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Evaluation Model for Sustainable Development of Settlement System

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Abstract: Sustainability of settlement systems is of greatest relevance in political and socio-economic stability all over the world. The development effectiveness of a rural settlement system involves the solution of a number of matters in sustainable development, namely social welfare and environmental balance, economy and industry development, improving the pipeline and utility infrastructure, and improving the efficiency of the decision-making process. Currently, the sustainability of a rural settlement system is one of the key objectives in regional planning in post-Soviet countries. The introduction of new tools for assessing and managing the settlement system development is particularly true for Belarus, as a country with a strong focus on agricultural industry. The research aim was to develop and approve a model for evaluating the settlement system development. The research methods were based on the complex and interdisciplinary approaches, namely the system-element approach, the comparative analysis, spatial and mathematical modelling, factor analysis, and the cartographic analysis. The model was approved by practical consideration for evaluating the development of the analogue object at the local planning level. The practical relevance of the research is associated with the potential for using the model as a significant tool in land use planning. The model employs both quantitative and qualitative evaluation to obtain alternative solutions towards sustainable development of rural areas. Another advantage of the model is its multifunctionality, which enables: (1) sustainability evaluation of a settlement system, (2) establishment of regional planning priority areas, and (3) development of specific measures for ensuring the sustainability of a regional settlement system and its elements.

Keywords: sustainable development; regional planning; rural settlement; settlement system; system approach

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1. Introduction

The development issues of settlement systems are of great relevance for solving land-use planning problems for European region and beyond. The most relevant urban and regional planning research publications related to this field of knowledge are focused on conservation of rural landscapes under urban expansion [1–3], spatial and socioeconomic resilience of rural areas [4–6], introduction of new instruments for sustainable rural development [7], economic transformation in rural areas [8,9], spatial temporal development [10–12], environmental and economic aspects [13,14], social and demographic criteria [15–17], land use planning [18,19], historical and cultural features [20–23], ecosystem studies [24,25], changes in rural settlement system [26,27], and modeling peri-urban areas [28–30].

The settlement structure in Belarus includes two main units, namely (i) urban settlements, and (ii) rural settlements. The major difference between rural and urban settlements according to planning standards in Belarus is the population size. Local government authorities employ the settlement classification for solving issues related to changes in administrative structure (Table 1).

Table 1. Settlement classification by population in Belarus.

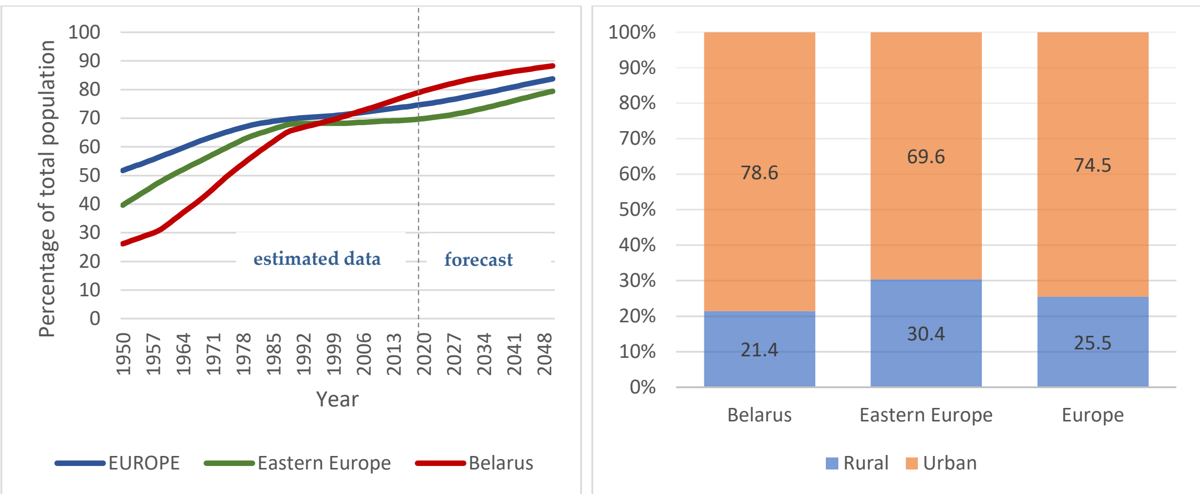
Urban Settlement Type	Population Size	Rural Settlement Type	Population Size
Major	more than 500,000		
Largest	from 250,000 to 500,000	Largest	more than 1000
Large	from 100,000 to 250,000	Large	from 500 to 1000
Medium	from 20,000 to 100,000	Medium	from 100 to 500
Small	from 5000 to 20,000	Small	less than 100

The rural settlement system is a socio-natural-technogenic system which develops in response to external and internal conditions determining the settlement types/forms and drivers revealing the settlement processes [31–36]. The rural settlement system, due to its peculiar properties, is sensitive to a range of external factors such as natural disasters, hygiene-related diseases, technogenic influences, and management planning [37,38]. Thus, in the context of the current epidemiological situation, it can be safely said about a downtrend in urbanization, which is due to the need of risk mitigation in coronavirus-busting efforts [39,40]. The effectiveness of rural settlement development ensures social welfare and environmental balance, economic and industrial growth, the improvement of pipeline and utility infrastructure, the reformation of decision-making procedures, and the optimization of managerial decisions.

The research on rural settlements in Belarus is underpinned by its special role in a settlement structure, in which rural zone cover is a considerable part of the total area (about 1/3). Currently Belarus is the most urbanized country in the European region [41,42], so there is a significant influence on the rural settlement structure (Table 2, Figure 1). Figure 1a shows that Belarus has experienced rapid urbanization from the late 1950s to the early 1990s. Slowdown in the process of urbanization was caused by the collapse of the USSR. Belarus has entered a new historical period as an independent country and chosen another way of rural settlement development.

Table 2. Population census data in Belarus (from the end of the XIX century to the present time).

Population Census Year	1897	1939	1959	1970	1979	1989	1999	2009	2019	2020
Urban, %	13.5	20.8	30.5	43.3	54.9	65.4	69.3	74.3	78.4	78.6
Rural, %	86.5	79.2	69.5	56.7	45.1	34.6	30.7	25.7	21.6	21.4



(**a**) (**b**)

Figure 1. Population structure in Belarus as compared to its subregion and region (**a**) percentage of urban population, from 1950 to 2050; (**b**) proportion of urban and rural population. Source: own study.

Therefore, the formulation of advanced assessment and management tools in regional planning can be particularly relevant for Belarus. The network of agro-towns as local centers of the settlement system in Belarus is evenly distributed over the country, thereby corresponding to a modern concept of multifunctional development, typical for many European countries, including Poland, Germany, Spain, etc. [43–46]. With this background the rural settlement system of Belarus could be used as a comparable for testing the evaluation model. The research aim was to develop and approve the model for evaluating the development of settlement system. The settlement system has a historicism feature in conformity with the system concept. This matter is worth special mention and was exhaustively covered in our earlier studies [43]. We analyzed the settlement system in Belarus for the period from the beginning of the 20th century to the present. The research results showed that the model must contain a number of significant aspects such as socioeconomic, ecological, and administrative. The research hypothesis is the statement that the proposed model contains historical-genetic, spatial, and functional criterion available from analysis of rural settlement structure as the socio-natural-technogenic system [47]. The model allows us to provide the design research at any planning level and obtain alternative design solutions, which are necessary for forming a sustainable system of settlements including rational geographical distribution of agricultural industry as well as a provision of a safe and comfortable living environment.

2. Research Background and Literature Review

There is a wealth of research on the subject of sustainable development of territories all over the word. V.A. Ilyichev, V.V. Kolchunov, and N.V. Bakaeva [48] proposed the paradigm of biosphere compatibility which is based on the singleness of city area and environment. A number of studies on environmental precautions of municipal facilities and transport recently tested the paradigm [49,50]. The authors proposed to describe the components of the natural-socio-technical structure using a system of equations including the following: (i) a natural environment component that affects the spread and accumulation of man-made pollution sources; (ii) a social environment component, including education and culture; and (iii) a technical component describing the system parameters depending on the planned solution concept.

An important research trend is related to ‘Green Building’ as well the creation of the ‘Green Standards’ system based on the concept of nature-like technologies in a living environment and biopositive innovative products proposed by V.I. Telichenko and M.Yu. Slesarev [51]. The concept hypothesis is that a ‘green’ living environment must match the criterion of sound ecological and technological balance within a specified time span. This balance can be obtained in constructive and technological consistency of ‘green’ products to the organizational and technological forms of ‘green’ or ‘nature-like’ construction production [52,53].

A number of studies are focused on the environmental safety in construction and utilities complex. The studies are focused on environmentally friendly technologies in construction, building materials manufacturing, reconstruction, and recultivation of disturbed areas [54–57].

Most recent studies on the subject of settlement development are aimed at determining the sustainability factors at varied levels of land use planning. The researches [8,15] show the role of social economy institutions and social innovation in the development of rural areas. The authors of [16] identified three key factors for achieving the sustainable development goal for rural areas in Spain: physical, demographic, and socioeconomic characteristics. The model proposed in [17] is based on hierarchical relations consisting of three basic criteria of sustainable development: economic, social, and environmental. The aim of the study on regional development in Poland [43] was to show the impact of transport component on the sustainable socio-economic development. The research in [58] focuses on social and economic factors and management system. The authors assessed the impact of the above factors on the sustainable development of rural areas in the current context.

Summarizing the above with regard to a system analysis, it is possible to apply these approaches to more complex area elements. Specifically, settlement system as a complex socio-natural-technogenic structure which includes five components is often called the pentagon concept. The original pentagon model contains five key factors namely (i) software/knowledge, (ii) hardware/research facilities, (iii) finware/financial support, (iv) ecoware/environmental amenities, and (v) orgware/institutional support systems. Such an approach has been successfully implemented in research on energy policy, assessment of municipal facilities development, transport infrastructure, and rural areas. The results obtained from the studies [59–64] showed the methodological quality of the pentagon concept. Some models involved the original factors while others were adapted in accordance with research issues. Thus, the model for evaluation of sustainable rural development formulated by Akgun, Baycan Levent, and Nijkamp [61] includes physical, social, economic, locality, and creative systems. The models obtained in previous authors research [31,32] contain physical, social, economic, environmental, and administrative systems.

3. Materials and Methods

3.1. Reseach Area

The research area was Zavaločycy local council which is located in Hlusk district, Mahilioŭ oblast, Belarus (Figure 2). The local council was employed as a comparable of the local-level planning, which is specific to the settlement network of Mogilev region and Belarus Republic as a whole. The local council includes 14 rural settlements with a population of 960 people. The average population of settlements is 69 people. The average settlement-pair distance is 4.0 km. The center of council (agro-town of Zavaločycy) is located 23 km from the district center (Hlusk town) [65].

3.2. Evaluation Model

3.2.1. Conceptual Model

Currently, the evaluation models in urban and reginal planning are based on socio-economic, pipeline, and utility infrastructure criteria and generally include three or four criteria groups. The existing models do not contain an administrative criterion required for the decision-making processes. Table 3 outlines the criteria considered by these evaluation models.

Table 3. Criteria considered by the existing evaluation models for settlement systems. Source: own study.

Model of Balanced Sustainable Rural Development [16]	Model of Sustainable Development of Ethno-Villages [17]	Model of Sustainable Rural Development [26]	Model of Sustainable Development of Rural Region [27]	Model of Rural Settlement Consolidation [58]
Socioeconomic	Economic	Economic	Manufacture	Economic
Physical	Environmental	Transport	Environment/Heritage	Ecological
Demographic	Social	Ecological and social	Population	Social
		Engineering and technical	Infrastructure	Engineering

Categorizing the models above according to their criteria allowed us to identify four common criteria: economic, ecological, social, and engineering (physical). The conceptual basis for evaluation process includes five criteria groups: ecological, economic, administrative, physical, and social, which define the key factors of sustainable rural development and provide the requirements for effective management at any planning level [32].

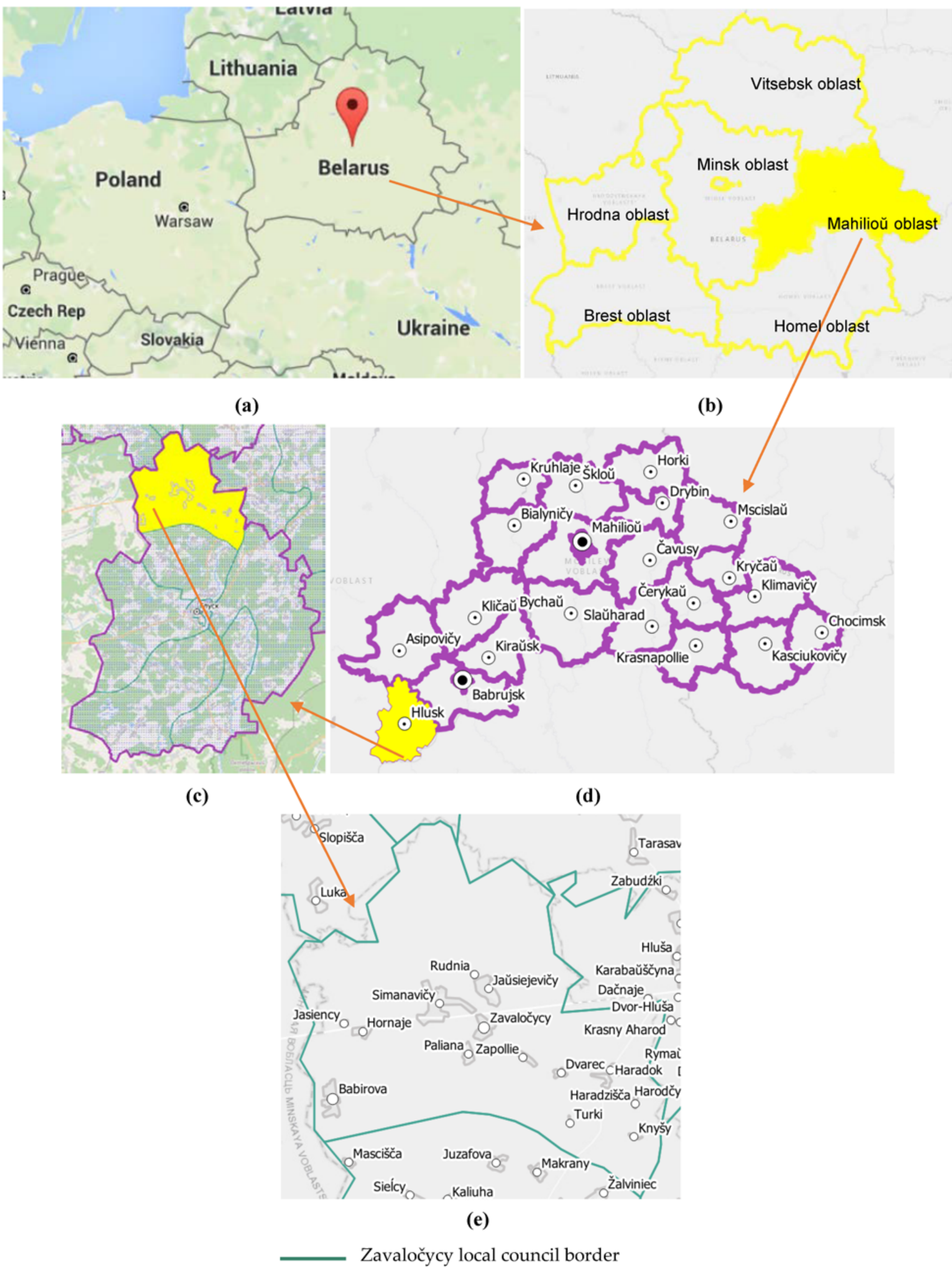


Figure 2. Location of the Zavaločycy local council. Source: own study. (**a**) Belarus location, (**b**) Mahiliou oblast location, (**c**) Hlusk district location, (**d**) Zavaločycy local council location, (**e**) Zavaločycy local council map.

The ecological system defines an environmental quality and potential as well as an environmental capacity under the influence of anthropogenic factors; an environmental impact of manufacture. The economic system contains indicators that characterize economic activity. The administrative system defines the groundwork for solving administrative and managerial issues, including the decision-making quality and means. The physical system defines the production sphere, which determines the welfare and living standards. The social system defines the quality of social opportunities in rural areas. The second level goal was identifying the complex of model subfactors, which provide the background for development criteria: the physical system is specified by the development level of pipeline and utility infrastructure, the social system by the social capital and community structure, the economic system by the degree of economic diversification and fiscal capacity, the ecological system by the ecosystem resilience to the anthropogenic impact, and the administrative system by the administrative capability in decision-making.

3.2.2. Mathematical Model

The evaluation process includes three main steps: standardization of measured values, criteria weighting, and determination of the complex development index.

Step 1. Standardization of measured values.

The evaluation model includes indicators and n objects; the measured value of i-th indicator for j-th object is recorded as t_{ij}. The standardized value of i-th indicator for j-th object is denoted as s_{ij}, and was calculated as follows:

$$s_{ij} = \varphi_{ij}\left(t_{ij}, t_{i,et}\right). \tag{1}$$

If the value of the i-th indicator is an extremely large, the calculation formula is as follows:

$$s_{ij} = \frac{t_{ij}}{t_{i,et}}. \tag{2}$$

If the value of the i-th indicator is an extremely small, the calculation formula is as follows:

$$s_{ij} = \frac{t_{i,et}}{t_{ij}}. \tag{3}$$

Step 2. Criteria weighting.

The criteria weights were calculated as follows:

$$\alpha_i = \varphi\left(\frac{1}{n}\sum_{k=1}^{n} q_{ik}\right), \tag{4}$$

where α_i is the weighting coefficient of the i-th indicator; n is the expert group size; and q_{ik} is measured value of i-th indicator weight by k-th expert.

Step 3. Determining the complex development index.

The complex development index for j-th object (E_j) was calculated as follows:

$$E_j = \sum_{i=1}^{n} \alpha_i \cdot s_{ij}. \tag{5}$$

The range of the complex development index E_i is 0 to 100. The larger the E_i, the higher the development level for rural settlement.

3.2.3. Settlement ranking

We used two parameters for ranking the rural settlements by the development level: geometric mean $\overline{E}$ and standard deviation σ_E.

Geometric mean of the development index was calculated as follows:

$$\overline{E} = \sqrt[j]{\prod E_j}, \tag{6}$$

where j is the number of rural settlements and E_j is the complex development index for j-th rural settlement.

Standard deviation of the development index was calculated as follows:

$$\sigma_E = \sqrt{\frac{\sum\left(E_j - \overline{E}\right)^2}{j-1}}, \tag{7}$$

where E_j is the complex development index for j-th rural settlement; $\overline{E}$ is the geometric mean of the development index; and j is the number of rural settlements.

We identified six classes of development level, depending on E_j value, with class I corresponding to the highest level and class VI to the lowest one. The classification results are shown in the Table 4.

Table 4. Six-level classification of rural settlement development.

Development Class	Development Level	Calculation Algorithm
I	Highest	$E_j < \overline{E_j} - 2\sigma_E$
II	High	$\overline{E_j} - 2\sigma_E \le E_j < \overline{E_j} - \sigma_E$
III	Average	$\overline{E_j} - \sigma_E \le E_j < \overline{E_j}$
IV	Below average	$\overline{E_j} \le E_j < \overline{E_j} + \sigma_E$
V	Low	$\overline{E_j} + \sigma_E \le E_j < \overline{E_j} + 2\sigma_E$
VI	Lowest	$E_j \ge \overline{E_j} + 2\sigma_E$

4. Results

The first step was classifying the development criteria by using the principles of sustainable development for rural areas and combining the previous research [22]. Table 5 shows the system of evaluation criteria for rural settlement development. Specifying the measured values of indicators was based on non-expert methods as follows: documental, analytical, experimental, and registration, followed by standardization of values.

Table 5. Rural settlement system evaluation criteria.

Criteria Group	Indicator	Literal Symbol
Physical	Transport infrastructure accessibility	P_1
	Utilities availability	P_2
Social	Social infrastructure accessibility	P_3
	Data network availability	P_4
Economic	Worksite accessibility	P_5
	Business environment	P_6
Environmental	Protection against the pollutions	P_7
	Environmental resource quality	P_8
Administrative	Administrative status	P_9
	Administrative efficiency	P_{10}

The indicator weights were determined by application experts in urban planning and rural residents (37 people). The invited experts were familiar with the region and its historical conditions. Study limitations refer to applying the weights for evaluation of another regions in Belarus or countries with a similar planning system, such as post-Soviet countries.

We determined the values of averaged estimates, the opinion consistency of experts, intervals of true values, and normalized indicator weights, as well as ranking the development indicators. The results of the statistical processing of the survey findings are listed in Table 6. The values of the average opinion rating vary from 2.29 to 4.37. The values of dispersion vary between 0.45 and 0.79. The values of standard deviation vary from 0.66 to 0.86. The values of confidence interval vary between 0.0014 and 0.0019. The values of the variation coefficient show that the expert opinion consistency is at the middle level (ν_i = 0.16 ... 0.25).

Table 6. Results of statistical processing of the survey findings.

Indicator	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
Average opinion rating q_{icp}	4.11	4.26	4.09	4.23	4.37	3.57	3.77	4.31	2.29	3.83
Dispersion $\sigma^2(q_i)$	0.57	0.61	0.79	0.48	0.48	0.66	0.77	0.75	0.45	0.50
Standard Deviation $\Delta(\overline{q_i})$	0.75	0.77	0.87	0.68	0.68	0.80	0.86	0.85	0.66	0.70
Confidence Interval t_a	0.0016	0.0016	0.0019	0.0014	0.0014	0.0017	0.0018	0.0018	0.0014	0.0015
True Value q_{i+}	4.1155	4.2584	4.0873	4.2296	4.3724	3.5728	3.7730	4.3158	2.2866	3.8296
True Value q_{i-}	4.1131	4.2559	4.0841	4.2276	4.3704	3.5701	3.7698	4.3127	2.2848	3.8275
Variation Coefficient ν_i	0.18	0.18	0.21	0.16	0.16	0.22	0.23	0.20	0.29	0.18

Table 7 shows the results of weighting the indicators. The most significant indicator is 'Worksite accessibility'; the least significant is 'Administrative status'.

Table 7. Results of weighting the indicators.

Indicator	Literal Symbol	Indicator Weight α_i	Indicator Rating R_i
Transport infrastructure accessibility	P_1	0.106	5
Utilities availability	P_2	0.110	3
Social infrastructure accessibility	P_3	0.105	6
Data network availability	P_4	0.109	4
Worksite accessibility	P_5	0.113	1
Business environment	P_6	0.092	9
Protection against the pollutions	P_7	0.097	8
Environmental resource quality	P_8	0.111	2
Administrative status	P_9	0.059	10
Administrative efficiency	P_{10}	0.099	7

In this paper we propose an algorithm for determining the absolute values of indicators (Table A1). We have adopted a hypothetical analogue rural settlement with the best values of indicators in the settlement group as a reference for the research. The values of absolute and relative values of indicators are presented in Tables A2 and A3 respectively. Table A4 shows the matrix of the evaluation results.

The results of evaluating the development level of rural settlements in the Zavaločycy local council are presented in Table 8.

Table 8. Classification of rural settlements in Zavaločycy local council by development level.

Rural Settlement Name	E_j	E_j Value Limits	Development Level
Zavaločycy	68.42	>70.99	Highest
Babirova	55.04	61.01–70.99	High
Hornaje	51.57	51.03–61.01	Average
Haradok	48.56		
Simanavicy	44.34		
Jausiejevicy	43.76		
Zapollie	40.75	41.05–51.03	Below average
Haradzisca	39.75		
Knysy	39.60		
Jasiency	39.46		
Turki	39.17		
Rudnia	36.42		
Paliana	34.98		
Dvarec	33.63	31.07–41.05	Low

The obtained values of the development indexes E_j for rural settlements vary from 34.99 to 68.42. Zavaločycy and Babirova have the highest and high development levels.

Figure 3 shows the factors which are the most significant for sustainable rural development: (1) accessibility of transport infrastructure, and (2) availability of data network.

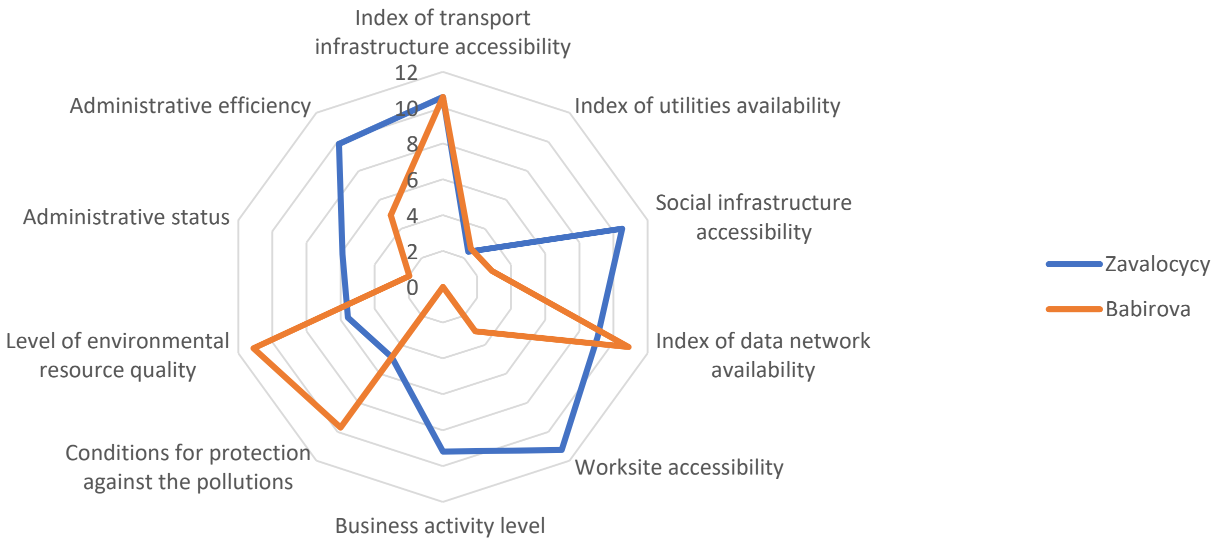


Figure 3. Diagram of the complex development index for the settlements Zavaločycy and Babirova.

5. Discussion

5.1. Findings and Implications

The empirical results show that the proposed model is a new synthetical and quantitative integration evaluation method. The model varies depending on specific conditions, provides the complex development index, and defines the critical points for ensuring the sustainability of settlement system. The model involves evaluating the development of rural settlements by the key propriety areas for ensuring the sustainability of settlement system. The proposed model enables us to solve several problems of practical importance typical for rural settlement system, such as the multi component structure requiring a multicriteria nature, stakeholder participation, and scenario analysis. The advantage of the model is its multifunctionality which ensures the possibility of evaluating the system development at any planning level. The test results confirmed the suitability and effectiveness of the proposed model as illustrated by the Zavaločycy local council as an analogue object of the local planning level which is typical for the settlement system of the Mogilev region and the Republic of Belarus as a whole. The evaluation results showed the model relevance for setting the development priorities and ensuring the specific measures for achieving the sustainable development of the settlement system and its elements. The land use planning system has a multilevel structure of settlement units (from settlement to regional planning), which suggests a universality of the proposed model. It is conceivable that the selected indicators are possible to apply for the development evaluation of both rural settlements and higher territorial units. Thus, the absolute value of an indicator may be defined in light of the unit level. This feature allows us to evaluate the system sustainability at any level, set the development priorities, and build a strategic vision for rural settlement system and its elements.

5.2. Future Research Directions

Further tests for the evaluation model are needed in the future. We intend to evolve the proposed model as we gain research experience in urban and regional planning, including the accumulation of experimental data in order to correct and improve the management of the criteria system for ensuring the sustainable development of rural settlements. We also intend to carry out the comparison analysis of the proposed model with respect to other well-known evaluation algorithms, such as the entropy method, and validate it by testing on the current analogue object. We consider testing the proposed model's applicability to larger, more urban settlements as one of the future research directions.

6. Conclusions

This study has analyzed the Belarus settlement system, which has undergone major changes in the Soviet and post-Soviet periods. We proposed a mathematical representation of the conceptual model for evaluating the development level of rural settlements. The evaluation aim is to obtain a complex development index of rural settlements (E_j). We proposed a six-level system for classifying rural settlements according to their relative development level, which is defined using two parameters: geometric mean and standard deviation.

On the basis of the proposed model, the rural settlements of the Zavaločycy local council were classified according to their relative development level. It should be noted that the Zavaločycy local council was used as a comparable object at local planning level, which is typical for the settlement system of the Mahilioŭ oblast and the Republic of Belarus as a whole. The obtained results showed that the centers of the local settlement structure—Zavaločycy and Babirova—have the highest development level and are indicative of the sustainable settlement system.

The proposed model serves as a new tool for a development evaluation of settlements and rural settlement system as a whole. The model involves both qualitative and quantitative indicators, which are related to specific conditions and allow to obtain a complex development index and define the critical points for sustainable development of the settlement system. The model involves the evaluation of the rural settlements development in key propriety areas for sustainability of the settlement system. The model is an approach to solving a number of practical issues typical for rural settlement system: (i) multi-component structure, (ii) multicriteriality, (iii) stakeholder participation, and (iv) scenario analysis. The key feature of the model is its flexibility, which allows (i) evaluation of the system sustainability at any planning level, (ii) identification of the development priorities, and (iii) formulation of a long-term vision of the rural settlement system and its units. The experimental results show that the proposed model is relevant for determination of development priorities, as well as meaningful steps to promote sustainable development of the settlement system and its units.

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Appendix A

Table A1. Algorithm for determining the absolute values.

Indicator	Unit Measure	Algorithm	Basic Indicators/Annotations
Index of transport infrastructure accessibility (Q1)	-	$I_t = \frac{L_n}{L_f}$	L_n—coverage area of transport services, km; L_f—actual distance between settlement and transportation facility, km
Index of utilities availability (Q2)	-	$I_u = \frac{n_w}{n_{tot}} + \frac{n_c}{n_{tot}} + \frac{n_g}{n_{tot}}$	n_w—number of households with central water supply; n_c—number of households with sanitary piping; n_g—number of households with gas-supply; n_{tot}—total number of households
Social infrastructure accessibility (Q3)	hour	$T_s = \frac{L_s}{v}$	L_s—actual distance between settlement and social infrastructure facility, km; v—average speed, kmph
Index of data network availability (Q4)		$I_d = \frac{n_d}{n_{tot}}$	n_d—number of households with data network; n_{tot}—total number of households
Worksite accessibility (Q5)	hour	$T_w = \frac{L_w}{v}$	L_w—commute, km; v—average speed, kmph
Business activity level (Q6)	unit per 1000 people	$B = \frac{n_f}{N_{tot}}$	n_f—number of farm households; N_{tot}—total population, 1000 people
Conditions for protection against the pollutions (Q7)	score	2-point scale: 1—unsatisfactory conditions, 2—satisfactory conditions	The score points were defined by application experts
Level of environmental resource quality (Q8)	score	2-point scale: 1—unsatisfactory quality, 2—satisfactory quality	The score points were defined by application experts
Administrative status (Q9)	score	3-point scale: 1—usual rural settlement, 2—agro-town, 3—the center of local council	The score points were defined by application experts
Administrative efficiency (Q10)	score	2-point scale: 1—poor administration, 2—efficient administration	The score points were defined by application experts

Table A2. The matrix of absolute values of the development criteria in the Zavaločycy local council.

Indicator	Zavaločycy	Simanavicy	Jausiejevicy	Rudnia	Paliana	Zapollie	Dvarec	Turki	Haradok	Haradzisca	Knysy	Babirova	Hornaje	Jasiency
Index of transport infrastructure accessibility	30.00	2.31	1.43	1.03	1.43	8.57	3.75	1.36	30.00	1.07	0.81	30.00	5.66	2.31
Index of utilities availability	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	2.00	0.00
Social infrastructure accessibility	0.05	0.10	0.12	0.12	0.05	0.09	0.12	0.15	0.14	0.22	0.24	0.19	0.10	0.14
Index of data network availability	0.83	1.00	1.00	0.62	0.56	1.00	0.41	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Worksite accessibility	0.05	0.10	0.12	0.12	0.05	0.09	0.12	0.15	0.14	0.22	0.24	0.19	0.10	0.14
Business activity level	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conditions for protection against the pollutions	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00
Level of environmental resource quality	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Administrative status	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Administrative efficiency	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A3. The matrix of relative values of the development criteria in the Zavaločycy local council.

Indicator	Zavaločycy	Simanavicy	Jausiejevicy	Rudnia	Paliana	Zapollie	Dvarec	Turki	Haradok	Haradzisca	Knysy	Babirova	Hornaje	Jasiency
Index of transport infrastructure accessibility	1.00	0.08	0.05	0.03	0.05	0.29	0.13	0.05	1.00	0.04	0.03	1.00	0.19	0.08
Index of utilities availability	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	1.00	0.00
Social infrastructure accessibility	1.00	0.50	0.43	0.43	1.00	0.60	0.43	0.33	0.38	0.23	0.21	0.27	0.50	0.38
Index of data network availability	0.83	1.00	1.00	0.62	0.56	1.00	0.41	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Worksite accessibility	1.00	0.50	0.43	0.43	1.00	0.60	0.43	0.33	0.38	0.23	0.21	0.27	0.50	0.38
Business activity level	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conditions for protection against the pollutions	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00
Level of environmental resource quality	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Administrative status	1.00	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Administrative efficiency	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Table A4. The matrix of the evaluation results for settlements in the Zavaločycy local council.

Indicator	Zavaločycy	Simanavicy	Jausiejevicy	Rudnia	Paliana	Zapollie	Dvarec	Turki	Haradok	Haradzisca	Knysy	Babirova	Hornaje	Jasiency
Index of transport infrastructure accessibility	10.6	0.82	0.50	0.37	0.50	3.03	1.32	0.48	10.60	0.38	0.29	10.60	2.00	0.82
Index of utilities availability	2.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	10.96	0.00
Social infrastructure accessibility	10.52	5.26	4.51	4.51	10.52	6.31	4.51	3.51	3.95	2.43	2.25	2.87	5.26	3.95

Table A4. *Cont.*

Indicator	Zavaločycy	Simanavicy	Jausiejevicy	Rudnia	Paliana	Zapollie	Dvarec	Turki	Haradok	Haradzisca	Knysy	Babirova	Hornaje	Jasiency
Index of data network availability	9.06	10.89	10.89	6.70	6.13	10.89	4.48	10.89	10.89	10.89	10.89	10.89	10.89	10.89
Worksite accessibility	11.26	5.63	4.82	4.82	11.26	6.75	4.82	3.75	4.22	2.60	2.41	3.07	5.63	4.22
Business activity level	9.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conditions for protection against the pollutions	4.86	4.86	9.71	9.71	9.71	9.71	9.71	9.71	4.86	9.71	9.71	9.71	9.71	9.71
Level of environmental resource quality	5.56	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11
Administrative status	5.89	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96
Administrative efficiency	9.86	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93
Complex development index E_i	68.42	44.35	43.76	36.42	34.99	40.75	33.63	39.18	48.57	39.75	39.61	55.05	51.58	39.47

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