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Prioritising urban green spaces using accessibility and quality as criteria

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Abstract. Urban green spaces are a critical component of cities, providing environmental, social, cultural, and economic benefits. To support smart(er) decisions by city planners and managers, this study aims to investigate how open data sources could be integrated into urban green space management. Specifically, it proposes a novel GIS-based method to prioritise urban green space in a resource-constraint scenario so that social benefits are maximised. To quantify the social benefits, the methodology is based on the WHO indicator, which recommends access to at least 0.5-1 ha of green space within 300 metres' linear distance to all the city residents. The approach assigns each urban green space an 'accessibility score' based on its significance in the city, and a 'quality score' based on its performance on different quality parameters (size, greenness, quietness, and safety). Urban green spaces are ranked with respect to these two scores, enabling to prioritise spaces under resource constraints such as water shortage, limited staff, or budget. This approach is demonstrated through a case study on a mid-size German city and is transferable to other cities worldwide with varying weightage factors.

1. Introduction

Whether in parks, along streets, inside forests, or in any other form, the green spaces in an urban area provide multifaceted benefits, including environmental, social, and economic [1]. The World Health Organisation (WHO), defines Urban Green Spaces (UGS) as the collection of all kinds of vegetation present on public or private land within a city, irrespective of its size and function [2]. Studies have shown the beneficial role of UGS in protecting and enhancing local biodiversity, increasing water retention, improving social cohesion, and carbon sequestration as well as regulating local micro-climate [3, 4, 5, 6]. Regular exposure to an UGS is found to boost physical and mental well-being [7, 8]. It also provides an opportunity for recreation, especially in highly congested and densely populated neighbourhoods and for low-economic communities that cannot frequently afford other means of recreation. The significance was evident during the recent COVID-19 pandemic when researchers observed a rise of up to 350% in the usage of public parks [9]. UGS helped people to recreate even under strict lockdown measures while maintaining adequate social distance.

Taking into account the enormous benefits obtained from UGS, the United Nations in its Sustainable Development Goals set a target 11.7 that aims to provide universal access to safe, inclusive and accessible, green and public spaces for everyone. WHO as well recommends 'access to at least 0.5-1 ha of green space within 300 metres' linear distance to all the city residents' [2]. Moreover, the Convention on Biological Diversity (CBD) in Germany set a target to provide publicly accessible UGS with a diverse range of qualities and functions within walking distance to every urban household [10]. Therefore, to provide sufficient UGS accessibility, city governments need to plan newer greening areas in addition to protecting existing UGS. This, however, encounters dual challenge from urbanisation. First, as the urban population increases, the higher housing demand puts constant pressure to colonise the open and green spaces. Second, as the population density rises, the per capita UGS availability deteriorates. This commonly leads to crowding and occasionally uneven distribution of UGS, especially affecting low-income communities that are highly dependent on public parks and playgrounds for affordable recreation. Therefore, it is critical to monitor the status of UGS accessibility and take required steps to maintain and enhance it.

Furthermore, constant management is required to maintain the UGS in healthy conditions. This involves watering, application of fertiliser and pesticides, pruning of trees, cutting, lawn mowing, tree stability inspection, cleaning leaf litter, and maintenance of recreational facilities. However, it might not be possible to provide ample management support to all the UGS in the case of limited/constrained resources such as water, budget, staff or equipment. For example, in case of water shortage due to droughts or as experienced recently, limited personnel during pandemic. In such cases, it becomes indispensable to prioritise the UGS that need to be preserved. The prioritisation should be done so that either benefits are maximised, costs are minimised, or resource constraints are satisfied or all together, depending on the decision-makers' preference.

This study proposes a novel GIS-based method to prioritise the UGS management under resource constraint scenarios. The main objective is to prioritise in a manner that the total benefits from UGS are maximised. However, to simplify the case, the present study solely incorporates public accessibility as a single parameter measuring social benefit. Previous studies such as [11] and [1] have analysed the amount of UGS accessible by city residents, but the distribution in terms of quality is largely missing in the existing literature. Although, both WHO and CBD only refer to 'quantity' access of UGS in their targets, the model endeavours for a greater ambition of ensuring that this access is also of 'high-quality'. Moreover, establishing a linkage between the analysis of field data and management decisions such as prioritisation is mostly absent in the literature until now. Therefore, the study aims to investigate how open-data sources can be integrated into the decision-making of UGS management. This is the major contribution of this study at hand. In the following sections, the methodology is described, followed by the results, the discussion, and conclusions.

2. Methodology

The methodology aims to assign a prioritisation index to each UGS based on two criteria: its significance in providing social benefit measured in terms of public accessibility, and, its performance on various quality parameters. Each of these criteria is assessed with a score; namely, *Accessibility Score* (S_A) and *Quality Score* (S_Q), measured by means of defined parameters. In all cases, a normalised score value between 0 to 10 is derived by applying a feature re-scaling on individual parameters. In the case of positive scaling, the highest score was equated to the highest parameter value while in the case of negative scaling it was the opposite. The overall score is then derived by combining the two subscores by user-defined weight. Consequently, the UGS are ranked in priority according to their score, where a higher score value gets a greater/higher priority. The methodology comprises of four parts. The first part focuses on identifying the available UGS in the cities. The second and third part include quantifying the above-mentioned two scores, S_A and S_Q. The last part include determining the prioritisation index for informed decision-making.

Table 1: Different labels used in Open Street Map for tagging UGS.

Key	Label
landuse	allotments, cemetery, farm, forest, grass, heath, meadow, orchard, park, recreation ground, scrub, vineyard
natural	tree
places	farm
POIs	dog park, golf course, graveyard, park, picnic site, zoo, playground

2.1. Green Space Availability

A free and open-source Geographic Information System, QGIS, was used to perform the spatial analysis to determine the UGS accessibility of a city's population. Initially, a vector layer designating the city's administrative boundary was imported. This is based on the premise that city governments are usually responsible for managing UGS within their administrative jurisdiction. Subsequently, an OpenStreetMap (OSM) dataset for the city is introduced [12], which comprises numerous layers delineating various features within a city. For this study, the feature layers consisting of buildings, roads, water, land-use, natural, places, and points of interest (POIs) were used. Each of these layers is reprojected into a common co-ordinate referencing system (CRS) and is spatially clipped by the extent of the city boundary.

Subsequently, UGS are identified from the imported OSM layers using tag values listed in Table 1. A filter operation is applied to match the key field of the layer with the tag values and only the matching polygon features are retained. Next, the filtered polygons are merged into a single layer that will delineate all the UGS in the city. In this process, an UGS might get repeated or overlapped in some instances due to repeated tagging in different OSM layers. Moreover, in a few instances, an UGS is identified as a group of adjoining polygons instead of one large polygon. Therefore, to reduce data redundancy, such mini-polygons are combined into single elements by using the dissolve function. Furthermore, all UGS smaller than 50 m^2 are eliminated from the dataset. Thus, street trees and tiny UGS are not considered further in this study. All the remaining UGS are suitable for the public usage and henceforth referred to as *Available Green Spaces*.

2.2. Accessibility Score

In this part, proximity analysis is done to evaluate the UGS accessibility in the city. It should be highlighted that accessibility is defined here in terms of 'walking accessibility', which implies the possibility of reaching UGS by foot using permanent pathways. To simplify the computation, circular buffer approach is used to check the accessibility in linear distance. To concur with the WHO recommendation, circular buffers with 300 m radius are created with each building unit as a punctiform centre to obtain the buffered building area layer. Subsequently, the sum of all UGS areas that overlap with this buffer represents the quantity of UGS area accessible by particular buildings' residents. Accordingly, the buildings with less than the minimum recommended 0.5 ha of UGS in their buffer are classified as buildings without sufficient UGS accessibility. To find the number of city residents that do not have access to sufficient UGS, a population density map containing residents/ha is used. The population density layer is intersected with the buildings layer and multiplied with its area value to obtain the number of residents living in a particular building. The summation of population is done for the buildings without access to sufficient UGS which gives us the percent of population that is impacted by the deficit.

In the next step, the contribution of each UGS → i in maintaining the accessibility is quantified with an *Accessibility Score* (S_{A}). The score is defined as the equally weighted aggregation of two components: *Building coverage score* (S_{C}) and *Essentiality score* (S_{E}) (see Equation 6). The first component, $\mathrm{S_C}$, measures the number of residential buildings that benefit from a particular UGS. The second component, $\mathrm{S_E}$, quantifies the criticality of a particular green space in maintaining accessibility. Throughout the text, a variable symbol implies the total score for all UGS, whereas, variable with a subscript i is used to describe the computation for a single UGS 'i'. The calculation of the scores is elaborated in the next paragraphs.

Once again, circular buffers with a 300 m radius are created, but this time with each UGS as a polygon-shaped centre. All UGS and their respective buffer area will represent the total city area benefiting from UGS. This buffered UGS layer is then spatially intersected with the building vector dataset. Now, the summation of building area for those buildings elements that are in conjunction with a buffered UGS area is referred as *Building Area Covered* (A_{BC}) by UGS $i \,\epsilon\, [1, g]$, and is computed by Equation 1, where g represents the total number of available UGS (above the threshold size). Accordingly, the residents living within area $\mathrm{A_{BC}}$ will have access to sufficient UGS within walking distance. Next, a log transformation is applied on $A_{\mathrm{BC_i}}$ to reduce the skewness of the size values between very small and very large UGS. Furthermore, logged $A_{\mathrm{BC_i}}$ values are positively re-scaled using Equation 2 to derive the associated *Building Coverage score* ($S_{\mathrm{C_i}}$). Those UGS that are accessible by a higher quantity of building area will score higher on $\mathrm{S_C}$.

For $i \,\epsilon\, \mathbb{N} \,:\, i \,\epsilon\, [1, g]$, g = *Total Available Green Spaces*

$$A_{\mathrm{BC_i}} = (Green\ Space\ Area_{\mathrm{i}} + Buffer\ Area_{\mathrm{i}}) \cap Building\ Area \tag{1}$$

$$S_{\mathrm{C_i}} = \frac{10 \times (log_{10}\ A_{\mathrm{BC_i}} - max(log_{10}\ A_{\mathrm{BC_i}}))}{max(log_{10}\ A_{\mathrm{BC_i}}) - min(log_{10}\ A_{\mathrm{BC_i}}))} + 10 \tag{2}$$

In the next step, the *Essentiality score* (S_{E}) is computed. For this, the buffered building area layer is spatially intersected with the green space vector dataset. As calculated in the earlier step, those UGS elements that have at least some overlap with the buffered building area can be considered as accessible by that building and its residents. The total count of such intersecting elements yields number of *Green Spaces Accessible* (G_{A}) (Equation 3), where b represents the total number of buildings in a city. The buildings with a G_{A} value greater than 0 have access to atleast 1 UGS within walking distance. As the $\mathrm{G_A}$ values are in a narrow range, they are directly re-scaled using Equation 4 to derive the associated score $S_{\mathrm{E_j}}$. Here, negative re-scaling is applied to take into account the inverse relation between $G_{\mathrm{A_j}}$ and $S_{\mathrm{E_j}}$. Accordingly, buildings having access to merely a singular UGS will score highest on $S_{\mathrm{E_i}}$. In contrast, buildings with several UGS within 300 m will score lower. In the subsequent step, $S_{\mathrm{E_i}}$ for each UGS is calculated as the mean $\mathrm{S_{E_j}}$ of all the buildings that are located within the buffer zone around the UGS determined by Equation 1.

For $j \,\epsilon\, \mathbb{N} \,:\, j \,\epsilon\, [1, b]$ and $i \,\epsilon\, \mathbb{N} \,:\, i \,\epsilon\, [1, g]$, b = *Total buildings*

$$G_{\mathrm{A_j}} = count((Building\ Centroid_{\mathrm{j}} + Buffer\ Area) \cap Green\ Space\ Area) \tag{3}$$

$$S_{\mathrm{E_j}} = \frac{10 \times (\ G_{\mathrm{A_j}} - min(\ G_{\mathrm{A_j}}))}{min(\ G_{\mathrm{A_j}}) - max(\ G_{\mathrm{A_j}})} + 10 \tag{4}$$

$$S_{\mathrm{E_i}} = \overline{S_{\mathrm{E_j}}}\ ,\ \forall\ (j \cap Building\ Area\ Covered_{\mathrm{i}}) \tag{5}$$

Lastly, the *Accessibility Score* (S_{A}) is calculated by averaging $\mathrm{S_C}$ and $\mathrm{S_E}$ with equal weightage (Equation 6). The score characterises the impact of any UGS in providing UGS accessibility to city residents. Therefore, UGS with greater $\mathrm{S_A}$ reflects its prominence in providing higher social benefits and thus should be prioritised higher.

$$S_{\mathrm{A_i}} = 0.5 \times (S_{\mathrm{C_i}} \; + \; S_{\mathrm{E_i}}) \tag{6}$$

2.3. Quality Score

The second part of the methodology focuses on the quality aspect of UGS described by the *Quality Score* (S_{Q}). The quality of an UGS is a subjective issue that depends on several characteristics for its depiction. It includes the proximity to residents, size, diversity of species, free public access, quietness, recreational facilities, and safety [13]. In the context of this study, the quality of UGS is defined as its cumulative performance on selected quality parameters, namely size ($\mathrm{S_{Q,A}}$), greenness ($\mathrm{S_{Q,G}}$), quietness ($\mathrm{S_{Q,N}}$), and safety ($\mathrm{S_{Q,S}}$) (as in Equation 11). In the case of evaluating the size, the area of the particular UGS was directly used to assign a score. Since a larger area will provide higher ecosystem services, the UGS with the biggest area was assigned a maximum score. Moreover, the skewness in the area distribution of UGS due to a few disproportionately large UGS was reduced by log transformation. Subsequently, the values were positively feature-scaled to derive a corresponding score $\mathrm{S_{Q_i,A_i}}$ according to Equation 7. Further, to assess the greenness, the mean Normalised difference vegetation index (NDVI) value was computed for each UGS from Sentinel-2 satellite data. NDVI is an effective indicator to identify green vegetation based on the spectral reflectance of plants. Accordingly, the UGS with a greater NDVI value will likely have a high density of trees and therefore provide higher ecosystem benefits. So, the NDVI values were positively feature-scaled, such that UGS with the highest NDVI value will obtain the maximum score. This operation to derive $\mathrm{S_{Q_i,G_i}}$ is given in Equation 8. To evaluate the quietness in the UGS, the average noise level (dB) for each UGS is obtained from the available Noise Map. Following this, the score $\mathrm{S_{Q_i,N_i}}$ for noise is derived by negatively feature-scaling the mean noise values such that UGS with a higher noise value obtain a lower score. This is shown in Equation 9 below. Similarly, the score $\mathrm{S_{Q_i,S_i}}$ for safety is derived by negatively feature-scaling the number of criminal offences recorded in the particular district. This is shown in Equation 10 below.

For $i \; \epsilon \; \mathbb{N} \; : \; i \; \epsilon \; [1, g]$,

$$S_{\mathrm{Q_i,A_i}} = \frac{10 \times (log_{10}Green\ Space\ Area_{\mathrm{i}} - max(log_{10}Green\ Space\ Area_{\mathrm{i}}))}{max(log_{10}Green\ Space\ Area_{\mathrm{i}}) - min(log_{10}Green\ Space\ Area_{\mathrm{i}})} + 10 \tag{7}$$

$$S_{\mathrm{Q_i,G_i}} = \frac{10 \times (\overline{NDVI} - max(\overline{NDVI}))}{max(\overline{NDVI}) - min(\overline{NDVI})} + 10 \tag{8}$$

$$S_{\mathrm{Q_i,N_i}} = \frac{10 \times (\overline{Noise} - min(\overline{Noise}))}{min(\overline{Noise}) - max(\overline{Noise})} + 10 \tag{9}$$

$$S_{\mathrm{Q_i,S_i}} = \frac{10 \times (Crime - min(Crime))}{min(Crime) - max(Crime)} + 10 \tag{10}$$

Finally, the overall *Quality Score* ($S_{\mathrm{Q_i}}$) is calculated by combining the individual scores obtained on all quality parameters by respective weights (Equation 11). The model allows to adapt the weights according to the preferences of residents and decision makers' priorities. For example, a survey done in the City of Karlsruhe identified lower noise and pollution as extremely important criteria for UGS usage among the residents [14]. So a higher w3 value should be considered for that city. However, for the purpose of this case study, all the quality parameters are weighted equally and therefore all weights are set to 0.25. Accordingly, the UGS that are bigger in size, consist of dense and mature trees, have a quiet neighbourhood, and are located in districts with lower crime rates, will classify as a high-quality UGS. Overall, the score characterises the ability of UGS to provide higher ecosystem benefits and satisfy the user's needs. Therefore, UGS with greater $\mathrm{S_Q}$ should be prioritised higher.

$$S_{\mathrm{Q_i}} = w1 \times (S_{\mathrm{Q_i,A_i}}) + w2 \times (S_{\mathrm{Q_i,G_i}}) + w3 \times (S_{\mathrm{Q_i,N_i}}) + w4 \times (S_{\mathrm{Q_i,S_i}}) \tag{11}$$

2.4. Prioritisation

In the last part, a prioritisation order is obtained by averaging the *Accessibility Score* (S_A) and *Quality Score* (S_Q) with desired weightage factors that might vary between decision-makers. Depending on the weightage values, the significance of the quality of accessibility will change against the quantity. This is given in Equation 12.

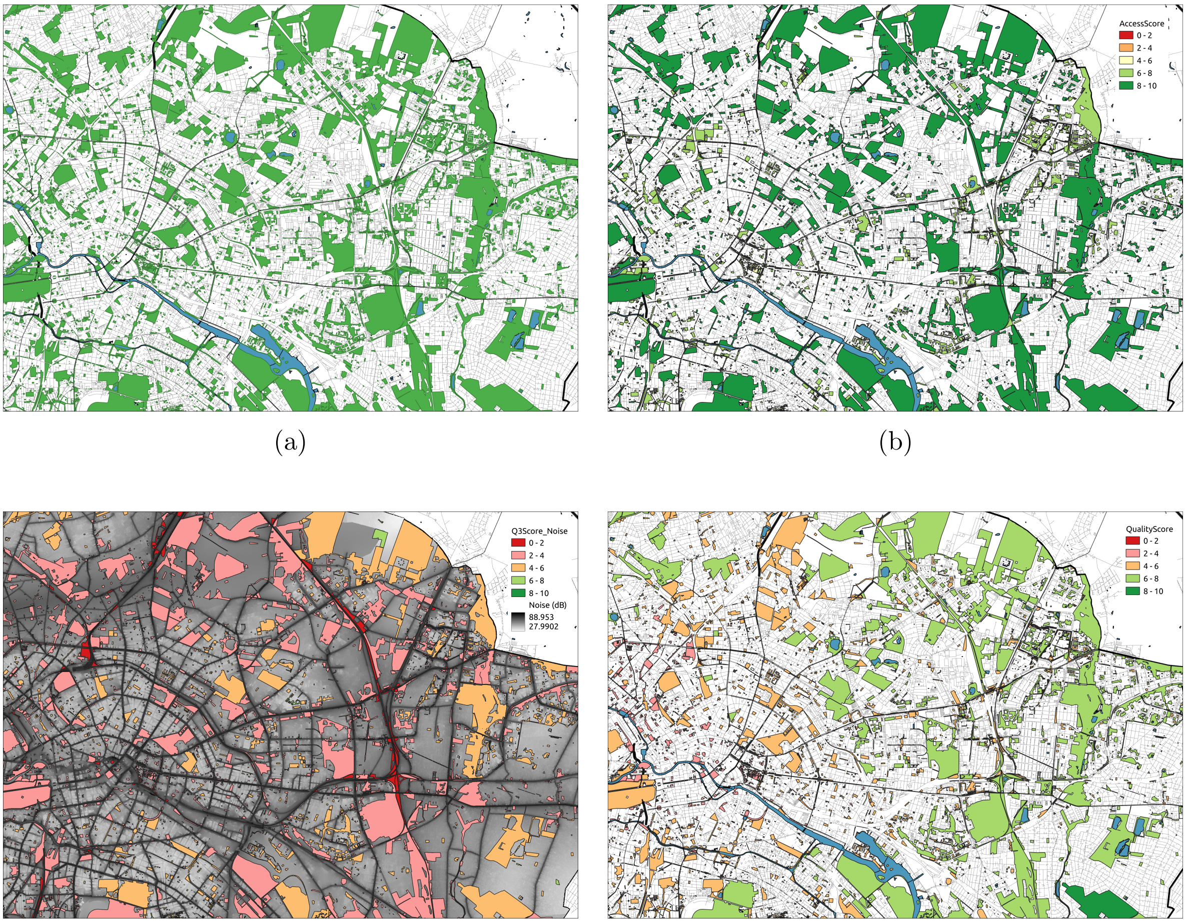
$$Prioritisation_{\mathrm{i}} = w1 \times (S_{\mathrm{A_i}}) + w2 \times (S_{\mathrm{Q_i}}) \tag{12}$$

3. Results

The described method is applied to a case study on the City of Berlin and results are presented in this section. Berlin is the capital and largest city of Germany with around 3.6 million inhabitants and a city area of 89100 ha. The mean population density in the city is about 130 residents/ha. The city is mainly flat in topography and is located on the Spree river, surrounded by numerous lakes and woodlands. To analyse the UGS accessibility in Berlin, the OSM dataset was accessed from the Geofabrik GmbH portal. Later, all the input datasets were reprojected into a common CRS, ETRS89 / LCC Germany (E-N), and imported into the QGIS software. After combining the relevant tagged elements, a layer containing all UGS was obtained. A snapshot of this step is presented in Figure 1a. Almost one-third of the city's area comprises of green spaces such as parks, forests, rivers, and lakes. In total, 12,486 UGS elements were identified using the OSM dataset. The UGS included in the analysis range from $50\mathrm{m}^2$ to $30.57\ \mathrm{km}^2$ of area. In total, 47,473 residents were found to have less than the minimum 0.5 ha of UGS area accessible.

Subsequently, the available UGS are analysed together with the buildings layer to derive the *Accessibility Score* (S_A). A map presenting the performance of UGS on $\mathrm{S_A}$ is given in Figure 1b. It is visible that $\mathrm{S_A}$ for the UGS in the shown section range between 6-10 and the majority of them have a score higher than 8. Furthermore, the available UGS are analysed together with secondary data sources to derive the *Quality Score* (S_Q). To determine the greenness, we used the median NDVI values from cloud-free Sentinel-2 image with 10 m spatial resolution for the Year 2020. The Strategic Noise Map 2017 [15] which provides total noise values from traffic sources, was used to determine the mean noise levels in UGS. Figure 1c presents an example from the study area to demonstrate the impact of noise levels on the $\mathrm{S_{Q,N}}$. In the figure, the mean noise level at any point is indicated by the intensity of the grey colour. It can be observed that UGS surrounded by streets/highways with higher noise levels obtain lower $\mathrm{S_{Q,N}}$. Additionally, the Crime Atlas 2020 published by police crime statistics of Berlin [16] was used to determine the number of criminal offences that occur in various city districts. A map presenting the total performance of UGS on $\mathrm{S_Q}$ is given in Figure 1d. Despite the high accessibility of UGS in most parts of the study area, we find that in particular, the inner-city UGS have a medium or low *Quality Score*.

The performance of UGS in Berlin on the two scores, S_A and S_Q is described in Table 2. It is evident from the mean and median scoring that overall UGS perform considerably better on accessibility criteria than on quality. This can be attributed to complementary behaviour observed in the components of $\mathrm{S_A}$. The UGS located on the fringes of the city usually had lower $\mathrm{S_C}$ due to the fewer number of houses in the vicinity. At the same time, the houses in that region were as well dependent on a single UGS available nearby, therefore, giving it a higher $\mathrm{S_E}$ score. As a result, lower $\mathrm{S_C}$ were compensated by higher $\mathrm{S_E}$ and vice versa. On the contrary, a



(a) (b)

(c) (d)

Figure 1: (a) Illustration of *Available Green Spaces* in the City of Berlin; section of city centre and Eastern Berlin. (b) Map of the UGS indicating the *Accessibility Score* (S_A) (c) Map of the UGS indicating the Quality Score for Noise (S_{Q_i,N_i}) (d) Map of the UGS indicating the overall *Quality Score* (S_Q)

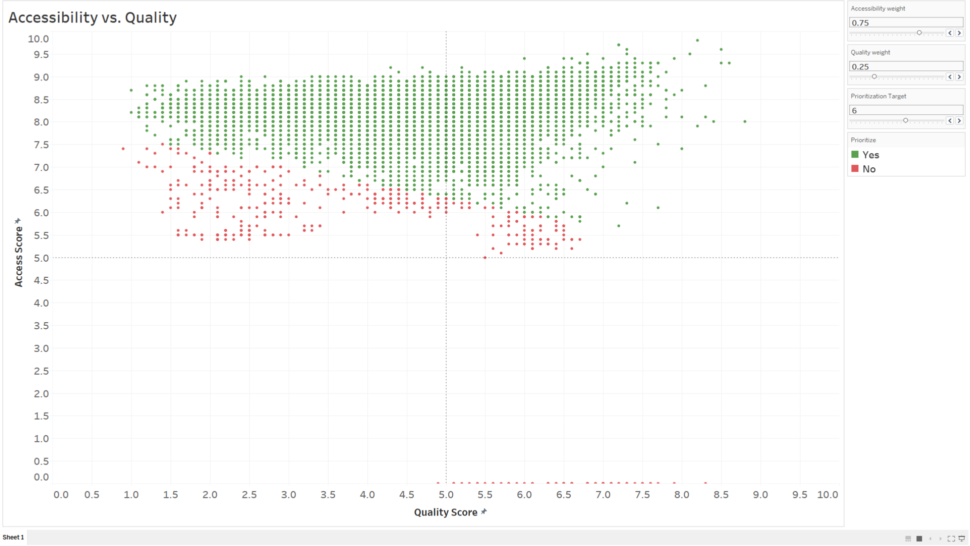
Table 2: Performance of UGS in Berlin on defined *Accessibility Score* (S_A) and *Quality Score* (S_Q).

	Minimum	Maximum	Mean	Median	Standard deviation	Coefficient of Variation
S_A	0	9.8	8.2	8.4	0.82	0.1
S_Q	0.9	8.8	4.7	4.8	1.24	0.26

higher coefficient of variation in S_Q reflects the large variability among the UGS in performance on quality parameters.

Finally, the obtained S_A and S_Q are plotted on a scatter plot to visualise the distribution of scores among the UGS. This is presented in Figure 2. According to this, the UGS to be prioritised are selected using the prioritisation order calculated by aggregating both the scores with their corresponding weights. At present the values of $w1$ and $w2$ required for Equation

11 are fixed at 0.75 and 0.25, respectively, to simulate the present priorities that emphasises on providing the 'quantity' access to UGS. Then, the decision-makers in city departments can select the minimum target of prioritisation order for prioritising the UGS. In this example, the target was chosen as 6. Therefore, all the UGS having an aggregated total score greater than 6 will be highlighted as a priority. These are marked with green colour in Figure 2. So, in the case of resource-constrained scenarios, the management of these UGS needs to be prioritised. Moreover, the scatter plot categorises the UGS into 4 groups with high/low accessibility in pair with high/low quality. Using this information a precise management plan can be devised for each type of UGS. For example, measures should be taken to improve the quality in UGS type (high accessibility, low quality) as it will benefit many residents.



Accessibility weight
0.75

Quality weight
0.25

Prioritization Target
6

Prioritize
🟩 Yes
🟥 No

Figure 2: A scatter plot showing performance of UGS on S_A vs S_Q for prioritising UGS with a minimum total score of 6.

4. Discussion

The methodology described in the previous section illustrates an approach to take management decisions such as prioritisation based on the field data. This is done using two criteria; namely, accessibility and quality. As only the open datasets are used in this study, the results are reproducible for any part of/cities in the world based on the availability of the data. However, there also exists a possibility of missing data in this case. The method used to create an UGS layer based on the tagged information from the OSM data might have introduced errors depending on the accuracy of the data. Also note that a circular buffer approach, as used here for proximity analysis is a simplistic determination of linear access between two points. Unlike the network analysis approach or Manhattan metric, the chosen approach does not incorporate the aspect of actual physical access through public roads and pathways. Hence, it might underestimate the actual distance between a residential building and nearby UGS. However, this method has the advantage of faster computing time and therefore allows for multiple iterations required for continual decision-making and management. Moreover, all types of buildings are included in the buildings layer, which also include commercial buildings, and industrial estates. So in a likely case, an area with lack of UGS can be a storage warehouse and therefore, not actually affecting any residents' accessibility. Additionally, no differentiation between public and a private UGS have been made. As some of the UGS such as golf park, private gardens, farms, might be only available to private communities, the actual accessibility is likely to be lower than the current estimates. Moreover, the quality of an UGS depends on numerous factors. Taking this complexity into account, this study takes a representative sample of criteria, and develops a numerical quality score for UGS. Nevertheless, the method is open to integrate further criteria as they may emerge in different contexts or different cities. Furthermore, it can be observed that higher weightage is assumed for the accessibility criteria (0.75) in comparison with the quality (0.25). This is done on the basis of the current expectations set by the German government policy as well as WHO recommendation, where the focus is exclusively on providing the access to a sufficient quantity of UGS without any targets with respect to the UGS quality. Though, this can be easily adapted in the model according to city's needs and priorities. Also note that the scope of current analysis was limited to the benefit side of the UGS while the cost part was not included. As a result, a UGS is prioritised solely on the basis of derived benefits without considering the input costs/resource requirements. This might lead to inefficient allocation of resources if the UGS with greater cost per unit of benefit (resource efficiency) is prioritised higher than the one with lower.

5. Conclusions and Further Research

The developed method has for the first time, implemented the UGS benefit criteria for informed decision making in UGS management. The benefit is measured using UGS accessibility and quality as an indicators, while the decision to be made is of prioritisation. The model uses open datasets in an automated way to estimate the residents impacted by the lack of UGS accessibility and show the distribution of UGS quality in the city. Moreover, through prioritisation order, it highlights the contribution and criticalness of each UGS in maintaining the required level of accessibility according to WHO recommendations. This can support local authorities in park/forest departments to efficiently allocate the limited resources in constrained scenarios and maximise the benefits. Thus, it provides an integrated framework to evaluate the UGS benefits and subsequently use it for decision making. However, the method needs further elaboration with respect to differentiation of buildings by type (residential/non-residential), segregation of UGS by type (public/private), with respect to the integration of further benefit criteria (environmental and economic), and the extension of factors within existing criteria e.g. UGS quality can be further enhanced by adding parameters like biodiversity and availability of leisure/sport equipment. Furthermore, the variation of score weights and their impacts on decision-making require further research. In the future course of work, varying combinations of different weightage factors will be evaluated through a sensitivity analysis. Moreover, along with estimating the benefits derived from UGS, the resources required to maintain a UGS will be calculated for a more comprehensive evaluation.

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