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Energy aspect of improving the public city passenger transport system in Sarajevo

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A R T I C L E I N F O

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A B S T R A C T

In the last 5 years, several projects have been initiated in Sarajevo Canton that are focused on strengthening the identity of the city, promoting and implementing the concept of urban mobility, green and smart city. The issue of energy efficiency is included in all projects and from that aspect, among other things, the improvement of the public city passenger transport service is observed. This paper analyzes the state of public urban transport from the energy aspect, the savings that are achieved, the methodology for calculating savings and the effects that would be achieved through the implementation of planned projects for the development and reorganization of public urban passenger transport.

1. Introduction

Projects in the last 5 years in Sarajevo Canton are aimed at strengthening the identity of the city with the concept of urban mobility, green and smart city. To achieve this goal, a green economy transition approach is essential, involving the construction of low-carbon and resilient economies, and includes three categories of projects, reducing greenhouse gas emissions, increasing resilience to climate change and other environmental benefits (including improving resource efficiency, reducing local pollution, improving resilience and ecosystem restoration.

There are several transport systems on the network of lines in Sarajevo Canton that use different energy resources. [1] A significant number of vehicles have diesel engines.

Reliance on public urban transport, in the concept of urban mobility, is inevitable, so the issue of energy efficiency (EE) is very topical in the process of improving the public urban passenger transport service. [4]

[1] This article has been presented at the 8th International Conference "Towards a Humane City", 11-12 November 2021, N. Sad, Serbia

Given the fact that the state of the vehicle fleet changes over time, that new projects seek to propose more energy efficient systems and that for each city energy management is imperative, it is necessary to know the methodology for determining the savings achieved by specific measures and effects to be achieved. realization of planned projects of development and reorganization of public city passenger transport. [2], [6] In addition to the above, it is necessary to build a system for monitoring and verification of energy savings (SMiV) that contains Internet applications. [3], [10]

2. Recent and existing activities relating to the public urban passenger transport sector in sarajevo canton

Existing and recent activities related to the public transport sector in Sarajevo energy efficiency:

- Feasibility study for the extension of the tram line from Ilidža to Hrasnica (2015)
- Green Cantonal Action Plan for Sarajevo (2019)
- Development of Sarajevo public transport and Sarajevo city roads, technical, economic, environmental and social analysis (2019-2020)
- Main project for overhaul of tram line (2018-2020)
- Sustainable Urban Mobility Plan ("SUMP") (published in September 2020).
- The SUMP predicts that a total of € 379 million will need to be invested between 2021 and 2025 in order to achieve, inter alia, the following goal: reduce CO2

emissions by 12% (or 57,505 tons of CO_2); increase the share of low-carbon public transport vehicles to 60% (currently to 30.7%); increase the number of public transport without engines by 200% (from 78 to 234); increase the coverage of the public transport system by 10%.
- Project "Development of public transport in order to increase mobility and reduce air pollution" in Sarajevo, Japan International Cooperation Agency ("JICA") (2019-2021 / 2022)
- Technical and economic analysis for the introduction of an adaptive traffic management system along the tram corridor in Sarajevo (2021-2022)

Current issues and projects related to the energy aspect include the "Study of e-mobility in Bosnia and Herzegovina" which should assess the short and medium term market potential and readiness to introduce electric vehicles (EV) in selected cities, as well as the development and design of charging infrastructures in at least three selected cities and the installation and use of RES (solar photovoltaic systems) to charge electric vehicles on the road along at least one of the busiest highways. The study should include: Market study (macro) and policy; Assessment of investment in charging infrastructure; Assessment of potential economic benefits; Market (micro) and immediate opportunities of the private and public sector; Impact on the energy sector; Stakeholder Awareness Raising and the e-Mobility Plan.

3. Methodology for determining energy savings in public transport of passengers

Energy efficiencies for the transport sector, to which public urban transport also belongs, cover energy consumption in passenger and freight road, rail and inland waterway transport. To determine energy savings in public transport, it is necessary to define energy efficiency indicators and the calculation procedure. [1]
The European Commission has developed recommendations for two types of approaches to data collection and savings budgeting. The top-down approach is based on national statistics, and the bottom-up approach is linked to a series of equations used to directly calculate energy savings for each implemented project.

3.1Energy efficiency indicators in public transport

Energy efficiency indicators for the transport sector cover petrol and diesel consumption together. It is also possible to separate the consumption of these two fuels and calculate the indicators separately for each of them, in order to take into account the effect of fuel change. [6]
Total energy savings in the sector are calculated by summing the realized savings by individual types of vehicles and by individual forms of transport.

This does not take into account the negative savings that occur when the indicator in the reporting year is higher than the indicator in the reference year. [9]
The use of preferred energy efficiency indicators gives more accurate results, which are closer to the actual technical energy savings. Minimum indicators are likely to underestimate savings because they include the impact of non-energy efficiency parameters.

3.2 Determining energy savings when replacing existing and procuring new vehicles in public transport

Measure EE, replacement of existing and procurement of new, more efficient vehicles (T1), refers to the calculation of energy savings in case of replacement or procurement of new vehicles in local government units, government agencies and companies. Unit energy savings are defined as the product of the difference between the average fuel consumption per unit length (100 km) before and after the implementation of the measure in question and the average annual distance traveled by the vehicle. [11]

3.2.1 Calculation method

In this measure, which provides a way to determine the savings when replacing or buying new more energy efficient vehicles, two typical cases are distinguished:

a) Replacing old vehicles with new, more efficient vehicles.

In this case, the calculation is based on the difference in fuel consumption of old and new vehicles, multiplied by the average annual mileage and the number of cars replaced. An example of this case is the replacement of old petrol or diesel vehicles with new vehicles that use petrol, diesel, LPG, CNG, electricity or hybrid drive. In the case of vehicle modifications, the budget is identical.

b) Procurement of new more energy efficient vehicles.

In this case, the savings are calculated based on the difference between the unit fuel consumption of the reference vehicle and the new vehicle, multiplied by the average annual mileage and the number of cars planned for purchase. An example of this case is the purchase of new vehicles that use gasoline, diesel, LPG, CNG, electricity or hybrid propulsion.

The calculation of energy savings for both cases is given by the expression (1):

$$FES = \frac{FC_{prije} \cdot f_{C_{prije}} - FC_{poslije} \cdot f_{C_{poslije}}}{100} \cdot D \cdot n \qquad (1)$$

Where is:
FES (kWh/year) - Total annual energy savings
FC_{prije} (l/100 km ili kg/100 km) - Fuel consumption of old vehicles
$FC_{poslije}$ (l/100 km ili kg/100 km) - Fuel consumption of new vehicles
$f_{C_{prije}}$ (kWh/l ili kWh/kg) - Fuel consumption to energy consumption conversion factor of old vehicles
$f_{C_{poslije}}$ (kWh/l ili kWh/kg) - Fuel consumption to energy consumption conversion factor of new vehicles
D (km/god) - The average distance a vehicle travels per year
n - Number of replaced or new vehicles within the EE project.

3.2.2 Input data

Taking into account the relation for the calculation of energy savings, it is necessary to have information on the average fuel consumption of old and new vehicles, as well as their average annual mileage. In the case of purchasing a new more energy efficient vehicle, it is necessary to have information about the fuel, as well as its average consumption.

3.2.3 Reference values

It is recommended to always use the actual consumption values before and after the implementation of the measure, but in case of lack of some data it is necessary to determine the reference values. [11], [9]

1. Fuel consumption and conversion factor
In the case of the analysis of the measure of procurement of new more energy efficient vehicles, for values FC_{prije} i $f_{C_{prije}}$ reference values are taken depending on the type of vehicle. When purchasing new electric or hybrid vehicles, the data on fuel consumption for a petrol car, for FC_{prije} i $f_{C_{prije}}$ respectively.

2. The average distance a vehicle travels per year
Reference values for the average distance traveled by the vehicle during the year for Bus is D=54.500 (km/god).

3.2.4 Emission reduction CO_2

The annual reduction of CO_2 emissions as a consequence of the implementation of the measure of replacement of existing or purchase of new vehicles can be determined by the term, [5]

$$E_{CO_2} = \frac{e_{prije} \cdot FC_{prije} \cdot f_{C_{prije}} - e_{poslije} \cdot FC_{poslije} \cdot f_{C_{poslije}}}{100 \cdot 1000} \cdot D \quad (2)$$

Where is: E_{CO_2} (t/god) - Emission reduction CO_2
e_{prije} =0,267 ($kgCO_2$/kWh) - Emission factor for fuel consumed by an old vehicle
$e_{poslije} = 0{,}202$ ($kgCO_2$/kWh) - Emission factor for fuel consumed by a new vehicle

3.2.5 Lifetime measures

The lifetime of the measure of replacement or purchase of new more efficient vehicles is 8 years (100,000 km).

4. Energy savings, co_2 emissions and energy costs in public passenger transport in Sarajevo

Energy efficiency in public urban passenger transport in Sarajevo could be improved if diesel vehicles were replaced by Compressed Natural Gas - CNG vehicles. The hypothesis was tested using the previously described methodology for the case of replacing old vehicles with new, more efficient vehicles in two ways:
- based on the actual values on the structure of the vehicle fleet of the passenger transport company (KJKP GRAS) and fuel consumption for 2020.
- based on reference values.

1. Actual fuel consumption values (Diesel→CNG)
Diesel fuel consumed in 2020. is 1.310.151,71 (litre)
D =54.500 (km/year) - The average distance a vehicle travels per year
$n = 80$ (vehicles) Diesel Bus+Minibus replaced or new vehicles
FC_{prije} =40 (l/100 km) - Fuel consumption of old vehicles - Diesel
$FC_{poslije}$ =36 (kg/100 km) - Fuel consumption of new vehicles- CNG
$f_{C_{prije}} = 10{,}03$ (kWh/l)-Fuel consumption to diesel consumption conversion factor
$f_{C_{poslije}} = 13{,}30$ (kWh/kg)-Fuel consumption to CNG consumption conversion factor

According to expression (3), the total annual energy savings for 80 vehicles were calculated FES

$$FES = \frac{(40 \cdot 10{,}03 - 36 \cdot 13{,}3)}{100} \cdot 54500 \cdot 80 = -2.912.480 \text{ (kWh/year)}$$

Savings per vehicle FES_1 =-36.406(kWh/year).

2. Fuel consumption reference values
D =54.500 (km/year) - The average distance a vehicle travels per year
$n = 80$ (vehicles) - Number of replaced or new vehicles within the EE project
FC_{prije} =27,2 (l/100 km) - Fuel consumption of old vehicles - Diesel

$FC_{poslije}$ =25,4 (kg/100 km) - Fuel consumption of new vehicles- CNG
$f_{C_{prije}} = 10{,}03$ (kWh/l)-Fuel consumption to diesel consumption conversion factor
$f_{C_{poslije}} = 13{,}30$ (kWh/kg)-Fuel consumption to CNG consumption conversion factor

Total annual energy savings for 80 vehicles according to expression (1) FES

$$FES = \frac{(27{,}2 \cdot 10{,}03 - 25{,}4 \cdot 13{,}3)}{100} \cdot 54500 \cdot 80 = -2.834.174 \text{ (kWh/year)}$$

Savings per vehicle FES_1 =-35.427,2(kWh/year).

Annual emission reduction CO_2 when replacing existing vehicles with new ones it is determined via formula (2) for input values:

e_{prije} =0,267 ($kgCO_2$/kWh) - Emission factor for diesel fuel
$e_{poslije}$=0,202 ($kgCO_2$/kWh) - CNG emission factor

For one vehicle annual emission reduction CO_2 is

$$E_{CO_2} = \frac{0{,}267 \cdot 27{,}2 \cdot 10{,}03 - 0{,}202 \cdot 25{,}4 \cdot 13{,}3}{100 \cdot 1000} \cdot 54500 = 3{,}846379 \text{ (t/year)}$$

For 80 vehicles annual is $E_{CO_2} = 80 \cdot 3{,}846379$ =307,7103 (t/year).

Annual energy procurement costs [7], [8]

$c_{dizel} = 2{,}10\ (KM/l)$ - price of diesel fuel; $c_{CNG} = 1{,}30\ (KM/l)$ - price CNG
For one vehicle, the difference in the cost of purchasing energy is
$\Delta C_1 = Cprije - Cposlije$ (KM/year) , where is:
$Cprije = FC_{prije} \cdot c_{dizel} \cdot D$ (KM/year) $-$ $diesel\ procurement\ costs$;
$Cposlije = FC_{poslije} \cdot c_{CNG} \cdot D$ (KM/year) $-$ $CNG\ procurement\ costs$

$$\Delta C_1 = \frac{FC_{prije} \cdot c_{dizel} - FC_{poslije} \cdot c_{CNG}}{100} \cdot D = 13.134{,}50 \text{ (KM/year)}$$

For 80 vehicles annual is $\Delta C = \Delta C_1 \cdot n = 13.134{,}50 \cdot 80 = 1.050.760{,}00$ (KM/year).

<u>Conclusion of the savings analysis</u>: From the energy aspect, the variant of transport with diesel vehicles is more favorable, and from the aspect of CO2 emissions and energy costs, the variant with CNG fuel is more favorable.

5. Conclusion

Based on the conducted analysis of the benefits of fleet replacement in public passenger transport, it can be concluded that energy savings, CO_2 emissions and energy costs do not have to be on the same side, favorable or unfavorable.

Special attention should be paid to ensuring that investments are on the path of low emissions and environmental impact. For the same transport work of one or more vehicles, it is more favorable that there are energy savings when purchasing vehicles. Energy costs should not carry the greatest weight when choosing a supplier in the procurement process.

Consultants should take these considerations into account in project preparation and gather relevant data in order to select the more favorable option.

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