Electric Buses in Operation: The Chattanooga Experience

THOMAS W. DUGAN

In the early 1990s the City of Chattanooga, Tennessee, and the Chattanooga Area Regional Transportation Authority (CARTA) were looking for an innovative approach to the need for a downtown shuttle. As a result of finding a solution to this problem, the transit system has embarked on the most extensive electric transit vehicle program in the United States. The program now uses electric buses made with existing technology and actively participates in developing new electric vehicle technologies, testing vehicles and components, manufacturing electric transit vehicles, and formating the Electric Transit Vehicle Institute. The history of the program, the policy and operational issues that were addressed by the CARTA governing board and management staff, and the areas of consideration for transit systems considering the use of electric transit vehicles are provided, as are the author's thoughts concerning the future of electric transit vehicles. Emphasis is given to the policy and organizational concerns that face a transit system seeking to implement a new technology from the perspective of an agency whose focus is on the actual real-life operation of electric buses rather than short-term demonstration programs.

Chattanooga, Tennessee, unlike many other southern urban centers, became a manufacturing center after the Civil War. The availability of inexpensive, low-grade iron ore led to the development of many foundries and related manufacturing industries. At one time in the 1950s Chattanooga had the highest number of manufacturing employees per capita of any city in the United States. Chattanooga's location, in a valley surrounded by ridges and mountains, inevitably led to one of the worse air pollution problems in the country. By the mid-1960s Chattanooga was consistently being rated among the worse three urban areas of the country in terms of air pollution.

Government and private-sector leaders came together in the early 1970s to develop plans to change the air quality of the region. Some regulations were already in place, and local leaders wanted to get ahead of the air quality requirements that were sure to come in the future. Local industries made large investments in equipment to clean the air, and today Chattanooga is in full compliance with all clean air regulations. As such it is one of the few urban areas in the country not facing onerous regulations concerning air quality and mitigation measures.

Chattanooga continues to have some environmental problems. Parts of the creek tributary system off the Tennessee River are heavily polluted. Mobile air pollution (from automobiles, etc.) is beginning to become a concern just as the stationary pollution sources were in the 1960s. But these issues are now seen not as an impediment to economic development but rather as a source of future economic development. The solving of environmental problems is seen as a process that leads to the development of new industry and to the identification of Chattanooga as a center for innovation and change.

Chattanooga Area Regional Transportation Authority, 1617 Wilcox Boulevard, Chattanooga, Tenn. 37406.

In the 1980s two additional developments that would have a major impact on the development of electric transit vehicles in Chattanooga took place. First, the form of government changed. As a result of a civil rights suit, the old commissioner form of government was replaced by a strong mayor-city council form of government. The commissioner form of government had five commissioners, elected at-large, who functioned as the legislative branch of local government but who also had executive branch responsibilities over their individual departments—finance, police and fire, recreation, education, and public works. The new form of government has an elected mayor and nine council members elected from districts.

There have been several positive aspects to the new council form of government. One aspect of the council that has had a profound effect on the issues of environment and electric bus development was the election of citizen-representatives who brought to the council a view that the issues of environment and quality of life were better handled on a local rather than a regional, state, or federal level. In addition these council members believed that Chattanooga could become a leader in the development of solutions to traditional urban problems, solutions that emphasized new thoughts, new technologies, and new policies, and that such solutions could provide the foundation for future economic development in the city and the region.

A second development was the active participation in community affairs by members of the economic elite. Historically, in Chattanooga, the wealthy families had always participated in support of the arts, private education, and charities. In the mid-1980s, however, funding and leadership began to appear in the areas of education, downtown development, housing, and economic development. Chattanooga Venture, a private nonprofit corporation, was organized to develop a broad, community-based process of developing lists of community priorities and then to function as a facilitator of new programs to address these issues. Chattanooga Neighborhood Enterprises was created with the visionary goal of securing adequate housing for every family in Chattanooga. The Chattanooga Education Foundation was formed to provide additional resources and new perspectives to the public education system. Each of these agencies has received strong financial support from private foundations.

The RiverCity Corporation was also formed during this time period. A private, nonprofit organization, the RiverCity Corporation has a Board of Directors that represents the private and the public sectors. The purpose for the organization is the planning and development of the central business district, with particular emphasis on the north area adjacent to the Tennessee River. For the first time an organization was in place with all the key players on board to focus on downtown and riverfront development. Through the provision of private and public financial support a

core group of professionals was hired and an urban design studio was established. In addition the most progressive experts in the country were brought in to participate in the development of the downtown plan. Through this effort the creation of the downtown shuttle and parking system, proposed by the Chattanooga Area Regional Transportation Authority, was planned, fine-tuned, and placed in a position of prominence.

CHATTANOOGA'S TRANSIT SYSTEM

The Chattanooga Area Regional Transportation Authority (CARTA) is a traditional provider of public transportation services to the Chattanooga area. It operates a 60-bus fleet, employs about 120 persons, and is governed by an 11-member Board of Directors appointed by the political subdivisions that provide its funding. As the downtown planning process was under way CARTA was requested to develop a transportation plan to tie the elements of the downtown plan together.

Downtown Chattanooga is a long, narrow geographic area stretching from the Tennessee River in the north to the I-24 Interstate highway in the south. East and west it ranges from approximately 6 to 10 blocks wide, with a freeway bordering the western edge and a ridge bordering the eastern boundary. Development in the downtown gravitates to three areas: the riverfront to the north, the Miller Park district in the center, and the Choo-Choo resort area in the south. This distance extends about 2 mi. The distance involved caused a problem to planners in that it was beyond walking distance, and yet the plan would not work if it depended on the automobile.

The north end of the downtown has seen major development in the past 3 years. The Tennessee Aquarium, a $45 million, privately financed facility, opened in 1992 and recorded 1.5 million visitors in its first year. A new visitors' center has opened within the $6 million Ross' Landing plaza that surrounds the aquarium. Within 2 blocks the first downtown housing built in 30 years opened in 1992, a new children's museum was to have broken ground in early 1994, and new restaurants have been opening at a rate of one every 6 months.

The central area of downtown is anchored by the Miller Park and Miller Plaza developments and the office complex of the Tennessee Valley Authority and continues to be the commercial and retail center of the downtown. To the south the area around the Choo-Choo resort is under current planning to expand the Warehouse Row development, a very successful retail-office complex specializing in direct, upscale outlets.

The transportation solution to the problem of tying together these development centers was developed by CARTA in 1991 and was composed of two parts. The first part was the location of parking garages at the key entrances to downtown to act as intercepts for the automobile traffic. The second part was a high-quality, high-frequency shuttle system that would connect the intercept garages with downtown destinations. This system would permit local workers and out-of-town visitors to leave their automobiles at one location and use the shuttle to move about town. In addition the revenues from the parking facilities would provide the funding necessary for the operation of the shuttle.

To this end CARTA applied for and received approval of a $19.6 million grant from FTA for the parking facilities, vehicles, and construction of passenger stations. Of the total, $15.7 million will come from FTA and about $2 million each will come from the Tennessee Department of Transportation and the City of Chattanooga.

The issue then confronting CARTA and the community was the choice of vehicles for the shuttle.

POLICY ISSUES AND ELECTRIC VEHICLES

Community Requirements

As CARTA began the process of selecting a vehicle type for the shuttle it was provided with a set of criteria by community leaders through the downtown planning process. The shuttle had to be of equal quality to the developments in the downtown, it had to be something more than just a ride—it had to be an experience in and of itself, it had to serve as a connector to the developments, and it had to have a positive impact on the environment.

The word *quality* is used extensively in the literature body. In terms of development that Chattanooga has experienced in the last 3 to 5 years, however, the meaning was obvious to CARTA planners. The Tennessee Aquarium is considered among the top three aquariums in the United States. The plaza that surrounds the aquarium was designed by some of the leading urban designers in the country and has become an attraction on its own. The community was not interested in its downtown transportation system being something other than a unique, innovative form that would become another part of the statement that the city was making about its future.

To make certain that the shuttle attracted people from their automobiles, the system had to be more than just a ride—it had to be an experience. Local workers and visitors should be interested in using the shuttle because of its identity and not just as a method of getting from one place to another.

The shuttle system had to be designed in a way to connect the many locations in the downtown area. The connection not only had to be made by locating the routing near the various locations but it also had to be through well-defined passenger boarding areas, distinct graphics, and an effective informational system. The system design also had to have the ability to be expanded and modified as new developments were opened. And, finally, given the city's recent commitment to environmental issues, the shuttle had to be environmentally acceptable.

CARTA Board Policy Concerns

For CARTA the issues separated into both board-level policy issues and staff-level operational issues. The board was concerned with community needs, environmental issues, community support for the CARTA program, financial resources, and broader community issues such as economic development and environmental impacts. The CARTA staff focused on operational issues such as vehicle dependability, functionality of the technology, organizational resources in terms of skills, and the ability to deal with change, labor relations, and vehicle maintenance.

The CARTA Board of Directors is unique within the transit industry. It is both active in its participation in transit activities and is also visionary within an industry that is more known for its conservatism than its willingness to take risks. Taking its cue from a community dedicated to innovation and new approaches to old problems, the board set about for a vehicle that would be

unique and environmentally beneficial and that would provide for the opportunity for economic development expansion.

The CARTA staff found it difficult to keep up with the visions of the board. CARTA, as noted before, is a traditional, fixed-route, diesel fuel–using bus system. The existing buses were very dependable, no new skills or training were required, the service fit with existing labor and management agreements, and of greatest import, no change was necessary. Initial thoughts from the staff focused on buses that were designed to look like vintage trolleys rather than a new technology.

After an initial investigation into a vintage rail trolley system, CARTA turned its attention to electric, battery-operated buses on the basis of a series of articles that chronicled the use of such vehicles in Santa Barbara, California. After a series of visits to Santa Barbara by CARTA board members and top management, the decision was made to pursue this type of vehicle. At this point CARTA retained the services of a local person who had broad and successful manufacturing experience and who was looking for a new business opportunity. His mission was to answer the following questions: Does electric technology that would result in a vehicle that CARTA could use in the downtown shuttle exist today, is anyone making such a vehicle, and if not, could the vehicle be made in Chattanooga?

Thus in late summer 1991 CARTA made a decision to pursue a technology and a vehicle that had not yet been demonstrated to be able to match the rigors of regular use in an urban setting. Even the Santa Barbara experience was in a very moderate climate, with little topographical diversity and ridership levels below what was expected in Chattanooga. The opening of the Tennessee Aquarium in May 1992 required that CARTA place a shuttle in operation using 35-ft diesel fuel–using buses. What had been expected to be a shuttle operation that would carry 10,000 to 20,000 passengers per month became a critical component of the downtown experience, transporting between 50,000 and 100,000 passengers per month. The Santa Barbara vehicle had a seating capacity of 22 passengers, whereas the diesel bus in Chattanooga sat 37 and was already being overwhelmed during peak periods.

The Chattanooga consultant hired by CARTA investigated electric vehicle technology in the United States and Europe and returned with the following results: (a) the existing technology was sufficient to support an electric shuttle bus for use in the CARTA downtown project, (b) no company was currently manufacturing a vehicle that would meet CARTA's needs, and (c) it was feasible to develop a manufacturing organization in Chattanooga to design and build an electric, battery-powered bus for use in Chattanooga and for export to other cities in the United States. What followed was the creation of Advanced Vehicle Systems (AVS), a start-up company in Chattanooga formed to produce electric transit vehicles.

Another outcome of this investigative phase of the program was the development of a relationship between CARTA and Electrotek Concepts, a private company that operates the Electric Vehicle Test Facility in Chattanooga. This facility, originally built by the Tennessee Valley Authority and leased to the private sector, is the only facility in the world that is exclusively dedicated to the testing of electric vehicles and electric vehicle components. The staff at the facility has over 70 years of combined experience with electric vehicles and has done testing for some of the largest companies in the world. Electrotek Concepts functions as an independent testing laboratory for the electric vehicle industry. Both CARTA and AVS developed relationships with Electrotek to provide testing and technical assistance in the development of their electric buses.

Thus the CARTA Board of Directors had met and exceeded their goals. CARTA would be using a new technology, they had the complete support of the political and business communities, the vehicle would be environmentally positive, and the decision had resulted in the creation of a new manufacturing enterprise in the city. Up to this point little attention had been paid to the issues that confronted the CARTA staff in terms of actually operating this new type of vehicle. The positive attention that attached itself to this new vehicle overshadowed any operational concerns that might have been in the minds of the CARTA staff. In fact the can-do attitude of the Board was contagious and permeated through top management.

Creation of Electric Transit Vehicle Institute

CARTA and Chattanooga, as a result of plans to implement what would become the largest electric transit vehicle fleet in the world, began to receive calls from various concerns interested in the program. Electric vehicle component manufacturers, other transit systems, electric utility companies, and representatives of state and federal agencies made contact with CARTA to be briefed on the Chattanooga program. As a result of this interest the CARTA board formed the Electric Transit Vehicle Institute (ETVI), a private, nonprofit organization whose mission is to further the development and use of electric transit vehicles. ETVI was provided a grant by CARTA to initiate its work.

The CARTA Board of Directors also granted funding to ETVI to be used to buy two electric buses. Knowing the lengthy process of receiving grant approval and not wanting to lose momentum created by the decision to use electric buses and the resulting positive response, CARTA leadership wanted to use ETVI as a method of getting electric buses on the streets of Chattanooga as soon as possible. Thus the first two electric buses were ordered from Specialty Vehicle Manufacturing Corporation of Downey, California, and were dedicated into service by the Administrator of FTA in June 1992.

The first electric buses received by CARTA were 6.71 m (22 ft) long, were 2.34 m (92 in.) wide, and had an overall height of 2.51 m (99 in.). The vehicle seated 22 passengers or 19 passengers with one wheelchair. Wheelchair accessibility was provided through a ramp built into the ramp at the entrance of the vehicle. The nominal curb weight was 5,488 kg (12,100 lb), with a gross vehicle weight of 7,711 kg (17,000 lb). The top speed was rated at 64.5 km/hr (40 mph), with an acceleration of 23 sec from 0 to 40 km/hr.

The unit was powered by a direct-current motor rated at 32 kW (continuous) with separate armature and field connections. Nominal input was 216 V. The motor was manufactured by Nelco. The vehicle included a transistorized controller to control power to the motor armature and the motor field separately using independent chopper circuits. This chloride controller had a nominal input of 216 V, with a maximum armature current of 390 A, a maximum field current of 20 A, and a maximum regeneration current of 200 A.

The traction battery was configured by using 108 cells with a nominal voltage of 2.0. The cells were series connected in four batteries of 27 cells with a nominal battery voltage of 54. The 54-V batteries were series connected to provide a nominal traction

battery of 216 V. The cells were capable of delivering 500 A intermittently for periods of up to 90 sec and 200 A continuously without damage to the cell.

The cells were lead acid that used flooded electrolyte. Cells had a nominal weight of 20.4 kg (45 lb) each and a nominal capacity of 375 A-hr. Nominal energy was 73 kWhr at a 5-hr rate at 25°C (77°F).

CARTA Staff Policy Issues

In June 1992 CARTA thus entered the new world of electric buses. The vehicles had no air-conditioning or heating and had windows that were totally removable (thus either it had windows or it had no windows); there were no parts manuals, maintenance manuals, or operators' manuals; and no program for staff training had been developed. The ability of CARTA as an organization to accept change was now to be put to the test.

It was known that the political, business, and other community leaders were very supportive of the program. Adequate funding had been provided for the operation and maintenance of the vehicles. AVS was still in the start-up stage but had entered into a joint development agreement with Specialty Vehicles and was available to provide a direct, local contact with the vehicle manufacturer. In addition public acceptance and support for the new vehicles was very strong from the first day. Many Chattanoogans expressed pride that CARTA took the lead in this area, and more than one visitor to the city requested information on the vehicles to take home to their transit system.

The positive political and community environment made the change easier for top CARTA management to accept. It did not initially, however, help at the line level in the CARTA organization. The maintenance department took an attitude of benign neglect in the hope that this fad would go away. The scheduling department had never before had to deal with a vehicle with a limited number of hours during which it could operate, and the impact of this fact on the scheduling of vehicles and routes was troublesome. The marketing department was concerned about the lack of interior and exterior advertising space on the vehicle, all of which had been completely sold on the diesel shuttle buses. The operations department was concerned about the training needed for drivers of the electric bus, because it had regenerative braking and the range of the vehicle would definitely be affected by the habits of the driver.

CARTA top management was faced with dealing simultaneously with a series of issues. First, management had to confront head-on the issue of technological change. Second, they had to deal with the immediate use in service of a new technology. Third, they had to deal with nonvehicle issues that would be affected by the new vehicle, such as scheduling, marketing, and support facilities.

Dealing with Change

For all the talk about humans being bored, in a rut, or unhappy with repetitive tasks, the fact is that change is more stressful than the status quo. CARTA management embarked on an undefined and unplanned process to encourage change, and it was stressful to openly acknowledge that change. Meetings were held with drivers, mechanics, and staff in which the plans for the electric buses were discussed and questions answered. It was emphasized that this new program would help all phases of the CARTA operation as it pertained to local financial support for public transportation. Opportunities for career advancement and training were emphasized. Fears concerning possible obsolescence of existing skills were put to rest. And above all there was an honest empathy for the concerns, fears, and stress. The feelings of the members of the organization were treated as real.

In the area of drivers, special attention was given to training the shuttle drivers on the use of the electric bus. Information was provided to them so that they could respond to questions from riders. Printed materials that could be given to riders who wanted technical information were developed, and ETVI was identified as a source for further information. News stories that highlighted the drivers as well as the vehicles were prepared. AVS organized meetings for drivers so that they could receive input for future design changes with the next generation of electric buses.

Meetings were also held with the maintenance personnel. Assurances were provided that there would continue to be a steady workload for diesel mechanics. At the same time employees who had an interest in the electric buses were encouraged to let management know of their interest. Additional training was offered through the local technical college. AVS established a standing committee of maintenance employees to provide continuous input to the manufacturer, with the membership of the committee rotated so that all employees could be involved. One particular employee who had the electrical knowledge and demonstrated a keen interest in the new vehicles was promoted to a position of leadman—electric vehicles.

In retrospect a better job could have been done in preparing the organization for the change that occurred. However the key to successfully implementing the electric bus into the CARTA system was the acceptance and acknowledgment of the difficulties that would be faced by the individuals responsible for the vehicles and the service. Then the continuous participation by these individuals permitted them to help design the program rather than be forced by the program to change in response.

Immediate Use of New Technology

The difficulties noted were exacerbated by the need to introduce the vehicles into service immediately. The first question to be answered was what range could the new vehicles provide? When delivered the vehicles came with 375-A-hr battery packs. However these were temporary batteries on loan until the new batteries could be delivered to CARTA. The vehicles were introduced into service in 4-hr blocks of time. This was expanded to 6 hr and then to 8 hr. The range for the buses appeared to be about 120 km (75 mi). Acceleration was good, and the top speed of 64.5 km/hr (40 mph) was above what was needed for the shuttle route, although it did pose a minor problem on the routing of the bus from the CARTA facility to downtown and back, which normally used a highway with an 80-km/hr (50 mph) limit.

When the new batteries were delivered it was found that the original 375-A-hr batteries were being replaced with 300-A-hr battery packs. Confusion on this issue centered on whether CARTA wanted to incorporate battery exchanges as a regular part of the daily service cycle. The 300-A-hr battery packs were smaller and much easier to get in and out of the bus. CARTA agreed to use the new battery packs and experiment with battery exchanges. The result was a reduction of range to about 97 km (60 mi) with an operating day of 6 to 7 hr. The difficulties in

scheduling battery exchanges led to a decision to adjust the vehicle schedule to match the expected range of 97 km.

The initial two vehicles had many problems, primarily with the steering and suspension. There was a great deal of contact between Chattanooga and Santa Barbara, California, for the first 3 to 4 months, and major modifications of the vehicle were undertaken. However the basic propulsion system (the batteries, motor, and controller) operated flawlessly.

The next issue was matching CARTA's staff resources to the new buses. CARTA has a professionally trained maintenance staff for diesel buses, and as part of that staff there are persons with significant knowledge in electrical systems and theory. However CARTA had to rely a great deal on the manufacturer's representatives and the technical personnel from the vehicle component manufacturers to get through the first few months. During that time AVS was beginning to develop its core staff and assisted CARTA in the maintenance troubleshooting. Also Georgia Power in Atlanta had purchased two similar vehicles right after CARTA, and there was constant communication between the two maintenance staffs. AVS arranged joint meetings of Georgia Power and CARTA staffs to discuss the good and bad points of the vehicles and the changes that each agency had made on their vehicles.

A series of related events required CARTA to reshape its policy on staffing for the electric bus fleet. In early fall 1992 CARTA went out for bid for 12 electric buses. Four of these were to be 22-ft models similar to the ones already received and eight were specified to be capable of carrying up to 30 passengers, a vehicle never before produced. AVS and Specialty Vehicle, in a joint arrangement, were awarded the contract. In summer 1993 ETVI participated in two consortia that were successful in securing funding from the Advanced Research Projects Administration (ARPA) of the U.S. Department of Defense that would result in two additional electric buses incorporating the leading technology for demonstration and use in Chattanooga. Thus CARTA had to plan for the receipt of 14 additional electric buses by the end of 1994.

The interest that developed in the Chattanooga program and that led to the creation of ETVI continued to accelerate. One or both of CARTA's electric buses were routinely being shipped to various cities for demonstrations. The buses went to Minneapolis, Miami, Memphis, Boston, Philadelphia, and on three separate occasions (including President Clinton's Inauguration), Washington, D.C. Although ETVI took care of much of the planning and supervision of these demonstrations, there was a great deal of CARTA staff and maintenance time dedicated to these projects.

CARTA continued to upgrade the existing vehicles. Propane heating systems were installed in late fall 1992. An experiment using cellular phones in place of traditional radios was completed (but it was not a success). And in summer 1993 CARTA planned service additions to the downtown shuttle that would place its spare vehicle ratio at a precariously low level.

With these additional strains on the staff, particularly in the maintenance area, it was decided to create a new electrical position and add two positions to the maintenance division. Even with the decision made, the lead time to get the staff to a level necessary in numbers and skills to deal with a small fleet of electric buses was estimated to be between 6 months and 1 year.

Nonvehicle Issues

The process of scheduling transit buses and drivers is a technical skill in which the objective is to minimize the pay time required to operate the bus service. Huge numbers of variables and constraints must be factored into the equation, such as the hours and days of operation, guaranteed pay time, pay penalties for overtime and spread time, and the comparison of added cost for increased personnel versus increased built-in overtime. At CARTA one area in which the scheduler was not concerned was in the operating range of the bus. The traditional diesel bus could stay out all day and the scheduler had only to worry about assigning persons to drive the vehicle. The electric bus, in its current configuration, cannot stay out all day, so a new variable was added to the scheduler's equation. If CARTA decided to use battery exchange as a means of extending the vehicle range, additional variables were introduced concerning the pay time for the driver while the vehicle was being recharged.

For the marketing department, the electric vehicle created an uncertainty surrounding advertising revenues. The downtown shuttle with the diesel buses had been totally sold in terms of interior advertising. The new 22-ft vehicles had no interior advertising, and the plans for the 30-ft model were incomplete. The current buyers of the space wanted some assurance as to future advertising, and the marketing department wanted to be able to calculate potential revenue from this activity. Although this may appear to be a small issue, the buyers of the space were among the downtown merchants who had most strongly supported the development of the shuttle and the revenue from the space generated nearly $30,000 annually for CARTA.

The storage and recharging of the vehicles required further consideration. The round-trip distance between the CARTA facility and the downtown starting point for the shuttle is 6 mi. This meant that approximately 10 percent of the operating range of the electric bus was being used to get it to and from the route. Initially this led to a view that a downtown location for storage and recharging would be preferable. However the cost of building and staffing a satellite facility was unacceptable. Also the downtown location, if only used for storage and recharging, would still mean that cleaning and maintenance would have to be done at the main facility.

The storage and recharging of the original two vehicles is currently done in one bay of the CARTA maintenance facility. Plans are now under way for the modification of the existing storage facility or the construction of a new facility for the larger electric fleet. Experts in electric vehicle technology have been brought in to deal with issues of thermal management, hydrogen gas dispersion, and acid leaks. Issues involving safety and environmental protection are receiving priority treatment.

The handling of the issues that confronted the staff have primarily been accomplished on the run. Many were understood before the first vehicle arrived and were dealt with, others were known but waited for a solution until some operating experience was gained, and others were never anticipated. Finally there are those issues that have yet to be resolved.

CURRENT STATUS OF CHATTANOOGA PROGRAM

As of September 1, 1993, CARTA owned and operated three electric buses. Four additional vehicles were expected to be delivered within 30 days, including one of the 31-ft buses that incorporates a radical design involving a second rear axle that supports the entire battery assemblage, which can be removed from the rest of the vehicle in less than 10 min. By the end of 1993 an additional

seven vehicles were expected. In mid-1994 two vehicles being developed under the ARPA program were to have begun operation in Chattanooga. Thus by the end of 1994 CARTA will own and operate between 10 and 16 electric buses, the largest known fleet of electric transit vehicles in the world.

ETVI has received financing from CARTA, the Tennessee Department of Transportation, the Tennessee Valley Authority, FTA, and the U.S. Department of Defense to underwrite its activities. Currently ETVI is working with CARTA to develop training programs for staff, drivers, and mechanics; supervising the ARPA demonstration projects in Chattanooga; developing a central data base for electric transit vehicles; and gathering transit and electric utility input on the design of future electric buses.

At this time the project would have to be credited as being a success. The vehicles are operating every day, are well received by the riders, and are supported by local leaders. Regional, national, and even international interest has continued to grow. At least one group representing utilities, transit, manufacturers, or government is making contact with CARTA and ETVI each week, with groups regularly visiting Chattanooga to meet with the manufacturer (AVS), the user (CARTA), the test facility (Electrotek), and ETVI, all in one geographic location. This living laboratory presents a unique opportunity to advance the state of the technology.

DECISION TO IMPLEMENT ELECTRIC TRANSIT VEHICLE PROGRAM

The transit industry is a conservative industry. Very little funding has been committed to research and development. Vendors who serve the transit industry have little incentive to conduct such research given the relatively small market that transit represents. A significant number of people are employed in the industries that manufacture and service internal combustion engines and heavy-duty transmissions. Although such industries would not be significantly disrupted by changes from diesel and gasoline to natural gas and propane, there could be a significant economic displacement if there was a wholesale switch to electricity as the fuel of choice.

The technical expertise found within much of the transit industry is not attached to electrical theory and practice. On the other hand the utility industry is not experienced, for the most part, in the transportation area, particularly electric buses. The battery technology being used by CARTA and Santa Barbara is not new. In fact the same systems were being tested in the early 1970s as a result of the first energy crisis.

Thus any transit system wanting to begin on the path toward electric buses will be faced with some obstacles. But there are rewards also. Federal environmental and energy regulations are making the continued use of diesel fuel and, in the future, internal combustion engines much more difficult, if not impossible. The public's awareness of environmental protection has been enlarged and the "old, smelly bus" will increasingly be under attack, whereas those systems that select environmentally beneficial options will have strong public support.

The author has had the opportunity to discuss the electric transit vehicle issue with several in the transit industry and representatives of the utility and private manufacturing industries, and it appears that there are six issues that a community needs to address before deciding to enter the field of electric buses.

First, the local political and business community must support the program. There must be a positive environment within which the transit agency or utility may operate. There must be a recognition by the local leaders that this is still a new territory in which temporary setbacks are the norm.

Second, the leadership of the transit system must have a vision. This unusual foresight must look past the initial difficulties and grasp the long-term benefits and potential. It is very easy for a board of directors, a city council, or top management to initially accept the concept only to reverse course when difficulties arise. Transit systems are normally judged by being dependable, not innovative. The introduction of a new technology requires a long-term commitment, not just a short-term demonstration period.

Third, there must be a commitment of resources necessary to get the job done. Preliminary data at CARTA indicate that electric buses will be less expensive to operate over the long term. But the initial implementation of the program requires added investment in training, facilities, tools, and staff time. Fuel costs in terms of cents per mile are about 50 percent of the fuel cost per mile of the diesel bus. Normal maintenance costs (preventative, minor repairs, component replacement) are also about half for electrics compared with those for diesels. Record-keeping at CARTA during the initial months of operation of the electrics has not been exact, but Santa Barbara numbers are nearly identical in terms of fuel and basic maintenance costs, being about one-half for electrics. However until electric fleets are operated long enough to incorporate life cycle costs such as battery replacement, structural degradation, and motor repair and replacement, it cannot be asserted (without condition) that the long-term costs of electrics will compare favorably to those of diesels. At this point it is known only that the operating costs to date have been lower.

Fourth, acceptance of change must be integrated throughout the organization. U.S. public transportation has long been mired in a philosophy of continuing to do things that it knows will not work with the hope that they will. Traditional fixed-route services, old-fashioned labor and management relations, and continued use of big, aesthetically displeasing urban buses are examples of this philosophy. For example many labor contracts do not envision a day when bus drivers would pull their vehicle into a rapid recharging station and connect the vehicle for a short battery charge, requiring instead that an additional maintenance employee be used to do the recharging. Whether or not electric buses are the way of the future, transit organizations must become welcomers of change, not entrenched opponents.

Fifth, there must be a partnership relationship between the transit system and the vehicle and component manufacturers. Normal procurement procedures involving the writing of voluminous specifications and the selection of the product on a price basis will not work in the electric vehicle industry. The technological changes occurring daily require the relationship to be fluid to take advantage of new developments. The normal hostile relationship between vendor and buyer must be replaced with a collaborative effort in which both parties realize that their success is directly tied to the success of the other party.

Sixth, the transit system must go into the project understanding that an electric vehicle will not satisfy the same requirements as a diesel bus. Developments are now under way in air-conditioning and heating systems, battery development, range extension through auxiliary power units, rapid recharging, and battery exchange systems. All are focused on trying to get the electric vehicle to act more like a diesel vehicle. But the fact is that the

industry has not yet reached that goal. Even so the existing electric transit vehicle can, conservatively stated, meet 25 percent of the needs of most urban public transportation systems. Most transit systems place vehicles in service for 2 to 4 hr during the morning peak and again in the afternoon peak. Thus electric buses could be used for this additional demand period and be recharged in between these periods and during the evening. For example CARTA needs 45 peak buses for its regular service, whereas only 25 are operated all day long.

FUTURE OF ELECTRIC TRANSIT VEHICLES

It is not difficult to envision alternative scenarios for electric transit vehicles in the future. Technological developments that would solve problems dealing with range and horsepower very well may quickly appear. Another energy crisis could galvanize federal support for alternative fuels at a level necessary to move from the drawing board to the road. On the other hand the continued disproportional level of work being done in other alternative fuels may yield positive results before positive results are obtained for electric vehicles. Work on totally different propulsion systems, such as the fuel cell, may make current thinking about alternative fuels obsolete.

The recommendations that follow are those of the author, an operator of urban public transportation systems for the past 20 years. They are not technical in nature, because that is not his background. They are policy oriented and focused on the issues that will result in the best possible environment for the continued development and use of electric transit vehicles. In fact the recommendations could just as well be for alternative fuels. There are actions required by the national government, the private sector, and the transit community. These actions provide the minimum foundation necessary to sustain an effective program of introducing new technologies to the transit industry.

1. The federal government must continue and expand, when possible, programs such as the FTA challenge grant, the U.S. Department of Defense ARPA program, and the Technology Reinvestment Program. These programs all share a common requirement of local matching funds (normally in a one-to-one ratio), thereby ensuring a commitment from the local agency. In addition these programs are broadly defined to permit the maximum level of innovation and flexibility in project design and implementation.

2. The federal government should, within the programs noted, increase the emphasis on practical demonstrations of new vehicles and technologies. Basic research must continue to be funded, but there is far too little work being done in the demonstration of the new technology in real-life operating environments. There is a growing concern that a continuation of the current approach to electric vehicle research and development will lag behind the practical application of technology that is occurring in Europe and Japan. CARTA is placing new electric buses in regular service upon completion of their manufacture without waiting for the normal testing and evaluation process to be done by the manufacturer. Although this poses a risk to the operating organization, it accelerates the development of the technology by providing for the rapid feedback from the operator to the manufacturer.

3. The private sector, including vehicle manufacturers, component manufacturers, and utility companies, must develop knowledge of public transit operations. There has been a tendency for vehicle design and component development to come from the viewpoint of the technical staff of the provider rather than as a response to the needs of the transit system. This point of view may have resulted from the initial target being private automobiles and light-duty vehicles. But CARTA in 1 year will introduce more people to the concept of electric vehicles than the major automobile manufacturers may do in the next 10. Although the long-term focus will undoubtedly be on the much larger automobile, van, and small truck market, the short-term developments must be responsive to the needs of the transit community.

4. Process must replace product in the relationship between the transit operator and the vehicle manufacturer. Formalized, price-based procurement will need to be replaced with negotiated procurement that permits constant change through the construction process. The technology is changing so rapidly that a transit property will probably receive a vehicle much different from the original specifications. Indeed transit systems should demand the right to take advantage of improvements throughout the construction process.

This raises questions that will need to be addressed by the transit system, the manufacturer, and the funding agencies. How can price be determined given the fluid nature of the process? In the development of new technological approaches to electric buses, what level of risk should be borne by the transit system compared with that borne by the manufacturer? How will traditional warranty issues be handled? How will product improvements be provided to existing customers? How will the large development costs be distributed over a relatively small buying population?

5. For electric transit vehicles to succeed transit systems must take risks and accept change. This will require leadership from the community, the governing bodies, and top management. It will require a commitment to training and resource allocation sufficient to support the new vehicles. It will require changing practices that have been held sacred in the transit industry for nearly 50 years. And it will require a long-term view rather than the normal next-day perspective. CARTA could have purchased a few vehicles for use in its downtown shuttle, thereby receiving a snapshot of the electric vehicle technology. Instead the decision was to change the organization to be able to handle a changing technology, thereby buying a moving picture rather than a snapshot. This decision, critical to the overall success of the program, requires the organization to accept constant change and, in fact, to require constant change.

6. Ultimately the success of electric transit vehicles will come when one transit system makes the commitment to completely replace its fleet with electric buses—and then shows others that it can be done. When a person owns two automobiles, he or she becomes attached to one over the other and finds ways to limit the use of the less desirable vehicle. Transit systems that have more than one type of bus will find that one is preferred over another and inevitably is used more extensively. But when the fleet is of one type the entire organization must come together behind that vehicle and commit the resources necessary to maintaining the service to the community.

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