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IMPROVEMENT OF THE NORMATIVE MONETARY EVALUATION OF SETTLEMENT LAND IN THE ECOLOGICAL CONTEXT

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Abstract. The ecological factors affect not only the quality of life and health of settlement residents but also the real property market and land valuation indicators. However, no previous Ukrainian study has considered ecological factors during calculating the normative monetary valuation (NMV) of settlement land. Much uncertainty still exists about the nature of selecting ecological factors, their calculating, interpreting and application. This study aims to identify the ecological factors and their indexes and propose a new approach for defining the ecological impact on the NMV of the settlement land and evaluation units. A retrospective study collected infrastructural, environmental, and ecological data for the Kharkiv city, covering the years 2014–2019. The empirical methods and GIS tools were used to evaluate and interpret the data. The indexes characterising the ecological condition led to an increase in the minimum index for the normative monetary land value within the evaluation districts from 9.71 USD/sq. m. to 12.00 USD/sq. m. and the maximum value – decreased from 101.60 USD/sq. m. to 86.34 USD/sq. m. The new approach takes into account the area of environmental factors distribution within the evaluation unit and proves usefulness in understanding the actual ecological impact on the NMV of settlement land. Overall, this study has demonstrated that the size of land valuation is slightly influenced, although not significantly, by ecological factors.

Keywords: ecological factor, land valuation, settlement land, pollution, ecological condition, normative monetary valuation, spatial database.

Introduction

A valuation of the land is required because the principle of payment for land use is a mandatory for all landowners and land users in Ukraine. Land use payments applies to land owners and users of state or municipal land plots in the form of land tax and lease fee. These payments are billed based on the normative monetary valuation of and plots (adjusted for the annual indexation) or the area of land plots for which the normative monetary valuation is not set. The normative monetary valuation (hereinafter abbreviated as NMV) of land plots is the capitalised rental income from the land plot, calculated according to the established and approved norms (Verkhovna Rada Ukrainy [VRU], 2001, 2004). Rental income is an income received from the land as a factor of production, depending on the quality and location of the land plot (VRU, 2004). NMV of land plots is carried out for determination of land tax, state fee on an exchange, inheritance and gifting of land plots, rental fee on state-owned and communal land plots, losses of agricultural and forest production, the value of land plots with a total area more than 50 hectares for placing open structures for sports activities, as well as for the process of the development of indicators and mechanisms of economic stimulation of rational land use and protection (VRU, 2004).

NMV of land plots is one of the foundations of efficient use of land resources, an important economic mechanism and an element of the implementation of regulatory land policy and the land tenure improvement.

There are three types of NMV: NMV of settlement land, NMV of non-agricultural land outside the settlement and NMV of agricultural land. Laws and regulations define the application scope of these NMV. This paper is focused on NMV of settlement land. Settlement land is all land of all categories for the main purpose of use, which are located within the administrative boundaries of settlements (villages, towns and cities).

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The current method of calculating the NMV of settlement land is based on the rent basis (Kabinet Ministriv Ukrainy [KMU], 1995). Land rent is the income that can be obtained from land as a factor of production depending on the quality and location of the land (VRU, 2004). In a settlement, the amount of rental income depends on such factors as the location of the settlement in the territorial systems of production and settlement network, the level of engineering and transport arrangement, climatic and engineering-geological conditions, architectural-landscape and historical-cultural value, the ecological condition of the settlement, as well as the functional use of land (KMU, 1995; VRU, 2004; Ministerstvo Ahrarnoi Polityky [MAP], 2016). Therefore, the calculation of the NMV of settlement land should be approached comprehensively, taking into account the influence of all these rent-generating factors. Today, each land valuation expert independently (at his own discretion) chooses a list of rent-generating factors and ways of displaying and interpretation. As a result, there are significant differences in the NMV of settlement land.

The influence of rent-generating factors on the NMV of the settlement land is expressed through a system of increasing (coefficient greater than "1") and decreasing (less than "1") coefficients. Some of the coefficients are fixed by the Method for normative monetary valuation of settlement land (KMU, 1995) (hereinafter – NMV Method) and do not require calculation, some are calculated according to the equations given in the Procedure for normative monetary valuation of settlement land (MAP, 2016) (hereinafter – NMV Procedure). The Method and Procedure of NMV have undergone various changes and additions, but their core has not changed since 1995 and still does not meet modern economic and legal conditions of land tenure.

The existing body of research on NMV suggests that certain rent-generating factors have to be clarified. Pronko and Samborska (2014) concluded that NMV of settlement land must take into account market factors, which are formed under the influence of demand, supply and quality characteristics of land plots. While Kovalchuk and Patychenko (2017) argue that, the calculation of NMV of settlement land should take into account the size of permanent population for the beginning of the year. Other researchers (Palekha & Kolosiuk, 2013a, 2013b; Lykhohrud, 2015a, 2015b; Samoilenko, 2016) have substantiated the need to introduce a new approach to determining the normative rental income of the settlement land. Several researchers indicate that the economic and planning zoning of the settlement territory needs significant adjustment (Kolosiuk & Naiko, 2016; Shulhan et al., 2016).

However, *no previous study* has given sufficient consideration to ecological factors during calculating the NMV of settlement land. Much *uncertainty* still exists about the nature of the selection of ecological factors, the list of relevant indexes for valuation, the procedure for calculating and interpreting the results and their application in the calculation of the NMV of settlement land.

Due to that, the present work *aims* to identify the ecological factors and their indexes and to improve the present approach of defining the ecological impact during conducting the normative monetary valuation of the settlement land and evaluation units.

This paper, firstly, presents the current procedure of NMV of settlement land and the formation of ecological factors spatial database. Then, a new approach of defining the ecological impact on the normative monetary valuation of the settlement land and single evaluation units is given. And finally, a detailed analysis and interpretation of ecological impact on the NMV of settlement land by present and new approaches are reported.

1. Materials and methods

The study area is the land and individual evaluation units in Kharkiv City of Kharkiv oblast (province) in the northeast of Ukraine (Figure 1). The second largest city in Ukraine. The main topography of the city is the river

Figure 1. Location of the study area

valleys and watershed areas. The total area of 370 km^2 is categorized as built-up area (64%), agricultural land (17%), forestland (12%), land without vegetation (4%), ponds, rivers, wetlands (3%).

The basic ecological parameters of the Kharkiv City were collected during 2014–2019 years by using Scientific and Technical Report on the implementation of works on updating engineering and geological data and data on the ecological quality of the territory for the normative monetary valuation of the land; Reports of the Department of Ecology and Natural Resources; Reports on the state of the environment; ecological passports; different information on the ecological condition of the city; maps of the location of the pollution objects of the surface layer of the atmosphere and electromagnetic radiation; schemes of administrative, cadastral and evaluation division of the city territory.

The study used the *methods* of the empirical level: description, observation, measurement, comparison, and generalisation. In addition, specific scientific methods were applied: cartographic, geoinformation modelling (overlay, interpolation, buffering), and statistical (ranking and grouping).

2. The results of the research

According to the current legislative framework (KMU, 1995; MAP, 2016), rent-generating factors are taken into account at all stages of calculating the normative monetary valuation of land: during calculating the average (base) value per one sq.m. of settlement land, the land value within the evaluation districts and the value of land plots of various functional use.

It should be noted that ecological factors affect not only the quality of life and health of city residents but also the real property market and land valuation indicators. In our opinion, this influence is expressed through the analysis of rent-generating factors at the regional, zonal and local levels. For example, the land value will be lower if the settlement is located in a zone of technogenic or radiation pollution (for example, from the Chernobyl accident), or it may increase if the city has resort status (regional rent-generating factors). At the zonal level, the influence of rent-generating factors is investigated at the level of administrative districts in city, city blocks, a set of city blocks and evaluation districts. An example of such impact maybe the location of the evaluation district into the noisy zone from the highway, passing by the city, but only pollutes part of its territory. At the local level, the influence of each ecological factor on a single land plot is investigated. In this regard, it becomes necessary to rationale the system of ecological factors and their indexes for the NMV of the settlement land.

As noted earlier, the process of calculating the value of land plots is complicated by the fact that, in addition to ecological factors, it is necessary to take into account such rent-generating factors as the convenient location of the land plot, the level of its infrastructural arrangement, the architectural, landscape, historical and cultural value of the territory of the settlement. Accordingly, it becomes necessary to express these factors in the form of mathematical values, which will allow in the future carrying out a more accurate calculation of the NMV of the settlement land. Nowadays, NMV of the settlement land is calculated by using a generally accepted approach to taking into account the influence of rent-generating factors through the coefficient of the comprehensive index of the territory quality. However, there is no unified approach to choosing the rent-generating factors and the calculation of their impact. Each land valuation expert or valuation team independently (to his or their own discretion) chooses a list of rent-generating factors, methods of their representation and interpretation and calculating the comprehensive index of the territory quality. This leads to significant differences in the NMV of the settlement land.

2.1. Procedure for settlement land valuation, ecological factors and formation the spatial database

Based on the analysis of literature and current legal framework (KMU, 1995; VRU, 2004; MAP, 2016; Dičiūnaitė-Rauktienė & Maliene, 2016; Dekhtiarenko et al., 2002; Shypulin et al., 2015) and reports about ecological condition of Kharkiv city, we can conclude that calculating the NMV of settlement land should take into account the complex effect from ecological factors on the territory of the settlement as a whole, a single land plot and a set of land plots. It is proposed to use the following ecological factors:

- At the level of the settlement: location in the zone of pollution from the Chernobyl nuclear power plant and the city's status as a resort;
- At the level of evaluation districts of the settlement: ecological condition of the surface layer of the atmosphere, ecological condition of soils, level of noise, level of electromagnetic pollution;
- At the level of a single land plot: location of the land plot in the sanitary protection zone; location of the land plot in the water protection zone; location of the land plot in the zone of restricted development by the level of atmospheric air pollution; location of the land plot in the building restriction zone by the level of the electromagnetic field voltage; location of the land plot in the zone where the permissible noise level from the railway, highways, electrical substations and airports is exceeded; location of the land plot in the zone of soil contamination by heavy metals, in the territories occupied by natural hips and waste heaps.

It is proposed to use the above ecological factors for the normative monetary valuation without fail, taking into account the fact of their influence on the evaluation unit. For this purpose, it is necessary to have up-to-date data on ecological factors affecting the quality of life, conditions and activities in cities (Dičiūnaitė-Rauktienė & Maliene, 2016). A lack of data is an important factor affecting NMV of settlement land.

The application of GIS in valuation practice has been identified with several benefits (Dekhtiarenko et al., 2002; Martynova et al., 2019; Nyarko & Lemmen, 2008; Oud, 2017; Wyatt, 1995, 1997; Yu et al., 2007) such as automation, systematization and processing of source cartographic and tabular data; implementation of spatial, overlay, interpolation and surface analysis of the database of evaluation units; carrying out quality preparing and displaying of the results of monetary valuation. That is why, the GIS technologies (in this study, it was Quantum GIS) was used in the process of taking into account ecological factors for the NMV of the settlement land that made it possible to form a spatial database of ecological factors. Mathematical and statistical processing made it possible to express the cumulative impact of ecological factors on the NMV of the settlement land through a coefficient characterising the ecological status of the territory. The procedure for taking into account ecological factors and displaying the corresponding layers of data at each stage of calculating the normative monetary value of settlement land is given in Table 1.

Table 1 shows that the calculation of the NMV of settlement land in Ukraine is carried out on the principle of general to partial – from the territory of the settlement as a whole to a single land plot. Therefore, in order to determine the impact of ecological factors on the NMV of settlement land, it is necessary to form a database of spatial data areas of ecological factors impact at the regional (settlement as a whole), zonal (evaluation districts within the settlement) and local (single land plot) levels.

At the first stage of creating a database of spatial data of ecological factors of the Kharkiv city, the layer "Boundary of the evaluation area of the Kharkiv city" (UA63120270010096107_mot.shp) is formed, with the type of object(s) for this layer – a polygon. The situation of dividing the territory of a city into districts is typical for Ukraine. Therefore the spatial database should have a layer "Administrative districts of the Kharkiv city" (UA63120270010096107_admin.shp) with the type of objects – a polygon (see Figure 2). The "Administrative districts of the settlement" layer is not used for calculating the normative monetary valuation of the city's land, but in the future, the boundaries of evaluation districts of the settlement are tied to the boundaries of the administrative districts of the settlement. These layers are created on the total area of the settlement within the prescribed limits and are polygon (system of adjacent polygons). Polygons in this layer should be topologically correct, and the sum of the areas of administrative districts of the settlement should be equal to its total area.

Legislative base on NMV of settlement lands (KMU, 1995; MAP, 2016) determines that each stage of the calculation corresponds to its location index (*Lc*), the value of which depends on the influence of regional, zonal and local rent-generating factors. For example, in the beginning – during calculating the average (base) value of settlement land – the influence of ecological rent-generating factors is expressed through the indexes *Lc*1-3 and *Lc*1-4 (Eq. (2), Table 1). The index *Lc*1-3 is applied if the settlement has the status of a resort and ranges from 1.5 to 3.0 (positive rent-generating factor). The index *Lc*1-4 characterises the location of the settlement on the territory exposed to radioactive contamination as a result of the Chernobyl disaster and can have a value from 0.5 to 0.8 (negative rent-generating factor) depending on the contamination zone (exclusion, unconditional (mandatory) resettlement, guaranteed voluntary resettlement). These indexes are fixed by legislation (MAP, 2016), and do not require a separate layer in the spatial database of ecological factors. Information about the indexes values from the group *Lc*1 is included in the layer UA63120270010096107_mot.shp in the form of attribute information.

Detailed accounting and calculation of the influence of ecological factors on the NMV of settlement land are

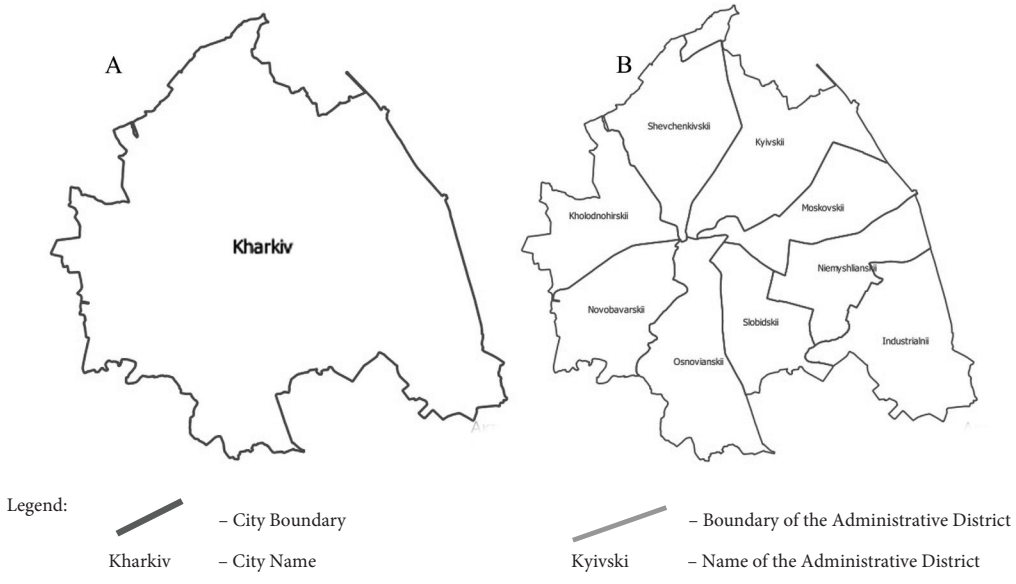

Figure 2. Scheme of the layer of administrative-territorial division of the Kharkiv city

Table 1. The procedure of calculating and displaying data of NMV of settlement land considering ecological factors

Factor and index names	Abbreviation	Unit	Description / Computational equation	Equation no.	Displaying on a spatial database	
					Layer name	Layer description
Regional level – location and status of the settlement						
Average (base) value of settlement land depending on regional factors of location:	*Vnl*	UAH/sq. m.	$Vnl = \frac{C \times Rr}{Cr} \times Lc1$	(1)	UA00000000000000000_mot.shp	Object – the settlement territory, object type – polygon, parameters type – decimal number (real)
– costs for development and arrangement of the settlement territory	*C*	UAH/sq. m.	Statistical reporting data on the physical and cost indicators of the engineering and infrastructure arrangement of the settlement			Parameters type – decimal number (real)
– rate of return	*Rr*	–	6%, NMV Procedure (MAP, 2016)			Parameters type – integer
– capitalisation rate	*Cr*	–	3%, NMV Procedure (MAP, 2016)			Parameters type – integer
– regional coefficient considering the importance and status of the settlement in the national, regional and local systems of production and settlement	*Lc*1	coefficient	$Lc1 = Lc1\text{-}1 \times Lc1\text{-}2 \times Lc1\text{-}3 \times Lc1\text{-}4$ Defined by annex to NMV Procedure (MAP, 2016)	(2)		Parameters type – decimal number (real)
Zonal level – evaluation districts of the settlement						
Land value within evaluation district of the settlement:	*Vnz*	UAH/sq. m.	$Vnz = Vnl \times Lc2$	(3)	UA00000000000000000_region.shp	Object – the evaluation district territory, object type – polygon, parameters type – decimal number (real)
– average (base) value of settlement land depending on regional factors of location	*Vnl*	UAH/sq. m.	Calculated at the regional level	(1)		Parameters type – decimal number (real)
– zonal coefficient characterises the urban quality of the settlement evaluation district	*Lc*2	UAH/sq. m.	$Lc2 = Ii$			Parameters type – decimal number (real)
Comprehensive index of the territory quality of the settlement evaluation district:	*Ii*	coefficient	$Ii = S_i \times W_{Si} + U_i \times W_{Ui} + E_i \times W_{Ei} + C_i \times W_{Ci}$	(4)		Parameters type – decimal number (real)
– index of transport and functional convenience of the territory for the settlement evaluation district	*Si*	coefficient	Calculated for each evaluation district. Land valuation experts are free to choose assessment methods: expert, sociological or GIS analysis			Parameters type – decimal number (real)
– index of engineering and infrastructural arrangement of the territory for the settlement evaluation district	*Ui*	coefficient				Parameters type – decimal number (real)
– index of social attractiveness of the environment for the settlement evaluation district	*Ci*	coefficient				Parameters type – decimal number (real)
– index of the ecological condition of the territory for the settlement evaluation district	*Ei*	coefficient				Parameters type – decimal number (real)

Continued Table 1

Factor and index names	Abbreviation	Unit	Description / Computational equation	Equation no.	Displaying on a spatial database	
					Layer name	Layer description
– the weight of the corresponding index	W(S;U;E;C)i	coefficient	It is calculated based on the conclusion of the valuation experts			Parameters type – decimal number (real)
Index of the ecological condition of the territory for the settlement evaluation district	E_i	coefficient	$E_i = B_i \times W_B + G_i \times W_G + N_i \times W_N + Z_i \times W_Z$	(5)	UA00000 00000000 0000_Eco.shp	Parameters type – decimal number (real)
– index of the ecological condition of the surface layer of the atmosphere for the evaluation district	B_i	coefficient	$B_i = \frac{S_{Bi}}{S_{Bmid}}$	(6)	UA00000 00000000 0000_atmPol. shp	Object – area of pollution of the surface layer of the atmosphere, object type – polygon, parameters type – decimal number (real)
– index of ecological condition of soils for the evaluation district	G_i	coefficient	$G_i = \frac{S_{Gi}}{S_{Gmid}}$	(7)	UA00000 00000000 0000_ groundPol.shp	Object – area of soil contamination by heavy metals, object type – polygon, parameters type – decimal number (real)
– noise index of the evaluation district	N_i	coefficient	$N_i = \frac{S_{Ni}}{S_{Nmid}}$	(8)	UA00000 00000000 0000_noise. shp	Object – area of acoustic pollution, object type – polygon, parameters type – decimal number (real)
– index of electromagnetic pollution of the evaluation district	Z_i	coefficient	$Z_i = \frac{S_{Zi}}{S_{Zmid}}$	(9)	UA00000 000000 000000_ elfield.shp	Object – area of electromagnetic pollution, object type – polygon, parameters type – decimal number (real)
– the weight of the corresponding index	$W_{(B;G;N;Z)i}$	coefficient	It is calculated based on the conclusion of the valuation experts			Parameters type – decimal number (real)
– the value of the corresponding ecological factor of the evaluation district	$S_{(B;G;N;Z)i}$	coefficient	0 – there is pollution 1 – there is no pollution			
– the average value of the relevant ecological index for the settlement	$S_{(B;G;N;Z)mid}$	coefficient	$S_{(B;G;N;Z)mid} = \frac{\sum S_{(B;G;N;Z)i}}{N}$	(10)		
– the total number of evaluation districts in settlement	N	pieces				

End of Table 1

Factor and index names		Abbreviation	Unit	Description / Computational equation	Equation no.	Displaying on a spatial database	
						Layer name	Layer description
Proposed new approach	– the value of the corresponding ecological index in the evaluation district	$S_{(B;G;N;Z)i}$	coefficient	Calculated for each evaluation district by dividing the area of distribution of the ecological index in the evaluation district by the total area of the evaluation district	(11)		Parameters type – decimal number (real)
	– the weighted average value of the distribution of the relevant ecological index on average in the settlement	$S_{(B;G;N;Z)mid}$	coefficient	$S_{(B;G;N;Z)mid} = \frac{\sum S_{(B;G;N;Z)i} \times P_i}{\sum P_i}$	(12)		Parameters type – decimal number (real)
	– the area of the evaluation district of the settlement	P_i	sq. m.	Calculated for each evaluation district			Parameters type – decimal number (real)
Local level – single land plot							
Normative monetary valuation of a single land plot:		*Vn*	UAH/sq. m.	$Vn = Vnz \times Cf \times Lc3$	(13)		
– land value within evaluation district of the settlement		*Vnz*	UAH/sq. m.	Calculated at the zonal level	(3)	UA000000 00000000 000_region.shp	Object – the territory of evaluation district, object type – polygon, parameters type – decimal number (real)
– coefficient of functional use of land plot		*Cf*	coefficient	Defined by annex to NMV Procedure (MAP, 2016)			Parameters type – decimal number (real)
– the coefficient of local evaluation factors		*Lc*3	coefficient	Defined by annex to NMV Procedure (MAP, 2016)			Parameters type – decimal number (real)
						UA000000 00000000 000 – settlement code (Ministerstvo Rozvytku Hromad [MRH], 2020)	

conducted at the stage of calculating the zonal coefficient *Lc*2. For this purpose, the territory of the settlement (in our case is Kharkiv city) is divided into evaluation districts – territorially and functionally defined formations, within which the assessment of the consumer properties of the settlement land is carried out (Dekhtiarenko et al., 2002). The allocation of evaluation districts within settlement is carried out in compliance with the following rules:

- Each evaluation district should have a uniform functional and planning use;
- Evaluation districts may be limited by the axes of highways of the city-wide and regional levels, by the railroad allotment boundaries, by the axes of natural restrictions (rivers, streams, canals, ditches, etc.), by the boundaries of administrative districts of the settlement;
- The area of one evaluation district should be comparable to the microdistrict (also known as Neighbourhood Unit) of multi-storey buildings or to the residential block (group of residential blocks) of a manor buildings;
- The amalgamation of all evaluation districts should provide full coverage of the settlement's territory within the established boundaries;
- The evaluation districts should not include the railway right-of-way except the station forecourt (Dekhtiarenko et al., 2002).

Considering the above, a layer "Evaluation districts of a Kharkiv city" (UA63120270010096107_region.shp) is created with the type of objects – a polygon. The evaluation districts were allocated within the Kharkiv city and tied to the boundaries of its administrative districts. Polygons in this layer are formed topologically correctly, and the sum of the areas of the evaluation districts should be equal to the area of the city (see Figure 3).

In order to take into account the maximum number of rent-generating factors, an assessment of each evaluation district of the city should be conducted and a comprehensive index of the territory quality (*Ii*) for each district should be calculated. Based on the value of the *Ii* index, we subsequently calculated the zonal coefficient *Lc*2. The calculation of the comprehensive index of the territory quality for the evaluation districts (*Ii*) is carried out by weighing individual indexes reflecting the value of Kharkiv city land, namely: transport and functional convenience of the territory (S_i); engineering and infrastructural arrangement of the territory (U_i); social attractiveness of the environment (C_i); ecological condition of the territory (E_i). Due to the restrictions established by the purpose of the article, detailed attention has been paid specifically to improving the present approach for the calculation of the index of the ecological condition of the territory (E_i).

As already noted, the ecological condition of the territory of the evaluation districts is expressed by the comprehensive index (E_i) that combines the action of various ecological factors. Analysis of the literature on the topic of research (Dekhtiarenko et al., 2002; Nyarko & Lemmen, 2008; Oud, 2017; Wyatt, 1995, 1997; Yu et al., 2007), technical documentation for NMV of settlement land of Ukraine and available information has allowed highlighting the following ecological indexes for the Kharkiv city: the level of pollution of the surface layer of the atmosphere (B_i); the level of soil contamination by heavy metals (*Gi*); the level of acoustic pollution (*Ni*); the level of electromagnetic pollution (*Zi*). It was recommended to calculate the index of the ecological condition by determining the share of the area of one or another ecological index in the total area of the evaluation district of the settlement (Eqs (6)–(9), see Table 1).

The analysis of the technical documentation for NMV of settlement land of Ukraine showed that only a small proportion of the valuation experts use GIS tools for evaluation the ecological condition of the settlement. The vast majority of land valuation professionals use an expert method of valuation based on the evaluation of the

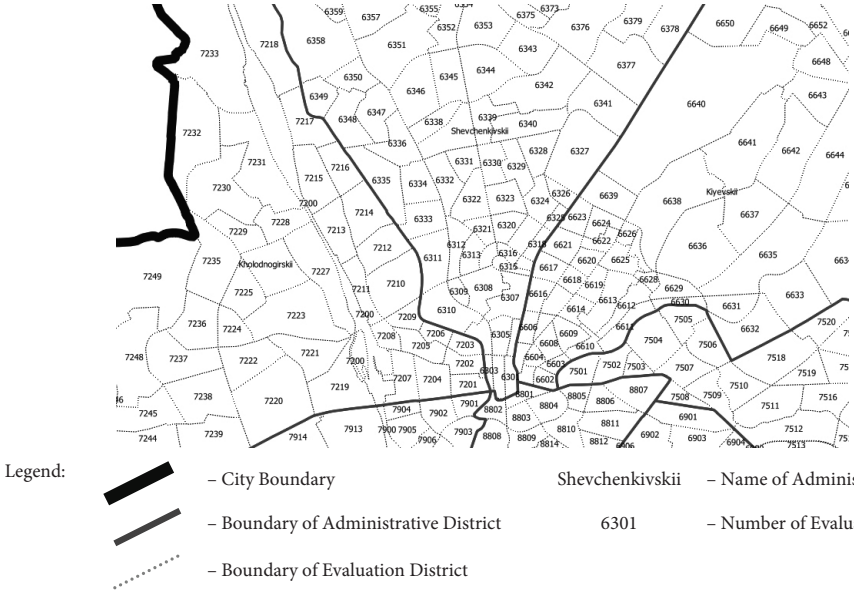

Figure 3. A fragment of the evaluation zoning of the territory of the Kharkiv city

conditions of the settlement by a group of experts. In addition, the land valuation teams do not take into account the share of the contaminated area in the total area of the evaluation district of the settlement. Only the fact of the presence or absence of an ecological factor on the territory of the evaluation district is taken into account. Accordingly, a rigid value of the pollution factor is applied: "0" – if there is a polluting factor, "1" – if there is no polluting factor.

According to the generally accepted approach, the index of ecological condition for each ecological factor is calculated by dividing the pollution coefficient of the district by the average value of the corresponding pollution in the settlement. The calculation is carried out according to the equation (5) (see Table 1). Let's give an example for the evaluation district 6301 of Kharkiv city. The index of ecological condition of the surface layer of the atmosphere for the evaluation district 6301 is equal to 0 (such kind of pollution was detected within evaluation district). It was calculated that the average index value of the ecological condition of the surface layer of the atmosphere for the city is 0.0703. Thus, the index of ecological condition of the surface layer of the atmosphere for the evaluation district 6301 will be (Eq. (6)):

$$B_{6301} = \frac{0}{0.0703} = 0 .$$

Similar calculations were made for other ecological indexes:

- the index of ecological condition of soils is: G_{6301} = 0 / 0.0937 = 0;
- the noise index is: N_{6301} = 0 / 0.0313 = 0;
- the index of electromagnetic pollution is: Z_{6301} = 1/0.4941 = 2.0238.

Thus, according to the present approach, the current index of ecological condition of the territory for the evaluation district 6301 is (Eq. (5)):

$$E_{6301} = 0 \times 0.39 + 0 \times 0.28 + 0 \times 0.22 + 2.0238 \times 0.11 = 0.2226.$$

Since Ukraine has not formed and legislated a unified approach to evaluate the ecological condition of settlement land, it is recommended to evaluate the ecological condition by creating integrated spatial database of ecological factors and calculate the index of the ecological condition for each evaluation district.

2.2. A new approach to determining the ecological impact

It is well known that air pollution in cities is one of the most important factors that affect the quality of the environment (Chen & Kan, 2008). The main air pollutants in cities are vehicles and industry (Vlachokostas et al., 2010). However, the evaluation of the ecological condition of the atmosphere takes into account the level of pollution either from vehicles or from industrial facilities. At first, it happens because is not always a full information database concerning pollution type is available. Second, not all land valuation experts are willing to investigate air pollution in detail. And, finally, a significant drawback of the current NMV Procedure is the lack of an approach to accounting for several types of pollution within the framework of one ecological factor. In our opinion, one of the ways to solve the existing problem is to change the approach for evaluating the ecological condition of the settlement territory and to use GIS instruments for taking into account ecological impact in more detail.

It is proposed to calculate the index of the ecological condition by dividing the area of the distribution of the ecological factor within the evaluation district by the weighted average of the corresponding ecological factor in the average of the settlement (Eqs (11)–(12), see Table 1). To test this hypothesis, the interpolation method of the Quantum GIS software (QGIS), namely Inverse Distance Weighting (IDW), was used. The essence of this method is to weigh the distances from a data collection point (stationary or mobile laboratory) to an unknown point, the value of which must be determined. In this study, the

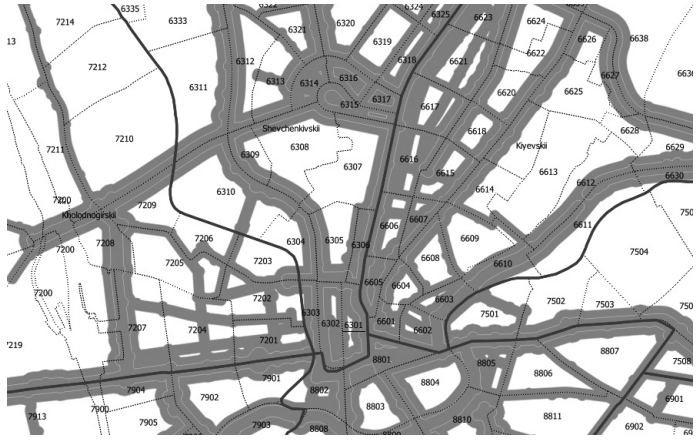

Figure 4. A fragment of pollution of the surface layer of the atmosphere of the Kharkiv city

evaluation of the ecological condition of the surface layer of the Kharkiv city's atmosphere (W) was carried out based on the results of observations at stationary stations using the air pollution index for individual impurities (sulphur dioxide, nitrogen oxide, ammonia, lead, copper, zinc, chromium, etc.). The weighing was performed based on an additionally created point layer (UA63120270010096107_Atm.shp) with the attribute of the maximum permissible concentration of the most polluting substance, taking into account the weighting coefficient.

At first, two additional layers added the layer "Pollution of the surface layer of the atmosphere" (UA63120270010096107_atmPol.shp): "Pollution of the surface layer of the atmosphere from vehicles" (UA63120270010096107_atmTransport.shp) and "Pollution of the surface layer of the atmosphere from industrial facilities" (UA63120270010096107_AtmInd.shp). This is due to the presence of various causes of pollution. The layer "Pollution of the surface layer of the atmosphere" reflects the carriageways of highways of the citywide and regional significance. The spatial database of pollution from vehicles was created by applying the buffering method. A layer "Pollution of the surface layer of the atmosphere from industrial facilities" was formed, according to a similar approach. Second, the overlaying the layers of pollution from vehicles and industrial facilities helped to form the holistic layer of pollution of the surface layer of the Kharkiv city's atmosphere and to calculate the general level of intensity of such pollution. In turn, this allowed us to find out the area of uncontaminated territory in the total area of the Kharkiv city. At the final stage, the index of the ecological condition of the surface layer of the atmosphere for each evaluation district of the settlement was determined (Eq. (6), see Table 1). A fragment of pollution of the surface layer of the atmosphere of the Kharkiv city is shown in Figure 4.

As an example, let us calculate the index of the ecological condition of the surface layer of the atmosphere for the evaluation district 6301. The total area of the evaluation district 6301 is 101242 sq. m. According to the developed spatial database, the unpolluted area of the surface layer of the atmosphere in this district is 5581 sq. m. Thus, the value of the ecological condition of the surface layer of the atmosphere within the evaluation district 6301 is (Eq. (11)):

$$S_{B6301} = \frac{5581 \text{ sq. m.}}{101\ 242 \text{ sq. m.}} = 0.0551 .$$

Using the IDW method, it was found that the weighted average value distribution of the ecological condition of the surface layer of the atmosphere (S_{Bmid}) on average for the Kharkiv city is 0.6937. Therefore, the index of the ecological condition of the surface layer of the atmosphere for the evaluation district 6301 is (Eq. (6)):

$$B_{6301} = \frac{0.0551}{0.6937} = 0.0795.$$

The next step was the evaluation of the ecological condition of soils. The basis for the evaluation was the data of the control points of the Kharkiv Regional Centre for Hydrometeorology regarding soil pollution with such heavy metals as lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), iron (Fe), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn). In order to generalise the level of soil contamination, the total index (Zc) is calculated by dividing the sum of the concentration factors of pollutants by the background indexes. This index is widely used in the sanitary and hygienic evaluation of soil pollution (Alekseev, 2008; Korzhnev, 2005; Stoops, 2010) and is calculated by the specialists of the Kharkiv Regional Centre of Hydrometeorology.

In the research, an appropriate point layer (UA63120270010096107_groundPol.shp) was created to visualise the control points of observation and the values of the total index of soil pollution (Zc). At the next stage, by using the Spline method, a spatial database of planar objects with pollution levels was created: less than 16 Zc, from 16 to 32 Zc, from 32 to 128 Zc and more than 128 Zc. Further, these levels of pollution were overlaid on the evaluation districts of the city for calculation of the areas of soil pollution by heavy metals. It should be noted that the authors faced difficulties in assessing the impact of the intensity of soil pollution by heavy metals on the NMV of settlement land. That is why it was decided to compare the level of the ecological condition of soils within each evaluation district of the Kharkiv city according to the generally accepted approach – by the index of the ecological condition of soils (Eq. (7), see Table 1). For example, for the evaluation district 6301 is set, that its entire territory is polluted by heavy metals (see Figure 5). It means that the index of the ecological condition of soils (G_i) is equal to 0. In further studies, the authors are planning to investigate and solve the problems of taking into account the influence of the intensity of soil pollution by heavy metals on the indicators of the NMV of the settlement land.

It has already been noted that transport is the main source of noise in the city. Therefore, an additional layer UA63120270010096107_transport.shp (object type – line) was created to build a spatial database of the noise level of the Kharkiv city. This layer displays the axis of highways of regional, district importance, the axis of streets, tram, railway tracks and air transport, the noise from which exceeds the permissible level. Then, the buffers have been built that show noise pollution in the city by using the QGIS Variable Width Buffer tool. All this made it possible to form a general noise pollution layer (UA63120270010096107_noise.shp, type – polygon) of the Kharkiv city and overlay it on the territory of the evaluation districts of the settlement (see Figure 6).

The comparison of the evaluation districts of the city by the level of noise pollution was carried out by the noise index (Eq. (8), see Table 1). Using the example of the evaluation district 6301, we calculate the noise index. It was found by the developed spatial database that the

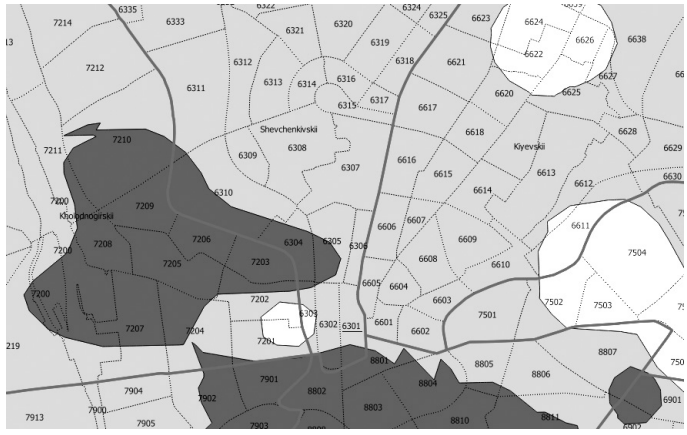

Figure 5. A fragment of a layer of soil pollution by heavy metals of the Kharkiv city

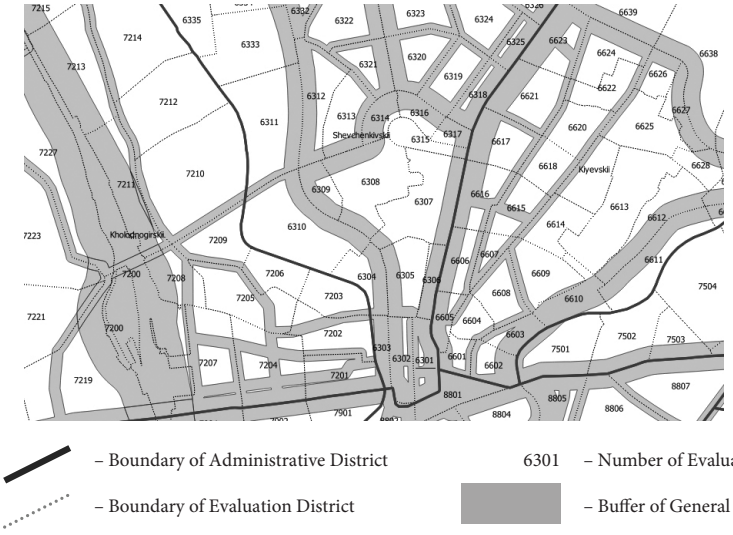

Figure 6. Fragment of the general noise pollution layer of the Kharkiv city

area without acoustic pollution within district 6301 is 8178 sq. m. Thus the noise value is (Eq. (11)):

$$S_{N6301} = \frac{8178 \text{ sq. m.}}{101\ 242 \text{ sq. m.}} = 0.0808 .$$

The weighted average value of the noise level (S_{Nmid}) on average in the Kharkiv city, calculated by using the IDW method, is equal to 0.6713. Thus, the general noise index of the evaluation district 6301 is (Eq. (8)):

$$N_{6301} = \frac{0.0808}{0.6713} = 0.1204 .$$

The last ecological factor, the impact of which remains to be evaluated, is electromagnetic pollution. Electromagnetic pollution is caused Pollution caused by electromagnetic fields and resulting electromagnetic radiation generated by power lines, electrical equipment, mobile and cordless phones, radar, electrical household appliances, etc. (Redlarski et al., 2015). The main sources of electromagnetic pollution in cities are radar-, radio- and television stations for various purposes, which operates in the radio frequency band, as well as power lines, which consist of overhead high-voltage lines and electrical substations. The initial information for developing the layer of electromagnetic pollution of the spatial database were the reports of the sanitary-epidemiological station and sanitary passports of the objects. A layer of electromagnetic pollution was especially overlaid on the evaluation district layer of the city to determine the area occupied by electromagnetic pollution in each evaluated district and to compare these districts by pollution level.

As for the previous ecological factors, let us calculate the electromagnetic pollution index using the example of

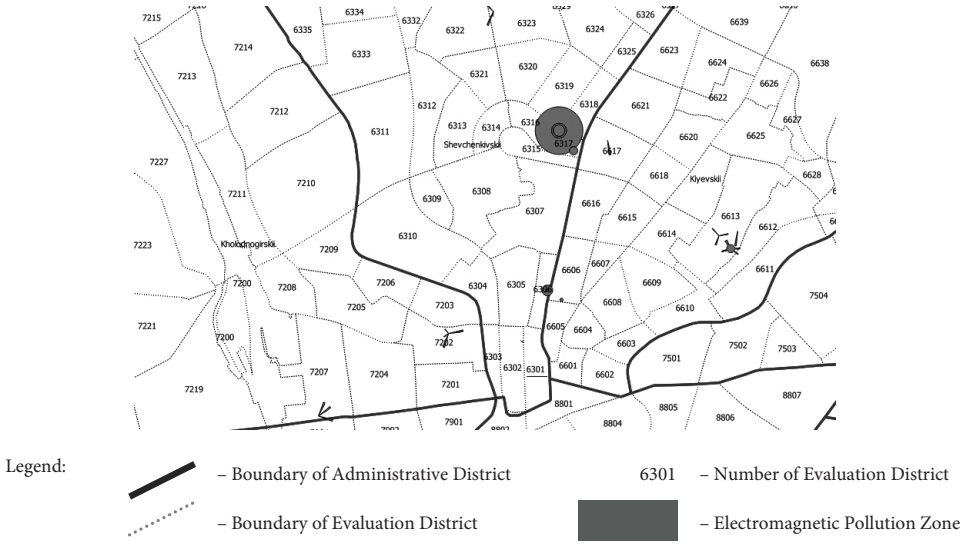

Figure 7. Fragment of the electromagnetic pollution layer of the Kharkiv city

the evaluation district 6301. As can be seen from Figure 7, the entire area of evaluation district 6301 is not subject to electromagnetic pollution. Thus, the value of electromagnetic pollution is (Eq. (11)):

$$S_{Z6301} = \frac{101\ 242 \text{ sq. m.}}{101\ 242 \text{ sq. m.}} = 0.0551 .$$

It was found, by using the IDW method, that the weighted average value distribution of the electromagnetic pollution (S_{Zmid}) on average for the Kharkiv city is 0.9557. Thus, the index of electromagnetic pollution for the evaluated district 6301 is (Eq. (9)):

$$Z_{6301} = \frac{1}{0.9557} = 1.0463 .$$

The value of the electromagnetic pollution index is greater than one. It means this index is a positive rent-generating factor and will contribute to increasing the normative monetary value of land within the district.

The next step is to calculate the index of the ecological condition of the territory for each evaluation district of the Kharkiv city by weighing individual ecological factors (Eq. (5), see Table 1). The analysis of the results of the NMV of the settlement land of Ukraine in the past years made it possible to determine the weight coefficients (W) for each index for evaluating the ecological condition of the Kharkiv city: W_B = 0.39 for pollution of the surface layer of the atmosphere, W_G = 0.28 for soil pollution by heavy metals, W_N = 0.22 for acoustic pollution and W_Z = 0.11 for electromagnetic pollution. An example of calculating the index of the ecological condition of the territory for the evaluation district 6301 is as follows (Eq. (5)):

$$E_{6301} = 0.0795 \times 0.39 + 0.0000 \times 0.28 + 0.1204 \times 0.22 + 1.0463 \times 0.11 = 0.1726.$$

Comparative characteristics of the calculation of the index of the ecological condition of the territory of the evaluation district 6301 according to the present and proposed new approaches are given in Table 2.

Table 2. Comparative characteristics of the index of the ecological condition of the territory of the evaluation district 6301 by the present and new approaches

Index names	Abbreviation	Index value by:	
		present approach	new approach
The value of the ecological condition of the surface layer of the atmosphere on average in the Kharkiv city	S_{B6301}	0	0.0551
The weighted average value of the surface layer of the atmosphere	S_{Bmid}	0.0703	0.6937
Index of the ecological condition of the surface layer of the atmosphere	B_{6301}	0	0.0795
The value of the ecological condition of soils	S_{G6301}	0	0
The weighted average value of the ecological condition of soils on average in the Kharkiv city	S_{Gmid}	0.0937	0.9557
Index of ecological condition of soils	G_{6301}	0	0
The value of the noise index	S_{N6301}	0	0.0808
The weighted average value of the noise index on average in the Kharkiv city	S_{Nmid}	0.0313	0.6713
Noise index	N_{6301}	0	0.1204
The value of electromagnetic pollution	Sz_{6301}	1	1
The weighted average value of the electromagnetic pollution on average in the Kharkiv city	S_{Zmid}	0.4941	0.9557

End of Table 2

Index names	Abbreviation	Index value by:	
		present approach	new approach
Index of electromagnetic pollution	Z_{6301}	2.0238	1.0463
Index of the ecological condition of the territory for the settlement evaluation district	E_{6301}	0.2226	0.1726

It should be noted that similar calculations were made for all other 511 evaluation districts of the Kharkiv city. Comparing the present and new indexes of the ecological condition (E_i) of the evaluation districts of the Kharkiv city, it was determined that, according to the generally accepted (present) approach, the minimum value of this index is 0.0000, and according to the new proposed approach, the minimum value is 0.1151. The maximum existing value of the ecological condition index (E_i) is 12.8093, and according to the new approach – 2.3488. This indicates a decrease in the variability of the ecological condition index due to a more detailed consideration of the ecological rent-generating factors available in the Kharkiv city. This is also evidenced by the values of the standard deviation. So, the standard deviation of the index of the ecological condition of the territory for the evaluation district (E_i) for the generally accepted approach is 2.1649, and for the new one – 0.5389. This means that the new indexes deviate less from the average value of the index of the ecological condition of the territory than the present one (see Table 3).

The performed calculations make it possible to display the value of the index of the ecological condition of the evaluation districts (E_i) on the territory of a single administrative district of a Kharkiv city and for the city as a whole in a single layer of the spatial database. The ecological condition of the territory and the evaluation districts layers of the Kharkiv city were overlaid. It was made possible to group the evaluation districts into five groups with equal intervals by the level of the ecological condition and compare the evaluation and administrative districts with each other. The evaluation districts were grouped by using the "Graduated Sign" module of the QGIS software. An example of a comparison of the index values of the ecological condition of the territory of the evaluation districts of the Kharkiv city by present and the new proposed approach is shown in see Figure 8.

Table 3. Statistical analysis of the index of the ecological condition of the territory of the evaluation districts for the Kharkiv city

Index	Value of the index of the ecological condition by:	
	present approach	new approach
Minimum	0.0000	0.1151
Maximum	12.8093	2.3488
Average	2.0327	1.0206
Standard Deviation	2.1649	0.5389

To determine the influence of the index of the ecological condition of the territory of the evaluation districts on the NMV of the land, it is necessary to calculate the comprehensive index of the territory quality of the evaluation districts for the Kharkiv city (I_i) by weighing individual indexes reflecting the value of settlement land (Eq. (4), see Table 1). To calculate the weighting (calibration) indexes, the Kharkiv city normative monetary valuation of the land of previous years, the normative monetary valuation of land in other settlements of Ukraine and expert evaluations of the weight values were analysed. As a result, the

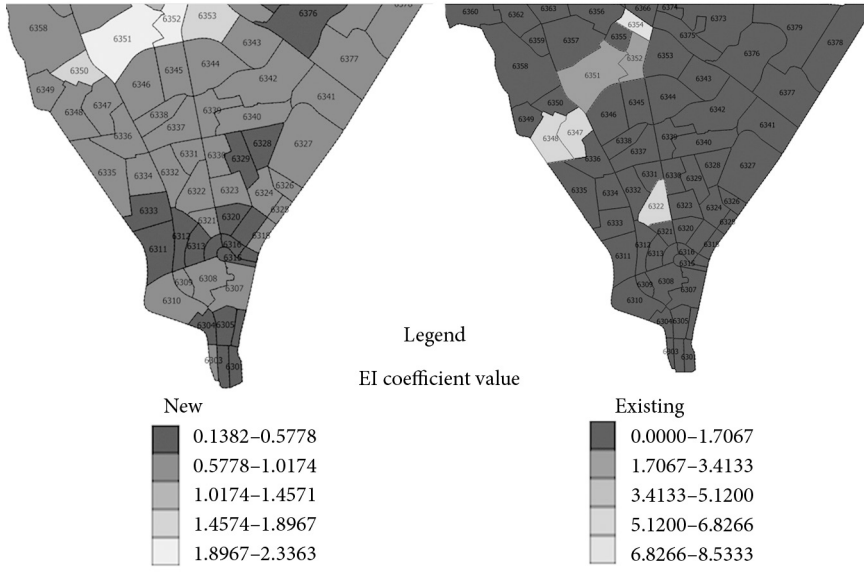

Figure 8. Fragment of comparison the level of the ecological condition by present and the new proposed approach

following weight (W) indexes were established: $W_S = 0.45$, $W_U = 0.22$, $W_E = 0.15$ and $W_C = 0.18$.

Now it is possible to calculate the impact of the indexes of the ecological condition of the territory for the evaluation districts (E_i) on the comprehensive indexes of the territory quality of evaluation districts for the Kharkiv city (I_i). As an example, let us calculate the comprehensive index of the territory quality for evaluation districts 6301. The comprehensive indexes calculated by the existing (I_{6301ex}) and the new ($I_{6301new}$) approaches are (Eq. (4)):

$$I_{6301ex} = 5.0677\times0.45 + 3.5563\times0.22 + 0.2226\times0.15 + 3.0205\times0.18 = 3.6399;$$

$$I_{6301new} = 5.0677\times0.45 + 3.5563\times0.22 + 0.1726\times0.15 + 3.0205\times0.18 = 3.6324.$$

Thus, the ratio of the new *Ii* to the existing one is *0.99*. The *Ii* index remains almost unchanged within the evaluation district 6301. The analysis of the ratio of the comprehensive index of the territory quality for the evaluation districts have found out:

- One evaluation district has a ratio Ii_{ex}/Ii_{new} from 0.2 to 0.4;
- 21 evaluation districts $0.4 < Ii_{ex}/Ii_{new} <= 0.6$;
- 27 evaluation districts $0.6 < Ii_{ex}/Ii_{new} <= 0.8$;
- 50 evaluation districts $0.8 < Ii_{ex}/Ii_{new} <= 1.0$;
- 388 evaluation districts $1.0 < Ii_{ex}/Ii_{new} <= 1.2$;
- 21 evaluation districts $1.2 < Ii_{ex}/Ii_{new} <= 1.4$;
- 4 evaluation districts $1.4 < Ii_{ex}/Ii_{new} <= 1.6$.

In general, for the Kharkiv city with total number 512 evaluation districts, 300 of them have the ratio of the existing *Ii* to the new one is close to 1.0 (see Figure 9), the average value of $Ii_{ex}/Ii_{new} = 1.02$, the minimum is 0.39, the maximum is 1.52 and standard deviation 0.16.

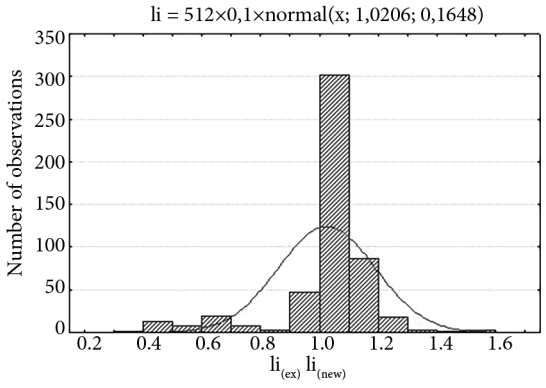

Figure 9. The chart of the ratio of the comprehensive index of the territory quality of the evaluation districts within the Kharkiv city by the present and new approaches

3. Analysis and interpretation of results

The results obtained made it possible to analyse and interpret the data in the context of their influence on the normative monetary value of the Kharkiv land. The present average (base) land value of the Kharkiv city on 01.01.2021 is 639.78 UAH/sq. m., or 22.57 USD/sq. m. (according to the official rate of the National Bank of Ukraine of 28.35 UAH / USD). Based on it, the normative monetary value of land was calculated for each evaluation district of the Kharkiv city by using the present and new comprehensive indexes of the territory quality of the settlement evaluation districts (Eq. (3), see Table 1). Analysis of these calculations is shown in Table 4.

Table 4. Comparative analysis of the normative monetary value of land within the evaluation districts of the Kharkiv city by present and new approach

Index Name	Land value within evaluation districts by:			
	present approach		new approach	
Minimum, USD/sq. m.	9.71		12.00	
Maximum, USD/sq. m.	101.60		86.34	
Average, USD/sq. m.	45.88		45.88	
Standard Deviation, USD/sq. m.	18.07		18.16	
Statistical grouping				
Intervals of land value within evaluation districts, USD/sq. m.	Frequency	Percentage from all observations, %	Frequency	Percentage from all observations, %
0.00 < *Vnz* <=20.0	39	7.6	43	8.4
0.20 < *Vnz* <=40.0	166	32.4	161	31.4
0.40 < *Vnz* <=60.0	186	36.3	186	36.3
0.60 < *Vnz* <=80.0	113	22.1	114	22.3
0.80 < *Vnz* <=100.0	7	1.4	8	1.6
0.100 < *Vnz* <=120.0	1	0.2	–	–
Total	512	100.0	512	100.0

As can be seen from Table 4, the improvement of the approach to the application of indexes characterising the ecological condition, on the example of the Kharkiv city, led to an increase the minimum index for the land value within the evaluation districts from 9.71 USD/sq. m. to 12.00 USD/sq. m. However, at the same time, the maximum value of this index decreased from 101.60 USD/sq. m. to 86.34 USD/sq. m. The average land value within the evaluation districts of the city did not change and, as a result of calculations for both approaches, is 45.88 USD/sq. m. Nevertheless, the improved approach has a standard deviation of 0.09 units more from the average land value than the present one. This indicates a more accurate account of the uneven impact of ecological factors on the NMV of

settlement land. The grouping of indexes of monetary land valuation in the evaluation districts of the city by equal intervals showed that the improved approach increased the number of evaluation districts (from 39 units to 43 units) with a land value up to 20 USD/sq. m. However, the number of evaluation districts decreased from 166 to 161 by the land value from 20 USD/sq. m. to 40 USD/sq. m. The number of evaluation districts remained almost unchanged in the other intervals.

It should be noted that the developed spatial database makes it possible to calculate the share of the area land plot influenced by the ecological factors. It helps to determine the intensity of each ecological factor and more accurately calculate the normative monetary value of the land plot. That is why we will define (as an experiment) the impact intensity of ecological factors on the NMV for a single land plot located in the evaluation district 6301. Therefore, the total area of the land plot for the construction and maintenance of trade building (commercial use) is 989.1345 sq. m. The land plot value of a certain functional use is determined taking into account the peculiarities of its location (local factors) within the economic planning zone. According to the NMV Procedure (MAP, 2016), the index values of local factors (indexes) is constant. Only the fact of the presence or absence of these factors on the land plot is taken into account. It was found out, by the spatial database, that the evaluated land plot is located within the area of impact of six different local factors. These factors are represented by local indexes for the locality of the land plot within the evaluation district (see Table 5). The values of local indexes are determined based on the share of the area occupied by the local factor on the land plot, as well as taking into account the conditions of the NVM Procedure (Par. 10, MAP, 2016). The product of local indexes for each factor should not be lower than 0.50 and higher than 1.50.

In addition, it has been found out that some ecological local factors have an impact on a part of the evaluated land plot. Thus, the factor of the location of the land plot in the area of restricted development by the degree of atmospheric air pollution occupies 872.7491 sq. m., and the area of exceeding the permissible noise level from roads spreads to 359.7307 sq. m. The index of influence and the value of the coefficient of local evaluation factors were calculated by the new approach. It was led to value decreasing compared to the present index. At the same time, the entire territory of the land plot is in the zone of soil contamination. Therefore, the local coefficient is equated to the normative one (0.95). Calculations of the NMV for a single land plot according to the present and new approaches are given in Table 5.

The calculations show that the use of the developed spatial database and a new approach to the impact of ecological factors led to a decrease in the land plot value. So, the NMV of commercial use of land plot decreased by 64.81 USD per square meter or, in terms of the total

Table 5. The NMV of a single land plot for the construction and maintenance of trade building according to the present and new approaches in the Kharkiv city

Index name	Number of formula according Table 1	The value of index by:	
		present approach	new (improved) approach
The area of land plot, sq. m. (*P*)	–	989.1345	
Average (base) value of settlement land depending on regional factors of location, USD / sq. m. (*Vnl*)	1	22.57	
The number of evaluation district	–	6301	
Zonal coefficient characterises the urban quality of the settlement evaluation district (*Lc*2)	4	3.6399	3.6324
Local indexes for the locality of the land plot within the evaluation district			
the zone of walking distance to the city centre (*Lc*3-1)	–	1.2	1.2
the zone of pedestrian accessibility to highways of increased city-formation importance (*Lc*3-2)	–	1.2	1.2
the zone of pedestrian accessibility to high-speed urban and external passenger transport (*Lc*3-3)	–	1.15	1.15
the zone of restriction of building by the degree of atmospheric air pollution (*Lc*3-4)	–	0.95	0.84
the zone of exceeding the permissible noise level from the road (*Lc*3-5)	–	0.97	0.86
soil contamination zone (*Lc*3-6)	–	0.95	0.95
The aggregate coefficient of the local evaluation factors ($Lc3 = Lc3\text{-}1 \times Lc3\text{-}2 \times Lc3\text{-}3 \times Lc3\text{-}4 \times Lc3\text{-}5 \times Lc3\text{-}6$)	-	1.45	1.14
The coefficient of functional use of land plot (*Cf*)	–	2.50	2.50
The normative monetary value of the land plot per one sq. m. ($Vn_{sq.m.} = Vnl \times Lc2 \times Lc3 \times Cf$)	13	297.74	232.93
The total normative monetary valuation of land plot ($Vn = Vn_{sq.m.} \times P$)	–	294 507.03	230 399.89

area, by 64,107.13 USD. Of course, from the point of view of local governments, such a decrease in the value of a land plot is negative. Since, the size of the land tax will decrease by 1.3 times – in proportion to the size of the decrease in the NMV of the land plot. However, from the point of landowner view, the decrease in value is a kind of compensation for the use of the land plot with a negative environmental impact.

Conclusions

This study has raised important questions about the nature of measuring the impact of ecological factors on NMV of settlement land. In line with the analysis of the present NMV procedure for settlement land, the ecological factors that affect NMV of land within the evaluation districts were classified into four main types: ecological condition of the surface layer of the atmosphere, ecological condition of soils by the level of heavy metal pollution, noise level from transport and level of electromagnetic radiation. A spatial database to evaluate the ecological factor effects at the regional (settlement as a whole), zonal (evaluation districts of the settlement) and local (single land plot) levels was also developed by QGIS tools.

In this respect, a new approach for measuring the indexes of the ecological condition of the settlement territory and single evaluation units to determine the normative valuation of land was developed. This approach can be used at different stages for calculation NMV of settlement land, mainly at zonal and local valuation levels. This approach, for the first time, takes into account the area of environmental factors distribution within the evaluation unit and proves usefulness in understanding the actual ecological impact on NMV of settlement land.

Overall, this study has demonstrated that the size of land valuation is slightly influenced, although not significantly, by ecological factors. The research also points to the potential value of a new approach because it allows taking into account an infinite number of indexes for each environmental factor and expresses their impact on the NMV of land in the form of a coefficient.

Although, the study area is the Kharkiv city, the proposed approach to analyse ecological factors effects can be utilised in other settlements of Ukraine because of the unified NVM procedure. However, some parameters related to this approach would need to be adjusted according to the regional, zonal and local practical situation, if applied in other settlements. In further studies, we should conduct comprehensive effects of the single harmful impurities of the intensity of pollution of the surface layer of the atmosphere and soil contamination on NMV of settlement land.

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Author contributions

Conceptualization, AP; Methodology, OT; Validation, AP & OT; Investigation, OT; Writing-Original Draft Preparation, OT; Writing-Review & Editing, AP; Visualization, AP & OT; Results interpretation, AP & OT.

Disclosure statement

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References

Alekseev, Yu. (2008). *Tiazhelye metally v ahrolandshafte*. PYIaF RAN (in Russian).

Chen, B., & Kan, H. (2008). Air pollution and population health: a global challenge. *Environmental Health and Preventive Medicine*, *13*(2), 94–101. https://doi.org/10.1007/s12199-007-0018-5

Dekhtiarenko, Yu., Lykhohrud, M., Mantsevych, Yu., & Palekha, Yu. (2002). *Metodychni osnovy hroshovoi otsinky zemel v Ukraini: naukove vydannia.* Profi (in Ukrainian).

Dičiūnaitė-Rauktienė, R. & Maliene, V. (2016). Environmental factors influencing urban land use. *Baltic Surveying*, *4*, 12–19. https://llufb.llu.lv/Raksti/Journal_Baltic_Surveying/2016/Journal_Baltic_SurveyingVol4_2016-12-19.pdf

Kabinet Ministriv Ukrainy. (1995). *Pro metodyku normatyvnoi hroshovoi otsinky zemel naselenykh punktiv: Postanova Kabinetu Ministriv Ukrainy vid 23.03.1995, No. 213*. http://zakon2.rada.gov.ua/laws/show/213-95-п (in Ukrainian).

Kolosiuk, A., & Naiko, A. (2016). Ekonomiko-planuvalne zonuvannia terytorii naselenykh punktiv. Chomu normatyvno-metodychna baza yikh otsiniuvannia potrebuie korehuvannia. *Zemlevporiadnyi visnyk*, *8*, 22–26 (in Ukrainian).

Korzhnev, M. (2005). *Ekolohichna heolohiia: pidruchnyk*. VPTs "Kyivskyi universytet" (in Ukrainian).

Kovalchuk, I., & Patychenko, O. (2017). Population size as a factor for formation of land value in settlements. *Zemleustrii, kadastr i monitorynh zemel*, *4*, 52–58. https://doi.org/10.31548/zemleustriy2017.04.052

Lykhohrud, O. (2015a). Shchodo vdoskonalennia normatyvnoi hroshovoi otsinky zemel naselenykh punktiv. *Zemlevporiadnyi visnyk*, *10*, 30–33 (in Ukrainian).

Lykhohrud, O. (2015b). Udoskonalennia normatyvnoi hroshovoi otsinky naselenykh punktiv v suchasnykh umovakh. *Zbalansovane pryrodokorystuvannia*, *3*, 26–29 (in Ukrainian).

Martynova, N. G., Budarova, V. A., Moskvin, V., Dubrovskiy, A. V., & Malygina, O. I. (2019). *The use of GIS technologies for the management of the enterprise*. https://revistaespacios.com/a19v40n37/a19v40n37p24.pdf

Ministerstvo Ahrarnoi Polityky. (2016). *Pro zatverdzhennia Poriadku normatyvnoi hroshovoi otsinky zemel naselenykh punktiv: Nakaz Ministerstva Ahrarnoi Polityky ta Prodovolstva Ukrainy vid 25.11.2016, No 489*. https://zakon.rada.gov.ua/laws/show/z1647-16#Text (in Ukrainian).

Ministerstvo Rozvytku Hromad. (2020). *Kodyfikator administratyvno-terytorialnykh odynyts ta terytorii terytorialnykh hromad*: *nakaz Ministerstva rozvytku hromad ta terytorii Ukrainy vid 26.11.2020, No 290*. https://zakon.rada.gov.ua/rada/show/v0290914-20#n9 (in Ukrainian).

Nyarko, J. O., & Lemmen, C. (2008, July 3–11). Improving land value information process through the use of geo-information

technology. In J. Chen, J. Jiang, & S. Nayak (Eds.), *Proceedings of XXIst ISPRS Congress, ISPRS Archives* (Vol. XXXVII, Part B4, pp. 905–910). International Society for Photogrammetry and Remote Sensing (ISPRS). http://www.isprs.org/proceedings/XXXVII/congress/4_pdf/161.pdf

Oud, D. A. J. (2017). *GIS based property valuation* [M.S. thesis]. Dept. of Geographical Sciences-Geo-Information Applications and Management, Delft University of Technology (TUD), University of Twente (UT) – ITC Utrecht University (UU), and Wageningen University & Research (WUR). http://www.gdmc.nl/publications/2017/MScThesis_DjamiljaOud.pdf

Palekha, Yu., & Kolosiuk, A. (2013a). Reformuvannia metodolohii normatyvnoi hroshovoi otsinkyzemel naselenykh punktiv v Ukraini. *Biznes-navihator*, *2*(31), 183–191 (in Ukrainian).

Palekha, Yu., & Kolosiuk, A. (2013b). Normatyvna hroshova otsinka zemel na rubikoni zmin. *Zemleustrii i kadastr*, *2*, 60–67 (in Ukrainian).

Pronko, L. M., & Samborska, O. Y. (2014). Metodyka vyznachennia bazovoi vartosti zemel naselenoho punktu. *Naukovyi visnyk Khersonskoho derzhavnoho universytetu*, *5*(2), 257–260 (in Ukrainian).

Redlarski, G., Lewczuk, B., Żak, A., Koncicki, A., Krawczuk, M., Piechocki, J., Jakubiuk, K., Tojza, P., Jaworski, J., Ambroziak, D., Skarbek, Ł., & Gradolewski, D. (2015, February 25). The influence of electromagnetic pollution on living organisms: Historical trends and forecasting changes. *BioMed Research International.* https://doi.org/10.1155/2015/234098

Samoilenko, L. (2016). Problemy onovlennia normatyvnoi hroshovoi otsinky zemel naselenykh punktiv ta mozhlyvi shliakhy yikh vyrishennia (na prykladi m. Berezan Kyivskoi oblasti). *Cuchasni dosiahnennia heodezychnoi nauky ta vyrobnytstva*, *2*(32), 103–106 (in Ukrainian).

Shulhan, R., Yanchuk, O., & Romanovska, Yu. (2016). Zastosuvannia metodu vporiadkuvannia obiektiv zhidno z naborom oznak pry provedenni ekonomiko-planuvalnoho zonuvannia terytoriinaselenoho punktu. *Problemy bezperervnoi heohrafichnoi osvity i kartohrafii: zbirnyk naukovykh prats*, *23*, 41–46 (in Ukrainian). https://periodicals.karazin.ua/pbgok/article/view/7065

Shypulin, V., Palekha, Yu., & Shterndok, E. (2015). *HIS-tekhnolohii v otsintsi zemli ta nerukhomoho maina: navchalnyi posibnyk*. KhNUMH im. O.M. Beketova (in Ukrainian).

Stoops, G. (2010). Micromorphology as a tool in soil and regolith studies. In G. Stoops, V. Marcelino, & F. Mees, *Interpretation of micromorphological features of soils and regoliths* (pp. 1–13). Elsevier Science. https://doi.org/10.1016/B978-0-444-53156-8.00001-5

Verkhovna Rada Ukrainy. (2004). *Pro otsinku zemel: Zakon Ukrainy vid 11.12.2003, No. 1378-IV.* https://zakon.rada.gov.ua/laws/show/1378-15#Text (in Ukrainian).

Verkhovna Rada Ukrainy. (2001). *Zemelnyi kodeks Ukrainy vid 25.10.2001, No. 2768–III*. https://zakon.rada.gov.ua/laws/show/2768-14#Text (in Ukrainian).

Vlachokostas, Ch., Nastis, S., Achillas, Ch., Kalogeropoulos, K., Karmiris, I., Moussiopoulos, N., Chourdakis, E., Banias, G., & Limperi, N. (2010). Economic damages of ozone air pollution to crops using combined air quality and GIS modelling. *Atmospheric Environment*, *44*(28), 3352–3361. https://doi.org/10.1016/j.atmosenv.2010.06.023

Wyatt, P. J. (1995). Using a geographical information system for property valuation. *Journal of Property Valuation & Investment*, *14*(1), 67–79. https://doi.org/10.1108/14635789610107507

Wyatt, P. J. (1997). The development of a GIS-based property information system for real estate valuation. *International Journal of Geographical Information Science*, *11*(5), 435–450. https://doi.org/10.1080/136588197242248

Yu, S. M., Han, S. S., & Chai, C. H. (2007). Modelling the value of view in real estate valuation: A 3-D GIS approach. *Environment and Planning B: Planning and Design*, *34*(1), 139–153. https://doi.org/10.1068/b32116

Abbreviations

IDW – Inverse Distance Weighting.
MAP – Ministerstva Ahrarnoi Polityky ta Prodovolstva Ukrainy.
MRH – Ministerstvo rozvytku hromad ta terytorii Ukrainy.
NMV – Normative Monetary Valuation.
VRU – Verkhovna Rada Ukrainy.