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Forecast for the Development of Electric Vehicle Charging Infrastructure in Berlin

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Abstract:

Purpose: *Local authorities are increasingly deciding to implement environmentally friendly solutions in cities, thereby contributing to reducing the negative effects of transport. The main aim of this article is to verify this development.*
Design/methodology/approach: *The article employs a mixed-methods approach combiningcase study methodology, literature review and statistical analysis. It utilizes Holt-Winters method, in which the model calculations take into account the smoothed value of the forecast variable over time, i.e. F, and the smoothed value of the trend growth over time, i.e., S. The study incorporates data from industry documents, official reports and statistical sources, offering both quantitative and qualitative insights into the current state and future prospects of electromobility in Berlin.*
Findings: *An efficiently designed network of charging stations contributes to a greater share of alternative fuel vehicles in overall traffic volume and urban transport networks, reducing air pollution and noise emissions and positively impacting the health and quality of life of residents due to the possibility of reducing the number of conventionally powered vehicles.*
Practical Implications: *Due to rapidly advancing urbanization processes and the associated development of cities, the demand for transport services is growing.*
Originality/Value: *Ensuring an optimal number of charging points for electric vehicles is becoming a significant problem, particularly in the case of individual transport.*

Keywords: *Urbanization, individual transport, urban transport, management, sustainable urban development, transport policy, electric vehicle charging infrastructure.*

JEL code: *A1, R4, R5, O1, L94, Q01.*

Paper type: *Research article.*

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1. Introduction

The dynamic growth of cities is now generating problems in terms of the movement itself by different modes of transport and the prevailing traffic. The growing demand for transport services and the need to meet it is forcing city managers to look for solutions. An efficient and effective transport system in a city should reduce existing transport problems, mainly in terms of accessibility.

This is all the more important as accessibility deficiencies in the case of electric vehicle charging infrastructure in conurbations are a source of other problems, such as increased pollutant and noise emissions and the resulting deterioration in residents' health and quality of life. CO2emissions from car transport in EU cities account for more than 40% of emissions from the entire transport sector, according to European Commission data (https://ec.europa.eu/). Individual transport modes have an inherent advantage over public transport in that they provide door-to-door transport, which makes individual transport more attractive to the potential user.

Transport policy at international, national, regional or local level, as well as urban competition, necessitates the search for solutions to improve accessibility to environmental solutions. These solutions can be technological, technical and organisational. The implementation of technological solutions involves high financial outlays, but brings them closer to the higher goal of improving the health and lives of city dwellers.

The authors of this article focus on the question of how the authorities in the German capital aim to improve the availability of electric vehicle charging points and stations. The subject of the research is one of the largest European capitals, Berlin. The subject of the research is the solutions introduced in its areas in the EV charging infrastructure. The paper uses the methods of source analysis, descriptive analysis, the method of deduction and the Holt-Winters forecasting method.

2. Literature Review

Current projections and estimates assume that by 2050, 68% of the world's population will live in urban areas. The trend of people migrating from rural areas to cities or to the urban fringe has continued since 1950 (https://www.un.org/). Many countries around the world have taken steps to intensify urbanisation processes (Pradhan *et al.,* 2021), which have implications for ongoing changes in land use in cities and neighbouring zones, the spread of non-agricultural activities, the acceptance of and adoption of urban customs and standards (Szymańska, 2007).

The city, being a key point in human functioning, promotes the satisfaction of the life needs of its citizens (Kijewska, 2016). As people migrate from rural to urban areas, their social needs evolve. However, the evaluation of needs does not change their type, only their level (Szołtysek, 2005). As a result of urbanisation progress, there is a shift towards pro-environmental solutions in urban areas (Noussan, 2020). Due to the nature of the urban system to serve its users, this poses a challenge to its managers.

Urban transport plays an important role in the functioning of urbanised areas. It is a set of interdependent and coordinated activities, the end result of which is to ensure the flow and service of the movement of people and goods within a given agglomeration (Kosobucki, 2013).

The fulfilment of urban transport tasks is possible thanks to the transport infrastructure, means of urban transport, transport offer, as well as the integration and coordination of the network of all modes of transport in the area of a given agglomeration. Infrastructure in cities exists in three dimensions, physical, technological and information and communication technology, or ICT for short, and services.

Physical infrastructure is referred to as the only non-intelligent infrastructural component of cities, it is made up of linear and point infrastructure (Mohanty, 2016). Linear infrastructure components include roads, railways, inland waterways, among others; point infrastructure distinguishes stops, stations/terminal loops, interchanges, car parks, vehicle inspection stations, passenger service stations and electric vehicle charging points and stations (Wyszomirski, 2008).

Means of transport in urban transport have specific design solutions that determine how they are used. All means of transport present in the urban transport area can be divided according to: the way they are used, the type of energy used for propulsion and the type of routes they travel on. Means of transport by mode are divided into individual, group and collective. Selected means of urban transport can be classified into several categories, depending on how they are used at any given time (Wyszomirski, 2008). Table 1 shows the most important modes of transport currently used in European cities, taking into account the functional variable of how they are used.

Table 1. *Functional classification of urban transport modes*

Means of urban transport		
Individual: **bicycle, car, moped, taxi**	Group: car, (incl. carsharing), taxi	Collective: bus, trolleybus, tram, metro, railway, ship

Source: *Own elaboration based on https://www.europarl.europa.eu/.*

The car is of particular importance in the transport service of cities, providing the greatest spatial accessibility, allowing the movement of people and goods on a door-to-door basis (Giannopoulos, 2010). At the same time, it is a major source of pollution and noise in cities.The development of modern urban agglomerations requires a constant search for new urban transport solutions to improve the quality of urban travel. The new solutions may concern many spheres of activity.

However, in the coming years, as global trends indicate, implemented solutions will focus on the following areas (CATiF *et al.,* 2012):

- planning, organising and managing sustainable transport systems,
- low-carbon transport techniques and technologies,
- transport financing for both maintenance and upgrading of existing assets, as well as the implementation of new infrastructure investments in terms of climate strategies,
- reducing conventional individual transport in favour of new alternatives, particularly in the centres of large European cities.

The aim of these measures is, on the one hand, to make better use of the potential that already exists and, on the other, to exploit new transport potential. Urban transport is highly susceptible to change, but is constrained by high implementation costs (Janczewski and Strzelczak, 2009). In addition, due to the spatial constraints of cities, the expansion of infrastructure is hampered and also the work to upgrade it has not kept pace with the rate at which people migrate to cities (Pradhan, 2021).

Developed cities of the world are competing with each other in designing and implementing agglomeration-friendly solutions (Anthopoulos and Fitsilis, 2014). A key aspect is the drive to reduce traffic congestion by conventionally powered vehicles in cities, while taking into account the principles of sustainability.

The policies of the European Union, its member states as well as other countries around the world have to deal with the problems: achieving economic goals, energy independence and climate change depend on the policies and objectives pursued by individual countries, regions and decisions taken at local level (https://ec.europa.eu/).

3. Research Methodology

The paper uses the Holt-Winters method, in which the model calculations take into account the smoothed value of the forecast variable over time, i.e. F, and the smoothed value of the trend growth over time, i.e., S. The formulae are as follows:

$$F_1 = y_1$$

$$S_1 = y_2 - y_1$$

$$F_t = \alpha y_t + (1-\alpha)(F_{t-1} + S_{t-1})$$

$$S_t = \beta(F_t + F_{t-1}) + (1-\beta)S_{t-1}$$

where: y_t - data of the considered time series; α - data smoothing coefficient, $\alpha \in [0,1]$;

β – trend smoothing coefficient, β∈ [0,1].

The initial values of the smoothing coefficients are chosen arbitrarily and then optimised using the MS Excel add-in Solver.

The forecast y_t^* for period t≤n is calculated from the formula:

$$y_t^* = F_{t-1} + S_{t-1}$$

Whereas for period t>n:

$$y_t^* = F_n + (t-n)S_{t-1}$$

where: n - number of elements of the time series.

The mean absolute percentage forecast error was used to test the accuracy of the forecast:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{Y_t - Y_t^*}{Y_t}\right| \cdot 100\%$$

4. Research Results and Discussion

Berlin has a complex and highly efficient urban transport system. Without it, the metropolis of 3,769,962 inhabitants could not function efficiently (https://download.statistik-berlin- brandenburg.de/). However, the transport requirements of this city are constantly changing, so the demand for new solutions in the area of improving accessibility to charging infrastructure for electric vehicles used for personal transport is very high. This is due to the need to reduce the environmental effect of transport.

The design and implementation of new solutions in the field of transport in Berlin relies on the cooperation to a greater extent of the private sector, NGOs, research and development units, both domestic and foreign. The ability of all actors involved to carry out tasks depends on the improvement of the regional transport of Berlin and neighbouring Brandenburg (VBB *et al.,* 2021).

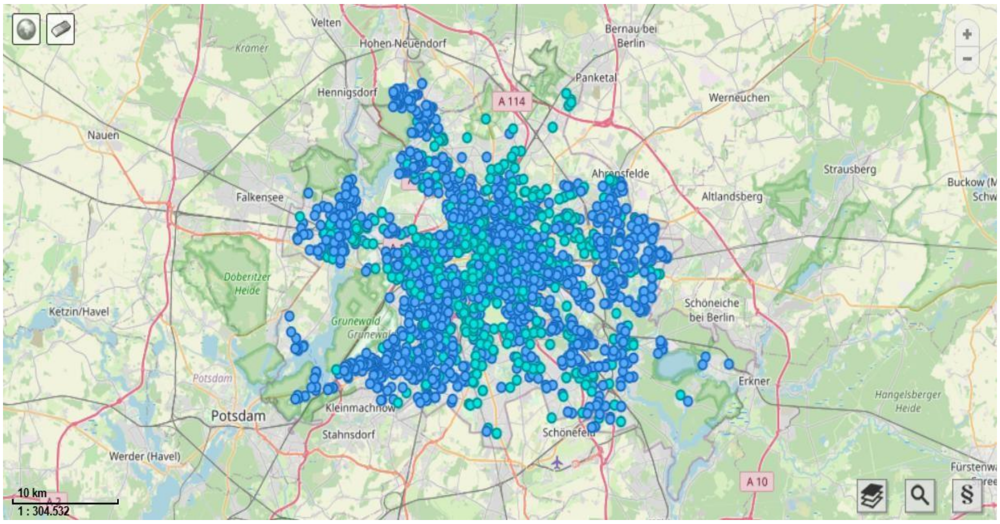
The charging infrastructure being set up by the Berlin municipal authorities for EV users in personal transport is divided into charging points with general access in public spaces and with public access on private land. At the end of the second quarter of 2024, there were more than 4,700 publicly accessible charging points in public and private spaces in Berlin. More than 2,500 of these were located on public streets and squares. A total of around 1,200 new charging points in public space were established in 2023 alone.

Most of these charging points are being built and operated on behalf of the state of Berlin. Private charging infrastructure operators are also rapidly expanding and operating new charging infrastructure. In 2022, a share of the creation of 1,360 charging points has been allocated to external operators. Currently, some of these have already been built or are waiting to be built. The advantage of the unified charging infrastructure concept is non-discriminatory access for mobility providers all EV users can charge their vehicles at any charging station of any operator in the public space under agreed conditions.

Berlin's public charging infrastructure is complemented by a growing number of charging points in public spaces on private land, e.g. in private car parks at supermarkets, petrol stations, etc.

However, it is in these areas most of the expansion of the charging infrastructure will have to take place in the future. The reason for this is the diverse and partly competing requirements for the use of public space in a growing city such as Berlin. An overview of the current state of development in public space and with public access on private land is presented in the excerpt from the map "Energy Atlas of Berlin":

Figure 1. *Map of the distribution of electric vehicle charging points in Berlin, with access in public space and with public access on private land*



Source: *https://www.berlin.de/.*

The study analysed the development of the EV charging infrastructure with a distinction between infrastructure with public access and infrastructure with limited access - only available to the public. The data is for the period 2016-2024 and was obtained from Berlin's official website https://energieatlas.berlin.de/#.

Table 1. *Number of charging stations in Berlin*

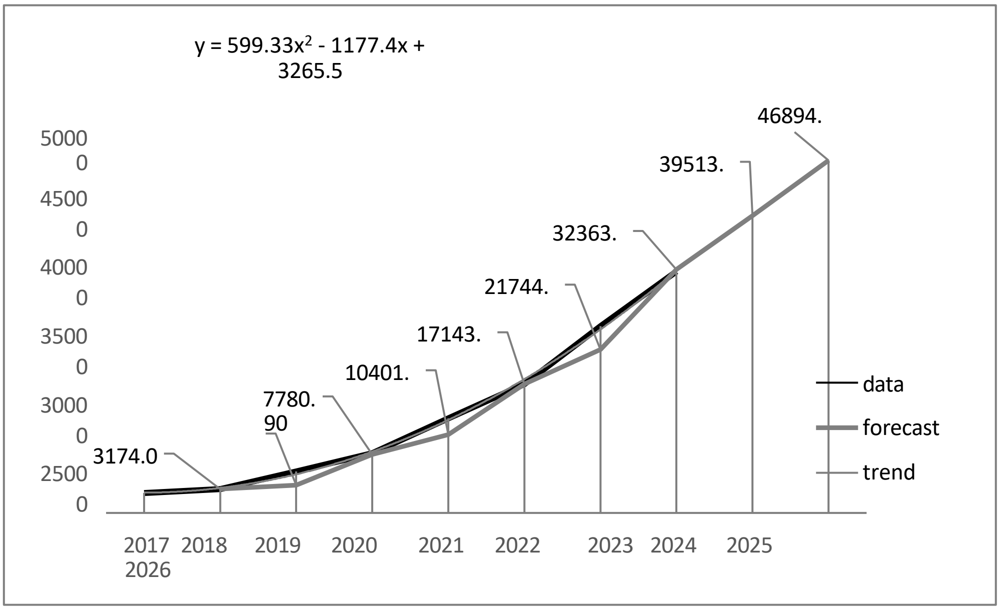
year	2016	2017	2018	2019	2020	2021	2022	2023	2024
public charging stations	0	2646	3174	5527	7944	12601	17143	24837	32127
publicly accessible charging stations	238	376	516	848	1513	1809	2284	4005	5063

Source: *https://energieatlas.berlin.de/#.*

To investigate the further development of the infrastructure, a forecast was calculated. The data collected is characterised by an upward trend and a lack of seasonality, which was the main rationale for applying the Holt-Winters method.

Forecasts of chargers were calculated for two consecutive years taking into account the breakdown of all chargers and publicly available chargers. As previously mentioned, when analysing the data presented in the graph, it was found that the data is characterised by an upward trend. For all charging stations, this is a polynomial trend (Figure 2).

Figure 2. *Results of the forecast of publicly available charging stations according to the Holt-Winters model, including the trend of the data*



Source: *Own study.*

After calculations for the Holt-Winters method, the forecast for 2025 was 39513.78 chargers, and for 2026 as many as 46894.15. The solver indicated optimal values of α= 0.9728 and β=1.0000. The forecast error was estimated at 9.39%, which is highly correct.

The largest increase in the formation of all chargers was recorded in 2019, up 74.13% (Table 1.) compared to the previous year, and the average rate of change for the years studied was 42.86%.

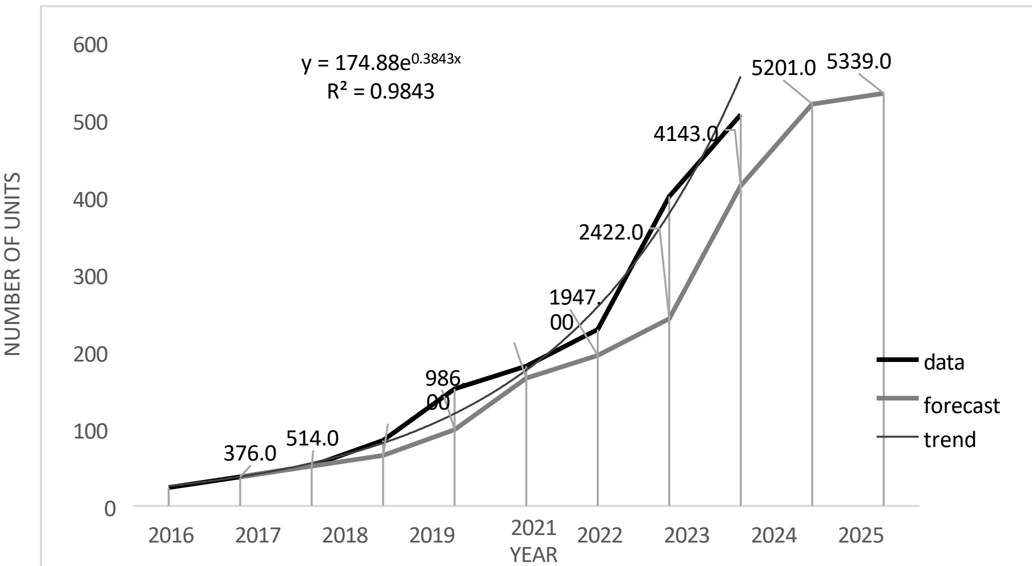
***Table 2**. Analysis of the development of charging stations with limited access*

year	charging stations [units]	year-on-year increase [units]	[%]
2016	0		
2017	2646	2646	
2018	3174	528	19.95%
2019	5527	2353	74.13%
2020	7944	2417	43.73%
2021	12601	4657	58.62%
2022	17143	4542	36.04%
2023	24837	7694	44.88%
2024	32127	7290	29.35%

Source: *Own study.*

The forecast for publicly available chargers in 2025 is 5201.00 units and in 2026. 5339.00 (Figure 3.) In this case, the optimal values of α= 1 and β=0. The error was set at 17.41%, which also indicates a reliable result.

***Figure 3**. Results of the forecast of restricted charging stations according to the Holt-Winters model, including data trend*



Source: *Own study.*

In the case of chargers for public use, their largest increase was recorded in 2020 and was 78.42% compared to the previous year (Table 3). The average rate of change for the data indicated was 46.55%.

Table 3. *Analysis of the development of charging stations with limited access*

year	Charging stations [units]	year-on-year increase [units]	[%]
2016	238		
2017	376	138	57.98%
2018	516	140	37.23%
2019	848	332	64.34%
2020	1513	665	78.42%
2021	1809	296	19.56%
2022	2284	475	26.26%
2023	4005	1721	75.35%
2024	5063	1058	26.42%

Source: *Own study.*

Among all chargers, those with public access according to the forecast for 2025 will account for 13.16% and for 2026. 11.39% , representing greater calls on the public sector.

5. Conclusions

Charging infrastructure for electric vehicles is an important factor influencing the development of electromobility in cities. However, it is important to keep in mind the optimal number of charging stations so that the opportunities to use them do not limit drivers. The main limitation of electric vehicles is the capacity of the batteries and therefore the range of these vehicles, which is relatively low.

Charging infrastructure has a huge impact on the development of electromobility, so significant measures need to be taken to increase the availability of publicly accessible charging points in public spaces, which will provide consumers with a guarantee that an electric vehicle can be treated on an equal footing with a combustion engine vehicle.

This paper presents a study on the forecasting of charging station infrastructure, with a breakdown of chargers generally available in public space and those with public access on private land. It was found that the data showed a strong upward trend, with a polynomial trend for all chargers and an exponential trend for public chargers.

The forecast of public access charging stations showed for 2026 as many as 46894.15 units, an increase of 45.96% compared to 2024, and limited access charging stations 5339 units, an increase of 5.45% compared to 2024. The exponential growth in EV infrastructure development predicted by the study is a challenge for the environment.

Forecasting the number of charging stations plays a key role in providing information for decision-makers' decisions, such as the need to expand utilities. An important aspect to consider further is the energy capacity of the city and the country, and whether an assessment of accessibility, i.e. whether the distribution of chargers takes into account social and spatial aspects (e.g., lower income city neighbourhoods). Determining precise forecasts influences the correct management of resources and allows the city to react quickly with regard to sustainability aspects, among others.

Further research would need to take into account other factors, such as electricity prices, fuel prices, the price and performance of electric cars and other aspects. All these factors will make it possible to prepare for the development of electromobility, taking into account the assumptions of sustainability.

The development of charging infrastructure increases consumer confidence and encourages the purchase of electric cars, which will reduce greenhouse gas emissions and local pollution. By using renewable energy sources, charging stations become part of a green energy ecosystem.

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