

Original Research

SUSTAINABLE TRANSPORT AND FIGHT AGAINST POLLUTION, CASE STUDY

DOI: 10.5937/EcoTER26516S

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Abstract

Environmental pollution represents one of the greatest contemporary environmental problems that has a significant impact on people's health and quality of life. One of the main sources of pollution is traffic, especially through the emission of harmful gases from motor vehicles, increased traffic congestion and the excessive use of fossil fuels. Therefore, the need for the introduction of sustainable transport systems is becoming more pronounced. This paper deals with the role of sustainable transport in reducing pollution, with particular emphasis on urban public transport and the application of electric vehicles. Through an analysis of public transport and the possibilities for implementing ecological transport solutions, the benefits of using sustainable transport systems are seen.

Keywords: pollution, line, electric, sustainable, public.

INTRODUCTION

According to research, especially in urban environments, the largest source of air pollution and noise comes from transportation. To reduce negative environmental effects, the implementation of sustainable transportation systems is proposed. Sustainable transportation refers to modes of transport that are sustainable in terms of their social and environmental impacts. The components for assessing sustainability include the specific vehicles used for road, water, or air transport; the energy source; and the infrastructure used to accommodate the transport.

Existing urban mobility habits are characterized by continuous urban expansion and a dependence on automobiles. Sustainable transportation arises in this context to reduce the negative impact associated with this increased urban mobility and to promote more environmentally friendly modes of transport.

The city of Bitola already has public city transportation; the vehicles run on diesel fuel, which further pollutes the environment. The public city transportation lines are not just urban; some of them also serve the nearby rural areas. This research focuses on route no. 14 from Scheherazade to the village of Kravari. Calculations have been made for the implementation

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of a new line with an electric vehicle. A comparative analysis has also been conducted between the current diesel-powered system and an electric one.

MATERIALS AND METHODS

Bitola is the largest urban center in the fertile and largest Macedonian plain, Pelagonia, and the second-largest city in the Republic of Macedonia, with an area of 320 km². The city of Bitola is located in the far southwestern part of the Republic of Macedonia.

The municipality comprises 65 villages, including the village of Kravari. Kravari is a rural village located southwest of the city of Bitola, about 5 km from the city center. The population is predominantly engaged in agricultural and livestock activities, while the rest of the residents are employed in services and industry in Bitola.

- **Demographics:** The population is age-diverse, but there is a noticeable trend of young people migrating to the city and abroad. Families average 3–5 members.
- **Infrastructure:** The village is connected by a paved regional road to Bitola. Public transportation is limited, with a few bus routes per day.
- **Education and Healthcare:** There is an elementary school in the village, but high school students travel to Bitola. Access to healthcare services is limited, so residents often use healthcare facilities in the city.

The rural area of Kravari is also served by public city transportation. Line 14 has 28 stops. It starts from Sheherezade, makes a full circle past the Faculty of Education, the Hospital, and the City Park, going first to the village of Bistrica, then to the village of Kravari where it stops at three stations, and then returns back past the train station stop, Karposh 4, to Bela Chesma.

The first public transport vehicle departs from the Sheherezade station at 6:00 AM, and the last departure is at 7:30 PM. The first public transport vehicle in the rural area of Kravi, at the Kravi 1 stop, is at 6:35 AM. The next one is at 7:35 AM, one hour later. At the same Kravari 1 station, the public transport vehicle stops at 6:35 and 7:35 AM, then the next service is from 11:35 AM to 3:00 PM. The vehicles run on one-hour intervals; at 3:00 PM, the vehicle does not appear at the station, nor does it at 6:00 and 7:00 PM. This analysis shows that the vehicles run at an irregular frequency, are late, or do not appear at the stop at all, which makes public transportation less attractive for the residents of Kravari. Figure 1 shows public city transport line number 14, along with the stops. The method used in this research is the household survey questionnaire.

The household survey questionnaire is a research method used to collect data from individuals or households in order to analyze behaviors, attitudes, opinions, or demographic information. This method is popular in sociological and economic research, as well as in marketing.

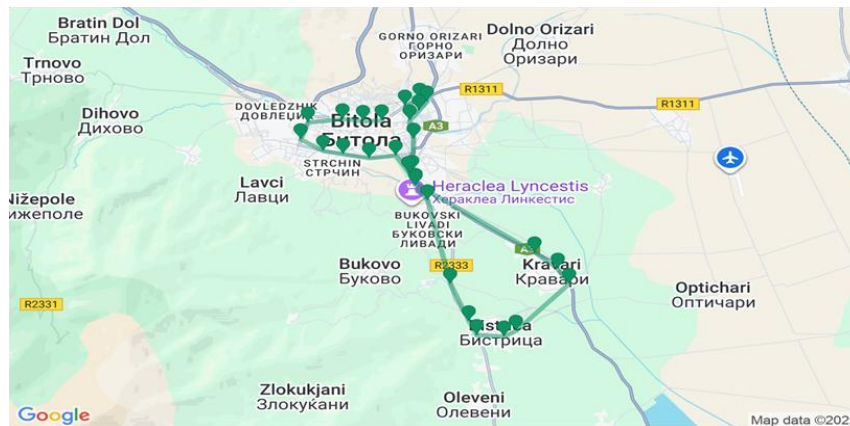


Figure 1 Public city bus line No.14

The survey was conducted on December 20, 2024. Although the residents of Kravari cite the regularity and frequency of public transportation as their priority, the analysis indicates that some of the problems can also be overcome through organizational and operational measures, such as introducing a full-day schedule, combining bus and minibuss services, introducing a new fleet of vehicles that pollutes less and is quieter, and clearly defined protocols for replacing a vehicle in case of a breakdown. Such measures allow for an improvement in service quality without a significant increase in costs. Given that the biggest problem is the lack of a direct line to Kravari, the proposal is to introduce a new line, as shown in the image 2.



Figure 2 Proposal for a new public city transit line

RESULTS AND DISCUSSION

The distance of the analyzed Sheherazad–Kravari route is approximately 12 km one way, while the return route to the starting point is about 7.74 km. The total distance per round trip is approximately 20 km. With a turnaround time of 50 minutes, the resulting average operating speed is about 24 km/h, which is characteristic of rural public transport with stops in settlements.

The turnaround time for the analyzed route is determined based on the total distance and the actual operating speed characteristic of rural public transportation. For a distance of approximately 20 km and an average operating speed of around 24 km/h, the calculated

turnaround time is approximately 50 minutes, which is consistent with the field conditions and the existing traffic regime.

In reality, two vehicles can be used, one in each direction, for backup, service stability, or that vehicle can be operated as a minibus only during peak periods.

But what if we look at the revenues and costs for a single trip? In Bitola, the service is provided by standard buses, and the ticket price is 30 denars.

We know that these are rural areas with very few residents who use public city transportation. So from this, the following arises:

If we have standard vehicles that are 12 meters long, diesel fuel at a price of 64.5 denars/liter, an average number of 50 passengers per trip, and a line length of 20 kilometers per trip, and the price increases to 40 denars, we get the following calculations in Table 1.

Table 1 Introduction of a new line with a diesel-powered vehicle

Category	Per Turn	Daily (8 turns)
Fuel	516 denars/turns	4.128 denars/day
Driver	193 denars/turns	1.544 denars/day
Depreciation	260 denars/turns	2.080 denars/day
Maintenance	240 denars/turns	1.920 denars/day
Total	1.189 denars/turns	9.512 denars/day
Revenue	2.000 denars/turns	16.000 denars/day
Profit	811 denars/turns	6.488 denars/day

Given that we need to care for the environment, we should strive to implement sustainable transportation systems, including electric public city transit. The consumption of an electric 12-meter city bus is 1.15 kWh/km. The price of electricity in Macedonia during the analysis period was 23.629 denars/kWh. A new 12-meter electric city bus in the EU typically has a purchase price of around 300,000 to 600,000 euros, which is generally higher than that of a diesel bus. However, total cost of ownership (TCO) analyses often reveal that electric buses are comparable or even cheaper over their lifetime due to lower energy and maintenance costs.

Charging infrastructure: The additional costs for depot charging systems, which can add significant investment and range from 10,000 to 30,000 euros per vehicle.

Electric buses are typically charged once a day, usually overnight. However, high-demand or long-distance routes may require additional short top-ups during the day, known as opportunity charging. Modern electric buses can travel between 150 and 350 km on a single charge. The exact distance depends on the battery size, passenger load, terrain, and temperature. City buses with moderate battery sizes (around 300–400 kWh) typically complete their daily routes without recharging. But if routes include hills, heavy traffic, or cold weather, the range can be reduced. Bus manufacturers offer different battery options, so cities can choose the right balance between weight, cost, and range. Some electric buses also use regenerative braking to recapture energy during stop-and-go driving, extending the battery's lifespan throughout the day.

A standard electric bus has an overall lifespan of 12 to 15 years, with some manufacturers and studies suggesting they can last up to 20 years with proper maintenance and battery management. This is comparable to, or potentially longer than, the typical 10- to 15-year lifespan of a diesel bus. The battery is the most critical component, and its lifespan is usually 8 to 10 years in automotive applications before its capacity drops to about 80%. At this point, the battery can be replaced and repurposed for other uses, such as energy storage, while the bus chassis continues to operate.

Accordingly, calculations were made for the deployment of an electric bus, and the final results are presented in Table 2.

Table 2 Introduction of a new line with a electric-powered vehicle

Indicator	Value	Note
Energy consumption	1.15 kWh/km	Average cost for a 12 m electric bus
Electricity price	23.629 denars/kWh	Source: gorivo.mk
Cost per km	27.17 denars/km	$1.15 \times 23,629$
Cost per trip	543 denars/cycle	20 km per trip
Driver cost per trip	193 denars/cycle	Salary 34,000 denars/month
Depreciation per trip	450 denars/cycle	Price 18,000,000 denars, 800,000 km
Maintenance cost per trip	160 denars/cycle	8 denars/km
Total cost per trip	1,346 denars/cycle	Total of all costs
Number of trips per day	8	Operating time ~8 hours
Total daily cost	10,768 denars/day	$1,346 \times 8$
Revenue per trip	2,000 denars/cycle	50 passengers $\times$ 40 denars
Daily revenue	16,000 denars/day	8 trips
Daily financial result	+5,232 denars/day	Revenue – expenses

According to the analysis conducted, we can say that the diesel bus is currently more cost-effective, mainly due to lower depreciation. However, the electric bus has advantages in terms of maintenance and environmental protection, making it a better solution for sustainable urban transportation in the long run.

CONCLUSION

Public urban transportation is one of the most important segments of urban planning and the sustainable development of cities. In recent years, many cities have been transitioning from diesel buses to electric buses for environmental, economic, and technological reasons.

Electric public transportation represents a modern and sustainable solution for urban environments. Although the initial investment is higher, the long-term benefits for the environment, health, and operating costs are significant.

Diesel buses still have an advantage in terms of range and lower initial cost, but their negative impact on the environment is gradually making them a less attractive solution.

For this reason, a large number of cities around the world are gradually transitioning to electric public transportation as part of their sustainable development and pollution reduction strategies.

In rural areas and on longer routes where passenger numbers are lower but distances are greater, diesel buses can be simpler to implement, given the fuel infrastructure and the lower charging/infrastructure requirements.

Electric buses are best suited for routes with frequent charging, short distances, and higher environmental standards, such as the central city lines in Bitola. For rural areas, additional charging infrastructure is required for them to be efficient.

ACKNOWLEDGEMENT

The authors are grateful to the students of the Faculty of Technical Sciences in Bitola. They were third-year students (winter semester) who were taking the Traffic Planning course. They are also grateful to the residents of the rural village of Kravari who agreed to be interviewed.

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