Open Space between Residential Buildings as a Factor of Sustainable Development – Case Studies in Brno (Czech Republic) and Vienna (Austria)

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Abstract. The characteristics of open spaces between residential buildings have, as authors suppose, an impact on the sustainable development of urban areas. Spatial arrangement and accessibility of these spaces, the type and height of surrounding buildings, the quantity and character of greenery, and many more characteristics influence the quality of environment, and the quality of life of local residents. These and further characteristics of the open spaces between residential buildings influence the ecological stability of the area, its hygienic qualities, the intensity and way of using by various social groups, and also the prices of real estates. These qualities indicate the environmental, social and economic sustainability of the urban area. The proposed research methodology assessed specific indicators of sustainability within a range from 0 to 10 points. 5 points correspond to the general standard in the area, 0 points indicate degradation, and 10 points indicate the highest contribution to sustainable development. Observation methods, questionnaire survey, statistical analyses, and methods of measurement were used to determine the values of the given indicators. The paper analyses the impact of the open spaces between residential buildings on sustainability via the case studies performed in the Central European cities of Brno, Czech Republic and Vienna, Austria. Two forms of residential urban structures in the City of Brno in the Czech Republic were selected for the analysis: the closed courtyards in the urban block from the 19th century and the open spaces in the housing estates constructed under socialism in the 20th century. The question is, if the different forms of spaces between residential buildings influence the sustainability of urban area and satisfaction of inhabitants in different ways. A complementary case study in Vienna indicates that inhabitants of a housing estate in Vienna, as well as inhabitants of housing estates in Brno, highly appreciate the meaning of large green open spaces between buildings. The paper presents results of basic research. The results indicate that the sustainability of open housing estate forms is higher than the authors expected.

1. Introduction
50% of all people over the world live in the cities. Life of people takes place not only in the buildings, but also in the open space between them [1]. There is a limited amount of these places in the cities. Open spaces between residential buildings represent a valuable place where people spend time in contact with other people and nature near their home. The character of these spaces can, as assumed, have a significant impact on the quality of environment, the quality of life and therefore on the sustainable development of the area.
The open spaces between residential buildings are part of an urban structure and a conception of the cities. Two types of urban structures which appear in a large number in post-socialist cities of central Europe are: courtyards in closed urban blocks from the 19th century, and open spaces surrounding houses in high-rise panel housing estates constructed under the socialism era in the 20th century. Sustainable development of housing estates is often discussed considering the intensity and way of using of the open spaces between residential buildings. How do the open spaces in housing estates affect the character of the environment? Do the residents use these open spaces and consider them as important for their quality of life? Can the importance of these open spaces compete with the significance of the closed courtyards in the centre of the city? The case studies carried out in the Central European city of Brno are trying to answer these questions.

Open high-rise housing estate development occurs not only in post-socialist Central European cities, but also in Vienna, Austria. Vienna did not pass the socialist period which could distort the socio-economic relations. Do the residents of a housing estate in Vienna have the same opinion on the importance of open spaces between residential buildings as the residents of housing estates in Brno? The case study carried out in the area of Vienna – Wohnpark Alt Erlaa is trying to answer these questions.

The list of indicators and characteristics has been compiled taking into account the literature review of existing research. The following characteristics of the open spaces can influence the hygienic qualities of environment. Grass surfaces and tree shades efficiently reduce the high surface temperature [3]. Urban greenery reduces the air temperature in the urban area, at least on the local scale [4]. Greenery is legitimately becoming a part of architectural and urban conceptions, which is documented in several published projects [5, 6]. Different forms of buildings help to mitigate the level of traffic-induced noise in the open spaces [7]. Other characteristics of open spaces may have impact on social qualities of neighbourhood. The level of noise pollution in the environment is perceived differently by various social groups, with higher sensitivity in the middle-aged people [8]. There are other factors as air pollution that have a strong influence on the health of communities and their social development [9]. The presence of greenery in public space may also influence the feeling of safety [10]. Greenery, water and quality public space can influence the price of surrounding real estate [11, 12].

The aim of the study is to explore the correlations and impacts of the open spaces between residential buildings on the sustainable development of the area. The paper presents results from a total of six case studies in Brno and Vienna.

2. Methods
2.1. Methods and obtaining of data
This paper aims to identify some relationships between characteristics of open spaces and selected indicators of sustainability. The analysis of the relationship between the characteristics of the open spaces and the indicators of sustainability allows to identify the advantages and disadvantages of specific forms of open spaces in a broader sense.

The basic characteristics of the open spaces include: location of the space within the city and its transport connections, the quantity and character of greenery, the way of use of the open spaces, the ownership of the spaces and surrounding buildings, etc.

The characteristics of the open spaces between residential buildings can influence the ecological stability of the area, its hygienic qualities, the intensity and the way of using by various social groups and the prices of local real estates. These qualities indicate the environmental, social and economic sustainability of the urban area.

A multi-criteria decision making method was used to evaluate the quality of open spaces between residential buildings, where the indicators of sustainability were used as the criteria. The selected indicators of sustainability are grouped into four main pillars: ecology, hygiene, society and economy. Each indicator was evaluated on the scale from 0 to 10 points when the median value (5 points) referred to common standards in the area, 0 points referred to degradation of the measured indicator, and 10 points referred to the maximal contribution of the phenomenon to the sustainable development. If a
given indicator could only attain unfavourable values, it was evaluated on a scale from 0 to 5 points (e.g. manifestations of vandalism). If a given indicator was not assessed or not determined in the studied area, it was assigned the neutral value of 5 points and was not depicted in colour in the pertinent tables. The median values for certain indicators (diversity and number of activities, numbers of visitors, etc.) were determined on the basis of preliminary observations in a pilot study of the area BV2 on the Brno-Vinohrady housing estate. The median values in questionnaires corresponded to a neutral perception of the given phenomenon.

Consideration was given to the importance of the individual indicators of sustainability by means of weightings – an index that converted the points awarded for a partial indicator or group of indicators. This weighting index was developed by dividing the overall weighting of 100 among the individual pillars of sustainability, subsequently among framework aggregated groups of indicators, and finally among partial measurable indicators. Specialists in the individual pillars of sustainability performed the allocation of weightings and the definition of indicators on the basis of mutual coordination. The environmental pillar was divided into an ecological pillar and a hygiene pillar. Of the total weighting of 100 %, 10 % was allocated to the ecological pillar, 25 % to the hygiene pillar, 35 % to the social pillar, and 30 % to the economic pillar. The resultant value of weighted points in the sustainability pillar is equal to the sum of weighted points in the framework aggregated indicator. The resultant value of weighted points in the framework aggregated indicator is equal to the sum of the weighted points of the partial indicators. The weighted points of the partial indicators were obtained as the product of the points and weightings of these indicators divided by 10, where the number 10 represents the maximum of available points.

To determine the values of selected and identifiable indicators, the following methods were used: the observation, questionnaire survey among the residents of related houses, the statistical analysis, and the analysis of real estate prices.

A field observation was the source of the information about the investigated locality. It was performed by the researchers who were focused on the information about the manner and frequency of using the open space, and on the occurrence of pathological phenomena which potentially influence the feeling of safety in the investigated space. Measuring of the data about quality of environment was part of the observation, i.e. measuring of temperature, humidity and acoustic pressure. The observation was held from 12 to 15 o’clock. This information was used to determine the hygienic indicators. It is a confirmation of the studies which argue that high-grown greenery can positively affect the microclimate and it reduces air temperature in summer. Also, the grass surface and tree shades help to reduce surface temperature [3]. Urban greenery legitimately reduces the air temperature in the urban area [4].

Another source of information was a questionnaire survey among the inhabitants of the adjacent residential buildings. During 2–3 weeks there were approximately 150 questionnaires collected, which means that 35 % were successful. This investigation aimed at the manner of using the space, at the way the users perceived it, whether they feel safe, and last but least at the feeling of belonging to the given locality. The questionnaire investigation served to quantify some social indicators.

Subsequently the index of residents’ satisfaction [q] was quantified. The source of data to quantify the satisfaction index was also the questionnaire answers. The index is a proportional ratio of the total sum of the concrete points obtained from the respondents’ answers to the maximal sum of available points. It expresses the level of inhabitants’ satisfaction; the higher evaluation, the higher satisfaction. The index of satisfaction reflects the answers to the questions concerning e.g. frequency and purpose of the visits in the investigated space, the feeling of safety, aesthetic quality, neighbourhood relationship, feeling of home, interest in the arrangement of the space, and the perception of noise, wind, dust and smell.

The analysis of the statistical data was used to get the data about the social structure of the residents in the adjoining houses. The main source of data was the 2011 census and a comparison of data from the 2001 and 2011 census performed by the Czech Statistical Office [13]. The data about population age structure, economic activity and education structure (among the residents older than 15 years). The
source of information about the property prices and the rents were the statistics of the real estate agency Real Spectrum [14].

2.2. Study areas
The city of Brno with almost 400 000 inhabitants is the second largest city in the Czech Republic and represents a typical post-industrial city in the Central Europe. The city offers examples which represent various periods and various urbanistic concepts. Vienna, the capital city of Austria, is similarly as Brno a representative of a post-industrial city in the Central Europe although the number of inhabitants (1.741 million) is markedly greater.

Two forms of residential structures in the City of Brno in the Czech Republic were selected for the analysis: closed courtyards in closed urban blocks from the 19th century, and open spaces in high-rise block housing estate constructed under the socialism era in the 20th century.

2.2.1. Courtyards in the city centre of Brno (spaces BS1–BS2). The surveyed spaces are courtyards inside closed urban blocks of four- to six-floor residential buildings from the second half of 19th century which are located in the wider city centre of Brno. The paper presents results of two case studies, labelled BS1 and BS2. The courtyards with a significant proportion of well-maintained low and fully-grown greenery are not accessible to public. The BS1 courtyard is partly used by the primary and nursery school. All courtyards are the property of the city which maintains them. The adjoining buildings are owned by a cooperative or association of flat owners. The locality is close to the city centre and represents an attractive place of housing which is undergoing continuous renovations. The sale and rent prices of housing and commercial space in the locality are above the average within the city of Brno.

2.2.2. The spaces between residential buildings in the housing estate in Brno-Vinohrady (BV1–BV2). The survey was performed on two public spaces between residential buildings in the prefabricated concrete panel housing estate in Brno-Vinohrady, in the eastern part of the city. The surveyed spaces labelled BV1–BV2 are located on the plots owned by the city who maintains them. BV1 labels a space with a significant amount of well-maintained low and full-grown greenery. The BV1 space surrounds a twelve-story prefabricated block of flats in private ownership. The BV2 labels the space with a significant amount of well-maintained low and full-grown greenery. The space is surrounded by two residential buildings; in the south, it is a four-story building with flats in private ownership, in the north it is an eight-story building owned by the city. The prefabricated concrete panel housing estate was completed in the socialist era in the second half of 1980s. The housing in this housing estate is considerably popular thanks to its vast services and amenities as well as affordable prices. The only significant drawback is a lack of parking spaces.
2.2.3. The space between residential buildings in the housing estate in Brno-Lesná (BL). The survey was focused on the BL public space between two eight-story apartment buildings in the prefabricated concrete panel housing estate in Brno-Lesná, in the northern part of the city. This vast space with a maximum proportion of low and full-grown well-maintained greenery is located on the property of the city who maintains it. The flats are owned by the residents. The housing estate which was conceived as an open complex of buildings in the greenery was completed in the socialist era in the second half of the 1960s. Housing in this Brno-Lesná estate is popular thanks to the natural environment and extensive greenery that is an object of interest of the residents. The estate is probably also popular as the professionals evaluate it as the best prefab housing estate in Brno. It is inspired by the Tapiola housing estate in Helsinki, Finland. There is a live discussion about its potential to become a protected monument [16].

2.2.4. The space between residential buildings in the housing estate in Vienna – Wohpark Alt Erlaa (WA). The article presents the results of investigation in the public space WA between two 22- to 26-storey apartment buildings in the Wohpark Alt Erlaa housing estate which is located in the Vienna – Leising city part in the southern part of the city. The studied open space with a large amount of greenery is located on the properties owned by the city which maintains them. The flats in the buildings are managed by a company whose majority is owned by the city of Vienna. The construction of the housing estate was completed in mid-1980s. A great advantage of this housing complex is the quality of available services and facilities, including a swimming pool on the roof, parking spaces in the underground parking garages, and a system of disposal and collection of household waste.

3. Results and discussions

The following table presents a summary of the indicators and the pillars of sustainability for the analysed case studies. The following commentaries summarize the significant or outstanding phenomena reflected in the indicators.

3.1. Ecology

The closed courtyards in the city centre (BS1 and BS2) and the spaces between the residential buildings in the prefab housing estate Brno-Vinohrady (BV1 and BV2) show good evaluation in terms of ecological quality of the area. The spaces between buildings in the housing estates Brno-Lesná (BL) and Vienna – Wohpark Alt Erlaa (WA) show, in comparison with the studies BS1, BS2, BV1 a BV2, the highest evaluation. The reason is especially their largeness and ecological interaction with the surroundings. In all cases the spaces have a significant amount of maintained greenery which includes diverse species. The evaluated spaces generate a good ecological quality which is not generally standardized in urban areas.
Table 1. Table of Sustainability Indicators.

| Pillar/ Weighted points | Partial measurable indicator | Points BS1 | Points BS2 | Points BV1 | Points BV2 | Points BL | Points WA | Weight |
|-------------------------|------------------------------|------------|-----------|-----------|-----------|-----------|-----------|--------|
| **Ecology [x]**         |                              |            |           |           |           |           |           |        |
| 1-1-1                   | size                         | 4.0        | 5.0       | 6.0       | 5.0       | 9.0       | 9.0       | 1.67   |
| 10                      | interaction with the surroundings - decisions | 2.0        | 3.0       | 8.0       | 8.0       | 8.0       | 7.0       | 0.83   |
| 5.74                    | interaction with the surroundings - water | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.83   |
| 6.05                    | shape                        | 9.5        | 9.0       | 2.5       | 4.0       | 3.0       | 8.0       | 1.67   |
| 5.55                    | biodiversity of desirable tree species | 6.0        | 9.0       | 8.0       | 4.0       | 8.0       | 8.0       | 0.45   |
| 5.45                    | age of desirable tree species | 5.0        | 5.0       | 6.0       | 6.0       | 7.0       | 7.0       | 0.45   |
| 6.36                    | occurrence of undesirable tree species | 10.0       | 10.0      | 10.0      | 10.0      | 9.0       | 8.0       | 0.45   |
| 6.92                    | occurrence of undesirable herbs | 10.0       | 10.0      | 9.0       | 9.0       | 8.0       | 7.0       | 0.45   |
| 1-2-4                   | desirable animals living in the wild | 3.0        | 3.0       | 3.0       | 3.0       | 5.0       | 4.0       | 0.45   |
| 1-2-5                   | ability to collect rainwater  | 5.0        | 5.0       | 4.0       | 4.0       | 4.0       | 4.0       | 0.45   |
| 1-2-6                   | natural quality of water area | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.45   |
| 1-2-7                   | naturalness of bank zones    | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.45   |
| 1-2-8                   | aquatic animals living in the wild | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.45   |
| 1-2-9                   | density of vegetation       | 5.0        | 5.0       | 6.0       | 6.0       | 8.0       | 7.5       | 0.91   |
| **Hygiene [y]**         |                              |            |           |           |           |           |           |        |
| 2-1-1                   | reduction of temperature extremes | 6.0        | 6.0       | 7.0       | 6.0       | 5.0       | 5.0       | 1.92   |
| 25                      | reduction of humidity extremes | 9.0        | 9.0       | 7.0       | 7.0       | 7.0       | 7.0       | 1.92   |
| 15.70                   | reduction of sunburn in summer | 6.5        | 6.5       | 10.0      | 4.0       | 6.5       | 7.0       | 0.96   |
| 17.45                   | reduction of insulation outside summer | 2.0        | 2.0       | 4.0       | 4.0       | 3.0       | 3.0       | 0.96   |
| 13.91                   | reduction of windiness       | 7.5        | 7.5       | 3.0       | 7.5       | 6.0       | 6.0       | 1.92   |
| 15.01                   | dust control                | 9.0        | 9.0       | 6.0       | 7.0       | 7.5       | 7.0       | 1.92   |
| 16.27                   | level of acoustic pressure  | 7.1        | 7.1       | 5.0       | 6.0       | 5.0       | 5.1       | 1.28   |
| 16.55                   | reduction of external noise from traffic | 10.0       | 10.0      | 7.5       | 7.5       | 7.0       | 8.0       | 0.64   |
| 2-6-2                   | noise nuisance from the neighbourhood | 4.3        | 4.1       | 3.2       | 4.1       | 4.2       | 3.8       | 0.64   |
| 2-6-4                   | local noise nuisance        | 3.7        | 3.3       | 3.5       | 3.9       | 3.8       | 3.8       | 0.64   |
| 2-6-5                   | pleasant natural sounds     | 7.0        | 7.0       | 9.0       | 7.0       | 9.0       | 8.0       | 0.64   |
| 2-7-1                   | local smell nuisance       | 4.0        | 4.6       | 3.7       | 4.1       | 4.4       | 4.2       | 0.96   |
| 2-7-2                   | pleasant natural smell     | 7.0        | 9.0       | 7.0       | 6.0       | 9.0       | 9.0       | 0.96   |
| 2-8-1                   | rate of insect nuisance    | 4.3        | 4.3       | 3.9       | 4.0       | 4.4       | 4.2       | 1.92   |
| 2-9-1                   | cleanliness of the space    | 5.5        | 9.5       | 5.0       | 7.0       | 8.0       | 9.0       | 3.85   |
| 2-10-1                  | limitation of chemical pollutants | 6.0        | 6.0       | 6.0       | 6.0       | 8.0       | 8.0       | 3.85   |
| **Society [z]**         |                              |            |           |           |           |           |           |        |
| 3-1-1                   | change in the number of residents | 8.0        | 9.0       | 6.0       | 0.0       | 9.5       | 5.0       | 1.75   |
| 35                      | residents age structure given in the census | 5.0        | 3.4       | 2.5       | 2.5       | 0.0       | 5.0       | 1.75   |
| 22.38                   | residents age structure in survey | 10.0       | 8.0       | 7.0       | 5.0       | 5.0       | 1.0       | 1.75   |
| 21.47                   | gender diversity of the space users | 9.6        | 5.0       | 5.5       | 10.0      | 5.0       | 4.0       | 1.75   |
| 19.70                   | subjective state of health  | 7.5        | 6.9       | 7.0       | 6.3       | 7.0       | 8.8       | 7.00   |
| 17.98                   | educational structure of residents | 8.5        | 4.8       | 4.9       | 4.9       | 3.0       | 10.0      | 0.58   |
| 21.06                   | median of monthly income   | 7.5        | 6.3       | 7.5       | 7.5       | 6.0       | 5.0       | 0.58   |
| 22.30                   | unemployment               | 5.6        | 10.0      | 4.6       | 4.0       | 7.5       | 5.0       | 0.58   |
| 3-3-3                   | ethnic diversity           | 5.0        | 5.0       | 6.0       | 6.0       | 6.0       | 6.0       | 0.58   |
| 3-3-4                   | feeling of safety in the locality by day | 4.1        | 4.7       | 3.7       | 3.0       | 4.7       | 4.6       | 0.58   |
| 3-3-5                   | feeling of safety in the locality by night | 3.6        | 3.8       | 3.1       | 2.3       | 3.7       | 4.4       | 0.58   |
| 3-3-6                   | feeling of safety in the space | 8.4        | 9.0       | 6.5       | 5.3       | 8.2       | 9.5       | 0.58   |
| 3-3-7                   | display of vandalism       | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.58   |
| 3-3-8                   | traces of using drugs      | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.58   |
| 3-3-9                   | groups drinking alcohol    | 5.0        | 5.0       | 5.0       | 5.0       | 5.0       | 5.0       | 0.58   |
| 3-3-10                  | untrustworthy strange persons | 5.0        | 5.0       | 5.0       | 4.1       | 4.6       | 4.6       | 0.58   |
Pillar/Weight/Partial measurable indicator | Points BS1 | Points BS2 | Points BV1 | Points BV2 | Points BL | Points WA | Weight
---|---|---|---|---|---|---|---
3-3-12 | "good address" | 7.7 | 8.0 | 5.4 | 5.8 | 8.9 | 7.8 | 0.58
3-4-1 | diversity of activities | 2.7 | 2.7 | 5.4 | 3.9 | 3.8 | 2.9 | 1.00
3-4-2 | frequency of activities | 3.8 | 5.1 | 9.7 | 5.6 | 8.4 | 7.5 | 1.00
3-4-3 | maximum number of visitors | 1.5 | 7.5 | 1.7 | 1.5 | 1.5 | 1.0 | 1.00
3-4-4 | average number of visitors | 7.3 | 5.7 | 4.5 | 1.5 | 1.5 | 3.4 | 1.00
3-4-5 | space covers the needs | 6.7 | 7.5 | 4.7 | 4.7 | 8.0 | 8.8 | 1.00
3-4-6 | perception of aesthetic quality of the space | 6.5 | 7.6 | 4.2 | 5.4 | 8.1 | 8.6 | 1.00
3-4-7 | pleasant view | 3.9 | 5.6 | 5.7 | 5.6 | 8.2 | 7.5 | 1.00
3-5-1 | feeling of home | 7.7 | 7.1 | 5.4 | 5.2 | 9.0 | 9.0 | 1.40
3-5-2 | perception of residential mobility | 6.5 | 4.6 | 6.3 | 8.4 | 8.7 | 8.6 | 1.40
3-5-3 | "longtime residency" | 7.4 | 6.7 | 8.8 | 9.7 | 9.5 | 8.9 | 1.40
3-5-4 | relationship with neighbours | 6.9 | 6.3 | 5.4 | 5.2 | 7.8 | 8.5 | 1.40
3-5-5 | participation in maintenance of the space | 0.6 | 2.8 | 2.2 | 2.3 | 4.3 | 2.5 | 1.40
3-5-6 | building plot | 7.5 | 7.5 | 0.8 | 0.8 | 2.0 | 5.0 | 4.29
3-5-7 | apartment | 7.5 | 7.5 | 4.0 | 4.0 | 4.0 | 5.0 | 0.61
3-5-8 | shop | 10.0 | 10.0 | 5.0 | 5.0 | 5.0 | 5.0 | 0.61
30 | 4-1-1 | economy | 5.0 | 4.5 | 6.0 | 5.0 | 5.0 | 5.0 | 0.61
21.98 | 4-2-1 | manufacturing and storage | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 0.61
21.41 | 4-2-2 | built-in parking space | 10.0 | 10.0 | 4.0 | 4.0 | 4.0 | 4.0 | 0.61
16.60 | 4-2-3 | outdoor parking space | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 0.61
16.85 | 4-2-4 | parking space in a separate garage | 10.0 | 10.0 | 6.7 | 6.7 | 6.5 | 6.5 | 0.61
18.22 | 4-2-5 | apartment | 8.7 | 8.7 | 4.2 | 4.2 | 5.0 | 2.8 | 0.61
4-3-1 | shop | 10.0 | 10.0 | 2.5 | 2.5 | 4.0 | 5.0 | 0.61
4-3-2 | administration | 6.5 | 6.5 | 5.0 | 5.0 | 5.0 | 5.0 | 0.61
4-3-3 | manufacturing and storage | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 0.61
4-3-4 | built-in parking space | 10.0 | 10.0 | 5.0 | 5.0 | 5.0 | 5.0 | 0.61
4-3-5 | outdoor parking space | 10.0 | 10.0 | 6.0 | 6.0 | 6.0 | 6.0 | 0.61
4-3-6 | parking space in a separate garage | 10.0 | 10.0 | 5.0 | 5.0 | 5.0 | 5.0 | 0.61
4-4-1 | occupancy of apartments | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 2.14
4-4-2 | use of commercial spaces | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 2.14
4-5-1 | upkeep costs per unit area | 5.0 | 4.5 | 6.0 | 5.0 | 5.0 | 5.0 | 2.14
4-5-2 | upkeep costs per resident | 8.2 | 5.0 | 6.0 | 6.2 | 3.0 | 5.0 | 2.14
4-6-1 | tidiness and technical condition of the space | 3.5 | 7.5 | 5.0 | 7.5 | 6.0 | 8.0 | 1.43
4-6-2 | tidiness and technical condition of the furnishing elements | 5.5 | 5.5 | 5.0 | 6.0 | 10.0 | 8.0 | 1.43
4-6-3 | tidiness and condition of the vegetation | 3.5 | 5.5 | 5.0 | 7.5 | 10.0 | 9.0 | 1.43
4-7-1 | median monthly income | 5.5 | 4.0 | 6.0 | 5.0 | 4.0 | 7.0 | 4.29

3.2. Hygiene
All analysed spaces create a hygienically quality environment, only the BV1 space is slightly below average. In case of the BS1 and BS2 spaces it is worth mentioning the capacity of closed blocks to reduce the level of acoustic pressure and to eliminate the outside traffic noise. The BV1, BV2, BL and WA spaces do not have such capacity. Moreover, in comparison with the other spaces, the BV2 space lacks the capacity to eliminate winds. All spaces are able to raise the humidity to a desired level. In the BL and WA spaces are present significantly pleasant natural sounds and smells. The comfort of staying in the surveyed inner courtyard is considered of good to very good level. It might be added that the residents of all adjoining buildings around the surveyed spaces perceive the comfort very positively and in case of BL and WA spaces the feelings are often uncritically strong.
3.3. Society

The social indicators of sustainability are above the standard in all surveyed spaces, none of the localities is considered a socially degraded area.

The number of residents in the buildings around the BS1 and BS2 spaces in the centre of Brno is stabilized when the decrease between 2001 and 2011 is only 2%. The age structure (40 years) corresponds with the median age in the country; there are more seniors than children in this area. The ratio of residents with higher than primary education is higher than the state average (85%) reaching 89% [13]. The gender diversity in the space seems to be balanced. Using of the spaces is strengthened by the feeling of safety in the BS1 and BS2 courtyards. The level of safety and good maintenance is enhanced by the fact that the courtyards are not open to public. According to the questionnaires, the BS1 and BS2 spaces satisfy the residents’ needs. The residents consider the place their home. The local respondents have shown a unique willingness to get financially involved in the maintenance of the courtyards if they were more used by children.

The buildings in the Brno-Vinohrady housing estate suffer from the decrease of residents; between 2001 and 2011 there was an average decrease of 10% in this housing estate. According to the census in the analysed buildings, the age structure shows a predominance of children under 14 years to the seniors, where the ratio is roughly 2:1. The ratio of the residents of the prefab blocks of flats with higher than primary education reaches the state average (85%), [13]. Using of inner courtyards in the housing estate is decreased by a lower feeling of safety. The numerous inner courtyards more likely do not satisfy the residents’ needs.
The age structure of the residents in Brno-Lesná housing estate shows a prevalence of children to seniors (83:17). The ratio of residents with higher than primary education reaches 83.2 % [13]. The inner courtyard is perceived as a very safe area and it satisfies the residents’ needs. A significant phenomenon in Lesná housing estate is “longtime residency” when residents rarely move out of this locality. The residents consider the place a very good address.

In case of the Vienna Wohpark Alt Erlaa housing estate (WA) the statistical data were not obtained. In other indicators the WA case study is very similar to BL study. The residents state a strong feeling of home, there are very good relations among neighbours, and the residents rarely move away. The residents perceive the locality as a good address.

3.4. Economy
The BS1 and BS2 case studies benefit from their location in the city centre. They are popular in spite of the higher prices which exceed the city average [14].

The prices of flats in Brno-Vinohrady (BV1 and BV2) and Brno-Lesná (BL) housing estates are below the city average; the rents in Brno-Lesná (BL) housing estate are average with exception of the sales prices of the outside parking space which in both cases exceed the city average as there is a considerable lack in both locations.

The prices of rented flats in Vienna housing estate were eventually obtained and are lower than the city average. Generally higher average prices of rented flats in Vienna increase the considerable share of newly built flats available to numerous, well-to-do residents of the Austrian metropolis.

It might be stated that the economic parameters of the evaluated case studies are significantly influenced by the characteristics of the locality as a whole, by its facilities and connection to public transport.

3.5. Overall sustainability
The overall sustainability of the evaluated case studies [s] consists of the sum of the points in the partial pillars of ecology [x], hygiene [y], society [z] and economy [w]. The following Table 2 presents the overall sustainability [s] as well as the Satisfaction Index [q] (see section 3.6).

| Overall Sustainability [s] | Residents’ Satisfaction Index [q]: Ø (min./max.) |
|---------------------------|-----------------------------------------------|
| BS1                       | 65.8                                          | 69.7 (59.2/87.3) |
| BS2                       | 66.4                                          | 66.4 (55.5/80.2) |
| BV1                       | 55.5                                          | 58.2 (48.4/70.1) |
| BV2                       | 55.0                                          | 56.5 (45.0/69.8) |
| BL                        | 60.5                                          | 73.4 (59.5/88.4) |
| WA                        | 64.0                                          | 82.2 (71.5/87.8) |

The overall balance suggests that the most sustainable spaces seem to be the case studies in the Brno-centre locality (BS1, BS2). This result is given by several facts. The spaces between buildings in the closed block development are, in comparison with other case studies, slightly above the average in terms of ecology, moreover they create hygienically quality spaces which are comparable with the spaces dominated by natural features (BL, WA). The BS1 and BS2 case studies are also above the average in terms of society. The resulting economical sustainability of the BS1 and BS2 case studies exceeds the other spaces. The Brno-Vinohrady housing estate (BV1 a BV2) is the opposite of Brno-centre locality (BS1, BS2) although it does not mean that it is an unsustainable area with unclear future. Two more case studies localized in BL and WA housing estates show a good overall sustainability where the high ecological, hygienic and social quality of the area is indicated by the weighted points in the relevant
pillars of sustainability. In case of BL and WA, the economic sustainability analysed by the selected indicators is slightly lower, although in case of WA a significant part of the indicators was not obtained, which decreases the relevance of the conclusions.

3.6. Residents' Satisfaction Index

The “Residents' Satisfaction Index” [q] was calculated from the answers in the questionnaires completed by the residents living around the investigated space. The index is a percentage ratio of the sum of the particular points gained for the answers against the maximum number of points; thus it expresses the residents' satisfaction: the higher the evaluation, the higher the satisfaction.

The following table shows the overall balance of sustainability [s] and the Residents' Satisfaction Index [q] for the analysed case studies.

The satisfaction of residents closely relates to the character of the particular locality and local development. A considerable share of satisfaction might be caused by the environmental parameters of the locality. The residents living in the buildings in Brno-centre locality (BS1 and BS2) have expressed high level of satisfaction. Closed, calm and quiet courtyards with relatively higher humidity of air are protected from winds, dust and unwanted visitors. The courtyards and adjoining buildings are also located near the city centre.

Slightly different situation might be in the housing estates whose concept is to be open housing development. In case of Brno-Vinohrady (BV1 and BV2), the respondents expressed a relatively lower satisfaction with the location. They perceive the area as being uniform and plain; the spaces between buildings do not significantly influence the quality of environment. The residents do not have an outstanding feeling of home here; they do not consider it a good address.

A considerable satisfaction was expressed by the residents in Brno-Lesná housing estate (BL). The reasons might have environmental base, although the residents have a tendency to overrate some hygienic facts. There objectively might occur balanced temperatures with fewer extremes in summer period. The perception of satisfaction is also influenced by the psychological impact of staying in natural environment which positively stimulates the feelings. The residents have the feeling that they live in the park moreover there are vast forests within the walking distance from the housing estate. Living on a hill surrounded by greenery, in a calm, hygienically quality environment, without large fluctuation of residents, in a housing estate with a strong, publicly discussed unique image, these are the probable factors influencing the satisfaction of local residents. The residents’ satisfaction cannot be lowered by the economical demands on maintenance of the space between buildings as this is not perceived by the residents of Lesná, in a locality with an outstandingly quality natural environment, the highest within the evaluated spaces.

The respondents of the Vienna – Wohnpark Alt Erla (WA) housing estate declared, in comparison with other case studies, the highest satisfaction, which might be related to a generally more positive attitude of local residents. But there must be other reasons of the satisfaction. The developed and varied WA park creates a favourable microclimate and presents a calm place in a busy metropolis. The quality and vast WA park thus emphasizes the uniqueness of this metropolitan locality with quality, above the standard services (church) and good transportation services. The local residents, similarly as the residents of Lesná (BL), appreciate the quality natural environment. The natural features of the urbanized area are perceived both by Vienna and Brno respondents as outstandingly important for the quality and image of their home.

Generally, it can be stated that the residents’ satisfaction with living in certain localities and buildings is the result of many factors.

A significant role is certainly played by technical aspects, e.g. the indicators of occupancy rate (space per resident, number of residents per room), indicators of technical conditions of the flats, their disposition, etc. that were not included in this research.

The quality of environment forms the second significant group of factors; its level is influenced by several parameters of the space between buildings, which is confirmed by some published studies, namely the influence of greenery [3, 4] and the type and height of the buildings around the space [7].
The third factor is the quality of neighbourhood. Good relations with neighbours can be considered as very important, sometimes also decisive for the development of local community. Good relations with neighbours enhance the feeling of home.

Within the presented methodology the observed satisfaction of residents is reflected in the partial indicator of "good address".

4. Conclusions

The case studies presented open spaces between buildings as a part of two different urban conceptions. The courtyards in closed blocks and open spaces in housing estates of free standing high-rise blocks were presented. The results suggest that both conceptions may provide quality housing. The spaces between buildings may create hygienically quality environment. And local residents perceive the influence of the environment on their quality of life.

According to the results of the research, the closed courtyards in the locality Brno-centre (BS1 and BS2) have a considerable importance for sustainable development of the area and for the satisfaction of local residents. The residents perceive the courtyards as a valuable, safe place to relax. The courtyards create an environment with a considerably higher quality than the surrounding streets. The hygienic quality of the environment in the courtyards is on average roughly at the same level as in the observed inner courtyards in the housing estates which are dominated by natural features (BL and WA). It has been proved the significance of hygienic parameters as well as the feeling of safety in the closed courtyards.

In the Brno-Vinohrady housing estate (BV1 and BV2) with a lower social potential of sustainability, the spaces between buildings are uniform, featureless and they are numerous, which lowers their significance for social interaction. As the residents have suggested in the survey, the spaces should be differentiated and suitable for particular use. Nevertheless, it is necessary to state that the interest of young families about housing in the housing estate contradicts the unfavourable prognosis. It is supported by affordable prices of the housing as well as good services in the locality.

There might be a different situation in distinctive housing estates, as for example in the Brno-Lesná housing estate (BL) where the significance of the extensive spaces between buildings with abundance of quality and maintained greenery is enhanced by their considerable environmental contribution which is comparable to the contribution of staying in the suburban nature. Also the significance of these spaces might be enhanced by a long-lasting discussion about the good and specific image of this locality. Local residents in Lesná (BL) perceive these discussions intensively. Similarly, the residents of Vienna – Wohpark Alt Erlaa housing estate (WA) perceive the significance of the large green spaces between the buildings. Austrian society, unlike Czech society, did not undergo the socialism era which might have deformed some socio-economic conditions. Nevertheless, the respondents’ opinion in the WA case study more or less corresponds to the opinion of the respondents in the BL case study. Thus it might be stated that the vast green spaces between the buildings in the housing estate development might have significantly positive influence on the satisfaction of the local residents. Such spaces might considerably compete with the significance of closed courtyards. The results indicate that one of the conditions is an above standard environmental quality, regular maintenance enhancing the feeling of safety, and the overall good image of the locality. This image is also a reflection of the uniqueness of the urban conception as well as the expected above standard environmental conditions in the area.

In general, it might be stated that significant characteristics of open space between buildings are the type and height of the buildings, their arrangement, and the character of the greenery. The greenery influences the hygienic conditions and attractiveness of the area. Open space between buildings represents a significant and irreplaceable potential for increasing of the residents’ quality of life. The quality environment might also contribute to the creation of good image of the locality.

The overall balance of sustainability of the area and the residents’ satisfaction shows that the analysed urban conceptions have succeeded in all cases to create good exterior conditions for housing. Architects and urban planners were generally aware of the significance of open, green space between buildings for the recreational and social use, for the satisfaction of local residents. A suitable urban form which
reflects the conditions of wider area and also supports the uniqueness of the locality may significantly influence the sustainability of the area and satisfaction of local residents.

In conclusion it is necessary to state that this text provides a number of data which might be further processed, analysed, variously evaluated and interpreted. Nevertheless, it would be suitable to continue in the study of spaces between buildings. It might be possible to observe the dynamics of the development in the defined areas, extend the case studies to other types of residential areas or eventually in other cities, and to continuously develop the methodology of this study.

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