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Multi-perspective quality of life index for urban development analysis, example of the city of Brno, Czech Republic

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ABSTRACT

Urban system present dynamic systems, where many interactions take place and revealing deeper spatial relations of the urban system and the quality of life is a necessary part of decision-making process in sustainable urban development. The proposed multi-perspective index aims to evaluate the urban quality of life on the basis of five groups of factors and in combination with a cluster analysis it enables a deeper insight of the urban system and its spatial organization. The study is based on quantitative and publicly available data. In total 41 environmental, demographic, social, economic and technical indicators were included. The data used were collected with a clear methodology by official institutions, such as the Czech Statistical Office, the Czech Hydrometeorological Institute, the Ministry of Health and the European Union's Earth observation programme Copernicus. Using these kinds of data sources ensures the feasibility and transferability of the method to other cities in the Czech Republic but also to other countries, where data on a similar basis are collected. The case study of Brno, Czech Republic, helped to identify disparities in living conditions among the city districts. The influence of historical city development on the quality of life was revealed using cluster analysis.

1. Introduction

Quality of life (QoL) influences many fields of human activities, e.g. economics, population health and health expenses, and determines development requirements. The need for its evaluation becomes crucial for the sustainable development of regions including urban systems. Two basic approaches can be distinguished, subjective and objective (Yonk et al., 2017). The subjective approach emphasizes individual preferences, satisfaction and overall happiness (Kahn & Matsusaka, 1997; Brooks, 2008; Balestra & Dottori, 2012; Weziak-Białowolska, 2016). The most widely used method is a survey (Balestra & Sultan, 2013; Weziak-Białowolska, 2016; Yonk et al., 2017). This approach is applied, for example, with the World Happiness Report (Helliwell et al., 2019), or OECD Better Life Index (OECD, 2018), however in this case the subjective approach is combined with the objective one. The objective approach is used to define and quantify the QoL, e.g. Human Development Index (UNDP, 2020) or World Development Indicators (World Bank, 2009). In this case, indicators linked together refer to the economic, social and health fields.

Aiming to reach global sustainable development goals and Agenda 21 respectively, three general groups of factors can be taken into account – economic, environmental and social. However, the issues appear to be more complicated and such a generalization is not suitable in most cases. Significant factors determining QoL depend on region, evaluated entity and data availability, i.e. describing QoL for a state requires different concept than for smaller entities such as counties or cities. Even, when focusing specifically on urban environment, it is problematic to find a consensus in QoL assessment. An overview of local-scaled QoL indices in Table 1 shows the wide span of involved factors. Furthermore, not all of the sustainable development goals are reflected sufficiently.

Some studies prove that a holistic approach is necessary for QoL assessment, because single dimension measures are too narrow to fully capture differences (Petit-Boix et al., 2017; Zhu, 2001). At the same time, it is important that factors involved in the concept are easy to interpret for policy makers and city management (Hiremath et al., 2013;

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Huovila et al., 2019). This article presents a concept and methods, which can serve as a tool for monitoring and changes detection of QoL in the urban environment. The dataset size, comparability and availability at the level of a city district play a crucial role in reaching urban sustainable development (Przybylowski et al., 2021). The applied methods are modifiable and applicable in any urban environment and can be feasible and efficient tool in many decision-making processes in urban policy, which usually require complex research studies.

2. Factors for quality of LIFE assessment

Indicators should always be comprehensible and easy to interpret, should state clear information, which is based on relevant variables consistent over time, and allow comparison (Gabrielsen and Bosch, 2003; Dizdaroglu, 2015). Furthermore, according to Yonk et al. (2017) indicators should be created with the use of publicly available data, which enables a transferability of the methodology and comparability of results over time and space.

The proposed index was created by combining 41 factors that were grouped into five categories representing the environment, demography, socio-economics structure, housing availability and the technical parameters of housing.

2.1. Environmental factors

The physical quality of the environment has a crucial influence on people's health and is also significant for people's subjective perception of the environment (Kahn, 2002; UNDP, 2020).

Generally, two groups of environmental factors can be distinguished according to their impact on human health and well-being. Factors with a positive effect and an ability to improve amenities belong among environmental benefits. On the other hand, environmental burdens comprise factors that cause a deterioration of amenities and have a negative effect on human life.

One of the most used environmental benefits is urban green infrastructure both of a large scale, e.g. urban forests, city parks, gardens, alleys, and small green areas such as green belts, green roofs, riverbanks etc. It is considered a crucial factor for population health due to its ecosystem regulating services, such as microclimate regulation and water partitioning (Lakes et al., 2014; Livesley et al., 2016; Nitschke et al., 2017).

Another positive effect of greenery is its ability to reduce air and noise pollution as described by Bealey et al. (2007), Tiwary et al. (2009), and Islam et al. (2012).

Greenery also provides cultural ecosystem services, which positively affect mental health, because greenery helps with relaxation, stress relief and overall welfare (Lafortezza et al., 2009; Streimikiene, 2015; Young et al., 2020).

Another environmental benefit factor is water, often taken as a blue infrastructure. The benefits of proximity and access to water to human health and well-being were studied by Haase (2015), Grellier et al. (2017) and White et al. (2020), mentioning among others, flood protection and rainwater management, air cooling and overall climate change adaptation (Dugord et al., 2014; Gunawardena et al., 2017).

Pollution characteristics are widely used to represent the environmental burden in the context of QoL (Darçın, 2014; Dizdaroglu, 2015; Eurostat, 2019; Streimikiene, 2015). The greatest attention in the urban environment is paid to air pollution. The main negative impact of air pollutants on human health are respiratory infection and asthma, lung cancer, cardiovascular disease and increasing mortality rate (Bose et al., 2018; Ghorani-Azam et al., 2016; Smith et al., 2013) but several studies are also devoted to subjective life satisfaction (Luechinger, 2010; Zheng et al., 2015). Indicators used for air pollution assessment in cities are the concentration of particulate matter PM_{10} and $PM_{2.5}$ (Schwela, 2000; Smith et al., 2013; Darçın, 2014; Streimikiene, 2015; Bose et al., 2018; Eurostat, 2019), ground-level ozone (Schwela, 2000; Smith et al., 2013; Streimikiene, 2015), nitrogen oxides NO_x (Schwela, 2000; Smith et al., 2013; Darçın, 2014), sulphur oxides SO_x (Luechinger, 2010; Smith et al.,

Table 1
Overview of methods and factors used for QoL evaluation.

	Reference	Zhu (2001)	Li and Weng (2007)	Weziak-Białowolska (2016)	Yong et al. (2017)	Oppio et al. (2020)	Amiraslani (2021)	Patil and Sharma (2022)
	Entity	City	Block group	City	County	City district	City district	City
	Method	DEA	WSA	2level logistics regression	Confirmatory factor analysis	Hedonic price regression	SQL queries	WSA
Factors and number of indicators describing each factor	Population density	1	1	1	–	–	1	–
	Housing density	–	1	–	–	–	–	–
	Housing prices/ rental prices	2	2	–	–	1	–	–
	Housing infrastructure	–	–	–	2	5	2	2
	Housing size	–	1	–	–	1	1	–
	Education	–	1	–	4	–	1	–
	Income	1	4	2	2	–	–	2
	Unemployment rate	–	1	1	1	–	–	1
	Health/health care	1	–	1	4	–	–	–
	Greenery	–	1	1	–	–	1	5
	Impervious surface	–	1	–	–	–	–	–
	Land surface temperature	–	1	–	–	–	–	–
	Air pollution	–	–	1	–	–	–	–
	Noise pollution	–	–	1	–	–	–	–
	Cleanliness	–	–	2	–	–	–	–
	Public safety	1	–	1	2	–	1	2
	Accessibility	–	–	1	2	4	1	9
	City infrastructure	3	–	4	–	12	1	–
	Gender	–	–	–	–	–	–	4
	Other	2	–	4	1	–	2	–

DEA = data envelopment analysis; WSA = weighted sum approach.
Other factors e.g. Martini price, loaf of French bread price, CO_2 production, vehicle per capita, public complaints.

2013; Darçın, 2014; Zheng et al., 2015), carbon monoxide CO (Schwela, 2000), volatile organic compounds (Darçın, 2014) etc.

Another important factor influencing environmental burden is noise pollution, which is believed to lead to insomnia, hearing loss, depression, anxiety and concentration disorders (Aydin & Kaltenbach, 2007; Dizdaroglu, 2015; Lakes et al., 2014).

2.2. Demographic factors

Demographic factors are considered to be important determinants of the overall QoL (Tobiasz-Adamczyk et al., 2011). Cross-sectional representative data of population aged above 80 in Catalonia (Spain) from 2011 to 2016 show the impact of demographic factors (age, gender, education, etc.) on the health-related QoL (Alcañiz & Solé-Auró, 2018). Changes in the age structure are reflected in the demographic ageing of the population, which is associated with an increase in the proportion of older people. The post-working age group (65+ years) is often at risk of a decline in QoL due to retirement, resulting in social isolation or reduced financial resources, but also a higher risk of disease (Hübelová et al., 2021).

The QoL is also influenced by educational attainment, which affects the choice of occupation, the level of wages, the level of housing, etc. It is believed that people with higher education and financial income have a higher QoL than less educated and poorer people (Veugelers, Yip, & Kephart, 2001; Veugelers, Yip, & Mo, 2001). Education improves subjective well-being and increases access and opportunities in the labour market and economic resources (Ross & Willigen von, 1997). The effect of education is reflected in the quality of human capital, which makes a place more attractive and desirable and increases the QoL (Shapiro, 2006).

2.3. Socio-economic factors

Socio-economic factors are related to an individual's socio-economic status, which can be assessed by occupational class, and manifest as a socioeconomic gradient (Britton et al., 2008; Pruchno et al., 2010). People with lower socio-economic status have lower income, higher rates of morbidity, disability and premature mortality, and associated lower QoL (Frank et al., 2003; Matthews et al., 2005). Negative lifestyle habits such as smoking, inappropriate diet and low physical activity are more common in lower socio-economic groups (Lynch et al., 1997).

Most studies report similar findings, with a lower occupational class (Kaikkonen et al., 2009) and poor economic situation (Aittomäki et al., 2010) increasing the likelihood of negative QoL ratings. Work and employment themselves affect individuals and groups through material and psychosocial factors (Bültmann & Siegrist, 2020). The study of QoL and population health status should take into consideration factors related to occupational activity (Szemik et al., 2020).

2.4. Housing factors

A built-up environment has significant effects both on physical and mental health. Negative effects of a built-up environment include residential density and housing quality (Evans, 2003) as well as the quality of the social and physical environment (Bonnefoy, 2007; Krieger & Higgins, 2002; Liu et al., 2017). Poor-quality housing is associated with various negative health outcomes, including chronic disease, injury or poor mental health (Howden-Chapman et al., 2011; Krieger & Higgins, 2002; Palacios et al., 2021). Housing quality in terms of the physical condition refers to the indoor air quality, space per individual, age of dwellings, home safety, presence of harmful inorganic or organic substances etc. (Adamkiewicz et al., 2011; Bonnefoy, 2007; Streimikiene, 2015). Indoor air quality in particular has an impact on respiratory and cardiovascular illness, allergic symptoms, cancers, and premature mortality (World Health Organization, 2010; World Health Organization, 2018) and is affected mainly by indoor combustion sources, tobacco smoking or wood and coal heating (Kwag et al., 2021; Wyss et al., 2016). The size of living space is a determinant used in QoL indices such as the OECD "Better Life Index" (OECD, 2011) and the "European QoL Survey" (Eurofound, 2012). Modernization and renovation of old dwellings bring demonstrably positive changes to the QoL and health of residents (Palacios et al., 2021).

Inequalities in the QoL, and in health, are due to the availability and affordability of housing. It becomes evident that where housing demand exceeds supply, housing becomes one of the expressions of inequalities (Jensen et al., 2021; Shaw, 2004).

Housing is commonly considered to be "affordable" when a family spends less than 30 % of its income to rent or buy a residence. The lack of affordable housing affects families' and individuals' choices and supports the movement of lower-income families often to unsafe, overcrowded living places with a lack of resources for health promotion (Braveman et al., 2011). All these problems connected to housing point to the legitimate demand for balanced housing policies may help reduce health inequality (Chung et al., 2020).

3. Methodology

The proposed QoL index was constructed employing 41 indicators, where environmental factors incorporate 8 indicators, demographic factors 6 indicators, 13 indicators represent socio-economic factors, housing infrastructure comprises 11 indicators and 3 indicators characterize housing availability.

3.1. Indicators and data

Factors considered for environmental index construction include both environmental benefits and burden. Environmental benefits refer to green and blue infrastructure. Environmental burden is represented by indicators related to air pollution, noise pollution and distance from public greenery. As most of the environmental indicators are continuous phenomena, processing data using GIS software was necessary. For details, see Floková et al. (2021). Remotely sensed (RS) data, which were used for green and blue infrastructure evaluation, were gained from the European Union's Earth observation programme Copernicus. The advantage of RS data is identification of small areas of greenery, grass belts and solitaire trees, regardless of the ownership structure, so using such data is common in recent studies (Congalton, 2015; Lakes et al., 2014). Air quality is monitored by the Czech Hydrometeorological Institute and published regularly, so data about air pollutant concentrations were adopted from this source. Data for noise pollution evaluation were taken from official noise maps referring to the L_{den} indicator (day-evening-night noise burden, methodology stated by European Directive 2002/49/EC), which are published by the Ministry of Health, Czech Republic.

Data for constructing demographic, socio-economic and housing infrastructure index were adopted from the Population and Housing Census database (CZSO, 2011).

The last factor group, housing availability, combines the possibility and affordability of housing. For this index, Census data were combined with price maps created by Brno local government. Detailed description of factors and data sources is in Table 2.

3.2. Index construction

Various data sources were integrated into a dataset representing individual city districts. The WSA (Weighted Sum Approach) method was used. The method is based on the assumptions of linearity and the maximization of all partial utility functions, which were obtained by min-max standardization of the original input data. Formula (1) was used for maximization and (2) for minimization factor type.

Table 2
Factors for QoL index construction.

	Factor	Description	Unit	Type	Data source
Environmental factors	Forests and large green areas	The share of forest and greenery of an area larger than 25 ha or line greenery long 100 m at least in the overall district area	%	MAX	CORINE LC 2018 (EEA (European Environmental Agency) Copernicus Land Monitoring Service, 2018a)
	Small greenery	The share of small greenery units in the overall district area	%	MAX	Grassland (EEA (European Environmental Agency) Copernicus Land Monitoring Service, 2018b), Riparian zones (EEA (European Environmental Agency) Copernicus Land Monitoring Service, 2018c), Street Tree Layer (EEA (European Environmental Agency) Copernicus Land Monitoring Service, 2018d)
	Green infrastructure accessibility	The share of address points exceeding than 10 minutes walk distance from public greenery	%	MIN	Local government Brno: own analysis
	Water bodies	The share of waterbodies in the overall district area	%	MAX	ZABAGED (ČÚZK, 2021)
	Watercourse density	The watercourse length in the area unit	*km/m*^{2}	MAX	ZABAGED (ČÚZK, 2021)
	NO_2 concentrations	Average annual concentrations per district	*μg/m*^{3}	MIN	Summary Tabular Survey 2019 (CHMI (Czech Hydrometeorological Institute), 2019)
	$PM_{2,5}$ concentrations	Average annual concentrations per district	*μg/m*^{3}	MIN	Summary Tabular Survey 2019 (CHMI (Czech Hydrometeorological Institute), 2019)
	Noise burden	Noise level weighted by a share of a noise level polygon in the overall district area	*dB*	MIN	Noise maps (Ministry of Health, 2019)
Demographic factors	Age index	Proportion of over the age of 65 per persons younger than 15 years old	%	MIN	Population and Housing Census database (CZSO, 2011)
	Dependency index I	Age-population ratio of those not in the labour force (the dependent part ages 0 to 14) and those in the labour force (the productive part ages 15 to 64)	%	MAX	
	Dependency index II	Age-population ratio of those not in the labour force (the dependent part over the age of 65) and those in the labour force (the productive part ages 15 to 64)	%	MIN	
	Average age	Average arithmetic weighted: the numerator takes the sum of the products of age by the size of the population that reached it.	*years*	MIN	
	Without education and primary school (incl. unfinished)	Proportion of persons without education and primary school (incl. unfinished) to the population aged 15 and over	%	MIN	
	University education	Proportion of persons without university education to the population aged 15 and over	%	MAX	
Socio-economic factors	Agriculture	Share of the number of employees in agriculture in the number of all persons aged 15 and over	%	MIN	
	Industries	Share of the number of employees in industries in the number of all persons aged 15 and over	%	MIN	Population and Housing Census database (CZSO, 2011)
	Construction	Share of the number of employees in construction in the number of all persons aged 15 and over	%	MIN	
	Wholesale and retail, repair and maintenance of motor vehicles	Share of the number of employees in wholesale and retail; repair and maintenance of motor vehicles in the number of all persons aged 15 and over	%	MIN	
	Transport	Share of the number of employees in transport in the number of all persons aged 15 and over	%	MIN	
	Accommodation and food services	Share of the number of employees in accommodation and food services in the number of all persons aged 15 and over	%	MIN	
	Information and communication activities	Share of the number of employees in information and communication activities in the number of all persons aged 15 and over	%	MAX	
Socio-economic factors	Finance and insurance	Share of the number of employees in finance and insurance in the number of all persons aged 15 and over	%	MAX	
	Real estate, professional, scientific and technical activities	Share of the number of employees in real estate, professional, scientific and technical activities in the number of all persons aged 15 and over	%	MAX	
	Public and social administration and defence	Share of the number of employees in public and social administration and defence in the number of all persons aged 15 and over	%	MAX	Population and Housing Census database (CZSO, 2011)
	Education	Share of the number of employees in education in the number of all persons aged 15 and over	%	MAX	
	Health and social care	Share of the number of employees in health and social care in the number of all persons aged 15 and over	%	MAX	

(*continued on next page*)

Table 2 (*continued*)

	Factor	Description	Unit	Type	Data source
	Not identified	Share of the number of employees in not identified in the number of all persons aged 15 and over	%	MIN	
Housing infrastructure	Average age of inhabited houses	Age of permanently occupied houses	*years*	MIN	Population and Housing Census database (CZSO, 2011)
	Occupied flats	share of permanently occupied flats from all flats	%	MAX	
	Central heating: boiler room in the house on solid fuels	Share of houses with central heating on solid fuels from all permanently occupied houses	%	MIN	
	Central heating: boiler room in the house on gas	Share of houses with central heating on gas from all houses	%	MAX	
	Technical equipment: gas in the apartment	Share of apartments equipped with gas from all houses	%	MAX	
	Water supply in the apartment	Share of apartments equipped with water supply from all apartments	%	MAX	
	Warm water	Share of apartments equipped with warm water from all apartments	%	MAX	
	Connection to the sewer network	Share of houses connected to the sewer network from all houses	%	MAX	
	Cesspool	Share of houses connected to the cesspool from all houses	%	MIN	
	Own flush toilet	Share of apartments with own flush toilet from all flats	%	MAX	
	Private bathroom, shower	Share of apartments with private bathroom, shower from all flats	%	MAX	
Housing avail.	Number of inhabited houses	Share of permanently occupied houses from all houses	%	MAX	Population and Housing Census database (CZSO, 2011), Local government Brno: own analysis
	Living space per person	Space in m^2 for one person	m^2	MAX	
	Housing price	Median price of housing in the city district according to municipality price map	*CZK*	MIN	

$$r_{ij} = \frac{y_{ij} - A_j^-}{A_j^+ - A_j^-} \tag{1}$$

$$r_{ij} = \frac{A_j^+ - y_{ij}}{A_j^+ - A_j^-} \tag{2}$$

A_j^+ denotes the highest value of this criterion (factor), $A_j^+ = \max_i y_{ij}$, and A_j^- denotes the lowest value of this criterion, $A_j^- = \min_i y_{ij}$. For each alternative (city districts) a_i and each factor f_j the standardized values r_{ij} were calculated according to the data y_{ij}. Partial indices $I(a_i)$, i.e. environmental EI, demographic DI, socio-economic SEI, housing infrastructure HI and housing availability HA, were calculated according to formula (3).

$$I(a_i) = \sum_{j=1}^{k} v_j r_{ij}, \forall i = 1, \cdots, p. \tag{3}$$

All factors were weighted equally; $v_j = 1$. The resulting QoL index for a district a_i is a mathematical combination of variables that reflect multiple selected dimensions, see Eq. (4).

$$QoL(a_i) = EI(a_i) + SEI(a_i) + EI(a_i) + HI(a_i) + HA(a_i) \tag{4}$$

In our case, the higher the QoL value, the more favourable the situation in the region. The QoL index ranges from 0 to 1. The calculations were performed in MS Excel and its supplement Sanna, GIS analysis and vi-

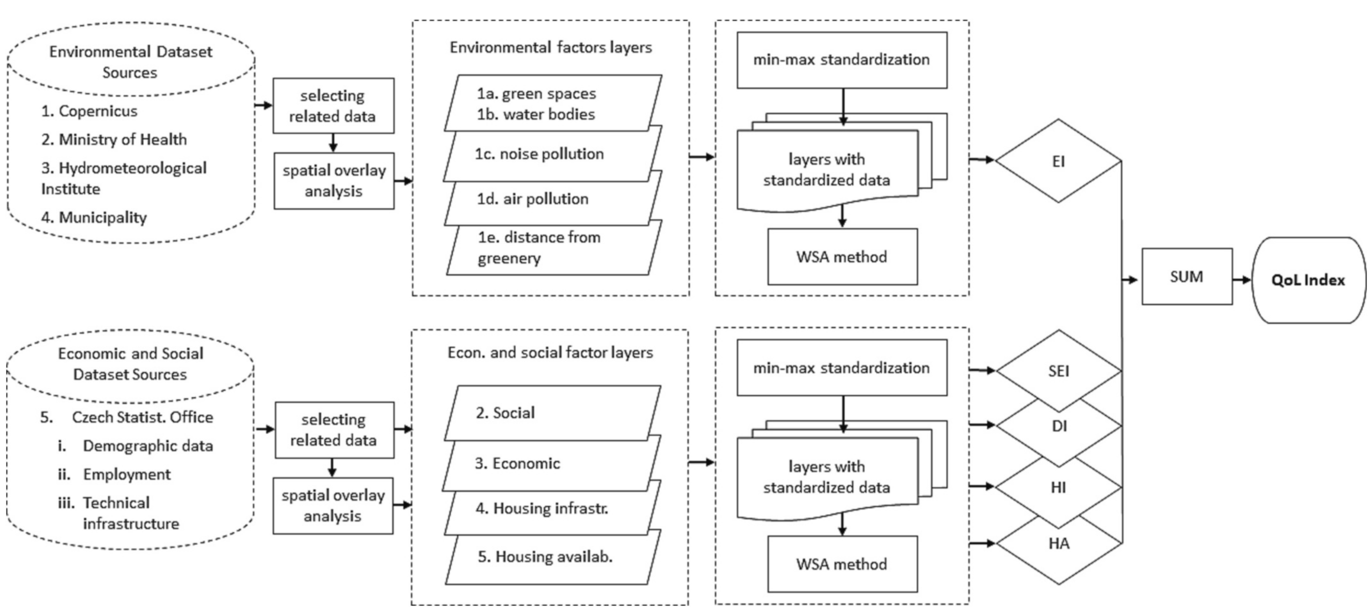

Fig. 1. Workflow of the QoL index construction (own elaboration).

sualizations in ArcGIS Pro 3.0.1 and QGIS 3.28.3. A workflow of the index construction in displayed in Fig. 1.

3.3. Study area

The case study focuses on the area of the city of Brno, Czech Republic. It is the second-largest city in the Czech Republic. About 400 thousand people live there. The city is divided into 29 heterogeneous districts, both according to area and according to the number of inhabitants (see Fig. 2). The average number of people in each district is about 13.5 thousand, while seven districts exceed 20,000 inhabitants and on the contrary, nine districts have less than 5000 inhabitants, the most populous is Brno-Stred with 64,000 people while Oresin has only 600 inhabitants. The districts' areas are no less heterogeneous. The smallest district (Utechov) occupies an area of 1.18 km^2, the largest district (Bystrc) takes up 27.24 km^2. Similar miscellaneous aspects can be found in the landscape character, land use and functional organization. There are districts with a univocally urbanized character, high population density and industrial areas, but also rural districts with fertile ground and some parts even have a reasonably high share of forests.

4. Results

Once the individual indices for each group of factors were computed, they were visualized in maps displaying five categories according to index value. The visualization gives a better overview of the results, but the spatial arrangement of values varies a lot for individual factor group indices (see Fig. 3).

In addition, a new visualization tool was used for bivariable maps construction, where two variables are displayed at the same time (see Appendix A).

4.1. Quality of life index in the city of Brno

The overall QoL index was calculated as a sum of individual factor group indices values. The resulting value incorporates all five groups of factors chosen for QoL evaluation and enables a comparison of units/ districts. The visualization in the map (Fig. 4) enables the gaining of broader spatial relations. The lowest values of the QoL index can be identified in the districts where the low values of most individual indices cumulate. A group of under-average QoL index values appear in the south-east part of the city. This part of the city bears the burden related to transport infrastructure due to the presence of highways and an international airport and related infrastructure (see Fig. 2.), such as logistic centres and business complexes, which significantly worsen aesthetics and life conditions. In such areas, a lower socio-economic index often occurs.

On the other hand, a concentration of above-average values appears in the north-west and north periphery, where most of the criteria stay above average. This is given by the presence of a water body, a high share of forests and a propitious socio-economic structure resulting from suburbanization processes, which brought mostly young families with higher income to the edge of the city, witch positively influences socio-economic, demographic and housing infrastructure indices.

4.2. Cluster analysis

Employing the partial indices EI, SEI, DI, HI and HA as variables, K-medoid clustering was applied. Considering pseudo F-statistics of the dataset, four clusters of city districts were obtained (see Fig. 5). This multivariate classification method turned out to be very useful to reveal common characteristics and relations among QoL, individual criteria and urban development. Main cluster characteristics are listed below:

Industrialized and agricultural periphery:

- more or less unfavourable QoL.

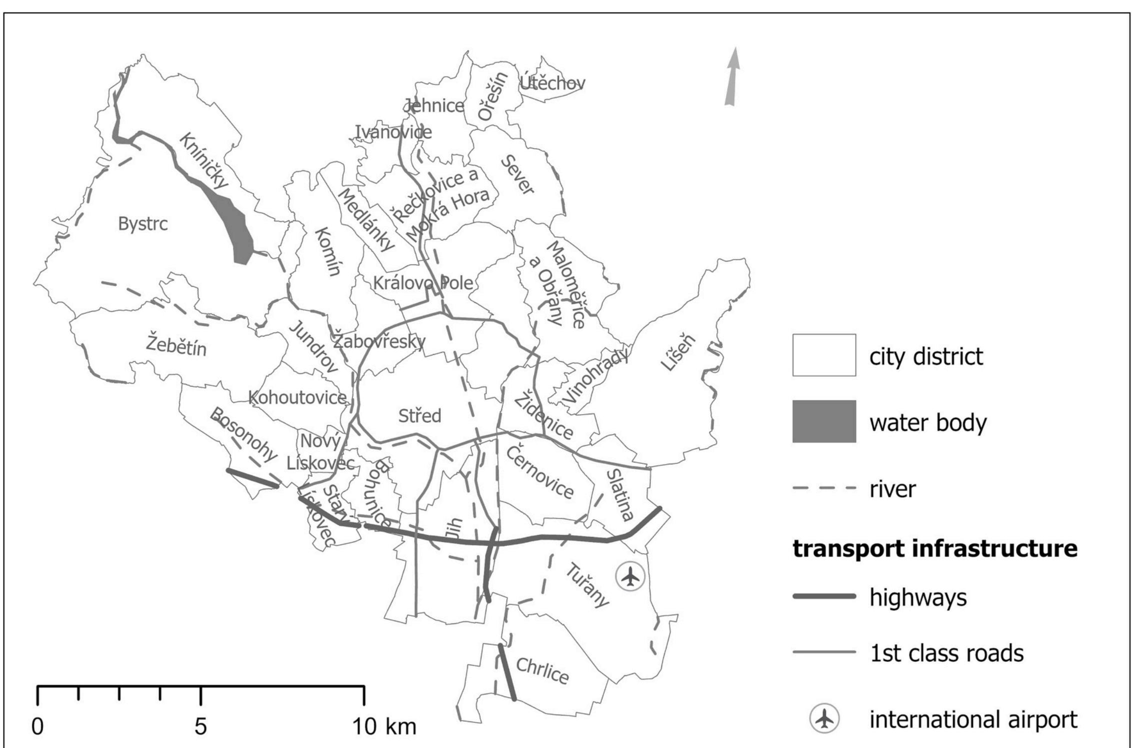

Fig. 2. Topography of the city of Brno, the Czech Republic (own elaboration).

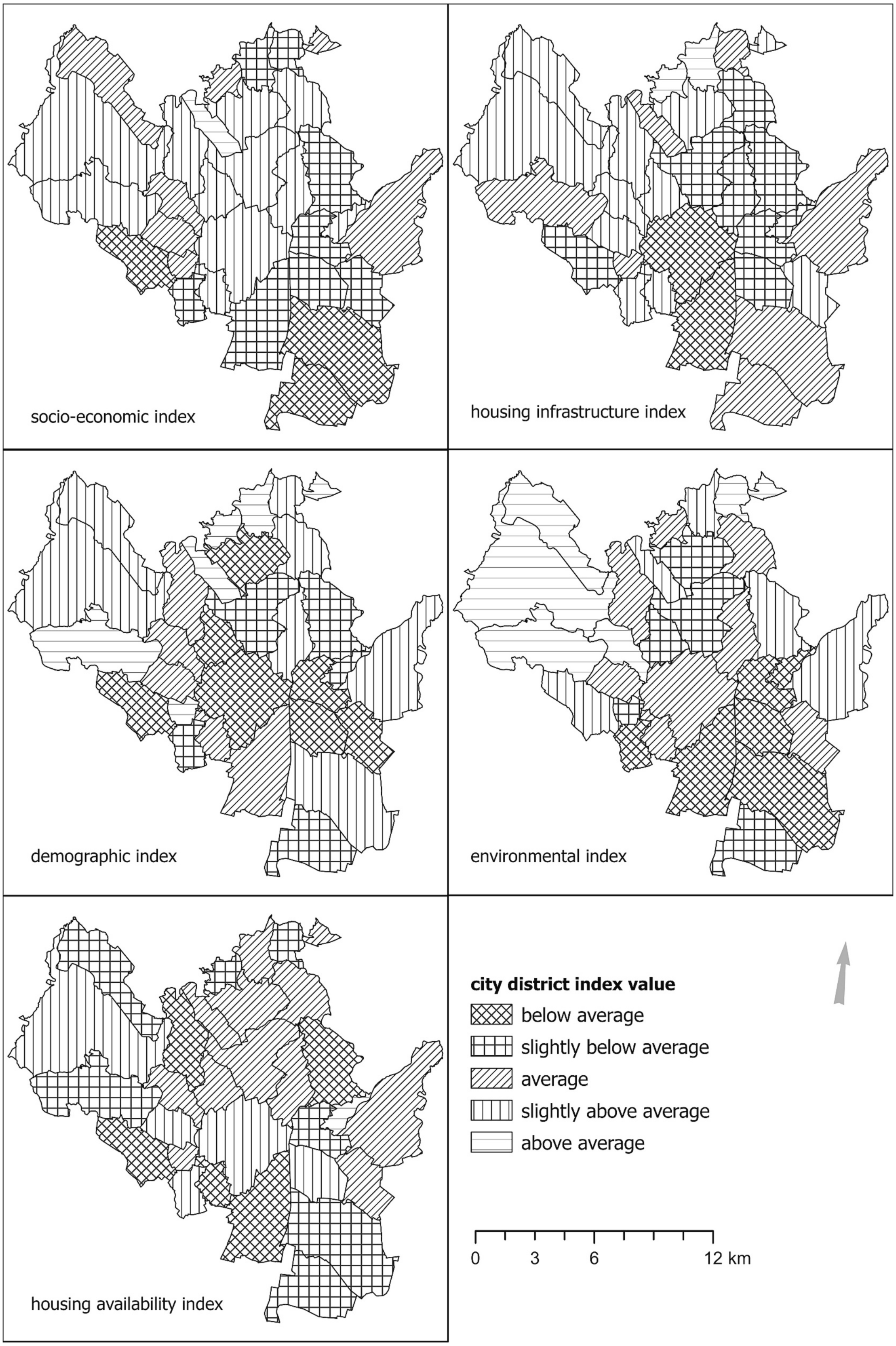

Fig. 3. Individual indices for Brno city districts (own elaboration).

- districts with an industrial tradition from the 20th century, determined by railway presence, and also originally independent rural areas with traditional agricultural production, which have recently become areas of industrial and commercial development due to their excellent highway accessibility.
- an unfavourable ratio of educational structure including an above-average share of people with an incomplete or only basic education and, on the other hand, a below-average share of people with completed higher education, suggests a higher concentration of underprivileged social classes.

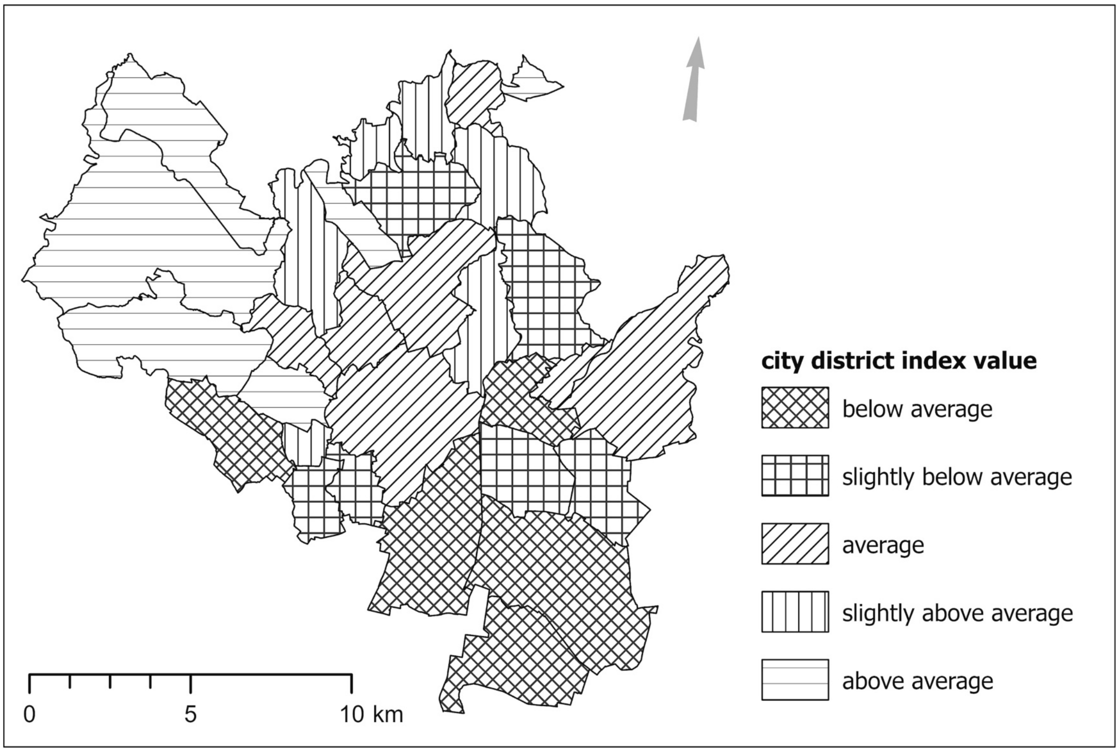

Fig. 4. QoL index in the city of Brno (own elaboration).

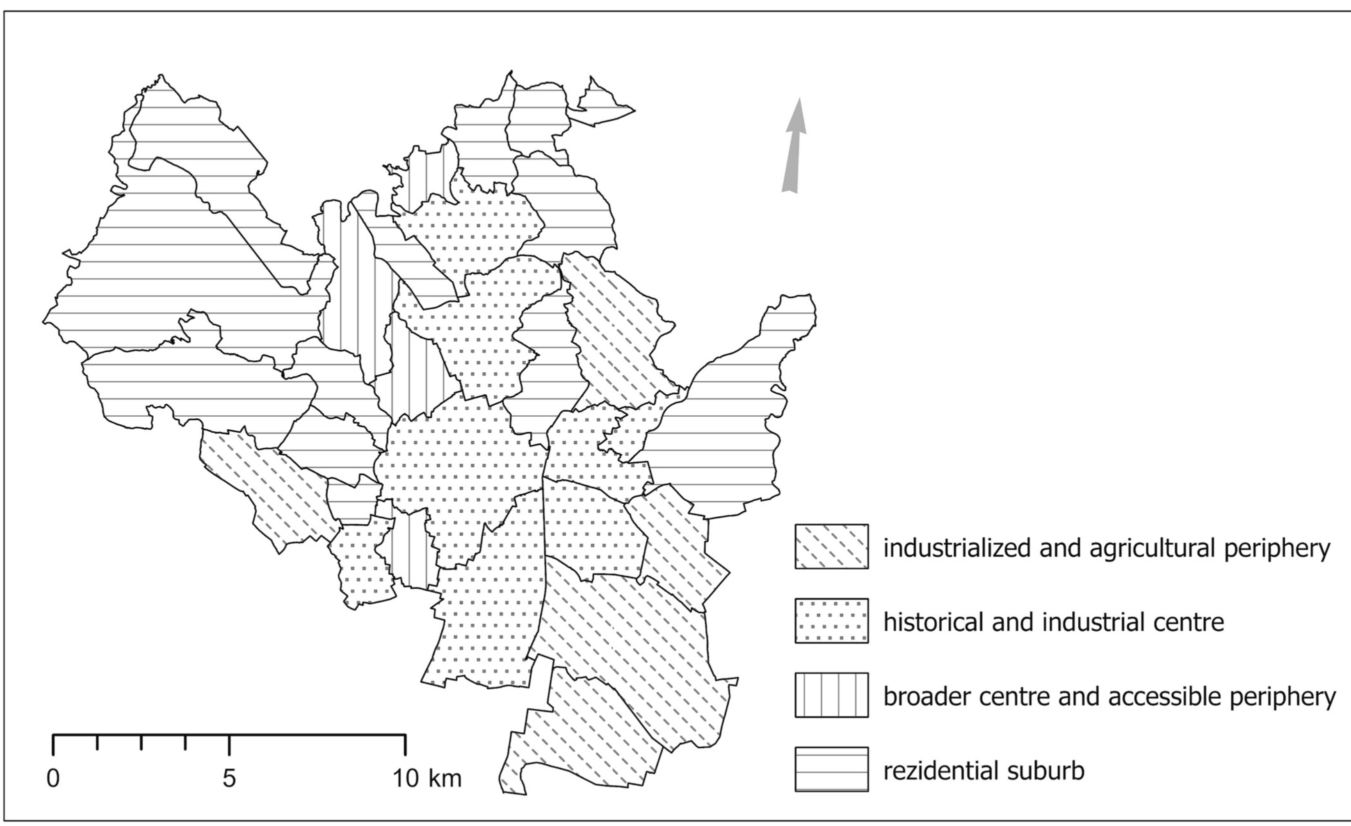

Fig. 5. District clusters emerging from the cluster analysis (own elaboration).

- employment corresponds to the educational structure and is unfavourable in terms of QoL.
- the housing infrastructure does not fully meet modern standards, obsolete houses and flats with non-ecological heating are typical here. A lower availability index shows insufficient housing development in the area.
- the environmental index is very low, because of a low or even absent share of forests and a high burden caused by strong transport intensity and related commercial infrastructure.

Historical and industrial centre:

- not very good QoL.
- the area of the historical centre and connected traditional industrial areas developed especially at the beginning of the past century, converted to residential and commercial areas after losing their original function (brownfields). It also involves extended residential areas developed in the 70s and 80s of the 20th century, facilitated by convenient road connections.
- reaches the average concerning age structure and according to the educational and socio-economic structure, it is slightly below average.
- the housing stock is mostly obsolete and also provides one of the smallest living area sizes, which leads to an under-average median of housing prices typical for this area.
- is attractive for its proximity to the city centre and excellent transport connection, but due to high transport intensity and building density, it ranks worst according to the environmental index.

Broader centre and accessible periphery:

- reasonably high QoL.
- reasonable transport accessibility, interconnection of the city centre and close outskirts, a higher housing infrastructure standard, consisting of old houses, both single-family houses and apartment buildings, which were supplemented by dwelling areas with blocks of flats in the 1970s.
- a significant share of non-built-up (agricultural) areas, beneficial transport accessibility is at the expense of noise and air pollution.
- an above-average share of the elderly and a higher age index.
- the educational structure shows significant share of graduates which corresponds to the socio-economic index reflecting proportion of professions requiring higher education, i.e. public administration, health and social care and education, reaches above-average values.
- the presence of main roads, such as an outer and inner-city ring road or a highway, causes a deterioration of amenities, specifically higher values of NO_x concentrations and noise pollution, but these burdens are partially compensated by the presence of forests and other green infrastructure.

Residential suburb:

- the most favourable QoL.
- districts, which have fulfilled the residential function of the city in the past and nowadays.
- very good environmental conditions and continuous housing development.
- the quality of housing stock is high, but that comes along with lower housing availability due to high prices.
- the housing development in the present and recent past is reflected in a low age index and an above-average share of graduates.
- the environmental index is the highest among all districts in the city, benefiting from the high proportion of forests and other greenery and a large water body in the north-west part.

5. Discussion

QoL is a multidimensional concept, hence its determination requires multidimensional assessment, which incorporates economic, social, environmental and some other indicators (Dizdaroglu, 2015; Lakes et al., 2014; Lambiri et al., 2007; Yonk et al., 2017). At the same time, it is important to distinguish between the subjective QoL (Balestra & Sultan, 2013; Yonk et al., 2017; Helliwell et al., 2019) and objective QoL (UNDP, 2020; Yonk et al., 2017), but the availability of databases for assessment on different regional levels cannot be omitted either.

The research is focused on the QoL assessment on a local level, urbanized city area, which was represented by individual city districts. The life quality of city inhabitants is determined by the urban system character (Grimm et al., 2008; Lakes et al., 2014). Five domains were involved in the proposed multi-perspective index: (i) environmental, (ii) demographic, (iii) socio-economic, (iv) housing availability and (v) housing infrastructure. Each domain is represented by a group of indicators, corresponding to QoL studies (Fayet et al., 2020; Lakes et al., 2014; Lambiri et al., 2007; Streimikiene, 2015). The set of indicators is purposely designed using publicly available datasets, so both the time and space transferability of the method can be ensured (Dizdaroglu, 2015; Yonk et al., 2017). Nevertheless, a comparison of the results could be disputatious, because spatial indices are combined in various studies in different ways and assessed by different methods. Individual studies are also based on various geographical frameworks, which complicate their comparability (Abel et al., 2016; Fayet et al., 2020).

Factors influencing the (objective) QoL include examples that induce a discussion of the presented results. The comparability limits of individual studies for different regional levels are distinguishable: (i) in the studies focused on the (above)national level, the typical factors are mainly geographical aspects (localization in the periphery or central part, climate, topography and its influence on the character of economic activities, services availability etc.) (Faka, 2020; Fayet et al., 2020). The geographical aspects project the results on the local level (urban environment) too, because of their influence on historical and contemporary development potential, but a detailed spatial perspective also enable determining other relevant factors (in the case of this study, the persistent consequences of industrialization from the period of the industrial revolution and centrally controlled economy of the socialist era can be named). (ii) environmental (Lambiri et al., 2007; Streimikiene, 2015; White et al., 2020), demographic (Bhatti et al., 2017; Tobiasz-Adamczyk et al., 2011) and socio-economic fields (Aittomäki et al., 2010; Kaikkonen et al., 2009) are denoted as common for both the local and (above)national level with a similar impact on the QoL. It is important to distinguish factors in the aforementioned fields and their impact on QoL from the perspective of positive (greener and blue infrastructure, graduates, high socio-economic status, etc.) and negative (noise pollution, high air pollutant concentrations, unfavourable age and education structure, social deprivation, etc.) (Gershoff et al., 2009; Fayet et al., 2020). (iii) factors related to housing infrastructure and housing availability are not considered at the (above) national level, or just in a context with other factors (Szabo et al., 2019), but these factors are of high importance for the local level, and at the same time, they are strongly influenced by local conditions.

The model based on the accessibility of public geospatial data is crucial for public administration and the private sector, because implementing the use of spatial models facilitates efficient decision-making for subsidy allocation concerning sustainable development in the city (Martines et al., 2017).

6. Conclusion

The QoL index means a powerful tool for local governments and decision-makers for monitoring and evaluating the impact of urban development on the environment and society. It is based on quantitative data and incorporates different aspects that determine QoL. Examining individual aspects helps to identify inequities in the city's development.

The index construction enables creating common characteristics of city districts from the perspective of QoL. A K-medoid cluster analysis was used for this purpose and four clusters of districts were distinguished. The similarities and dissimilarities in the city could be identified.

The method application in the case study in the city of Brno enables stating the following conclusions:

- the spatial variability of index values varies significantly for partial factor group indices.
- the cluster analysis helped to reveal that the historical city development significantly determines the QoL in the individual parts of the city.
- contemporary transport infrastructure and related commercial development negatively influence the QoL in adjacent districts.
- districts vulnerable to environmental injustice can be identified in the south-east part of the city, where the negative environmental index combines with negative socio-economic characteristics.
- progressive and wealthy districts with high housing and environmental conditions and positive demographic and socio-economic structure are concentrated in the north-west districts and north outskirts.

In this study, data from the Population and Housing Census database from 2011 were used. A following research currently focuses on the same method application using latest data from the Population and Housing Census held in 2021. This enables further achievement in monitoring and the evaluation of changes in the city development and its effect on the urban environment and society. Apart from educational and research aspects, they reflect contemporary post-industrial societies and local authorities' pursuits and aspirations forming a real impact on planning, urban and architectonic activities undertaken in urban areas.

CRediT authorship contribution statement

Ludmila Flokova: Conceptualization, Methodology, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision and Funding acquisition. Dana Hubelova: Conceptualization, Methodology, Data Curation, Writing - Original Draft, Writing - Review & Editing. Alice Kozumplikova: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing. Jan Caha: Writing - Review & Editing, Visualization. Lenka Janosikova: Writing - Review & Editing, Visualization. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Data availability statement

Some data that support the findings of this study are available from the corresponding author upon reasonable request. Some data generated or used during the study are available in a repository online in accordance with funder data retention policies. Some data used during the study were provided by a third party. Direct requests for these materials may be made to the provider as indicated in the Acknowledgements.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2023.104338.

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