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Implementation of GIS Tools in the Quality of Life Assessment of Czech Municipalities

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Abstract: Although quality of life is a phenomenon with a significant geographical component, its assessment is often only based on non-spatial statistical data. In Czechia, there are currently several assessments of quality of life at the level of municipalities, yet they do not consider the spatial aspect of the input indicators. This study uses the existing quality of life index compiled by the research agencies Median and the Aspen Institute, whose input indicators related to the accessibility of services and facilities have been redesigned to capture real-world phenomena more appropriately with GIS (Geographic Information Systems) tools using network analysis. In accordance with the original methodology, an adjusted index of quality of life was compiled. An update of indicators resulted in a more accurate description of quality of life. The differences between the original and the adjusted index were mainly seen in the areas around the larger cities, where quality of life has significantly risen. On the other hand, rural/rather rural areas experienced a slight decrease in quality of life with the change of inputs. The mapping of the resulting index documents the disparities in quality of life across Czechia and contributes to the discussions on the topic of quality of life in Czechia with new up-to-date reference data.

Keywords: quality of life; index; Czechia; accessibility; spatial

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1. Introduction

In the modern world, the quality of life is a vast, often discussed topic that presents a difficult concept to grasp in postmodern society, due to its multidimensionality and complexity. Quality of life is linked to human existence and the meaning of life itself and is a means of seeking the key factors in our existence, and in understanding ourselves [1]. It explores the material, psychological, social, and other conditions that provide for a healthy and happy life. It has received attention since the mid-20th century, when experts began to realize that rapid economic growth does not necessarily bring with it a higher standard of living. The first use of the term "quality of life" in modern science is often attributed to the English economist Arthur Cecil Pigou in the early 20th century [2]. However, it did not receive a significant focus in modern history until the 1960s, when societies in the United States and Western Europe were growing richer but their life satisfaction was not increasing. This relationship between increasing wealth and non-increasing, or in some cases decreasing satisfaction, is known as the Easterlin paradox [3,4].

Scientific research is attempting to better define quality of life. Yet there is no single definition of the term because of its complexity and multidimensionality. Liu [5] commented on the lack of a single definition and said that there were as many quality of life definitions as people. According to Wallace [6], quality of life includes the psychological and sociological dimensions of living, experiencing cultural, sporting and leisure activities, satisfying interpersonal relationships, having functioning family relationships and the ability to adapt to (or influence) changes occurring in life. According to Felce and Perry [7], quality of life is defined as an overall general well-being that comprises objective descriptors and subjective evaluations of physical, material, social and emotional well-being, and the extent of personal development and purposeful activity. Emerson [8] defines the quality of life as the satisfaction of an individual's values, goals and needs through the actualisation of their abilities or lifestyle. Further concepts of theoretical models of quality of life are presented in many studies, see, e.g., [9–13].

Despite long-standing research activities, the study of the concept of quality of life is still attractive in today′s post-industrial society, which brings with it a shift in employment to the tertiary and quaternary sectors, higher living standards, an increase in leisure time and in individualisation and democratisation. Interest in the topic can also be seen in the activities of international organisations, such as the European Union (for the current initiatives within the European Union, see, e.g., [14–16]), the United Nations [17], and the Organisation for Economic Cooperation and Development [18]. Comprehensive quality of life assessments can provide a useful basis for state and local governments in planning, decision-making and the allocation of local development funds. The detailed monitoring of relevant indicators (expressed as both synthetic and sub-components) capable of capturing the changes achieved through these efforts should therefore be an important part of ongoing policies and planning activities.

As with many other phenomena, quality of life needs to be measured. However, due to its abstraction, it cannot be measured directly, as there is no quality of life indicator that can be universally applied (the subjective perception of personal satisfaction could be considered an exception). Therefore, the generally accepted approach is to decompose the phenomenon into its measurable components or into the different processes involved in the formation of quality of life, which are eventually represented by an aggregate (or separate) measure in the form of an index. As Pacione [19] states, measuring quality of life has the following benefits: the production of some baseline measures of well-being against which we can compare subsequent measures and identify trends over time; the knowledge of how satisfactions and dissatisfactions are distributed through society and across space; an understanding of the structure, dependence and interrelationship of various life concerns; the identification of normative standards against which actual conditions can be judged in order to inform effective policy formulation; and the monitoring of the effects of policies in reality.

Within the topic of quality of life, two main dimensions are usually distinguished - objective and subjective [19–21]. While the subjective dimension of quality of life primarily focuses on each individual′s subjective perception of his or her life, the objective dimension is shaped by the external environment in which people live. This is influenced by a number of local aspects (economic, social, environmental, etc.) that can be referred to as quality of life *domains*, further described by specific indicators. For this reason, some authors [22–24] use the terms quality of place or potential quality of place. This definition only highlights the unmentionable geographical aspect of the quality of life phenomenon. A similar perspective is found in the work of Helburn [25], who states that "quality of life is always more or less related to a particular area, and tends to vary from place to place". The existence of a geographical dimension of quality of life is further highlighted by [20,26,27].

Despite the great interest in the topic, there is a lack of consensus among quality of life models on how to monitor and measure quality of life. This problem has two basic levels: the first problem is conceptional and deals with the question of which domains (and their corresponding indicators) to include in the assessment. There will probably never be consensus on this issue. A diverse selection of domains can be found in many studies [28–31]. Massam [20] formulates criteria that should be taken into account when identifying appropriate quality of life indicators. These include: the frequency of use of the indicators in other studies/publications; the ability to measure the indicators using credible and reliable data; whether the indicators chosen clearly reflect specific areas of quality of life and whether the selection of such areas can be considered relevant; whether each indicator measures a single domain of quality of life and whether these areas are independent of or correlated with each other.

The second level of the quality of life measurement problem deals with the aggregation of indicators into comprehensive information in the form of a synthetic index. An index is a dimensionless measure, easily perceived and comparable, containing complex information that is the result of synthesis. The assessment of quality of life using synthetic indices is one of the most frequently mentioned approaches in the literature, and is addressed in the works of Martín and Mendoza [28], Greyling and Tregenna [32]; Bérenger and Verdier-Chouchane [33], or Somarriba and Pena [34]. From a mathematical point of view, a number of numerical procedures are suggested, the most commonly used in the literature are the basic arithmetic of standardized values [35,36], and the use of multivariate statistics [30,37,38], DEA (data envelopment analysis) [28,39,40], as well as indices based on the distance in multidimensional space [34,41,42] and the fuzzy approach [33,43]. Macků and Barvíř [44] performed a comparison of different aggregation methods over the same input data of 24 indicators to test the robustness/differences in the different approaches.

1.1. Quality of Life in Czechia

Quality of life is usually assessed within countries, to varying levels of detail. To examine the geographical aspect of quality of life in detail, it is necessary to focus on as much administrative detail as possible, in order to observe the spatial differentiation in the area of interest. In Czechia, there are few detailed studies focusing on the assessment of quality of life at the level of individual municipalities. Murgaš and Klobučník [45] examine the municipalities of Czechia in terms of the "Gold Standard of Quality of Life", expressing the criteria of a "good" life. According to the authors, the essence of the golden standard of quality of life is "quantifiable manifestations of an age-old archetypal human desire common to all humans throughout human history, the desire to live a long, healthy life, to have a family, to be surrounded by children and later grandchildren, to be educated, to have meaningful work that is fulfilling, to be considered a good person and to have a good reputation. Further assessments of quality of life at the municipal level have been conducted by the research agencies Median and the Aspen Institute (their research has never been published in a scientific journal, only at the conference [46] and in Czech media [47]). The authors identified 14 key quality of life indicators, which were aggregated into an index as a weighted sum of standardized values. On the basis of this comprehensive assessment, peripheries and cores of quality of life were identified within individual regions. Regional inequalities across countries are presented by Prokop [46] as one of the most significant problems in the development of Czech society.

1.2. Integration of GIS in the Quality of Life Research

A large portion of the existing studies (including the two from the Czech environment) mainly use aggregated statistical data to describe indicators, and this gives spatially biased information. The Median and Aspen Institute study uses indicators, such as distance to district town, accessibility of kindergartens, accessibility of secondary schools, and accessibility of health facilities. However, these indicators are only non-spatial in nature; they are in binary form and reflect the availability/unavailability of facilities (availability of kindergartens), with availability expressed as population per facility (availability of secondary schools and availability of health facilities). At the same time, this information is aggregated to a higher administrative unit (MEP; municipality with extended powers) than the targeted municipalities. This use of statistical data does not reflect the real geographical availability and accessibility.

GIS is an essential tool for spatial data analysis and visualisation; its methods could be used to estimate the overall quality of life and to evaluate its distribution in geographical space. GIS can also be used to assess relationships between individual input indicators or between the output quality of life index and indirect contextual factors. In particular, for an assessment containing indicators from the environmental domain, extensive spatial data sources or remote sensing data can be used. For instance, a significant aspect of quality of life is its relationship with the land use/land cover (LULC), which can serve as an indirect indicator of several variables [48], such as the quality of the landscape [49]. GIS technologies have been used by Li and Weng [30], who used GIS to combine remote sensing data and socioeconomic variables from US Census 2000. Similarly, remote sensing data-derived inputs for the quality of life assessment have been processed in the GIS environment in the study by Rao et al. [38].

The application of GIS tools plays a key role in large-scale assessment of urban quality of life. At this level, the resolution of statistical data is often limited and is therefore complemented by indicators derived from detailed spatial data, such as urban greenery, accessibility to specific services, housing density [50], or traffic intensity [51]. The limited use of GIS in quality of life studies has been pointed out by Mittal et al. [52], which can be seen as an opportunity for greater involvement of the GIS tool in quality of life assessment. Another applicability of GIS also for the topic of subjective-oriented well-being is presented by Davern and Chen [53] in the form of a GIS-based methodology. They also emphasise the link between social topics (such as quality of life) and spatial studies.

Based on the assumption of the relevance of GIS for quality of life assessment, the research question that was established for this paper concerns whether it is possible to refine the quality of life assessment in Czechia by implementing geographical information systems (GIS) that would more accurately depict the actual state of indicators related to the topic of accessibility.

1.3. Aims of the Study

The quality of life index, compiled by Median and the Aspen Institute, adequately covers the complexity of the quality of life. The omission of the spatial aspect from some of the indicators opens up the potential for their refinement, and thus a subsequent improvement in the overall quality of life index. The aim of this paper is to update selected quality of life indicators that focus on accessibility to services and institutions, using GIS tools to describe actual accessibility in geographic space. Subsequently, the quality of life index will be constructed. Finally, the impact of changes in the indicator design on the overall quality of life index and its spatial distribution across Czechia will be evaluated.

The study aims to enrich the existing methodological framework for quality of life assessment using GIS tools, which can inspire further case studies from other geographical areas. As mentioned, there are currently only a limited number of detailed studies focusing on the quality of life in Czechia. The update and refinement of one of them contributes to the discussion in the Czech academic and policy-planning environment. The study brings new data that can serve as useful reference information in the analysis of other social phenomena, such as voting behaviour or the assessment of social exclusion, which has, unfortunately, been increasing in Czechia in recent years.

The stated objectives will attempt to test the hypothesis of whether a different expression of the indicators plays a significant role in the overall context of the quality of life index. Another hypothesis expects that the most significant changes (decline in quality of life) will be evident in areas distant from larger cities. These expectations will be tested by changing the input indicators using GIS tools. Standard statistical methods, such as linear regression or correlation, will verify the subsequent evaluation of the significance of this change.

2. Materials and Methods

2.1. Data Sources

The methodology proposed in a study by Median and the Aspen Institute [46] was used to re-create the index. In order to present the most relevant and up-to-date results, the input indicators have been recalculated using the most recent input data in comparison with the original study. The input indicators for the quality of life model are summarized in Table 1. Table A1 provides more detailed information on the input indicators.

Table 1. Overview of quality of life indicators (original Median and Aspen Institute indicators).

Indicator	Administrative Detail
Unemployment rate	municipality
Foreclosures	municipality
Employment in industry	municipality
Crime index	police district
Emissions	MEP (municipality with extended powers)
Accessibility of district centres	municipality
Accessibility of kindergartens [1]	municipality/MEP
Accessibility of secondary schools	MEP
Accessibility of health care facilities	MEP
Availability of high-speed internet	municipality
Life expectancy of men	MEP
Population growth	municipality
Divorce rate index	district
Religiously affiliated population	municipality

[1] municipalities with inaccessible kindergartens are those where there is no kindergarten in the village or the number of children per kindergarten in the MEP is higher than the median.

A total of 4 indicators, namely (1) accessibility of kindergartens, (2) accessibility of secondary schools, (3) accessibility of health care facilities and (4) distance to district town, were adjusted in the next steps using network analysis in GIS software. The aim of the adjustment is to reflect the actual accessibility of the target service from each municipality, not just its presence. More detailed information on the adjusted input indicators is provided in Table A2.

The main data source was the public database of the *Czech Statistical Office,* from which, data on the total population between 2014-2019 were used, with details on municipalities. In addition, we used the total number of divorces and marriages in 2019 with details per district, the population at each year of age in 2020, and life expectancy in 2019, with details per administrative district of municipalities with extended jurisdiction. The religiously affiliated population and the number of economically active people in the population, broken down by sector of economic activity, was obtained from the *2011 Census of Population, Housing and Dwellings*. *The Ministry of Labour and Social Affairs* is the data source for data on the unemployment rate in the municipalities in 2019. Data on the total number of foreclosures in municipalities in 2020 were also obtained from the same source. Data on the total number of criminal offences were provided by the *Police of the Czech Republic*. Specifically, the total number of criminal offences (without internal classification) in the territory of police departments in 2019 was acquired. To obtain information about air pollution, publicly available data from the *Czech Hydrometeorological Institute*, entitled *Areas with exceeded emission limits* in 2019, were used. These data are provided in the form of a 1 km^2 vector grid, covering the entire territory of the Czechia and containing information on how the area exceeded the emissions of pollutants listed in Act No. 201/2012 Coll. Using spatial tools, the values from the grid were converted to the area of the administrative division by MEP: the grid was cut by the *Split* tool according to the MEP boundaries. Subsequently, the *Spatial Join* tool was used to assign to each MEP the area values from the grid tiles located in the MEP's territory and to calculate the proportion of the area above the pollution limit. The data on fast internet availability in 2018 were downloaded from the *Public Consultation Project* of the *Ministry of Industry and Trade*, detailing the basic settlement units.

As can be seen from Table 1, not all the input data followed administrative resolution at the municipality level, as unfortunately they are not available in such detail. Where this occurred, the same parent value was used in the final index calculation for all municipalities in the district.

For the purpose of updating the indicators using GIS tools (specifically network analyses), the road network and the location of target facilities (kindergartens, secondary schools, district towns and health facilities) were required. The location of health facilities was obtained from the *National Register of Health Service Providers*, which provides complete information on all health service providers in Czechia. Only general hospitals were selected from all facilities because they provide general health care and therefore have the most indicative information about health care availability. Data on secondary schools and kindergartens, up-to-date for 2020, were obtained from the *Register of Schools and Educational Establishments* from the portal of the *Ministry of Education, Youth and Sports*.

The road network for the network analysis was extracted from Open Transport Maps, which are freely available in shapefile format for all European NUTS 3 units. A speed attribute has been added to the road layer, representing the average speed of movement on road sections. The average speeds (Table 2) were taken from Hudeček et al. [54] and assigned to sections according to their class and maximum speed limits. Multiplying the average speed and the road section length gave the time required to travel through the section. This attribute was used in the network analysis to calculate the accessibility. The *BuildupP* point layer from the *Data200* dataset, managed by the *Czech Office of Surveying* and Cadastre, was chosen as the most appropriate representation of the municipalities and represents the centroids of built-up area of the municipality.

Table 2. Average speed on different types of roads.

Road Class	**Average Speed [km/h]**	
	outside the build-up area	build-up area
highway	115	–
expressways	105	65
primary roads	70	35
secondary roads	60	30
tertiary roads	35	25

2.2. Methods

The first step in calculating the quality of life index was to standardize the indicators to the same scale (using standardisation by standard deviation). The accessibility-related indicators were updated using network analysis methods to more accurately reflect the accessibility of each service. Network analyses were conducted in ArcGIS Pro 3.0 by ESRI, *Network Analysis* extension. Accessibility of target facilities and services was addressed using the *Closest Facility Analysis* method (the *Closes facility* tool from the *Network Analysis* extension). The input for this type of network analysis are two point layers: facilities and incidents. The algorithm searches for the best route from each incident to the nearest facility. Accessibility was measured as the time required to reach the best time-accessible facility from the point representing the municipality. The calculation was based on the product of the average speed and the length of the road section. Moreover, a directionality restriction has been set, specifically so that one-way roads are only passable in the correct direction. The direction attribute has been available from the source data. When calculating the accessibility of a district town, it was necessary to ensure that the accessibility value was calculated using the main town of the district in which the municipality administratively falls, not just the best accessible district town. Since the result of the network analysis is the time required to reach the target, the accessibility class indicators are actually treated as a measure of inaccessibility, which logically corresponds to the resulting time calculated by the network analysis. However, the term of accessibility is retained because it is defined and commonly used in GIS oriented studies [55,56].

The quality of life index is calculated as a weighted sum of standardized values of the input indicators. The weights of the indicators were adopted from the original study [46], and are presented in Appendix A. Each indicator needs to be logically evaluated if it is seen as an input (a higher value of the indicator has a negative impact on quality of life) or an output (a higher value of the indicator has a positive impact on quality of life) of quality of life. This information is also held in Appendix A in the column Impact, using the characters '+' and '-'. A total of two indices were created - one according to the original study with only time-updated indicators, and a second adjusted index that includes indicators based on geographic accessibility.

Spearman′s correlation coefficient was used to statistically evaluate similarity between the original and the updated quality of life indexes. A multiple linear regression model was constructed to assess the effect of changes in the individual indicator, and the relative strength of the regressors was observed using dominance analysis [57], using the *dominanceanalysis* package for R. All of the non-spatial tasks were processed in R or MS Excel.

3. Results

3.1. Original Index

First, the original index designed by Median and Aspen Institute was reconstructed using only statistical data. By updating the input indicators over time, a version of the original index was created to be as up-to-date as possible (see Appendix A for temporal resolution). The original index will serve as a reference in subsequent analyses. A visualization of the index is presented in Figure 1.

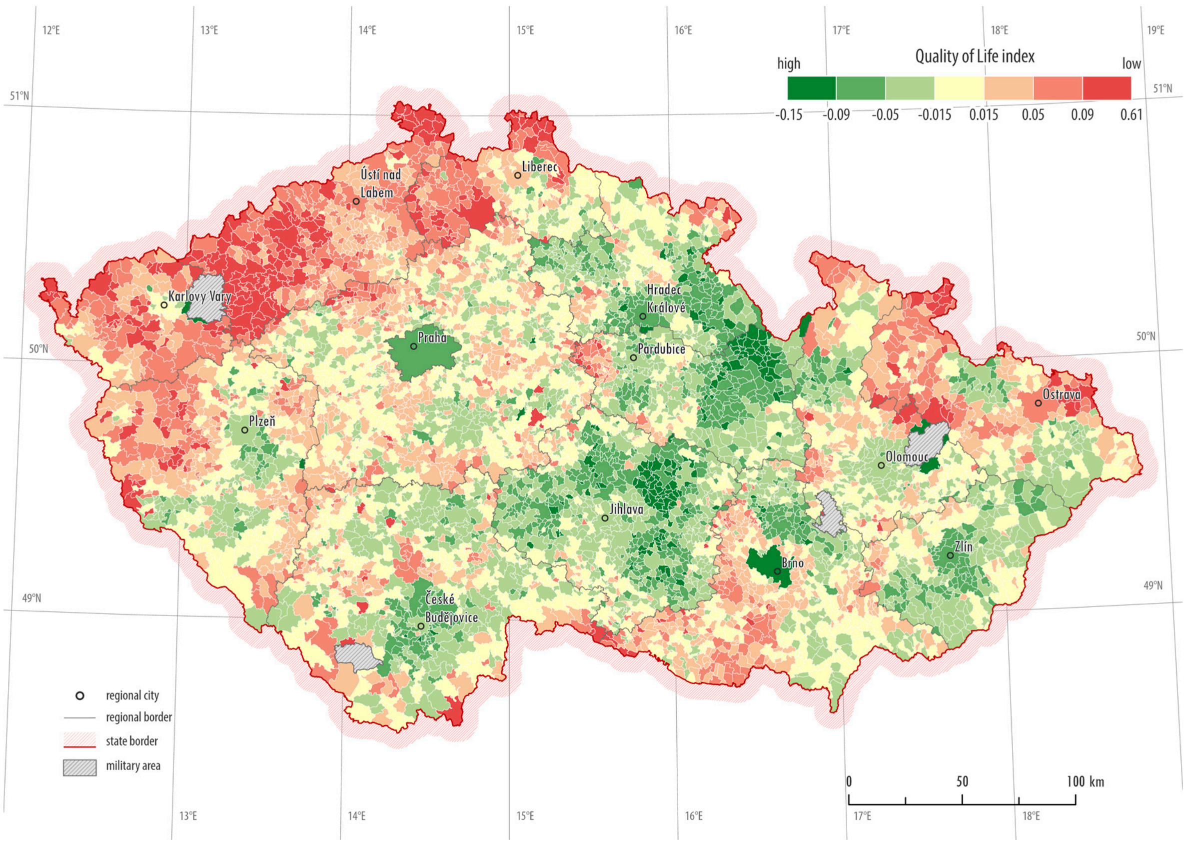

Figure 1. Original index with time-updated input indicators.

3.2. Accessibility Indicators

For each municipality, new accessibility values for the district centre, kindergartens, secondary schools, and health facilities were calculated using network analyses. Basic descriptive statistics for each area of accessibility are summarized in Table 3, and a spatial visualization of these indicators is presented in Appendix B.

Table 3. Geographical accessibility of individual facilities and services [rounded minutes].

Indicator	Min	Max	Mean	Median
Accessibility of district centres	0	74	23	22
Accessibility of kindergartens	0	36	3	2
Accessibility of secondary schools	0	44	10	10
Accessibility of health care facilities	0	63	20	19

Accessibility to the district centre is assessed using the travel time by car from the centroid of the municipality to the town office address. The average travel time from a village to the matching district centre is 23 min, and the median is 21.5 min. The difference between the mean and median is the result of very high values for several remote border municipalities. Municipalities on the inner periphery also show high values.

The accessibility of kindergartens is assessed as the travel time by car from the municipality's centroid to the nearest kindergarten. The number of kindergartens is the highest of all surveyed facilities in Czechia (7080 by 2020), and their average accessibility is significantly the best, three minutes. A kindergarten is accessible within five minutes in 76% of all the municipalities. Especially in larger cities, the kindergarten network is so dense that the generalized accessibility relative to the centroid of the municipality is lower than average. The only municipality from which no kindergarten is accessible within 20 minutes is Kalek in the Ústí nad Labem region.

Accessibility to secondary schools is assessed as the travel time by car from the centroid of the municipality to the nearest facility providing secondary education. The average time is 10 min. However, only 904 municipalities have access to a secondary school within 5 min. The majority of the municipalities are within the 8–10-min interval. The most inaccessible municipalities (maximum of 44 min) are located in the mountain border areas, specifically in the South Bohemia Region (south-west of Czechia).

The accessibility of health facilities is assessed as the travel time by car from the municipality's centroid to the nearest hospital by car. The accessibility of health facilities largely corresponds to the accessibility of district centres, as the district centre and the location of the nearest hospital are identical in many cases. This corresponds to the mean (20 min) and median (19 min), which are similar to the availability of the district town. The worst accessibility is observed in the mountainous border areas in the southwest of the country, as well as in the remote border areas in the north and northeast.

3.3. Adjusted Index with Accessibility Indicators

In addition to reconstructing the original index and updating it over time (see Section 3.1), a new index was also constructed, which additionally replaced original accessibility indicators with new, GIS-based accessibility indicators. The standardised values of the indicators were again multiplied by the same weights taken from the Median and Aspen Institute indexes, as in the case of the original index. A visualization of the adjusted index is provided in Figure 2.

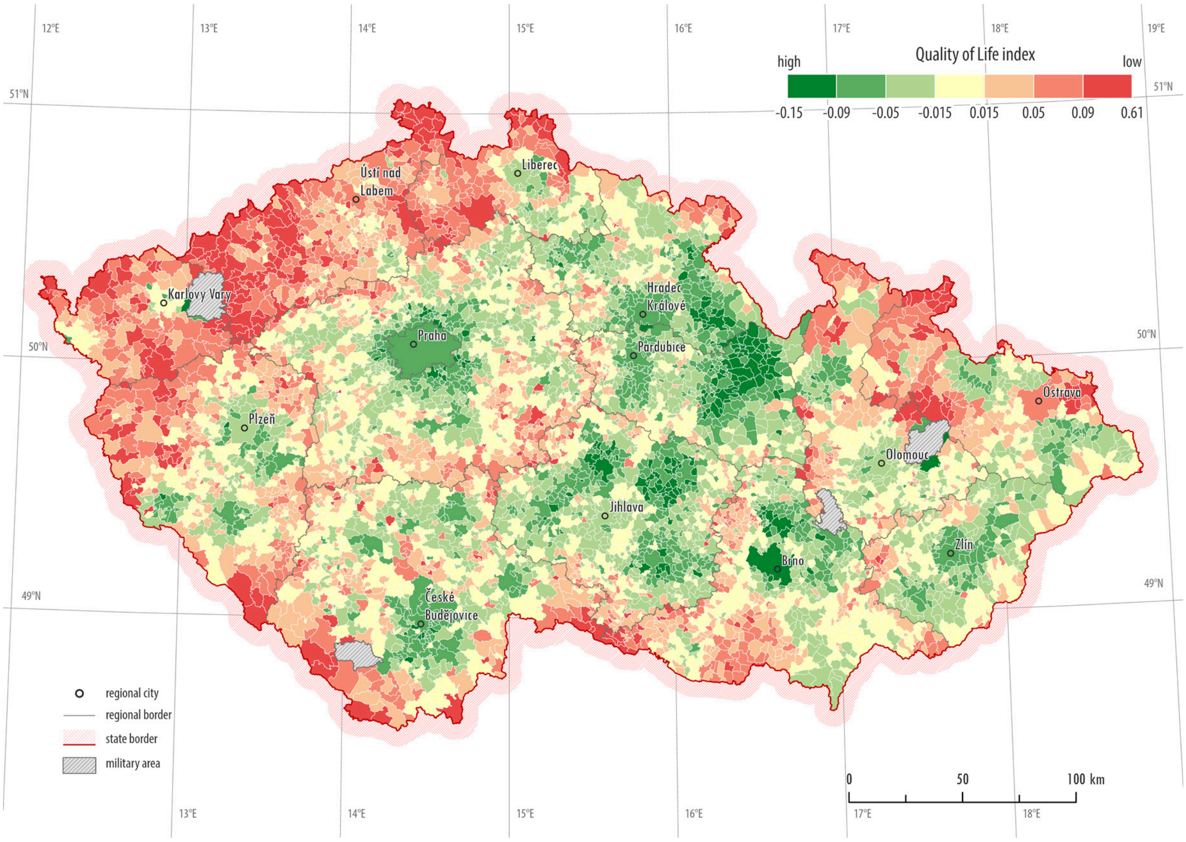

Figure 2. Adjusted index with accessibility indicators based on network analyses.

The lowest value of the index, and therefore the highest quality of life (because of the sign and the logical evaluation of some indicators and their weights, negative resulting values are understood to be the best in the context of quality of life) is found mainly in the municipalities in the north-south belt running through the centre of the country, from Rychnov nad Kněžnou, through Ústí nad Orlicí to the districts of Žd'ár nad Sázavou, Třebíč, and Havlíčkův Brod. Then, there are some large cities and their nearby catchment areas, e.g., Prague, Hradec Králové, České Budějovice, Brno, and Zlín. Low quality of life is typical for most of the municipalities in the Ústí and Karlovy Vary regions, the Bruntál district and large parts of the southern border municipalities. A rather lower quality of life is also characteristic of the inner peripheries, following the borders between the regions.

3.4. Evaluation of Changes

The visual analysis (Figures 1 and 2) reveals the preservation of a similar spatial trend in both variants of the index: high quality of life values are cumulated in the areas of large (regional) cities in both cases, and the belt on the border between Moravia and Bohemia stands out, where the largest continuous concentration of high values lies in the border area between the Pardubice and Olomouc regions. Low values typically persist in the border belt of north-west Bohemia, the second hotspot being the Bruntál region. Both of these locations are known as excluded areas with socio-economic problems in Czechia [58].

A non-spatial comparison of the original and the adjusted index (Figure 3) shows that the trend in the data remains similar. A correlation with r = 0.86 indicates a strong linear relationship between the compared indices. Both indices show several large outliers in the right part of the histograms (low quality of life values). These are also confirmed by the skewness coefficient (1.454 for the original index, 1.488 for the new index) and the deviation from a normal distribution (tested by the Kolmogorov–Smirnov test).

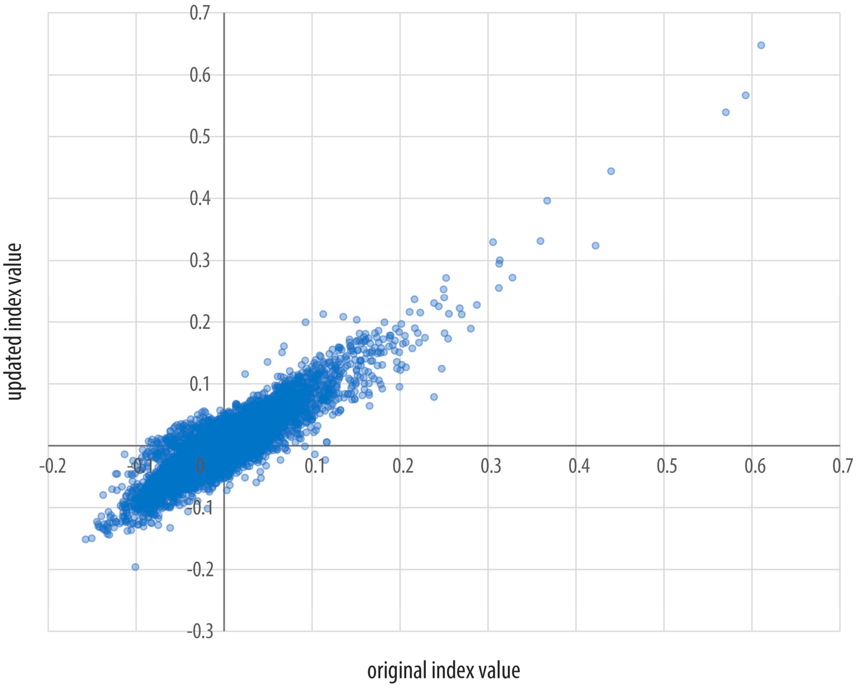

Figure 3. Non-spatial comparison of the original and adjusted index.

The observed variability was further examined spatially using the differences between the indices. The absolute difference between indices is not appropriate and not clearly interpretable due to the use of a sum of standardised indicators. Therefore, in order to observe the change, the indices were transformed into rankings (1st for the municipality with the highest quality of life and 6258 for the municipality with the lowest quality of life), and then the changes in quality of life were expressed by the change in rankings (Figure 4).

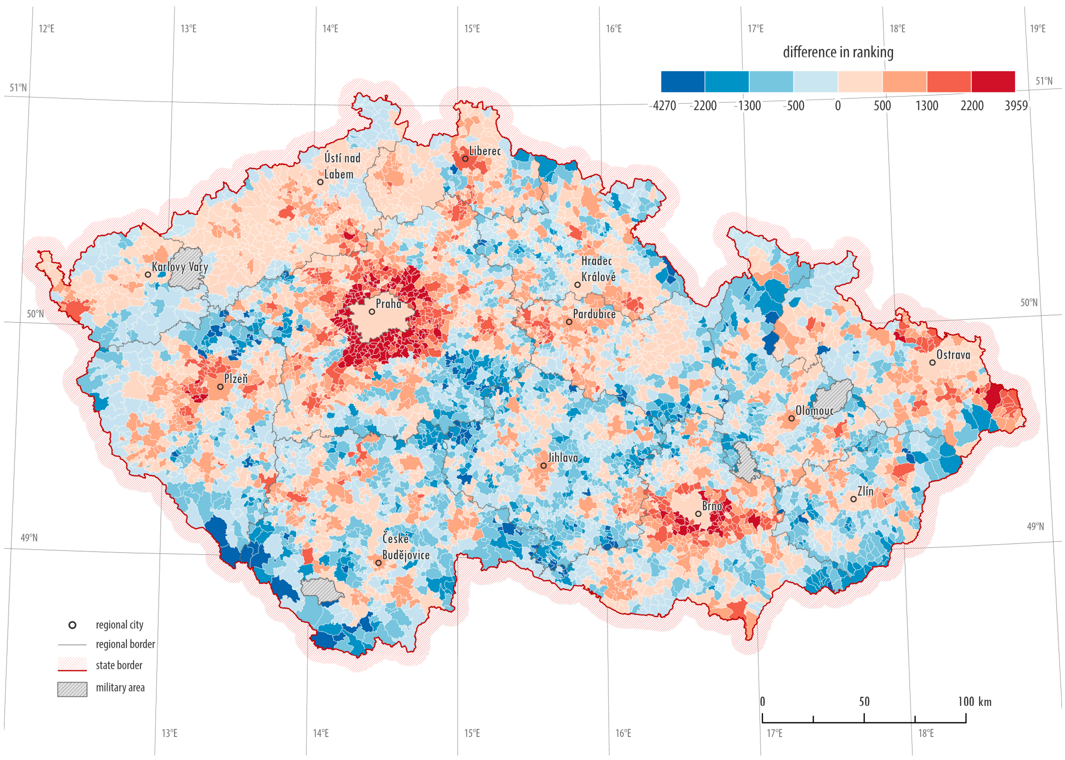

Figure 4. Difference in the ranking of individual municipalities.

The spatial visualization of the changes in quality of life primarily shows an increase of the values in the vicinity of large cities, especially around Prague, Brno, Ostrava, and Plzeň. On the other hand, the greatest decline is visible on the south-western state border and also on the borders of the districts of Benešov, Kutná Hora, and Pelhřimov, possibly between the districts of Plzeň North and Rakovník. All these areas are either mountainous border areas or inner peripheries. The distribution of changes therefore illustrates the importance of using accessibility analyses instead of simply assessing the presence of a service in a municipality or statistically expressing the number of inhabitants per facility in an administrative unit. In this way, the geographical approach to the processing of input indicators highlights more weaknesses the less accessible areas, distant from the primary civic services (schools, health facilities).

To assess the impact of the index adjustment, a number of municipalities whose scores were significantly changed by the adjustment were examined. We define a significant change as a change in the ranking by more than 620 positions (in both directions of ranking), which corresponds to approximately 10% of the values in a total of 6 254 municipalities. Such a change was observed in 39% of all municipalities. A significant change (increase/decrease in ranking by more than 1.560 positions, corresponding to 25% of the base set) occurred in 11% of the municipalities, while an extreme change (increase/decrease in ranking by more than 3,130, corresponding to 50% of the base set) occurred in only 1% of all municipalities. On the basis of these brief statistics, it can be concluded that the importance of updating the quality of life index was not negligible for a large part of the sample.

In order to more accurately statistically evaluate changes in the index's construction, changes in the relative importance of each input indicator on the index were observed. Regression models were constructed with the quality of life index as the dependent variable and the individual indicators in the positions of the explanatory variables. It is assumed that in the updated index, due to increased variability, the effect of the updated accessibility indicators will be greater. The value of the coefficient of determination R^2 of the full model is 1 for both indices, as the input indicators fully explain the variability of the index as the dependent variable. The relative importance of the input indicators is different in the two models and the coefficients are summarized in Table 4.

Table 4. Parameters of regression models between indices and input indicators.

	Original		**Adjusted**	
Indicator	β	R^2	β	R^2
Unemployment rate	0.01126	0.166	0.01126	0.157
Foreclosures	0.06362	0.267	0.06363	0.249
Employment in industry	0.08521	0.011	0.08522	0.010
Crime index	−0.00055	0.098	−0.00056	0.079
Emissions	0.06427	0.029	0.06427	0.026
Accessibility of centres	0.00111	0.040	0.00081	0.056
Accessibility of kindergartens	0.02122	0.026	0.00300	0.039
Accessibility of secondary schools	0.00005	0.018	0.00146	0.038
Accessibility of health care facilities	0.00006	0.033	0.00092	0.072
Unavailability of high speed internet	0.00866	0.017	0.00866	0.007
Life expectancy of men	−0.01535	0.169	−0.01535	0.160
Population growth	−0.18731	0.076	−0.18731	0.075
Divorce rate index	0.00083	0.016	0.00083	0.006
Religiously affiliated population	−0.0004	0.032	−0.0004	0.025

For all indicators updated using GIS tools, we observe an increase in relative importance, as the variability of their values, and therefore their importance for the whole model has increased. For the indicators *Unavailability of high speed internet* and *Divorce rate index*, a decrease in significance of one order of magnitude was observed. The results confirm that the use of spatially based indicators plays a more significant role in the model, as these indicators, due to their greater variability and detail, have a greater impact on the quality of life index itself, and better complement the statistical data with the same level of detail.

3.5. Intensity of Changes in Territory Types

The observed findings suggest that quality of life is related to the character of an area in terms of its urban/rural delimitation. Lower quality of life values are observed in the inner peripheries and border areas, which are typically rural regions. Larger cities are characterised by a rather better quality of life. Therefore, the change in quality of life index was also explored in the context of the municipality′s association with rural/urban space, as proposed by Pászto et al. [59], and performed using the fuzzy sets approach. Municipalities were classified into three categories: more rural or rural type (degree of membership at interval ⟨0; 0.4⟩), intermediate type (degree of membership at interval ⟨0.4; 0.6⟩) and rather urban or urban type (degree of membership at interval ⟨0.6; 1⟩. Subsequently, changes in quality of life were observed for these different types (Figure 5). This non-spatial assessment confirms the results found by the visual analysis: on average, the greatest decline occurs in rural/more rural type municipalities. The remaining categories show, on average, an improvement in the quality of life. No more significant differences are observed between the rather urban to urban and the intermediate type (median values of change are 452 and 441). The intermediate type has a greater degree of variability.

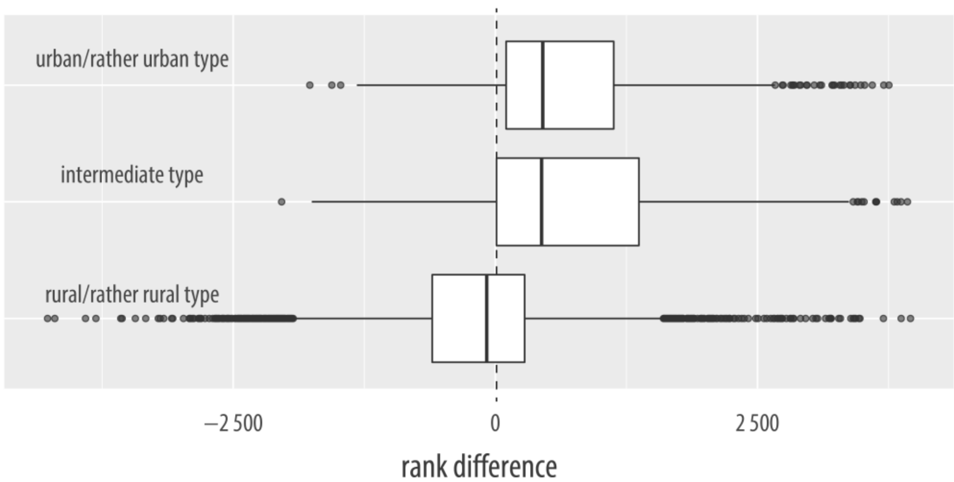

Figure 5. Changes in the quality of life index in municipalities according to rural/urban classification.

4. Discussion

The present study innovates the methodology for quality of life assessment established by Median and the Aspen Institute by modifying selected indicators using GIS tools. The new adjustment procedure has caused significant changes in the assessment of quality of life in Czech municipalities. We are aware of several challenges that were identified during the process.

The first limitation of the presented results is the principle of GIS applied analyses in the context of the data used. Network analyses solve the task of the accessibility of selected targets quite accurately. However, this is always only on the basis of specified input parameters. In our approach, generalized values of average speed on different types of roads were used in accessibility modelling. More accurate data on actual speeds exist only in the form of commercial datasets which, unfortunately, were not available for the purposes of this study. Other aspects of accessibility modelling, such as the quality of roads, which may be poor especially in remote border areas, and thus negatively affect travel times, cannot be taken into account. Similarly, the analysis does not include, for example, information on traffic, which is again an important aspect in the assessment of accessibility in larger cities. Furthermore, accessibility within large cities is strongly generalised by the principle of using the distance between the municipality centroid and the target location. Simplification is also present in the conceptualisation of the modelled availability: the network analysis results only in an algorithmic finding of the best scenario based on geographical distance and speed on the available routes. Furthermore, aspects, such as the real capacity of health or school facilities, the real demand for these services defined by the population in a specific catchment area, and the specific subjective preferences of the population, do not enter the model. These preferences play a major role, for instance in the choice of secondary school or kindergarten. This last aspect in particular is completely uncapturable on the scale of this analysis.

Another example of uncertainty at the level of input indicators can be seen in the case of the accessibility of district centres. This aspect is present in the paper even though district authorities were abolished in Czechia in 2003. The districts as territorial units are still maintained and this division is still used, e.g., for the needs of the police, courts, and labour offices. In addition, the district town is the nearest town to most municipalities with some type of elementary services, such as educational institutions, cultural facilities, or shopping centres.

Although the analysis attempts to capture the spatial nature of the phenomena as well as possible and to be as detailed as possible, not all input data can follow the municipality classification. Unfortunately, a number of input data are not registered at all in the details of the municipalities, e.g., life expectancy or criminality index. In the case of divorce rates, although input data are available at the municipality level, in a number of municipalities, no divorces occurred and thus would remain at zero. For this reason, the data were aggregated to higher administrative units, MEP. The emissions indicator was treated similarly. Input data at the 1 km^2 grid may be suitable for smaller municipalities. Hence, the aggregation to the MEP level has been applied.

Using real-world accessibility modelling, the new updated index can be considered more accurate compared to the original, which used only statistical data. This claim is particularly evidenced by the significant changes around large cities, where the unnatural effect of indicators linked to administrative units has been replaced by the more natural behaviour of accessibility-related phenomena. Assuming that GIS analyses represent a suitable tool for modelling the representation of the real world [60], we argue that the use of adjusted accessibility indicators is a more appropriate solution for assessing quality of life. Validation of the quality of life phenomenon is very problematic. It is not possible to conduct a direct validation, as relevant reference information would only be available from a survey on the subjective satisfaction of the Czech population at the level of individual municipalities. Such a survey has never been carried out and probably will not be carried out due to the enormous staff, time, and cost requirements. The potential space for validation lies in comparing the results with similar existing studies. Currently, there are only a few of these at the municipal level in Czechia. A comparison with the work of Murgaš and Klobučník [45] is possible. The spatial trend of their index expressing the Gold Standard of Quality of Life coincides with our results in key places: they also identify the regions of Northwest Bohemia and Northeast Moravia as areas with low quality of life. High quality of life is similarly observed in the southern part of the border between Bohemia and Moravia. The correlation between our results and the Murgaš and Klobučníks index shows a value of r = 0.53.

It is also difficult to measure the actual change that the adjusted index represents. The relative change in the importance of individual indicators was captured by the regression model described in Section 3.3, but quantifying the overall contribution of the updated index is complicated. To assess the impact of the index adjustment, a number of municipalities whose scores were significantly changed by the update were examined.

Finally, it must be taken into account that our findings provide only one perspective on the topic of quality of life. As pointed out in the theoretical section, quality of life is a very broad topic and approaches to grasping it vary considerably from author to author. However, the methodology used by Median and the Aspen Institute [46] is, in our opinion, well chosen, as it attempts to comprehensively take into account the important aspects and indicators of quality of life, and it is the result of the activities of a group of experts who have long been working on social issues in Czechia.

5. Conclusions

The aim of the study was to implement GIS tools (more specifically accessibility analysis) in the quality of life assessment and to evaluate the impact of indicator adjustments on the overall index. Based on an existing study, an adjusted quality of life index for municipalities in Czechia was created. Indicators of accessibility of district centres, health facilities, kindergartens, and secondary schools were reworked using network analyses, during which time accessibility from the centroid of the municipality to the best accessible facility or to the respective district centre was addressed. By handling the spatial data more appropriately, selected indicators of quality of life related to accessibility to the infrastructure of basic intermittent services are more accurately captured. Although the findings from the case study apply only to Czechia, it can be a methodological inspiration for applying it to other similar environments, with regard to the socio-economic nature of the territory (similarity of European regions investigated in the typology proposed in a previous study by the authors [61]).

Although the adjustment of four of the 14 indicators has not fundamentally altered the spatial trend of the distribution of quality of life in Czechia, significant changes can be observed in the area of interest. This is particularly so in the vicinity of large cities, where there has been an increase in the quality of life associated with proximity to the target services, while the opposite trend can be observed in the rural inner periphery and in remote mountain border areas, as proven by observing changes in quality of life in three categories of municipalities according to rural/urban classification. The differences in quality of life between urban and rural areas are thus widening, which supports our hypotheses established in the introduction. While the original accessibility indicators were mostly valid for a higher administrative unit (e.g., district), the processing of selected indicators using GIS tools provides continuously changing values that refine the overall assessment and therefore offer a more realistic view of the phenomenon of quality of life. The resulting index indicates the lowest quality of life in most parts of the Ústí and Karlovy Vary regions and in parts of the Moravian-Silesian region. Rural areas of the inner peripheries also appear to be of concern. In contrast, a higher quality of life is evident in the regional capitals of the wealthier regions and in their nearby municipalities. A relatively high quality of life was also observed in some rural areas of eastern Bohemia, Vysočina, and the Zlín Region, which are not often mentioned in this respect.

A number of findings emerge from the evaluation that can be applied to public policy direction of Czechia. Strong spatial inequalities are evident across the territory, with the main excluded regions clearly standing out. These are similar in a number of indicators, such as unemployment rates, social exclusion, foreclosure rates, and crime rates. In particular, economic indicators exacerbate regional disparities, and the progressive indebtedness and foreclosures from the poorer part of the population give way to an intractable cycle of increasing social disparities. Investing not only in the quality, but also in the accessibility of the education system can be a partial solution to these problems. In terms of accessibility to basic infrastructure, border mountain areas and rural regions, usually on the borders between counties and far from larger cities, are typically excluded. These areas would deserve targeted support for the development of transport infrastructure and accessibility services to make it easier for local residents to get to the needed services. The main contribution of the study to the scientific literature on quality of life is to provide a valid quantification of the phenomenon of quality of life. This can be a useful reference for evaluating other social issues, e.g., monitoring election results in relation to contextual factors that significantly influence the voting behaviour of the population, as the quality of life is one of the most important of these factors.

In future research on the quality of life in Czechia, it would be useful to process more time cross-sections and assess the spatiotemporal development of this phenomenon. Furthermore, as mentioned in Section 4, the model needs to include the real capacity of healthcare facilities and schools and the demand for these services in the form of a reachable population. These aspects could be included in the study but require closer collaboration with the relevant authorities to obtain the necessary input data.

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Appendix A

Table A1. Input indicators of the original index according to the Median and Aspen Institute study: the definition of input indicators remains unchanged, they have been updated to the most temporally available values.

Indicator	Unit	Year	Administrative Detail	Model Weights	Impact [1]
Unemployment rate	%	2019	municipality	0.01684	−
Foreclosures	number per capita	2020	municipality	0.02407	−
Employment in industry	% of economically active	2011	municipality	0.00768	−
Crime index	number of inhabitants per offence	2019	police district	−0.01194	+
Emissions	% above the pollution limit	2019	MEP	0.01175	−
Accessibility of district centres	km (Euclidean distance)	2020	municipality	0.00866	−
Accessibility of kindergartens	binary (yes/no)	2020	municipality	0.00895	−
Accessibility of secondary schools	pupil per school	2020	MEP	0.00797	−
Accessibility of health care facilities	citizens per health care facility	2020	MEP	0.00843	−
Unavailability of high-speed internet	categories 1–3 [2]	2018	municipality	0.00651	−
Life expectancy of men	year	2019	MEP	−0.01692	+
Population growth	%	2014–2019	municipality	−0.01473	+
Divorce rate index	number of divorces per 100 marriages	2019	district	0.00459	−
Religiously affiliated population	%	2011	municipality	−0.00490	+

[1] +: a higher value of the indicator has a positive impact on the quality of life (outputs); −: a higher value of the indicator has a negative impact on the quality of life (inputs). [2] 1 - New Generation Access (NGA) network coverage ≤ 40%; 2 - NGA network coverage > 50% by no more than one operator; 3 - NGA network coverage > 50% by more than one operator. NGA networks are access networks that use optical elements and can deliver broadband internet access services from 30 Mbit/s. The classification has been defined within the *Public Consultation Project* of the *Ministry of Industry and Trade.*

Table A2. Input indicators for the adjusted index: accessibility indicators recalculated using network analysis.

Indicator	Unit	Year	Administrative Detail	Model Weights	Impact
Unemployment rate	%	2019	municipality	0.01684	–
Foreclosures	number per capita	2020	municipality	0.02407	–
Employment in industry	% of economically active	2011	municipality	0.00768	–
Crime index	number of inhabitants per offence	2019	police district	−0.01194	+
Emissions	% above the pollution limit	2019	MEP	0.01175	–
Accessibility of district centres	minutes	2020	municipality	0.00866	–
Accessibility of kindergartens	minutes	2020	municipality	0.00895	–
Accessibility of secondary schools	minutes	2020	municipality	0.00797	–
Accessibility of health care facilities	minutes	2020	municipality	0.00843	–
Unavailability of high-speed internet	categories 1–3	2018	municipality	0.00651	–
Life expectancy of men	year	2019	MEP	−0.01692	+
Population growth	%	2014–2019	municipality	−0.01473	+
Divorce rate index	number of divorces per 100 marriages	2019	district	0.00459	–
Religiously affiliated population	%	2011	municipality	−0.00490	+

Appendix B

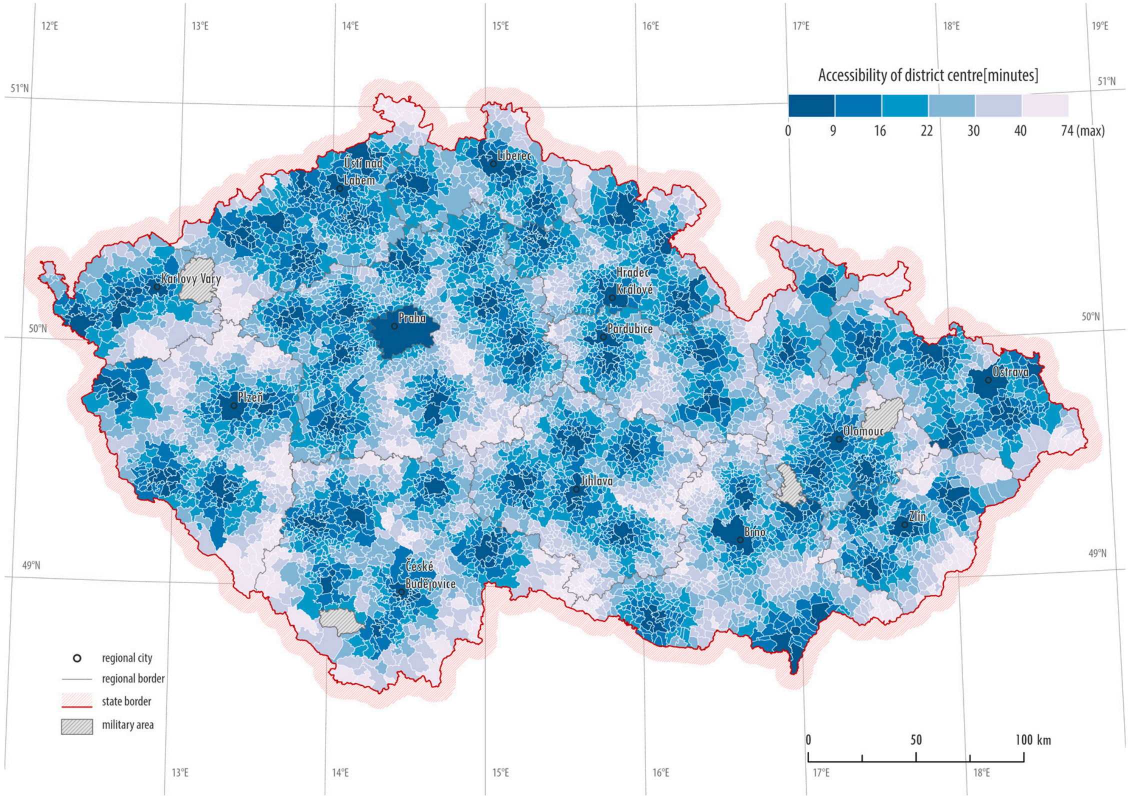

Figure A1. Accessibility of district centres.

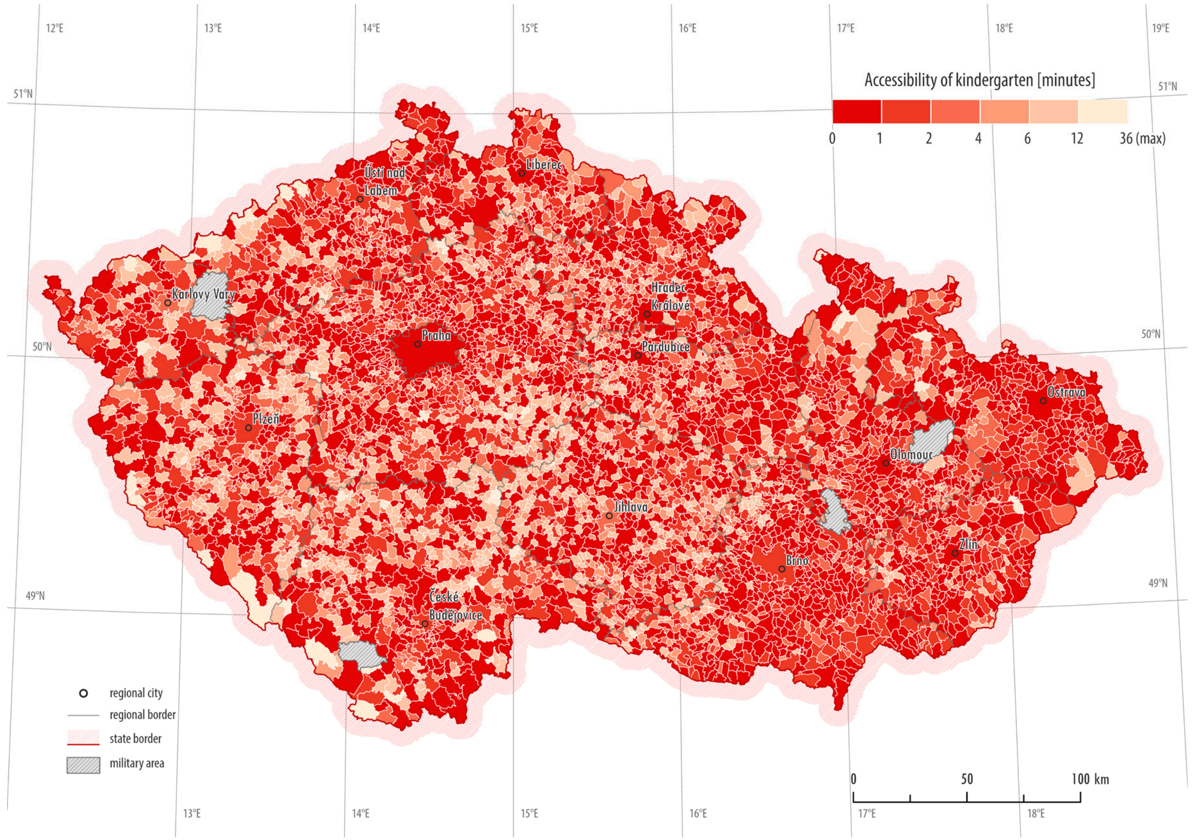

Figure A2. Accessibility of kindergartens.

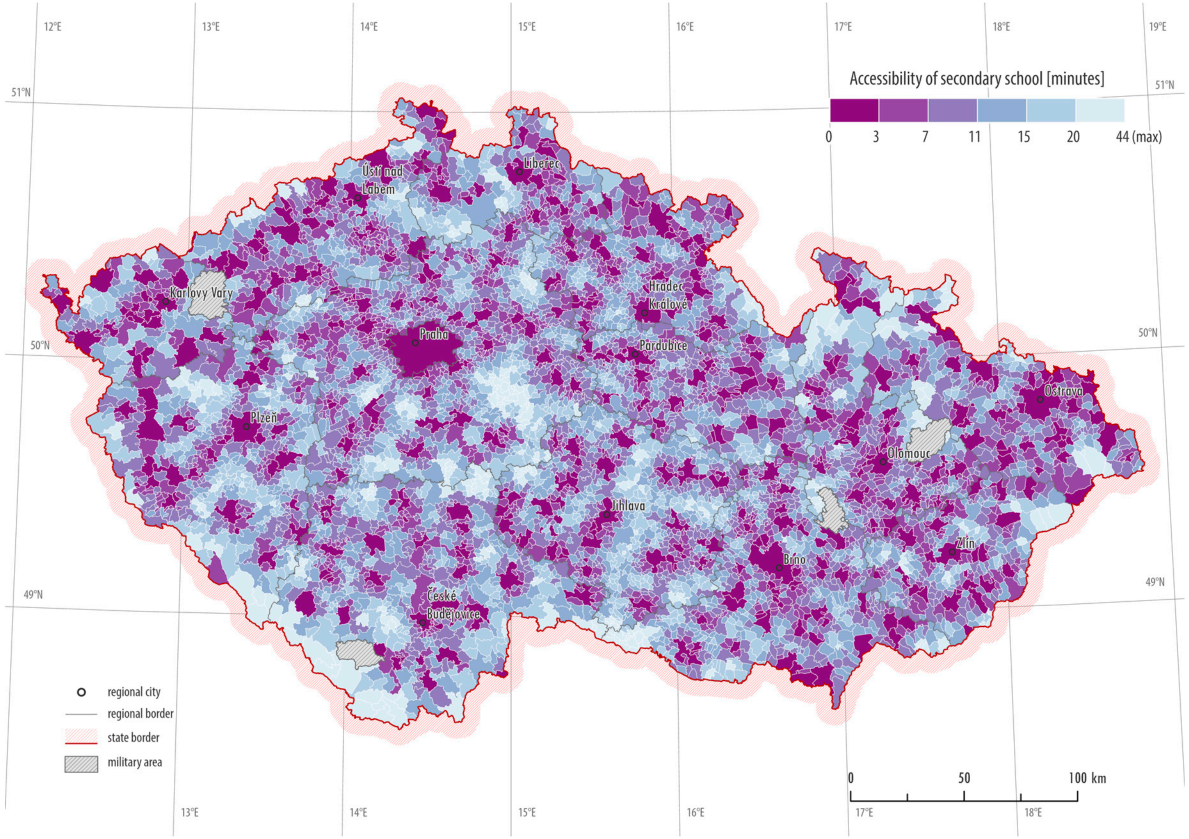

Figure A3. Accessibility of secondary schools.

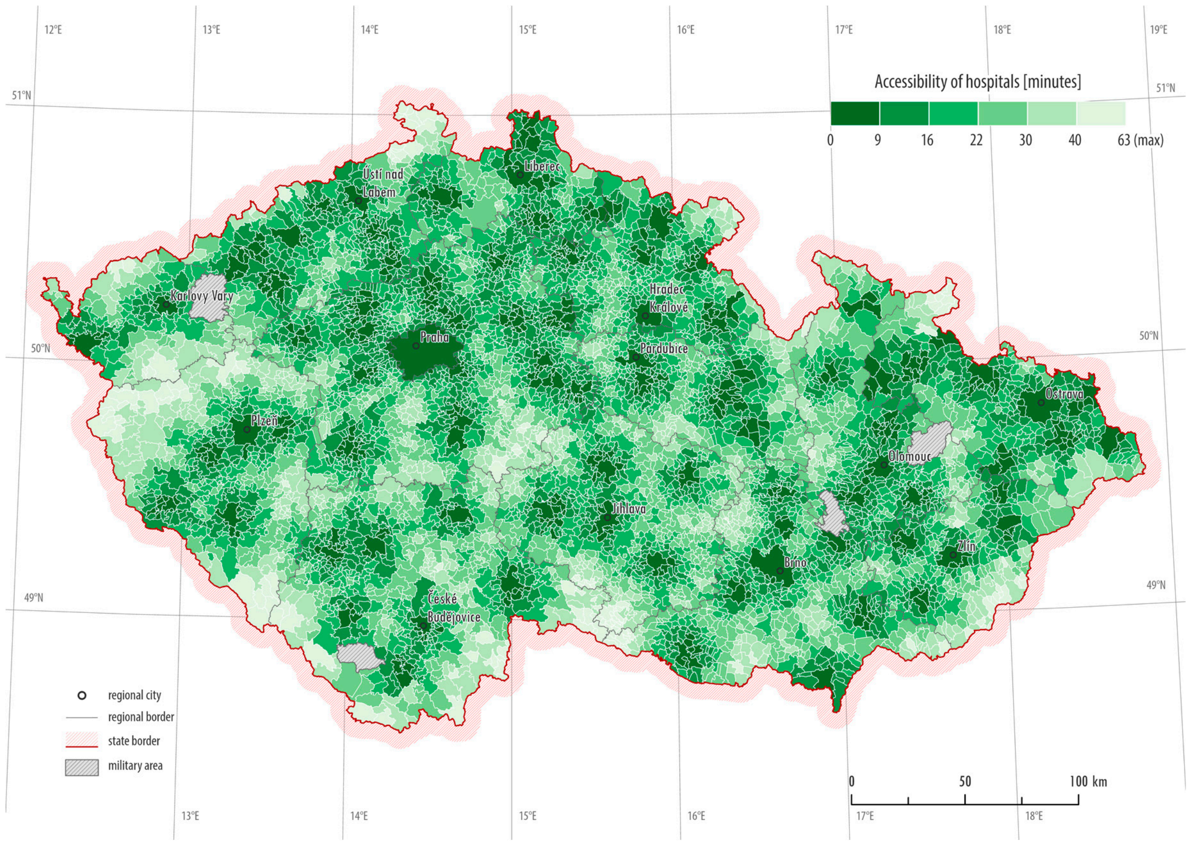

Figure A4. Accessibility of health care facilities.

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