Benefits and Pitfalls of Emotional and Mobility Meb Mapping. A Case Study of Two Czech Cities

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Abstract

The aim of the paper is to describe the advantages and weaknesses of participatory mapping and to compare them with a questionnaire survey. This case study focuses on two medium-sized cities and their surrounding municipalities, Ostrava (OV) and Hradec Kralove (HK), both located in the Czech Republic. The study works with a questionnaire survey from the research agency STEM/MARK (n=536, PAPI method 86%, CAWI method 14%) from 2022. The main objective of this research was to find out the mobility goals of seniors. Overall, respondents reported 479 goals, with respondents identifying 23 types of important goals in HK and 24 types in OV, with shopping (37 and 24% respectively), doctor (19 and 22%), family (10 and 13%), walking (8 and 6%) and friends (5 and 4%) identified as top priorities. Maximum clustering was assessed at a distance of 370 m for web mapping targets ($p<0.05$). Survey targets reached maximum clustering at a distance of 140 m in HK and 200 m in OV ($p<0.05$). The results of web mobility mapping show that natural places and parks are the most common attractive places for respondents. On the other hand, in OV, locations with noisy people or homeless people, as well as industry and brownfields, are identified as repulsive places. In HK, roads, traffic and some public buildings are perceived as the main repulsive places. The perception of railway stations is ambiguous. This study contributes to the discussion on the validity of participatory mapping, showing the importance of careful survey design and data preprocessing. The results from the web mapping were compared with the results from the questionnaire survey (PAPI method) to better describe the advantages and weaknesses of web mapping.

1. Introduction

The popularity of participative mapping is continuously growing and is becoming an essential tool in involving citizens in urban planning, architectural solutions and transport design. Citizens can quickly and easily review proposals and variants, explore models and visualizations, express their opinions, pin comments, and vote on their favourites (Ribeiro and Ribeiro 2016). Participative mapping is sometimes linked to discussion in a dedicated group on social media such as X or Facebook.

Such local and usually temporal projects are coupled with global platforms where people can continually develop a joint mapping project such as Ushahidi or OpenStreetMap (Pánek, 2016, 2019). The primary conceptual frameworks of emotional data collection have been specified by Griffin and Mcquoid (2012).

Emotional maps and comparable local mapping tools are used extensively in Czechia, particularly when mapping citizens' attitudes towards both physical and social features of the urban environment. Quantitative assessment of mapping results can help urban planners gain a better understanding of citizens' perceptions and improve the targeting of planned measures (Camara, Camboim, and Bravo 2021). Discussion sometimes arises about the validity of such mapping, complementation or substitution of traditional questionnaire surveys.

The objective of the paper is to discuss the benefits and weaknesses of such tools and to compare them with traditional questionnaire surveys. The specific research question is if there are substantial differences between mobility destinations reported by the respondents of a PAPI (pen-and-paper-interview) questionnaire and those recorded by a web-based survey. The role of open-source technology is emphasized in relation to the use of OSM, Leaflet, R and dbsmss.

2. Data and Materials

The case study is focused on two middle-sized Czech cities, Ostrava (OV) and Hradec Kralove (HK), and selected rural municipalities in their vicinity. Since the goal of the project is to explore seniors' perception, accessibility, and spatial mobility, all participants are seniors (age 65 and above).

The questionnaire survey was conducted in 2022 by the research agency STEM/MARK (n=536, PAPI method 86%, CAWI method 14%; 30 trained interviewers).

Quota sampling used stratification by age, gender, territory, and urbanization based on census data.

Any surveys' raw data contains some inaccuracies, mistakes, or strange answers from people who misinterpret the questions, misuse the tools, give trial answers, want to tamper the data or outputs, or have other concerns (e.g., losing privacy). In the quota-based survey, deviations from the anticipated quota shares may lead to the removal of some respondents or the need to conduct an additional survey. To meet planned quotas 40-46% of the questionnaires were additionally collected in two villages. The data's temporal consistency is, however, weakened by such modifications.

The primary aim of the survey was to discover seniors' mobility targets. We asked for their dwelling location and, in free text, for a list of up to four of their most important targets, ranked by their perceived importance, written in descending order. We asked for addresses or other relevant details in order to specify the residences' and the targets' locations.

Respondents reported 1666 targets (3.1 targets per respondent on average).

Simultaneously, the emotional and mobility web map applications were released. The intention was to parallelly map typical mobility targets along with the associated feelings and perceptions.

Both on-line surveys were promoted by local clubs, social services and seniors' homes.

In the emotional map application, respondents mark one or more locations, including attractive and repulsive places, obstacles to movement, attractive and repulsive paths, and their approximate dwelling location. They also define their age group and mobility limitations. The location of dwelling is specified by a large symbol (a circle) to avoid respondents' fear of privacy loss. Each marked target can be further characterised by 16 reasons with a multiple-choice option (incl. free text) for attractivity or repulsivity of this location or path. Furthermore, the respondents specify the frequency of their visits and provide details about factors influencing the positive or negative feelings associated with this location or path. Three main factors were described in detail - weather conditions, time (temporal conditions, schedule) and social aspects of the visit (such as going with others or by oneself) (Horak et al. 2022).
Respondents recorded 107 attractive places, 45 repulsive places, 30 barriers, 68 attractive paths and 21 repulsive paths.
In the mobility map, respondents again indicate their age group and select a region for a detailed description. Then they begin to list one or more of their favourite locations in the following categories: home, workplace, retail, pharmacy, post office, doctor, supermarket, ATM, place of worship, services, park, restaurant, visiting family or friends, garden or cottage, or other place. It was possible to skip questions if the respondent did not wish to mark any locations, and they had the option to mark extra points for each question. After marking each point, they can indicate the applicable mode of transport and frequency of attendance.
A total of 479 targets were reported by respondents. The results section contains a description of the typology in detail.
Quota sampling was not applied on the web mapping data. Only respondents who were 65 years of age or older and who lived in the HK and OV regions were considered relevant.

3. Methodology

3.1 Processing of locations from questionnaires

Questionnaires were processed in two directions – target classification, and their geocoding.
First, the inspection of free-text records allows for the elimination of unusual and odd targets while also classifying them into predefined target categories. The exploration discovered 27 categories suitable for formalization and classification.
Further, geocoding using the Google Maps Geocoding API was carried out. The googleway R library's geocode() function was applied to each address, sending the request via the API. The not null answers returned longitude and latitude coordinates.
A snippet of function utilizing Google API is as follows:

```
geocode_addresses <- function(adress) {
  result <- geocode(adress)
  if (!is.na(result$lon) & !is.na(result$lat)) {
    return(c(lon = result$lon, lat = result$lat))
  } else {
    return(NA)
  }
}
```

To be able to conduct geocoding via the API, Google API key is needed. The key is available for free and it can accessed after enabling the Geocoding API extension in the Google developer portal.
While some earlier testing indicates that it can successfully geocode Czech addresses in about half of case (e.g., Fojtík et al., 2016, where Google Maps Geocoding API succeed in 54% of cases while Here Maps API reached 53%), the current results for our cases are far worse: 22% in HK and 18% in Ostrava. This demonstrates that using free text is not satisfactory and that a more sophisticated solution is required. We decided to apply a wider range of geocoding methods to increase the accuracy.
An exploration of location types was performed to better understand locations' variability and the writing styles.
The procedures listed below were applied in the given order:

1) Automatic geocoding using an address (full address or a partial address such as a street name)
2) Matching both the reported travel time and the name of target with relevant candidates. It was necessary to find all corresponding target types in the database based on OSM, search the shortest path in QGIS and measure travel time for various available targets with the corresponding name. Then match the most appropriate target according to the type and travel time reported by the respondent.
3) Match the name of the target in the database. In the case of multiple outputs (results), the closest one was selected.
4) Manual interpretation using all available information.

To fulfil tasks No.2 and 3, we utilized OpenStreetMap geodataset "Point of interest" (POI for short). OpenStreetMap (OSM) is a collaborative project that creates a free editable map of the world. It emerged in 2004 (Hakla and Weber, 2008) and has since grown into a vast repository of geographic data contributed by volunteers from around the world (Neis and Zipf, 2012). Unlike proprietary mapping services like Google Maps, OSM data is open and freely available for anyone to use, download, or modify under the Open Database License (ODbL).
The OSM database contains various types of geographic information, including (Neis and Zipf, 2012):
Nodes: represent single points on the map, such as a particular building or landmark.
Ways: represent ordered lists of nodes that represent linear features like roads, rivers, or hiking trails.
Relations: used to describe more complex spatial relationships between elements, such as a route composed of multiple ways, etc.
OSM's point of interest dataset is comprised of nodes tagged with specific attributes to denote various features including, but not limited to, restaurants, hotels, parks, hospitals, schools, gas stations, and ATMs.
These tags allow users to search for and identify points of interest within the map data. Additionally, OSM supports the addition of custom tags, enabling contributors to annotate the map with a wide range of information beyond the basic categories.
The OSM POI dataset was downloaded from https://www.openstreetmap.org/ using Geofabrik's free download server. The Czech Republic subregion's data were downloaded in the .shp.zip format. POIs for our study regions, Hradec Kralove and Ostrava, were filtered using municipality boundaries and spatial operations.

In our case, geocoding was successful only for 65% of records. Among these, 18% were geocoded by utilizing the complete address, 53% were automatically geocoded by finding the nearest matching destination, 24% were geocoded manually with interpretation, and 5% were geocoded but only to the centre of the street (respondent provided only the street/square name).

3.2 Development of web mapping

The EmotionalMaps.eu platform was utilized in the development of web mapping applications. This platform uses a MySQL database and PHP on the backend, and the Leaflet library on the frontend, according to Panek et al. (2021). The website's interactivity is mostly handled using the open-source JavaScript library jQuery (https://jquery.com/). The open-source front-end development framework Boostrap (https://getbootstrap.com/) is used to design the layout and user interface components. Since 2014 this platform was used in over 200 various emotional mapping projects in several European countries (Pánek et al. 2021). The web mapping application doesn't require installation, registration, or other specific plugins, in contrast to Ushahidi, Umap, ArcGIS Online, and numerous other applications. It is compatible with all browsers.

GeoJSON format is used to store data received from the front end in the MySQL database by utilizing the ST_GeomFromGeoJSON function. This function converts the supplied GeoJSON data into a geometry and saves it as a geometry object in the database. GeoJSON is an open format that may be used to encode and represent a wide range of geographic features and data structures, including properties that are non-spatial. All the respondent characteristics, feelings and system attributed data are recorded in this study.

User_id is automatically generated for each session, thus multiple inputs from one person are not distinguished.

Through the web applications, the respondents were asked about their favourite and repulsive places and paths, barriers (emotional maps) and mobility destinations (mobility maps) coupled with recording purposes and preferences.

The processing of exported GeoJSON data is done via the following steps:

a) Data clearing – trials and errors need to be eliminated. Verifying the date of data insertion and comments is a helpful method for this process.
b) Adding a municipality identifier using spatial join
c) Importing GeoJSON data to the database for further processing such as adding respondent classification to each feeling item
d) Calculating distances between a residency and targets. Euclidean distances were calculated in the database, road distances were processed in QGIS.
e) Visual verification of paths and points

3.3 M-function

To analyse the spatial distributions of targets, M-function was utilized. The M function, originally defined by (Marcon and Puech, 2010), is a cumulative function that provides, for each distance, the relative frequency of neighbours of a given type in relation to the same ratio throughout the entire study region. A Case-Control Design of this function was introduced in (Marcon et al., 2012) where the benchmark point set represents controls and the cases point set represents all points of interest. The concept behind the case-control M function is as follows. Consider an area in which various facilities (e.g., shops, banks, theatres, etc.) are located. Facilities of a selected type (cases) are considered as clustered, if the proportion of cases is larger than the proportion of the whole population (controls) in the vicinity (Lang et al., 2020).

The R programming language and the "dbmss" library were used to calculate the M function values. The "dbmss" package contains spatial statistic functions of distance to characterize the spatial structures of mapped objects (Marcon et al., 2015). The "dbmssEnvelope" object, particularly "MEnvelope", was utilized to calculate the M and global envelope values. Iteration was used to compute the global envelope: At every step (i.e., distance (r)), the simulations that reach one of the top or lower values at any distance are eliminated. The process is repeated until parameters "Alpha" and "Number of simulations" are reached. At all distances, the global envelope is generated with the remaining upper and lower boundaries. Interpolation is used if the exact ratio cannot be reached (Marcon et al., 2020). The parameters of the MEnvelope function were defined as follows:

```
autoplot(
        MEnvelope(
                DATA,
                r = seq(0,1000,50),
                NumberOfSimulations = 1000,
                Alpha = 0.05,
            ReferenceType = "controls",
                NeighborType = "cases",
              CaseControl = TRUE,
                SimulationType = "RandomLocation",
                Global = TRUE),
        LegendLabels=c("Observed", "Expected", "Confidence\n envelope"),
        main = "M function", cex.main=1)
```

To calculate the M function, OSM POI was used for an underlying (benchmark) dataset.

Filtered points of interest serve as controls for the M function's Case-Control variant.

Two case-point sets were analysed for each city: questionnaire targets and web mapping targets, and the results were compared.

4. Results

4.1 Basic issues

An analysis of respondent records assembled by 3 distinct methods indicate and document certain typical issues that arise when these methods are used. Among the most important issues, the following ones are demonstrated – bias in the samples of respondents, issues with recording geometries, and accuracy of the target locations. Finally, we discuss the differences in targets, which represent the survey's main goal.

4.1.1 Bias in the samples of respondents: The differences of the respondents' profiles between the three methods of survey demonstrate a strong bias towards younger and healthier seniors in the case of web mapping (Figure 1).

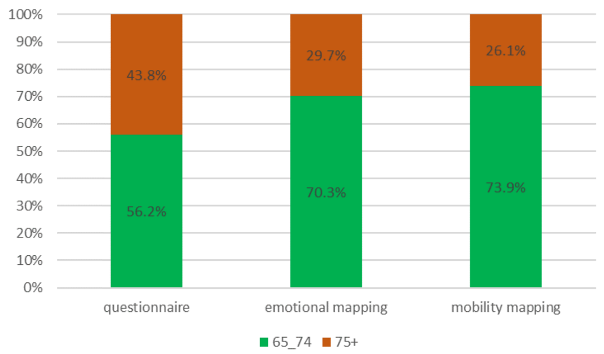

Figure 1. Age distribution of respondents of questionnaires, emotional and mobility mapping.

4.1.2 Different accuracy of target locations: The accuracy of location varies. While the web mapping application instantly provides coordinates for each location, the targets from questionnaires require geocoding. A higher ratio of unlocated targets is typical for questionnaires, which is due to the inability to record the target's entire address (usually respondents do not know such details).

4.1.3 Issues with recording geometries: The biggest problems were encountered when drawing lines to specify attractive and repulsive paths. We obtained only 32 records from OV and 29 records from HK, with evident errors in 19% and 40% of records, respectively (Figure 2). Cleaning such data requires expert inspection to distinguish valuable records (Figure 3).

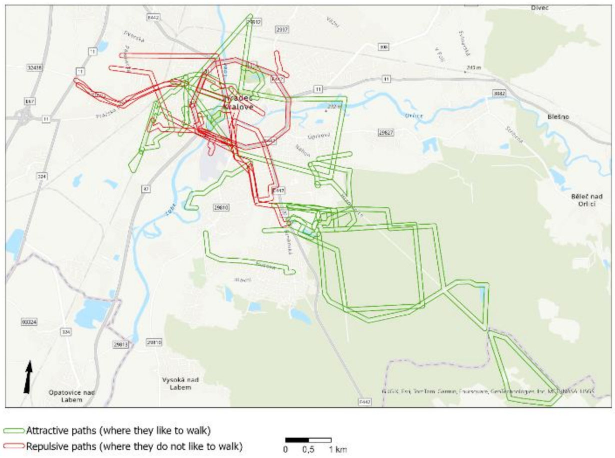

Figure 2. Originally recorded paths in the HK region (with errors).

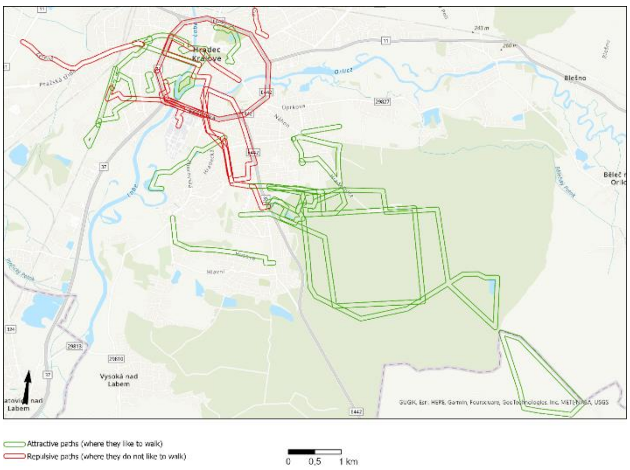

Figure 3. Cleaned recorded paths in the HK region.

4.2 Places identified by questionnaires and by web mapping: The dwellings of questionnaire respondents were recorded in high rates ranging from 93-97% (Figure 4) which is sufficient for further analysis.

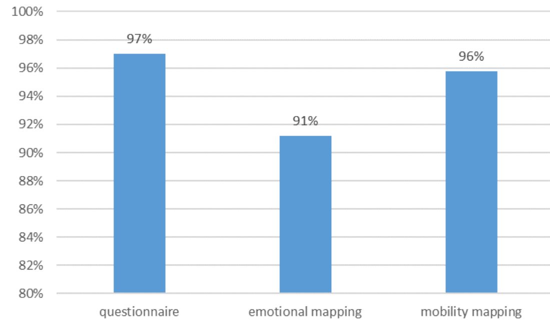

Figure 4. Share of located dwellings in questionnaires, emotional and mobility mapping.

Questionnaire respondents identified 23 types of important targets in HK and 24 in OV, with the following main priorities: shopping (37 and 24%, resp.), doctor (19 and 22%), family (10 and 13%), walking (8 and 6%), and friends (5 and 4%). A further issue is that 5% of free-text destinations contained multiple targets.

The **web emotional mapping** provided 182 point locations (fig. 5). Among the attractive places, we identified natural places (45% in both cities), parks (OV 23%, HK 15%), green streets (HK 11%), sport facilities (OV 10%), houses, public buildings, hypermarkets, and railway stations. Places with loud people (OV 35%), industry (OV 23%, HK 5%), roads and traffic (OV 6%, HK 22%), public buildings (HK 17%), brown fields (OV 12%), parks, hypermarkets, houses, railway stations and other similar sites were considered repulsive. Respondents in both cities demonstrate similar attitudes towards attractive places (mainly nature and parks), with some minor differences that can be seen (e.g., OV respondents' preferences for sport facilities). However, a clear divergence in the types of repulsive places is recognised between the cities – residents of HK complain mainly about roads, traffic and some public buildings; residents of OV express strong concerns about localities with loud/homeless people, industries and brown fields.

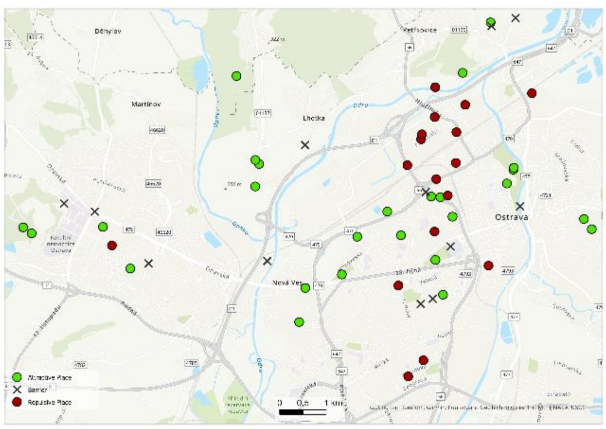

Figure 5. Distribution of recorded emotional places in Ostrava.

The **web mobility mapping** requested specification of favourite locations for one or more targets in the 13 categories, the respondent's residence, and the "other" target (specified by free text). Respondents identified 16 kinds of important targets in HK (Figure *6*) and 12 in OV (Figure *7*) with the following priorities: retail (15 and 12%, respectively), supermarket (12 both), pharmacy (12 and 10%), post office (11 and 10%). Such a flat distribution is caused by the respondents' tendency to mark only one target per category.

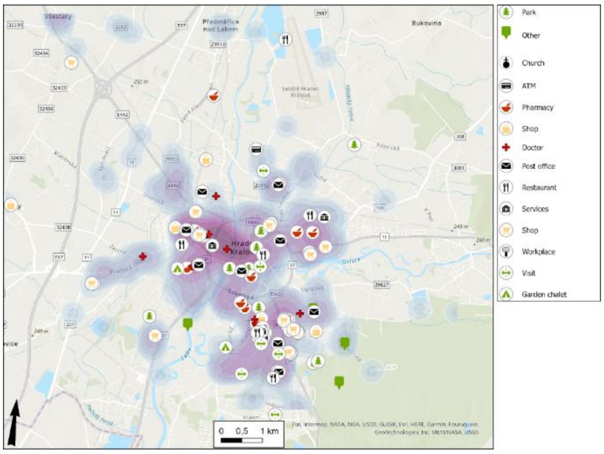

Figure 6. Distribution of registered (recognized) mobility targets in Hradec Kralove.

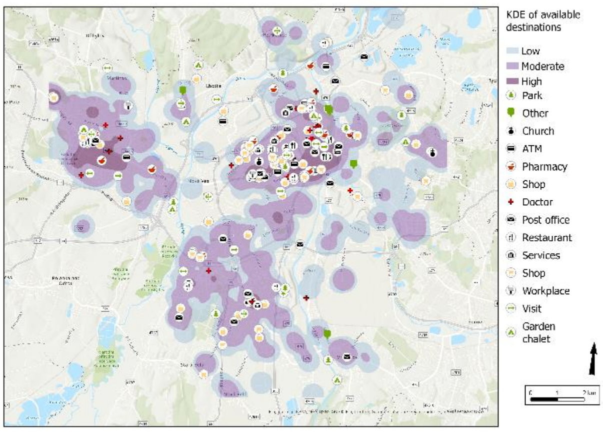

Figure 7. Distribution of registered (recognized) mobility targets in Ostrava.

4.3 Comparison of targets

One of the most important issues is whether we can discover the same targets or at least identify their distribution according to the same pattern (the same placement strategy) from different survey sources.

The average Euclidean distance of targets around each dwelling is 2,781 m in the case of geocoded questionnaires and 7,048 m in the case of web mobility mapping. Average road distance (calculated by the QGIS shortest path using OSM data) is 3,811 m for questionnaires and 10,042 m for web mobility mapping. These values indicate much larger radii of targets selected by web survey respondents than PAPI respondents.

To analyse and compare distribution of targets we applied analysis of distances between dwelling and relevant targets for each respondent and analysis of targets' clustering.

The clustering of both indicated targets (questionnaire and web mapping) compared to all targets available in OpenStreetMap is confirmed by the M-function (Figure 8-Figure 11).

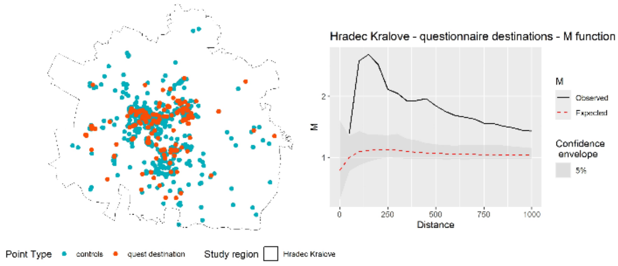

Figure 8. Spatial distribution and M-function for questionnaire targets in Hradec Kralove.

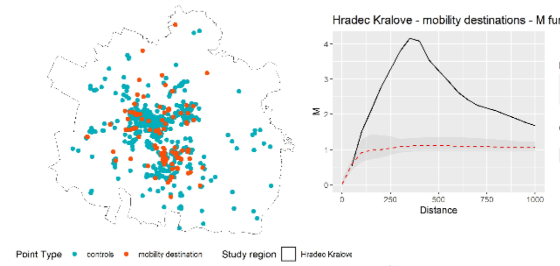

Figure 9. Spatial distribution and M-function for online mobility targets in Hradec Kralove.

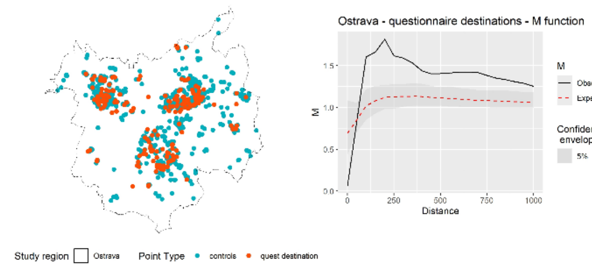

Figure 10. Spatial distribution and M-function for questionnaire targets in Ostrava.

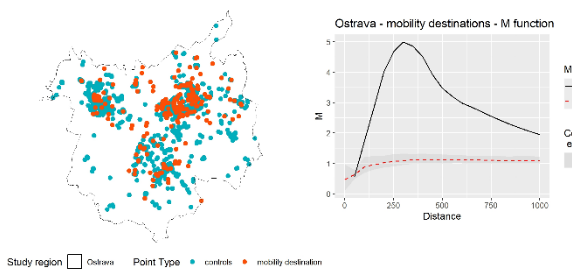

Figure 11. Spatial distribution and M-function for online mobility targets in Ostrava.

The maximal clustering was evaluated at a distance of 370 m in the case of web mapping targets (p<0.05). This was confirmed in both cities (Figure 9, Figure 11) and represents an interesting coincidence. It indicates that the target clusters' average size is roughly this diameter.

The questionnaire targets reached their maximal clustering at a distance of 140 m in HK and 200 m in Ostrava (Figure *10*) for (p<0.05) (Figure 8). These sizes may be interpreted as an average diameter of target clusters in these cities. Cluster sizes are larger in Ostrava than in HK, which is explained by the city's larger area, and less compact, more fragmented form of urbanisation which was imprinted onto the POI pattern.

The results confirmed much shorter distances and smaller clusters of targets in the case of questionnaire surveys than in the web mapping.

It suggests that, in contrast to web-based online targets mapping, researchers utilising traditional questionnaire surveys (the PAPI approach) may have anticipated recording targets in considerably closer neighbourhoods to the respondents' dwelling and at shorter distances.

5. Discussion

Many scholars discuss advantages and disadvantages of PAPI method versus electronic mode of surveying, however not specifically for target or emotional mapping. They usually emphasise the ease of use of PAPI (no technical expertise required, easy to administer, and easy to analyse the output data), better sample coverage and a broad reach to include a variety of population members, better control of the questionnaire and flexibility to assist respondents, higher response rate, and improved safety (respondents data protection, higher willingness to answer sensitive questions) (e.g., Bowling 2005, Tourangeau et al. 2000). Personal, face-to-face interaction between an interviewer and a respondent is an important aspect that increases the legitimacy of the survey, the response rate and motivation of respondents. However, it can also lead to interviewer biases due to social desirability, “yes-saying” or Hawthorn effects, and problems with communication style (Bowling, 2005).

Our results confirm these common benefits and highlight mainly the positive influence of trained interviewers which helps to establish an unbiased quota sampling and population coverage, increases the response rate and assists respondents to understand questions or, in post-processing, helps to clarify some recorded answers. However, for mapping of targets we can see additional important disadvantages. A limited range (length) of PAPI questionnaires due to limited time for each respondent issued in a limited number of specified targets. In our case only 3 targets per respondent on average.

The main problem is to specify location of targets. Rarely are respondents able to provide a full address of their targets. They do not know the address of the common targets such as a shop, services, worship, offices, cemetery, etc. For specific targets such as family members, relatives, or friends they are usually not willing to record the full address due to privacy protection. There are minor sets of targets where the precise location is expected such as workplace (employer), where the address is less sensitive. Some answers for target cannot be located at all. Some answers (e.g., walking, family, dog, trip, garden, sport) indicate misinterpretation and recording the purpose instead of the location.

Furthermore, respondents who lack adequate computer skill and do not have enough training are not able to reliably record more complex geometries than simple points. Especially line strings following scattered or diverging paths may be difficult to be accurately recorded.

On the other hand, the electronic mode of surveying is usually well-received due to its efficient data collection and processing, cost reduction, usage of predefined options, follow-up capability, and lack of interviewer bias (Tourangeau et al. 2000, Wikstrøm 2023). Based on our web mapping results we can underline the design’s attractiveness, its ability to reduce cognitive burden (customized map design using tools such as zoom or pan, use of illustrative pictures or icons, interactive help), error reduction (consistency monitoring and integrity constraints), and ability for accurate positioning of the targets which was crucial for our goal. The main disadvantages include lack of respondent profile validation, respondents’ bias towards more technically skilled and wealthier people, privacy concerns, low response rate, and potential for duplicate responses. When comparing web mapping to questionnaires, we discovered 18 percentage points fewer seniors 75 years of age and older using the tool. Serious age bias was also discovered in the web-based major participatory planning exercise that was carried out in Helsinki (Kahila-Tani et al., 2015), where different locations were indicated on a map. Very old age groups were underrepresented (6 times for 70+) and very young group were overrepresented (9 times for age<19).

Differences between the applied PAPI method and web mobility mapping are imprinted in differences of recorded targets. The free text used in questionnaires enables one to distinguish 23-24 categories of destinations, while 13 predefined categories for web mapping was extended by only 3 additional categories from optional free text reporting. The most important destinations in all survey modes are shops which is in accordance with many other authors (Vidovićová et al., 2013, Engels and Liu 2011, Zhang et al. 2019). The other categories are similar, but the frequencies and priorities are different for each mode and also different from the ratio/priorities declared in other case studies (Plazinic, Jovic 2018). These differences reflect the differences in various social contexts, mainly between countries.

The analysis of distances from a residence to an indicated real target shows more clustering for questionnaire targets around a residence than for those from web mobility mapping. The average distance from dwelling to destinations are significantly shorter for targets collected by the PAPI method than by the web mobility mapping. However, the selection of closer destinations in the questionnaire is influenced by the age bias of respondents and by the limited number of requested targets (up to four).

We have applied the M-function which represents a basic analytical tool easily available due to dbmss library for R. More advanced interpretation is provided by the W function (Kukuliac, Horak 2017) which is able to distinguish and describe various complex clustering situations and would be exploited in future research.

Our results of emotional mapping indicated that the natural places and parks are perceived by respondents as the most frequent attractive places (68% in OV, 60% in HK). It confirms the results from Olomouc where 25% of the answers mentioned city parks as pleasant public spaces (Pánek, 2019). Many divergent results are found for repulsive places. In OV, localities with loud or homeless people are marked the most, followed by industries and brown fields. In HK, roads, traffic and some public buildings are perceived as the main repulsive places. The perception of railway stations is ambiguous (some people label the HK railway station as attractive and others as a repulsive place). In Olomouc the main train station was the place where people often felt unsafe (16% of answers). As in Ostrava, areas associated with groups of homeless people are among other unsafe places in Olomouc as well (Pánek, 2019). This, however, was not emphasized in HK.

6. Conclusion

The study contributes to the discussion on the validity of participatory mapping and sheds a light on the importance of careful survey preparation and thorough data pre-processing.

Emotional maps document different attitudes and preferences mainly for repulsive places, while attractive locations receive a similar evaluation. It seems to reflect local conditions and more sensitive perceptions of negative environmental factors.

For a better description of the pros and cons of web mapping we compared their results with results of the traditional questionnaire survey (PAPI method). The main benefits are the effective data collection and processing, the use of predefined options, the potential for follow-up, the absence of interviewer bias, the improved design, and the ability of accurate target positioning.

On the other hand, the main disadvantages include no validation of the respondent profile, respondents' bias towards wealthier and more technically skilled people, privacy concerns, and low response rate.

The results of target spatial distribution confirm significant differences between data obtained from questionnaires and web mobility mapping. Joining and analysing such data together is challenging. Researchers must be aware selecting the appropriate survey mode, match their expectations with the available tools and methods, allot enough time for pilot studies, modify questionnaires for the intended purpose and respondent group, use well-trained interviewers for face-to-face surveys, find appropriate marketing strategies, distribute the survey legitimately and widely to achieve a high response rate and accuracy, apply strict data control for web mapping and other validation rules, verify the validity and reliability of the results prior to conducting subsequent analyses and interpretations.

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