Accelerating Public Charging Infrastructure: Micro-Level Approach Enables Efficient Planning of Charging Locations Based on Suitability of Public Space

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Abstract. Expanding public electric-vehicle (EV) charging infrastructure is a pressing municipal need, yet planning is slowed by site-specific public-space constraints. To address this challenge, we developed a method that considers all possible sites for charging infrastructure in public space and conducts a suitability analysis based on potential conflicts, including preservation orders, overlays with bike lanes, and vegetation protection. Our method incorporates demand data to identify hotspots for infrastructure placement. A buffer-based analysis is applied to each suitable site, assigning the best-scoring locations. We applied our method to a neighborhood in Berlin, Germany, and obtained a selection of sites that meet demand without generating conflicts in public space. This study delivers a high-resolution output and a flexible framework for diverse urban settings, making the charging infrastructure expansion process more efficient.

Keywords: Public charging infrastructure · Electric vehicles · Suitable location choice · Multi-criteria evaluation

1 Introduction

Switching motorized individual mobility to electric vehicles (EVs) reduces CO_2 emissions, local air pollutants, and noise, delivering public health [1, 2] and energy-security benefits [3].

Germany has 1.4 million BEVs and 2.9 million PHEVs in stock (1.1.2024) [4]. The country has the objective of 15 million EVs in 2030. While most charging occurs at home or work, dense urban areas often lack private parking, making publicly accessible chargers essential [5]. Expanding public charging infrastructure boosts local EV adoption [6, 7] and is a pressing public-sector priority. Recent public-sector initiatives and a growing body of research have produced robust forecasts of charging demand and a suite of meso-scale placement methods [8, 9]. Berlin, for example, has operated a science-driven, model-based planning programme for over a decade, involving the development of a location concept, contract awarding procedure, and user information platforms [10].

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D. Esztergár-Kiss et al. (Eds.): TRAconference 2026, LNMOB, pp. 484–491, 2027.
https://doi.org/10.1007/978-3-032-37207-9_58

Existing studies reliably estimate the number of public chargers needed and provide large and medium scale placement concepts. Nevertheless, translating these models into exact sites is still a time-intensive task, that involves multiple parties and factors such as historic preservation and vegetation protection. We present a method that integrates demand forecasting with a public-space suitability assessment, providing a decision-support tool to determine exact charging locations. By coupling these steps, the approach markedly reduces the effort required for site-specific planning. The approach is tested in a central district of the city of Berlin, Germany.

The paper is structured as follows: First, we describe the methodology of the approach. Second, we present and discuss the results. Third, conclusions are drawn.

2 Methodology

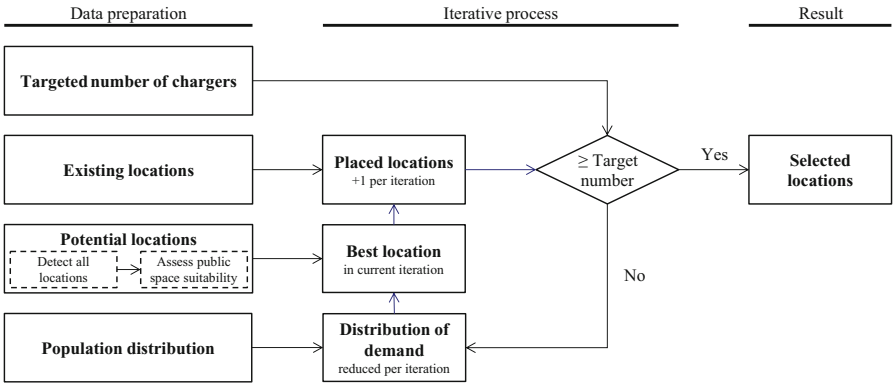


Fig. 1. Methodological approach.

The workflow (Fig. 1) comprises three stages: data preparation, an iterative placement process, and the final result. Data preparation involves gathering and preparing necessary input data, including the targeted number of chargers, the distribution of the existing charging infrastructure, the detection and suitability analysis of all possible sites for infrastructure expansion, and the distribution of the population in the study area. The iterative algorithm then calculates demand around each candidate location and assigns charging stations to the top-scoring locations, reducing demand in surrounding areas to ensure balanced coverage. The following section describes the steps in more detail and defines the input data. First, the case study area is introduced.

2.1 Case Study Description

We apply the method to a $\approx 1.5\ km^2$ part of Kreuzberg, Berlin (Fig. 2), with a population of 24,209 inhabitants in 2021 [11]. The area is dominated by dense early-20^{th}-century residential blocks, with some northern industry, cultural sites, and mixed-use ground floors. Street parking is prevalent because private backyard spaces are scarce. The river Spree forms the study area's northern boundary.

2.2 Data Preparation

The study adopts "neighborhood charging" [12], which comprises overnight charging in public parking close to the drivers' homes where private parking is limited. This service is provided by AC chargers with a maximum power of 22 kW [13]. Other charging behaviors, including workplace and retail charging, are excluded due to unavailability of proxy demand data required for street-scale allocation.

Targeted Number of Chargers. The method requires a targeted charger count, which may be set by policy or derived from demand-forecast models [14] and determines the infrastructure size needed to meet the foreseen demand. In our scenario, we assume 100 normal-speed chargers (two per station), resulting in 50 stations.

Existing Locations. Existing locations are obtained from public data from the German Federal Network Agency [15]. For this study, we retain only the 11 street-mounted normal-speed stations within the study area (as of 6.7.2024) (Fig. 2(c)).

Potential Locations. The method for selecting potential locations involves two successive stages: detection of all feasible sites and public space suitability assessment.

Detection of all Feasible Sites. Only street-side public parking bays are used; private yards and commercial lots (e.g., supermarket car-parks) are excluded because they fall outside municipal planning. An aerial-imagery detection algorithm provides georeferenced bays with capacity and orientation [16]. A GIS routine creates a point for every two adjacent bays and displaces the point 80 cm onto the sidewalk [17]. This procedure yields 2,920 potential locations within the study area (Fig. 2(a)).

Public Space Suitability Assessment. Each candidate is overlaid with the geometric representations of the spatial constraint layers listed in Table 1. The shape and size of every constraint buffer are defined by municipal preferences or literature-derived values. The set of criteria applied depends on data availability, data quality, and the relevance of each constraint to the study. Figure 2(a) presents the suitability analysis of all potential charging sites. It flags 53.5% (1,563) of the sites as conflicting and retains 46.5% (1,357) as conflict-free locations for the iterative placement process.

Population Distribution. We use address-level population data from the German Federal Agency for Cartography and Geodesy [11] as a spatial proxy for "neighborhood charging" demand [12]. Households with private garages, which typically enable home charging [23], are filtered out. The result is a set of georeferenced points representing the distribution of the relative demand. Parcel-level EV registration data would enhance accuracy, such data remain unavailable at sub-neighborhood resolution for Berlin. Our analysis operates at a finer scale than existing municipal datasets.

The relative demand distribution (Fig. 2(b)) shows a primary concentration in the study area center, with secondary clusters northwest/southeast. The demand distribution analysis is confined to study area limits, creating artificial central concentration. It is also crucial to consider the network accessibility, as hard borders impede the flow of connections. In this case, the data on the north side of the river was not considered.

Table 1. Criteria for public charging station suitability.

Criteria	Format	Value	Justification	References
Proximity to existing charging stations	Minimum distance	10 m	Qualified estimation after data analyses and observation	[18, 19]
Protection of tree roots	Minimum distance	Crown +1.5 m	[20]	[19]
Proximity to planting areas	Minimum distance	1 m	Buffer to enable use of station	[19, 21]
Conflict with road furniture	Minimum distance	2 m	Furniture size + utilization buffer	[22]
Proximity to memorials	Minimum distance	5 m	Qualified estimation after data analyses and observation	[21]
In front of protected buildings	Boolean attribute	No	Space occupying the sidewalk in front of protected buildings	[19, 22]
Conflict with bike lanes	Minimum distance	1.9 m	Standard lane width + utilization buffer	[17]
Reserved parking spaces	Boolean attribute	No	Information contained in parking space data	[22]
Insufficient sidewalk width	Minimum distance	1.8 m	Standard minimal sidewalk width	[17]

2.3 Iterative Placement

This step consists of four stages. The algorithm initiates by distributing demand proportionally to population density, then subtracts coverage from existing infrastructure. Iteratively, it selects the highest-demand candidate location and reduces demand within its area of influence. This cycle repeats until the target charger count is achieved, ensuring spatial coverage without over-concentration. The area of influence defines each station's service radius, while the demand reduction value quantifies its capacity to satisfy local charging needs.

Area of Influence. The area of influence defines each station's service radius, determined by the maximum 5-min walking distance from parked vehicles to residences [12, 23], assuming an average walking speed of 1.4 m per second [24]. The 5-min walking distance is then converted to meters, considering the urban fabric and walkability of the network [25]. As this study is applied to a dense urban environment, the area of influence around each charger is defined by a radius of 300 m.

Demand Reduction. The demand reduction value quantifies each charger's coverage capacity, calculated as total demand divided by target stations [26]. For 24,209 inhabitants in the area and 50 stations, each charger covers 484.2 inhabitants (24,209 ÷ 50). Upon station placement, this value is uniformly subtracted from demand units within the 300-m influence area, ensuring spatially balanced coverage.

Location Selection. The algorithm initiates by applying demand reduction around existing chargers to establish the residual demand field. This is then used to initiate the iterative placement process for additional charging infrastructure. The selection of the best placed location at each iteration depends on the quantity of demand calculated within the area of influence of each candidate location. The demand reduction method is applied to the selected location, updating the demand distribution, which is then used to select the next best located candidate. This iterative process continues until the targeted number of chargers is reached. The resulting dataset contains a selection of locations for the installation of new charging infrastructure.

3 Results and Discussion

The method identified 39 new charging locations (Fig. 2(c)) to complement the 11 existing stations, yielding a total of 50 stations as targeted. The resulting charging stations are concentrated in two major clusters. The bigger one is located in the center of the area, coinciding with the highest demand area, which also received the first placements (indicated by the number in Fig. 2(c)). Another cluster is located around the southeast corner. The northwestern area received minimal new stations due to existing infrastructure coverage. The selected locations tend to be distant from the boundaries of the study area, as demand outside these boundaries is not considered.

This contribution offers a high-resolution output, unlike earlier studies in this field [9, 27, 28]. The main advantage is the assessment of public space suitability, which allows for the inclusion of micro-scale barriers hindering charger placement. This approach provides a more detailed and accurate solution for charging infrastructure planning. The automated workflow excludes 53.5% of potential sites due to spatial conflicts, significantly reducing manual review burden for planners.

Nevertheless, the presented approach has limitations and undergoes iterative improvements. Currently, we cannot consider available connection power in the electricity grid, as obtaining this data is difficult in Germany due to confidentiality concerns.

Furthermore, the tool will be enhanced by integrating the results of a charging demand forecast model [14], which integrates spatially explicit EV penetration rates and charging behavior patterns, to generate dynamic targeted number of chargers as input, enabling the consideration of varying power requirements across future scenarios.

Currently, the spatially high-resolution distribution of charging demand is based on population density only. To further optimize the spatial distribution and draw a more realistic picture, the tool will also integrate data for other charging behaviors, such as charging at work or during shopping, facilitating a more complete and efficient planning approach.

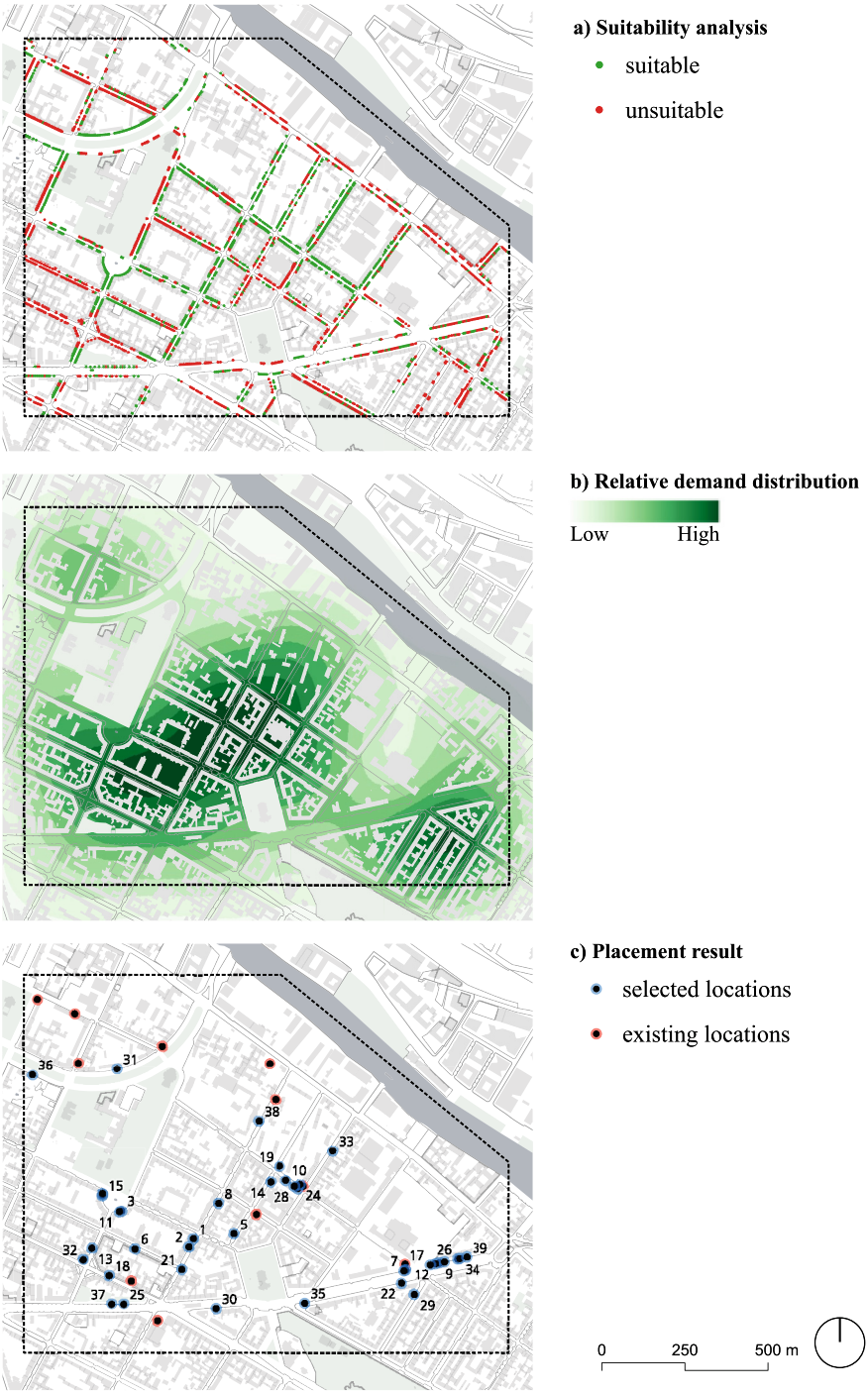


Fig. 2. Potential location suitability analysis (a), relative demand distribution based on population data (b), and result of the iterative charging infrastructure placement process (c).

4 Conclusion

In this study, an automated workflow for placing public charging infrastructure in a high spatial resolution is developed. The method includes on-site evaluations of the suitability of public space for placing charging infrastructure. An iterative placement process defines optimal exact sites. Results show that we can assess the local conditions in the public space and derive a subset of charging locations. Providing exact sites for the expansion of public charging infrastructure based on both, demand analyses and suitability of the public space is a new development and a significant added value towards earlier research. The approach therefore serves as a planning support and significantly simplifies the local effort for planning the expansion of public charging infrastructure. The proposed method is transferable and can be applied in diverse urban contexts and adapted to the framework conditions, needs and preferences of each municipality.

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