Study on EV Charging Station Location Planning Based on the Load Balance Principle with Agent-based AnyLogic Simulation

Ruifeng Shi [1], Shiyao Zheng [1], Chaoqun Zhang [1], Li Zhang[2]

1. School of Control and Computer Engineering, North China Electric Power University, Beijing 102206, China
E-mail: shi.ruifeng@126.com

2. The High-Technology Research and Development Center, The Ministry of Science and Technology, Beijing

Abstract: Electrification of the transportation sector is gradually becoming a global trend due to the environmental benefits of electric vehicles (EV), which not only helps to reduce greenhouse gas emissions, but also helps to reduce the burden of fossil fuel resources need. In order to analyze and evaluate the performance of different EV charging station location schemes, a pre-built AnyLogic Urban Dynamics model with considering population, business, housing, and transport infrastructure is employed to simulate the private EV electricity demand per hour in this paper. Furthermore, two typical EV charging station location schemes for Beijing City's urban area is adopted to illustrate the performance difference between these models, in which the ***plan A*** showed a serious load unbalance problem by contrast to the ***plan B***, which further demonstrates the value of our simulation model on helping the decision maker with such issues. We can find that the optimal EV charging station will avoid the waste of resource and meet the charging requirement.

Key Words: Electric vehicles, Charging station location planning, Agent-based modeling, AnyLogic

1 INTRODUCTION

Over the past two decades, China has experienced a high growth in motor vehicle population. Beijing, as China's political and cultural center, has suffered from the rapid vehicle growth and air pollution in recent years [1, 2]. The vehicle stock of Beijing has reached 5.3 million by the august 2013[3]. The rapid growth of vehicle stock in Beijing brings tremendous pressure not only on the road traffic, but also in energy consumption and environmental protection. In order to reduce the adverse effect of rapid growth of automobiles, new energy vehicles have been rapidly developed in the last few years [4]. As one of the first demonstration cities of "Ten Cities & Thousand Units Energy-saving and New Energy Vehicles Pilot Demonstration" Project, Beijing began to provide purchase subsidies for private consumers to encourage them to adopt new energy vehicles, in June 2010 [5].

In the future, with the increasing amount of electric vehicles, the load forecasting of charging stations will become an important issue for decision making in the power system. Reasonable charging station location planning will greatly promote the electric power supply quality for EV industry and improve the efficient use of electric energy.

Previous researches on EV simulation were mostly built up on Matlab platform without considering the urban dynamics theory. Differently, in this study, an Anylogic-based urban dynamics model was developed to simulate and evaluate the performance of the different EV charging station location strategies, which helps the decision maker to find more proper one by considering the load balancing problem between different stations.

2 THE AGENT-BASED SIMULATION SYSTEM of EV CHARGING STATION ON ANYLOGIC PLATFORM

2.1 Problem Description

In this paper, the AnyLogic model template adopted is the Agent-based Urban Dynamics. Figure 1 depicts the map of the range in Beijing's Second Ring, which includes the information of population, business, housing, and transport infrastructure. Figure 2 shows the layout of the urban area. The two types of active agents in the model are people and enterprises. We divide the city into 5 separate zones that differs from business and habitation comfort. People can change job if they feel uncomfortable (for example, due to high living expenses and low salary), and they can also move from one zone to another. People travel between home and work with private cars or by public transport. Zone properties on-the-fly can be changed and users' decisions can be observed immediately.

This work is supported by Nature Science Foundation of China under Grant Number 61203100, and the Fundamental Research Funds for the Central Universities (Grant Number 13MS19).

978-1-4799-3708-0/14/$31.00

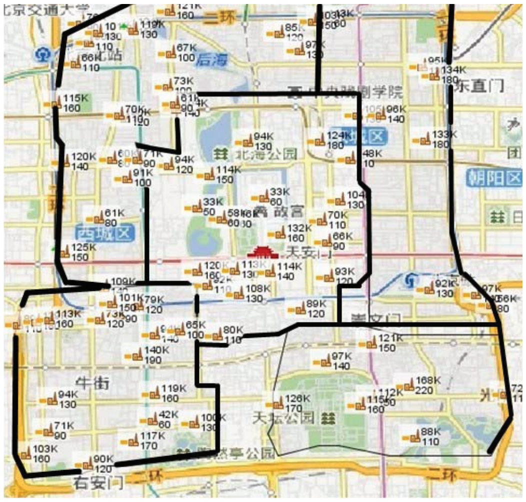


Fig 1. the mainland of Beijing second ring

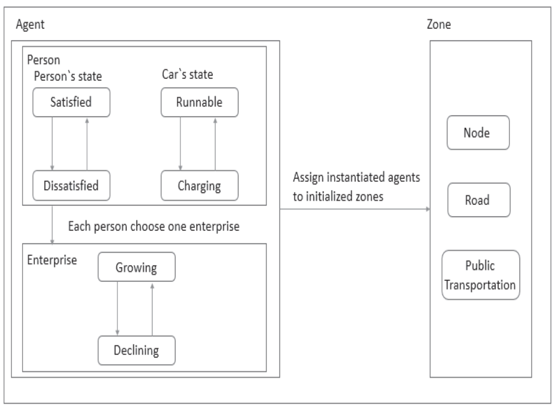


Fig 2. System structure chart: statechart

2.2 Simulation Environment – AnyLogic

AnyLogic is a programming and simulation environment, mainly aiming at modeling of hybrid systems, based on JAVA. It allows the user to combine different techniques and approaches such as differential equations, discrete events and agent based systems. These combination possibilities make it a very interesting tool for simulation of complex systems. A clear advantage of AnyLogic is the possibility to use JAVA code at any place of the program and thus expand or adopt the model to the programmers needs. Another neat feature of AnyLogic is the possibility to immediately create a JAVA applet of a working model, allowing it to be put on websites or distributed. In version 5.5 it took quite some time until one became accustomed with the program-layout, version 6.0 restructured the GUI, but still requires the user to get acquainted with it [6].

2.3 Agent-based Modeling with Anylogic

The Anylogic platform provides three types of simulation methods, including Agent-based model, discrete event model and system dynamics model. We employ the Agent-based modeling method in Anylogic to construct our urban dynamics system for EV charging station layout planning [7].

Agent-based modelling (ABM) technique is a powerful simulation method and has a lot of successful industrial applications during the past few years [8]. When constructing an agent-based model, the system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. Agents may execute various behaviors appropriate for the system they represent—for example, producing, consuming, or selling. Repetitive competitive interactions between agents are a feature of agent-based modeling, which relies on the power of computers to explore dynamics out of the reach of pure mathematical methods [9, 10].

2.4 State-based behavior: statecharts

In the agent-based modeling practice, Statecharts are extensively used to specify behavior of agents. Statecharts enable you to graphically capture different states of the agents, transitions between them, events that trigger those transitions, timing, and actions that the agent makes during its lifetime. Such construct as composite states enables to specify modes of agent operation. Agent may have several Statecharts working in parallel and interacting: this is useful when one models several aspects of the agent's life, e.g. education and family[11]. A Statechart is a visual construct that enables users to define event-driven and time-driven behavior of various objects. Statecharts are used a lot in agent based models, and also work well with process and system dynamics models.

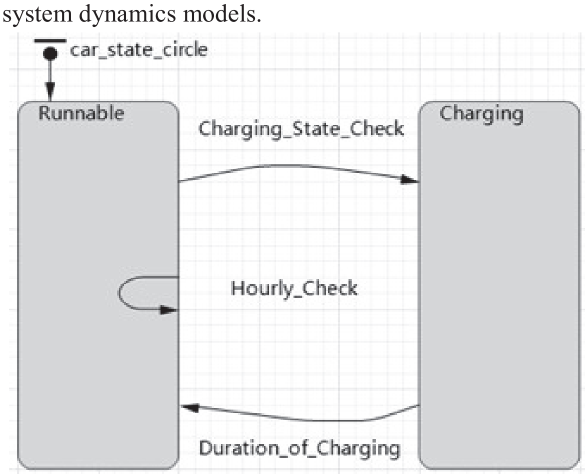


Fig 3. Car's Statechart definition in Anylogic

Statecharts consist of states and transitions. A state can be considered as a "concentrated history" of the object and also as a set of reactions to external events that determine the object's future. The reactions in a particular state are defined by transitions exiting that state. Each transition has a trigger, such as a message arrival, a condition, or a timeout. When a transition is taken, the state may change and a new set of reactions may become active. State transition is atomic and instantaneous. Arbitrary actions can be associated with transitions and with entering and exiting states.

As shown in the Figure 3, a Statechart of a car shifting between two states, named runnable and charging. Every car will be initialized as runnable, and the state of the car will be checked once an hour.

3 CASE STUDY

3.1 System Description

This paper will simulate two different programs about electric vehicle charging station location to obtain the approximate number of charging vehicles in different stations, thus we can configure and plan the position and number of the charging station.

This paper is based on the number of vehicles on each charging station per hour for statistical. Currently, the relevant departments usually choose better combination from multiple existed addresses which have mature condition. This article assumes that the planning department will locate and plan in the large traffic areas. As is showed in the Figure 1, we assume that the main electric vehicles flow is generated at the 12 point, among which there are 5 charging stations called 1-5 power station. We consider that there are 500 electric vehicles running within the range of the Second Ring Road of Beijing.

3.2 Parameters Setting

The car state will be checked once an hour and during different periods, the possibility of the car is charging will be variant. The charging time will be calculated according to both the energy balance and the charging mode chosen, namely fast-charging and slow-charging. In the model, an hourly timer is set to draw an hourly-updated time plot to forecast and display the EV load. The parameters setting are showed in the Table1.

Table1 Parameter settings

EV electricity demand per car	13 kwh/100km
Charging Mode	slow/fast
Private EV charging time(0%–100% slow)	5 hours
Private EV charging time(0%-100% fast)	0.8 hours
Fast mode charging power	45kw
Slow mode charging power	7kw
Possibility to charge (7pm – 7am) (slow)	0.7
Possibility to charge (7am – 5pm) (slow)	0.2
Possibility to charge (7pm – 10am) (fast)	0.1
Balance of battery when charging starts	$N(0.6,0.1^2)$

3.3 Results Analysis and Discussion

When running the Anylogic simulation, we can obtain several EV charging station location planning solutions, in which two typical schemes are selected for demonstration and discussion.

3.3.1 Location Scheme of *Plan A*

Figure 4 shows the program of ***Plan A***. Solid dots indicate the charging station location, and hollow points represent some large flow distribution points for electric vehicles.

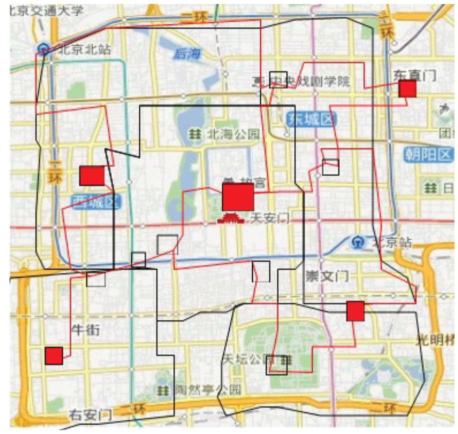
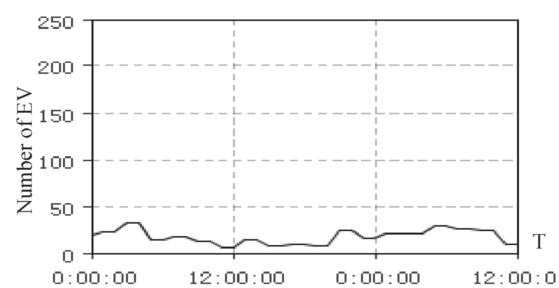
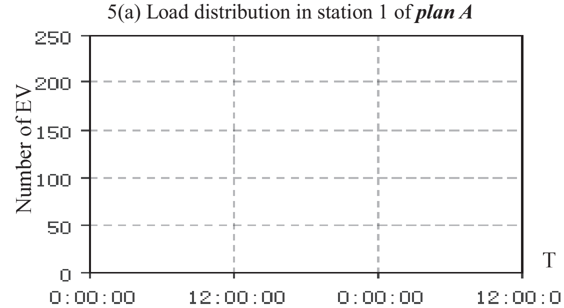


Fig.4. location program of *Plan A*

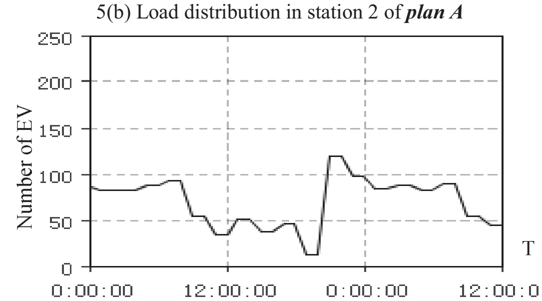
The number of vehicles' changing map of 1-5 charging station within 24 hours at different time are showed as follows in Figure 5, in which vertical coordinate means the number of EVs on the moment and the horizontal coordinate means the time of day.



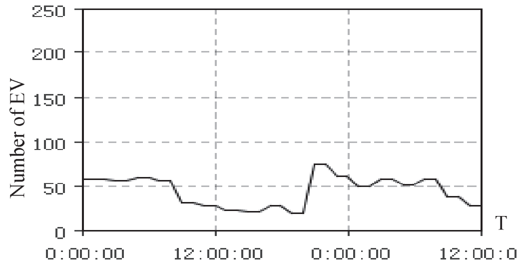
5(a) Load distribution in station 1 of ***plan A***



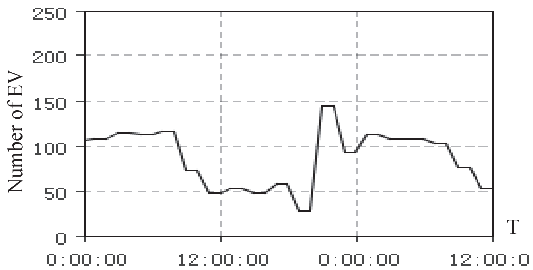
5(b) Load distribution in station 2 of ***plan A***



5(c) Load distribution in station 3 of *plan A*



5(d) Load distribution in station 4 of ***plan A***



5(e) Load distribution in station 1 of ***plan A***

Fig.5 Load distribution of each station in *plan A*

3.3.2 Location Scheme of *Plan B*

As showed in Figure 6, the Solid dots of *Plan B* shows the potential charging station location, and the hollow points represent some large EV charging needs in the region.

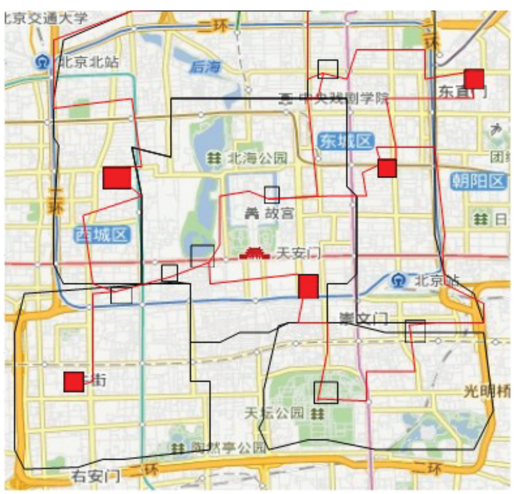
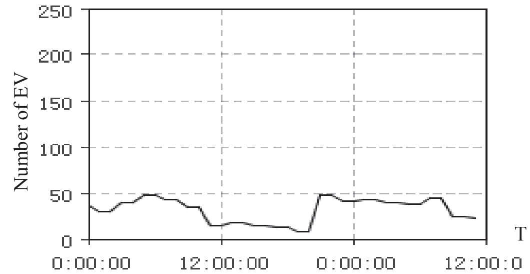
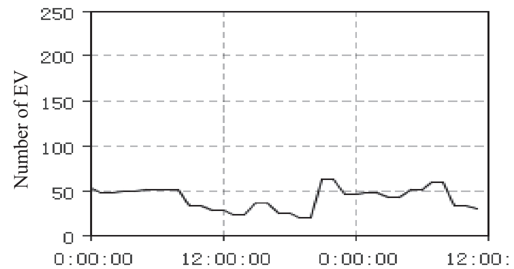


Fig 6. location program of *Plan B*

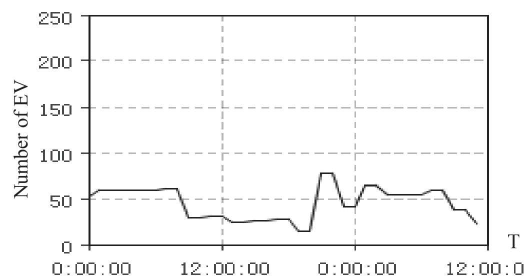
The number of vehicles' changing map of 1-5 charging station within 24 hours at different time are showed as follows in Figure 7, in which vertical coordinate means the number of EVs on the moment and the horizontal coordinate means the time of day.



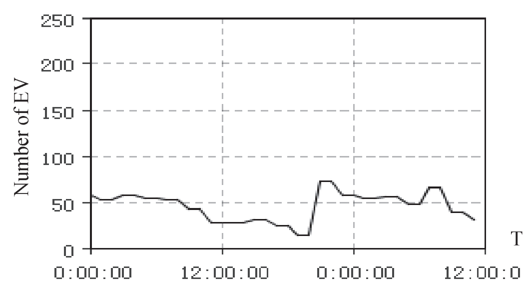
7(a) Load distribution in station 1 of *plan B*



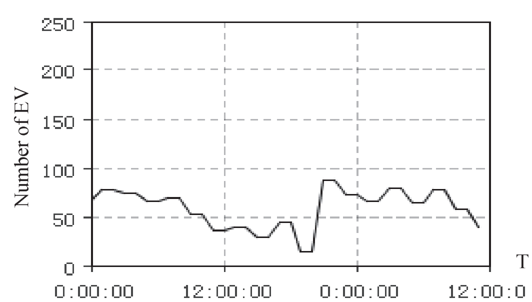
7(b) Load distribution in station 1 of *plan B*



7(c) Load distribution in station 1 of *plan B*



7(d) Load distribution in station 1 of *plan B*



7(e) Load distribution in station 1 of *plan B*

Fig.7 Load distribution of each station in *plan B*

As is showed in the ***Plan B***, all of the five stations have average load. This situation not only greatly ensures the rational allocation of charging requirements, but also avoids the waste of resources.

3.3.3 Analysis and Discussion

By comparing the two programs namely ***plan A*** and ***plan B***, we can find that different EV charging station plans will have a great impact on the local traffic and charging need in the same area. The ***plan B*** in contrast with ***plan A*** obviously has obvious advantages in some aspects. For example, it plays an active role in load balancing and the rational use of energy.

4 CONCLUSION

In this paper, by comparing the two plans for EV stations, we obtain a more reasonable result. The study shows that the rational layout of EV stations can prevent the waste of electric energy and meet the charging requirement for electric vehicles.

5 ACKNOWLEDGEMENTS

The authors would like to thank for Mr.Renfei Zou for his help with building the basic Anylogic model.

REFERENCES

[1] China Automotive Technology and Research Center. China Automotive Industry Yearbook[M]. Tianjin: China Automotive Industry Yearbook House, 2011. (in Chinese).

[2] Wang M, Huo H, Johnson L. Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO2 Emissions through 2050. Argonne:Argonne National Laboratory, ANL/ESD/06-6, 2006.

[3] http://www.bjjtgl.gov.cn/publish/portal0/

[4] He K, Huo K, Zhang Q. Oil consumption and CO2 emissions in China's road transport: current status, future trends, and policy implications. Energy Policy, 2005, 33(12):1499~1507.

[5] Yang Z, Wu Y. Projection of Automobile Energy Consumption and CO2 Emissions with Different Propulsion/Fuel System Scenarios in Beijing. in the Proceedings of 2nd IEEE International Conference on Remote Sensing, Environment and Transportation Engineering (RSETE), 2012: 1-4.

[6] Emrich S, Suslov S, Judex F. Fully Agent-Based Modelling of Epidemic Spread Using AnyLogic. Proc. EUROSIM. 2007: 9-13.

[7] Heindl A, Pokam G. Modeling software transactional memory with AnyLogic. In the Proceedings of the 2nd International Conference on Simulation Tools and Techniques. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, 2009: 10.

[8] Bonabeau E. Agent-based modeling: Methods and techniques for simulating human systems. Proceedings of the National Academy of Sciences of the United States of America, 2002, 99(Suppl 3): 7280-7287.

[9] Epstein J M, Axtell R. Growing artificial societies: social science from the bottom up. The MIT Press, 1996.

[10] Axelrod R M. The complexity of cooperation: Agent-based models of competition and collaboration. Princeton University Press, 1997.

[11] Borshchev A, Filippov A. From system dynamics and discrete event to practical agent based modeling: reasons, techniques, tools. In the Proceedings of the 22nd international conference of the system dynamics society, Oxford,UK,2004.