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RENEWAL OF BUSES AND REGISTRATION OF NEW BUSES IN THE SLOVAK REPUBLIC AND THE CZECH REPUBLIC

Jozef Gnap, Marek Dočkalik*

University of Žilina, Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport Univerzitná 8215/1, 010 26 Žilina, Slovakia

** marek.dockalik@stud.uniza.sk*

The use of alternative fuels and the use of vehicles meeting the strictest emission standards can contribute to improving the impact of road transport on the environment. Therefore, it is also very important to restore buses, which can affect the environment in cities to a certain extent. Achieving an increase in the number and share of ecological buses is possible through several tools. The contribution is focused on the analysis of the EU directive on the support of ecological and energy-saving road transport vehicles and the study of the number and share of ecological buses in European countries, and the data for the Slovak Republic and the Czech Republic, which can also be compared for the same period, are processed in more detail. Due to the growth rate of the number of ecological buses during the period under review, it can be seen that in the Slovak Republic it is definitely necessary to increase the number and the proportion of buses that have a more favourable impact on the environment and are considered ecological.

Keywords: environment, buses, EU directive, standards

1 INTRODUCTION AND LITERATURE REVIEW

In order to achieve the elimination of negative effects on the environment, the European Union is determined to gradually build a sustainable and decarbonized energy system. This results in various accepted commitments to reduce greenhouse gas emissions and efforts to green transport. Solutions must be comprehensive and focused on passenger and freight transport, individual and public transport. A special area is the improvement of the quality of the environment in cities, which can be contributed to a certain extent by ecological buses and increasing their number and share in cities. This can be achieved through various policy initiatives, including measures that support increased use of public passenger transport and the use of public procurement to support ecological vehicles.

Many papers deal with the investigation of, for example, the deployment of electric buses or buses with other alternative fuels and their contribution to reducing the impacts of bus traffic on specific lines of public passenger transport, especially on-air quality such as e.g. [1, 2]. The authors of the paper [3] dealt with a similar issue of renewing diesel-powered buses for new electric-powered buses, from the point of view of sustainable public transport and reducing CO_2 emissions. The procurement prices of vehicles with alternative propulsion are currently higher than vehicles with standard conventional propulsion. The cost aspect can be an obstacle in the renewal of the vehicle fleet [4], therefore the authors of the study [5] focused on the assessment of the investment in electric buses or, in the second alternative, the investment in electric buses in combination with buses using CNG as a source of propulsion. The aim of the paper [6] is to carry out an analysis of the feasibility, consequences and costs of a project to modernize bus mass transport in Milan, where the fleet should consist of 1,150 electric buses by 2030. The results of a life cycle assessment study of the electrification of public bus transport in the context of a sustainable urban development strategy [7] showed that increasing the share of electric buses in urban environments can be very beneficial for human health and climate change, if the electricity used to drive electric buses is produced from a sufficient number of low-emission and emission-free energy sources. Renewal of the vehicle fleet of urban public transport brings positive impacts on air quality in cities, which is confirmed by contribution [8], therefore it is also crucial from the point of view of cities to clearly support these activities. The results of a study from Brazil [9] confirm that the renewal of the vehicle fleet is necessary to fulfil societal environmental goals, and the authors also proposed a method for evaluating the ecological efficiency of public bus transport. Electrification of bus fleets is expected to grow in most cities due to its significant environmental benefits. These advantages include lower traffic noise, which can be achieved by using a greater number of electric vehicles [10]. Certain restrictions may occur in connection with the procurement and operation of electric buses, therefore the authors of the article [11] focused on planning the operation of these buses with regard to the charging infrastructure and the need for charging while minimizing operating costs, and planning the operation of vehicles from the point of view of the application of social legislation is certainly important in road transport [12]. Contributions that examine the need for an electrical system for recharging the batteries of electric buses are specific if they were to be deployed in urban public transport [13]. The authors of the paper [14] paid special attention to compressed natural gas (CNG) buses and their comparison with conventional diesel-powered buses, which have a dominant share in countries such as Serbia. Currently, diesel with a certain proportion of bio-component is also used, and the study [15] provides a comprehensive overview of the measurement of the effects of different bio-diesel mixtures on the characteristics of exhaust emissions of city buses in real operating conditions, while the preparation of the fuel mixture of a conventional internal combustion engine is very important from the point of view of emission production [16]. The ecologization of vehicle fleets of carriers that provide urban or suburban bus transport will have to be the subject of contracts for services in the public interest,

and in public procurement, it will also be necessary to take into account the cost aspect related to the operation of vehicles using alternative types of propulsion [17]. A similar issue is addressed in contributions where the authors focused on investigating whether passengers are willing to pay extra for their fares if ecological buses were used in urban public transport [18] and also by examining the competitiveness of public passenger transport before the crisis caused by the Covid-19 pandemic [19]. Preference for buses in traffic can also help to increase the public's interest in urban bus transport, for example by using dynamic control at intersections, which can also lead to lower emissions [20]. Closely related to this is the achievement of lower travel time, which is very important for passengers, and this issue was examined by the authors in the paper [21]. It is therefore necessary to build attractive public transport on busy sections, as this can bring considerable benefits from the point of view of road traffic and emissions [22]. Many contributions, such as [23, 24, 25], are aimed at investigating the impact of the Covid-19 pandemic on public transport, urban transport and the consequences for road transport, with a focus on emission production and fuel consumption [26]. In connection with the Covid-19 pandemic, the authors of the study [27] focused on ways to improve ventilation in public transport buses.

The target of the research and the specificity in relation to the articles analyzed in the literature review is to examine the development and current status of bus renewal in selected countries with regard to EU legislation and obligations to reduce greenhouse gas emissions and also with regard to efforts to green transport. An important area is improving the quality of the environment in cities, to which ecological buses can contribute to a certain extent and increasing their number and share in cities and regions, which the authors deal with in the paper.

2 MATERIALS AND METHODS

The authors of this paper conducted the research according to the following steps, where the course of the research itself is described:

Step 1: Analysis of EU legislation in relation to the required shares of ecological buses.

Step 2: Examination new bus registrations in Europe, the share of ecological buses and the factors influencing their share.

Step 3: Examination the number and share of ecological buses in selected states over a longer period of time.

Step 4: Expression of the average growth rate of the number of ecological buses in selected states.

Step 5: Examination of requirements, technical and operational standards of buses in public procurement.

2.1 Scope of the EU Directive 2019/1161 on the promotion of ecological and energy-efficient road transport vehicles

EU Directive 2019/1161 on the promotion of green and energy-efficient road transport vehicles requires member states to ensure that contracting authorities and procurement entities take into account energy and environmental impacts during the vehicle's lifetime, including energy consumption and CO_2 emissions, when procuring certain road transport vehicles and certain pollutants in order to promote and stimulate the market for green and energy-efficient vehicles and to improve the contribution of the transport sector to the Union's environment, climate and energy policies [28].

EU Directive 2019/1161 applies to procurement through:

- contracts for the purchase, leasing, rental or instalment purchase of road transport vehicles entered by public contracting authorities or procurement entities, as long as they are subject to the obligation to apply the procurement procedures specified in EU directives 2014/24 and 2014/25. Under the conditions of the Slovak Republic, these should be above-limit orders entered by public contracting authorities and contracting authorities, the subject of which is the purchase, leasing, instalment purchase or rental of a vehicle, which is covered by the EU Directive 2019/1161,
- contracts for services in the public interest in the sense of the regulation of the European Parliament and the Council (EC) no. 1370/2007, the subject of which is the provision of passenger road transport services by vehicle, which is covered by EU Directive 2019/1161 and the average annual value of the service, or its range expressed by the number of kilometres driven per year exceeds the value of 1,000,000 € or 300,000 km [29],
- service contracts set out in Table 1, if public contracting authorities or procurement entities are subject to the obligation to apply the procurement procedures specified in EU directives 2014/24 and 2014/25. In the conditions of the Slovak Republic, these should be over-limit orders entered by public contracting authorities and contracting authorities, the subject of which is the service listed in Table 1, if it is provided using a vehicle covered by EU Directive 2019/1161 [28].

Table 1. Services subject to EU Directive 2019/1161

Services subject to EU Directive 2019/1161	
Public road transport services	Personal road transport services for special purposes
Irregular passenger transport	Waste collection services

Services subject to EU Directive 2019/1161	
Road transport of postal items	Transport of parcels
Mail delivery services	Parcel delivery services

Processed based on [28]

2.2 Ecological vehicle

EU Directive 2019/1161 states for each member state of the European Union what the minimum percentage shares of ecological vehicles should be in the total number of road transport vehicles included in the summary of all contracts subject to the given European Union directive. When procuring vehicles that are subject to the scope of the mentioned directive and trying to meet the minimum percentage shares of ecological vehicles in the total number of vehicles, it is important to comply with the conditions of the definition of an ecological vehicle according to this specific directive. By means of these legislative measures, there is an effort to increase the market share of ecological vehicles, possibly also vehicles for which the concept of heavy vehicles with zero emissions is used. The characteristics of vehicles that are considered ecological vehicles, or heavy vehicles with zero emissions, are shown in Table 2.

Table 2. Ecological vehicles and heavy vehicles with zero emissions

<table>
<tr><th colspan="2"></th><th>Category</th><th>until 31.12.2025</th><th>from 1.1.2026</th></tr>
<tr><td rowspan="4">ecological vehicle</td><td rowspan="3">ecological light commercial vehicle</td><td>M1</td><td rowspan="3">CO_2 g/km: max. 50
PM a NO_x from emission limits Euro 5 and Euro 6: 80%</td><td rowspan="3">CO_2 g/km: 0
PM a NO_x from emission limits Euro 5 a Euro 6: does not apply</td></tr>
<tr><td>M2</td></tr>
<tr><td>N1</td></tr>
<tr><td rowspan="3">ecological heavy commercial vehicle</td><td>M3</td><td colspan="2" rowspan="3">using alternative fuels:
electricity, hydrogen, biofuels (from biomass), synthetic and paraffinic fuels, natural gas (CNG and LNG), liquefied petroleum gas (LPG)</td></tr>
<tr><td>N2</td></tr>
<tr><td>N3</td></tr>
<tr><td colspan="2" rowspan="3">heavy commercial vehicle with zero emissions</td><td>M3</td><td colspan="2" rowspan="3">using alternative fuels and emits less than 1 g CO_2/kWh or emits less than 1 g CO_2/km</td></tr>
<tr><td>N2</td></tr>
<tr><td>N3</td></tr>
</table>

Processed based on [28]

Alternative fuels are fuels or energy sources that serve, at least in part, as a substitute for fossil petroleum sources in energy supplies for transportation and that have the potential to contribute to the elimination of carbon emissions and improve the environmental characteristics of the transportation sector. Vehicles of categories N2, N3, and M3 using alternative fuels can be considered an ecological vehicle. Vehicles of categories M1, M2 and N1 must meet the limit shown in table 2, otherwise the vehicle cannot be considered ecological.

When focusing on the category of M3 vehicles, it is possible to state with regard to the currently available vehicles on the market that buses using alternative fuels, electricity and compressed or liquefied natural gas, or liquefied petroleum gas, are used as ecological vehicles in bus transport.

2.3 Required shares of ecological vehicles

It is the duty of the member states of the European Union to ensure that the required minimum target values for the procurement of ecological vehicles are observed when procuring vehicles and services subject to the scope of EU Directive 2019/1161. These percentages are listed separately for each member state of the European Union and depending on the reference period. There are two reference periods, the first is the period from 2 August 2021 to 31 December 2025. The second reference period is the period from 1 January 2026 to 31 December 2030. In the event that new target values are not adopted for the period after 1. January 2030, the target values set for the second reference period will continue to apply in the following five-year periods.

The set minimum procurement target values for the share of light commercial vehicles are identical for the first and second reference periods. For trucks of categories N2 and N3 and buses of category M3, there are differences between the reference periods in the minimum required values for ecological vehicles. In the second reference period, a higher share of ecological buses is required compared to the first. In the case of buses, these percentage shares are much higher compared to trucks, in the second reference period the shares are in most cases over 50%. This creates a requirement that half, or even more, of the buses be so-called ecological and also in this way the quality of public passenger transport and the quality of the environment in cities increased. It is also important to note that half of the minimum target value of the share of ecological buses must be met through the procurement of zero-emission buses, as defined by the term "zero-emission heavy commercial vehicle".

The date of conclusion of the contract is decisive for the calculation of the minimum share for the reference period [30].

The required minimum shares of ecological vehicles in the Slovak Republic that are subject to the scope of EU Directive 2019/1161 are listed in Table 3.

Table 3. Minimum procurement target values for the share of ecological vehicles in Slovakia

	From August 2, 2021 to December 31, 2025	From January 1, 2026 to December 31, 2030
M1, M2, N1	22%	22%
N2 and N3	8%	9%
M3	34%	48%

Processed based on [30]

The minimum procurement target values for the share of ecological vehicles in the Slovak Republic specified in the Act on the Support of Ecological Road Transport Vehicles are completely identical to the values specified for the Slovak Republic in Directive 2019/1161, even if it would be possible to have higher percentage values in the Slovak legislation and require a higher share of ecological vehicles.

In some member states of the European Union, compared to Slovakia, the required procurement target values for the share of ecological vehicles are higher. In fig. 1, specific minimum required values for vehicle category M3 according to EU Directive 2019/1161 for each member state are given. The figure also shows data for the United Kingdom. It is clear from the data that higher percentages of ecological vehicles will be required especially in the countries of Western and Northern Europe, since in these countries there is already much more use of vehicles with an alternative type of drive or vehicles that meet the conditions of the definition of an ecological vehicle, since these countries they consider the topic of ecology and the environment to be very important. In the category of M3 vehicles, these shares are much higher, in the first reference period it is in most cases at the level of 41% to 45%, and in the second reference period it is a value from 59% higher, in most cases up to 65%. In this way, the operation of public bus transport, especially with ecological vehicles, will be ensured.

On the contrary, there are also states for which minimum target procurement values for the share of ecological vehicles are set to a certain extent. This mainly concerns the Baltic states, the V4 states and the states of the Balkans and South-Eastern Europe. According to the EU directive 2019/1161, the specified required values are only minimum, and each state can commit to higher values through its own legislation. The Slovak Republic is also among the states where the required target value for the procurement of ecological vehicles is lower compared to the states of Western and Northern Europe. As the UK was until recently a member state of the European Union, minimum procurement targets for the share of green vehicles were also set, the same as for most Western European countries.

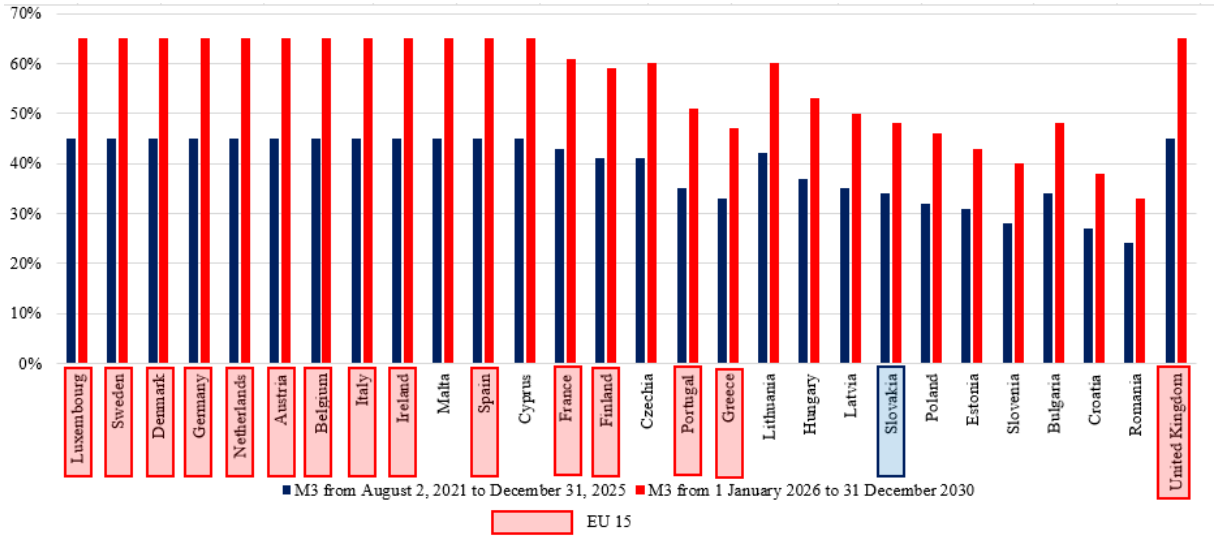

Fig. 1 Minimum procurement target values for the share of ecological vehicles in the EU member states in the M3 vehicle category [authors based on [28]]

The procedure for awarding a contract for services in the public interest in passenger transport in the Slovak Republic, in which the call for tender proposals was sent for publication by August 1, 2021, will be completed according to the regulations effective until August 1, 2021 [30]. This means that in such cases it is not necessary to comply with the required minimum shares of ecological vehicles within the framework of the fulfilment of contracts for services in the public interest.

2.4 Transposition of the EU Directive 2019/1161 on the support of ecological and energy-efficient road transport vehicles in EU countries

EU member states should bring into force the laws, other legal regulations and administrative measures necessary to comply with Directive 2019/1161 on the promotion of ecological and energy-efficient road transport vehicles in EU states by August 2, 2021 and inform the European Commission thereof without delay.

As of 25/03/2022, an analysis was carried out, the aim of which was to find out how the EU member states transposed EU Directive 2019/1161 on the promotion of ecological and energy-efficient road transport vehicles into their national legal systems. In order to find the measures taken by EU member states to transpose the directive into national law, an extended search using EUR-Lex was used [31].

According to published data as of 25/03/2022, EU Directive 2019/1161 with celex number of the legal act 32019L1161 was transposed into national law by 21 states: Denmark, Estonia, Finland, France, Greece, Netherlands, Croatia, Ireland, Latvia, Lithuania, Luxembourg, Malta, Germany, Poland, Portugal, Austria, Romania, Slovenia, Slovakia, Spain, and Italy [32].

On the contrary, some states have not yet fulfilled this obligation and have not transposed EU Directive 2019/1161 into national law. Specifically, it concerns 6 countries: Belgium, Bulgaria, Cyprus, Czech Republic, Hungary, and Sweden.

The Slovak Republic is among the states that have already transposed the directive into their national law through Act 214/2021 Coll. on the support of ecological road transport vehicles from May 4, 2021, which entered into force on August 2, 2021.

3 RESULTS

3.1 Registration of new buses

The target of the EU, but also of all states, should be to eliminate the negative impacts of human activities on the environment. One of these areas is road transport and the environment in cities and towns. In addition to the use of alternative propulsions in individual car transport, attention must also be paid to public passenger transport as a tool for improving the environment. One of the good solutions is to eliminate vehicles with a conventional type of propulsion in cities, make public passenger transport more attractive and use buses with an alternative type of propulsion. When examining the total share of buses with an alternative propulsion in individual European states for 2020, it can be seen that the highest share is in Sweden and the Netherlands (26.6% and 20.8%). The effort is to increase the total number of buses with an alternative type of propulsion, and this is also possible through legislative measures. An important factor is certainly the state's support for the purchase of these vehicles and their various benefits, but the standard of living and people's attitude towards the environment is also an important factor. Fig. 2 shows the share of buses with an alternative type of propulsion in Europe in 2020 [33]. Also, in this figure, the value of GDP per capita is recalculated for individual states. Knowing the shares of buses with alternative propulsion in European countries and the calculated GDP per inhabitant, the interrelationship between selected indicators was investigated through correlation analysis and correlation coefficient calculation:

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} = 0{,}3030 => \text{moderate degree of binding} \quad (1)$$

where:

r – correlation coefficient,

x_i – share of buses with alternative propulsion in individual European countries,

$\bar{x}$ – the average value of the share of buses with alternative propulsion in European countries,

y_i – GDP per inhabitant in individual European countries,

$\bar{y}$ – the average value of GDP per inhabitant in the European countries.

Based on the calculation of the correlation coefficient, it follows that there is a certain dependence between the share of buses with alternative propulsion and GDP, namely a moderate degree of connection. Therefore, it is possible to claim that, in addition to the level of development of the states, other factors influence the decision to procure an ecological bus, which can be, for example, the availability of gas stations, legislative restrictions, subsidies, discounts, benefits for ecological vehicles and, last but not least, the company's approach to the topic of environmental protection.

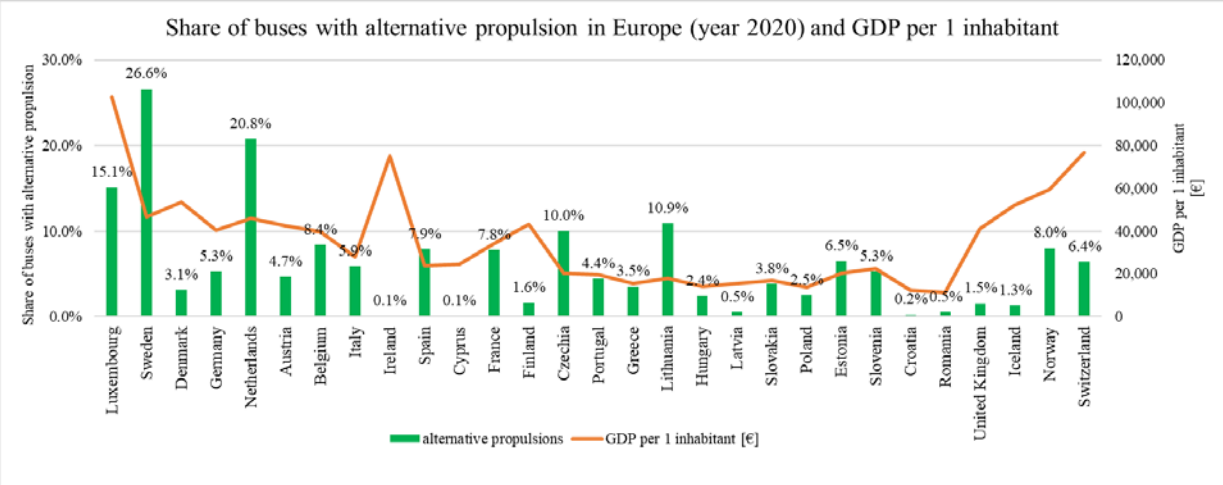

Fig. 2 Share of buses with alternative drive in Europe (year 2020) and GDP per 1 inhabitant [authors based on [33]]

In the paper, the authors mainly focus on M3 category buses. Category M3 vehicles are motor vehicles with more than eight seats in addition to the driver's seat, with a maximum mass exceeding 5 tonnes, regardless of whether these motor vehicles have an area for standing passengers [34, 35].

From the available data on registered vehicles as of April 12, 2022, it is possible to obtain information on M3 category buses, according to the year of registration. The data is divided according to the number of registered buses in a given year, of which the number of registrations of new buses and buses with an alternative type of propulsion, i.e. ecological vehicles using electricity, CNG or LNG as a source of propulsion, is also listed. It can be seen that dozens of ecological buses were registered in the Slovak Republic during the observed period, but it is not possible to claim that there is an increasing trend in the share of ecological buses from new registered buses. In some self-governing regions, such as Bratislava, Nitra, Banská Bystrica and Košice, public procurements for carriers providing services in the public interest were carried out in 2020 and 2021, and there were no requirements for the use of vehicles with an alternative type of propulsion in the technical and operational standards. In practice, these contracts are usually valid for 10 years.

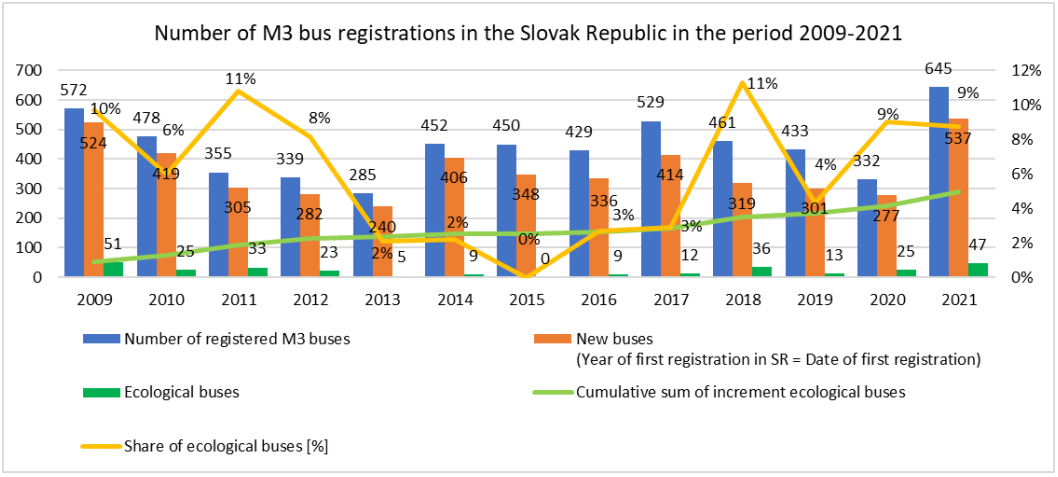

Fig. 3 Number of M3 bus registrations in the Slovak Republic in the period 2009-2021

Fig. 3 also shows the cumulative total of registrations of ecological buses in the period 2009-2021, on the basis of which it is also possible to calculate the average growth rate of this number of ecological buses through the following relationship:

$$\bar{k_t} = \sqrt[n-1]{\frac{y_n}{y_1}} = \sqrt[13-1]{\frac{288}{51}} = 1{,}1551 \Rightarrow 15{,}51\% \quad (2)$$

where:

$\bar{k_t}$ – average growth rate [-]

y_n – the last value of the cumulative sum of the registrations of ecological buses [-]

y_1 – the first value of the cumulative sum of the registrations of ecological buses [-]

n – the number of periods examined [-]

The calculation shows that the average growth rate of the number of ecological buses in the monitored period in the years 2009-2021 reaches a value of 1.1551. This means that, on average, the number of ecological buses increased by 15.51% in the given period.

In the Czech Republic, the situation in this area is slightly different, although from 2015 to 2021, the number of ecological buses increased by tens to hundreds every year. Compared to the Slovak Republic, there was also a higher share of ecological buses among the newly registered buses, but there is also no visible growing trend in the share of ecological buses. The average growth rate of the number of ecological buses was also calculated for the Czech Republic:

$$\bar{k_t} = \sqrt[n-1]{\frac{y_n}{y_1}} = \sqrt[13-1]{\frac{1907}{24}} = 1{,}4399 => 43{,}99\% \quad (3)$$

where:

$\bar{k_t}$ – average growth rate [-]

y_n – the last value of the cumulative sum of the registrations of ecological buses [-]

y_1 – the first value of the cumulative sum of the registrations of ecological buses [-]

n – the number of periods examined [-]

Due to the calculation and comparison of the average growth rate of the number of ecological buses, it can be seen that in the same period there is a higher growth rate in the Czech Republic, since on average the number of ecological buses increased by 43.99% year-on-year in the given period.

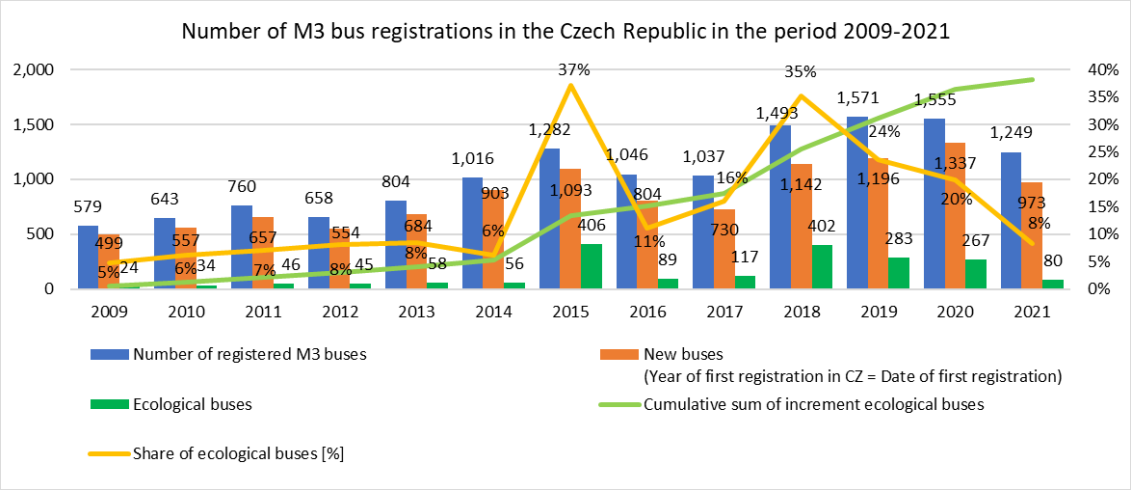

Fig. 4 Number of M3 bus registrations in the Czech Republic in the period 2009-2021

When examining in more detail the number of M3 category bus registrations in the Slovak Republic, broken down by region, it can be seen in Fig. 5 that over the past 4 years, ecological buses have been procured mainly in the Banská Bystrica region, the Žilina region and the Bratislava region. This is mainly due to the fact that in the city of Banská Bystrica, public transport operations are also provided by CNG-powered vehicles, and the Transport Company of the city of Žilina also procured a certain number of ecological buses, either with hybrid or electric drive, during the renewal of the vehicle fleet. In other regions, ecological buses were not registered or only a very small number. It is, therefore, possible to assume that thanks to the new law on the support of ecological vehicles, the number and total share of ecological buses in Slovakia will increase in the future.

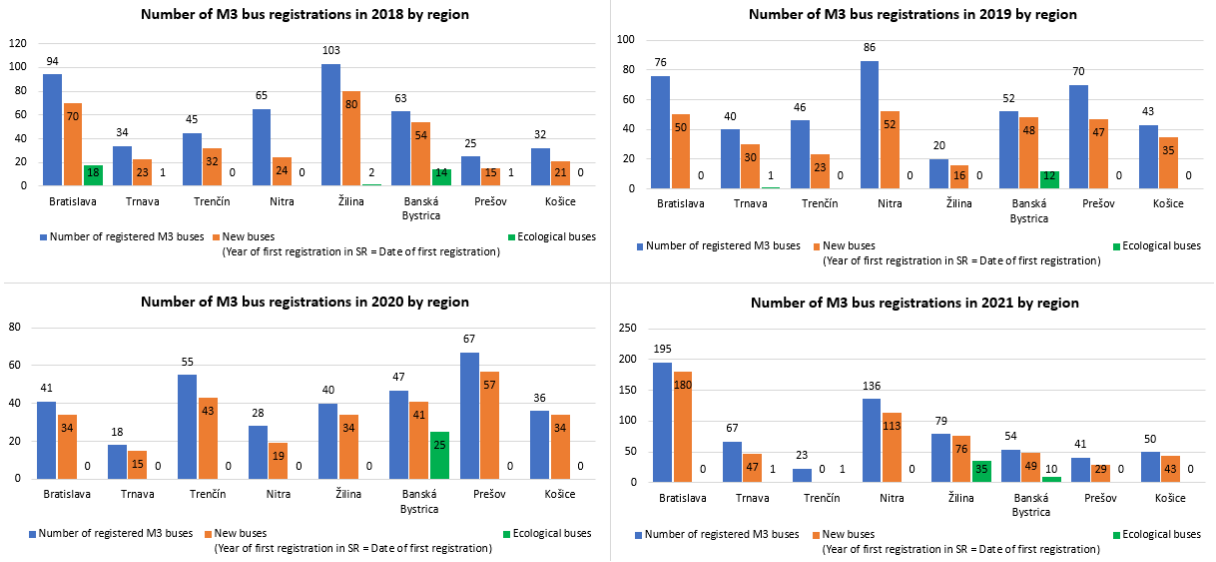

Fig. 5 Number of M3 bus registrations in the Slovak Republic in the period 2018-2021 by region

3.2 Technical and operational standards of buses

Achieving a higher number and share of ecological and low-emission buses within urban and suburban bus transport is also possible through the establishment of technical and operational standards. These standards are usually part of public procurement for carriers providing services in the public interest. In the technical and operational standards, it is possible to determine the required type of propulsion and the possible share of the use of vehicles with an alternative type of propulsion.

Until the entry into force of the EU Directive 2019/1161 on the promotion of ecological and energy-efficient road transport vehicles in the EU states and national regulations, public procurers and carriers were not forced to procure ecological vehicles with an alternative type of propulsion. As part of the technical and operational standards, there were, therefore, no conditions for the use of vehicles with alternative propulsion, such as in the Košice self-governing region, where public procurement required that the average age of vehicles not exceed 9 years, the age of no vehicle may exceed 14 years, at least 20% of vehicles may not exceed 5 years of age, and all vehicles must be equipped with a relief brake. The requirements for vehicle propulsion and use of alternative fuels have not been determined [36].

Similarly, in the case of public procurement for the provision of transport services in the public interest in the territory of the Banská Bystrica region, a condition was established that the maximum age of vehicles should not exceed 10 years, and vehicles must also meet the requirements of the Euro VI emission standard and above. The requirements for vehicle propulsion and use of alternative fuels have not been determined [37].

However, there are also examples when even before the directive and the law on the support of ecological vehicles came into effect, the public procurement authority decided to require the carrier to use ecological vehicles. It goes, for example, o the city of Banská Bystrica, where the public contracting authority, when announcing a public tender for a trolleybus and bus operator, established within the quality criteria that the share of ecological buses within public transport must be at least 40% [38]. Also similarly, e.g. the Transport Company of the city of Žilina also renewed its vehicle fleet using ecological vehicles, as new trolleybuses, buses using hybrid propulsion and electric propulsion became part of it. This fact was analyzed by the authors [8], where they confirmed that the renewal of the vehicle fleet of urban public transport brings positive effects on air quality in cities.

Although there is a higher number and share of ecological vehicles in bus transport in the Czech Republic compared to the Slovak Republic, public procurement authorities did not require buses with alternative propulsion. For example, in the Vysočina region, where bids were submitted until 16 July 2021, the annexe to the technical and operational standards stated the condition that the carrier may use vehicles with a conventional or alternative propulsion engine and must meet the emission limits of the Euro VI standard, or stricter if they are in the course of performance of the contract established. The requirements for vehicle propulsion and use of alternative fuels have not been determined [39].

In the region Stredočeský, tenders should be issued in the course of 2022, and the validity of the contracts will be 10 years in the case of carriers using diesel-propulsion buses and 15 years for zero-emission, i.e. electric or hydrogen-propulsion buses. In the future, the share of emission-free vehicles should increase in the region. Currently, there are approximately 1,260 public transport buses in operation in the region, and from 2025, 50% to 60% of them should be emission-free [40].

In some public procurements, even in the Czech Republic, there are requirements for the use of ecological buses, such as in the city of Prostějov. Until July 8, 2022, carriers can submit offers to ensure the transport service of the city of Prostějov by city bus transport in the years 2024 - 2033. The carrier implements urban transport in accordance with the valid technical and operational standards of the Integrated Transport System of the Olomouc Region, namely "standard C" and it must transport of public transport buses, which ensure the transport part of the entire transport performance in the zone with public transport operations (lines 1, 11, 41, 51, 61). All vehicles according to this standard must be low-floor and must be alternative CNG propulsion [41].

The most frequently requested technical and operational standards, which were found in the analyzed public procurements for operators of suburban or urban bus transport in the Slovak Republic or the Czech Republic, are listed in Table 4.

Table 4. Selected required technical and operational standards of buses

Average age of vehicles, e.g. 9 years	The highest age of vehicles, e.g. 14 years
Brake system - relief brake	Emission standard - Euro VI
Propulsion – conventional or alternative propulsion	A certain share of ecological vehicles
Low-floor buses	

In contrast to the presented cases, the authors present different cases from France, as the best- or worst-case examples for the considered region to learn from.

The city of Paris, for example, decided that by 2025, only buses without a diesel engine using diesel as a source of propulsion should provide bus transport in the city. The transport company of the city of Paris signed framework contracts with a total of five electric bus manufacturers for the supply of new vehicles worth 825 million €. The aim of

this step is to achieve emission-free bus transport in the city. Contracts with bus manufacturers Bluebus/Bolloré, Irizar, Iveco, MAN and Solaris were concluded for the delivery of almost 450 new vehicles in 2022 and 2023 [42].

The French city of Montpellier also decided to renew its fleet in a similar way, but cancelled the order for 51 hydrogen-powered buses. According to the city's calculations, the operating costs of hydrogen-powered buses would be six times higher than operating electric buses, since operating hydrogen-powered buses would cost 3 million € per year compared to 500,000 € for electric buses - or in unit terms, the operating costs of a hydrogen-powered bus are 0.95€/km and the operating costs of an electric-powered bus are 0.15€/km. The city administration states that hydrogen-powered buses are 150,000 € to 200,000 € more expensive than electric-powered buses. For this reason, the city of Montpellier is currently withdrawing from the purchase of hydrogen-powered buses and will reassess its position in the future, depending on hydrogen prices and bus operating costs. It is also important to note that China is currently the world leader in electric buses. There are already more than 500,000 electric buses in this country [43].

4 DISCUSSION AND CONCLUSION

The importance of renewing the vehicle fleets of urban or suburban bus transport operators is indisputable from an ecological point of view. Vehicles with an alternative type of propulsion should reduce the negative effects of road traffic on the environment. The paper analyzed the share of ecological buses in European countries and, in more detail, the number of registrations of buses and ecological buses in Slovakia and the Czech Republic. Currently, the share of new registrations of ecological buses in Slovakia is low, and the same was the case during the period under review. In the Czech Republic, this situation is slightly better, also based on the higher growth rate of the number of ecological buses. Since there can be various obstacles for carriers that discourage the purchase of ecological buses, there are initiatives and instruments through which states, or the European Union, stimulate the purchase of ecological vehicles and in this way contribute to the protection of the environment. The paper focused on the EU directive 2019/1161, the aim of which is to increase the share of ecological buses through the specified percentages of ecological buses procured under the contracts to which it applies. Therefore, even in contracts for public services, or already in public procurement, there are conditions in the technical and operational standards, thanks to which it is possible to require the use of ecological vehicles and also to increase the quality of services provided in bus transport with other requirements.

The paper also examines the interdependence between the share of ecological buses and the recalculated GDP per inhabitant in individual European countries. According to the correlation coefficient, it follows that there is a moderate degree of connection between the indicated indicators. However, other factors can influence the increase in the share of ecological buses, not only the economic development of the state, therefore another subject of research, e.g. through correlation and regression analysis, the impact of other factors and indicators on the share of ecological buses can be expressed. The cost-effectiveness of buses with conventional propulsion and alternative propulsion in connection with the increase in the price of diesel, electricity, operating costs and the comparison of the cost of a bus using diesel and an alternative source of propulsion may be the subject of further investigation.

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6 REFERENCES

[1] Chang, Ch., Liao, Y., Chang, Y. (2019). Life cycle assessment of alternative energy types e including hydrogen e for public city buses in Taiwan. International Journal of Hydrogen Energy, vol. 44, 18472-18482, DOI: 10.1016/j.ijhydene.2019.05.073

[2] Correa, G., Munoz, P.M., Rodriguez, C.R. (2019). A comparative energy and environmental analysis of a diesel, hybrid, hydrogen and electric urban bus. Energy, vol. 187, 115906, DOI: 10.1016/j.energy.2019.115906

[3] Todoruț, A., Cordoș, N., Iclodean, C. (2020). Replacing Diesel Buses with Electric Buses for Sustainable Public Transportation and Reduction of CO2 Emissions. Polish Journal of Environmental Studies, vol. 29, no. 5, DOI: 10.15244/pjoes/112899

[4] Pelletier, S., Jabali, O., Mendoza, J. E., Laporte, G. (2019). The electric bus fleet transition problem. Transportation Research Part C: Emerging Technologies, vol. 109, 174-193, DOI: 10.1016/j.trc.2019.10.012

[5] Fabianova, J., Janekova, J. (2021). Assessment of investment in electric buses: A case study of a public transport company. Open Engineering, vol. 11, no. 1, 907-914, DOI: 10.1515/eng-2021-0089

[6] Borghetti, F., Longo, M., Mazzoncini, R., Panarese, A., Somaschini, C. (2022). Transformation of an existing urban bus line: Milan Full Electric project. Transportation Research Procedia, vol. 60, 84-91, DOI: https://doi.org/10.1016/j.trpro.2021.12.012

[7] Jakub, S., Adrian, L., Mieczysław, B., Ewelina, B., Katarzyna, Z. (2022). Life cycle assessment study on the public transport bus fleet electrification in the context of sustainable urban development strategy. Science of The Total Environment, vol. 824, 153872, DOI: 10.1016/j.scitotenv.2022.153872.

[8] Konečný, V., Gnap, J., Settey, T., Petro, F., Skrúcaný, T., Figlus T. (2020). Environmental Sustainability of the Vehicle Fleet Change in Public City Transport of Selected City in Central Europe. Energies, vol. 13, no. 15, 3869, DOI: 10:3390/en/13153869

[9] Bermond, V., Caliman, R. R., Rosa, R. D. A., Pereira, E. P., Carvalhaes, B. B. (2019). A method to assess the eco-efficiency of a public bus transportation service. International Journal of Sustainable Transportation, vol. 13, no. 8, 567-581, DOI: 10.1080/15568318.2018.1490467

[10] Esmael, F. A., Falah, Z. A., Mahmoudi, J. (2021). Modelling and analysis of an urban road traffic noise pollution: Case study of an interrupted flow traffic noise at a signalized intersection. Journal of Applied Engineering Science, vol. 19, no. 4, 1150-1162, DOI: 10.5937/jaes0-29921

[11] Perumal, S. S., Lusby, R. M., Larsen, J. (2021). Electric bus planning & scheduling: A review of related problems and methodologies. European Journal of Operational Research, DOI: 10.1016/j.ejor.2021.10.058

[12] Poliak, M., Beňuš, J., Nica, E. (2021). Analysis and research plan of commercial truck drivers' potentially dangerous driving behaviors caused by the changes of Regulation (EC) No. 561/2006. Transportation Research Procedia, vol. 55, 79-86, DOI: 10.1016/j.trpro.2021.07.172

[13] Csiszár, C., Csonka, B., Földes, D., Wirth, E., Lovas, T. (2019). Urban public charging station locating method for electric vehicles based on land use approach. J. Transp. Geogr. 2019, vol. 74, 173–180, DOI: 10.1016/j.jtrangeo.2018.11.016

[14] Ivkovic, I., Kaplanovic, S., Sekulic, D. (2019). Analysis of External Costs of CO2 Emissions For CNG Buses i n Intercity Bus Service. TRANSPORT, vol. 34, no. 5, 529-538, DOI: 10.3846/transport.2019.11473

[15] Rajaeifar, M.A., Tabatabaei, M., Aghbashlo, M., Nizami, A., Heidrich, O. (2019). Emissions from urban bus fleets running on biodiesel blends under realworld operating conditions: Implications for designing future case studies. Renewable and Sustainable Energy Reviews, vol. 111, 276-292, DOI: 10.1016/j.rser.2019.05.004

[16] Šarkan, B., Loman, M., Synák, F., Richtář, M., Gidlewski, M. (2022). Influence of Engine Electronic Management Fault Simulation on Vehicle Operation. Sensors, vol. 22, no. 5, 2054, DOI: 10.3390/s22052054

[17] Hensher, D. A. (2021). The case for negotiated contracts under the transition to a green bus fleet. Transportation Research Part A: Policy and Practice, vol. 154, 255-269, DOI: 10.1016/j.tra.2021.10.006

[18] Saz-Salazar, S., Feo-Valero, M., Vazquez-Paja, B. (2020). Valuing public acceptance of alternative-fuel buses using a Latent Class Tobit model: A case study in Valencia. Journal of Cleaner Production, vol. 261, 121199, DOI: 10.1016/j.jclepro.2020.121199

[19] Poliak, M., Poliaková, A., Mrníková, M., Šimurková, P., Jaskiewicz, M., Rafał, J. (2017). The Competitiveness of Public Transport. J. Compet, vol. 9, 81, DOI: 10.744/joc.2017.03.06.

[20] Kalašová, A., Hájnik, A., Kubaľák, S., Beňuš, J., Harantová, V. (2022). The impact of actuated control on the environment and the traffic flow. Journal of Applied Engineering Science, vol. 20, no. 2, 305-314, DOI: 10.5937/jaes0-33043

[21] Alomari, A., Al-Omari, A., Aljizawi, W. (2022). Evaluation of travel time reliability in urban areas using mobile navigation applications in Jordan. Journal of Applied Engineering Science, vol. 20, no. 3, 644-656, DOI: 10.5937/jaes0-35118

[22] Kushchenko, L. (2022). The analyzing of personal and public transport traffic flows on Belgorod agglomeration. Journal of Applied Engineering Science, vol. 20, no. 3, 700-706, DOI: 10.5937/jaes0-35593

[23] Marra, A. D., Sun, L., Corman, F. (2022). The impact of COVID-19 pandemic on public transport usage and route choice: Evidences from a long-term tracking study in urban area. Transport Policy, vol. 116, 258-268, DOI: 10.1016/j.tranpol.2021.12.009

[24] Rothengatter, W., Zhang, J., Hayashi, Y., Nosach, A., Wang, K., Oum, T. H. (2021). Pandemic waves and the time after Covid-19–Consequences for the transport sector. Transport Policy, vol. 110, 225-237, DOI: 10.1016/j.tranpol.2021.06.003

[25] Zhou, H., Wang, Y., Huscroft, J. R., Bai, K. (2021). Impacts of COVID-19 and anti-pandemic policies on urban transport—an empirical study in China. Transport policy, vol. 110, 135-149, DOI: 10.1016/j.tranpol.2021.05.030

[26] Harantová, V., Hájnik, A., Kalašová, A., Figlus, T. (2022). The Effect of the COVID-19 Pandemic on Traffic Flow Characteristics, Emissions Production and Fuel Consumption at a Selected Intersection in Slovakia. Energies, vol. 15, no. 6, 2020, DOI: 10.3390/en15062020

[27] Querol, X., Alastuey, A., Moreno, N., Minguillón, M. C., Moreno, T., Karanasiou, A., Felisi, J. M. (2022). How can ventilation be improved on public transportation buses? Insights from CO2 measurements. Environmental research, vol. 205, 112451, DOI: 10.1016/j.envres.2021.112451

[28] EU Directive 2019/1161 on the promotion of ecological and energy-efficient road transport vehicles.

[29] Regulation of the European Parliament and the Council (EC) no. 1370/2007 on services in the public interest in rail and road passenger transport.

[30] Act 214/2021 Coll. on the support of ecological road transport vehicles and on the amendment of some laws.

[31] EUR-Lex. from https://eur-lex.europa.eu/advanced-search-form.html?action=update&qid=1634651486378, accessed on 2022-06-07.

[32] EUR-Lex. from: https://eur-lex.europa.eu/search.html?SUBDOM_INIT=MNE&DTS_SUBDOM=MNE&DB_CELEX_OTHER=32019L1161*&DTS_DOM=NATIONAL_LAW&lang=sk&type=advanced&qid=1634646517813&page=1, accessed on 2022-06-03.

[33] ACEA. Vehicles in use Europe 2022, from https://www.acea.auto/files/ACEA-report-vehicles-in-use-europe-2022.pdf, accessed on 2022-06-09.

[34] Regulation (EU) 2018/858 of the European Parliament and of the Council on the approval and market surveillance of motor vehicles and their trailers, as well as systems, components and separate technical units intended for such vehicles.

[35] Act no. 106/2018 Coll. on the operation of vehicles in road traffic and on the amendment of some laws.

[36] Košice self-governing region. Quality standards IDS East, from https://www.uvo.gov.sk/vyhladavanie-zakaziek/detail/dokumenty/435404, accessed on 2022-06-15.

[37] Banská Bystrica self-governing region, Technical and operational standards, from https://josephine.proebiz.com/sk/tender/13457/summary, accessed on 2022-06-16.

[38] Banská Bystrica, from https://imhd.sk/bb/doc/sk/19753/Mesto-Bansk%C3%A1-Bystrica-vyhl%C3%A1silo-verejn%C3%BA-s%C3%BA%C5%A5a%C5%BE-na-trolejbusov%C3%A9ho-a-autobusov%C3%A9ho-dopravcu, accessed on 2022-06-16.

[39] Region Vysočina, Technical and operational standards, from https://ezak.kr-vysocina.cz/contract_display_8893.html, accessed on 2022-06-17.

[40] Region Středočeský, from https://www.dnoviny.cz/verejna-doprava/stredocesky-kraj-pripravuje-tendry-na-dopravu-za-desitky-miliard-korun, accessed on 2022-06-17.

[41] Prostějov, Technical and operational standards IDSOK, from https://tenderarena.cz/dodavatel/seznam-profilu-zadavatelu/detail/Z0004148/zakazka/520789, accessed on 2022-06-18.

[42] Zdopravy. from https://zdopravy.cz/obri-zakazka-na-elektrobusy-pariz-objednala-u-peti-vyrobcu-autobusy-za-825-milionu-eur-2-91655/, accessed on 2022-06-20.

[43] Rechargenews. from https://www.rechargenews.com/energy-transition/french-city-drops-order-for-51-hydrogen-buses-after-realising-electric-ones-six-times-cheaper-to-run/2-1-1143717, accessed on 2022-06-22.

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