CHAPTER 1

A Brief History

The trolley bus is an electrically powered vehicle that first appeared on the scene in Europe at the turn of this century, but its technological development can be traced back to the drawing boards of designers and planners in the early 1880s. Unlike the motor or diesel bus, the trolley vehicle operates quietly, gives off no exhaust, accelerates quickly, performs well on hills, and runs on electrical energy that is not necessarily dependent on oil--a fact that is contributing to the renewed interest of transit system operators in the trolley bus mode.

Trolley bus systems, i.e., the power substations, overhead electrification, and vehicles, are also attracting attention because of their possible applications in areas where environmental, topographical, or fuel considerations are of primary importance and where ridership is high but not great enough to justify rail transit.

The trolley is powered by electricity delivered to the bus from a pair of wires located about 18.5 ft above the road with a 2-ft separation. Two trolley poles are mounted side by side on the bus roof. Each is topped by a grooved carbon shoe on a swivel mount. A spring at the base of the pole presses the shoe to the wire so that it remains in contact with the underside of the wire as the bus moves forward. Although it must follow the wire, the trolley bus can deviate about 13 ft from the centerline of the wire for curbside passenger stops or to bypass improperly parked vehicles or other obstacles.

The body and running gear of a trolley bus are generally very much like those of a motor bus. Because the motor buses are built to standardized designs and use components that are identical or similar to those for trucks, they benefit from the lower costs of volume production. However, the power-collection and propulsion systems are unique to the trolley bus and, therefore, more costly. But because the propulsion system is durable, the trolley bus has a long economic life (motor buses may be purchased every 5 to 10 years; trolley buses have known 20- to 30-year service lives). Sometimes propulsion components are reused when the bus body is replaced.

The electrification subsystem is an essential part of the complete trolley bus system. The two overhead wires cover the entire route in both directions, plus garage and emergency routings. They must be supported above the roadway, usually by strengthened utility poles, span wires, and specialized hardware so that the bottom surface of the wires is smooth and unobstructed. Specialized hardware is used at junctions for turnouts and crossovers--with as much as a ton of equipment supported above the streets at complex intersections. Trolley buses operate from about 600-650V direct current (DC). Thus, substations are required at intervals of approximately 1 to 5 miles to convert commercial alternating current (AC) power to the proper DC voltage with protective switching.

The deployment of trolley buses can be traced through five distinct periods. The birth of trolley bus technology and the first actual in-service use of a trolley extended from the 1880s to 1915. The first trolley bus was developed by Werner von Siemens in Germany and was put into revenue service in 1901 in Konigstein-Bad Konigsbrunn, Germany. The first commercial trolley bus operation in the United States may have been in 1910 on a short route in Hollywood, California, as a connection between the Pacific Electric Railway and a small settlement in Laurel Canyon. In 1911 trolley buses were running in Bradford and Leeds, England. One went into service in 1913 in Merrill, Wisconsin, but lasted only about 1 year.

Possibly the first trolley bus that went into revenue service anywhere was in Konigstein-Bad Konigsbrunn, Germany in 1901 (photograph courtesy of Siemens Company).

The second period in the history of the trolley bus is generally recognized as beginning in 1921, after a 7-year hiatus primarily because of World War I. It extended until about 1926.

In the early 1920s there were new efforts at establishing trolley bus services. Toronto used four Packard trolley buses for 3 years, starting in 1922 on the Mt. Pleasant Line. On New York's Staten Island, 23 vehicles built by the Atlas Truck Company were operated. The Oregon Avenue Line in Philadelphia was established at that time and is unique in that it remained in continuous operation for nearly 40 years. None of the other U.S. trolley bus lines of this period lasted for more than a few years.

Some of these early vehicles were primitive by today's standards, but they were functional. Some designs were taken from the gasoline buses of the day; others resembled small streetcars on high wheels. Solid, rather than pneumatic, tires were the rule. By the late 1920s, larger and better motor buses were being developed. Manual gear shifts were not satisfactory in city buses, and gasoline-electrics became available. The gasoline engine turned a compact generator, and the electric power was used by electric motors that drove the rear wheels. In a technical sense, it was a simple matter to replace the engine and generator with trolley poles and a control system.

The third period, from about 1927 through the early 1950s, saw the trolley bus gain its maximum deployment in North America. In 1927, 12 vehicles were running in Rochester, New York. In 1928, 10 began service in Salt Lake City, Utah, and 16 more a year later. Trolley buses came of age with a large Chicago installation in 1930-1931. Six routes were set in the northwest section of the city, a residential district that had been built in the 1920s. Trolley buses required less investment than extending the tracks of neighboring streetcar lines. The Central Avenue Line, a 15-mile crosstown route, handled 50,000 passengers/day. Although the ridership was sufficiently high to justify street railway operation under normal circumstances, the route included a long bridge over railroad tracks that was not strong enough to carry streetcars. The trolley buses operated on a headway as short as 45 seconds in rush hour. This showed that the mode had real possibilities in city transportation service.

In 1939, the Twin Coach Company built this semi-articulated trolley bus, which bent in the vertical direction only (photograph courtesy of Flxible).

At the beginning of this third period, the trolley bus was used largely to feed existing street railway lines or was placed on routes that did not warrant the investment in street railway facilities. However, this was quickly followed by using trolley bus technology to replace street railways. The trolley bus soon became the predominant mode on many of the country's major transit systems. With the exception of the war years, 1941 to 1945, the number of trolley buses used grew steadily.

The largest installations before World War II were in Seattle, Washington, and in New Jersey. Seattle completely converted its electric and cable-drawn streetcar lines to trolley buses in 1939-1940. The system had approximately 100 route-miles and 300 trolley buses, some of which ran continuously until 1978 when the remaining system was shut down for a complete rebuilding. Today some 109 vehicles operate over 55 route-miles.

In New Jersey, Public Service Coordinated Transport (now NJ Transit) operated an extensive route system with streetcars and some motor buses that served several cities and many smaller towns. In the early 1930s, the company experimented with trolley operation of gasoline-electric buses, retaining the engine and generator for a dual-service vehicle. After a successful trial, about 400 new All-Service Vehicles were bought in the mid-1930s, most of them from Yellow Coach and a few from Mack. Approximately 200 more were converted to gasoline-electric in the company's own shop. Some routes were only partly wired, i.e., operated electrically to the end of the wire where the driver retracted the poles and started the gasoline engine. But Public Service Coordinated Transport was one of the first transit companies to buy diesel buses with automatic transmissions. It moved quickly after World War II to convert its streetcar and trolley bus lines to this mode; the last of the All-Service Vehicles was retired in 1948.

A new trolley bus crests the 18 percent "counterbalance" hill on Queen Anne Avenue North in Seattle; the famed Space Needle is in the background (photograph by J.P. Aurelius).

Trolley buses had their heyday in the years following World War II. The fourth period in their history stretched from the 1950s through the early 1970s. During this time, the trolley bus--although still in competition with streetcars--was recognized as an attractive alternative on the public transit scene. But many problems were beginning to develop. These problems contributed to the almost total disappearance of the trolley bus with a speed that practically paralleled the trolley's success before the 1950s. The availability of larger, high-performance diesel buses, the overall decline of the transit industry, and the changing economics of trolley bus operations combined to retire this mode from all but a handful of North American cities. By the end of this fourth period only 10 systems in North America still retained trolley bus operation. In the United States these included Boston, Philadelphia, Dayton, Seattle, and San Francisco. In Canada systems that survived could be found in Toronto, Hamilton, Edmonton, and Vancouver. One system operated in Mexico City.

The fifth period in the history of the trolley bus started in the early 1970s and continues to the present. It is marked by rekindled interest in trolley bus technology not only from the perspective of new designs of totally new vehicles but also from the perspective of building on the best parts of the past technological development and making new applications to meet current and future transit requirements. During the last several years, every trolley bus operator in the United States and Canada has purchased new vehicles. Interest has been renewed as a result of changes in the relative cost of diesel fuel. Increased concern about the environment has also prompted transit companies to look at the trolley bus as an alternative and/or supplement to the existing transportation system.

Toronto began the modern trolley bus era in North America in the late 1960s by buying unpowered Flyer buses and installing rehabilitated electrical gear in its own shops (photograph by J.P. Aurelius).

A new Brown Boveri/GM Diesel Division trolley bus is shown in Edmonton (photography courtesy of Brown Boveri/TRM Industries, Inc.).

Both in North America and in other parts of the world where trolley bus operations have been an integral part of the transportation system, this period has also witnessed the introduction of new technology that relates to propulsion system hardware; the complete rebuilding and expansion of an existing system; and the installation of an entirely new system in Guadalajara, Jalisco, Mexico.

In the chapters that follow in this report, a variety of factors pertinent to trolley bus technology and application are presented. Selected materials are included, where appropriate, to enhance the summaries provided on (a) updates on current operating trolley bus systems, (b) vehicles and propulsion systems, (c) system infrastructure, and (d) applications of the trolley bus.

With its poles locked down and the gasoline engine turning its generator, an All-Service Vehicle drives away from the overhead wires (photograph courtesy of NJ Transit).

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CHAPTER 2

Perspectives on the Trolley Bus

In an age of high technology, supersonic transports, high-speed rail, and the natural urge to get from point A to point B in the fastest time possible, the trolley bus may at first glance appear to be an anachronism whose time has come and gone. Such is not the case, according to a number of prominent individuals in the transportation community who addressed participants at the Workshop on Trolley Bus Applications in Seattle, August 29-September 1, 1982.

Robert A. Makofski, conference chairman, noted: "In 1962, or even in 1972, the idea of a workshop on trolley buses would have been greeted with genuine indifference, if not disdain. Yet today in 1982 many of us are here because of a belief that we are about to see the second coming of the trolley bus.

"The trolley bus has a continuing and perhaps expanding role to play in public transportation. That role will depend on the city, the route, and the environment. Most people recognize that such advantages that accrue to the trolley bus such as more rapid acceleration, its hill-climbing ability, the improved impact on the environment, and the potential conservation of oil must be balanced against the higher initial investment cost, the visual intrusion of overhead wires, and the decreased flexibility associated with being tied to a wire."

Makofski stressed: "The purpose of this conference is to aid in identifying the applications and the technology that can affect the balance in favor of the trolley bus." He explained that participants would be made aware of the current status of operating systems in the United States and abroad, as well as considerations of many factors related to trolley bus development and system technology.

Neil Peterson, representing Seattle Metro, emphasized one significant factor that has contributed to the success of the trolley bus operation in Seattle--the cooperation and involvement of both the general public and the area's elected officials. Such cooperation, generated by public information efforts, helped stave off the movement to eliminate the trolley bus altogether. Peterson noted that the topography of Seattle with its many inclines was a natural for the trolley in addition to other advantages such as its relatively quiet operation and lack of pollution.

He observed that by 1990 Seattle will have some 125 miles of trolley line compared with about 55 today. Future plans call for increased use of dual-mode vehicles.

Duane Berentson, Secretary of the Washington State Department of Transportation, observed: "Trolley buses are only a part of the total public transportation system--a very important part." The state "looks at all forms of public transportation to provide the best alternative for the area served. Thus, the overall goal is a balanced system serving our diverse population with its varied settlement patterns."

"The application for the use of trolley buses in the dense urban areas is desirable and appropriate. If the present testing of trolleys that have the capability to operate on either electricity or diesel fuel proves successful, it would make trolleys, at least the rubber-tired versions, much more flexible and usable on routes exhibiting both high and low densities."

The Washington State transportation official emphasized: "Public transportation is not static, but a modal concept that needs constant attention in a changing technological and social situation. The trolley bus concept is both old and new, socially rejected and accepted, fixed rail and rubber tired. These diversities and the practical and clean operation of the vehicle put trolleys in an appropriate and dynamic place, and we must continue in our efforts to improve this viable public transportation mode."

Aubrey Davis, UMTA's Region 10 Administrator, represented UMTA Administrator Arthur E. Teele, Jr., at the conference and stated the agency's "strong interest in and support for the trolley bus as a viable and effective transit alternative. [Recognizing that] it may be unrealistic to expect that trolley buses will again be a dominant urban transit mode in this country, there is considerable renewed interest in the capacity of this mode to meet certain modern transit needs.

"Clearly, trolley bus systems have numerous advantages that make them particularly attractive in light of the current economic and political realities. Like all electric transit, this mode offers independence from diesel fuel and the uncertainties in its price and availability that will undoubtedly persist through this century. Less than 16 percent of U.S. electric power is obtained from petroleum and the percentage is expected to decline. This means that the trolley buses will be increasingly independent from petroleum of any kind. This factor, in and of itself, is a tremendous advantage."

Trolley systems are "environmentally attractive in that they offer an option for meaningful air quality improvements in areas of concentrated pollution such as the central business districts of many of the nation's cities....There are also economic factors that are equally attractive."

Davis also explained: "Actual experience with trolley bus systems here in the United States and abroad, as well as UMTA-sponsored research efforts, will result in more flexible deployment of trolley buses that could lead to further operating cost savings....Since 1975, UMTA has contributed some $100 million to the revitalization of trolley bus operations in Boston, Dayton, Philadelphia, San Francisco, and Seattle. A total of 673 new trolley buses have been put into service in recent years so that all existing fleets have been renewed....We are currently providing $660,000 for a research project that will provide a comparative evaluation of trolley coach propulsion systems.

"UMTA is also funding research to develop a flywheel energy storage system for urban transit vehicles. The use of this flywheel technology can result in dramatic reductions in the amount of overhead wire needed for trolley buses."

Davis concluded by noting that the trolley bus is not "a panacea that will be the ultimate solution to this nation's urban transit needs, but it is an affordable, environmentally attractive mode that certainly should be considered as communities seek the appropriate mix of technologies that will best serve the needs of their citizens."

George Krambles of Terence J. Collins Associates, Inc., Schaumburg, Illinois, cautioned that "in addition to the purely technological problems, there are operational, institutional, and economic concerns to be overcome if the penetration of the trolley bus into the whole public transit market is to become significant." Krambles used the rise and fall of the trolley bus in Chicago to illustrate his remarks.

"The cost of operating trolley buses in Chicago was becoming significantly greater than that of motor buses in the same service. Trolley buses were burdening the system with service regularity and control problems over and above those caused by the fast-slipping reliability of the existing 20-year-old hardware....Although trolleys comprised less than 9 percent of the fleet, they resulted in 44 percent of the tow-ins. Delays and hazards due to the exposed overhead wires, a problem accentuated by Chicago's hundreds of low-clearance underpasses, were worsening....Delivered to the vehicle, electric power was costing 60 percent more per bus-mile than diesel."

"The replacement of Chicago's last 200 trolley buses with motor buses in early 1973 provided immediate cost relief, minimized capital investment at a critical time in the transit system's rehabilitation program and resulted in improved service performance for the nearly 30 million riders per year using the affected routes."

Economic constraints, Krambles went on to observe, "have always weighed heavily against new trolley bus starts or conversions because of the relatively high portion of investment needed for fixed facilities--mainly poles, wires, and substations. Under moderate passenger traffic, investment in fixed facilities is likely to exceed the investment in vehicles. And while the fixed facilities have to be able to serve the maximum load, they cannot easily be partly relocated or stretched to reach new territory if traffic on the original alignment goes into a slump. During the period between 1948 (order) and 1951 (delivery) of a single order of 349 trolley buses for Chicago, ridership declined so rapidly that unanticipated investment had to be made immediately in 27 route-miles of fixed facilities in order to usefully employ all the new buses."

On the other hand, Krambles stressed: "Only in those cities where transit gets a price break in buying electricity from a municipal utility does there appear to be a significant advantage in the cost of delivered power compared with diesel fuel--despite OPEC.

"In the United States, for trolley bus application to emerge further as a public policy preference, there needs to be found a way for private power companies to provide electricity for public transit use at a lower rate than commercial customers pay."

Furthermore, new support technologies for communication and service control have made it easier to live with the special constraints of "being bound to wire.

"The trolley bus is vulnerable to delay and resulting service irregularity resulting from having to progress pretty much in a fixed sequence along the fixed route of the overhead wires...but what a boon it would be for the operating department if a trolley dual-mode bus could work any route whether or not it was wire-equipped....Limited dual-mode bus propulsion already exists, using battery, internal combustion motor, or flywheel as the second source....Through expanded and improved technology, we can and must reduce the operational, institutional, and even the economic problems that have so far held the trolley bus to a minor role in public transit and technology."

In the chapters that follow the common themes expressed by the individuals quoted here are dealt with in detail. These themes serve as catalysts for an examination of the trolley bus system's advantages and disadvantages, technological advancements, and applications in urban areas both in the United States and abroad.

CHAPTER 3

Updates on Trolley Bus Systems in Operation

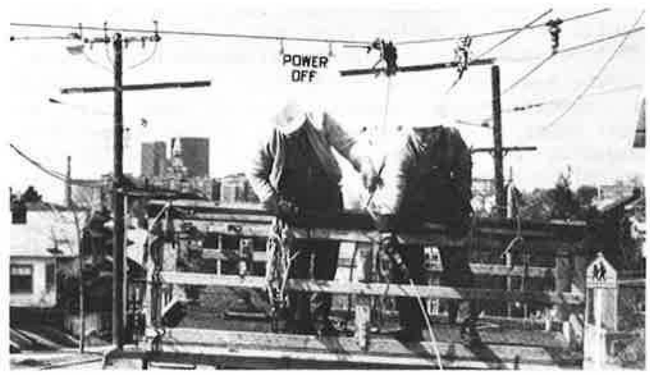
Ridership, difficult terrain, air and noise pollution, the presence of subways, and the availability of feeders to rail lines are some of the factors that need to be considered in the development of new trolley bus systems or in the enhancement and expansion of systems already in place. How these factors, as well as others, have influenced existing systems in four North American cities and in Europe overall and how they can be viewed by those metropolitan areas considering the start-up of new systems were the focus of five presentations, which are summarized below. The edited texts of these presentations, as well as a paper describing developments in Brazil, are included in the Selected Materials section of Chapter 3.

IN SEATTLE . . .

George Benson, a member of the Seattle City Council and of the Council of the Municipality of Metropolitan Seattle (Seattle Metro), examined the public endorsement of trolley coaches that was responsible for the initial installation of the mode in Seattle during the late 1930s and again for its rehabilitation and expansion in the late 1970s. During the earlier period the then City Municipal Railway was faced with the need to modernize an antiquated rail system. To improve the condition of transit services in Seattle, replacement of the entire rail system with gasoline-powered buses was proposed. This plan was met with disfavor and abandoned. In 1939 a new proposal was advanced that included the development of a fleet of 235 trackless trolleys and 130 gasoline-diesel coaches. The public approved this plan, and some 18 months later the new system was in operation.

For about 20 years, the trolley bus operated successfully and then all but disappeared during the 1960s. At that time it was further proposed that the entire system be replaced with buses, and the size of the system gradually decreased. The original 100 route-miles dwindled to about 26 route-miles.

The decline in the mode, however, prompted the formation of numerous citizen action groups who lobbied for support to retain electrified transit services. Through the efforts of such groups an initiative appeared on the 1964 municipal ballot to modernize the trolley system. Momentum continued for the retention of an electrified trolley bus system and, as a result, many public officials increased their support to make such a system a viable and integral part of the public transit operation in Seattle.



In 1976 Seattle Metro line crews put some size 0000 copper trolley wire up in place of the traditional size 00 bronze formerly used. The trial was a success, and most of Seattle's new trolley wire is 0000 copper (photograph courtesy of Joe Hawkins).

After the transfer of the transit system from the City of Seattle to Seattle Metro, the City Council requested a plan that called for replacing the entire system, doubling the route-miles to 55, and acquiring 109 new trolley buses. From that point Seattle Metro began the planning activity that has resulted in the city's expansive and widely used system--one that uses current state-of-the-art technology. The principal reasons for the system's success in attracting riders and in overall operations are related to (a) the public support for expansion and retention of the mode; (b) the involvement of community and professional organizations; (c) the support of the political infrastructure obtained through education and information dissemination efforts; and (d) the public relations campaign promoting the advantages of the trolley bus.

IN DAYTON . . .

Fred C. Dyer, General Manager of the Miami Valley (Ohio) Regional Transit Authority, discussed three aspects of the trolley bus operation in the Dayton area--the system's history, its recent expansion to a regional system and the impact on the trolley operation, and the need for new technology.

The first trolley bus application in Dayton occurred in 1933 when one of the five local companies providing transit services decided to convert one of its streetcar routes. Numerous additional routes were subsequently electrified, and in 1941 the five separate companies merged to form City Transit. After conversion of the last streetcar routes in 1947, Dayton operated approximately 200 trolley buses. The system continued to expand throughout the 1950s and into the early 1960s, while trolley bus systems in other parts of the country were shrinking or disappearing. During this period Dayton purchased used vehicles and equipment from other operators, and was able to put in place a modern system at low cost.

In 1972 the present authority assumed control over all services provided by City Transit. Although the Miami Valley Regional Transit Authority has the term regional in its title, it essentially represented a city system. So in 1979 the authority began the necessary action toward a referendum that would enable it to become a truly regional operation. This was effected, and shortly thereafter the system developed as one that arbitrarily terminated at the boundaries of the city or immediately adjacent suburban communities. This situation necessitated the extension of routes from their existing terminals into the suburban areas that had been annexed.

System expansion had to be accomplished quickly and, out of necessity, new diesel routes were initiated. Dayton is now considering the merits of trolley bus expansion versus the application of new off-wire technology to overcome the existing operating inefficiencies that have resulted.

Dayton is experimenting now with battery off-wire propulsion. Initial tests have indicated that such an arrangement does provide an effective emergency off-wire capability. Dayton will also be experimenting with a Renault battery trolley, which has improved operational characteristics and can be used in sustained off-wire service. If such tests are successful, this type of vehicle could possibly be used to expand existing trolley services into the new service territory. The authority is also evaluating the replacement of all existing substation equipment with modern, solid-state conversion apparatus.

Two significant factors in the Dayton experience were stressed. First, as in the Seattle experience, public opinion is a primary ingredient in the preservation and/or expansion of trolley service. Second, the enhancement of the flexibility of trolley buses requires the development of off-wire capabilities.

IN VANCOUVER . . .

Tom E. Parkinson, President of Tom Parkinson Transport Consulting, Ltd., Vancouver, undertook an extensive analysis of the Vancouver trolley bus system operation in 1978. The results of this analysis strongly favored retention of the trolley bus mode, which had been relatively stable with the exception of minor extensions made since the late 1940s. At that time, the former streetcar system had been abandoned. During the late 1960s and early 1970s, however, there was some doubt as to the system's future. In the absence of plans to convert the system to diesels, it was decided to update the trolley bus operation so that it could continue on a stronger and more efficient base.

The study, undertaken in 1978, indicated that the trolley bus operation in Vancouver enjoyed two distinct advantages when cost comparisons were made with diesel service. First, the cost of electricity was far less than that of diesel fuel. (Furthermore, the leverage exerted by fuel prices in today's economy is becoming much greater due to the rapid increases in energy costs.) Second, the cost of maintenance associated with trolley bus vehicles was far less than that related to diesel vehicles. The cost efficiencies realized in this area are more than sufficient to overcome the additional cost of overhead wire maintenance, which is not incurred with a complete diesel operation.

The cost efficiencies are further improved with the application of new technology. The advent of the chopper, for example, coupled with the use of regenerative braking, has the capability of reducing total power consumption in the range of 19 to 25 percent.

The Granville Mall in Vancouver is a pleasant shopping street. Private cars and trucks are banned; most traffic is electric trolley buses (photograph by J.P. Aurelius).

As part of the process to modernize the Vancouver system, it was decided to purchase 200 new vehicles. BC Transit, responsible for the Vancouver transit system, decided that a two-step procurement process was necessary. First, numerous vendors were invited to review and comment on the proposed specifications that the authority sought to incorporate in its new vehicle. After receipt of this information, necessary modifications were made to the specifications. Second, bids were solicited from interested manufacturers.

One of the features that will be provided by the new trolley buses is limited off-wire battery operation. Vancouver was able to purchase this option at a cost of approximately $2,000/vehicle. This system is simple and does not require a sophisticated propulsion control system. It will further provide an off-wire capability in at least 95 percent of the cases in which it is required. Such capability is oriented toward emergency situations.

The problem of vehicle weight was also considered. With the advent of new technology, the weight of trolley buses has increased; this siphons off some of the cost savings that could have been realized from reduced power consumption. Improved design and the choice of vehicle and equipment construction materials need the attention of manufacturers.

IN TORONTO . . .

Paul A. Wenning, Operations Planning Engineer for the Toronto Transit Commission (TTC), explained that the Toronto trolley bus system, operated by TTC, was introduced in the late 1940s and early 1950s. It was designed to replace streetcar operation. At present, eight routes are operating and the trolley bus is responsible for 3.7 percent of the total transit system mileage.

Toronto was the first North American city to consider the rehabilitation of its trolley bus system. In the late 1960s, when most cities were contemplating the removal of trolley bus systems, TTC decided to replace its trolley bus fleet. This decision was based on an in-house study that indicated that the trolley bus was more cost-efficient than diesels.

The province of Ontario, it was observed, has effected renewed interest in the trolley bus by offering a program that will reimburse transit commissions for 90 percent of the cost of installing trolley bus systems. TTC was also interested in trolley bus operations because (a) a surplus of trolley buses exists; (b) operating costs are lower than those for diesel service and such costs are likely to improve in the future; and (c) continued provincial support is likely.

The provincial program, coupled with some of the factors noted above, led TTC to examine its route structure for possible conversion to trolley bus operations. The criteria were proximity to existing trolley bus garage locations, proximity to the existing trolley bus network, and proximity to the existing electrical power network. As a result of this evaluation, 10 candidate routes were identified. Subsequently, these were reduced to two.

The TTC study also required consideration of the environmental effects of the trolley bus. Positively, the trolley bus contributes to reduced levels of noise and air pollution. It does, however, add to "visual" pollution because of the need for overhead contact and feeder lines. Although visual pollution can be reduced by undergrounding the feeder cables, it results in a significant capital cost penalty. Public concern about visual pollution was also expressed when specific routes were identified.

TTC investigated the energy intensity associated with trolley bus and other modes used in the Toronto metropolitan area. It found that the trolley bus had the lowest energy intensity from a consumption standpoint. In terms of megajoule per seat-kilometer, the trolley bus enjoyed an intensity of 0.026 compared with 0.042 for the subway, 0.043 for the streetcar, 0.54 for the diesel bus, and 0.66 for the commuter train.

Considering the total cost, i.e., operating and capital costs, TTC concluded that the trolley bus represents a marginal investment under present economic circumstances. Although the trolley bus results in operating cost efficiency when compared with the diesel, at present the savings on an annual basis are barely sufficient to amortize the capital cost of the system over its 30-year life.

IN EUROPE . . .

John D. Wilkins, Director of Operations Planning, NJ Transit Bus Operations, Inc., Maplewood, New Jersey, reviewed various aspects of the history, development, and operation of trolley bus systems in several European countries. It was observed that, with the exception of Eastern European nations, European trolley bus experiences paralleled those in North America. Numerous new systems were installed during the 1920s and 1930s and in the period following World War II. With the advent of the mass-produced diesel, however, the number of systems declined in the late 1960s and throughout the early part of the 1970s. In Eastern Europe, and Russia especially, the mode never was in disfavor and has prospered throughout the entire period since World War II.

The renaissance of the trolley bus first occurred in Switzerland in the late 1960s. VST, the Swiss public transit association, realized the need to replace the existing trolley bus fleets. The association approached Swiss industry with a request to design a new-generation trolley bus. Specifications required state-of-the-art technology in the areas, for example, of the application of chopper propulsion systems and improved off-wire capabilities.

A similar trolley bus renaissance occurred at approximately the same time in France. Cities such as Leon, Grenoble, St. Etienne, and Marseilles decided to rehabilitate and improve their systems following the energy crisis of the 1970s. Working with Renault, the French bus and truck manufacturer, a new standard trolley bus was designed that used the standard PR100 diesel coach body. The French design also included automatic retrievers to allow for unassisted raising and lowering of trolley poles and improved propulsion systems.

Europe's biggest contributions were advancements in trolley bus technology. For example, propulsion systems were developed. Chopper propulsion systems, originally developed by Brown-Boveri in the 1960s, can reduce power consumption in the range of 15 to 21 percent. With the application of regenerative braking, power savings can be increased. AC propulsion systems, although not new, have the capability of using commercially produced AC motors. These motors are available at lower cost and can be sealed to reduce maintenance costs.

Europeans have also routinely used overhead systems that are flexible and allow for faster travel speeds. Constant carbon contact (i.e., fittings designed so that the carbon is always in contact with the underrun) reduces wear and maintenance costs. High-speed switches allow speeds of up to 40 km/h on a straight through movement and 25 km/h on a divergent route.

In the area of current collection, Dornier has developed a system that will automatically raise and lower the trolley poles without requiring the exact positioning of the vehicle. Although this system is more sophisticated than that of the above mentioned Renault design, it is more expensive. Most European systems also use a trolley harp that is hinged, which allows for the absorption of lateral forces and decreases the potential for dewirements.

The Europeans also have available off-wire systems that, unlike their North American counterparts, have been found to be advantageous. Several European systems make use of such off-wire technology as Volkswagen engine-generators that provide for short-duration emergency capabilities and allow a speed of 30 km/h for operation on inclines that do not exceed 8 percent. This type of generator, however, is not generally applied where sustained operation is required. On the other hand, the Kirsch diesel, which has performance capabilities similar to those of the Volkswagen unit, is designed for sustained operation. In addition, the new PER180 bus, designed by Renault, provides full capabilities in either the electric or diesel mode.

At present, several projects being conducted in Europe could significantly alter the state-of-the-art technology for trolley buses. The Duo-Bus project, under way in Esslingen, West Germany, is being funded by Mercedes-Benz, Robert Bosch, and Dornier with support from the government of the Federal Republic of Germany. The project aims at developing a fully operational dual-mode system. Tests are being conducted with battery trolley buses and diesel trolley buses.

One feature of the diesel trolley bus is the use of a common drive train. Both the diesel and the electric motor supply power through a common transmission to the rear axle. When operating in the straight electric mode, this arrangement allows for the constant rotation of the electric motor, which greatly simplifies the type of propulsion control system that must be used.

Cost Project 303, being conducted under the auspices of the European Economic Community, has as its objective the technical and economic evaluation of the duo-mode trolley bus. This project will act as a focal point for the exchange of the pertinent research and studies that various country participants in the project generate. Of primary importance to the study are systems that have already developed duo-mode trolley buses (i.e., Switzerland, Germany, France, Finland, and Italy).

SELECTED MATERIALS

Seattle's Love Affair With Trolleys

George E. Benson

Public transportation is more than just a matter of getting from point A to point B. What happens in between is just as important as getting to the destination. It is a question of style, and the mode of public transportation a community prefers can reveal more about its character than dry statistics about passengers per mile or peak-hour capacity.

The people of Seattle love trolley coaches. Trolleys have been a major, if not dominant, component of Seattle's transportation system for more than 40 years. What does that say about the people of Seattle? It speaks to this community's fascination with science and technology and to its sophistication in weighing technological alternatives. Trolleys are just one element in a city history dominated by science and engineering: the regrading of Denny Hill, creation of a modern port, a visionary public electric utility, Boeing Aircraft, and the 1962 World's Fair.

In its early history, Seattle's public transportation system evolved in much the same way as did those in other cities. Privately owned streetcar companies sprang up to meet the public's needs and produced a patchwork of routes and modes of travel. We had horse-drawn trams, counterbalance cable cars, electric interurbans, and gasoline buses.

In the late 1930s this was no longer adequate. The population and area of the city had doubled and redoubled through immigration and annexation.

In 1936 the city's Municipal Railway recommended a system of gasoline-powered buses to the public, which was vetoed by the public. Three years later a new proposal, based on recommendations of the Beeler Organization of New York, was developed for a fleet of 235 trackless trolleys operated under 100 miles of wire, plus 130 gasoline and diesel coaches. This was approved by the mayor and the City Council in August 1939.

Eighteen months later, the system was in operation. It had been built and the debt of the old system retired for $10,200,000. Obviously it did not figure in the calculations of the new Transit Commission, but the inauguration of the new system in April 1941 gave Seattle one of the country's best public transportation systems--just in time for the war effort.

During World War II, 72 additional trolleys and 10 miles of wire were added to the system. It operated in this form until 1963 without interruption.

The end, however, had almost come in 1962. That year the Transit Commission proposed cutting back the trolleys and replacing them with new diesel coaches. There was even talk of completely eliminating the trolleys. Economics had changed, and the trolley critics argued that diesels were more efficient. The press complained about the "visual pollution" of trolley wires, and the 1940s-vintage trolleys were showing their age.

Many citizens, however, fought to save the trolleys. The Committee for Modern Electric Trolleys (COMET) was organized. COMET collected enough signatures to place an initiative on the 1964 ballot to modernize the trolley system. The group lost the vote but demonstrated enough political support to dissuade the Transit Commission from dismantling the trolley system. About 27 miles of the system were saved. This nucleus became the seed for an all-new system when the voters of King County authorized Metro to establish a regional transit system in 1972.

Metro is a consortium of Seattle, King County, and suburban city governments. It was created in the 1950s to establish a regional sewer and water quality utility to clean up Lake Washington and other area waters. Starting on January 1, 1973, Metro faced a new challenge: How to create a rational public transportation system out of the crazy quilt of city and private suburban bus systems it inherited. Trolleys were assigned a major role from the outset. The economics of public transit had changed again, and there was no question that trolleys were a wise investment.

In response to a request by the City Council, Metro provided a plan that called for replacing the entire system, doubling the lineage to 55 miles, and acquiring 109 new trolleys. It proved to be a more ambitious scheme than anyone anticipated.

I took my seat on the Seattle City Council and the Metro Council in 1974, so I got to wrestle with the problems of trolley modernization firsthand. No one had tackled an installation of the size we planned for a quarter of a century. The literature was scant, and it turned out that the maintenance crews on the old system knew as much, if not more, than the experts.

We eventually succeeded, and in the process much new technology was introduced, such as the neighborhood rectifier system, new wiring systems, the Fahslabend switch activators, and new chopper control systems on the trolleys.

Of course, new technology creates new problems, and we had our share. Lightning wreaked havoc in the first year, and the rectifiers turned the overhead wires into the world's largest radio antenna.

We have solved the lightning problem and we are working on the radio interference. One thing we had no problem with, however, was community acceptance. When my office polled 45,000 citizens along proposed trolley routes, more than 87 percent said that they wanted the service.

When the system is complete, the price tag will be about $41 million--four times the cost for a system half the size of the original.

We unveiled our Waterfront Trolleys on Memorial Day 1982. These are vintage tracked trolleys that