

## Innovations in the field of urban transport on the example of electric bus programmes in France and the Netherlands

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■ **Abstract.** The purpose of the study was to find out the economic and environmental feasibility of implementing electric bus programmes in France and the Netherlands considering their impact on municipal budgets, environmental indicators, and social development. The analysis of financial indicators, the cost structure of total cost of ownership, and socio-environmental effects found that the payback period for investments averaged 8-10 years in France and 6-8 years in the Netherlands due to different levels of regulatory requirements and the development of charging infrastructure. The cost structure showed that the share of purchases of electric buses was 45% versus 30% for diesel buses, while energy and maintenance costs were lower (35% vs. 55%, respectively). In France, energy costs for electric buses were 0.18-0.22 EUR/km versus 0.35-0.40 EUR/km for diesel buses, and maintenance costs were 0.12-0.15 EUR/km versus 0.18-0.22 EUR/km; in the Netherlands, the difference was smaller, but remained in favour of electric buses. The environmental impact was determined by reducing carbon dioxide emissions by 900-1,100 tonnes per year per 100 buses in France and 800-1,000 tonnes in the Netherlands. Social results included an 8-12% increase in passenger traffic in French agglomerations and 6-10% in Dutch medium and small cities, the creation of 5-7 thousand jobs in France and 3-5 thousand in the Netherlands, and the development of innovative sectors – battery technologies in France and digital services in the Netherlands. It has been proven that a centralised financing model in France provides stability, while a decentralised concession system in the Netherlands promotes faster adaptation and competition between carriers. The practical significance of the study was to determine the conditions of economic feasibility and socio-environmental benefits of electric bus programmes, the results of which can be used by authorities, municipalities, and transport operators to improve sustainable transport strategies and investment planning

■ **Keywords:** municipal budgets; total cost of ownership; energy; maintenance; depreciation; payback period; regulatory requirements

### ■ Introduction

The need to study the electrification of urban transport has emerged as a result of a combination of environmental, economic, and social challenges, including high levels of greenhouse gas and toxic compound emissions from diesel buses, rising fossil fuel costs, limited municipal budgets, and the need to meet climate commitments under the European Union and the Paris Agreement. The challenge lies in finding balanced solutions that combine reducing environmental impact with the economic sustainability of transport systems, ensuring the effective use of

investments, developing innovative sectors and creating additional social benefits for urban communities.

A literature review has shown that there is a strong empirical base on urban transport electrification and related policies in Europe. As part of the comparison of innovative energy technologies in road transport, J. Kraciuk *et al.* (2022) examined the dynamics of electric mobility adoption in the European Union countries and the impact of regulatory incentives on market performance. It was found that the increased use of support tools accelerated

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the diffusion of electric vehicle (EV) in public fleets and reduced the energy intensity of transportation in the medium term. European review by R. Ruggieri *et al.* (2021) focused on integrating electric mobility into the smart city paradigm, with an emphasis on infrastructure and digital services. The researchers showed that the complexity of urban solutions (charging infrastructure, tariff models, mobility data) correlated with higher acceptance rates for users and an increase in the share of public transport trips. N. Pohuda *et al.* (2024) conducted a comprehensive analysis of the functioning of the passenger transportation market across airlines, road transport, and railways, providing methodological approaches aimed at improving market efficiency and sustainability.

In comparative study on Mediterranean public transport systems, S.M. Miraftebzadeh *et al.* (2024) analysed the sustainability of electrification, considering the energy profile of the region and Urban operating conditions. It was shown that with predictable electricity tariffs and optimised charging schedules, there was a noticeable reduction in CO<sub>2</sub> emissions and stabilisation of operating costs. F. Pollák *et al.* (2021) considered interregional cooperation as a factor in accelerating electric mobility in the “catching-up” regions of Europe. The results showed that policy synchronisation and access to EU structural funds increased the effectiveness of pilot electric bus programmes and strengthened the institutional capacity of local authorities.

Focusing on the institutional dimension, a report by the European Commission’s Joint Research Centre, M. Stepniak *et al.* (2022), summarised the landscape of research and innovation (R&I) in public transport. It was found that the presence of common taxonomies and data standards made it easier to compare the results of electric bus tests and accelerated the scaling of technical solutions. In the study of local innovations in the field of sustainable mobility, S. Minami (2021) analysed municipal governance practices and policy tools. It was confirmed that the ability of local governments to innovate and coordinate stakeholders was associated with a higher rate of adoption of electric mobility and better operational results.

M. Połom (2021) provided a critical overview of the development of electric urban transport in Poland, taking into consideration historical institutional conditions. The study found that the heterogeneity of implementation was explained by differences in access to funding, local capacity, and consistency of national and urban strategies. H. Kryshal *et al.* (2024) analysed the ecological and innovative transformation of the urban infrastructure of Ukraine in the context of post-war reconstruction. The results showed that the environmental benefits of electrification were combined with economic effects in the context of institutional coordination, the availability of grant tools and the development of local competencies. K. Vakulenko *et al.* (2024) examined the inclusiveness of passenger services and the environmental impact in Ukrainian cities. It was found that the introduction of electric rolling stock was accompanied by an increase in the availability of transportation for certain groups of users and a reduction in local air pollution.

T. Borysova *et al.* (2021) focused on the priorities of marketing, competitiveness, and innovative development of transport operators in the context of a sustainable city. The study showed that the focus on service quality and partnerships with manufacturers contributed to faster commercialisation of electric bus solutions and formed sustainable demand models. The conference article by G.P. Kostenko *et al.* (2023) evaluated the potential of vehicle-to-grid (V2G) for the sustainability of the energy system in Ukraine. The results showed that two-way transport-network interaction provided additional system benefits, subject to appropriate tariff policies, technical standards, and battery system protection. Taken together, the sources analysed provided a consistent picture of the results regarding the environmental and economic consequences of electrification, the institutional conditions for scaling, and the technological prerequisites for integrating electric buses into urban networks. However, the need for standardised operational performance metrics, cross-country panel estimates of Total Cost of Ownership (TCO) based on real municipal budgets, causal and long-term estimates of social effects with confounder control, and a comparative analysis of the impact of concession and public-private mechanisms on the financial stability of urban carriers remained open; these aspects were key gaps for further targeted research.

The purpose of the study was to find out the economic and environmental feasibility of urban transport electrification considering their impact on municipal budgets, environmental indicators, and social development. To achieve this goal, the following tasks were set: to trace the evolution of state and municipal policies of urban transport electrification in France and the Netherlands; to conduct a comparative analysis of the total cost of ownership (TCO) and the economic efficiency of implementing electric bus programmes; to assess the environmental and social results of implementing electric buses in the context of sustainable urban development.

## ■ Materials and Methods

The study was analytical and comparative in nature and was conducted in 2024, based on retrospective data from 2009, when the first regulations of the European Union in the field of clean transport development were adopted. This approach helped to trace the evolution of state and municipal strategies in long-term dynamics and to identify key stages in the development of programmes. France and the Netherlands were chosen as the subjects of analysis because of their representativeness in the European transport space and the difference in electrification models: in France, the emphasis was on centralised state regulation and large-scale investment, while in the Netherlands – on decentralised governance mechanisms and partnerships with the private sector. This combination allowed comparing two different approaches and evaluating their effectiveness within the framework of common decarbonisation goals.

To achieve this goal, the method of comparative analysis was applied, which was used to investigate differences in financial and organisational models for implementing electric bus programmes. The source of this method was the regulations of the European Union, in particular, Directive 2009/33/EC of the European Parliament and of the Council (2009), Directive 2014/94/EU of the European Parliament and of the Council (2014) and the European Commission (2019). The new EU rules on zero-emission buses (European Commission, 2023), which defined the conditions for switching to zero-emission vehicles, were considered separately.

In part of the French national legislation, Law of France No. 2015-992 (2015), Law of France No. 2019-1428 (2019) and the electric vehicles quota system in corporate fleets (French Republic, 2024) were analysed. Of particular importance were the provisions (Law of France No. 2021-1104, 2021) and the requirement to equip buildings with charging stations (French Republic, 2025) that established the institutional basis for the development of electric mobility. For the Netherlands, the study was based on the Ministry of Infrastructure and Water Management (2016), a regional policy for implementing zero-emission zones (Dutch Municipalities Association, n.d) and the draft law on the implementation of Renewable Energy Directive III (RED III) (Government of the Netherlands, n.d). A comparative analysis of these documents revealed the strengths and weaknesses of the centralised French model and the decentralised Dutch approach.

The content analysis method was used to systematise texts of official documents, municipal reports, and programme materials. In France, the key source was the programme (Île-de-France Mobilités, 2025), which defined mechanisms for financing and coordinating transport policy in the capital region. Reports from municipal associations (Dutch Municipalities Association, n.d) documenting the implementation of zero-emission zones were particularly important for the Netherlands. The content analysis identified strategic guidelines, determined regulatory requirements for the purchase and operation of electric buses, and systematised state and local incentive tools for transport operators.

The economic analysis method was used to estimate the total cost of ownership of TCO of electric buses and diesel buses. As part of this method, procurement, energy, maintenance, and depreciation costs were compared. The source basis was data (International Energy Agency, 2025), which contained indicators of the cost of energy carriers and the dynamics of energy markets. Additionally, the study used materials from the European Environment

Agency (EEA), in particular (European Environment Agency, 2025a) and (European Environment Agency, 2025b), which allowed comprehensively assessing the environmental consequences of transport operation. The financial component of the analysis was provided by reports (European Investment Bank, 2025a) and (European Investment Bank, 2025b), which reflected lending and subsidy instruments in the field of sustainable transport. This method determined the long-term economic efficiency of electric buses and the level of financial burden on municipal budgets.

The interpretation of the results was based on a combination of quantitative and qualitative approaches. The quantitative indicators obtained based on data from the International Energy Agency (2025) and the European Environment Agency (2025a; 2025b) were compared with qualitative factors reflected in the legislative acts and municipal programmes of France and the Netherlands. This generalisation of different types of sources ensured the complexity of the analysis without excessive duplication of data and helped to form a holistic assessment of the economic, environmental and social effectiveness of electric bus programmes. The combination of normative, financial and statistical materials improved the validity of the results and provided a multidimensional assessment of the impact on transport systems.

## ■ Results and Discussion

### Evolution of urban transport electrification policies in France and the Netherlands

Regulatory support for transport electrification processes in the European Union countries is a key factor for creating stable conditions for the development of the electric bus market. European documents set out a single regulatory framework within which national governments specify requirements and develop their own mechanisms for their implementation. In France and the Netherlands, these acts reflect the strategic goals of decarbonisation and simultaneously form the financial and institutional prerequisites for the practical implementation of innovative solutions in urban transport. The established system of regulatory guidelines helped to compare the approaches of the two countries and assess the level of integration of their policies into European climate priorities. A summary of the documents adopted at the EU, France and the Netherlands showed their importance in forming the framework conditions for the transition to zero-emission transport. Table 1 shows the key legislative acts and defines their content, which directly affected the pace of implementation of electric bus programmes in these countries.

**Table 1.** Current regulatory documents of the EU, France, and the Netherlands in the field of transport electrification

Level	Year of adoption	Name of the document / act	Main provisions relevant to transport electrification
EU	2009	Directive 2009/33/EC “On the Promotion of Clean and Energy-Efficient Road Transport Vehicles”	Sets requirements for the consideration of environmental criteria in public procurement of buses and heavy transport.
	2014	Directive 2014/94/EU “On the Deployment of Alternative Fuels Infrastructure”	Defines the framework requirements for the development of the infrastructure of charging stations for electric vehicles.

Table 1. Continued

Level	Year of adoption	Name of the document / act	Main provisions relevant to transport electrification
EU	2019	European Green Deal	Establishes the EU's long-term strategy to achieve climate neutrality by 2050, including the transport sector.
	2023	New EU rules on zero-emission buses	Provide for a mandatory transition to zero-emission city buses from 2035.
France	2015	Loi relative à la transition énergétique pour la croissance verte	Defines national guidelines for reducing the use of fossil fuels, encourages the renewal of fleets through subsidies and tax incentives.
	2019	Loi d'orientation des mobilités (LOM)	Introduces requirements for the development of charging infrastructure, in particular for buildings with more than 20 parking spaces; the regulations have been applied since 2025.
	2019	Quotas for electric vehicles' share in corporate fleets	Companies with more than 100 vehicles are required to provide an EV share of at least 20% from 2025 and gradually increase to 70% in 2030.
	2021	Loi Climat et Résilience	Specifies measures to decarbonise transport, obliges municipalities to consider electric buses in purchases and expand zones à faibles émissions.
	2025	Obligation to equip non-resident buildings with charging stations	Obliges owners of buildings with more than 20 parking spaces to install at least one charging point and equip 5% of EV seats.
Netherlands	2016	Voluntary Agreement on Zero Emission Bus Transport	Assumes that all new buses from 2025 should be zero-emission, and the entire public transport fleet should be electric by 2030.
	2025	Introduction of zero-emission zones in cities	As of 2025, 15 cities have implemented zero-emission zones, and another 14 municipalities are planning until 2030.
	2024	Draft law on the implementation of RED III	Provides for the integration of updated requirements for the use of renewable energy in the transport sector; published in June 2025.

**Note:** EV – electric vehicle; RED III – Renewable Energy Directive III; zones à faibles émissions – low-emission zones introduced in French cities

**Source:** developed by the author based on data from the Directive 2009/33/EC of the European Parliament and of the Council (2009), Directive 2014/94/EU of the European Parliament and of the Council (2014), Law of France No. 2015-992 (2015), Ministry of Infrastructure and Water Management (2016), Law of France No. 2019-1428 (2019), European Commission (2019; 2023), Law of France No. 2021-1104 (2021), French Republic (2024; 2025), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

The analysis of Table 1 showed that EU policy forms the framework conditions within which France and the Netherlands implement their own transport electrification programmes. France focused on the legislative consolidation of long-term benchmarks and the introduction of mandatory quotas, which ensured stability in planning municipal purchases. The Netherlands, in turn, has adopted a more flexible model based on voluntary agreements with transport operators and the phased introduction of zero-emission zones. The European level of policy determined the final goals, while the national level set the pace and mechanisms for their implementation. A comparison of approaches showed that France focused on centralised regulation, while the Netherlands focused on partnership between the state and business, which

together increased the effectiveness of integrating the European framework into practice.

The implementation of public transport electrification programmes in the two countries had excellent organisational and financial priorities, which were reflected in the scale of investment, private sector participation, incentive system, and transition time horizons. To ensure a reasonable comparison of policies, these parameters were summarised, because they determine the effectiveness of the introduction of electric buses in urban transport systems. To this end, Table 2 presents a systematisation of the key characteristics of the national approaches of France and the Netherlands, which helped to identify the specifics of each model and their impact on the rate of transition to zero-emission transport.

**Table 2.** Comparison of the main parameters of implementation of electric bus programmes in France and the Netherlands

Country	Scope of investment	Share of private sector	Main incentives (subsidies / benefits / funding)	Transition time horizons
France	Île-de-France Mobilités programme: approximately EUR 5.7 billion for fleet renewal and infrastructure	Limited, mainly due to tenders for the operation of routes	Subsidies for the purchase of electric buses, tax incentives, government grants for infrastructure	Partial transition of the fleet in 2025-2029, with gradual coverage of large agglomerations

Table 2. Continued

Country	Scope of investment	Share of private sector	Main incentives (subsidies / benefits / funding)	Transition time horizons
Netherlands	Investment in charging infrastructure; USD 57 million for commercial charging stations	High, due to concession agreements with transport companies WW	SEBA scheme (subsidies up to USD 5,000 for zero-emission transport), financing of charging infrastructure	From 2025, all new buses are emission-free; by 2030, the fleet will be fully electrified

**Note:** SEBA – subsidy scheme for zero emission commercial vehicles; zero-emission – zero emission transport; Île-de-France Mobilités – regional agency that coordinates transport policy in the French capital region

**Source:** developed by the author based on data from the Ministry of Infrastructure and Water Management (2016), Île-de-France Mobilités (2025), International Energy Agency (2025), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

An analysis of Table 2 showed that France focused on centralised public investment, while the Netherlands relied heavily on private carriers under the concession model. The French incentives were aimed at supporting municipalities and implementing large-scale regional programmes, which allowed for a systematic upgrade of the bus fleet and infrastructure. In the Netherlands, financial support was mainly provided to businesses and the development of charging infrastructure, which stimulated the active involvement of the private sector. Time differences were also established: France envisioned a gradual transition over several years, while the Netherlands fixed more stringent and clearly defined implementation deadlines. As a result, the French model was centralised and gradual, while the Dutch model was characterised by decentralisation and a focus on partnership between the state and business.

Results of the study by M. Aldenius *et al.* (2022) confirmed that in the UK and Sweden, the main barriers to the development of electric bus transport remained high capital intensity of infrastructure and weak coordination between central and local authorities. The researchers showed that the effectiveness of programmes depended on the consistency of management decisions at different levels of government. These findings correlate with the results obtained: in France, centralised financing and state control provided stability, while in the Netherlands, the emphasis was placed on integrating municipalities and private operators into the implementation of transport policies. D.A. Hensher (2021) emphasised that the transition to green bus fleet required the application of negotiated contracts between authorities and transport companies. It was proved that this tool reduced financial risks and contributed to the development of trust between the participants in the process. This concept was consistent with the Dutch concession model, under which the private sector received expanded powers while meeting state climate goals.

The comparison of strategies established that France relied on centralised support and large-scale national investment, while the Netherlands developed a decentralised model with the leading role of regional authorities and private businesses. Both approaches were integrated into the common climate priorities of the European Union, but differences in management mechanisms led to different speed and nature of programme implementation. This differentiation helped to adapt the electrification process to the specific economic and social conditions of each country.

The evolution of electrification policies in France and the Netherlands has shown that the effectiveness of the transition is determined by the ability to combine government incentives, municipal strategies, and private investment. It was this combination that formed the gradual prerequisites for the introduction of a new technological basis for public transport. The obtained conclusions created the basis for further analysis of financial and operational characteristics that determine the economic feasibility and practical effectiveness of electric bus programmes.

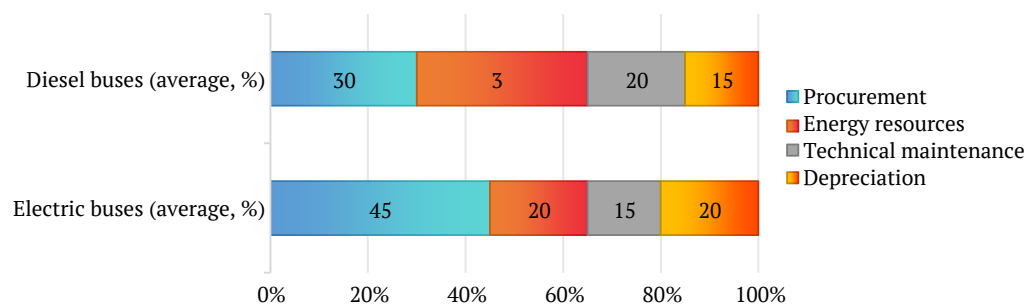
#### Comparative analysis of the cost of ownership of electric buses and diesel buses

The cost structure of TCO served as a basic indicator for assessing the economic efficiency of urban transport. In the case of electric buses and diesel buses in France and the Netherlands, it was formed in several key categories: vehicle purchases, energy costs, maintenance and depreciation charges. Generalisation of these parameters within the framework of the analysis identified the main patterns and demonstrated the presence of differences in the financial burden between different modes of transport, which were determined by both technical characteristics and features of energy markets.

Analysis of the cost structure showed that electric buses had higher initial purchase costs and a higher share of depreciation charges in TCO. Instead, diesel buses showed increased energy and maintenance costs, reflecting their reliance on fossil fuels and traditional technology solutions. The identified features confirmed different approaches to the development of financial strategies in France and the Netherlands, and determined the specifics of the long-term economic consequences of operating both types of transport. To detail these results, Figure 1 shows a systematisation of average cost values in TCO. Analysis of Figure 1 showed that electric buses were characterised by higher initial purchase costs – an average of 45% in the TCO structure, but had lower energy costs (20%) and maintenance (15%). Diesel buses, on the other hand, required less initial investment (30%), but their maintenance during the life cycle was more expensive due to the high share of energy costs (35%) and the higher frequency of repairs (20%). The ratio of depreciation costs also differed: for electric buses, this component was about 20%, while for diesel buses – only 15%. The difference confirmed that in the long run, electric buses have a better potential to reduce the total

cost of ownership. The generalised results highlighted the need to consider national characteristics of energy markets

and tax support instruments when assessing the economic feasibility of electric bus programmes.



**Figure 1.** Cost structure in TCO for electric buses and diesel buses on average by country (France and the Netherlands)

**Note:** TCO – total cost of ownership, which includes all costs associated with the purchase and use of a vehicle during the life cycle

**Source:** developed by the author based on data from Île-de-France Mobilités (2025), International Energy Agency (2025), European Environment Agency (2025a), European Environment Agency (2025b), European Investment Bank (2025a)

A detailed comparison of energy costs and maintenance helped to clearly identify the economic differences between electric buses and diesel buses in France and the Netherlands. These categories of expenses were crucial in the composition of TCO, as they formed the main financial risks and simultaneously identified potential benefits for

municipal budgets and transport operators. Generalisation of average indicators in terms of one kilometre travelled helped to objectively assess the long-term advantages of using electric buses, which confirms the relevance of their integration into urban transport strategies. For clarity, these parameters are shown in Table 3.

**Table 3.** Comparison of average energy costs and maintenance of electric buses and diesel buses in France and the Netherlands

Country	Type of transport	Average energy costs, EUR/km	Average maintenance costs, EUR/km	Share in TCO, %
France	Electric buses	0.18-0.22	0.12-0.15	35
	Diesel engines	0.35-0.40	0.18-0.22	55
Netherlands	Electric buses	0.20-0.24	0.13-0.16	38
	Diesel engines	0.37-0.42	0.19-0.23	57

**Note:** the table shows the average cost values per kilometre travelled

**Source:** developed by the author based on data from Île-de-France Mobilités (2025), International Energy Agency (2025), European Environment Agency (2025a), European Environment Agency (2025b), European Investment Bank (2025a)

Analysis of Table 3 showed that electric buses provided significant savings in both energy and maintenance costs compared to diesel buses. In France, the average energy costs for electric buses were only 0.18-0.22 EUR/km versus 0.35-0.40 EUR/km for diesel buses, which indicates a reduction in fuel costs by almost 50%. Maintenance costs were also lower – 0.12-0.15 EUR/km versus 0.18-0.22 EUR/km, which reduced the overall financial burden on municipal budgets. In the Netherlands, a similar trend was observed, although the difference between the cost of electric buses and diesel analogues was smaller (0.20-0.24 EUR/km versus 0.37-0.42 EUR/km), which was explained by the specifics of tariff formation for electricity and fuel. In general, electric buses showed consistently lower operating costs, which confirmed their superiority in terms of the life cycle and economic efficiency of transport systems.

The influence of incentive programmes on the economic attractiveness of electric mobility was confirmed in the paper by E. Macioszek (2021), who noted that tax

breaks and government subsidies formed key conditions for reducing the financial gap between traditional and electric transport. Similar results were confirmed in the analysis of French and Dutch practices: the first country focused on grants and preferential conditions for municipalities, while the second focused on compensation mechanisms for transport operators. This showed the universality of the impact of financial incentives on the development of electric bus programmes in various institutional environments. G.A. Ogunkunbi *et al.* (2021) found that the most effective model for the development of the electric transport market was formed under the condition of a combination of incentive and regulatory measures. It was shown that the simultaneous application of subsidies and regulatory requirements allowed reducing the financial risks of transport operators and increasing the competitiveness of electric buses in comparison with diesel vehicles. This result coincides with the practice of the Netherlands, where mandatory zero-emission

requirements were combined with support programmes for transport companies, creating favourable conditions for accelerated adoption of new technologies.

The structure of energy markets determined not only the cost parameters, but also the environmental characteristics of the implemented programmes. The French model was based on nuclear generation, which ensured tariff stability and low emissions for municipal operators. In the Netherlands, the focus was on gradually increasing the share of renewable energy sources, which helped to reduce the cost of electricity and increased the competitiveness of electric buses in the future. Thus, economic feasibility was combined with environmental benefits, creating the basis for long-term sustainable development of transport systems.

Similar dependencies were recorded in the study by P.A. Brehm & Y. Zhang (2021), where the example of the functioning of the Texas energy market showed that the organisation of the electricity market directly affected the efficiency of resource use and the level of environmental consequences. Comparing these results with the data obtained during the study in France and the Netherlands showed that regulatory mechanisms and the structure of the energy balance determined not only the cost of electricity for transport operators, but also the economic feasibility of switching to electric buses in the long term. The study by E.A.D. Galatoire *et al.* (2024) proved that the design of the electricity market in the Iberian region contributed to the development of a sustainable pricing system and created prerequisites for the large-scale introduction of renewable energy sources. The relationships identified between market organisation and the efficiency of

electrified transport development correlated with the results obtained in France and the Netherlands, where the long-term economic benefits of electric bus programmes were ensured by the stability of energy markets and support for state policies. This confirmed that the level of integration of the electricity market and transport policy determined not only cost indicators, but also the pace of transition to zero-emission transport.

#### Economic efficiency of electric bus programmes for municipalities

Financial models for the implementation of electric bus programmes determine opportunities and limitations for the development of urban transport, since the sustainability of investments and the speed of infrastructure modernisation depend on the financing structure. In France and the Netherlands, different approaches to managing financial flows have emerged, reflecting both the specifics of national budget systems and the level of private sector involvement. The study of these models allowed evaluating the effectiveness of centralised and decentralised mechanisms and determining their impact on the economic results of municipalities.

A comparison of financial models shows that in France, centralised investment and active participation of municipal programmes predominate, while in the Netherlands, concession agreements with private carriers play a key role. Both countries use international loans and grants, which reduces the burden on local budgets and ensures investment stability. Table 4 shows a systematic reflection of these financial models.

**Table 4.** Comparison of financial models for implementing electric bus programmes in France and the Netherlands

Financial model	France	Netherlands
Centralised investments	Significant government investments through national programmes and budget subsidies for the purchase of electric buses and the development of charging infrastructure	Limited application; the central government sets framework goals and provides co-financing for individual projects
Municipal programmes	Leading role of regional agencies (Île-de-France Mobilités) in financing procurement and coordinating transport strategies	Municipalities participate in route planning, but the main funding is provided by private operators
Concession agreements	Used in large cities, but the main focus is on state and regional funding	Main financing mechanism: private operators invest in the fleet and infrastructure as part of long-term concessions
International loans and grants	Active attraction of funds from the European Investment Bank and EU funds for the modernisation of urban transport systems	Used to support infrastructure projects, mainly in combination with private investment

**Note:** Île-de-France Mobilités – regional agency that coordinates transport policy in the French capital region

**Source:** developed by the author based on data from the Ministry of Infrastructure and Water Management (2016), Île-de-France Mobilités (2025), European Investment Bank (2025a), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

Analysis of Table 4 showed that the French financial model was characterised by a high level of centralisation and significant participation of municipal programmes, which ensured stability in the implementation of long-term investment projects. In the Netherlands, the model was more decentralised and was based on the activities of private operators who made key investments through the concession system. International loans and grants played a supporting role in both countries, compensating for local

resource shortages and contributing to the expansion of infrastructure projects. A comparison of these approaches confirmed that the centralised model of France provided a controlled and uniform implementation of transport innovations, while the Dutch strategy created conditions for faster adaptation and stimulated competition between carriers. Thus, differences in financial mechanisms reflect a balance between government obligations and market instruments in the field of urban transport.

The results of the analysis are consistent with the conclusions of S. Alotaibi *et al.* (2022), which proved that transport investment and the development of railway and urban transport infrastructure directly affected regional economic growth. It was confirmed that the centralised investments typical of France contributed not only to the renewal of transport systems, but also created a multiplicative effect for the local economy. A similar dependence was observed in the Netherlands, where financial decentralisation provided faster investment turnover and increased economic performance in the medium term. The paper by V. Foster *et al.* (2023) emphasised that the quality and scale of infrastructure investments determine the final socio-economic results. The researchers showed that projects supported by international credit institutions reduced risks for local budgets and provided better conditions for their payback in the long term. These findings highlight those found in France and the Netherlands, where the resources of the European Investment Bank have played a supporting but important role in stabilising funding for transport programmes.

C. Wang *et al.* (2021) showed that global financial crises and associated market shocks significantly affected the investment attractiveness of the transport sector. The researchers proved that adaptation through flexible economic and regulatory strategies has reduced the risks of long-term infrastructure projects. This is consistent with

the experience of France and the Netherlands, where government support combined with international financial instruments reduced the vulnerability of transport programmes to external economic fluctuations. L. Haywood & M. Jakob (2023) highlighted the role of Emissions Trading Scheme 2 mechanisms in the process of decarbonising the European Union's transport sector. The researchers proved that strict regulatory mechanisms created prerequisites for reducing the payback period for investments in clean transport due to market incentives and reallocation of costs between market participants. This result highlights the differences found: in France, regulatory rigidity provided stability in planning, while in the Netherlands, preference was given to market instruments that accelerated the adaptation of transport operators.

The assessment of the return on investment in electric bus programmes helped to determine under what conditions high initial costs were transformed into long-term economic benefits for municipalities. In France and the Netherlands, these parameters differed significantly depending on the level of government support, the rigidity of regulatory requirements, and the degree of infrastructure development. Generalisation of indicators helped to identify specifics in terms of payback and cost dynamics during the transport life cycle. To systematise these data, Table 5 shows the key conditions that determined the economic efficiency of investments in electric buses in France and the Netherlands.

**Table 5.** Key conditions for the return on investment in electric buses in France and the Netherlands

Parameter	France	Netherlands
Payback period	8-10 years (depending on the level of subsidies and electricity tariffs)	6-8 years (subject to compliance with the requirements for zero-emission transport)
Support level	High: state subsidies, municipal grants, soft loans	Average: compensation for operators, purchase benefits, concession agreements
Average reduction in operating costs over 5 years	25-30%	30-35%
Cost dynamics over the life cycle	High initial purchase costs ( $\approx 45\%$ TCO); gradual reduction in maintenance and energy costs	High initial costs ( $\approx 40\%$ TCO); rapid reduction of operating costs due to developed infrastructure

**Note:** Zero-emission – zero-emission vehicle that meets EU environmental standards

**Source:** developed by the author based on data from the Ministry of Infrastructure and Water Management (2016), Île-de-France Mobilités (2025), International Energy Agency (2025), European Investment Bank (2025a), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

Analysis of Table 5 showed that in France, the payback period for investment in electric buses was longer and averaged 8-10 years. This dynamic was attributed to high initial costs, which were gradually offset by reduced maintenance and energy costs during the transport life cycle. In the Netherlands, the payback period was shorter and amounted to about 6-8 years, which was ensured by strict regulatory requirements and a high level of development of the charging infrastructure. The French model was based on active government support, while in the Netherlands market mechanisms and a system of concession agreements with private operators played a key role. In both cases, a steady reduction in fuel and maintenance costs was a determining factor in economic feasibility.

N.T. Hosseinkhani (2025) proved that tariff policies played a crucial role in ensuring the economic stability of

transport systems. The researcher showed that changes in tariffs directly affected the payback period of infrastructure projects. This correlates with the patterns found in France and the Netherlands, where the stability or dynamism of tariff formation determined the speed of financial returns. The findings by D. Chattopadhyay & V. Foster *et al.* (2025) stressed that the regulatory challenges that accompanied the introduction of new energy and transport technologies required a balance between government control and market incentives. The researchers proved that the effectiveness of the policy depended on the ability to combine these elements. A comparison with the findings showed that centralised control prevailed in France, while the Netherlands used market instruments that reduced payback periods. D.T. Utomo & C. Dianita (2025) substantiated the use of a scenario approach to assess the economic

feasibility of infrastructure projects. The researchers noted that this method allowed considering the risks and variability of payback periods. This logic was consistent with the results of the analysis of France and the Netherlands, where adaptability to changes in financing and infrastructure development became an important factor in efficiency.

A summary of the results of the study confirmed that the implementation of electric bus programmes in France and the Netherlands created long-term economic benefits for municipalities. They were aimed not only at reducing operating costs, but also at creating new jobs, stimulating the innovation sector, and integrating advanced technologies into the transport infrastructure. The growing economic returns from electric buses formed a comprehensive framework for improving the sustainability of urban transport systems. Such dynamics opened up prospects for further assessment of broader socio-economic and environmental effects, which necessitated in depth analysis.

**Environmental and social benefits of urban transport electrification**

Reducing emissions of harmful substances is considered as one of the defining environmental effects that accompany the introduction of electric buses in urban transport. The transition from diesel buses to electric buses helps to reduce the amount of greenhouse gases and toxic compounds that previously had a significant impact on the environment and the health of the urban population. Similar trends were found for France and the Netherlands, but the level of reduction achieved depends on the structure of the energy balance and the specifics of each country’s transport systems.

To substantiate the results of the analysis, data on reducing CO<sub>2</sub>, NO<sub>x</sub> and particulate matter (PM<sub>2.5</sub>) emissions,

which are key indicators of the environmental impact of transport, were systematised. Generalised indicators allowed assessing the extent to which electric bus programmes in France and the Netherlands reduce the environmental burden in large urban agglomerations. Table 6 shows the average emission reductions per 100 electric buses, which allows directly comparing the environmental performance of the two countries. Analysis of Table 6 showed that electric buses in France provide a higher level of reduction in CO<sub>2</sub> emissions compared to the Netherlands, which is explained by the low-carbon structure of French energy focused on nuclear generation. In France, the average reduction in CO<sub>2</sub> emissions was approximately 900-1,100 tonnes/year per 100 buses, while in the Netherlands – 800-1,000 tonnes/year, that is, the difference reached about 100 tonnes/year in favour of French programmes. In the Netherlands, the reduction in emissions was also significant, due to a gradual increase in the share of renewable energy sources in the total energy balance. Nitrogen oxide (NO<sub>x</sub>) emissions in France decreased by 12-15 tonnes/year per 100 buses, while in the Netherlands – by 10-13 tonnes/year, which indicates a difference of about 2 tonnes/year between the implementation models of electric bus programmes. The decrease in particulate matter (PM<sub>2.5</sub>) was also noticeable: in France – 0.5-0.7 t/year, in the Netherlands – 0.4-0.6 t/year, which in both cases means a significant improvement in air quality in urban agglomerations. Thus, quantitative data confirm that electric buses are capable of annually reducing up to 1,100 tonnes of CO<sub>2</sub>, up to 15 tonnes of NO<sub>x</sub>, and up to 0.7 tonnes of PM<sub>2.5</sub> per 100 transport units, providing a significant reduction in the environmental burden and increasing the sustainability of urban transport systems (European Environment Agency, 2025a; 2025b).

**Table 6.** Reduction of emissions from the introduction of electric bus programmes in France and the Netherlands

Indicator	France (average values)	Netherlands (average values)
Reduction of CO <sub>2</sub>	≈ 900-1,100 t/year per 100 buses	≈ 800-1,000 t/year per 100 buses
NO <sub>x</sub> abbreviation	≈ 12-15 t/year per 100 buses	≈ 10-13 t/year per 100 buses
Particulate reduction (PM <sub>2.5</sub> )	≈ 0.5-0.7 t/year per 100 buses	≈ 0.4-0.6 t/year per 100 buses

**Note:** CO<sub>2</sub> – carbon dioxide; NO<sub>x</sub> – nitrogen oxides; PM<sub>2.5</sub> – particulate matter up to 2.5 micrometres in diameter  
**Source:** developed by the author based on data from the Law of France No. 2015-992 (2015), Law of France No. 2021-1104 (2021), Ministry of Infrastructure and Water Management (2016), International Energy Agency (2025), European Environment Agency (2025a), European Environment Agency (2025b), Dutch Municipalities Association (n.d.)

The social benefits of the development of electric bus programmes extend beyond the transport sector and cover broader socio-economic processes. They are manifested in increasing the attractiveness of public transport, creating additional jobs, stimulating innovative sectors, and creating a positive image of municipalities.

A comparative analysis of France and the Netherlands revealed both common features and differences in social effects that reflect different priorities of national strategies. Table 7 shows systematic indicators of social benefits from the implementation of electric bus programmes in the two countries.

**Table 7.** Social benefits of electric bus programmes in France and the Netherlands

Indicator	France	Netherlands
Increased passenger traffic	+8-12% in large urban agglomerations due to improved air quality and reduced noise	+6-10% in medium and small cities due to increased transportation comfort and development of zero-emission zones
Job creation	5-7 thousand new jobs in the service, battery production, and infrastructure sectors	3-5 thousand jobs, in particular in the field of digital services and charging network management

Table 7. Continued

Indicator	France	Netherlands
Development of innovation sectors	Activation of production of battery systems, development of training programmes for technical specialists	Promotion of smart mobility and integration of smart grid into urban transport
Improvement of the image of municipalities	Strengthening positions within the EU's national decarbonisation programmes and climate initiatives	Creation of a positive image through the introduction of zero-emission zones and partnership with private carriers

**Note:** zero-emission zones – zero-emission zones that limit the use of fossil fuel vehicles; smart grid – intelligent energy networks; smart mobility – digital solutions for optimising transport systems

**Source:** developed by the author based on data from Law of France No. 2015-992 (2015), Ministry of Infrastructure and Water Management (2016), Law of France No. 2019-1428 (2019), Law of France No. 2019-1428 (2019), Île-de-France Mobilités (2025), European Environment Agency (2025b), European Investment Bank (2025a), European Investment Bank (2025b), Dutch Municipalities Association (n.d.)

An analysis of Table 7 showed that in France, social benefits were mainly focused on job creation, capacity development, and educational programmes focused on training personnel for innovation sectors. In the Netherlands, the main focus was on digitalisation of the transport system and the introduction of smart mobility solutions, which reflected the priority of technological innovation in urban policy. In both countries, there was an increase in passenger traffic, but in France it was more pronounced in large agglomerations, while in the Netherlands this trend prevailed in medium and small cities. The development of a positive image of municipalities occurred in both cases, although the mechanisms for ensuring it were different: France integrated electric bus programmes into national climate strategies, while the Netherlands relied on local zero-emission zones. The overall results confirmed that electric bus programmes were not only a transport, but also a socio-economic tool for the development of urban areas.

The results of the analysis are consistent with conclusions of A.R. Patel *et al.* (2022), who proved that socio-economic factors of users determine the readiness to use electric vehicles in future smart cities. The researchers noted that the combination of availability of services and an increase in the level of environmental awareness affected the dynamics of demand. This finding was consistent with trends found in France and the Netherlands, where the increase in passenger traffic was attributed to increased transport comfort and improved quality of the urban environment. The study by J. Adamczyk *et al.* (2024) proved that the development of electric mobility depended on the interaction of economic and environmental factors. The researchers noted that financial support in the form of subsidies and tax incentives created conditions for the spread of electric transport, while environmental effects shaped the public legitimacy of programmes. This is consistent with the analysis of France, where large-scale government support was combined with climate priorities, and the Netherlands, where considerable attention was paid to the combination of economic feasibility and environmental benefits.

Electric mobility in the study was considered as a factor in the development of an innovative and sustainable economy, since institutional support, together with the promotion of private investment, created conditions for the integration of new technologies into the transport

sector, which was confirmed by the conclusions of U. Motowidlak & A. Bukowska-Pieprzyńska (2024). The consistency of these prerequisites with national approaches was manifested in the Netherlands through digitalisation and partnership between the state and business, while in France centralised regulation played a key role. The multidimensional effect of electrification – from the economy to energy and infrastructure – was explained by the ability to combine price incentives, grid development, and renewable integration, which is consistent with the findings of S. Mopidevi *et al.* (2022). Comparison with the results showed that in France, the stability of tariffs was ensured by low-carbon generation, while in the Netherlands, the growth of the share of renewable energy increased the long-term competitiveness of electric buses.

Strengthening climate responsibility and integrating transport projects into national strategies were interpreted as an additional channel for attracting investment and expanding international cooperation. As noted by P. Bastos *et al.* (2024), Latin American experience showed that partnerships between governments, financial institutions, and private companies have accelerated the introduction of electric buses, which was consistent with European practices of concessions and multi-level policy coordination. Based on the conclusions of R.A. Alarrouqi *et al.* (2024), technological operating conditions define additional reliability requirements: in hot climates, battery efficiency decreases by 10-15%, which requires adapted technical solutions and emphasises the versatility of engineering barriers. As noted by A.H. Yáñez *et al.* (2024), the development of charging infrastructure is a crucial factor in the stability of transportation, because its shortage creates risks for the regularity of transport operations. This can be traced in various regional models, from public investment to private network deployment.

A comparison of the results of France and the Netherlands confirmed that the social and environmental benefits of transport electrification combined common features and specific differences. Emission reductions and noise load reductions were common, while differences were driven by the energy structure and institutional regulatory policy mechanisms. This confirmed that the integration of social and environmental priorities into transport strategies created conditions for improving the sustainability

of urban systems and strengthening their capacity for sustainable development. Generalisation of the analysis proved that electric bus programmes formed long-term advantages that went beyond the transport sector. They combined environmental impacts with the creation of social benefits, increased confidence in municipal strategies, and provided a framework for assessing impacts in a broader economic and socio-environmental context. This complexity of effects made electric bus projects a key element in the transformation of urban systems in the direction of innovation and sustainability.

## ■ Conclusions

The study identified original approaches to the comparative analysis of electric bus programmes in France and the Netherlands, focusing on a comprehensive assessment of economic feasibility, environmental effects, and social benefits. It was determined that the return on investment in France averaged 8-10 years, while in the Netherlands it was shorter and reached 6-8 years due to a combination of strict regulatory requirements and a developed charging infrastructure. Analysis of the cost structure as part of the total cost of ownership showed that electric buses were characterised by a higher share of purchase costs (45% vs. 30% for diesel buses), but had lower energy and maintenance costs (together 35% vs. 55% for diesel analogues).

The results obtained confirmed the economic advantages of electric buses in comparison with diesel analogues. In France, energy costs for electric buses were 0.18-0.22 EUR/km versus 0.35-0.40 EUR/km for diesel buses, and maintenance costs were 0.12-0.15 EUR/km versus 0.18-0.22 EUR/km. In the Netherlands, the corresponding figures were slightly higher (0.20-0.24 EUR/km and 0.13-0.16 EUR/km for electric buses versus 0.37-0.42 EUR/km and 0.19-0.23 EUR/km for diesel ones), but the economic

advantage of electric transport remained. This confirmed the constancy of the trend regarding the lower cost of operating electric buses, regardless of the specifics of national energy markets.

Environmental and social results also demonstrated significant effects of transport electrification. In France, the reduction in carbon dioxide emissions was about 900-1,100 tonnes per year per 100 electric buses, in the Netherlands – 800-1,000 tonnes. Social benefits included an increase in passenger traffic by 8-12% in French agglomerations and by 6-10% in Dutch medium and small cities, the creation of 5-7 thousand new jobs in France and 3-5 thousand in the Netherlands. In addition, the development of innovative sectors was identified: the production of battery systems in France and digital services in the Netherlands. This confirmed that electric bus programmes performed not only a transport, but also a socio-economic function integrated into national sustainable development strategies.

The study had certain limitations related to the availability of statistical data, differences in cost accounting methods, and the impact of different tariff models on final results. Further research should focus on assessing the long-term effects of renewable energy integration, analysing the impact of climatic conditions on the operation of electric buses, and exploring the possibilities of scaling programmes in various regional contexts.

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## ■ Conflict of Interest

None.

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## Інновації у сфері міського транспорту на прикладі електробусних програм у Франції та Нідерландах

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■ **Анотація.** Метою статті було з'ясувати економічну та екологічну доцільність впровадження електробусних програм у Франції та Нідерландах з урахуванням їхнього впливу на муніципальні бюджети, екологічні показники та соціальний розвиток. У результаті проведеного аналізу фінансових показників, структури витрат у складі повної вартості володіння та соціально-екологічних ефектів було встановлено, що строк окупності інвестицій становив у середньому 8-10 років у Франції та 6-8 років у Нідерландах завдяки різному рівню регуляторних вимог і розвитку зарядної інфраструктури. Структура витрат засвідчила, що частка закупівлі електробусів становила 45 % проти 30 % у дизельних, тоді як витрати на енергоносії та технічне обслуговування були нижчими (35 % проти 55 % відповідно). У Франції витрати на енергоносії для електробусів становили 0,18-0,22 €/км проти 0,35-0,40 €/км для дизельних, а на технічне обслуговування – 0,12-0,15 €/км проти 0,18-0,22 €/км; у Нідерландах різниця була меншою, але зберігалася на користь електробусів. Екологічний ефект визначався скороченням викидів вуглекислого газу на 900-1100 тонн на рік на 100 автобусів у Франції та 800-1000 тонн у Нідерландах. Соціальні результати включали зростання пасажиропотоку на 8-12 % у французьких агломераціях та на 6-10 % у нідерландських середніх і малих містах, створення 5-7 тисяч робочих місць у Франції та 3-5 тисяч у Нідерландах, а також розвиток інноваційних секторів – акумуляторних технологій у Франції та цифрових сервісів у Нідерландах. Було доведено, що централізована модель фінансування у Франції забезпечувала стабільність, тоді як децентралізована система концесій у Нідерландах сприяла швидкій адаптації та конкуренції між перевізниками. Практичне значення дослідження полягало у визначенні умов економічної доцільності та соціально-екологічних переваг електробусних програм, результати якого можуть бути використані органами влади, муніципалітетами й транспортними операторами для вдосконалення стратегій сталого транспорту та планування інвестицій

■ **Ключові слова:** муніципальні бюджети; повна вартість володіння; енергоносії; технічне обслуговування; амортизація; строк окупності; регуляторні вимоги