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Received: 22/10/2023

Accepted: 17/11/2023

Published: 18/11/2023

DOI: 10.48088/ejg.n.kok.14.4.046.052

ISSN: 1792-1341



*Short Communication: Geographic Insights in Brief**

# Options for micro-mobility data visualization

**Nikola Koktavá[1,*] & Jiří Horák[1]**

[1] VŠB-Technical University of Ostrava, Czech Republic

* Correspondence: 460919@mail.muni.cz

**Abstract:** The growth in technology has led to the enhancement of open data sources and the development of user-friendly open-source visualization and analysis tools. The evolution of these tools has resulted in the expansion of various analytical and visualization techniques. This research concentrates on the visualization methods used in micro-mobility studies. It briefly defines micro-mobility, including the key factors that influence it. The motivation for writing this paper was to identify visualization methods that are suitable for representing a variety of micro-mobility data types. The aim of this paper is to briefly review a number of visualization methods that are widely used in micro-mobility research.

**Keywords:** Micro-mobility, visualization, cartography, transport geography

## 1. Introduction

Cartographic visualizations represent key tools for understanding and managing spatial mobility in the modern world. A map is seen as a communication medium that helps a reader to understand a given issue through graphical data processing (MacEachren and Ganter, 1990). If an appropriate visualization method is chosen, then the map can serve as a support in understanding the issue at hand, but otherwise, it may cause distortions that could result in poor decisions.

Micro-mobility is a sustainable urban transportation solution that addresses short-distance travel needs, such as first and last-mile trips (Abduljabbar, Liyanage, and Dia, 2021). Micro-mobility is the use of primarily active forms of transport. This is mainly individual transport, and the means of transport can be either owned or hired as a service. Micro-mobility components include bicycles, electric skateboards, hoverboards, electric scooters and more (O'Hern and Estgfaeller, 2020). In micro-mobility research, various parameters play a crucial role in determining the feasibility and comfort of a trip. These parameters include road gradient, surface type, stopping features, docking stations, and crosswalks, as well as the presence of trees, benches, rest areas, shade, and similar amenities.

Choosing the right visualization method for micro-mobility data can be challenging due to the diverse nature of the datasets, both in terms of content and spatial units. In micro-mobility research, the following components are often visualized: origin and destination points, routes between origin and destination, ways (sidewalks, pathways, cycling paths, cycling lanes, etc.), access points (transit stops, bike stations, etc.), barriers (curbs, steps, etc.), amenities (trees, shade, benches, pubs, repair services) and others. The choice of visualization depends on the type of users, data types and volume, purpose, time, software, etc.

The article aims to shed light on commonly used visualization methods and contribute to the understanding of their advantages and disadvantages.

## 2. Visualization methods for micro-mobility

Due to the frequent usage of point features in micro-mobility studies, the point map is one of the most frequently used methods of visualization, especially due to its simplicity. In micro-mobility, it is used to show the location of shared transportation providers (Štraub and Gajda, 2020), bike stands or docking stations (Gehrke et al., 2021; Peters and MacKenzie, 2019), or to show nodes on a sidewalk network (Rhoads et al., 2023). This method is not suitable for a large amount of data. For a large number of point-localized data, two types of visualizations are suitable: a dot map and, a proportional point map. The dot map is suitable for creating an idea of the distribution and density of the monitored trips, and clearly displays the origin and final destinations of trips (A. Li et al., 2022), on-street parking spaces (Kimpton et al., 2021) or accessibility of inhabitants to certain locations (Milias and Psyllidis, 2023). In micro-mobility, the proportional point map is used to determine the number of providers (Yang et al. 2020), the number of trips from origin to destination point (Qian et al., 2020) and the number of parking spaces (Pérez-Fernández a García-Palomares 2021) and is suitable for quickly identifying busy locations or popular origin-destination points. Proportional point symbol maps were also used to visualize several indicators of walkability (Bartzokas-Tsiompras et al., 2021).

The most straightforward approach for visualizing linear data is to employ a line map. This type of map enables the representation of transportation networks or cycling paths, as demonstrated by Ayfantopoulou et al. (2022). Line maps are also useful for depicting the route between

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two points (e.g., Liu and Miller, 2022). However, when dealing with large datasets, line maps can become cluttered and difficult to interpret. In such situations, it is recommended to utilize flow maps instead (Zaragozí, Trilles, and Gutiérrez, 2021), as they provide a clear representation of the flow between various destinations, however, unlike line maps, do not copy, for example, the road network. For both line maps and flow maps, we can add arrows to show the direction of travel.

The proportional symbols may show the determination of the number of providers in cities (Yang et al., 2020), the distribution of origin and destination locations (Qian, Jaller, and Niemeier, 2020), parking locations (Pérez-Fernández and García-Palomares ,2021), and accessibility assessment (Liu and Miller 2022), or may show the design of shared transportation locations (Ayfantopoulou et al., 2022). Furthermore, the line proportional symbols (Figure 1) are used for road network volume (McKenzie, 2020), for parking design and volume (Pérez-Fernández and García-Palomares, 2021), and for the distribution of origins and destinations (Qian et al., 2020).

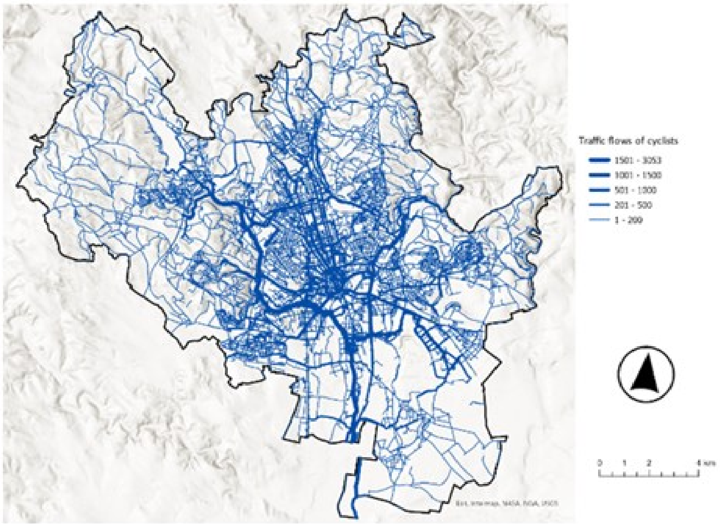


**Figure 1.** Traffic flows of cyclists in 2022, Data source: data.brno.cz

The choropleth map is widely considered to be the most commonly utilized method in thematic cartography (Slocum and McMaster, 2022). For visualizing micro-mobility data, it can be employed to represent the distribution of various events across different regions, such as accidents (Yang et al., 2020), impacted communities (Qian et al. 2020), the number of intersecting trips (Huo et al., 2021; McKenzie, 2019; 2020; Peters and MacKenzie, 2019), and the spatial distribution of resources or facilities (Jiao, Degen, and Azimian, 2022; Kimpton et al., 2021). A special treatment should be applied for data with significant outliers.

Isochrone maps (Figure 2) are well-suited for visualizing temporal accessibility (O'Sullivan, Morrison, a Shearer 2000; Wang et al. 2022). The advantage of this method is that it might be related to the real terrain (e.g., taking into consideration its steepness) and is not influenced by administrative borders. The disadvantage is that it is only suitable for displaying relationships of a maximum of two locations based on time availability.

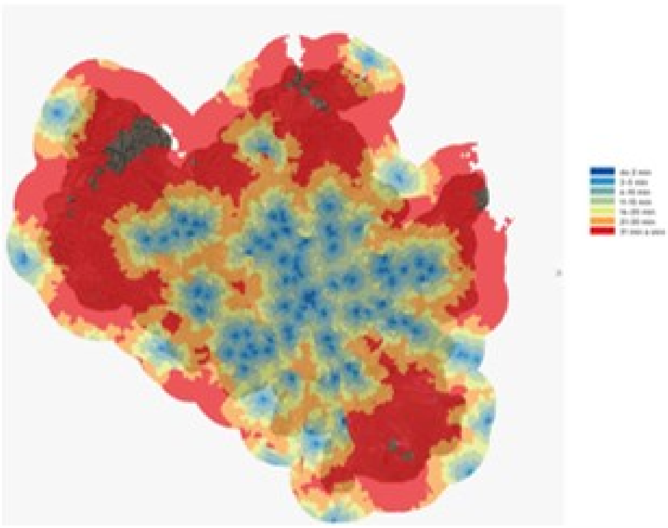

**Figure 2.** Walking accessibility to shops in Brno, retrieved from KAM Brno (©2023, http://webmaps.kambrno.cz/maloobchod/ - A map application dedicated to retail that provides information on retail accessibility by car, on foot or by bike)

https://doi.org/10.48088/ejg.n.kok.14.4.046.052

Among more advanced visualization methods 3D maps can be employed. They enable the presentation of data in high spatial resolution, joint portrayal of more features and delivery of more illustrative messages for policy makers (Figure 3). Usually, it is difficult to balance the amount of presented information, an appropriate axonometric projection and a scale. Users may face issues with spatial orientation and reading values. It seems such visualizations are effective especially in tools where readers may interactively change the view.

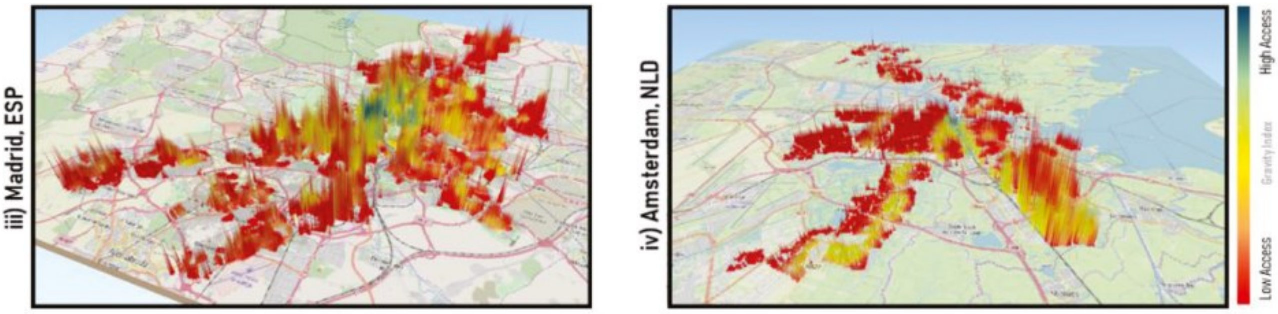


**Figure 3.** Distribution of Americans' migrants and their gravity-based accessibility scores to transit (Bartzokas-Tsiompras and Photis, 2019)

The kernel map is generally used to visualize the density of events (Figure 4). Different cell shapes (e.g., squares, diamonds, hexagons, triangles, etc.) and the various radii (bandwidths) can be set to properly model the spatial distribution of investigated phenomena. In micro-mobility research this method is appropriate for visualizing the density of origin or destination points (Ayfantopoulou et al., 2022; Heumann et al. 2021; Pérez-Fernández and García-Palomares, 2021), as well as the density distribution of provided services (Liu and Miller, 2022) or to view the density of pedestrian streets (Bartzokas-Tsiompras, 2022). Kernel maps are used by the Walk & the City Center website[1] for microscale walkability indicators for 26 European cities (Bartzokas-Tsiompras et al., 2021; 2023), 2021).

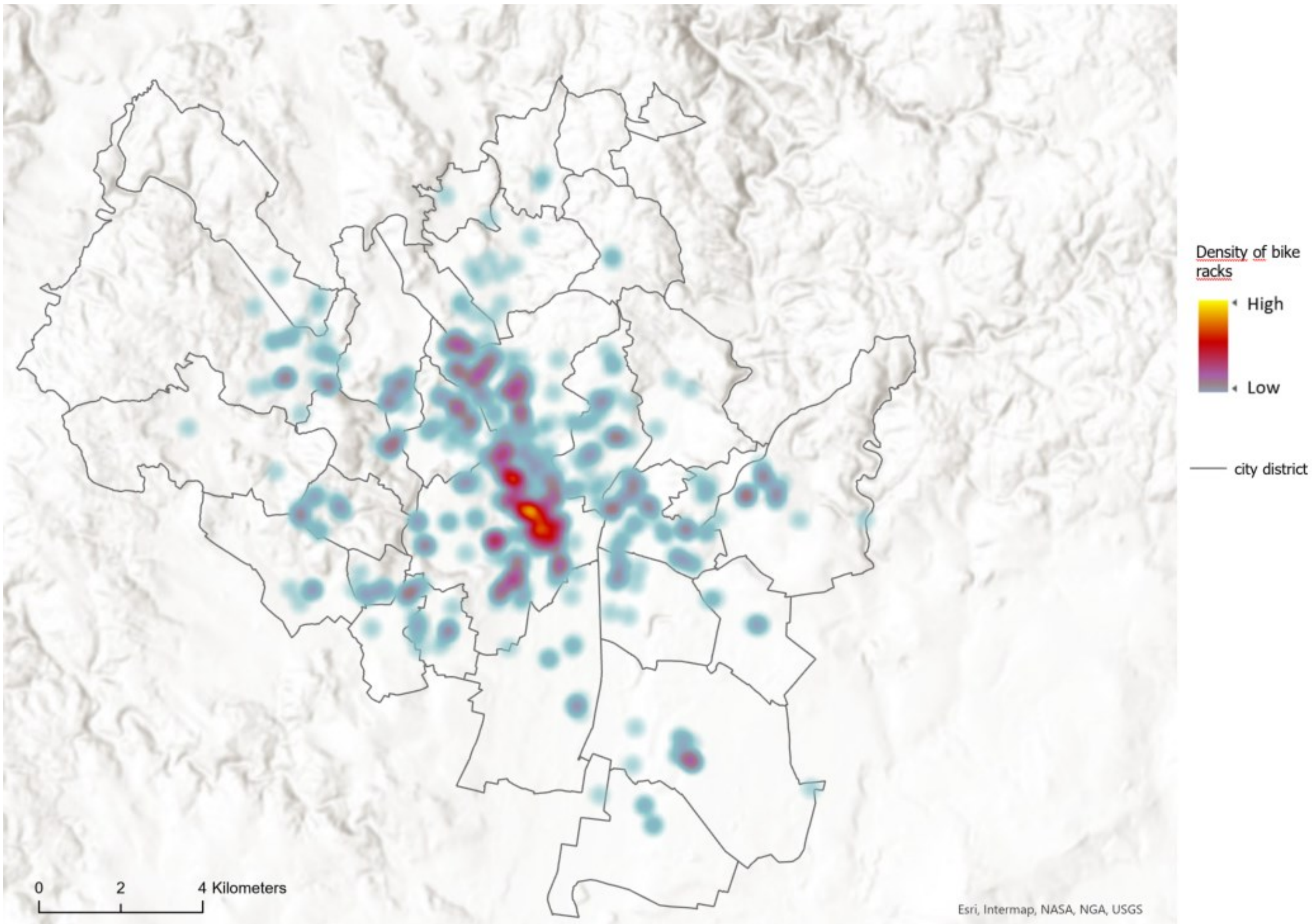


**Figure 4.** Density of bike racks in Brno in 2023 (data source: data.brno.cz, created by author)

[1] https://geochoros.survey.ntua.gr/walkandthecitycenter/

To depict the detail path of space-time mobility (H. Li et al. 2022; Thévenin and Vuidel, 2021), the space-time cube (Figure 5) method was employed. This is a 3-dimensional visualization that enables the simultaneous representation of distance and time. While this method is more computationally intensive than the previously described methods, it is well-suited for the analysis of smaller datasets. Zhao et al., 2021 used an interactive environment and used a space-time cube, correlation graphs and other methods to visualize mobility.

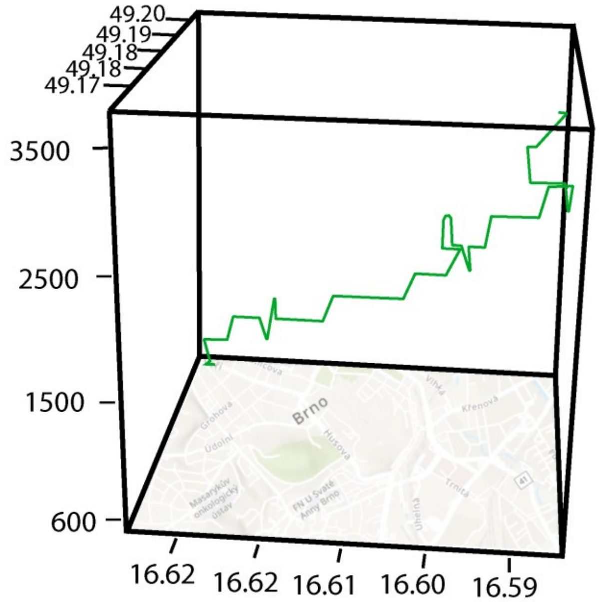


**Figure 5.** Space-time cube of the journey from origin to destination (self-sourced data). Note: Horizontal axes: LAT, LON; vertical axis time in seconds since the beginning of the journey

The Urban Mobility Fingerprint (Reimann, Gros, and Schmitt, 2017) is a method that aims to provide a picture of the movement of people and vehicles in a specific urban environment. It helps to identify areas with a greater need for improvement, to optimize public transport routing, to plan infrastructure investments and to create more efficient and sustainable urban mobility (Fortini and Davis 2018). The left side displays travel distances by car within a 15-minute range, while the right side illustrates the 'Street DNA,' indicating the deviation of routes from the direct connection, scaled by travel time (Figure 6).


**Figure 6.** Mobility Fingerprint and Street DNA of New York City, retrieved from (Reimann et al. 2017)

It is also useful to distinguish individual and aggregated methods of visualization. While individual visualization (e.g., point or line maps) provides accurate, detailed information, aggregated methods (e.g., proportional symbols, flow maps, choropleth maps, isochrones, or kernel density maps) utilize space-time aggregation to densify information and provide more clear patterns in cases of a high volume of individual data.

Aggregated methods can be useful for comparing spatial data on a large scale, but there is a risk that empirically defined zones will not be comparable. This is because the zones may be defined based on different criteria. One way to address this problem is to use a zoning system that

https://doi.org/10.48088/ejg.n.kok.14.4.046.052

is designed to be comparable, such as the ClockBoard zoning system. Another way to address the problem of comparability is to use statistical methods to adjust the aggregated values for different zones by taking into account features of the zones (Lovelace et al., 2022).

It should be noted that the present article is not exhaustive in its treatment of the methods used in micro-mobility research, but rather constitutes a compilation of the most frequently encountered methods in studies focused on micro-mobility visualization.

## 3. Recommendation

It is essential to recognize that simple visualizations might not always yield optimal results. Instead, it is advisable to experiment with various visualizations and carefully select the most suitable ones. Moreover, a judicious combination of individual visualizations can be employed to enhance the overall impact. Incorporating animations can further facilitate effective communication with the public. The choice of visualization should consider factors such as the intended users, the types and volume of data, the goal, the available time, and the software used. By considering these elements, researchers can create impactful visual representations of their data.

In most of the reviewed papers, there were maps which were lacking on certain cartographic aspects such as: incomplete legend (Kimpton et al., 2021; Liu & Miller, 2022; Peters & MacKenzie, 2019), missing legend (Agriesti et al., 2022), colour in the map did not match the colour in the legend (McKenzie, 2020), and a poorly chosen legend (Kimpton et al., 2021). There were also inconsistencies in the visualization of individual features, e.g., once the boundary was shown as a line the second time as a polygon (McKenzie, 2020).

In summary, the following criteria can be recommended for selection of a suitable visualization:

- Fidelity,
- Data volume,
- Readability,
- Aesthetic,
- Availability,
- Convenience of use.

Quadrant diagrams were created to support the selection of appropriate visualization methods (Figure 7).

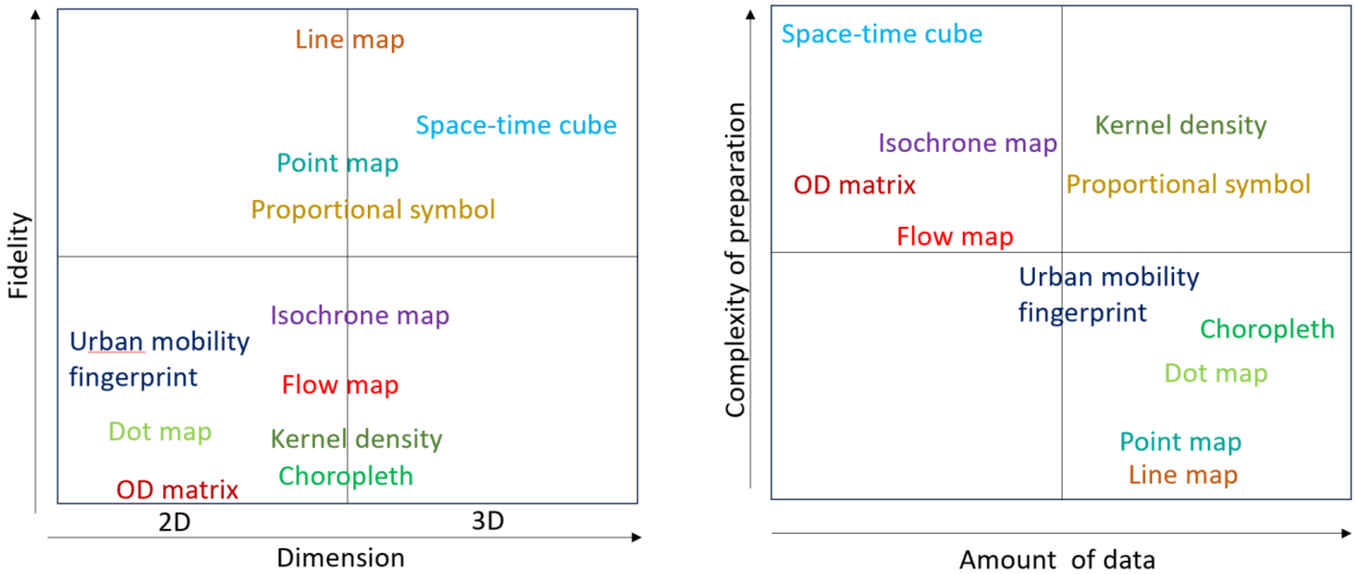


**Figure 7.** Position of selected visualization methods from the point of view of the fidelity, dimension, complexity of preparation, and data volume

To create cartographic visualizations, it is not obligatory to use only GIS software (e.g., ArcGIS). Many programming languages, especially open-source programming languages, provide useful tools for the creation of suitable visualizations (Lovelace, 2021). E.g., GeoPandas and Matplotlib libraries are available in Python, libraries ggplot2, sf and rgl are recommended tools in R.

## 4. Conclusions

In the reviewed papers, there was a lack of (good quality) maps and mostly only basic visualizations were used. The choice of visualizations should be based on the data used rather than on the simplicity of preparation. In this paper, the different types of visualizations used for displaying micro-mobility data were evaluated.

This article offers a brief overview of visualizations used in the field of micro-mobility. The findings are not based on any users' survey or experiment. Its primary intention is not to provide a detailed description, but rather to serve as a starting point for further exploration of visualizations in the context of micro-mobility. The limitations of this paper lie in its limited depth of analysis, which could be expanded by adding tools and programming languages used for visualizing micro-mobility data. Another possible approach is to test different visualization methods with their users using eye tracking and then to evaluate the results.

Visualizing micro-mobility data requires careful consideration of different visualization methods. The choice should be based on the type of data, the spatial units, and the specific research objectives. By using appropriate visualization techniques, researchers can effectively analyze and communicate micro-mobility data, leading to better decision making in urban transport planning and management.

https://doi.org/10.48088/ejg.n.kok.14.4.046.052

**Acknowledgement:** This study is partially supported by Grant of SGS No. SP2023/84, Faculty of Mining and Geology, VSB - Technical University Ostrava, Czech Republic.

**Conflicts of Interest:** The author declares no conflict of interest.

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