CASE STUDY

Electric Buses Energize Downtown Chattanooga

Poor air quality, traffic congestion, urban decay, and loss of revenue once plagued Chattanooga, Tennessee, an industrial city set in a valley surrounded by mountains. Electric buses became part of the solution to each of these problems when a group of citizens, business leaders, and government officials banded together to improve their hometown.

One Innovative Idea Leads to Another

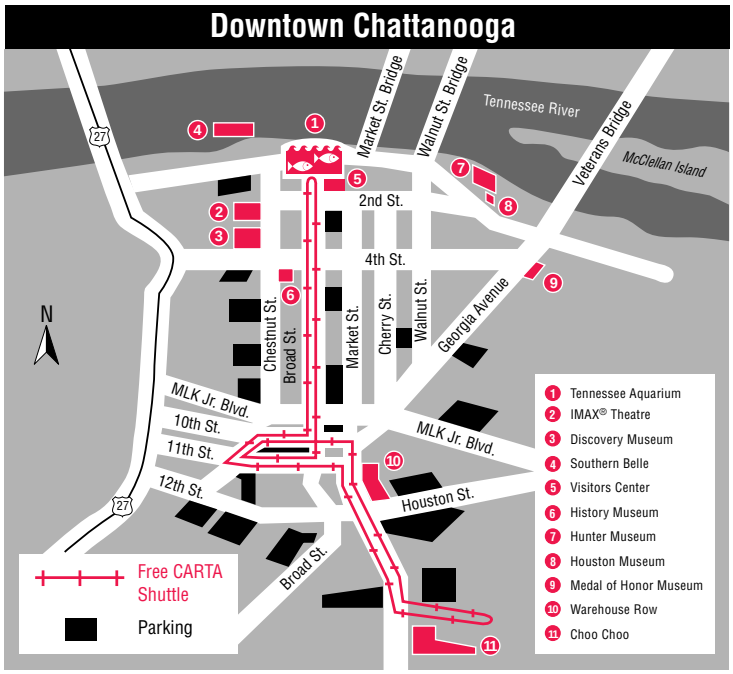
Chattanooga's downtown consists of three main parts: the riverfront (museums), Miller Park (business district), and the Chattanooga Choo-Choo Resort (shopping area). Constrained by its geographical location between a river and a mountain, the entire corridor stretches about 2 miles north to south and between 6 and 10 blocks east to west. As the downtown area was revitalized, it became apparent that a new mode of transportation was needed to reduce pollution, relieve traffic congestion, and free up land for development projects rather than parking lots.

The Chattanooga Area Regional Transportation Authority (CARTA) envisioned a two-part plan:

- Two parking garages located at either end of the downtown corridor to "intercept" cars and
- A free shuttle service to transport passengers between the garages and their final destinations, funded by parking fees.

Because of the city's severe air pollution, CARTA looked at several different kinds of alternative-fuel vehicles, including a vintage trolley. But the shuttle system needed to be more than just a ride – it had to reflect Chattanooga's new spirit. "We wanted the transportation to be an event in itself," says Tom Dugan of CARTA.

After visiting an electric bus operation in Santa Barbara, California, CARTA management boldly decided to move ahead with these zero-emission vehicles (electric buses produce no tailpipe emissions that could affect air quality). However, in the summer of 1991, when



this decision was made, no electric buses had been demonstrated to be reliable under the rigorous daily urban driving conditions Chattanooga's shuttle service would require. Although the technology was available, no company was building exactly the kind of vehicle CARTA needed. But unique opportunities supported the use of electric buses:

- CARTA management and the City of Chattanooga were open to new ideas.

- Funding from the Federal Transit Administration (FTA, $15.7 million), Tennessee Valley Authority ($2 million), and Tennessee Department of Transportation ($2 million) would cover the entire cost of the parking facilities and first electric buses. Dugan claims, "Without FTA, there would not have been a program."

An Idea Becomes Reality

To maintain the momentum while developing their own bus design, CARTA ordered two electric buses from Specialty Vehicle Manufacturing (SVM) Corporation, Downey, California, which had supplied the Santa Barbara vehicles. When the buses arrived in Chattanooga in June 1992, however, they were met by a staff that had no experience in working with electric vehicles. In fact, many employees were concerned that their skills in working with existing diesel buses would become obsolete.

CARTA management conducted meetings with the maintenance and operations staff to discuss the new buses and answer questions. They emphasized opportunities for training and career development. Maintenance mechanics were assured that they would continue to work on diesel buses, but those who were interested would be trained on the electric buses. Dispatchers learned to schedule the electric buses according to a driving cycle defined by the time it takes to charge batteries – in contrast to scheduling diesel buses that can run all day and be refueled in a matter of minutes. Drivers were instructed not only in operating the buses, but also in answering questions from passengers who want to know more about electric vehicles. All employees were encouraged to voice their opinions about the buses and suggest ways to improve the design.

CARTA estimates that it takes about 6 to 12 months to train an electric-vehicle staff adequately. Therefore, it relied on its suppliers for help in handling problems through the first few months. For example, the initial two buses encountered difficulties in the steering and suspension systems. The steering system was easily adjusted, but the suspension system needed major modifications. Both the front and rear ends of the buses were redesigned and retrofitted by SVM.

Partnerships Foster Technological Developments

In spite of rough spots, the first buses were successful: the CARTA staff gained experience in their use and maintenance, and their feedback helped SVM improve its bus design. But ordering buses from California was an expensive proposition. Seeing a unique opportunity, a local entrepreneur formed Advanced Vehicle Systems (AVS), a company to manufacture electric buses in Chattanooga. Working closely with SVM and CARTA, AVS aimed to develop an electric bus that would stand up to the rigorous conditions of an urban transit system. CARTA's willingness to work with prototypical vehicles allowed AVS to experiment with new ideas. By early fall 1992, CARTA placed an order for 12 electric buses to be built by AVS.

CARTA also received funding from the U.S. Department of Defense Advanced Research Projects Agency (DARPA) for two more electric buses, purchased from AVS. DARPA's Electric and Hybrid Vehicle Technology Program focuses on developing electric vehicles for military applications. CARTA tries out new technologies under actual working conditions for this program. Recent projects have tested a compressed natural gas (CNG)/hybrid electric bus, advanced batteries, and air-conditioning systems. Dugan explains, "DARPA's approach is to try something, and if it doesn't work, find a way to fix it."

Real-Life Testing

Today, between 600,000 and 750,000 passengers ride CARTA's electric buses along the 3 1/2-mile shuttle route each year. "The passengers absolutely love them," says Valerie Powell of the Electric Transit Vehicle Institute. Many Chattanoogans leave their cars in the parking facilities and ride the buses to their offices in the morning, to restaurants at lunch time, and back to the garages in the evening. For a growing number of downtown residents, the buses serve as the primary means of transportation. And for visitors, the buses have become an attraction in themselves – ridership increases dramatically during the summertime tourist season.

Fleet Facts

Fleet Type:	Public mass transit
Fleet Size:	81 vehicles, of which 16 are alternative-fuel
Alternative Fuel:	Electricity
Vehicle Type:	22- and 31-ft passenger buses
Location:	Chattanooga, Tennessee

Each 22-ft electric bus can carry 22 seated passengers and about 8 to 10 standees; the 31-footers can carry 25 seated passengers and 5 to 7 standees. A ramp built into the entrance to each bus accommodates wheelchairs. The buses stop at each block and are scheduled at 5-minute intervals over 16-hour days. Depending on the season, 3 to 8 electric buses are on the streets of Chattanooga at any given time.

Drivers needed to adjust to several features:

- On start-up, pressing harder on the accelerator does not immediately give greater power and may damage the controller. Once the bus is moving, however, acceleration is equivalent to that of a diesel bus.

- As soon as the accelerator is released, the bus slows down as its regenerative braking system uses the kinetic energy of the moving bus to charge the battery. This feature helps conserve the energy of the battery and extends the vehicle's range. If the bus is handled

correctly, the driver can coast to a stop without applying the power brakes at all.

- Air conditioning and heating systems are still in the developmental stage. Propane heating systems have been installed in some buses, but the drivers are often chilled by cold air coming through the entrance doors.

The range of the vehicles is affected by driving techniques, and CARTA monitors driver performance. When a bus's range is low, the driver receives additional training in operating techniques. Dugan has found that most drivers catch on right away, however, and need only a reminder now and then.

Because of the close relationship between AVS and CARTA, problems in the bus design are corrected quickly, and modifications are incorporated into the next design. For example, the steering and suspension systems have been upgraded with each generation of buses.

CARTA's buses have either direct current (DC) or alternating current (AC) propulsion systems. The older buses have DC systems, which are less expensive and have less complex controllers. The AC systems in the newer buses are smaller and lighter, have more power, and are more efficient at converting electric energy into mechanical energy. An AC system uses about 30% less electricity and weighs about 40% less than a DC system. The AC buses also seem to handle uphill grades better, but they have a lower range than the DC buses.

Battery packs are installed underneath the frame on the 22-ft buses and on the back of the 31-ft buses. The strain of the additional weight in the back has resulted in broken back axles on the 31-ft buses.

The availability of parts is another issue, because they are not being mass produced. If a critical part, such as a controller, is not immediately available, a bus could be out of commission for some time. AVS tries to keep one or two of each part in stock, but Powell says, "You can't expect an electric bus to perform the same as a diesel bus. If it's out of service for two weeks waiting for a controller, you need a backup. There's no answer until electric vehicles become more prevalent."

Care and Maintenance of Batteries

Chattanooga's first electric buses were charged at CARTA's main maintenance facility, which was a 6-mile round trip from the starting point of the shuttle route, 10% of the vehicles' driving range. CARTA needed to find a more efficient way to charge the batteries.

In August 1994, Shuttle Park South, a combined electric-bus terminal and 550-space parking facility, opened at a cost of $4.2 million. Located next to the Chattanooga Choo-Choo entertainment complex at the south end of the shuttle route, it houses the electric-vehicle maintenance facility, a battery changeout station, and the battery chargers.

Each bus has at least two sets of lead acid batteries. The battery packs for the DC buses weigh about 1,000 pounds, and they can easily be exchanged in about 10 to 15 minutes. These buses usually run on a freshly charged battery pack as the depleted pack is charged. The AC buses, on the other hand, have battery packs that weigh about 3,000 pounds and are not so easily replaced. If an AC bus is needed immediately, the batteries are changed out; otherwise, the batteries are charged in place inside the bus. A full charge takes about 6 to 8 hours, but a rapid-charge system is being developed that would charge a battery in 2 hours or less.

Paying for Itself

Operating costs for the electric buses are covered by parking revenues and lease of commercial space in the parking facilities. According to Dugan: "Operating costs are basically the same for diesel and electric. Labor cost is the most expensive line item, and it's the same for both types of buses. But there are environmental benefits to the electric buses." No tune-ups or oil changes means that maintenance costs are lower for electric buses than for diesel buses.

Shuttle Park North, CARTA's second parking facility, opened in June 1996 near the Tennessee Aquarium. It has space for 650 cars and houses a multiscreen theatre. Of the combined 1,100 parking spaces at the two parking facilities, 450 are monthly rentals, a good indication of the high usage factor of the shuttle system.

From Chattanooga to the World

The Electric Transit Vehicle Institute (ETVI), funded by CARTA, Tennessee Department of Transportation, Tennessee Valley Authority, FTA, and DARPA, was originally formed to operate the buses for CARTA. As CARTA became more proficient in operating the buses, and more inquiries arrived from other fleets considering electric vehicles, ETVI's focus shifted to public relations and promoting the design, production, and use of electric transit vehicles. Promotional activities show electric buses in action under realistic conditions:

- The Tennessee Valley Authority and the Electric Power Research Institute have installed an electric-vehicle research center with multimedia exhibits and hands-on displays at CARTA's Shuttle Park South. Visitors can tour both the research center and the terminal area to learn about electric vehicles.
- CARTA buses have been demonstrated in Minneapolis, Miami, Memphis, Boston, Philadelphia, and Washington, D.C.
- Three AVS-built buses (one from CARTA and two owned by Georgia Power) participated in the electric fleet at the 1996 Olympics in Atlanta, the largest electric-vehicle fleet ever assembled. The fleet was managed by ETVI, and CARTA and AVS mechanics and engineers provided technical support.

By the Numbers

Purchase Cost:	$160,000 to 180,000 for 22- and 31-ft electric buses
Fuel Cost:	$0.04 to 0.05/mile for electric; $0.16/mile for diesel
Maintenance Cost:	$0.045 to 0.075/mile for electric; $0.185/mile for diesel
Fuel Economy:	1.2-1.8 kWh/mile for electric; 4 mpg for diesel
Vehicle Range:	45-60 miles for electric
Top Speed:	40 mph for electric

- A new program, sponsored by the Tennessee Department of Transportation, allows local transit agencies throughout Tennessee to "borrow" an electric bus for a week. They operate and maintain the vehicle as part of their regular public transportation fleet. These demonstrations help agencies decide whether electric buses are appropriate for their locations by showing them not only the possibilities, but also the reality of electric vehicles.

- A memorandum of understanding has been signed in which CARTA and ETVI will provide technical expertise in building a pilot electric transit system in San Jose, Costa Rica, with funding from the Rockefeller Foundation. This project will test the use of electric buses in a developing country with a tropical climate and may lead to a new industry in this Central American nation.

"Everywhere we've gone, it's been a learning experience, both for us and the local communities," says Powell.

Future Plans

Someday, CARTA's public transportation fleet may consist entirely of electric vehicles. A third parking facility is also being considered. Meanwhile, CARTA and ETVI continue to develop and test electric-vehicle designs for urban and rural applications, particularly buses that can handle the uphill grades of the Tennessee mountains surrounding Chattanooga. Dugan feels the next wave is the CNG/hybrid electric bus, and CARTA has been testing a prototype.

CARTA and ETVI also continue to promote the use of electric vehicles, making sure that fleet managers understand all the necessary factors to make a good decision. As Powell says, "Before fleet managers make their choices, they should visit a facility operating electric vehicles so they understand the pitfalls as well as the advantages." Working together, CARTA and ETVI hope to eliminate those pitfalls and make electric buses the vehicle of choice for mass transit systems everywhere.

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This brochure has been reviewed by representatives of vehicle manufacturers, fuel providers, fleet operators, and federal and state governments.

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