Keywords

Routing algorithms, node embeddings, electric vehicle charging, accessibility, EV, Sweden

Aim

This research project will assess the accessibility of publically available electric vehicle charging points/charging locations and their variation between geographic regions across the city of Gothenburg. It will also assess the results against the specific demographics of more and less accessibility regions in order to highlight areas more or less likely to adopt a shift to electric vehicles.

When evaluating the importance of accessibility of public charging points, research has shown that this is one of the biggest influencers to an individual's choice in whether to own a fully electric vehicle (McKinsey Centre for Future Mobility, 2024). In addition, key factors of publicly available charging points such as charging speed, cost and service reliability are key considerations of drivers when choosing a point to charge. In an extensive study by the McKinsey Centre for Future Mobility (MCFM) (2024), more than four times the number of people highlighted speed and cost as a consideration for selection over factors such as the proximity to a driver's destination, shown in

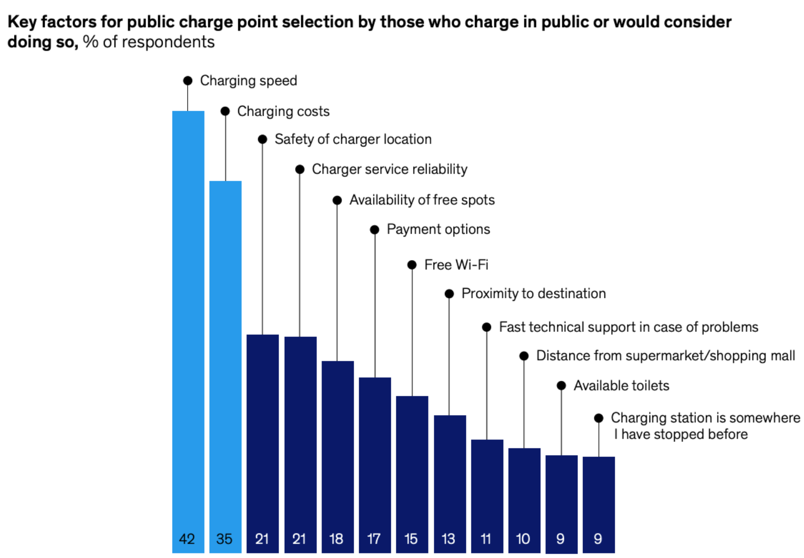

Figure 1.

Fig 1: McKinsey Centre for Future Mobility (MCFM), 2024, 'Key factors for public charge point selection by those who charge in public or would consider doing so'

Using a combination of both routing algorithms and node embeddings as the statistical foundation, this research will apply these methods to analyse the geographic road network of the city of Gothenburg and the locations of all charging points across the city. Demographic data of the associated neighbourhoods will then aid in supporting the underlying research goal and addressing several key research questions, which have been highlighted below.

Research questions

- What is the variability of accessibility of public charging points in the city of Gothenburg by geographic location?
- How does the availability of charging infrastructure correlate with income levels? Are lower-income neighbourhoods less likely to have more accessible charging points?
- Does the foreign-born status of a neighbourhood impact the likelihood of having a disproportionately lower access to public charging points, indicating the need for more wide-spread charging infrastructure?

Data

The two main data sources for this study will be road network data for the city of Gothenburg, along with electric vehicle charging network data for the same area. There are numerous suppliers of open source charging network data including various additional variables such as charge point type (type 2, CCS, CHAdeMO), uptime and number of chargers per point which can be used in this analysis. These additional variables will help in establishing a more accurate accessibility rating for each of the charging points when assessing the results.

In order to support the second research question addressing the regional demographics in relation to charging point accessibility, the publicly available RegSO (Regional statistical areas) database from Statistika (Sweden's Bureau of Statistics, 2024) will also be used. This dataset can provide a number of key demographics of each region within the city of Gothenburg, including foreign background, age, income levels and gender. An example of some available RegSO data has been provided in Figure 2.

	2022
Göteborg (Angered centrum-Agnesberg)	
Swedish background	
Male	684
Female	687
Foreign background	
Male	2 181
Female	2 228

Fig 2: Sample of the RegSO (Regional statistical areas) dataset for Gothenburg from Statistika

Method

The methods applied in this research paper were chosen based on their overall suitability for spatial road network analysis and their ability to model and analyse network dynamics within social systems. The first method chosen is routing algorithms, which uses the concept of *optimal paths* for data transmissions across a network. The second method to be used is node-embeddings, which instead maps nodes from the original network graph to vectors that allow for the proximity of nodes in space to portray their similarity or relationship to the original network. While routing algorithms emphasise data transmission efficiency, node embeddings contribute to a deeper understanding of the underlying structure and subsequent interactions within the network. Both of these chosen methods can work together to establish an accurate estimate of accessibility of charging points.

These two methods require the use of road networks of the local area, specifically the city of Gothenburg. This data is easily accessible and for this project an open-source R package such as `r package` can provide this data. In addition to the road network data, up to date charging point data will also be sourced and then applied to the road network in order to establish a network map of charging points across the city. This data can then be cleaned and processed into the appropriate format for applying a routing algorithm; additional R packages such as `sfnetworks` are built for handling this setup and preparing the datasets as an adjacency matrix. We can then apply an appropriate routing algorithm, such as dijkstra's algorithm, which then calculates the shortest paths from the `source node` to all other nodes. These distances, combined with additional data from the specific charging points, can then be used to establish an estimated level of `accessibility`.

When preparing for the additional node-embeddings method, the two datasets will be processed into nodes within a connected network of vectors and applied to the underlying graph (used previously for the routing algorithm). This can be achieved using an R package such as `node2vec` which simplifies this process. The resulting dictionary will then contain a set of vectors representing each node location (embedding), which can then be used to capture structural information of the nodes against the underlying network and again contribute to the estimation of a level of `accessibility` for each charging point.

The results of both models can then be combined with the demographic dataset from Statistika in order to test the remaining research questions and to identify any relationship between accessibility and regional demographics within Gothenburg City.

It is worth noting that the second method node embeddings is applied as a way to test the research questions against two different computational processes in order to support a stronger conclusion. It may arise that the first method alone is deemed sufficient in order to deliver substantial results with the chosen datasets.

References

McKinsey Centre for Future Mobility (MCFM), 2024, January 9, ‘Exploring consumer sentiment on electric-vehicle charging’, accessed 29 January 2024 <https://www.mckinsey.com/features/mckinsey-center-for-future-mobility/our-insights/exploring-consumer-sentiment-on-electric-vehicle-charging>

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