# Smart Planning: Different Participation Methods for Evaluating Spatial Attractiveness

*Christian Mueller, Ulrike Klein, Angela Hof*

(M. Sc. Christian Mueller, Bochum University of Applied Sciences, Lennershofstraße 140, 44801 Bochum, christian1.mueller@hs-bochum.de)

(Prof. Dr. rer. nat. Ulrike Klein, Bochum University of Applied Sciences, Lennershofstraße 140, 44801 Bochum, ulrike.klein@hs-bochum.de)

(Ass.-Prof. Dr. rer. nat. Angela Hof, Paris Lodron University of Salzburg, Hellbrunner Straße 34, 5020 Salzburg, Austria, angela.hof@sbg.ac.at)

## 1 ABSTRACT

The smart city approach provides many promising advantages considering overall planning efficiency in response to societal and ecological challenges. A smart city may only be as desirable as its performance in increasing the quality of life of its citizens. One benchmark is the level of citizen well-being and if they feel comfortable within the given space. This raises the question as to how an overall self-perceived well-being or "spatial attractiveness" can be measured and compared. In this study, different participatory concepts and methods were applied in order to measure and quantify spatial attractiveness. Firstly, a questionnaire-based survey was conducted. In the second step, a web map application for online participation was created and promoted using touchscreen devices. Additionally, ArcGIS for Desktop was used for gathering data as well as an analogue map on which citizens were ask to draw on. The questionnaire-based survey provided the most detailed information on citizens demands and the analogue map was the most easy-to-use method. However, data post processing for these surveys might be time consuming. As ArcGIS for Desktop required some prior GIS knowledge to be used properly, it proved to be less suitable for participative data collection. Results show that the web map application was suitable to gather considerable amounts of data in a relatively short time period. Consistent with the smart planning approach, the collected participation data can be accessed online in real time and effectively be implemented into sustainable urban planning. In a case study, the collected data were analyzed in combination with walking distances to facilities of basic goods and services. Plausibility checks were iteratively carried out in dialogue with local planning authorities and decision-makers. This study demonstrates approaches to merge citizen participation and spatial analysis into novel geospatial tools and to increase urban planning efficiency.

## 2 INTRODUCTION

In the 21st century urban decision makers find themselves simultaneously faced with a plethora of societal and ecological challenges, such as matters of antithetical land issue interests (Dai et al., 2001; Rojas et al., 2009), effects of urban heat islands (Oke, 1967; Arnfield, 2003), heavy rain and flood risk mitigation (Tyrna & Hochschild, 2010), the ecological conditions of freshwater bodies (EC 2000), clean drinking water supply (Kummu et al., 2010), consequences of demographic change (Champion, 2001; Danielzyk et al., 2010) and demand-adapted local supply with basic services (Libbe et al., 2010). Many of these issues seem to be best understood as interconnected components of a complex system, which is the city (Klein & Müller, 2012; H2020, 2015). One mayor advantage of the smart city approach is that it matches the interconnected nature of these complex systems with a holistic perspective which might create a basis for addressing urban challenges in an integrated way. This approach usually comprehends the smart city as a datafied self-monitoring and ICT-driven system which allows for real-time emergency response and highly efficient use of resources (e.g. Bowerman et al., 2000; Allwinkle & Cruickshannk, 2011). In addition to these rather technological aspects, human and institutional factors of smart cities have been emphasized which might augment community-based and humane policies and ensure an innovative and creative atmosphere (Nam & Pardo, 2011a, b; Neirotti et al., 2014). As promising as this approach might be, citizens might share concerns regarding the datafication of their city, namely overly technocratic governance, dependency on few large companies, susceptibility to software failures or cyber-attacks, enforced digital social inequities and privacy issues to the degree of over-surveillance of citizens (Chourabi et al., 2012; Kitchin, 2014). These concerns should be taken seriously and emphasize that smart cities can only be convincing for their citizens if the prime normative objective is to increase their overall quality of life.

One benchmark for this is the level of self-perceived well-being and if citizens feel comfortable within the given space. The perception of whether a place is attractive or not is highly subjective, individually different and geographically bound. This raises the question as to how spatial attractiveness can be quantified,


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compared and best integrated in a participatory way into everyday policy and decision making, such as traffic planning, notification of deficiencies or general reshaping of municipalities. In this meta-study, we applied and compared different participatory concepts and methods in order to measure and quantify spatial attractiveness. For the study area of Herdecke (Southern Ruhr-Area, North Rhine Westphalia, Germany) we investigated the advantages and drawbacks of (a) a questionnaire-based survey, (b) a web map application, (c) an offline map application and (d) drawing on an analogue map. We compare and assess the representativity of certain target groups, the willingness for participation, the level of detail of the obtained data and privacy issues for each of these methods. We furthermore evaluate the suitability of each method within the scope of the smart city approach.

Ultimately, we demonstrate as to how participation data can be merged with additional spatial information in order to develop a novel and smart geospatial analysis tool. For this purpose, we combine the obtained participation data with accessibility analysis for local facilities of basic services. Drawing on this example, we show how highly ICT-based aspects of the smart city concept can be used for augmenting citizen participation and providing new insights for a more evidence-base smart governance.

## 3 METHODS

### 3.1 Study Area

The city of Herdecke is located at the river Ruhr at the southern rim of the metropolitan Ruhr-Area, south of the larger cities of Bochum and Dortmund in Western Germany. The Ruhr-Area is an agglomeration of several larger and medium sized cities. It covers an area of approximately 4,436 km² and is inhabited by approximately 5 million citizens which results in a population density of about 1,200 citizens per km² (RVR, 2016). The city of Herdecke itself is inhabited by approximately 24,200 people. It is particularly affected by demographic change which can be observed in the whole region. Around the city center, 39.9 % of the total population is older than 60 years while this share of the population is even increasing. At the same time the total number of people living in this area has decreased by approximately 30.9 % in 10 years from the 2000 to 2010 (Lüneborg, 2013).

### 3.2 Questionnaire-based survey

This motivated the city's administration to launch a questionnaire-based survey in the summer of 2015 which primarily focused on living comfort for senior citizens but also the accessibility of local facilities. One questionnaire was sent to each of the 13,461 households within the city's boundaries. The questions were stated as multiple choices, Likert scales and free text. One Likert-scale question went into the "Wohlfühlfaktor" which is a German term describing the overall self-perceived well-being. As most of the questionnaires could be georeferenced on street-level or at least on the city-district-level, the "Wohlfühlfaktor" might be regarded as comparable to the term of "spatial attractiveness". Since the possibility to fill in the questionnaire online was only taken up by approximately 30 people, most of the questionnaires had to be digitized, categorized, georeferenced and organized in a excel-file as well as explicitly in space using a Geographic Information System (GIS). In order to assess the representativity of this survey, the numbers of participating citizens per demographic group and city district were compared to data provided by the local citizen registration office.

### 3.3 Web map application

In a second step, a web application was designed as one of three additional methods for citizen participation which were promoted by the local press and during two Christmas markets in Herdecke in December 2015. The main objective of this method was a very short participation time period of a maximum of 10 seconds in order to motivate as many citizens as possible of various demographic groups. In order to achieve this, the application was easy-to-use and stated only one obligatory question. After reassuring that the participants were citizens of the city of Herdecke, they were asked to evaluate the spatial attractiveness by using a topographic base map to point out where they would "feel good" or "not feel good" (Fig. 1). In addition, participants had the non-obligatory option to leave a comment and to assign themselves to one or more of the target groups "family with child up to the age of 11", "youngster up to the age of 18", "student or apprentice", "single or childless couple", "senior or mobility restricted citizen", "migratory background", "female", and/or "male". While conducting this survey, the interviewers aimed at specifically reaching out equally to all target groups which was facilitated by face-to-face communication. The application was prepared in ArcGIS 10.2 for Desktop, uploaded into a web map in ArcOnline and integrated into the final web application using the Web AppBuilder by Esri. Using touchscreen devices during face-to-face interviews considerably enhanced the usability of the application. Additionally, flyers with QR-codes and URLs were handed out to citizens allowing to participate using mobile phones or home computers.

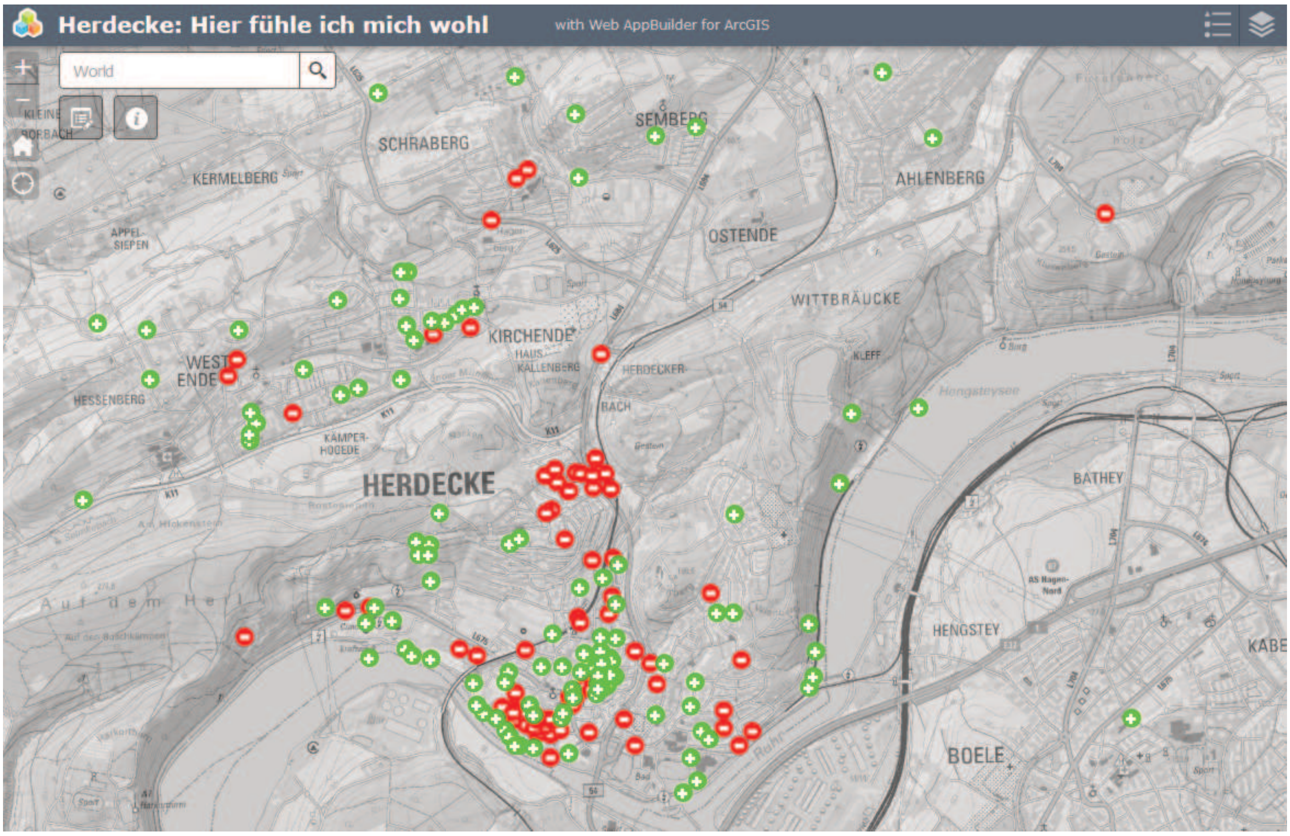


Fig. 1: User interface for the web map application to evaluate the spatial attractiveness in the study area (created with Web AppBuilder for ArcGIS by Esri; base map: WMS by Geobasis NRW).

## 3.4 Offline map application

Using five touchscreen devices at the same time generated a considerable volume of data of approximately 200 MB in one hour. This data had to be transmitted via an active internet connection. Given these large data volumes, a mobile internet connection proofed to be impractical. As Wi-Fi was only available at few spots in the city and within a limited radius around these spots, an offline version of the described web map application (section 3.3) was created directly in ArcGIS 10.2 for Desktop. For this purpose, base maps were downloaded from WMS-services in various resolutions and stored locally. Visibility scale ranges were applied to respective resolutions for a cleaner appearance and more intuitive use. The functionality of the online and offline versions of the application was the same, nonetheless, the offline version was not touch-optimized and required some prior GIS knowledge in order to be used properly.

## 3.5 Analogue map

It was assumed that the use of a touchscreen device might cause irritation and fear of contact by some participants, especially senior citizens, who might not be as familiar with these devices as the younger population. It was hypothesized that this might lead to a reserved participation and an underrepresentation of this target group. In order to avoid this and to involve these citizens, a fourth method was applied which was supposed to set the barrier to engagement and fear of contact as low as possible. For this purpose, an analogue map was printed out, on which citizens were asked to draw. This constituted the most simple and straightforward method of this study. The terminology of the stated questions were the same as in the online and offline versions of the map application (sections 3.3 and 3.4) which focused on spatial attractiveness.


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# 4 RESULTS

## 4.1 The surveys' representativities

For the questionnaire-based survey, the city administration of Herdecke sent one questionnaire to each of the city's approximately 13,461 households of which 2,060 valid questionnaires were sent back for analysis. This corresponds to a satisfactory participation ratio of around 15.3 %. Comparing the number of valid questionnaires by city district to population numbers provided by the local citizen registration office shows that no city district is considerably over- or underrepresented in this survey (Fig. 2). In contrast to this, comparing the relative participation per age groups to demographic data of the citizen registration office reveals that 18 to 67 year olds are highly underrepresented while senior citizens are considerably overrepresented in this survey (Fig. 3). As only one questionnaire was sent to one household and the age was given as the age of the oldest and youngest persons of this household, respectively, a comparison of these two datasets provides rather a broad overview than an exact picture of the representativity of each age group. As no additional demographic information, for instance, on gender, social status or migratory background was given in this survey, their respective representativity cannot be assessed.

The same holds true for the online and offline map applications and the analogue map. Too few participants assigned themselves to a target group in order to numerically assess the representativity of demographic groups. Nevertheless, face-to-face communication with citizens allowed the interviewers to consciously reach out to various demographic groups and also address non-German speaking participants, which might be important as about 10.6 % of Herdeckes population have a migratory background. This was very well perceived by the interviewed citizens and increased the overall willingness to participate. In the latter surveys, some places were more frequently evaluated as “feel good” or “not feel good” as others as can be seen in Fig. 4 in the next section (4.2). This is useful for further analyses and provides an informative picture for local decision makers. Although the distribution of the evaluated places is not homogenous, the whole study area is covered. In addition, the surveys were repeated at two sub centers of the city, assumingly reaching out to various target groups. Consequently, the spatial representativity is assumed to be high for the map applications and the analogue map.

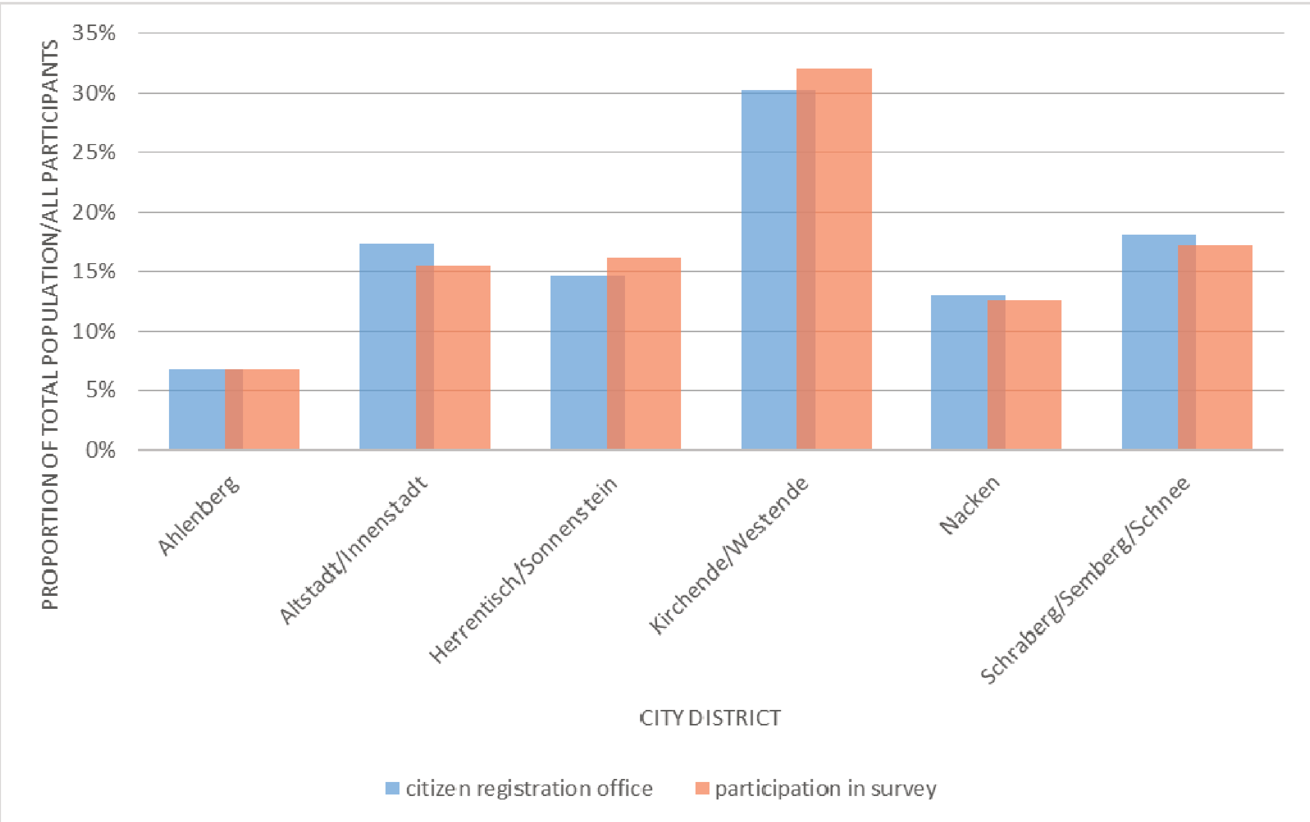


Fig. 2: Participation in the questionnaire-based survey by city districts compared to the actual population distribution as derived from citizen registration office data.

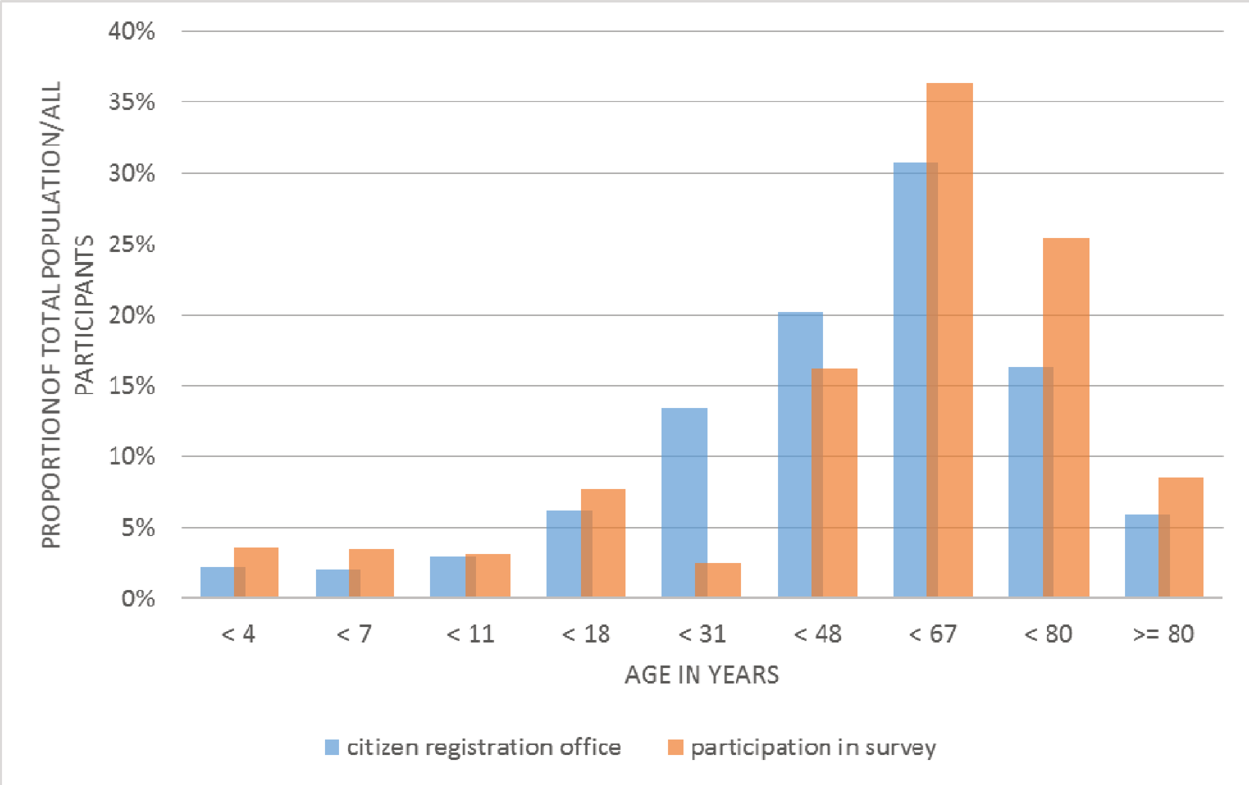


Fig. 3: Participation in the questionnaire-based survey by age groups compared to the actual age group distribution as derived from citizen registration office data.

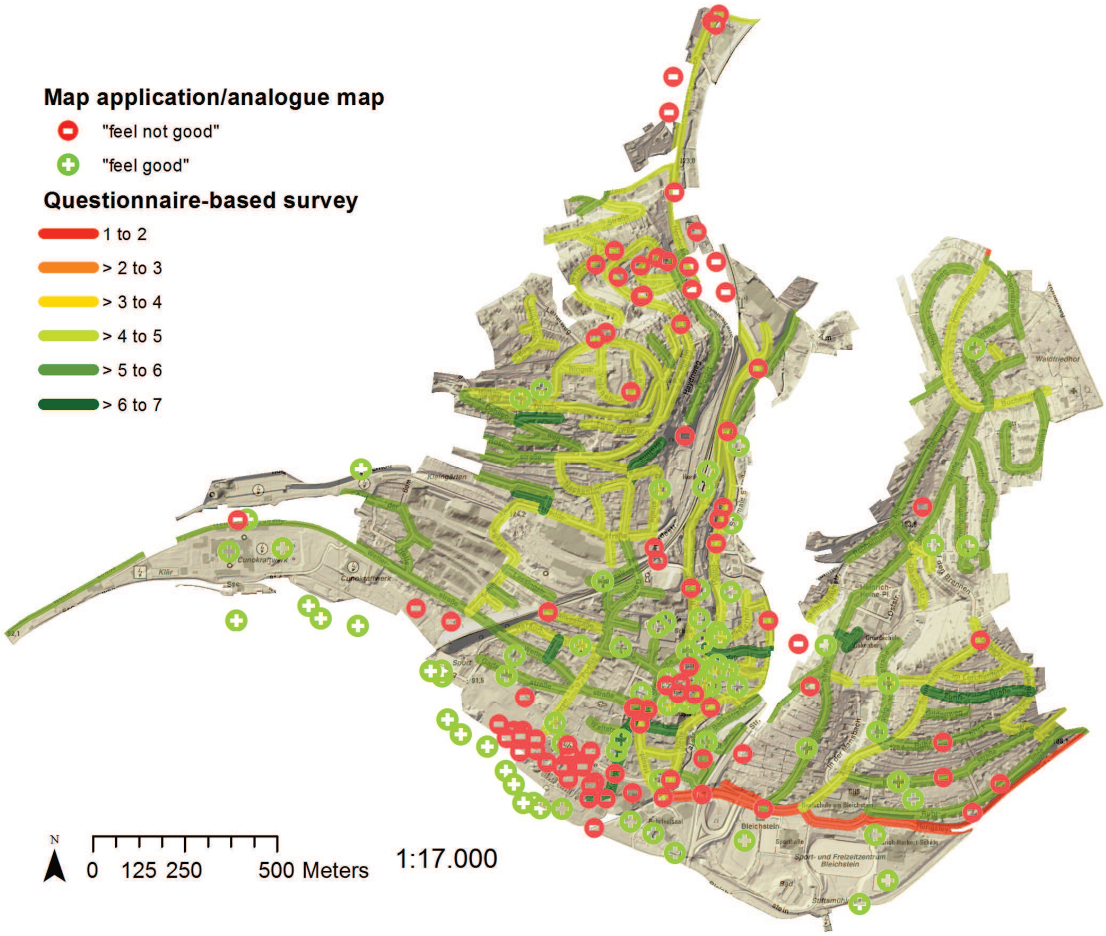


Fig. 4: Spatial attractiveness and "Wohlfühlfaktor" in the city centre of Herdecke as it was evaluated by the online and offline map applications, the analogue map and the questionnaire-based survey, respectively. For the latter, the medians on a Likert-scale from 1 (not attractive) to 7 (attractive) are shown per street (base map: WMS by Geobasis NRW).


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### 4.2 Spatial attractiveness in the study area

As can be seen in Fig. 4, the spatial attractiveness of the city center of Herdecke as evaluated by the questionnaire-based survey (shown as lines) can be assessed as overall positive (median = 5, on a 1 = negative, to 7 = positive scale). The inner city center and eastern parts of the city were evaluated as particularly attractive by the respective households. In contrast, one street in the south-eastern part of town which was often associated with noise from a nearby motorway received low and medium ratings by the inhabitants, just like northern parts of the city center which were often associated with lower social status and where recently a supermarket was closed.

In the map applications and the analogue map surveys (shown as points) the citizens of Herdecke were asked to evaluate places in the city rather than the own places of residence. Similar to the questionnaire-based survey, the inner and eastern parts of the city center were often rated as attractive while the described noise-stressed areas in the south-eastern parts and the northern parts of the city center were often perceived as not attractive. In addition, these surveys revealed that the river Ruhr which borders the city center to the south was frequently evaluated as attractive while participants would often state that they would not feel good near big construction sites which can be found on the riverside in the south of the city center and near the inner city.

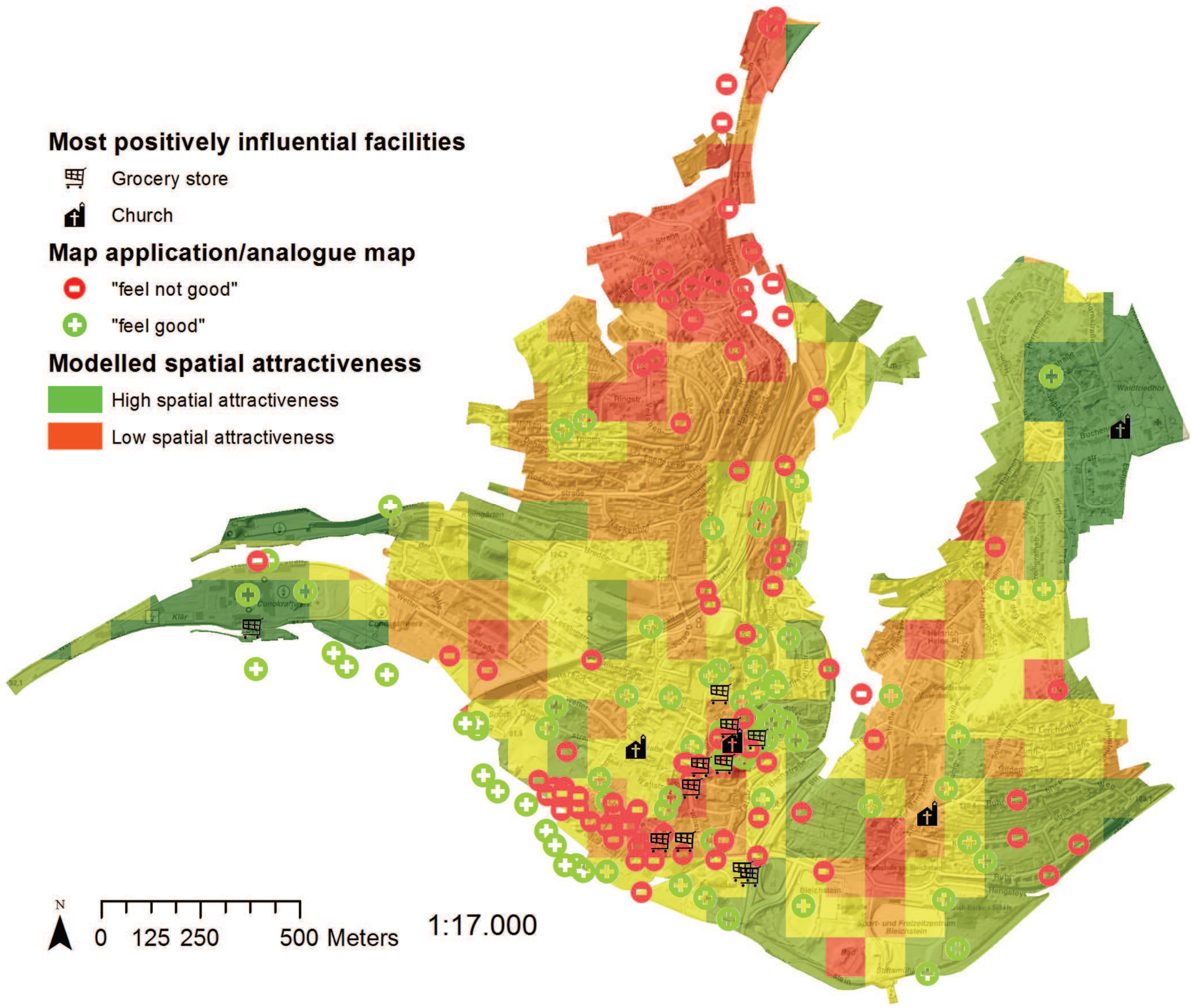


Fig. 5: Spatial attractiveness in the city centre of Herdecke as it was modelled by multi-variate spatial autoregressive analysis (SAR) considering network accessibilities of facilities as independent variables (sample size = 115, $F \approx 8.77$, $p < 0.001$, $R^2 \approx 0.33$, adjusted $R^2 \approx 0.29$, $\lambda \approx -0.63$, Likelihood ratio ≈ 2.46, p (LLH-test) ≈ 0.12; base map: WMS by Geobasis NRW).

## 5 USE-CASE: SPATIAL ATTRACTIVENESS AND ACCESSIBILITY OF FACILITIES

Data obtained with the offline version of the map application (section 3.4) and the analogue map (section 3.5) were integrated into the online dataset which was fed by the web map application (section 3.3). This integrated online dataset could be accessed in real-time. To demonstrate a use-case for this data source, the participation data was analyzed in combination with additional data sources, namely OpenStreetMap data and municipal data on facilities providing basic goods and services. For this purpose, an analysis grid with a cell size of 100 x 100 meters was defined and participation data were aggregated to this analysis grid. Using the Network Analyst extension for ArcGIS 10.2, the walking distance on roads and paths to the next respective facility, including stations of public transportation, was calculated for each grid cell midpoint. In a multi-variate spatial autoregressive analysis (SAR), the dependency of spatial attractiveness on the accessibility of facilities was investigated in R 3.2.1. As this dependency might decrease logarithmically with increasing distance, the logarithmic values of each walking distance was used as independent variables. Furthermore, only variables were used which showed no significant multi-collinearity (VIF value < 10).

This analysis provided a numeric description of spatial attractiveness as a function of walking distance to facilities. The $R^2$ value for this model was approximately 0.33 and the adjusted $R^2$ value was ca. 0.29, respectively (sample size = 115, $F \approx 8.77$, $p < 0.001$). The model did not show significant spatial autocorrelation ($\lambda \approx -0.63$, Likelihood ratio ≈ 2.46, $p \approx 0.12$) or heteroscedasticity (Breusch-Pagan-test: BP ≈ 7.57, $p \approx 0.27$). With a cross-validation value of approximately 0.17 the model can be evaluated as satisfactory stable.

As can be seen in Fig. 5, the derived regression equation could be used to extrapolate spatial attractiveness values to the whole study area. For this purpose, walking distances were multiplied according to the respective coefficients as they were given by the regression equation. For the study area, the facilities with the highest coefficients, thus the most positive influence on spatial attractiveness, were grocery stores and churches (~ 0.14 for both facilities).

## 6 DISCUSSION

The questionnaire-based survey provided local decision makers with a broad picture of citizens' demands on the street-level. In addition, the map applications and analogue map surveys shifted the study focus to a broader thematical and spatial scope, increased the spatial resolution and added some factors to the drawn picture, for instance to influences of the bordering river and that of bigger construction sites.

In this meta-study we assessed the advantages and disadvantages of four methods for citizen participation within the scope of the smart city approach (summarized in Table 1). In order to analyze the data obtained from the questionnaire-based survey, about 2000 questionnaires comprising 33 multiple choice, Likert-scale and hand written free-text answers of varying length had to be digitized, categorized, organized and georeferenced. This added up to a considerable task which was tackled over a time period of several months. The results constitute a broad data source for local decision makers on the citizens' demands on the street- or at least district-level. However, pre and post processing expenses do not allow for frequent repetitions of this survey or even real-time data acquisition and the interoperability with other data sources within the scope of the smart city approach is limited. As far as total population is concerned, the overall representativity of this survey of approximately 15.4 % of all households can be evaluated as high. The same holds true for the representativity on the spatial scale regarding participation per city district and also street level. Obtaining data on the address level might raise privacy issues and decrease the willingness to participate in the survey. Age groups were not represented in accordance with the actual demographic distribution. Furthermore, as the questionnaire was in German, it can be assumed that no non-German speaking citizen was considered in this survey. As no additional demographic information were given in the questionnaires, assertions about the representation of other demographic groups could not be made.

In contrast to the questionnaire, the spatial resolution and focus in the web map application, its offline version and the analogue map was shifted from the "Wohlfühlfaktor" as assessed by households to an evaluation of the spatial attractiveness of specific places in the city. Furthermore, the experimental design of only three purposeful stated questions was set out for a very short participation time period which would eventually increase the response and willingness of participants at the cost of level of detail of the obtained data. Accordingly, 266 points in space were evaluated in approximately six hours of which 168 points were obtained by the web map application, 75 by the offline map application and 23 by the analogue map. In addition, data pre and post processing expenses were low for the offline map application and even more straightforward for the web map application. This allows for frequent repetition and therefore a high spatial resolution of the data obtained by the offline map application and even real-time data acquisition by the web


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map application. Moreover, the latter provides high interoperability with other data sources and re-use for advanced geospatial analysis as was demonstrated in section 5. In contrast to this, post processing expenses for the analogue map method are high as each data point has to be digitized and integrated manually into databases in order to be further analyzed. Nevertheless, this method of directly drawing on a printed map was very well perceived by the participants due to its non-technocratic, intuitive and straightforward nature. Especially senior citizens took up on this opportunity of expressing themselves who might be not as familiar with touchscreen devices as younger participants. Therefore, the analogue map constitutes a reasonable supplement to the digital survey methods, especially the web map application. In contrast, the offline map application required some GIS experience for a proper use and was not touch-optimized. Additionally, due to its poor data interoperability, the suitability of the offline map application within the smart city approach has to be evaluated as low.

| | (a) Questionnaire-based survey | (b) Web map application | (c) Offline map application | (d) Analogue map |
|---|---|---|---|---|
| **Assessed parameter** | "Wohlfühlfaktor" in the context of living comfort for senior citizens | Spatial attractiveness | Spatial attractiveness | Spatial attractiveness |
| **Spatial resolution** | District- and street-level | Points in space | Points in space | Points in space |
| **Sample object** | Households | Places as points | Places as points | Places as points |
| **Sample size** | 2060 | 168 | 75 | 23 |
| **Overall participation rate** | ~ 15.3 % | not applicable | not applicable | not applicable |
| **Time required for participation** | Very long | Very short | Short | Very short |
| **Privacy issues** | High (for very high spatial resolutions, such as addresses) | Low | Low | Low |
| **Willingness of participants** | Low | High (in face-to-face contact) | High (in face-to-face contact) | High (in face-to-face contact) |
| **Spatial representativity** | Very high | Assumed to be high | Assumed to be high | Assumed to be high |
| **Target group representativity** | Low / Assumed to be low | Assumed to be high (in combination with d) | Assumed to be high (in combination with d) | Assumed to be high (in combination with b or c) |
| **Pre and post processing expense** | Very high | Very low | Low | High |
| **Data interoperability/ re-use** | Low | Very high | Low | Low |
| **Applicability for frequent repetition** | Very low | Very high (real-time) | High | Low |
| **Level of detail of obtained data** | Very high | Low (but purposeful) | Low (but purposeful) | Low (but purposeful) |
| **Overall suitability within the smart city approach** | Low | Very high | Low | Medium (in combination with b) |

Table 1: Comparison of the four assessed methods for citizen participation within the scope of the smart city approach. Green (red) backgrounds indicate high (low) suitability within a smart city.

Combining the collected data with additional data sources for geospatial analysis resulted in a statistical model which numerically describes spatial attractiveness as a function of walking distances to local facilities.

This model can be used to extrapolate the collected data on spatial attractiveness to larger areas, identify most influential facilities and assess consequences for future planning, such as the establishment or closure of a specific facility at a given location. This constitutes an example as to how the presented methods can be integrated in all three layers of a smart city according to Su et al. (2011), i.e. the perception layer (detecting spatial attractiveness as it is perceived by citizens), the network layer (providing the collected data online and in real-time) and the application layer (analyzing the data in combination with other big data sources). The moderate exploratory power of the model (adjusted $R^2 \approx 0.29$) might be due to the fact that solely walking distances to facilities and no additional aspects were considered to be influential on spatial attractiveness. For instance, the demographic structure, housing prices and psycho-socially aspects should be included in future analyses.

## 7 CONCLUSION

The questionnaire-based survey provided a broad data source with in-depth information on the demands of citizens on the district and street-level. Nevertheless, it might not be considered suitable for the smart city approach as data post processing, lacking interoperability and data re-use do not allow for a frequent repetition of this survey or, still less, real-time data acquisition. The offline map application in ArcGIS 10.2 for Desktop required some GIS experience for proper use which could have negative effects on the representativity, especially when no face-to-face communication with citizens takes place during the survey. Therefore, it might only be regarded as an emergency solution for citizen participation projects, if no internet connection can be established.

Within the scope of the smart city approach, applying web map applications in combination with analogue mapping methods can be recommended for engaging citizens to participate in urban planning. Promoting these methods in face-to-face communication with citizens proofed to be particularly beneficial as this allowed citizens to express themselves ingenuously, created a considerable deal of attention to the project and presumably increased the representativity of the collect data as interviewers were able to actively reach out to different target groups. In accordance with the smart city approach, these methods can enforce the feeling of ownership by the citizens, increase the evidence-base for local planning and greatly contribute to its transparency and acceptance (Mayer-Schönberger & Cukier, 2013; Kitchin, 2014). Furthermore, we demonstrated how the collected participation data can be merged with other data sources for geospatial analysis in a novel way which might lead to new insights for increasing urban planning efficiency.

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