GREENING OF FLEET IN TRANSPORT COMPANY OF OSTRAVA

[1]Marek ŠAFRÁNEK, [1]Iveta VOZŇÁKOVÁ, [2]Ivo FORMÁNEK

[1,2]VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU,
marek.safranek.st@vsb.cz, iveta.voznakova@vsb.cz

[2]VSPP, a.s. - Prague, Czech Republic, EU, ivo.formanek@vspp.cz

Abstract

Public transportation devalues the environment in the cities. It pollutes the air and increases noise. That is why transport companies tend to use alternative fuels for driving public transportation vehicles.

The portfolio of alternative fuels on the market is extensive and it will always depend on the particular conditions of a given transport company, i.e. which alternative fuel is the most suitable one for its fleet of vehicles. The main argument for introducing alternative fuels is represented by environmental reasons. However, these should always be bound to economic expediency. The use of alternative fuels in the Czech Republic is currently not too frequent, but some cities are already using transportation vehicles with alternative fuels and testing the economic aspects of these operation alternatives.

The objective of the article is to provide an analysis of the operation costs related to trolleybuses and buses and to determine which alternative seems to be more convenient on the lines serviced by trolleybuses. The research method especially included an analysis, synthesis, statistical evaluation of the given information obtained from studying scientific articles and from processing data provided by the Transport Company of Ostrava, a.s. (DPO).

Keywords: Alternative fuels, operational cost analysis, CNG, trolleybus, bus

1. INTRODUCTION

The objective of the article is to conduct an analysis of the operational cost of trolleybus lines and comparing it with the operational cost of buses driven by alternative fuel CNG (Compressed natural gas) on these lines. Furthermore, the article attempts to determine the most suitable alternative fuel for city transportation in Ostrava on the lines serviced by trolleybuses.

Urban public transportation forms a part of all modern cities. It is necessary for satisfying the transportation requirements of the city population. Its function will be determined by the given characteristics in relation to managing the needs for moving people, to the environment and to the investment demands of the given transport system. In order to achieve this goal, one needs perfect organization within the framework of an integrated transportation system and synchronization of technical development and all control, organizational, tariff, planning and investment activities.

Today’s dynamic environment, which is developing at a rapid pace, is linked not only to demanding requirements for the transport itself, but also for effectiveness, speed, safety and quality. Most of all, it asks questions related to the efficiency of the spent money.

Large cities particularly strive to reduce the environmental burden caused by transportation, resp. they try to reduce its impact to a minimum. The biggest problem of the current big cities is individual car transportation, which pollutes the environment by CO_2 emissions, increases the overall noise level and forms a very common negative phenomenon called congestion, which has many negative economic and environmental impacts. [1]

Congestion (or overloading) is formed when transportation demands exceed supply at a certain moment at a specific part of the transportation system. When this situation occurs, every vehicle disrupts the mobility of the others.

Possible congestion consequences:

- Loss of time of the drivers and passengers (waiting in traffic jams represents a nonproductive activity and slows down the regional economic growth),
- Delays that can result in late arrivals to work, school, meeting, etc.,
- Limited possibility to plan arrival times - long travel time reserves,
- Unnecessary fuel combustion - increased air pollution,
- Increased wear and tear of the vehicles - acceleration - braking, more frequent repairs,
- Stress and frustration of the drivers,
- Forming obstacles to ambulance vehicles, firemen vehicles, etc.,
- Greater accident probability. [2], [3]

One of the possible ways to make city transportation more environmentally friendly, thus reducing pollution, noise and costs related to transport services available to the population, is to limit car entries to the city, thus replacing the individual car transport by environmentally friendly urban public transportation. Urban public transportation (MHD) can be defined as a system of public transportation lines designated to provide transport services in a given city by urban public transportation means. Particular urban public transportation systems can be secured by buses, trams or trolleybuses. In cities with a population over one million people, these systems also include metro or above-ground rail routes serviced by trains.[4]

2. TECHNICAL ASPECTS

2.1. Trolleybuses - Description of the Technology

A trolleybus is a very well-known technology used in most of big cities. Trolleybuses are vehicles driven by an electric engine with a traction energy intake and discharge, designed for trolleybus lines and modified for road operation. Trolleybuses are semi-dependent vehicles since they are restricted by the position of the given trolleybus lines and the length of the rod collectors (in order to minimize the corresponding electric energy needs, “hybrid” trolleybuses can be used). Their basic principle is the use of two drives. One drive secures the vehicle operation without trolley lines. Either a combustion engine or an electric drive powered from accumulator batteries is used.[5]

The biggest advantages of electrically driven drives:

- lowest possible emissions into the environment as a whole,
- lowest possible consumption of nonrenewable resources,
- lowest possible noise level,
- lowest possible release of greenhouse gases like CO2. [6]

The biggest disadvantages of electrically driven drives:

- environmental burden related to the mining, production and liquidation of precious materials used for battery production,
- maintenance costs related to the given infrastructure and its modernization (traction lines),
- possibility of fast-growing electric energy prices in the future,

- future self-insufficiency of the Czech Republic when it comes to electric energy production (necessity to purchase electricity since the demand will be greater than the production in the Czech Republic). [7]

2.2. CNG Buses - Description of the Technology

Buses driven by CNG represent independent transportation vehicles characterized by a great flexibility and adaptability with regard to transportation demands within the frame of an urban public transportation system. The design and equipment of these buses allow for an increased occupancy rate in the urban public transportation system by the means of providing a bigger space for passengers and by reducing the number of seats considering the effective weight of the vehicles. The buses are used in all transportation networks of the urban public transportation systems as the only transportation means or as an integrated part of the transport systems in coordination with other transportation types.

The biggest advantages are:

- lower production of carbon monoxide by 95 % and lower noise level by 70 % when compared with buses driven by fossil fuels,
- biogas is created from waste, for example, at waste disposal sites, wastewater treatment plants, biogas stations, in which energy-producing plants are processed, etc. (circular economy concept - circular economy).

The biggest disadvantages are:

- dependency on the filling stations,
- raw material dependency on politically unstable countries. [8],[9]

3. OPERATIONAL AND ECONOMIC COMPARISON OF THE TROLLEYBUS AND BUS TRANSPORT IN THE CITY OF OSTRAVA

Two of the latest vehicles of a similar design of the Transport Company of Ostrava were selected for the comparison. The vehicles were of the same length with relatively identical weights. The only difference was their drives.

The Škoda 26 Tr Solaris trolleybus is a 12-meter, low-deck vehicle with an independent drive powered by traction batteries, continuously charged from the trolley lines. Without trolley lines, these vehicles can run for up to 12 km. Their engine's power output is 160 kW. Their approximate acquisition price amounts to 500,000 Euro. [15]

Figure 1 shows an electrically driven trolleybus 26 Tr Solaris. [11]

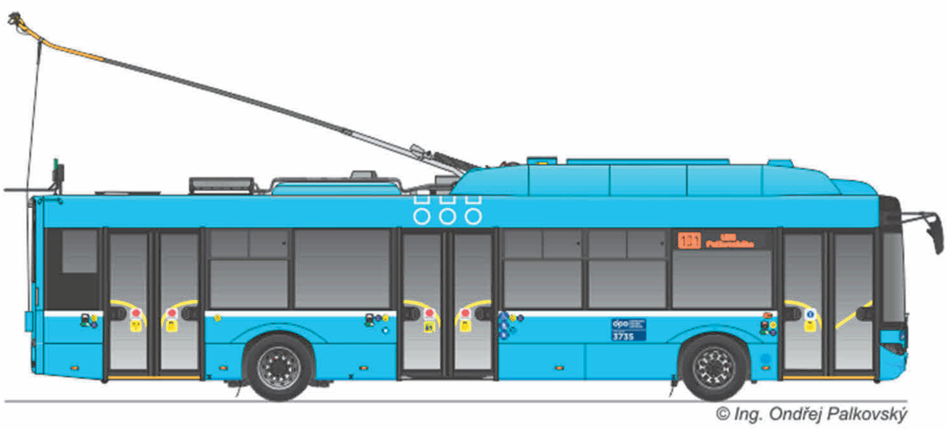

Figure 1 Škoda 26 Tr Solaris trolleybus

The Solaris Urbino 12 CNG bus is a 12-meter version of a low-deck bus driven by compressed natural gas. It is the most widespread Solaris bus with a power output of 265 kW. Its approximate acquisition price is 300,000 Euro.[14]

Figure 2 Solaris Urbino 12 bus with a CNG drive. [11]

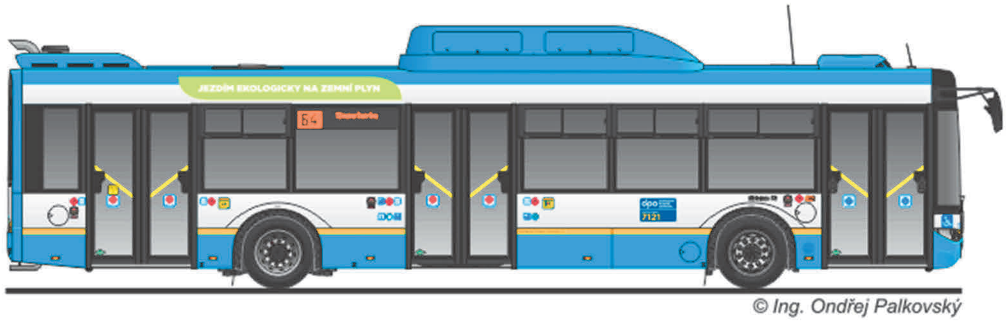

Figure 2 Solaris Urbino 12 CNG bus

Vehicle capacity

The transport capacity is the ability of individual transportation means to transport a certain number of people and objects. The capacity represents the offer of seats, area, space or effective weight for transportation purposes. From a statistical point of view, capacity in an urban public transportation system is defined as a vehicle's passenger capacity, which specifies the number of sitting and standing places. The maximal passenger capacity is limited by the overall weight of the vehicle. [12]

Diagram 1 compares the vehicle's passenger capacity of a Škoda 26 Tr Solaris trolleybus and a Solaris Urbino 12 CNG bus. There is a significant difference between the weights of these two vehicles. The trolleybus is 1000 kg heavier than the bus. The biggest difference between these two vehicles is in their respective passenger capacity. The bus can transport by up to 26 passengers more than the trolleybus.

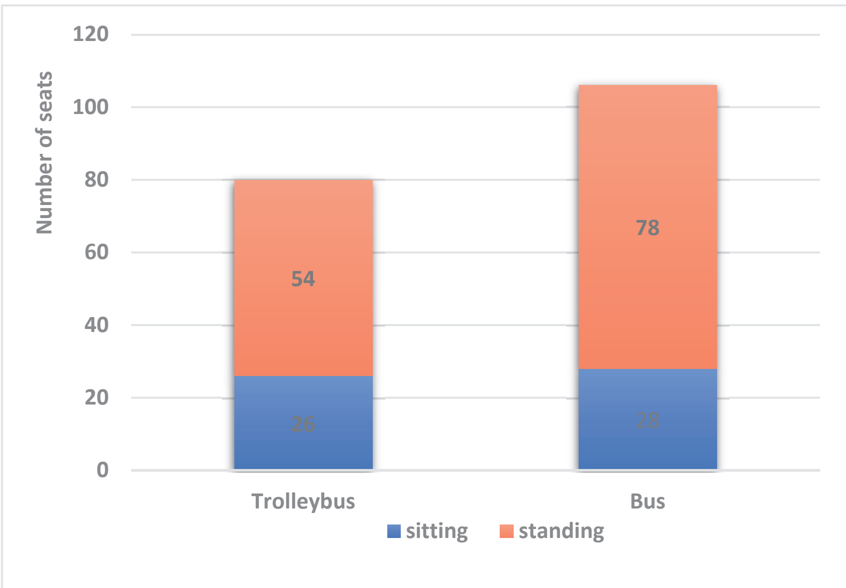

Diagram 1 Comparison of the passenger capacity of Škoda 26 Tr Solaris trolleybus and Solaris Urbino 12 CNG bus

Running speed

Running speed (also called maneuvering speed) is used for road transport purpose. Apart from the run time and standing times at individual stops, the denominator also takes into account the average delay of the vehicle at its final stop.

$$v_o = \frac{L}{t_j + n_z \cdot t_z + t_k} \qquad [\text{km.h}^{-1}]$$

where v_0 = running speed [km.h^{-1}]

L = line length [km]

t_j = running time on the line [h]

n_z = number of intermediate stops [number of]

t_z = average stoppage time at a single intermediate stop

t_k = average delay at the final stop. [13]

The values of the average running speeds of the trolleybuses and buses were slightly lower in 2018 compered to the previous years. The average running speed of the trolleybuses in 2018 was 14.27 km/h and the average running speed of the buses was 18.20 km/h. When going through intersection fixtures and frogs, the trolleybuses must observe the speed that is permitted for such fittings. These days, the frogs and intersection fittings allow for a maximal speed of 40 km/h. The drivers pass through these intersection frogs and fittings with a speed of approximately 35 km/h. Should they exceed the maximal permitted speed, the collectors could become damaged or the trolley lines overloaded, which could lead to transport outages. Buses do not have to deal with this issue.

Transport and transport capacity

This point includes overall capacity indicators for the trolleybus and bus transport. **Table 1** shows a transport capacity in driven kilometers per individual types of the transportation means. **Table 2** shows the number of transported people.

Table 1 shows transport capacities executed by DPO, a.s. trolleybuses and buses for the years of 2016 to 2018

		2016	**2017**	**2018**
Buses	thousands. kilometers driven	16.420	16.594	16.269
Trolleybuses	thousands. kilometers driven	3.061	2.866	3.128
Total	thousands. kilometers driven	19.481	19.460	19.397
Buses	%	84.29	85.27	83.87
Trolleybuses	%	15.71	14.73	16.13
Total	%	100.00	100.00	100.00

The share of individual types of means of transportation with regard to the number of transported passengers has recorded a growing trend when it comes to both the number of these passengers on trolleybuses as well as buses. The share of the kilometers driven has been slightly fluctuating, however, it is more or less similar. According to the tables shown above, the average number of transported passengers on trolleybuses per one kilometer driven in 2018 was 2.52 persons. In the case of buses, this number was 2.47 persons. The almost identical number of passengers transported per one driven kilometer for both types of the transportation means is the result of a different number of operated lines. The trolleybus lines pass through areas with large transportation demands, however, the number of these lines is small (a total of 13 trolleybus lines). The bus lines pass through peripheral parts of the city and their number is significantly greater (a total of 57 bus lines) than the number of trolleybus lines. [10]

Table 2 shows the number of transported passengers by DPO, a.s. trolleybuses and buses for the years of 2016 to 2018

		2016	2017	2018
Buses	thousands. kilometers driven	37.172	38.348	40.107
Trolleybuses	thousands. kilometers driven	6.960	6.640	7.890
Total	thousands. kilometers driven	44.132	44.988	47.997
Buses	%	84.23	85.24	83.56
Trolleybuses	%	15.77	14.76	16.44
Total	%	100.00	100.00	100.00

Comparison of individual tractions

When comparing the trolleybus and bus transports, we use the cost per 1 driven kilometer. The expenses related to one driven kilometer consist of the price of fuel, direct material (tires, operation liquids), direct salaries, direct write-offs, repairs, maintenance, other direct cost, operation and administrative expenses.

Table 3 shows expenses per 1 kilometer driven by electrically driven trolleybuses and by CNG-driven buses, the total number of the driven kilometers of all trolleybus lines in the city of Ostrava per calendar year and the running speed of these vehicles. [10]

Table 3 Cost pre km driven - vehicle running speed [10]

Vehicle	Per 1 km driven (EUR)	Total traveled km (thousands)
Trolleybus	2.59	3.128
Bus	1.58	X

Based on the values stated in **Table 3**, we can see that the total number of the kilometers driven by trolleybuses in 2018 was 3,128,000. The total cost amounted to 2.59 euros/driven kilometer. The total cost of the operation of the trolleybus lines in 2018 was 8,101,520 euros. Should the trolleybuses be substituted by CNG driven buses, which recorded a price of 1.58 Euro per one driven kilometer, the total cost of the operation of the vehicles on these lines would have amounted to 4,942,240 euros. This would have represented savings of 3,159,280 euros/year.

4 CONCLUSIONS

When compared with the previous years, it is clear that the trend of the passengers transported by the urban public transportation system is growing again. The Transport Company is successful in getting people back to using the urban public transportation system. This trend is most visible in the trolleybus transport. More and more people are choosing trolleybus transport over individual car transport. It is the result of the layout of the trolleybus lines, which are situated in the city center that is more densely populated than the peripheral parts of the city, which are serviced by buses. People also prefer this type of transport due to the fact that the formerly free parking lots in the city center and its close proximity are now subject to parking fees.

The assessment of the productivity of individual tractions based on the number of transported passengers per one kilometer driven resulted in approximately the same values. There is a significant difference between the total number of all persons transported by trolleybuses and buses. This difference is greatly influenced by the number of individual trolleybus and bus lines. The buses transported up to six times more passengers than trolleybuses. However, we need to consider the fact that the capacity of buses is greater from the perspective of the number of people one vehicle can transport.

The greater running speed of the buses is given by greater distances the buses need to drive. The buses service the city peripheries, where the traffic density is smaller and the buses can thus also boost a better gas mileage at higher speeds due to longer distances driven without frequent stops and repeated starts. Frequent starts and braking, which are quite normal due to congestion and a dense network of stops in the city centers, lead to more extensive wear and tear of the vehicles and thus also a shorter lifespan of the trolleybuses. Yet another fact to consider is the acquisition price of a trolleybus (510,000 Euro), which is almost twice as much when compared to the acquisition price (290,000 Euro) of a bus, which also has a longer lifespan.

Based on the calculated economic results, it is clear that the operation of CNG driven buses is economically more convenient than the operation of trolleybuses. From the economic point of view, the biggest problem of the trolleybuses lies in their electric drives. The price of electricity will grow due to the future self-insufficiency of the Czech Republic in its production and the necessity to purchase it from abroad. When coal-fired power plants will be phased out and nuclear power generation will be slowly developing. The trolleybus operation expenses in the future will increase. Yet another disadvantage of the trolleybuses is the necessity to manage and maintain the traction lines. This problem does not exist in the case of independent vehicles, such as buses. [16]

Buses are used in all public transportation system networks either as the only transportation means or in combination with other transportation types. The currently manufactured buses produce very low emissions and their noise levels are low. These vehicles are already relatively widespread. Should the given vehicle fleets be eventually fully replaced with environmentally friendly vehicles, it will be possible to replace trolleybuses with these buses.

The global trend towards pure mobility is focused on hydrogen technologies that are already implemented in normal bus operations in the USA, Japan, China, South Korea and some European cities (Hamburg, Milano, London, Oslo, etc.). In the Czech Republic, hydrogen propulsion in public transport is already being tested in Trutnov, Prague and Ostrava.

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic No. SP2019/62.

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