In traditional facility location problems, the objective is to determine the best locations for facilities in a

way to satisfy customer demand at fixed nodes of a network (see [1] for an overview of the facility location

literature). However, node-based models implicitly assume that drivers carry out a special round trip to a

station to recharge their battery and are thus not always suitable for modeling the EV charging stations location

problem. In particular, drivers traveling for long-distance trips recharge their battery while on their way to

another destination. In this case, demand should be modeled as a set of origin-destination flows representing

the various trips EV drivers are wishing to carry out. Hodgson [2] introduced the flow capturing location

model (FCLM), where an origin-destination flow is assumed to be ”captured” if at least one facility is located

anywhere on the corresponding path. The main issue when applying the flow capturing model for locating EV

charging stations is that it does not take into account the limited range of EVs. Kuby and Lim [3] extended

the flow capturing location model to incorporate the limited range constraint and defined the flow refueling

location problem (FRLP). In their model, an origin-destination flow is considered as refueled if and only if a

set of charging stations are built at carefully chosen locations on the shortest path between the origin and the

destination so that an EV driver is able to drive from the origin to the destination and back without running out

of fuel. Many extensions of the FRLP have been proposed since this seminal work. Limited charging station

capacities were considered e.g. in [4] and [5]. The possibility of using paths slightly deviating from the

shortest origin-destination paths was studied by Kim and Kuby [6], [7], Yildiz et al. [8] and Li et al [9].

Two types of charging stations (slow and fast charging stations) were studied by Wang and Lin [10] whereas

Arslan and Karasan [11] considered two types (hybrid and pure electric) of vehicles. Flow-dependent charging

delays induced by congestion at charging stations were introduced by Ghamami et al. [12].

Multi-period deterministic extensions of the flow refueling location problem were considered by three recent

works. Chung and Kwon [13] proposed a multi-period model in which new stations can be opened in a dynamic

way but stations built in a given period cannot be relocated until the end of the planning horizon. Their numerical

experiments showed the benefit of using a multi-period model as compared to the use of a myopic approach

based on the resolution of a series of single-period models. Li et al. [9] studied the multi-period multi-path

flow refueling location problem. Their model assumes that drivers are willing to deviate from shortest paths

and includes the possibility of relocating stations from period to period. In [14], Zhang et al. investigated the

multi-period flow refueling location problem. They considered charging stations with a limited capacity and did

not allow relocation of an opened station. They focused on modeling the influence of station siting decisions

on the demand growth pattern to model the fact that the adoption of EVs by drivers depends on the charging

opportunities.

However, it seems that until now, only a limited attention has been given in the literature to the stochastic

nature of the EV charging infrastructure planning problem whereas in practice, there are significant uncertainties

on the input parameters of the optimization problem to be solved. De Vries and Duijzer [15] and Lee and

Han [16] addressed the uncertainty of the vehicle range. Under a stochastic driving range, the coverage of an origin-destination flow becomes a matter of chance rather than a binary observation. Hence, the problem

modeling involves computing the coverage probability of each flow as the joint probability that each portion of

the corresponding path comprised between two opened stations will be shorter than the driving range. Other

works considered the uncertainty of the recharging demand. Hosseini and MirHassani [17] studied the problem

under uncertain traffic flows. They proposed a two-stage stochastic programming model in which portable

charging stations can be opened in the second decision stage in order to improve the expected flow coverage. Wu

and Sioshansi [18] studied a stochastic flow capturing location problem under recharging demand uncertainty

and proposed a two-stage stochastic programming approach. Miralinaghi et al. [19] addressed the uncertainty of

the refueling demand while considering a multi-period horizon. They proposed a robust optimization approach

in which infrastructure deployment solutions are assessed based on the worst-case demand scenario.

Literature review

The research on the location of electric vehicle charging stations

can be divided into the following three categories: one is to study

factors influencing the location of the charging station, the other is

to build a model for optimal location, and the third is the algorithm

associated with the model.

2.1. Influencing factors

There are many factors that affect the number and location of

charging stations, and the location of charging stations is influenced

by many factors, including economic problems of operators,

charging satisfaction of drivers, power loss of vehicles, traffic

congestion of transportation system and safety of power grid [20].

Falvo et al. Considering the electricity consumption of both electric

vehicles and subways, in order to use existing power plants as

much as possible to save energy [21]. Guo et al. Using the fuzzy

TOPSIS method to determine the location of the charging station

based on environmental, economic, and social standards [22].

Asamer et al. Calculated the charging demand based on the taxi

data, and determines the location of the charging station based on

many factors such as environmental conditions, electricity, and

laws [23].

Zhu et al. Studied the impact of user costs and charging station

costs on the number and location of charging stations. Studied the

influence of consumer preferences and total charging demand on

the location of charging stations [24]. Sun et al. Divided residents

into short distance and long-distance categories according to their

travel characteristics, so as to determine the number and location of

charging stations [25].

Although electric vehicles have good environmental and economic

benefits, the location of charging infrastructure needs to be

determined to meet the needs of electric vehicle users. Based on

this, they proposed a method to determine the optimal location

selection of EV charging stations based on a multi-objective

method. Pareto Frontier method is used to support the optimal

location decision process of charging stations. The results show that

the best charging station location for EV penetration in the medium

term can also adapt to long-term planning, and EV charging demand

is high [8]. In addition, some studies have fully considered

the impact of user behavior uncertainty on charging station location

[9].

2.2. Model construction

In order to study the optimal distribution and number of

charging stations, scholars have proposed many models.

Frade et al. studied the locations of charging stations in the

Portuguese capital and uses a maximal covering model to determine

the number and capacity of charging stations [26]. He et al.

analyzed the driving distance and charging demand of the car, and

established a double-layer mathematical model to solve the best

position of the charging station [27]. With the goal of maximizing

vehicle mileage, Shahraki et al. proposed an optimization model

based on vehicle driving patterns, and uses real data to determine

the location and scale of the charging station [28]. Wu et al. used

stochastic flow capturing location model (SFXLM) to optimize the

location and number of charging stations [29]. Tu et al. considered

time and space constraints to maximize the service level of ET and

charging stations for modeling, and studies the location of charging

station [30]. Luo et al. used a second-order planning model to study

the allocation of electric vehicle charging stations [31]. He et al.

established a two-level planning model based on the distance

traveled by the car to determine the best location of the charging

station [32]. Liu et al. modeled from battery characteristics and used

multi-objective biogeography-based optimization (M-BBO) approaches

to investigate the optimal strategy to meet the requirements

of different charging applications [33]. Mehrjerdi et al.

Modeled and optimized the charging network from the power and

capacity of charging facilities and energy storage battery systems

[34]. Roni et al. Used data such as vehicle driving time, queue

waiting time, and charging time for modeling, and analyzes the

impact of the number of charging stations and coverage on time

[35]. Lin et al. Established a multi-stage planning model for the

location and scale of charging stations based on the operating

characteristics and charging modes of electric buses [36]. Bouguerra

et al. Comprehensively considered the driving range, various

restrictions in reality, investment costs and user convenience, and

established a weighted model to determine the location and scale

of the charging station [37]. He et al. Considering the cost of batteries,

charging stations, and energy storage systems, and establishes

a mixed integer linear programming model to determine the

deployment of charging stations and the design of batteries and

energy storage systems [38]. Davidov et al. Started modeling from

the minimization of charging station layout cost, and studies the  
influence of mileage and service quality on charging station layout  
and total cost. From the perspective of minimizing the annual social  
cost [39].

Previous studies mainly focused on using optimization models

to deal with EVCS site selection that only considers quantitative

factors. Hosseini and Sarder proposed a Bayesian Network (BN)

model that considers both quantitative and qualitative (subjective)

factors [40]. Zhou et al. combined geographic information system

(GIS) and multi-criteria decision method (MCDM) for modeling to

determine the location of photovoltaic charging stations (PVCS)

[41]. Chen et al. Used a two-layer mathematical model to determine

the location and scale of the charging station by minimizing the

travel path and charging waiting time [42]. Luo et al. proposed a

location model for electric vehicle charging stations, taking into

account the impact of reservation service, idle rate during off-peak

periods, and waiting time during peak periods on improving

resource utilization and reducing total costs [43]. Zeng et al. proposed

an innovative station-level optimization framework to run

the optimal charging station pricing policy and charging plan. The

model combines human behavior and clearly and effectively captures

the charging decision-making process of drivers [44].

2.3. Model solving algorithm

In addition to building models, scholars have also used various

algorithms to solve the configuration problem of charging stations.

Sadeghi-Barzani et al. used MINLP optimization method and genetic

algorithm to determine the best location and scale of the

charging station [45]. Zhang et al. proposed a novel decentralized

valley-filling charging strategy, which designs a pricing scheme

through cost minimization and is compatible with device-level

multi-objective charging optimization algorithms [46]. Arslan

et al. used the Benders decomposition algorithm to study the

location of hybrid electric vehicle charging stations from the

perspective of maximizing mileage and minimizing transportation

costs [47]. Dong et al. used the SNN clustering algorithm to study

the planning method of charging stations on circular expressways.

From the perspective of minimizing the total cost [YYY]. Zhu et al.

studied the selection of the location of the charging station and the

number of chargers based on the genetic algorithm [48]. Xiang et al.

a new solution is proposed to integrate EVs and optimize the

location and size of charging stations, taking into account the

interaction between the power and transportation industries [49].

Brandstaetter et al. used two-stage stochastic optimization theory

and heuristic algorithm to solve the problem of charging station

layout [50]. Awasthi et al. combined genetic algorithm and particle

swarm optimization algorithm to determine the location and scale

of charging facilities in a city in India [51]. Wang et al. used an

improved genetic algorithm to analyze the charging station planning

problemgiven budget constraints and charging station service

capabilities [52]. Chen et al. divided the charging facilities into

charging stations and battery replacement stations, and used

multi-objective particle swarm optimization methods to determine

the ratio and distribution of the two [53]. Akbari et al. considered

the constraints of the charging station's power, charging time, and

travel distance, and used genetic algorithms to optimize the location

of the charging station [54].

Zhang et al. used the k-means cluster analysis method to analyze

the dynamic distribution of charging stations. From the perspective

of CO2 emissions and power limitation [55]. Liu et al. used particle

swarm optimization to study the location of bus charging stations

[56]. Straka et al. used the k-means clustering method, combined

with Dutch charging data to analyze, and studied the charging

behavior of users, which can help improve charging station

planning and charging technology [57]. Wu et al. combined

approximate dynamic programming (ADP) and evolutionary algorithm

(EA) to determine the best charging start time for each

electric vehicle, thereby reducing the operating cost of electric

vehicle charging stations and assigning charging locations [58].

Csisz\_ar et al. adopted the method based on hexagons and greedy

algorithm, introduced weighted multi-criteria method to evaluate

regional segments, and allocated charging stations within regional

segments [59]. Huang et al. From the perspective of maximizing the

profit of the charging station, used a genetic algorithm to determine

the location of the charging station [60]. Li et al. proposed an EV

charging station deployment strategy based on particle swarm

optimization algorithm to better determine the positioning of

charging stations and the number of charging piles. This strategy is

based on the non-uniform distribution of vehicles on the city scene

map, and also considers the distribution of vehicles at different

times, so that the strategy is more reasonable. A large number of

simulation results further show that this strategy is significantly

better than k-means algorithm in urban environment [XXXX]. Li et al.

takes microgrid composed of power distribution such as wind

power photovoltaic (PV), EVCs and energy storage system (ESS) as

the research object. The uncertainties of EV charging demand and

distributed renewable energy output are considered. A robust

optimization model of distributed energy charging station location

based on the combination of road network and power grid was

proposed [61].

To sum up, a large number of literatures have paid attention to

the optimal layout of charging stations, which shows that the

research of charging stations has attracted extensive attention.

Previous studies have mainly focused on various influencing factors

of charging station layout, the construction of optimal charging

station model, and the proposed different model solving algorithms,

and have made important contributions in these aspects.

The relevant research results are also the basis of further research in

this paper. At the same time, most of the existing literature studies

from the aspects of charging station technology, user needs and

behavior, environmental benefits and so on, and also reflects the

diversity of optimization methods. However, the optimal layout of

charging stations is rarely studied from the comprehensive

perspective of total social cost, and mature and recognized genetic

algorithms are used to solve the model. Also, typical charging station

cases like Ireland are seldom studied. Therefore, from the

perspective of total social cost, this paper constructs an optimal

distribution model of charging stations based on total social cost,

and iterates and simulates the optimal layout of charging stations

using a relatively recognized genetic algorithm with obvious advantages.

At the same time, in parameter setting, the model in this

paper no longer uses the traditional Euclidean distance, but calculates

the distance between the electric vehicle and the charging

station by introducing the road bending coefficient, so that the

model results are more in line with the actual demand. Finally, this

paper takes Ireland as an example and considers the demand for

charging stations in the five major cities of Ireland by introducing

coefficients to simulate the actual distribution of EV charging demand

in each city, so as to determine the optimal distribution

location of charging stations.

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