THE IMPORTANCE OF URBAN SPATIAL GRID DATA IN THE BUILDING VALUATION PROCESS

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ABSTRACT
The aim of this paper is to structure information on environmental characteristics that influence housing prices so that it can be effectively used in the valuation process through digital visualization. A suitable data platform for real estate valuation entities should contain information about the spatial data of the urban grid in a structured form that is stored digitally and accessible to all. OpenStreetMap can be considered as such a platform. It is a relatively user-friendly open tool that can be used for spatial and market analysis. This activity is very necessary in the valuation process as it is very time consuming and requires extensive data collection. This paper examines the environmental spatial characteristics in the urban grid to see whether or not they have an impact on the price of housing. These influences are examined using a non-parametric test that allows two groups or conditions to be examined. The Mann-Whitney U test is a test for ordinal data that is similar to a two-sample t-test. Nonparametric tests are used when a certain distribution of the data cannot be assumed. The paper concludes by presenting a systematic approach to incorporating information on the urban grid characteristics under investigation into open data platforms to streamline the property valuation process. The results can be suitably generalized to other commodities and markets.

KEYWORDS
Dataset, Information, OpenStreetMap, Property prices, Urban grid.
1. INTRODUCTION

The paper discusses the opportunity of applying digital visualization for real estate valuation. In the valuation process itself, quickly and clearly accessible information is essential for appraisers to do their work. The intention is to explore and structure information on the dependence of environmental characteristics on the market price of housing in cities. Cities occupy a very small part of the earth's surface, but consume large amounts of energy and generate about 75% of emissions (Bibri et al., 2020). Modern urban planning is now seeking to take environmental factors more fundamentally into account in urban development planning (Ostárek, 2021).

1.1 Digital visualization

Understanding urban spatial characteristics, i.e., data on site, location, population, air quality, and environmental characteristics, is essential for environmental assessment studies. Geographic Information Systems (GIS) and OpenStreetMap (OSM) make it possible to combine all the necessary data and inputs for an assessment. In comparison, GIS data are usually created and maintained by government or private organizations and are often expensive and poorly updated (Budhathoki et al., 2010). In contrast, OSM data are usually publicly available, free and frequently updated by users worldwide (Goodchild, 2007). Thus, data visualization through OpenStreetMap (OSM), an open source map, seems to be appropriate. The validity and usability of OSM data in several areas, namely Massachusetts in the USA, Bern in Switzerland and Beer-Sheva in southern Israel, was investigated by a research team led by Itai Kloog. In general, they were concerned with comparing the results of environmental exposure assessments using OSM versus government or commercial data. They evaluated the applicability using OSM data as a free of charge, global and easily accessible source of environmental data. They concluded that the fullness and positional precision of OSM data are generally very high in all regions and thus can be reliably used in environmental evaluation studies (Kloog et al., 2018). Exploring OpenStreetMap as a valuable source of global geospatial data useful to urban researchers was conducted by Geoff Boeing of Northeastern University. An analysis of U.S. street networks from OpenStreetMap at the metropolitan, town, and district scales—specifically every American city and town, urbanized area as defined by the Census Bureau, and neighborhood as defined by Zillow—was presented. It presents empirical findings on the form of cities and the characteristics of street networks in the U.S., with an emphasis on scales relevant to graph theory, shipping, urban design, and morphology, such as structure, connectivity, centrality, density, and resilience (Boeing, 2020).

1.2 Characteristics

In their article, Sander and Haight describe that the economic value of cultural ecosystem services in a given urbanized area is estimated using the hedonic pricing method they used three categories of variables, namely house characteristics, neighborhood characteristics, and environmental characteristics, to analyze the effect on housing prices (Sander and Haight, 2012). It is the data reflecting the characteristics of the neighborhood and the
environment around houses that provide the needs for housing that could be reflected in the public information system of cities. People consider several factors when choosing a house, and in urbanized areas they are an important factor in their choice. One important factor is public urban green spaces, represented most often by parks, because urban residents use the cultural services that these green spaces provide (Camps-calvet et al., 2016).

The close presence of urban greenery can help to shade buildings effectively, regulate the urban microclimate, regulate the ambient temperature and promote biodiversity. The ability of greenery to reduce carbon dioxide through photosynthesis contributes to reducing the carbon footprint, which has an impact on the resulting emissions and immissions. Green spaces also play an important role in noise protection (Fok and Law, 2018). On the other hand, some experts argue that green spaces do not belong in the city and this is mainly due to the loosening of the city just by green spaces and other elements of urban planning. The development of green spaces in city centres is blamed for reducing the density of development, decreasing services and employment opportunities and increasing crime in uncongested areas (Pondělíček, 2010). As well as public green spaces, it is advisable to incorporate water areas (blue space) into the urban space. In fact, most water areas contain vegetation and thus serve the function of greenery within the ecosystem, even though it is hidden under water (Bibri et al., 2020). Water areas are often used in urban planning as a decorative element of public spaces (Kleerekoper et al., 2012). In addition to its decorative and aesthetic importance, water helps to regulate thermal comfort due to its cooling effects, which have been studied by many researchers. The size of the water surface has a non-linear effect on air temperature. This means that several smaller lakes impact a larger area of a city than one large one. This effect can be observed for water surface areas as small as 4 m². (Robitu et al., 2006) Water surfaces can also have a temperature effect on more distant areas, where cooler air coming from the lake is driven by the wind and creates an air flow over a range of several kilometres (Theeuwes et al., 2013).

Location and distance from the centre are related to the availability of amenities in the urban area. In general, households prefer urban amenities nearby. Willingness to commute is related to potential parking constraints around town centres. The location of housing from amenities may be more distant the higher the cost of just covering the distance from the amenity and the higher the weight of the amenity in the utility function (Ng Chen Feng, 2008).

Noise is an environmental quality and public health issue in developed countries. The main source of noise is the transport sector. More than 20% of the population of the European Union is exposed to noise levels higher than those considered acceptable by the European Commission. High noise levels are mainly due to the increasing demand and capacity for transporting goods and passengers. The increase in noise levels in urban areas is also related to human activities and needs (Andersson et al., 2009). Urbanisation should aim to increase efforts to mitigate noise levels in the residential environment so as not to exacerbate the problem. (Nijland et al., 2003) A frequently used threshold below which no noise mitigation measures are taken is 55 dB (Nijland and Van Wee, 2005). An interesting finding is reported in the paper Beyond implicit prices. It is about obtaining theoretically consistent and also
elsewhere applicable values for noise avoidance from a hedonic model of house prices, where respondents reported that they were more bothered by noise from railways than from roads, and that it also affected the sale price of a property more (Bateman et al., 2007). Green spaces can play an important role in noise protection. For this reason, the integration of green spaces into a compact functional urban environment is suggested. These are mainly urban parks, street greenery, green corridors and green roofs (Yang et al., 2021).

Changing mindsets can make a major contribution to improving environmental quality while reducing climate change (Stern, 2011). One very significant factor contributing to climate change is the use of private vehicles instead of public transport. It is widely known that public transport is one of the most sustainable means of getting around a city. Private cars are increasingly finding their way into the wider city centre. The use of private cars contributes to environmental pollution, poor air quality, greenhouse gas emissions and immissions. Large cities have increasingly begun to restrict access and parking in and around their centres and wider surroundings. The aim is to push private vehicles to the edge of cities. Reversing the trend in household motor vehicle use, together with home heating, are the most important targets for reducing emissions and immissions (Collins and Chambers, 2005). The Kyoto Protocol estimates that the transport sector contributes up to 12% of greenhouse gases globally (Hunecke et al., 2010).

2. MATERIALS AND METHODS

2.1 Processing methods

The first task was to identify different characteristics of the urban space and environment. As the authors did in their similarly focused research, where these characteristics mainly included environmental and neighbourhood characteristics. The characteristics of the urban space in the neighbourhood were chosen for our research: distance from the city centre, a UNESCO-listed tourist site (specifically Villa Tugendhat), architecturally significant buildings included in the urban development, public green spaces, water areas, parking opportunities and major transport corridors represented by railways and main transport routes. In addition, we included the following environmental characteristics: crime rates, daytime and nighttime noise, total immissions, and surface temperature.

First, a search, selection and evaluation of selected sites in the area of Brno, Czech Republic was carried out. In these locations, 321 properties (apartments) for sale were identified and their sale prices were collected. The source of information was a public list, the so-called Cadastre of Real Estate of the Czech Republic, in which all purchase contracts from real estate sales have been digitally registered since 2014. As these sales took place between 2016 and 2021, the amounts were recalculated to the current price level using indices processed and subsequently published by one of the mortgage banks operating on the real estate market in the Czech Republic.
Testing and statistical analysis were performed using the nonparametric Mann-Whitney test. The Mann-Whitney test is a nonparametric test of the agreement of medians. This test allows comparison between two groups or conditions without assuming that the values are normally distributed, which corresponds to a Gaussian normal distribution. The Mann-Whitney test determines whether there is a statistically significant difference between two unrelated, independent groups on the dependent variable. The requirements are that two random independent samples are present, the data are continuous, and the null hypothesis states that the medians of the two samples are identical. The variable we care about and want to see if it differs between the two groups must be continuous. Continuous means that the variable can take on any reasonable value. This test was chosen on the basis of verifying and then rejecting the normality of the data collected for analysis.

2.2 Data collection

Public online interactive maps designed for this purpose were used to measure distances from the apartment to the place of interest (distance from the city centre, UNESCO monument, public greenery, water areas, etc.) Data on all environmental characteristics examined were obtained from a variety of available sources compiled at the state or city level.

The server https://mapakriminality.cz provides police statistics that are converted into simple table and map views. This includes information on crimes committed, from the less serious to the most serious. A crime index is then determined from the data. The crime index can then be easily retrieved for a particular mapped section of the city in which the property under consideration is located.

The noise map from ground traffic (road, rail and tram traffic) was prepared at the city level for the daytime period from 6 a.m. to 10 p.m. and also for the nighttime period. This map is not interactive, it consists of individual map sheets at a scale of 1:10 000 saved in PDF format. In the map sections, areas with the corresponding sound pressure levels in dB are colour coded. While the noise map is not user-friendly, the parking map offers a modern
application of information about parking zones, parking houses, parking lots, etc. throughout the city. View it at https://parkovanivbrne.cz/mapa/.

Specific data on immissions load were obtained from the feasibility study for the Brno city area, which is publicly available at https://brnenskeovzdusi.cz/dokumenty/. This was the total NO2 (nitrogen oxide) immission load at an average annual concentration. The pollutant NO2 is formed relatively quickly by the reaction of NO (nitric oxide) with ground-level ozone. Attention is given to NO2 because of its negative impact on human health. According to the authors of the feasibility study, the most important source of immission load is the car construction, stationary sources do not pose a significant problem for this pollutant.

The surface temperature data were obtained from a GIS application developed in collaboration with the Institute of Global Change Research of the Czech Academy of Sciences. The surface temperature image was taken by hyperspectral scanning of the Brno city area with a TASI 600 hyperspectral sensor on the last day of August 2019. GIS application available at https://gis.brno.cz/mapa/teplotni-mapa.

3. RESULTS

A normal distribution of the data was tested on the created database of 321 residential properties for sale. Due to the result where the P-value was < 0.05, it was evident that this was not a normal distribution and a non-parametric test would need to be used for further testing. The Mann-Whitney test was chosen as the paired nonparametric test.

Figure 2. Normality test for all data of database

Non-parametric Mann-Whitney test was performed at 0.05 level of significance, 95% confidence interval. It has been calculated separately for each of the urban space and environmental characteristics, namely distance from the city centre, UNESCO monument, architecturally significant building, public greeneries, water areas, railway, major traffic route, as well as for crime index, noise during day and night hours, parking facilities, immission load and surface temperature. The variable for all these tests was the market price of housing
units in the study area of Brno. The cut-off values for each parameter were selected based on information from peer-reviewed publications and together with the results are described below.

For the distance from the city centre a limit of 1 000 m was used. The effect of this distance on the market price of the dwelling unit was not evident. This is probably due to the study area, which included mostly sites close to the centre. It therefore shows that this indicator is not important if the differences in distance are small. The maximum distance from the centre was 4,500 m, the median distance was 2,000 m, if these values were multiples larger the study area would have been extended, the effect of proximity to the city centre would probably have been felt. Another indicator examined was the proximity of Villa Tugendhat, which is the most important functionalist monument in Brno and has been inscribed on the UNESCO list. For the hypothesis tested, a cutoff distance of 1,000 m was chosen. However, the effect of the proximity to Villa Tugendhat on the market value of the apartment unit was not evident. For the proximity of an architecturally significant building, the criterion was its location to the survey point. Here again, the hypothesis was accepted, i.e. the effect on the price of the housing unit was not proven. For the proximity to public greenery, a limit of 500 m was taken, which is a common walking distance in larger cities. It has also been shown to have an effect on surface temperature, immissions load and its need for human psychology and physiology. Its effect on the market value of a property has been demonstrated in our research. The same threshold of 500 m was chosen for proximity to railways and major traffic route. The effects of these indicators on the market value price of the selected points have not been demonstrated. This may be due to the ambiguous classification of this indicator as a positive or negative and different preferences when buying property in cities. The limiting value for the proximity to a water areas, which was considered to be a river, dam or mesic lake, was taken to be 500 m. This threshold is based on the fact that houses within approximately this distance are influenced by the positive factors of proximity to water areas in cities. The influence of proximity to water areas on the market value of a housing unit has been demonstrated. The existence of parking zones was taken as the limiting criterion for parking. Where parking zones exist, each dwelling unit has the option to park one vehicle for a low flat fee, and other vehicles parking in the portion of the city with a parking zone must pay per parking hour at the zone rates. This is why there are fewer cars in areas with parking zones and residents do not have a parking problem. The impact of this indicator on the market value of the property has been demonstrated.

For the crime index, its cut-off value of 2,000 was taken, which corresponded to the period from 2016 to 2021. For the crime index, no effect on the market value of the surveyed points was demonstrated. Again, it is appropriate to point out the narrowness of the study area given the slow but already proven gentrification of the city's problem neighborhoods. Some central parts of Brno are a good investment for investors, even if they are areas with higher crime rates. The price is therefore increasing in these areas due to gentrification. The limit value for noise, both at night and during the day, was taken to be 50 dB. Due to the dense network of traffic roads in the city of Brno, the statistical sets for noise mainly during the day were very unbalanced. There is a large urban noise smog which can hardly be avoided due to the heavy traffic. The effect of noise on the market value of a housing unit could not be
demonstrated. The total NO2 immission load was taken from the annual average concentration and a limit value of 36 μg/m3 was used. This limit value was chosen based on recommendations from other urban air studies. The effect of this indicator on the market value of a dwelling unit has not been demonstrated. However, this is a highly communicated topic and, unless the standard of living of the European population deteriorates significantly, the topic of immissions load and the choice of location for the purchase of real estate will be increasingly intertwined and monitored. The surface temperature limit has been set at 30°C. This value was used because it is the cutoff temperature for learning the so-called "tropical day", which can be perceived negatively by the population. A direct effect of temperature on market value has not been demonstrated.

Table 1 summarizes useful descriptive statistics for all independent groups compared. The first group includes the indicator under research in close proximity or at values acceptable and perceived as positive for the point under investigation. The second group always includes physical points examined within a given indicator that did not fit within the cutoff values. Based on the statistical test, a significant median difference was found for the examined effect of market value of real estate. This was done for all individual indicators. A point estimate is a parameter characterised by a single value, preferably close to the true value. The value of the point estimate is not indicative of the precision of the estimate and is quantified in absolute value in the descriptive statistics presented here.

Table 1. Summary descriptive statistics of Mann-Whitney test for the studied indicators and variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point estimate</th>
<th>95% CI</th>
<th>W</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from the city centre</td>
<td>1206</td>
<td>-4700;2437</td>
<td>9704,0</td>
<td>0,5067</td>
</tr>
<tr>
<td>UNESCO monument</td>
<td>4119</td>
<td>-9828;1776</td>
<td>1939,0</td>
<td>0,1754</td>
</tr>
<tr>
<td>Architecturally significant building</td>
<td>247</td>
<td>-4098;3670</td>
<td>8941,0</td>
<td>0,9060</td>
</tr>
<tr>
<td>Crime</td>
<td>289</td>
<td>-4274;4953</td>
<td>6339,0</td>
<td>0,9128</td>
</tr>
<tr>
<td>Public greenery</td>
<td>4945</td>
<td>1918;8009</td>
<td>39532,0</td>
<td>0,0017</td>
</tr>
<tr>
<td>Water areas</td>
<td>5279</td>
<td>-9257;-1433</td>
<td>5567,0</td>
<td>0,0080</td>
</tr>
<tr>
<td>Railways</td>
<td>896</td>
<td>-367;5422</td>
<td>5022,0</td>
<td>0,6924</td>
</tr>
<tr>
<td>Major traffic route</td>
<td>2307</td>
<td>-5144;612</td>
<td>18221,0</td>
<td>0,1181</td>
</tr>
<tr>
<td>Daily noise</td>
<td>1904</td>
<td>-1488;5349</td>
<td>39281,0</td>
<td>0,2691</td>
</tr>
<tr>
<td>Night noise</td>
<td>2042</td>
<td>-1000;5066</td>
<td>30725,0</td>
<td>0,1809</td>
</tr>
<tr>
<td>Parking</td>
<td>5582</td>
<td>2430;8550</td>
<td>40962,0</td>
<td>0,0006</td>
</tr>
<tr>
<td>Immission load</td>
<td>2314</td>
<td>-5207;619</td>
<td>16959,0</td>
<td>0,1204</td>
</tr>
<tr>
<td>Temperature</td>
<td>1487</td>
<td>-1902;5131</td>
<td>15207,0</td>
<td>0,3914</td>
</tr>
</tbody>
</table>
The results show that the proximity to public greenery, water areas and availability of parking have a statistically significant effect on the market value of residential urban apartments. Publications focusing on the environmental impacts of urban space argue that green and water areas help regulate the climate. Therefore, the authors of this paper have extended their case study by examining just the relationship between public greenery or water areas and the values of immissions load and surface temperatures. Thus, for further testing, the relationship of the indicators described above to market value was abandoned and replaced by the relationship of the urban space indicator to selected environmental characteristics, with the choice of different cut-off values inspired by environmental research. Within the same database, a Mann-Whitney test was performed at a significance level of 0.05, 95% confidence interval.

Table 2 summarizes useful descriptive statistics for the two independent groups of urban space indicators being compared, namely public greenery and water areas. The first group includes areas of public greenery in close proximity (located within 300 m of the selected point). The second group does not include public greenery in close proximity (located further than 300 m from the selected point). Based on the statistical test, a significant median difference was found for both examined environmental impacts caused by public greenery in close proximity to the selected physical point under research. Similarly for water bodies, the first group includes water areas in close proximity (located within 1 km of the selected point). The second group does not include water areas in close proximity (located further than 1 km from the selected point). Based on the statistical test, a significant median difference was found for both environmental impacts caused by water areas in close proximity to the selected physical point under research.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point estimate</th>
<th>95% CI</th>
<th>W</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Public greenery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily noise</td>
<td>5,000</td>
<td>0,001;5,001</td>
<td>67539,5</td>
<td>0,0041</td>
</tr>
<tr>
<td>Night noise</td>
<td>0,000</td>
<td>0,000;5,000</td>
<td>67042,5</td>
<td>0,0100</td>
</tr>
<tr>
<td>Immission load</td>
<td>0,600</td>
<td>0,000;1,130</td>
<td>66469,0</td>
<td>0,0253</td>
</tr>
<tr>
<td>Temperature</td>
<td>2,000</td>
<td>1,000;3,000</td>
<td>79133,0</td>
<td>&lt;0,0001</td>
</tr>
<tr>
<td><strong>Water areas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily noise</td>
<td>5,000</td>
<td>0,000;5,000</td>
<td>68137,5</td>
<td>&lt;0,0001</td>
</tr>
<tr>
<td>Night noise</td>
<td>5,000</td>
<td>5,000;4,999</td>
<td>69338,5</td>
<td>0,0086</td>
</tr>
<tr>
<td>Immission load</td>
<td>0,990</td>
<td>0,710;2,120</td>
<td>66833,0</td>
<td>0,0002</td>
</tr>
<tr>
<td>Temperature</td>
<td>2,000</td>
<td>1,000;3,000</td>
<td>67795,0</td>
<td>&lt;0,0001</td>
</tr>
</tbody>
</table>
4. CONCLUSION

The creation or restoration of public green spaces and water bodies in cities has been shown to have the potential to improve the overall climate and thus influence the quality of the urban environment. This fact, when linking the two research activities, means that noise during the day, noise at night, the value of immissions load and surface temperatures also have a secondary effect on the market value of residential urban dwellings. The research shows that the effect of proximity to public greenery, water areas and parking options should be considered when valuing urban properties. These indicators affect the market value directly. Electronic maps and information system of each city are needed to obtain data on these indicators quickly and conveniently. These information channels are available almost worldwide, but there is a need to link two different environments and combine their use. The influence of noise, immissions load and surface temperatures on the market value of housing units in a city has been shown to be secondary to the location of public greenery and water areas. Although these indicators do not directly affect the market value issue, their influence should not be neglected. It can also be inferred that the trend of taking into account the environmental qualities of an area when purchasing a residential property will grow. From this perspective, both the Geographic Information System (GIS) and OpenStreetMap (OSM) would be welcome information systems to clearly and quickly identify the data needed to assess the market value of properties. Previous research has shown that while GIS data is expensive and not very current, OSM data is free, publicly available and easier to update. For appraisers and the professional public, data that are out of date are of little value, which is why the use of OSM seems to be the optimal option. The aggregation of appropriate spatial data presented in this research and its digital visualization into OSM can also help to guide environmental design and related public space of cities.

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