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

## 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 Martin Lucas. He 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 range anxiety, which has become a constraint on developing the EV market. EVs' sales are lower than expected because of the potential users' anxiety range (Bonges and Lusk, 2016).

For urban sustainability, the government has also put forward initiatives to construct supporting infrastructure for EVs in the past and present. For instance, the Office for Low EVs demonstrates that there will be approximately £30 million in 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 multiple R packages such as "spat stat," "GISTools," 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 analyse urban spatial research topics. For example, researchers from the University of Texas at Dallas utilised R language tools to integrate spatial analysis in a GIS environment to the Texas Census (Koo, Chun, and Griffith, 2018). However, the challenge of representing data via spatial analysis 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 the spatial analysis method, to explore the distribution and density change of EV infrastructure in these two years. Firstly, the big data of charge points is pre-processed and cleaned from the UK government official website. One of the analysis methods is to apply spatial pattern analysis. It is based on the number of samples in two years. It compares their distribution and density to obtain the corresponding objective value. Besides, a reproducible analysis process is established using open source spatial analysis software RStudio, which applies the advanced spatial analysis methods in clean energy and explores spatial value content to contribute to urban sustainability. This paper uses the geographical distribution and charge points' density in each borough to understand the range of anxiety. It provides suggestions for the layout of EV infrastructure by interpreting the policy about new energy development.

## 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: 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. It is based on a geographical information system to select ideal locations for fast EV charging stations. Which helped Fastned, a Dutch innovation company, optimise the layout charge point (Ward, 2016).

In 2018, a team conducted this spatial autocorrelation study on the registration volume of UK electric vehicles and charging points' location distribution. It found that the local government's charging facilities, such as charging stations, positively correlate with the demand for electric vehicles. However, the electric vehicle market is differentiated because they found 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. On the other hand, facilities are located at transportation hubs such as railway stations (Element Energy, 2021).

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

## Methodology

This exploratory analysis mainly applies R language with multiple packages to 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 available for individuals and business data developers without charge (GOV.UK, 2020). Following the UK government website's guidance, the National Charge point 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 based on our spatial analysis (London Datastore, 2020). One of the variables called "GSS\_CODE" can be identified via "sf," an 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 "postcode" worthy of being utilised are selected into a new data frame called London\_NCR. Before dplyr, an R package, count the frequency for each GSS\_CODE in this processed dataset. The postcode\_lookup method from the PostcodesioR package is applied to look up GSS\_CODE by identifying each row's postcode. Finally, the data join method is used to merge two datasets (The shapefile and London NCR) based on two standard variables GSS\_CODE, which contributes to the visualization of the distribution and density.

图示

中度可信度描述已自动生成**Figure 1. The flow diagram of data cleaning and processing in RStudio**

## Limitation

In terms of the NCR dataset, it might not be particular for London's completeness of charge points if the suppliers or individuals did not register their details of charge points on the UK government website. Besides, the accuracy of charge points 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 are missing. To successfully and smoothly continue this spatial research, there is a likelihood that those rows with missing values are removed from the dataset. It can affect the data analysis result and conclusion.

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

## Conclusion

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

Considering the analysis reproducibility, the data format is one of the essential parts. Furthermore, more variables can be contained in spatial analysis of charge points, such as EV chargers' energy efficiency. It is appropriate for choosing map tools to choose the interactive map that 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 dimensions, such as temporal data. It is likely to collect more data in different years to analyse EV infrastructure development and obtain more valuable insights from temporal and spatial data.

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