

Figure 3. Economic analysis, Wellesley route.

rates. The effect of even a 2 percent variance from the 6.5 percent energy differential is apparent.

The preceding analysis does not allow for capital residual value at year 30, or for the installation of decorative poles. These factors would increase potential savings by an additional \$2.0 million. Also, the application of provincial subsidy to capital items improves the cost effectiveness of conversion from a TTC perspective.

#### SUMMARY

From a transit management point of view, there are definite advantages associated with undertaking a trolley coach conversion program: fuller use of existing trolley coaches, less reliance on diesel fuel, energy conservation, and so forth. However, these factors must be considered in relation to other key criteria such as cost effectiveness and public acceptance.

From a cost/benefit perspective, trolley coach conversion represents a marginal investment under present economic circumstances in Toronto. The real cost or saving associated with converting is quite sensitive to the future cost differentials between diesel fuel and electricity, which will evolve over the remainder of the century. This observation is made independently of financial incentives such as special capital or operating subsidies favoring trolley coach conversion.

The issue of public acceptance of new trolley coach routes continues to be a major concern. Public opposition to obtrusive overhead wires frequently arises, particularly in residential areas. Furthermore, new overhead wires and fixtures may contradict municipal programs to bury utility lines in underground ducts. TTC management is weighing and evaluating these opposing factors.

This paper has reviewed the socioeconomic aspects of trolley coach conversion within the present context of the TTC. In keeping with this overall theme and the contents of the preceding summary, the following areas of future research are suggested: (a) develop an accepted economic analysis methodology for use by transit properties in considering new/expanded trolley coach routes and (b) evaluate public attitudes toward new trolley coach overhead lines relative to overhead visual pollution versus lower noise and air pollution.

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# The Trolley Coach in Europe and Other Parts of the World

### John D. Wilkins

The European experience with trolley coaches paralleled that in North America. The earliest installations occurred shortly after the turn of the century. Numerous new systems were installed during the 1920s and 1930s and in the period following World War II. Many of these new installations replaced tram operations that were being abandoned.

The availability of mass-produced diesel buses led to a gradual decline and in some cases total abandonment of trolley coach operation. In England, for example, where there were numerous trolley coach operations, all systems had been abandoned with the closing of the Bradford system in 1972. In both East Germany and West Germany, which at one time had an excess of 50 systems operating trolley coaches, only six remained by 1977. Switzerland was the only country that continued with its trolley coach systems and few closures were experienced during the period when other systems were being withdrawn.

Generally, Eastern Bloc countries continued with their trolley coach operations. This is particularly true in the Soviet Union where the trolley coach has been the major mode in many systems. Although trolley coaches were being withdrawn elsewhere in the world, new system starts were being installed in Russia. Because there has been a level of activity similar to that for light rail, one must assume that national policy favors the use of electric propulsion wherever possible.

This paper briefly states the European experience in the recent past and indicates some of the directions being taken that will influence the trolley coach in the future.

#### SWITZERLAND

The trolley coach renaissance in Europe started in Switzerland, which had never really abandoned the trolley as a primary transit mode. In the late 1960s, VST, a public transit association, realized the need to replace the then existing trolley coach fleets operating on numerous systems throughout the country. VST approached Swiss industry to design a new-generation trolley coach vehicle. It did not seek to have the existing fleet replaced in kind but desired that state-of-the-art technology be incorporated in the new vehicles. The end result was the standard Swiss trolley coach.

It should be noted that in Switzerland three firms typically are required to furnish a completed trolley coach. One firm constructs the chassis, one firm constructs the coach body, and a third firm supplies the propulsion system. The end product supplied by the consortium incorporated numerous new features:

 Chopper control--a system designed to produce power savings in the range between 15 and 21 percent;
The standard design, which included a VW petrol engine to provide off-wire capabilities for greater distances than had previously been provided by battery off-wire propulsion; and

Articulated and two-axle versions.

Since these vehicles were introduced, they have been purchased by practically every trolley bus system operating in Switzerland. In this same period only two small systems have decided to convert their operations to diesel bus.

It should be indicated that the Swiss government has always had a policy of encouraging electric propulsion. Approximately 99 percent of all railway mileage in the country is electrified. This policy has carried over into urban transportation through encouragement of trolley coach systems and light rail systems. The Swiss have an abundant supply of hydroelectric power but must import 100 percent of all petroleum needs.

#### FRANCE

While the Swiss were energetically laying plans to rejuvenate and extend trolley bus operations, the French trolley coach also underwent a similar rebirth. In the mid-1970s five systems still retained trolley coach operation: Lyon, Grenoble, St. Etienne, Marseilles, and Nice. These systems decided to retain trolley bus operations primarily on the basis of projected shortages of petroleum products. The location of the five properties was also in close proximity to hydroelectric power, which lent credibility to the trolley coach. The French bus and truck firm of Berliet, a subsidiary of the Renault Corporation, proceeded to design a standard trolley coach that was made available to all operators. Similar to the Swiss experience, numerous additional features were incorporated in these buses at the time of manufacture or shortly after their delivery to the various properties. These improvements included sustained off-wire capability, automatic retriever, and propulsion control.

Based on French national policy, additional new trolley coach systems are beginning to appear in France. It is estimated that approximately five new systems will be put on line in future years. The first new system will be in the city of Nancy. As part of this new installation, the system will incorporate several additional features, which include (a) articulated vehicles and (b) bi-mode vehicles. Operation in Nancy will commence in the near future. All overhead lines have been installed and driver training has begun. To date seven of the articulated trolley buses have been delivered. A portion of the fleet will be equipped with the Alsthom freon-cooled chopper system. In addition to the application of state-of-the-art hardware technology, the Nancy system will include such features as reserved busways, reserved lanes, and a traffic preemption system that will speed the movement of trollev coaches.

IMPROVEMENT IN STATE-OF-THE-ART TECHNOLOGY

Some of the significant contributions made to the new era of trolley coaches are discussed below.

#### Propulsion Systems

The prior generation of trolley coaches relied almost entirely on resistance-type control. The new era of trolley coaches in Europe has ushered in a number of new propulsion systems.

#### Chopper Propulsion Systems

Brown-Boveri, as part of its effort in contributing

to the new Swiss standard trolley coach, developed a chopper propulsion system that has the capability of reducing power consumption up to 15 to 21 percent. Such systems have now been made available by competing firms, including Ansaldo of Italy, Siemens and AEG Telefunken of Germany, and TCO of France. The French firms of TCO and Alsthom are also offering chopper equipment that uses freon as the cooling agent. The Japanese firm of Toshiba and a Brazilian firm are also offering chopper propulsion systems to the trolley bus market.

#### AC Propulsion Systems

The Finnish firm of Stromberg has how made available an AC propulsion system that was first experimented with in Helsinki and in Winterthur, Switzerland. This system converts DC current to a pulsed current that can then be used in conjunction with an AC motor. The principal attributes of this system are its ability to use commercially produced AC motors, which are available at a lesser cost, and reduced need for maintenance efforts because the system can be sealed.

#### Overhead Line Systems

The new and existing systems in Europe are making extensive use of flexible overhead systems. This system has been in existence since the late 1930s when it was developed by Kummler and Matter. Two significant advances have been made in recent years: (a) all overhead fittings are designed so that the carbon is always in contact with the underrun thus reducing wear and maintenance cost, and (b) high-speed switches have been developed that eliminate the need to slow down whenever a special work is encountered. The flexible features of this overhead also allow for high-speed operation on tangent wire or wire that is subject to a slight curvature. The wire and the current collector are interwoven in such a manner that slight skips, which can cause dewirements, are avoided and the collector remains in constant contact with the overhead.

#### Current Collection Equipment

The current collector used in most European systems has typically been much different than that used in North America. The greater desire in Europe for off-wire capabilities provided the impetus to perfect a system that can raise and lower poles automatically with a minimum of effort. A brief description of European practices and innovations in these areas follows.

#### Automatic Retrievers

As part of the Duo-Bus project, Dornier, a German firm, has developed a system that will automatically raise and lower the trolley poles. The system is so designed that the coach can be in one of three preselected positions. For example, the coach may be immediately below the wire, to the left of the wire, or to the right of the wire. In those instances when it is necessary to use a non-programmed position for raising or lowering the trolley poles, the driver can manually perform this function from a console at the driver's station. Wire height is critical in this system. In most instances short spans must be provided at those locations where trolley poles will be routinely raised. Both raising and lowering procedures must be accomplished while the vehicle is at a standstill.

The French trolley bus system in Lyon also required the capability of raising and lowering poles automatically. Lyon opted for a much simpler system than that devised by the Germans. It is really a modification of a system used by Public Service Coordinated Transport, now New Jersey Transit, when it was experimenting with the D900 All-Service Vehicle in the early 1950s. This system requires that vehicles be precisely positioned and uses a pneumatic cylinder to raise and lower the trolley poles. A V-shaped pan on the wire guides the trolley shoe to the wire.

#### Trolley Harps

Most European systems use a trolley harp that is hinged. It is the function of this hinge to absorb lateral forces, thereby decreasing the number of dewirements associated with guick turns or abrupt changes in the path of the overhead.

#### Off-Wire Systems

Many European trolley bus operators have always felt the need to have some degree of off-wire capability. In earlier-generation coaches this capability was provided by a battery propulsion system that provided low performance for short distances to overcome blockages and other situations requiring movement away from the wire. The new-generation trolley coaches have generally incorporated improved off-wire capabilities. These capabilities fall into several categories.

1. Volkswagen engine-generator--The majority of new trolley coaches in Switzerland incorporates this type of off-wire capability. This unit allows for low-performance operation over far greater distances and provides the operator with additional time in which to react to situations that might require temporary dieselization. This system will allow for a speed of 30-35 km/h and for operation up inclines of 8 percent.

2. Kirsch diesel--This unit has been used in France, particularly in Lyon. In a normal urban street environment where there are insignificant grades, this unit will provide sufficient operating performance. The unit is not capable of providing for high-speed operation or operation on significant grades but can operate for sustained periods of time. At full load this unit will move at speeds in excess of 35 km/h and climb a grade of 8 percent.

3. All-service capability--This capability is currently being provided by Renault.

#### Vehicles

Unlike the experience in North America, many firms in Europe are offering trolley coaches that include state-of-the-art automotive improvements. Some of these manufacturers are noted here.

1. Switzerland--There are generally two firms involved with the actual coach construction: the Swiss firm of FBW, now a subsidiary of Mercedes Benz; and Saurer, a chassis manufacturer. Hess provides the coach body for practically all of the Swiss standard vehicles.

2. Austria--The firm of Graf and Stift has made available numerous coaches to systems in Austria and has also exported vehicles to Bergen, Norway. Graf and Stift is an affiliate of M-A-N.

3. France--Renault Industries offers a variety of trolley coaches to the French and world market. A PER180 is currently on loan to Seattle for demonstration purposes.

4. Hungary--The Hungarian firm of Ikarus (Mogert Trading Company) has been a major supplier of articulated coaches in the Eastern Bloc countries. 5. Czechoslovakia--The firm of Skoda is currently making available two types of coaches to the Eastern European market. These coaches include the 9TR, the older model, and the more recently designed model, 14TR.

6. Russia--The foreign trading arm of the U.S.S.R., Energonach Export, is making available the ZIU-9 model to the export market. Although this coach is crude in comparison with the other European buses, it has been exported to such places as Colombia and Greece.

7. Brazil--Marcopolo is the principal firm offering trolley coaches in this region.

#### TROLLEY BUS DEMONSTRATION PROJECTS

At present there are several projects taking place in Europe, which could contribute significantly to the state-of-the-art technology for trolley coaches. Some of these projects are described below.

#### Duo-Bus

The Duo-Bus project, currently under way in Esslingen, West Germany, is being undertaken by the firms of Mercedes Benz, Robert Bosch, and Dornier in cooperation with the Federal Republic of Germany. The first phase of this project produced a battery trolley coach vehicle. Based on the performance and data collected from this phase, a second phase was initiated, which involves two battery trolley buses, two diesel trolley buses, and one articulated vehicle propelled by both diesel and electricity.

When this vehicle is operating in the electric mode, the electric motor is rotating at all times, even when the coach is idling. This greatly simplifies the propulsion control apparatus that must be provided when the vehicle is operating in a straight electric mode. The disadvantages of this scheme appear to be that while operating in the electric mode, the vehicle does not have performance characteristics that are equivalent to that of a regular trolley bus.

#### Johannesburg, South Africa

Trolley coaches have operated in Johannesburg for a number of years. In the 1970s it was decided to gradually phase out all trolley coaches but to leave the overhead apparatus intact until such time as a final decision was made with regard to their disposition. In the late 1970s, partly due to a national South African policy of minimizing the import and use of petroleum-based fuels, it was decided to look at the attributes of a trolley coach renaissance in Johannesburg.

The trolley bus project involves numerous parties, including the national government, the local transport operator, and the city of Johannesburg. The decision was made to purchase seven different types of trolley buses and two diesel buses. The trolley buses would be a combination of articulated and double-decked buses and would also be equipped with both chopper and standard resistor controls. The vehicles would all be assigned to a particular route that had a variety of operating environments including busways and significant grades. The project would determine two things: (a) the costs associated with the trolley bus on a life-cycle cost basis when compared with a diesel, and (b) are the results significant enough to warrant the purchase of additional trolley coach vehicles in an expansion of the system? The demonstration will run through 1983.

#### Cost Project 303

Cost Project 303 is being conducted under the auspices of the European Economic Community. Its primary function is a technical and economic evaluation of the duo-mode trolley bus. This project will act as a focal point for the exchange of pertinent research and studies that have been conducted by various participants. Of primary importance are the off-wire systems currently seeing service in Switzerland, West Germany, France, Finland, and Italy.

#### WORLD TROLLEY BUS STATUS

During the last several years, there has been an intense amount of activity not only throughout Europe but also in the rest of the world related to improving existing trolley bus systems and implementing new starts.

#### Australia

New trolley bus starts are being reviewed in both Melbourne and Sydney.

#### Austria

At the present time, the three systems in Austria, including those in Salzburg and Lintz, have purchased new equipment and either have made or are planning extensions of trolley bus service.

#### Brazil

As part of a national program to reduce the dependence on petroleum-based products, there has been a renewal of interest in trolley buses in Brazil. In the city of Sao Paulo 200 new vehicles have been ordered. This system is now considering a significant expansion that could possibly see the need for more than 1,000 new vehicles in the years to come. This system is also considering the application of stateof-the-art technology for future equipment purchases. One new system is being constructed and in many others plant improvements are being made, new equipment is being purchased, and extensions are being considered.

#### Britain

The West Yorkshire PTE has conducted an extensive analysis of the feasibility of restoring trolley bus operations in Bradford, England. The study reviewed comparisons of trolley bus to diesel and comparisons of duo-mode to both trolley bus and diesel. It concluded that trolley buses are the most economical mode for the environment considered, followed by duo-mode buses and regular diesel buses. At present, construction funds are being sought from Parliament. It should be noted that Bradford was the last English system to operate trolley coaches.

#### Colombia

The existing system in Bogota appears to be purchasing a few new vehicles periodically from Russia. Other cities are said to be actively considering the purchase of new equipment.

#### Germany

Although the number of systems in Germany has greatly declined, those remaining are in the process of upgrading their fiscal plan. Kaiserslautern has purchased new equipment for its system and has made several route extensions. Solingen has made numerous extensions and has also experimented with differing types of overhead special work to determine which best suits its needs. Currently, an M-A-N demonstrator is helping to direct the city's efforts toward new vehicle procurement.

#### Greece

Athens has in recent years purchased a number of new vehicles from Russia. New routes are being considered.

#### Holland

Arnhem is in the process of reequipping its fleet.

Italy

There are numerous trolley coach systems throughout Italy. At present 5 to 6 smaller systems are in the process of reequipping their fleet and modernizing their systems. Some of the larger operators, such as in Milan and Torino, have not made definite decisions regarding the future status of trolley coach operation.

#### Mexico

For many years the STE system in Mexico City has relied on second-hand equipment from North America as its primary source of buses. New equipment is being purchased with Toshiba choppers, and it is expected that this system may be greatly expanded in the years to come.

#### New Zealand

The city of Wellington is in the process of reequipping its existing trolley fleet. Although there have been some problems with the consortium approach to procuring new vehicles, it appears that the problems are near solution and the vehicles in service will be replaced shortly. However, the problems experienced in Wellington were substantive enough to cause the city of Auckland to drop its proposed plan for system modernization.

#### Norway

Bergen, the one system remaining in Norway, is completely reequipping its fleet with new buses and is looking at possible extensions. New Graft and Stift buses are currently being delivered.

#### Eastern Bloc

The Eastern Bloc countries are also upgrading and expanding the use of the trolley coaches. Although complete documentation is not available, the trolley coach appears to be a major component of the surface urban transportation network in many major Russian cities. The demand for trolley coaches in Eastern Bloc countries is about 1,200 vehicles/year.

#### CONCLUSION

This has been a brief presentation of the status of the trolley bus in Europe and to a certain extent the remainder of the world outside of North America. Nevertheless, it shows that the trolley coach mode is receiving serious consideration throughout the world.

The general conclusion derived from this activity is that although trolley coaches will not become the predominant transit mode, they are being seriously considered for specific applications where economic and environmental considerations dictate that it is the superior mode. Clearly, the trolley coach renaissance is not a passing phase; rather it will firmly establish the role for trolley coaches for the remainder of this century and a good portion of the next.

## Trolley Bus Development in Brazil

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The first Brazilian trolley bus experience dates back to 1949 in the city of Sao Paulo. A 7.2-km one-way overhead wire line was built and operated with 16 vehicles. After its introductory phase and its acceptance as a convenient mode of transport, Sao Paulo experienced a rapid expansion of the system through the introduction of new lines. The principal objective was the replacement of tramway services.

Between 1953 and 1967, another 10 cities introduced trolley bus systems: Belo Horizonte, Recife, Rio de Janeiro, Salvador, Niteroi, Santos, Porto Alegre, Campos, Araraquara, and Fortaleza. In recent years, all these cities and Sao Paulo have been under common pressures that discouraged system expansion and upkeep. These pressures included the lack of spare parts for imported equipment, absence of a real program for local manufacture of components, and hesitation in the application of resources, plus the false impression that individual transport would be substituted for transit systems. Thus, in 1973, only Sao Paulo, Recife, Araraquara, and Santos continued operating trolley bus systems.

The 1974 oil crisis, as well as the concern about environmental pollution, increased the demand for public transport in the large and medium-sized cities. These were the main reasons for resuming feasibility studies to reintroduce trolley bus systems. In 1977 an Interministerial Labour Group, formed by technicians of the Planning, Transport, Power, and Mining Ministries, finished a report that gave top priority to the expansion of existing trolley bus systems as well as to the short-term introduction of new systems.

The technical specifications for vehicles, overhead hardware, and rectifying substations were developed in 1978. The aim was to use advanced technology comparable to the most modern systems in Europe and North America.

All the cities in Brazil where the trolley bus survived have devoted their efforts to rehabilitation and expansion. Ribeirao Preto started operating its new system in March 1982, and several cities have already concluded or are making technical feasibility, economical, and financial studies.

#### SAO PAULO UPDATE

The Sao Paulo trolley bus operation started in 1949. From 1949 to 1958, the Companhia Municipal de Transportes Coletivos (CMTC) increased its fleet from 16 to 155 vehicles--an increase totally supported by imports. In 1958 Brazil started manufacturing trolley buses. Initially this activity was carried out by private companies and thereafter by CMTC. Around 1964, CMTC had difficulties in importing vehicles and component parts required for fleet maintenance. CMTC was forced to manufacture trolley buses in its own service workshop. By 1969, 139 new vehicles were built and an additional 38 were remanufactured from the existing fleet. At the end of the 1960s, CMTC owned 233 trolley buses, 129 km of one-way overhead electric line, and 13 rectifying substations (10,500 kW), which were required to operate 12 lines.

To a large extent, these lines were projected with the idea of reaching residential quarters, without consideration for the global needs of a transit system. The routing of the trolley bus lines was the same as that used for the creation of new omnibus lines. Vehicles circulated through narrow streets in search of passengers without concern for an increase in the commercial speed or better exploitation of the trolley bus transporting capacity.

The Sistran Plan, concluded at the beginning of 1976, addressed the technical, economical, and financial feasibility of a new trolley bus system for Sao Paulo. The new system called for 280 km of twoway overhead line to be used on 400 km of individual route miles. Some 1,280 vehicles will be circulating. The installed power capacity will be 198,000 kW and the approximate transport capacity will reach 600 million passengers/year. The budget for this project, including engineering, installation, and acquisition of equipment, has been estimated at (U.S.)\$830 million.

The federal government authorized CMTC to implement the plan, which is divided into five stages. CMTC is responsible for the development of technical specifications and the establishment of an operation pattern that characterizes the trolley bus as a system of high transport capacity. The first stage, which consists of 200 new biaxial trolley buses, 15 rectifying substations, almost 50 km of two-way overhead line, and 1 garage, was completed by the end of 1981. The second phase is now being built and includes 210 biaxial vehicles, 14 rectifying substations, and 59 km of wire network. The location of the corresponding garage is still under study.

CMTC is now involved in the planning for subsequent phases and in determining the equipment, installation, and necessary investments to complete the Sistran Plan, as well as the construction of a new type of articulated trolley bus. At the same time, a project for rehabilitating the vehicles, networks, substations, and garage corresponding to the old system is also being developed.

For Sao Paulo, which today has almost 9 million inhabitants and an area of  $150 \text{ km}^2$ , the trolley bus represents not only an option for transportation services but also provides a way of attending to transport necessities by offering an improvement in the quality of living.

#### RECIFE UPDATE

Recife is the capital of the Pernambuco State and is the main population center in the Brazilian Northeast. It is also the center of a metropolitan region with 2.5 million inhabitants. The trolley bus system first instituted in 1959 has 8000 kW of installed power, 100 km of wire network, and 140 vehicles. The system uses Brazilian, American, and French equipment. During the 1970s, Recife's trolley bus system started to decline, as did the remaining trolley bus systems in Brazil.

Several rationalization and public transport improvement programs are under study in the metropolitan area of Recife. The recuperation and expansion program of the trolley bus system is the subject of one study. In accordance with studies made in 1980,