents of SAE J1708 for transmitting on-board Information Level data defend its low baud rate of 9600 bits per second by bring up the fact that J1708 is:

a) faster than J1939 and LonWorks
b) fast enough for on-board use and faster than the baud rates used for off-board radio transmission
c) faster than CAN-based networks
d) all of the above

5) An open communications network is one where:

a) Information broadcast on the network is open for all devices to *send*
b) Information broadcast on the network is open for all devices to *receive*
c) Information broadcast on the network is open for all devices to *send and receive*
d) Information concerning communications protocols are open to the public

6) Data can be exchanged between different on-board communications networks by use of a:

a) Gateway
b) Diode
c) Central Data Exchange Network Rectifier (CD-ENR)
d) Pro Link™

7) Data stored in the on-board drivetrain system can reveal information about the operator's interaction with the brake pedal.

a) True
b) False

8) In a multiplexed system, the on/off control of existing on-board electrical devices such as lights, windshield wipers, and door interlocks can be changed by:

a) Reprogramming the system with a laptop computer or similar device
b) Moving the dip switches in proper sequence on the CPU
c) Replacing the Multiplex Relay Module (MRM)
d) All of the above

9) Which of the following technologies are NOT used to improve the accuracy of GPS-based AVL systems:

a) Dead Reckoning
b) Differential GPS
c) Selective Availability
d) Signposts

10) With regard to AVL, GIS refers to the:

a) On-board control unit
b) On-board display unit
c) Communications network that connects the bus to the base station
d) **The underlying basemap that contains the network of municipal streets, highways, and other roads**

11) Infrared sensors can be used in an APC system to count passengers.

a) True
b) False

12) In transit communications, the term "refarming" applies to:

a) adopting a standard approach to radio signal transmissions
b) narrower radio frequency bands
c) eliminating RFI (radio frequency interference)
d) using older signpost AVL with newer GPS systems

MAINTENANCE TEST

1) In electricity, unlike charges:

a) attract
b) repel
c) remain neutral
d) explode

2) Ohm's law expresses the relationship between:

a) current, voltage, and resistance in a circuit
b) series, parallel, and series-parallel circuits
c) conductors, magnetism, and electromagnetism
d) electromagnetic induction and radio suppression

3) In Ohm's law, ohms equals:

a) volts divided by amperes
b) amperes divided by volts
c) amperes times volts
d) battery voltage minus battery amperes

4) The basic unit of resistance is the:

a) ohm
b) current
c) electron
d) proton

5) Excessive resistance in a circuit can be caused by:

a) poor connections
b) corrosion
c) partially broken wires
d) all of the above

6) When a switch is open:

a) power or ground does NOT flow through it
b) power or ground DOES flow through it
c) the switch is in need of repair or replacement
d) the switch is subjected to possible water intrusion

7) A diode is an electrical device that:

a) does not allow current to flow at all
b) allows DC current to flow
c) allows AC current to flow
d) accelerates the flow of current

8) In an electrical circuit, an ammeter can be used to measure:

a) ohms
b) current
c) ams
d) voltage

9) To measure current through a component, the meter is placed in:

a) series with the component
b) parallel with the component
c) both of the above
d) none of the above

10) To measure voltage across a component, the meter is placed in:

a) series with the component
b) parallel with the component
c) both of the above
d) none of the above

11) Which symbol of the multi-meter screen is used to indicate that the input is too large:

a) Ø
b) ¥
c) OL
d) OC

12) One millampere of current flow equals:

a) 0.1A
b) 0.01A
c) 0.001A
d) 0.0001A

13) In a series circuit, if the voltage remains constant while the resistance is doubled the current will:

a) double
b) decrease by one-half
c) increase by one-half
d) short circuit

14) In a circuit with a 10 ohm and a 15 ohm resistor connected in parallel, the total resistance of the circuit is:

a) 6 ohms
b) 12 ohms
c) 18 ohms
d) 25 ohms

15) Cold cranking amps are a measure of the:

a) alternator output
b) alternator field current
c) battery's ability to maintain electrical current discharge
d) engine's ability to start when ambient temperatures fall below zero-degrees F

16) If the positive terminal of 12V battery #A is connected to the negative terminal of 12V battery #B and battery #A is properly grounded, batteries #A and #B will:

a) short circuit and possibly explode
b) be wired for 24V
c) be wired for 6V
d) none of the above

17) Assuming that the voltage regulator and the alternator are not damaged, no voltage at the voltage regulator "POS" terminal will cause the charging system to:

a) charge normally
b) overcharge
c) undercharge
d) not charge at all

18) In a multiplexed electrical system, there are no traditional hard-wired connections.

a) True
b) False─Hard-wired connections are made from switches and electrical devices (e.g., lights, etc.) to the multiplex modules

19) In a multiplexed electrical system, LEDs are typically used to:

a) indicate circuit integrity and aid in diagnostics
b) link all system-wide modules
c) provide power to circuits over 12 volts
d) replace electro-magnetic relays

20) With the introduction of SAE J1939 for drivetrain integration, a SAE J1708/1587 network is no longer needed.

a) True
b) False─Since SAE J1939 is not yet complete, the J1708/1587 network is needed for diagnostic purposes

21) The SAE J2496 cabling standard:

a) carries both clean power and data
b) carries clean power only
c) carries data only
d) defines the cable interface between anti-lock braking and other drivetrain components

22) SAE J1455 defines:

a) the environment in which E/E equipment must be capable of surviving
b) the previous generation of drivetrain data communication
c) the communication standard for multiplexing
d) the Recommended Practice (RP) for installing multiplex systems

23) The use of a CDPD service allows data to be transmitted between the bus and agency similar to a:

a) cell phone
b) GPS device
c) analog scanner
d) Common Digital Peripheral Device

24) LEDs are NOT used to illuminate:

a) headlights
b) dash warning indicator lights
c) running lights
d) brake lights

APPENDIX F

Sample Specification Language for Training

SAMPLE SPECIFICATION LANGUAGE FOR TRAINING
Delaware Transit Corporation, Technical Specification

13. TRAINING

Contractor shall provide the below require training as a minimum.

13.1 Training Deliverables

With respect to the instruction and assistance during the warranty period, contractor shall instruct DTC's maintenance personnel either on DTC property or at contractor's facility if it is within fifty (50) miles of DTC's maintenance base. All travel costs and living expenses beyond 50 miles shall be at the expense of the contractor. Following delivery of the coaches, DTC requires that at least one (1) qualified driver instructor be available for up to five (10) days following delivery of the coaches at DTC's property to instruct its Driver Training Department Instructors as to the proper operation of the coach and its accessories. Training is subject to schedule approval by DTC. Training will commence after receipt of first unit and will be accomplished at the discretion of the DTC and be completed not later than 60 days after delivery of the last vehicle. The classes will include "hands-on" as well as theoretical instruction. The following individual minimum training courses for a minimum of 15 persons per subject shall be provided to DTC:

Subject	Hrs per class	No. of Classes
Introductory Maintenance Orientation	4	10
Introductory Operations Orientation	4	10
Stores Training	4	2
Special Tools and Diagnostic Equipment	24	3
Engine & Transmission	40	1
Tune-up & Troubleshooting	8	5
Electric & Electronics Systems	8	5
Heating and Ventilation & Air Conditioning	8	5
Wheelchair	4	2
Fuel system	4	2

13.1.1. Training Videos

The following training videos on VHS format shall be delivered to DTC prior the delivery of first coach:

13.1.1.1 Front Suspension

13.1.1.2 Rear Suspension

13.1.1.3 Entrance Door Operation

13.1.1.4 Air Brake System

13.1.1.5 Electric System Componentry and Troubleshooting

13.1.1.6 HVAC Diagnostic Reader

13.1.1.7 Multiplex Wiring System

13.1.1.8 Maintenance Guidelines

13.1.1.9 Wheelchair Lift Operation

13.1.1.10 Engine Maintenance and Troubleshooting

13.1.1.11 Transmission Maintenance and Troubleshooting

13.1.1.12 Pneumatic System

13.1.1.13 Air Conditioning Maintenance and Operation

13.1.1.14 Drivers Orientation and System Operation

Delaware Transit Corporation
Technical Specifications

14. Manuals

Detailed and well organized maintenance, parts, and operator manuals covering all items "as built" on the coach shall be supplied by the Contractor prior to acceptance of first coach. Manuals shall be delivered in three ring binders with the sections separated with sturdy plastic divider pages with tabs. Manuals shall contain data required for preventive and corrective maintenance of all parts of the buses including but not limited to the following:

14.1 Operating and Repair Publications

14.1.1. General vehicle information and specifications.

14.1.2. A complete, well-developed troubleshooting guide covering all mechanical, electrical and electronic components, including engine, transmission, and HVAC units.

14.1.3. All preventive maintenance, lubrication and adjustment requirements.

14.1.4. Complete wiring and schematic diagrams and schedules for wire and cable sizes and ratings including actual cable lay-out, plus locations in the coach of all electric and electronic components.

14.1.5. Complete air and hydraulic diagrams showing locations in the coach of all air and hydraulic components. The air system diagram shall be a 11in. x 17in. CAD drawing with color coding, using actual printed colors to match systems.

14.1.6. Illustrative drawings, such as isometrics, exploded views or photographs identifying components in relationship to each other as mounted in the buses.

14.1.7. Components shown in exploded views with all parts clearly identified including Contractor part number.

14.1.8. Rebuilding procedures for all rebuildable components.

14.1.9. Detailed, well illustrated procedures for component change-out plus servicing, adjusting, testing, and run-in information as required.

14.1.10. Body and structural information and material specifications for major accident repair.

14.1.11. Seating and stanchion layouts and window diagrams.

14.1.12. 11 in. x 17 in. scale drawing of driver's compartment, detailing all driver switches, controls, control panels and equipment locations (to be approved by DTC).

14.1.13. Repair and calibration instructions and values.

14.1.14. List of special test equipment/tools required to maintain and repair systems down to the component level including part number and supplier source.

14.2 Parts Manuals

Illustrated parts manuals shall contain exploded views that show all parts used on buses as- built under this contract, and no other parts. The exploded views will show all fasteners and miscellaneous hardware. The manuals shall contain data arranged so that part numbers can be readily found and identified in the illustration for each system and subsystem component, assembly, subassembly or piece part from an orderly breakdown of the complete coach. It shall contain a ready reference part number index and part name index and be sufficiently well illustrated to identify items requiring repair, replacement, and storage for use in the maintenance of the buses. All subassemblies (such as wiper motors, starter motors, etc) shall have the original manufacturer's part number displayed at the beginning of the appropriate parts listing section. Lists shall include at least the following information for all parts as built:

14.2.1. Generic description and specifications

14.2.2. Contractor part number

14.2.3. Brand name, were applicable

14.2.4. Original manufacturer's part number (provide in separate cross reference binder)

14.2.5. Indication if the part is custom manufactured only on request

14.2.6. Standard hardware described by size, type, material and grade.

14.2.7. The parts manual shall include all original manufacturer names and addresses, all special tools, test and diagnostic equipment and their original manufacturer names and addresses.

14.3 Maintenance and Parts Manuals on CDROM

All manuals shall be provided on CD-ROM using software programs to be approved by the DTC. CD-ROM format and features shall include index and search by name, part number, assembly and subassembly. The DTC reserves the right to copy all information for future use. All software shall be available to the DTC. System to be approved by the DTC.

14.4 Parts Price List

The parts pricing list shall list all parts by alpha order starting with "a" and ending with "Z" and then in numerically ascending order starting with A0" and ending with A9". The parts list shall supply the purchase price (including freight), and a description of the part. Updated price lists will note all part number supercessions since last general issue of the price list. Unit of sale will be noted, e.g. each, minimum 5, per foot, etc.

14.5 Manual Quantities

The following shall be provided for coaches "as built".

14.5.1. Fifteen (15) sets current coach parts manuals

14.5.2. Fifteen (15) sets current coach maintenance manuals.

14.5.3. Fifteen (15) sets of coach electrical and air schematics shall be as built and printed on 12in. x 30in. stock, laminated in plastic.

14.5.4. Fifteen (15) sets current transmission maintenance manuals (if not included in coach maintenance manual).

14.5.5. Fifteen (15) sets engine maintenance manuals (if not included in coach maintenance manuals).

14.5.6. Fifteen (15) sets current engine, transmission, wheelchair and coach parts manuals.

14.5.7. Three hundred (300) standard operator's manuals.

14.6 Manual Updates

Maintenance and parts manuals must be updated to include all changes made to the coach during production and post-delivery retrofits authorized or requested by the Contractor and to correct all errors and omissions found by DTC. Changes required to the parts and maintenance manuals due to warranty and/or post delivery retrofits shall be completed within 90 days from the date of modification approval. Manuals shall be available from the Contractor for fifteen (15) years following acceptance of the last coach. Revised parts price lists will also be supplied as price changes. Parts shall be interchangeable with the original equipment and be manufactured in accordance with the quality assurance provisions of this contract. Prices shall not exceed the Contractor's then current published catalog prices.

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