**Exploratory spatial analysis: Distribution and density changes of electric vehicle charging point in London between 2019 and 2020**

## 1 Instruction

Electric vehicle (EV) infrastructure is of importance for sustainable urban development. “UK e-charging market is recognised as one of the most advanced in Europe.” said by Martin Lucas who is a partner of Watson Farley & Williams LLP, an international law firm (2020). “Solve both the problems experienced within cities and the problems caused by cities” is used to define the term of urban sustainability (European Commission, 2006). Compared with traditional energy cars, EVs have significant advantages in terms of carbon emissions. However, urban residents who purchase new energy vehicles have to face the range anxiety, which has become a constraint on the development of the EV market. The sales of EVs are lower than expected because of the range anxiety of potential users (Bonges and Lusk, 2016).

For the sake of urban sustainability, the government has also put forward initiatives for the construction of supporting infrastructure for EVs in the past and present. For instance, the Office for Low EVs demonstrates that there will be approximately £30 million funds to invest in charging infrastructure in the next five years (Office for Low Emission Vehicles, 2014). Apart from that, the briefing published in House of Commons Library point that “in the Road to Zero Strategy, the Government has committed £400m to the public-private Charging Infrastructure Investment Fund” (Dempsey et al., 2020).

R, a programming language has been widely used in spatial analysis with help of multiple R packages such as “spatstat”, “GISTools” and etc. For instance, urban spatial data analysis has been used in Geographical Information Systems (GIS) to support the local authority policy (Pedro, Silva and Pinheiro, 2019). There are cases where researchers combined R tools and GIS to analysis urban spatial research topic. For example, researchers from the University of Texas at Dallas utilised R language tools to integrate satial analysis in a GIS environment to the Texas Census (Koo, Chun and Griffith, 2018). However, the challenge of representing data via spatial analysis still remains.

In this report, the research question will be investigated and discussed --- How do the distribution and density of EV charge change in London between 2019 and 2020? The aim is to apply theories from GIS, especially spatial analysis method to explore the distribution and density change of EV infrastructure in these two years. Firstly, I pre-process and clean the big data of charge points from UK government official website. One of the analysis methods is to apply spatial pattern analysis, based on the number of samples in two years, and compare their distribution and density to obtain the corresponding objective value. In addition, a reproducible analysis process is established using open source spatial analysis software RStudio, which applies the advanced spatial analysis methods in the field of clean energy and explores the content of spatial value to contribute to urban sustainability. This paper not only uses the geographical distribution and the density of charge points in each borough to understand the range anxiety but also provides suggestions for the layout of EV infrastructure through the interpretation of the policy about new energy development.

## 2 Literature Review

On the topic of spatial analysis EV charge points, there is some corresponding research in regions outside the UK such as North America and China. Based on GIS technology (the correlation of spatial density), a team analysed the functions and performance of electric vehicle charging infrastructure from eight indicators such as charger's intensity. According to the research conclusions, it was proposed that the free parking policy should be restricted to increase the rate of EV adoption (Lucas et al ., 2018)

Moreover, some researchers also used an analytic hierarchy process approach for electric vehicle charging stations in Amsterdam based on a geographical information system to select ideal locations for fast EV charging stations which helped the Fastned, a Dutch innovation company to optimise the layout of charge point (Ward, 2016).

In 2018, a team conducted this spatial autocorrelation study on the registration volume of UK electric vehicles and the location distribution of charging points. It not only found that the charging facilities installed by the local government such as charging stations have a positive correlation with the demand for electric vehicles, but also The electric vehicle market is differentiated because they found in the data that the adoption rate of EVs in neighbouring regions is also positively correlated (Morton et al., 2018).

The distribution of charge points and their usage habits are also related to urban planning. Some researchers have found that commuters need to charge their EVs during the morning peak hours. On the one hand, the charging facilities are located in public places where they work, and on the other hand, there are also facilities located at transportation hubs such as railway stations (Element Energy, 2021).

There is a relationship between the distribution of EV infrastructure. The research team from Delft University of Technology constructed a dynamic space model for the development of electric vehicle charging infrastructure in a metropolitan area. After testing the usage scenarios of different charging stations, they pointed out that the demand for charge points in the centre of the city is less than the supply (Wirges, Linder and Kessler, 2012) However, this simulation was executed in 2012. Nowadays, with the increase in the production of EVs and the decrease in the cost, the demand for charge points in urban areas will be different from the situation in the past.

## 3 Methodology

This exploratory analysis mainly applies R language with multiple packages into this spatial research topic. The following contents are data source, data pre-processing, spatial analysis method and visualisation.

### Data source

The NCR, a database of charge points for electric vehicles in the UK, is not only available for individuals but also for business data developer without charge (GOV.UK, 2020). Following the guidance from the UK government website, National Chargepoint Registry (NCR) dataset was collected in CSV format.

Spatial data is available on the London Datastore official website. The shape format file called Statistical GIS Boundary is the original geographic boundaries data which is the basis of our spatial analysis (London Datastore, 2020). One of the variables called "GSS\_CODE" can be identified via "sf", a R package, to present the London borough polygons in multiple types.

### Data Pre-processing

As shown in Figure 1, NCR, the original dataset, is filtered by a rule. Those rows which contain "London" string value such as "London Borough of Islington" remain when it comes to the variable "county". In the next step, 11 columns such as "post\_code" which is worthy to be utilised are selected into new data frame called London\_NCR. Before dplyr, a R package, count the frequency for each GSS\_CODE in this processed dataset, postcode\_lookup method from PostcodesioR package is applied to look up GSS\_CODE by identifying post code for each row. Finally, the data join method is used to merge two datasets (The shape file and London NCR) based on two common variables GSS\_CODE, which contributes to the visualization of the distribution and density.

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**Figure 1. The flow diagram of data cleaning and processing in RStudio**

## 4 Limitation

In terms of NCR dataset, it might be doubtful for the completeness of charge points in London. if the suppliers or individuals did not register their details of charge points on the UK government website. Besides, the accuracy of charge point is not quite perfect since the people, who had registered their charge stations, might forget to or be late to update their status or other information.

In the data processing section, there are several rows whose values is missing. In order to successfully and smoothly continue this spatial research, there is a likelihood that those rows with missing values are removed from dataset. This can affect the data analysis result and conclusion.

It is a challenge to exam what extend can geometric map represent EV charge point data. Frequency of charge point in every borough is not always equal to the density. The size of area also plays an important role in spatial analysis of density.

## 7 Conclusion

When it comes to choosing topic, it is hard to find a dataset which contains factor related to environment sustainability. It is also difficult to get static location dataset from EVs dataset. Fortunately, EV charge point become a good analysis objective because its static spatial data. Challenge can be also found in data processing. It was a tricky problem how to identify which boroughs each charge point belongs to. Through long hours of effort, the solution was found that one of R packages can add GSS\_CODE to every row via applying a custom function in the loop.

Considering the analysis reproducibility, data format is one of most essential part. And more variables can be contained into spatial analysis of charge points such as energy efficiency of EV chargers. For choosing map tools, it is appropriate to choose the interactive map which can be manipulated in a simple GUI. This method can present more data visualisation in only one window.

In the future development of this analysis, there is a tendency to combine more dimension such as temporal data. It is likely to collect more data in different years to analysis the trend of development of EV infrastructure and obtain more valuable insights from temporal and spatial data.

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