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The Electric Trolleybus – its role in future transport systems

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Abstract

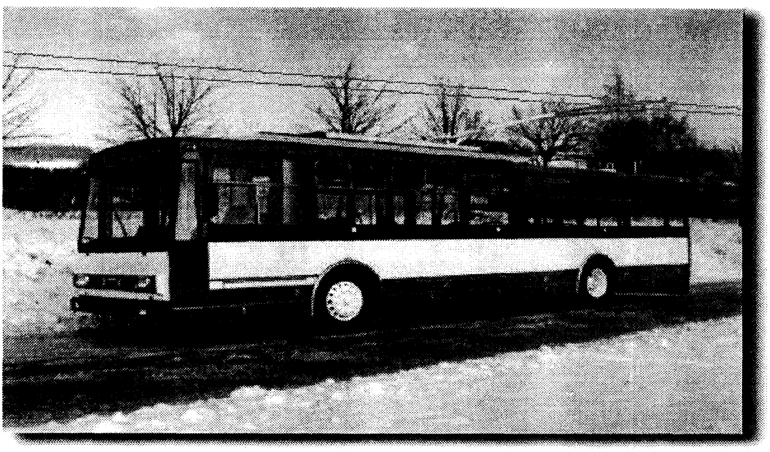
The trolleybus as a form of passenger transport has survived to the end of the century and in many parts of the world is thriving, with new developments in technology helping to create new opportunities for its increased use. Trolleybus operation makes sound economic sense on trunk routes that have the potential to maintain and attract consistent growth in passenger usage levels with reliable and high frequency services. The environmental benefits of the trolleybus are considerable and have gained new recognition in the fight to reduce fossil fuel pollution at the roadside. Emission comparisons between public transport modes are provided. Much of the criticism in past years of the visual impact of the overhead wiring has become less relevant with the advances in design of lightweight fittings and suspension techniques, some examples of which are discussed. Every passenger vehicle operator needs to know the true cost of operation. In recent years the difference in costs between diesel and electric power has swung in favour of the trolleybus, particularly due to the latest energy-saving traction motor controls. Tables derived from a multi-vehicle operator are given. Guidelines are offered as to the requirements for upgrading existing systems and the implementation of new installations. The importance of integrated transport policies has never been greater and must be addressed by all Governments in the run up to the New Millenium. Intelligent use of the electric trolleybus as part of this strategy is encouraged.

1 Introduction

On a worldwide basis trolleybuses have had mixed fortunes. Around 1930 onwards their suitability as tramway replacement vehicles had been recognised, allowing much of the electrical infrastructure to remain in place without major capital renewals. From a peak in numbers in the early 1950's there followed a rapid decline in their popularity as motor bus design and operating costs showed dramatic improvements.

Much criticism was levied against the trolleybus – it was slow in traffic, prone to dewirements, expensive to operate (no special terms available on electricity rates) and inflexible in route extension. In hindsight, many of these adverse comments have proved to be purely political and without substance. Poor maintenance procedures often led to slack wiring and vehicle breakdowns with little concern for the fare-paying passenger whose perception of the trolleybus service was one of unreliability.

However, many operators did not follow the trend to complete abandonment, choosing instead to retain basic systems and integrate them into larger transit operations. Subsequently, in the 1970's and 80's considerable efforts were made to upgrade and renew vehicle fleets to make the trolleybus more attractive. In this present decade major advances in traction control techniques and materials developments have led to a new awareness of the environmental and operational benefits of the electric trolleybus.



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2 Environmental Benefits

Trolleybuses use electricity as their prime motive power. It is the only source of energy that can be generated by all types of 'fuel' known to man – coal, gas, oil, nuclear fission, water (and wave), wind, solar and even waste material combustion. Every fuel has its own conversion efficiency from primary to secondary (heat) state, the difference in these chemical and molecular states being the direct cause of pollution. Whereas the petrol- or diesel-engine vehicle creates pollution at the roadside in a random way, that produced at the power station can be more easily contained. Modern technology can now 'scrub' the emitted gases to remove dust and soot particles and filter out noxious fumes.

It is often not appreciated that by fully loading a generating station the efficiency of energy conversion is increased in much the same way as the loading of an electric motor. A power station that runs continuously at higher efficiency can produce additional kilowatts at much reduced cost. Achieving this status involves considerable expertise by the generating authorities in switching loads from station to station and so any form of electric transport, usually operating for at least 18 hours a day, will provide useful 'base load'.

The amount of global motor traffic is increasing at an alarming rate and the existing road infrastructure and population centre layouts in many countries can no longer cope with the volumes. Road traffic congestion is widespread with slow moving vehicles creating pollution at ground level which is not only unpleasant but has long been considered as harmful to human life. Claims that modern internal combustion engines are 'clean' are often misleading as that statement is usually made in comparison with the older, less efficient engines of ten and twenty years ago. The electric trolleybus, however, emits negligible pollution (Table 1) and, like the tram or light rail vehicle, can safely run into areas of high population density, such as city centres and shopping malls.

The latest generation of trolleybuses being built or proposed for new systems combine high efficiency electronic control equipment with new lightweight traction motor technology. The result is lower running costs that outweigh the greater capital and infrastructure expenditure necessary to sustain trolleybus operation. In a recent comparison of vehicle costs one experienced operator found that the difference between the diesel bus and electric trolleybus was less than 0.1% (Table 2).

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Table 1 – Emissions - Diesel Bus vs. Trolleybus

Contaminate	Diesel (gm/km)	Trolley (gm/km)	Trolley/diesel
NO_x	18.60	1.27	0.07
CO	1.90	0.06	0.03
HC	1.34	0.00	0.00
SO_2	1.44	0.62	0.43
Particulate	0.56	0.012	0.02
CO_2	1.880	1.380	0.73

Per vehicle kilometre (18-metre length): fuel or primary energy based
Source: Gelderse Vervoer Maatchappij, Arnhem 1995

Table 2 – Operating Costs – Vehicle kilometre

Item	Diesel	Trolley	Tram
Depreciation	56,000	66,000	93,000
Interest	19,600	35,000	98,000
Maintenance	16,200	21,600	42,000
Materials	15,000	12,000	31,000
Energy	42,000	18,000	27,000
Taxes	4,500	-	-
Insurance	2,000	4,000	6,000
TOTAL	**155,300**	**156,600**	**297,300**
km (annual)	**60,000**	**60,000**	**70,000**
Costs per km	**2.58 (100%)**	**2.61 (101%)**	**4.24 (164%)**

Figures are in Dutch Guilders
Source: Gelderse Vervoer Maatchappij, Arnhem 1995

In the case of Arnhem, acknowledged as one of Europe's leading champions of the trolleybus, a fleet of 51 modern trolleybuses operates on a 55km system of five routes. The operator, GVM, attributes 10% additional ridership directly to the presence of trolleybuses, which are actively and positively marketed. Public perception of the trolleybuses is high and there is a strong sense of 'ownership' of the system.

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3 Trolleybus Trunk Route Planning

With operating costs now comparable with the diesel bus it is important that the additional major capital expenditure on the fixed electrical infrastructure is recovered as quickly as possible. Applying trólleybuses to trunk routes that have the most potential for high passenger usage and consistent growth in revenue is the only way to achieve this. Careful planning of these routes is therefore essential, the aim being to carry more passengers at a lower system cost.

Certain principles in route planning should be applied:

- Most direct route from outer termini to city centre or business complex.
- 'Key' stops at approximately 500 metres distance.
- Ability to achieve high average speeds to reduce journey times.
- 24 hour bus-only segregation lanes.
- Fully integrated traffic light control at major junctions and intersections.
- Reduction in complex overhead wiring layouts.
- Passenger inter-change facilities with 'feeder' routes (diesel bus).
- Capability of running high capacity articulated vehicles (up to 18 metres length) through central areas.
- Electronic ticket cancellation to reduce boarding times.
- Park-and-ride facilities near outer termini.
- Minimal competition from other transport operations.
- High frequency of service during peak hours.

The installation of the wiring on the trolleybus trunk routes should be to the highest standards to allow high-speed passage of the collector heads through the overhead points and crossings, thus reducing the risk of dewirements. Visual intrusion of the overhead can be minimised by the use of lightweight modern fittings and support catenary.

In a survey conducted by the Vancouver Transit Commission in 1996 it was found that users of the existing trolleybus services were supportive of a modernisation programme provided that the frequency and reliability of operation was increased and routes were extended or diverted to serve more business and shopping areas. The trolleybus service was considered to be the preferred means of city centre travel and the financial outlay to achieve full integration was not seen as an obstacle to progress.

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4 Trolleybus Infrastructure Requirements

To support trolleybus operation a fixed infrastructure will be required which for costing purposes should have a design life of at least 15 years. This timescale will ensure that an adequate return on investment is achieved before replacement becomes necessary. Quality of manufacture and installation must be high but there is little merit in over-engineering for longer life as advances in technology may well bring with it savings that can be incorporated at a later date on an existing system

Equipment for trolleybus operation can be summarised as follows:

1.	Depot/Office/Workshop	-	existing building (modified) or purpose built.
2.	Sub-stations	-	rectification of AC power supply to 600 or 750V DC.
3.	Cabling/Section Switching	-	distribution of DC supply.
4.	Overhead Wiring	-	lightweight, fully automated.
5.	Communications	-	intelligent traffic management and route selection system.
6.	Stops/Shelters/Displays	-	passenger information and comfort.
7.	Computer system	-	SCADA for data logging of vehicle movement, passenger numbers, energy consumption.
8.	Maintenance Plant	-	specialist service equipment.

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5 New Approach to Wiring

With the many advantages of electric trolleybus operation comes the disadvantage of having fixed wiring, which may be perceived as visual pollution of the skyline. It has, therefore, become essential to reduce the weight and size of overhead components and this is being achieved by moving away from the traditional cast brass or iron castings to extensive use of modern materials. Investment cast stainless steel and aluminium bronze fittings are almost half the weight of the old designs and cheaper to manufacture. Their lighter weight can be supported and fixed in position by parafil rope cross-spans or stainless steel span wires.

Parafil rope has been used successfully on some recent light rail installations but appears blacker in colour against the sky. It also has a smaller thermal stability range than stainless steel and can thus 'go slack' in high ambient temperatures causing problems for trolleybus operation which demands rigidly held overhead wiring at all times. Its lower initial cost is offset by the greater long-term maintenance requirements such that it is likely that all future trolleybus installations will use lightweight stainless steel in their construction. Roadside (or traction) poles can now be reduced to the minimum possible diameter and combined with street lighting wherever possible. In city centres it is infinitely more practical to use span wires anchored to buildings with eyebolts and avoid poles altogether.

Points and crossings have been designed which offer the maximum dynamic reaction with the twin overhead collector heads mounted on the roof of the trolleybus, enabling them to be negotiated at higher service speeds than with the previous cast brass and iron designs. Route changing is done by electric solenoids commanded by switching circuits in the overhead or by radio signal from the vehicle.

6 Trolleybus Design and Construction

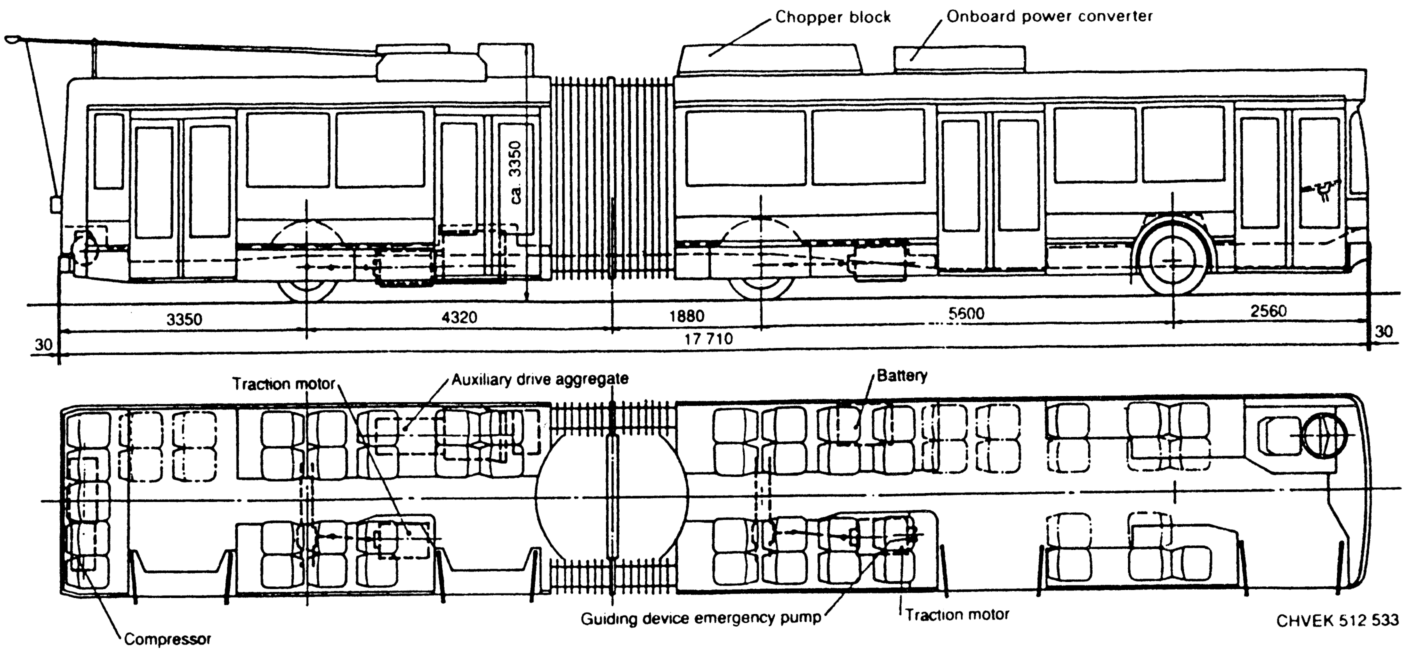
In several countries the trolleybus is already an advanced vehicle with some of the latest articulated models having seats for 40 – 50 passengers and up to 100 standing in an overall length of 18 metres. Its peak loading capacity is therefore considerable when combined with high frequency timetables. Rapid acceleration with full loading means that the trolleybus can maintain intense services on trunk route systems.

All new trolleybuses should use the latest technology in their design and construction but it must be emphasised that 'too much too soon' can produce reliability problems which must be avoided if credibility of this transport is to be retained. One particular feature that will do much to enhance acceptance is the low floor design with 'kneeling' action that further reduces step height at stops. Reliability of the actuating system necessary to provide the lowering has improved greatly in the past two years with much of the development work happening in the United Kingdom.

It will be of importance to existing and future operators of trolleybuses to have standard vehicles available that can be 'batch produced' to reduce the initial purchase costs. Manufacturers need to consider that both left and right hand drive trolleybuses will be required and the two options should be without cost penalty to the operator. Standard specification vehicles can readily gain individuality by the use of modern colour schemes and graphics. A typical 'International Design' trolleybus may be as shown.

Basic configuration	Single-deck Articulated
Passengers (including standing)	140
Overall length	18 metres
Overall height	3.5 metres
Motor Size	2 x 65kW AC Asynchronous
Control	Electronic AC Inverter
Braking	Regenerative and dynamic
Auxiliary Generator	55kW continuous rating
Driver Control	Intelligent graphic terminal
Number of axles	3 (2 driven)
Maximum speed (full electric)	65 kph
Maximum speed (generator only)	28 kph
Unladen weight	17 tonnes

Generator operation should be considered viable for limited 'off-wire' use only such as temporary diversions due to roadworks and depot manoeuvring. This is not to be confused with the full Duo-bus option.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17 710
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Traction motor
Auxiliary drive aggregate
Battery
Compressor
Guiding device emergency pump
Traction motor
CHVEK 512 533

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7 Funding Trolleybus Set-up Costs

The following costs are based upon recent research (Logicon Systems Ltd 1997) into the requirements of a modern trolleybus system. For the purposes of this research it was first necessary to establish the criteria for a 'typical' new turnkey trolleybus network which, after consultation with potential manufacturers and suppliers, was agreed as follows:

An installation of 50km of double-track overhead wiring, on five routes radiating out of a city centre, each with crossings and switches at junctions and branches. Intelligent route and traffic control throughout. 10 minute peak headway on all routes requiring 25 trolleybuses of 140-passenger capacity (initial system capacity of 20,000 passengers/hour).

Table 3 – Initial Costs

Item	Cost GBP	Cost USD	Cost DM
Consultancy and design	0.7M	1.1M	2.0M
Electrical sub-stations	3.5M	5.6M	10.0M
Electrical cabling works	3.0M	4.8M	8.5M
Diversion of services	3.0M	4.8M	8.5M
Overhead Wiring	7.5M	12.0M	21.4M
Depot/workshop (existing)	3.0M	4.8M	8.5M
Communications /SCADA	3.8M	6.1M	10.8M
Trolleybuses	7.5M	12.0M	21.4M
Passenger stops/shelters	1.0M	1.6M	2.8M
Marketing/contingency	1.0M	1.6M	2.8M
TOTAL	**34.0M**	**54.4M**	**96.7M**

Governments have the opportunity of proving their genuine commitment both to reducing private car dependence and improving the environment by **directly funding** new trolleybus installations. Where there is merit in encouraging investment from the private sector then this should be confined to the operation of the fleet. Obstacles to profitability must be reduced to a minimum by, for example, restricting competitive public transport operations and private car journeys into town and city centres.

The electric trolleybus should play a key role in the international transport industry to provide the passenger with quality, reliability and economy. Logicon Systems Ltd is a major advocate of this policy and is available to advise and assist in this objective.