





Integration of Electromobility into Public Transport Systems: A Case Study

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Abstract. This paper aims to investigate the integration of electromobility into public transport systems through a case study. Given the growing global environmental concerns and the need to reduce greenhouse gas emissions, electromobility is becoming a key factor in the transition to more sustainable forms of transport. This paper analyses the strategic, technical and social aspects of integrating electric vehicles into existing public transport systems. The case study highlights the challenges, opportunities and best practices associated with this integration through a comprehensive approach that includes quantitative and qualitative methodologies. Emphasis is placed on the analysis of infrastructure needs, such as charging stations, fleet modifications and intelligent control systems, which are essential for the effective integration of electromobility into public transport systems. Furthermore, the paper assesses the impact of electromobility. The case study findings provide important learning and recommendations for city planners, policymakers and public transport operators seeking to implement or expand electromobility in their systems. This paper contributes to the growing body of research on electromobility in the context of sustainable mobility. It offers valuable insights for the future development and integration of electromobility into public transport at a global level.

Keywords: Electromobility · Public transport · Electric bus

1 Introduction

In recent years, electromobility has become one of the main pillars in the fight against climate change and in the efforts to move towards more sustainable transport. The integration of electric vehicles (EVs) into public transport systems represents a significant step towards reducing greenhouse gas emissions, improving air quality and increasing energy efficiency. [1] The city of Prešov, as one of the leaders in innovation and sustainable transport in Slovakia, offers a unique opportunity to explore this pre-transition through a case study. This article focuses on integrating electro-mobility into public

transport in Prešov, including an analysis of the strategic, technical and social challenges and opportunities. Using a comprehensive approach that combines quantitative and qualitative research methods, we aim to provide an in-depth view of the integration process and its impact on urban mobility. In Prešov, as in many other cities, public transport is an integral part of the everyday life of the inhabitants. However, in the last decade the city has faced growing challenges such as increased emissions, congested transport infrastructure and rising energy costs. The implementation of electric vehicles in public transport represents a strategic response to these challenges while providing opportunities to improve efficiency and enhance sustainable mobility in the city. [2] In the introduction of this article, we focus on an overview of the current state and potential of electromobility in Prešov, identify the main motivations and goals of the city in the field of sustainable transport and define the key challenges it faces in integrating EVs into its public transport system. We further explore the infrastructure and technology requirements necessary for successful implementation, including the need for extensive charging infrastructure, fleet upgrades, and the introduction of intelligent control systems. This introduction provides a basis for further discussion of the case study results and how Prešov can serve as a model for other cities seeking to integrate EV mobility into their public transport systems.

1.1 Electromobility

Electromobility is a fascinating idea that better encourages the usage of electricity-based technology in the various modes of transportation as opposed to the conventional transportation system that consumes a significant amount of fuel to run. The very inception of electromobility enables the creation of subsequent infrastructure to support these kinds of vehicles as well as generate high-capacity batteries that will allow substantial mileage for the said vehicle [3].

The electromobility has its advantages and limitations, in addition, the advantages include versatility and zero pollution. The traditional transportation system heavily relies on fossil fuels like petrol, diesel, and coal as well as substances like liquefied petroleum gas and compressed petroleum gas reserves to function efficiently [4] These substances when oxidized through the regular heat engine create a high amount of energy as well as various other obnoxious gases that can permanently damage the delicate balance of the global environment.

Fossil fuel lead vehicles have been around for almost a century while going through decades of evolution and modification in their major as well as minor systems to accomplish the highest levels of perfection [5]. Traditional engines have become more powerful as well as fuel-efficient as humanly possible. However, the basic difficulties remain as usual for a suitable replacement for fossil fuels, which could probably go extinct by the start of the next century [6] (Fig. 1).

The graphical representation appropriately visualizes the general uptake in the number use of e-vehicles in the global prospect of public transportation. There is a sharp increase in public usage of e-vehicles by 18 million in the year 2022 compared to that it was only 11 million in the previous years. This explains the technological progress made by e-vehicle facilities around the globe. Electromobility helps to reduce the depletion of hydrocarbon from the earth, and therefore it helps to reduce environmental degradation.

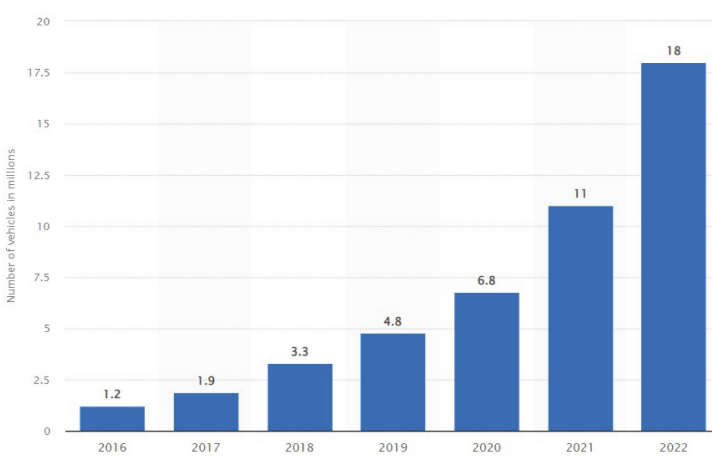


Fig. 1. Estimated plug-in electric light vehicle sales worldwide from 2016 to 2022 (in million units) [6]

In addition, to that Electromobility is nowadays gaining momentum because of different factors such as climate awareness and price reduction [7] Therefore, in smart cities the usage of electromobility is increasing day by day. Electromobility as well as its related infrastructure provides a compelling replacement for the public transportation approach. It is the responsibility of world governments as well as global conglomerates to forge a parallel system of replenishment for these latest electromobility-based vehicles that are also environment-friendly by nature. The prevalent lack of capability as well as the quality of batteries has made these sorts of vehicles mighty expensive for common people to bear [8].

1.2 Implementation of Electromobility into Public Transport

The various issues related to the research revolve around the correct execution of electromobility within the context of public transportation as well as how it can sufficiently enhance it. Electronic vehicles also contribute towards the betterment of the environment and its subsequent ecosystem by reducing the production of pollution.[9].

The greater involvement of electromobility within current civilian transportation can virtually reduce the service of fossil-fuelled vehicles in the immediate future. The prevailing extinction of various fossil fuel sources further increases the rise of alternative sources of fuel reserves that are led by electronic vehicles [10] (Fig. 2).

The above illustration highlights the overall procedure of electrification that is led by the public bus corporation in various metro cities across the world. In the current times, 33% of buses have been turned into e-vehicles by the year 2020. Moreover, the municipal corporations also target to increase that number by 33% at the end of the current decade. The study is developed to signify the different gifts of electromobility towards replacing the traditional transportation resources that the general population has availed of these many years. In addition, this research is highly significant as it

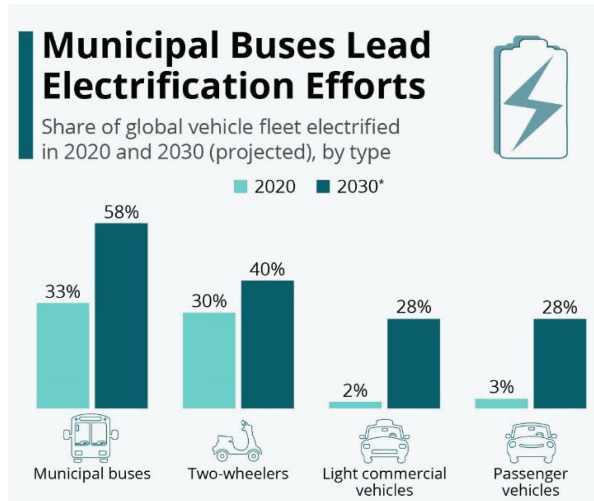


Fig. 2. Municipal Buses Lead Electrification Effort [11]

highlights different factors and possibilities of using electromobility in public transport and the research question and ratio les are highly impactful as it helps to identify the research aim [11].

2 Literature Review

This chapter is concerned with a critical analysis of several complex systems that have been used in public transport like charging systems as well as e-bus and different route planning of the vehicle using electromobility. The technologies that have been used to solve the problem related to the field and the environmental impacts of using electromobility have been discussed in this chapter. Additionally, there are several comparisons of other technologies used in transportation and the different methods are discussed briefly along with the reason for using electromobility [12].

2.1 Complex Systems in Public Transport-Chargers, e-bus and Route Planning

Public transportation uses electromobility to reduce the harmful emission of carbon dioxide gas from cars. However, to take advantage of the transports are taking several complex systems in the vehicles like charging systems rather than using harmful petrochemical fuels and along with that the use of e-bus is inhaling the scope to reduce the pollution in the air. The route planning of the e-transport is changed from traditional transportation. The reduction of harmful gasses reduces the chance of pollution in the air [13]. The cars are using chargers so that the battery of the transports can get power. However, by connecting the chargers the vehicles using the cars are getting energy (Fig. 3).

The figure in question illustrates how diesel buses contribute to air pollution through the emission of noxious gases, while electric buses obtain their power from electric

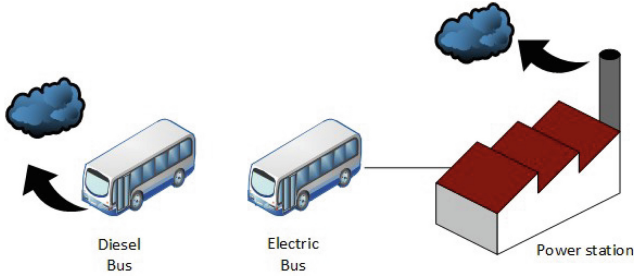


Fig. 3. Shift of emission of harmful gasses

power stations, which in turn release harmful gases into the atmosphere, causing environmental degradation. This suggests that pollution is being indirectly caused by efforts to combat environmental breakdown. The adoption of electric transportation involves the use of batteries and electronic methods, potentially reducing pollution outdoors through sophisticated charging systems and related technologies [14]. The market now offers various electric vehicle types, bolstering the adoption of electric cars and vehicles. Specifically, the utilization of Plug-in Hybrid Electric Vehicles (PHEV) diminishes the risk of pollution and the emission of dangerous gases. The convenience of using plug-in electric cars and the expansion of electromobility are contributing to efforts to minimize gas emissions (Fig. 4).

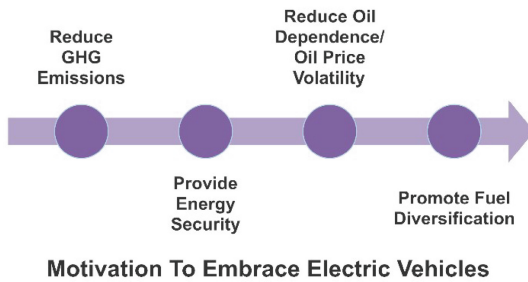


Fig. 4. Motivation for EVs

The above figure shows the positive side to adopting electric vehicle and this figure also indicate that everyone should embrace and adopt this to reduce pollution and sustain the environment. Each contains the negative and the positive side. The electromobility helps to sustain a secure environment as well as help to make a pollution-free environment. The negative side is that it needs to maintain and it is highly costly. The electro-mobility provides energy that is renewable and which can be diversified and it reduces fuel oil and greenhouse gas [15].

Presently, the world is getting polluted day by day and to reduce the harmful effects the authorities are deciding to adopt the complex systems of the e-transport. People are using private cars very much and due to that reason; the air is getting more polluted, and

the pollution can be reduced by taking public transportation. In first-world countries, people are using more private cars than getting into public transport [14]. Public transport can adopt the use of electron mobility systems. The charging systems are engaging more for the reduction of harmful gases. The air purifier can be established inside cars and the technologies are energized for the reason of less air pollution in the environment. The sustainable use of a route that is free from pollution and a cleaner and healthier destination can enhance the chance of a pollution-free environment [16].

2.2 Environmental Impacts of Using Electromobility

Electro mobility as well as its various prevalent characteristics can have a massive consequence on the refinement of the environment as well as its various aspects. It can be mentioned that the consequences of over-exerting the conventional public vehicular system that has been prominent for ages have created a huge wound in the face of the earth and its subsequent ecological system of beings [17]. The different end-products of traditional fossil fuels have increased the entire carbon emission levels that have contributed towards the planetary eco-logical phenomenon that is called global warming. The electro-mobility helps to sustain the environment and the above figure shows it is necessary to adopt electro-mobility various industries have shifted and changed their manufacturing style and adopted electro-mobility. Additionally, with the help of this process, the industry can successfully make the environment decarbonize. This has resulted in the natural cycle of climate being effectively hammered across several regions of the world leaving most of it with long-lasting consequences. It can be stated that the global average temperature scale has also risen to effective measures by a couple of degrees in the last century alone [18]. Moreover, animal, as well as plant lives, have also been reshaped by the overall change in the ecosystem caused due to global warming (Fig. 5).

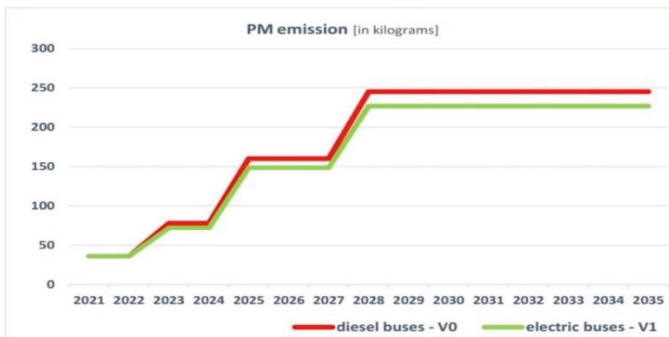


Fig. 5. Sustainability and emission [17]

As per the above figure, it can be mentioned that the global community is pressing towards enforcing electro mobility within the civilian vehicular design of the world in large-scale efforts to better combat the environmental downturn [18]. The e-vehicle has various added benefits which include electronic batteries as the source of fuel for these

vehicles that can mitigate the carbon emission levels in the environment. It can be stated that the sole basis of the electronic vehicular process involves electricity moving the vehicles rather than any external fuel-based approach. [19] Only the public can help in reducing the emission of harmful taking the use of public transport instead of taking private cars (Fig. 6).

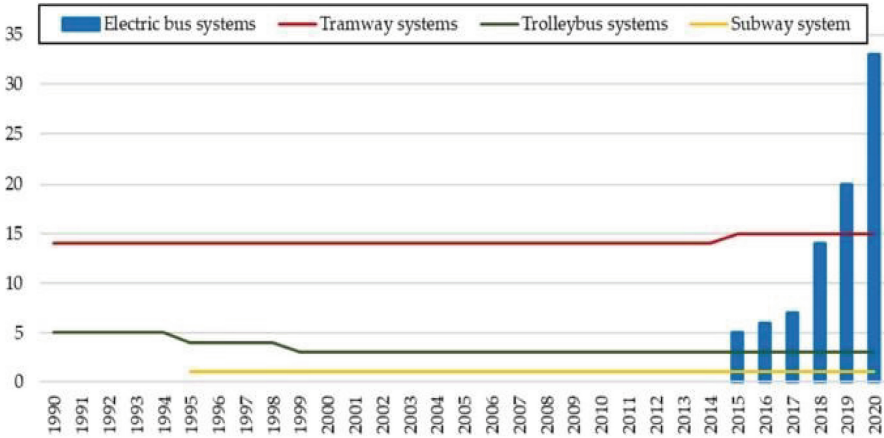


Fig. 6. Percentage of using public transport systems globally [19]

From the above picture, it can be stated that the use of different types of vehicles across the world from the year 1990 to 2020. The percentage of people using the electric bus system is around 35% in the year 2020. The low emission of harmful gases engaging consumers using e-bus is attracting consumers and the author of the bus organization is engaged in the service of the e-bus systems in the world. In strict vehicles, people are getting the service quicker and longer term and the changes of the gasses through the electric grid are acceptable in terms of reducing pollution. It can be mentioned that the world is getting polluted by the faults of humans and the enhanced use of harmful gasses [13]. For this reason, global warming is happening across the world and to reduce these effects of public transportation, the government of the country should take the necessary steps to improve the public transport system that uses electromobility.

2.3 Reason for Using Electromobility in Public Transport

The main reason behind using electromobility is to reduce the emissions of gasses from cars that are causing pollute the air and for this reason, public transport is using electromobility. The other reasons for using electromobility are that it is easy to ride the electromobility cars and buses and the less emission sound is another reason for using electromobility [20] Electromobility helps to bring a sustainable atmosphere and improve the quality of life as well as improve the urban form of life. It also helps to provide a suitable economy and business and through this, the local atmosphere and

the business can grow towards betterment. It also sustains the climate endeavor of the environment makes it more natural and connects the atmosphere by providing a pollution-less environment. It also helps to make travel more suitable and safer. [21] This is also used to get a cleaner and healthier sustainable destination and the changes of the harmful gases through the electrical grid are enhancing its scope to get a healthier and colder ride across the destination. The healthier and more sustainable the clearer destination is engaging the pole to adopt the use of electromobility in the transportation system in public vehicles [22]. The reduction of pollution can be done by the usage of the e-bus and charging systems of the vehicles. The batteries are energy to the systems of the electromobility cars and vehicles are giving energy to the cars [19]. The people of the world should use public transport despite using private cars. The engagement of more and more private cars in the world is ending the changes of pollution and due to this reason; people are suffering from air-causing diseases [23]. People are suffering from the respiratory system and asthmatic problems and to avoid taking medicines or inhalers and to reduce the effects of respiratory attacks, people are engaging in air purification [24].

3 Materials and Methods

Electric buses are a novel and unique technique of transforming public transportation in Prešov, Slovakia. They are an environmentally friendly, energy-efficient, and sustainable method of transportation that is gaining popularity around the world. Electric buses are being deployed in Prešov as part of a campaign to reduce emissions and enhance air quality. One of the primary benefits of electric buses is that they emit no pollutants, making them environmentally beneficial. This contrasts with regular diesel buses, which emit toxic fumes that can impair air quality and occupants' health. [25] Furthermore, electric buses are much quieter than traditional diesel buses, reducing noise pollution in cities (Fig. 7).

Electric buses are propelled by motors that are powered by a battery system [26] The batteries can be charged in a variety of ways, including slowly and quickly. Slow charging entails charging the batteries overnight or during off-peak hours when electricity consumption is lower. In contrast, fast charging can charge the batteries in as little as 30 min. Prešov has implemented electric buses on numerous routes around the city, notably line 4 from Sídlisko 3 to Sibírska. Solaris Bus & Coach, a leading European producer of electric buses, built the buses. The SOR EBN 8 electric bus has a range of up to 130 kms on a single charge, making it an excellent alternative for Prešov urban transportation (Fig. 8).

Prešov's electric buses have regenerative braking systems, which recover energy while braking and use it to replenish the batteries. This improves bus efficiency and reduces the amount of energy required to power them. The buses also include electric air conditioning and heating systems, which help to increase passenger comfort while lowering emissions.

Prešov's decision to deploy electric buses is a big step forward in the city's attempts to minimize its carbon footprint and improve air quality. It is also an opportunity for the city to demonstrate its commitment to sustainable transportation and set a good example

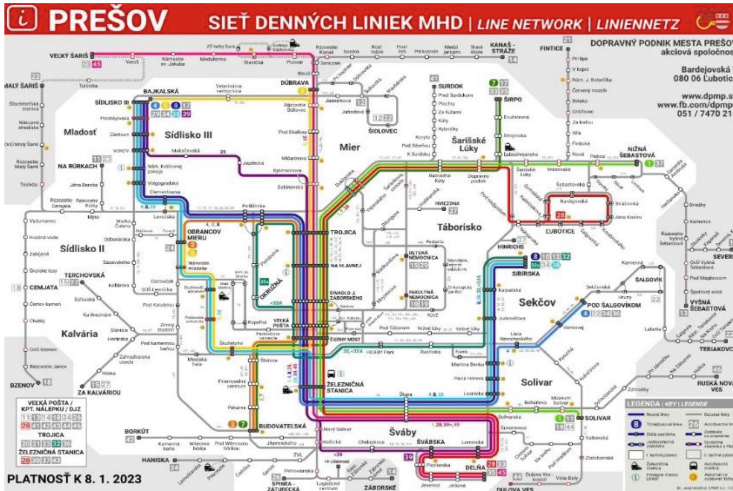


Fig. 7. Network of public transportation line in Prešov



Fig. 8. SOR EBN 8 electric bus in to Prešov city

for the rest of the region. Prešov is demonstrating that it is feasible to establish a clean, efficient, and dependable public transportation system that helps both the environment and the community by introducing electric buses. Overall, electric buses are a welcome addition to Prešov's public transportation system. They provide a more environmentally friendly and efficient alternative to regular diesel buses, while also improving air quality and lowering noise pollution. Prešov can continue to establish a contemporary and environmentally friendly public transportation system that fulfils the demands of its people and visitors by implementing more electric buses on new routes.

3.1 Analysis of Transport in the City Prešov

The public transportation system in Prešov is administered by the “Dopravný podnik mesta Prešov” (DPM Prešov) corporation. DPM Prešov was founded in 1956 and oversees providing transportation services in the city and neighboring areas.

The company has a bus and trolleybus fleet that serves 25 bus routes and six trolleybus routes. DPM Prešov provides special transportation services for disabled people, school transportation, and transportation for various events in addition to normal services. DPM Prešov employs around 200 people, including bus and trolleybus drivers, maintenance and repair workers, and administrative staff. The organization also maintains a driver training centre where new drivers are instructed and experienced drivers can refresh their skills. The organization is dedicated to offering its customers with safe, dependable, and efficient transportation services. DPM Prešov invests continuously in updating its fleet, adding new technologies to increase service quality, and ensuring that its employees are adequately trained and motivated.

DPM Prešov also provides other services, such as the renting of buses and trolleybuses for special events, as well as advertising opportunities on its vehicles, in addition to public transportation.

Overall, DPM Prešov is critical to the smooth and efficient operation of Prešov's public transportation system, offering residents and visitors with convenient and economical transit options. There's a more detailed explanation of the different routes and their route maps for public transport in Prešov:

BUS ROUTES:

- a. Lines 1 to 10: These bus lines connect the city centre with the suburbs, covering areas such as Solivar, Sekčov, Nižná Šebastová, and Veľký Šariš.
- b. Lines 11 to 20: These bus lines operate mainly in the eastern part of the city, covering areas such as Solivar, Ľubotice, and Záborské.
- c. Lines 21 to 25: These bus lines connect the city centre with the western suburbs, covering areas such as Šalgovík, Sídliisko III, and Haniska.
- d. Lines 26 to 30: These bus lines operate mainly in the northern part of the city, covering areas such as Sekčov, Šidlovec, and Nižná Šebastová.
- e. Lines 31 to 35: These bus lines connect the city centre with the southern suburbs, covering areas such as Delňa, and Širpo.
- f. Lines 36 to 40: These bus lines operate mainly in the industrial areas of the city, covering areas such as Surdok and Šalgovík.

The bus route map shows the different bus lines, stops, and connections between the lines. The map also indicates the wheelchair-accessible stops and vehicles, as well as the stops with ticket vending machines and validators. In general, public transportation in Prešov is dependable and reasonably priced, with frequent bus and trolleybus services connecting various parts of the city.

We have chosen 3 routes for the implementation of electric buses:

1. Line 4 from Sídliisko 3 to Sibírska Presov,
- Start at the Sídliisko 3 bus stop and take bus line 4 towards Sekčov. The estimated time for this leg is around 5 min.

- Get off at the Sídliisko Sekčov bus stop and wait for the next bus. The estimated waiting time is around 5–10 min.
- Take bus line 4 towards Sibírska from the Sídliisko Sekčov bus stop. The estimated time for this leg is around 10–15 min, depending on traffic conditions. • Get off at the Sibírska bus stop. The estimated total time for this journey is around 20–30 min.

2. Line 11 that Connects Na Rúrkach to the Solivar in Prešov

- Start at the Na rúrkach bus stop and take bus Line 11 towards Solivar. The estimated time for this leg is around 10–15 min, depending on traffic conditions.
- Get off at the Solivar bus stop. The estimated total time for this journey is around 10–15 min.

3. Line 18 Connects Bzenov to “Veľká Pošta” in Prešov

- Start at the Bzenov bus stop and take bus Line 19 towards Jarková ulica. The estimated time for this leg is around 15–20 min, depending on traffic conditions.
- The bus makes several stops along the way, including Vydumanec, Poliklinika and “Veľká pošta”.
- Get off at the Veľká pošta bus stop. The estimated total time for this journey is around 20- 25 min.

4 Results

The Solaris SOR EBN 8 can travel up to 130 km on a single charge. To compute the range with a 20% reserve, we must remove 20% of the entire range from the total range.

So, with a 20% reserve, the range of the SOR EBN 8 would be $130 \text{ km} - (20\% \times 130 \text{ km}) = 104 \text{ km}$.

As a result, the SOR EBN 8 range with a 20% reserve would be around 100 km. It should be noted that the actual range of the bus might be influenced by factors such as weather, topography, and passenger load.

The bus has a battery capacity of up to 172 kWh, which can provide a range of up to 130 km on a single charge. However, to ensure the safety and longevity of the battery, it is recommended to leave a reserve of 20% for the range to the electric charger, which reduces the effective range to 100 km.

Assuming the bus is operating on Line 4 in Prešov, Slovakia, a 15-km route that takes 30 min to complete in normal operation time, the bus could complete approximately 7 trips on a single charge. This computation takes the reduced range of 100 km and divides it by the distance of one trip (15 km), yielding 6,7 trips. It is crucial to note, however, that this calculation does not account for any pauses or idle time throughout the route, which would limit the bus's effective range.

Therefore, it is recommended to have charging stations strategically located along the route, to allow for recharging of the battery during breaks or idle times. The charging time will depend on the type of charging station used. According to the specifications on the Solaris bus website, the SOR EBN 8 can be charged in two ways: slow charging and fast charging.

When charging slowly, the bus can be charged to full in approximately 4 h. This type of charging is typically done overnight, when the bus is not in use, and is ideal for depots or bus stations.

When charging quickly, in about 55 min, the bus can be charged to 80% capacity. This charging method is faster, but it necessitates specialized charging infrastructure capable of delivering high power to the bus. It is perfect for charging stations strategically placed along the route, where the bus can be charged during idle periods or scheduled breaks.

5 Conclusion

Overall, it is feasible to introduce electric buses, such as the SOR EBN 8, to the public transportation system in Prešov or other cities and achieve considerable reductions in greenhouse gas emissions and air pollution through strategic placement of charging stations and careful route design.

Choose an electric bus route and analyze in this way whether it is worthwhile or not to introduce electric buses. How long does the journey take and what is the energy consumption, how much does it have to be charged? A detailed explanation for each of the three routes you've selected and the analysis of whether it's worth introducing electric buses, along with the journey time, energy consumption, and charging requirements. This type of route is typically characterized by frequent stops and starts, lower average speeds, and heavy traffic congestion. The journey time may vary depending on the distance and the level of congestion. In Prešov, this type of route could include areas such as the historic city center and the downtown area.

- Electric buses are particularly well-suited to this type of route, as they can recover energy through regenerative braking and can stop and start quickly without idling. This can lead to reduced energy consumption compared to traditional internal combustion engine buses. However, due to frequent stops and starts, electric buses may require more charging during the day, especially if the route is long.
- Firstly, for this route, we would need to consider the distance covered and the average speed of the bus. Since we do not have specific information about the route, let's assume that the distance covered by the bus in one trip is 15 km and the average speed of the bus is 30 km/h.
- The electric bus can travel up to 130 km on a single charge. However, to account for the reserve range to reach the charging station, let's assume that the actual range for one charge is 100 km. This means that the electric bus can complete 6–7 trips on a single charge.
- Next, let's consider the energy consumption of the electric bus. The SOR EBN 8 has a battery capacity of 172 kWh. Therefore, for a trip of 15 km, the energy consumption would be $15 \text{ km} \times 0,955 \text{ kWh/km} = 14,3 \text{ kWh/trip}$.

Finally, let's consider the charging requirements for the electric bus. The SOR EBN 8 can be charged in two ways - slow charging (4 h) and quick charging (up to 1 h). Since the electric bus can complete 7 trips on a single charge, it would need to be charged once every 7 trips. This means that for slow charging, the bus would need to be charged for 4 h every 7 trips. For quick charging, the bus could be charged for up to 1 h every 7 trips.

In conclusion, introducing electric buses for the “Only in the city” route in Prešov seems feasible based on the assumptions made. The journey time and energy consumption for the electric bus would be like those of a traditional diesel bus. The charging requirements would need to be carefully planned to ensure that the electric bus can complete its trips without running out of power. The research underlines the “analysis of the possibility of using electromobility in public transport” of Prešov by maintaining the secondary research approach as well as appropriate themes have also been developed. The research study highlights the possible benefits of using electromobility. The negative impact of utilizing electromobility, which can affect the environment, has been discussed in this research paper, which helps any other researcher to investigate this topic elaborately. Apart from that, the possible development of the electromobility in Prešov has also been evaluated in this study which helps to improve some transportation systems”. Thus, it can be stated that this research will be helpful in terms of supporting other researchers and help to gain detailed knowledge about several factors.

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