UDC 711.57:004.9

INFORMATION TECHNOLOGY OF FORMING THE EDUCATIONAL NETWORK OF THE TERRITORIAL COMMUNITY

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ABSTRACT

Context. Local government organizations have significant decision-making power in the field of education. This requires the development of understandable tools that help form a network of educational institutions that provide high-quality educational services. The object of the study was the process of forming an educational network (ENW) of the community in the implementation of territorial development projects as part of the reform of local self-government.

Objective. The goal of the work is to increase objectivity of decisions made in the formation of the ENW territorial community, summarizing demographic, infrastructural, personnel, economic factors when choosing the location of ENW facilities.

Method. The study of the classical placement problem and its further adaptation to real problems arising from the implementation of the education reform made it possible to represent ENW territorial communities as a set of independent complete bipartite graphs. In this case, to solve the problem of choosing the location of an educational institution on the network, an information technology (IT) was developed to form an ENW territorial community. Based on the adapted *p*-median model and methods of geospatial analysis, generalizing the requirements of the current legislation, a set of input and output parameters of IT and a set of its operations are formed. The representation of the IT structure in the form of an IDEF0-model clearly explains how a combination of various factors is processed and generalized when making decisions while creating ENW and looking for ways to improve it.

Results. The developed IT was investigated in solving the problem of forming a network of lyceums in the Kharkiv region using geospatial information, open statistical data and data on lyceums. The proposed accommodation options make it possible to achieve a general level of accessibility of specialized secondary education of almost 94%. IT has additional tools for solving the problems of transporting students to the place of study and home.

Conclusions. The experiments carried out confirmed the operability of the proposed IT. The generalization of the results obtained makes it possible to recommend it for practical use in solving the problems of analyzing the current state of ENW, finding ways to improve it and possible directions for development, as well as evaluating solutions related to the spatial planning of ENW.

KEYWORDS: *p*-median model, geospatial analysis, model of information flows of the process, IDEF0-model, accessibility assessments.

ABBREVIATIONS

ENW is an educational network;

IT is an information technology;

GIS is a geoinformation systems;

VGI is voluntary geographic information.

NOMENCLATURE

Λ is the admissible value of the spatial accessibility of the educational institution relative to the points of demand;

μ_j is the weight of the vertex u_j, depending on the number of students at the demand point D_i;

φ is an update function;

ψ is an output function, that generates an output data;

A is a set of operations that implement the ENW forming process;

D_i is a demand point (i=1, …, I);

E is a set of graph edges $K_{1,D_{I+1}}$;

I_Pr is a model of information flows of the ENW forming process;

$K_{1,D_{I+1}}$ is a complete bipartite graph as a graphical model "center – points of demand";

$L(\cdot)$ is a distance function between educational institution (center) and demand points;

N is the maximum number of students assigned to an educational institution;

N_{ENS} is an estimated number of students;

N_{PA} is a population in the planning area;

O is a set of output data the ENW forming process;

R is a location of the educational institution (center);

U is a set of graph vertices $K_{1,D_{I+1}}$;

V is a set of input data, incoming into an input of the ENW forming process;

(x_j, y_j) are graph vertex coordinates $K_{1,D_{I+1}}$;

Z is a set of documents, regulating the ENW forming process.

INTRODUCTION

Education is a vital "driving force" for the development of countries, a necessary proviso for achieving social, economic, political, and cultural advantages. Globally, it affects the level of employment of the country's population, the growth of its well-being, individual income, the distribution of wages, the efficiency of resources distribution, the state of health [1], becomes a key incentive and factor that allows countries to introduce new technologies, increase labor productivity, change production systems for development of society. Experts from the World Economic Forum emphasize that among

DOI 10.15588/1607-3274-2023-3-13

the key indicators that affect the level of economic and industrial development of the country, education takes the most important place (its importance is comparable to the development of Technology & Innovation and Global Trade & Investment) [2]. At the same time, according to the estimates of the economies of countries of the nascent archetypes, such as Cyprus, Saudi Arabia, Latvia, Ukraine, Bulgaria et al., a strong positive correlation (with a correlation coefficient) is recorded between the level of development of the drivers of production of the country and education outcomes score (Fig. 1).

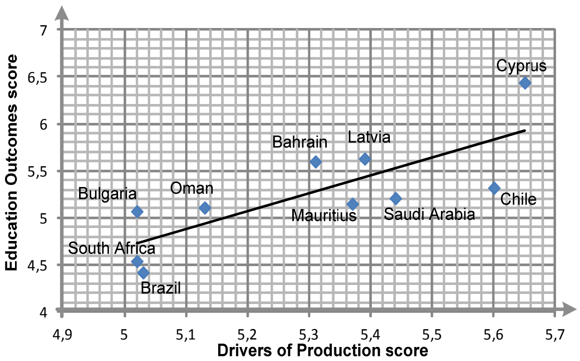


Figure 1 – The scatterplot (for the top-countries of the nascent archetypes) that illustrates dependence between indicators of drivers of production and education outcomes (According to the results of the analysis of work [2])

Therefore, education becomes a necessary condition for the effective transformation of production forces in the world of rapidly developing technologies, characterizes: the country's ability to respond to shifts in the labor market that are triggered by the Fourth Industrial Revolution, current labor force capabilities to adopt and use emerging technologies in production systems, the ability in the future to cultivate the right skills and talent of workforce [2].

The reform of local self-government, carried out in Ukraine since 2014, gives the authorities significant powers and functions to independently decide on the methods and resources for providing quality and affordable basic education in the respective territory. But the problems that are most often fixed at the local level (unequal occupancy of schools and classes, the lack of access to education for all children, the existence of a cumbersome school infrastructure with low occupancy in the presence of overcrowded schools, etc.) require the improvement of methodological approaches to the integrated development of territories and the development of effective tools for creating an educational network (ENW), which infrastructurally, organizationally, personnel, and financially will ensure the provision of quality education [3].

The object of study is the process of forming the educational network of the territorial community in the implementation of territorial development projects as part of the reform of local self-government.

To create conditions that ensure the provision of quality education, it is necessary to systematically study the existing ENW of the territorial community, identifying shortcomings and developing possible directions for its improvement in terms of changes that have occurred in connection with the education reform in the context of constantly changing legal norms, while there are no building requirements for the placement of educational institutions, establishments. Geospatial analysis methods are considered to be one of the most powerful and promising tools for solving such problems [4–6]. Therefore, in order to increase the objectivity of decisions made when forming the ENW of the community, it is necessary to expand the use of these methods, introducing approaches that, in the current economic conditions, will take into account the demographic characteristics of the settlements of the community, as well as the availability and prospects for the development of the existing ENW within the planning area.

The subject of study is the information technology for the formation of a territorial community educational network that uses geospatial analysis to determine the location of its infrastructure and find ways to improve it.

Therefore, the known sampling methods [4 – 14], which, unfortunately, are focused on assessing the availability of educational services, have excellent prospects for using information technology (IT) to form an educational community network.

The purpose of the work is to increase the objectivity of the decisions made when forming the educational network of the territorial community, generalizing various factors (demographic, infrastructural, personnel, economic) when choosing the location of its facilities.

1 PROBLEM STATEMENT

Consider the ENW facility as a center designed to meet the demand for educational services of students living in the planning area. In accordance with the J. Von Thunen model, the choice of the location of this center is subject to the provision of a minimum of transport costs, i.e.:

$$\underset{R}{\arg\min} F(R) = \underset{R}{\arg\min} \sum_{i=1}^{I} L(R, D_i) \,. \qquad (1)$$

Let us assume that the demand for educational services is unchanged, and the decision on which educational institutions (centers) to satisfy it is made centrally with the assignment of students from district to the corresponding territorial areas. In this case, there is a need to develop IT, focused on the use of geoinformation systems (GIS) in the processes of forming an ENW territorial community, which allows an educational institution to find R, given that

$$\sum_{i=1}^{I} L(R, D_i) \to \min \text{ for } \forall D_i \ (i = \overline{1, I}).$$

DOI 10.15588/1607-3274-2023-3-13

2 REVIEW OF THE LITERATURE

The modern concept of sustainable territorial planning of Professor C. Moreno is aimed at creating self-sufficient neighborhoods with the necessary functions for life, health care, education, etc. by decentralizing functions and services. In this regard, a territorial community is a complex socio-economic system for which the availability and accessibility of social infrastructure are of fundamental importance in ensuring the necessary quality of life for the population [4, 7]. For example, in the works of Ch. Jing et al. [4] or M. Ogryzek et al. [8] noted that the growth of cities increases the demand for education and other social services, leading to both positive outcomes and significant threats, affecting resilience. The spatial arrangement of social facilities, in particular educational institutions, plays an important role in organizing a number of economic processes, affects the attractiveness of places of residence, and leads to the movement of labor resources that are looking for better living conditions in their habitat. Similar studies of the urban ENW record uneven accessibility to social infrastructure and a trend towards a constant decrease in this accessibility [4, 8, 9]. However, a relatively small area of study (a city, its district or street) helps to solve a separate problem of placing an educational institution within a small area, but the results obtained are difficult to transfer to larger territorial counterparts (ENW of a district or region), take into account the influence of geographical factors when identifying inequality compulsory education. At the same time, in the generalizing studies of M. Kompil et al. [5] and A. Milbert et al. [9], the hypothesis about the uneven availability of services (including educational ones) in European countries is confirmed. The availability of services differs in urban areas and differs significantly between urban and rural areas, significantly increasing the average distance to services and inequality in education between rural and urban residents [5, 9].

Y. Gao et al. [10] analyze the inequality of compulsory education in terms of unbalanced spatial distribution, confirming the presence of educationally excluded areas – areas where the location of schools does not correspond to the real needs of residents. As noted in the work of J. Rao and J. Ye [11], attempts to reduce the gap between cities and rural areas by adjusting financial investments in basic education in rural areas and adapting the school map require significant efforts, affect rural areas and exacerbate the problem of educational disparity, in fact widening the gap between urban and rural areas, and between the rich and the poor people.

In this regard, the social infrastructure of Ukrainian regions also functions and develops very unevenly, leading to a significant imbalance in the field of social services provided to the population, which manifests itself in a massive decline in housing and communal services, consumer services, education, sports and medicine [12]. At the same time, it is noted that the governing bodies need an effective system that can help in analyzing the current state of the educational infrastructure, education itself and its progress, as well as in making decisions and formulating a policy for providing quality and affordable basic education in the relevant territory [6, 8, 10].

S. Agrawal and R. D. Gupta [6] suggest using GIS to analyze the current state of education in the region, as well as to identify possible problem areas in the study area. Focusing on gender inequality in education, on the demographic, social and economic situation in this area, the authors illustrate the advantage of geospatial analysis as an innovative way to critically study a variety of social and economic problems. These findings support D. Rodriguez-Segura et al. [13] and O. Mustapha et al. [14]. It is noted in their works that recent advances in remote sensing are making detailed geospatial population data available and can be used to pinpoint educationally excluded areas with unprecedented scale, detail, and cost-effectiveness [13], locating schools based on population size. population and their proximity, ensuring the sustainable development of territories [14].

Thus, regardless of the considered aspects of the problem of ENW territorial community formation, the literature review results confirm the following. The effectiveness of its formation is reduced due to the large size of the planning area, restrictions on the number of specialists involved in the analysis, and the reduction in funding allocated to local governments [3, 11, 13]. At the same time, studies of the potential of geospatial analysis methods confirm the possible reduction in socio-economic costs when the ENW facility is located in the context of the service area, taking into account a number of basic factors [6, 12, 14]:

– demographic, taking into account the demographic characteristics of settlements in the planning area;

– infrastructural, taking into account the availability and prospects for the development of the relevant educational infrastructure;

– economic, taking into account the correspondence of the volume of financing to the real needs and possibilities of the local budget, etc.

Therefore, in order to increase the objectivity of decisions made when forming an ENW territorial community based on the analysis of independent diverse data, it is necessary to introduce IT that combines spatial analysis technology with minimum distance methods, ensuring spatial accessibility (taking into account the real distance of students to the ENW object) and the availability of opportunities (taking into account the possibility of obtaining educational services in the existing ENW).

3 MATERIALS AND METHODS

The Law of Ukraine “On Education” guarantees equal rights to quality education, defining accessibility as “... a set of conditions that help meet the educational needs of individuals and provide each of them with equal opportunities to receive education ...” [15]. Local self-government bodies are responsible for the implementation of state policy in this area, plan and ensure the development of a network of educational institutions, guaranteeing their accessibility to all citizens living in the respective territory [3, 15]. Based on this, in model (1), the

DOI 10.15588/1607-3274-2023-3-13

places of residence of students can be considered as points of demand for educational services – D_i ($i=\overline{1,I}$), but, based on the idea of self-sufficient neighborhoods [7], consider the ENW territorial community model as a collection of complete bipartite graphs of the type $K_{1,D_{I+1}}$. From the condition of centralized assignment of students to the corresponding educational institution, each aggregate graph $K_{1,D_{I+1}}$ we will consider it an independent structure that has little influence on other columns of the ENW territorial community. Then, in the general case, while $i=1,...,I$ structure $K_{1,D_{I+1}}$ defines in the space a set of vertices $U=\{u_j \mid j=\overline{1,(i+1)}\}$ with coordinates (x_j, y_j) and a set of edges (without loops) $E=\{e_k \mid k=\overline{1,i}\}$.

Let's assume that at the top 1 of the graph $K_{1,D_{I+1}}$ an educational facility is located. Every vertex u_j $(j \neq 1)$ match the weight $\mu_j > 0$, the value of which depends on the number of students living at the point of demand D_i($j=i+1$, $\forall D_i$ while $i=\overline{1,I}$). In doing so

$$\sum_j \mu_j \le N, \tag{2}$$

which determines the possibility of obtaining educational services by the *N*-th number of students assigned to this educational institution.

The value of *N* is selected taking into account the differences and different possibilities for filling schools in rural and urban areas, which leads to significant fluctuations in its value [3, 16]. This is due to the fact that, for example, the number of students in a class in rural areas should be at least 5, ideally, it is necessary to provide an average occupancy rate for elementary schools of 13 students, for a gymnasium – 17 students and for a lyceum – 21 students. The average occupancy of classes in urban areas for all three levels is 25 students or more (ideally, 30 students per class) [16]. Thus, the value of *N* affects the maximum number of demand points and, as a result, the number of vertices in the graph $K_{1,D_{I+1}}$.

Each edge of the graph e_k corresponds to its length $l_k > 0$ (for $e_k=(u_1,u_j)$ while $j=\overline{2,(i+1)}$ introduced designation ($l_{1,j}=l_k$). In this case, for any pair of vertices (1,*j*) ($j \neq 1$) it is possible to find the function of spatial (territorial) accessibility as a function of distance (or length) $L((x_1,y_1),(x_j,y_j))$ between vertex 1 with coordinates (x_1,y_1) and vertex j with coordinates (x_j,y_j). Then formula (1) will take the form:

$$\underset{(x_1,y_1)}{\arg\min} F(x_1,y_1) = \underset{(x_1,y_1)}{\arg\min} \sum_{j=2}^{I+1} \mu_j L((x_1,y_1),(x_j,y_j)). \tag{3}$$

In the Law of Ukraine «On Complete General Secondary Education» it is mentioned, that «…every child has the right to receive education in the most accessible and closest institution to his place of residence" [16]. Therefore,

$$L((x_1,y_1),(x_j,y_j)) \le \Lambda \tag{4}$$
$$\text{for } \forall j=\overline{2,(i+1)} \text{ while } i=\overline{1,I}.$$

Inequality (4) limits the real distance from students to the ENW object, directly affecting the location of the educational institution (x_1,y_1).

Note that for all the importance (even at the legislative level) of the concept of spatial accessibility, its unambiguous definition does not exist. Most often (for example, in [9, 12, 17]), accessibility is discussed in the context of social services, considering it from different points of view.

By spatial accessibility, we mean "... a set of indicators for quantitative assessment, reflecting the ease with which a person (the population of a city, a separate municipality, etc.) can reach a certain object from their place of residence using different modes of movement ... [18]". This provides convenient and fast connections with all functional areas of the settlement, leads to an increase in the quality of life and social activity, reducing socio-spatial inequality [17, 18]. In this context, better accessibility means the shortest travel time, the limit of which, depending on the number of inhabitants of the settlement, is determined by the Building Code 2.07.01–89 "Urban planning. Planning and development of urban and rural settlements".

Thus, the solution of the placement problem and the search for the coordinates of the educational institution (x_1,y_1) are possible by multiobjective optimization while minimizing the function (3) taking into account the restrictions on the number of students (2) (in the context of the availability of opportunities) and the distance from students to the educational institution (4) (in the context of spatial availability).

Function (3) corresponds to the *p*-median placement model, for which the analytical finding of coordinates is possible by solving a system of differential equations of the form [19, 20]:

$$\begin{cases} \dfrac{\partial F((x_1,y_1))}{\partial x_1} = 0; \\ \dfrac{\partial F((x_1,y_1))}{\partial y_1} = 0. \end{cases}$$

Note that the presence of a significant number of demand points D_i while simultaneously observing constraints (2) and (4) leads to certain computational difficulties and requires the use of special algorithms and methods for finding coordinates (x_1,y_1), for example, using the ideas of geospatial analysis.

DOI 10.15588/1607-3274-2023-3-13

The search for a solution to the formed placement problem (3) in the presence of constraints (2) and (4) is implemented as part of the information process of the ENW territorial community formation. Based on the requirements of the current legislation, we systematize the information flows of this process and, using the author's research methodology [21, 22], conceptually represent it in the form of a set-theoretic model of information flows:

$$I\_\mathrm{Pr} = (V, O, A, \psi, Z, \varphi), \qquad (5)$$

the internal content of the sets of which is shown in Fig. 2.

In model (5), the set $V = \{v_1, v_2, v_3\}$ is converted to a set $O = \{o_1, o_2, o_3, o_4\}$ by successive implementation of set operations $A = \{a_1, a_2, a_3\}$, defined by a sequence [12, 13]:

Step 1. Assess the demographic situation and its trends in the planning area.

Step 2. Analyze the community's existing ENW.

Step 3. Choose the location of the educational institution.

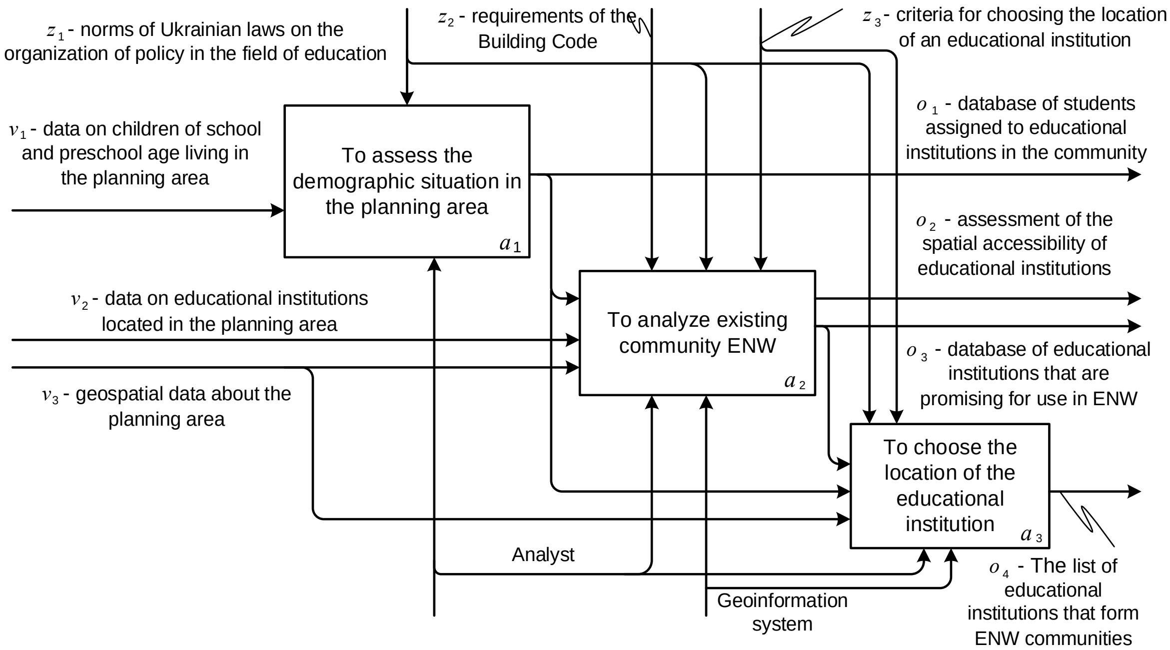


Figure 2 – IDEF0-model as a structure of information technology of forming the ENW territorial community

The set transformation is defined by the output function ψ – displaying the view [21, 22]:

$$\psi : A \times V \rightarrow O, \qquad (6)$$

the implementation rules of which are disclosed in Table 1, where each row corresponds to one operation of the formation of an ENW territorial community a_n $(n = 1,...,3)$, and the column is one valid input element of the set v_m $(m = 1,...,3)$. The cell at the intersection of a row and a column contains an operation a_n, the execution of which occurs when an element arrives at the input v_m, and the output element o_q $(q = 1,...,4)$, which will appear when the operation is performed a_n [22].

In Table 1, for example, upon receipt of an input v_3 to get the output o_4 during operation a_3 is required. In this case, is a necessary output o_1, obtained as a result of the operation a_1, output o_2, obtained as a result of the operation a_2 by summarizing input data v_2 and v_3, and output o_3, obtained as a result of the operation a_2.

Table 1 – Exit Function Tabular View (6)

Operations of the set A	Input elements of the set V		
	v_1	v_2	v_3
a_1	$a_1\|o_1$	$a_2\|o_1$	$a_3\|o_1$
a_2	–	$a_2\|o_2$	$a_2\|o_2$
a_3	–	$a_2\|o_3$	$a_3\|o_4$

To normalize the internal content of the information flows of the model (5) when converting input data into output data, a set of regulatory documents is required. They are determined by a set $Z = \{z_1, z_2, z_3\}$. The normalization rules are set by the update function φ [21, 22]:

$$\varphi : V \times Z \rightarrow V, \qquad (7)$$

which for each element of the set V specifies the implementation $v_m = \varphi(v_m, z_k)$ $\forall v_m \in V$, $\forall z_k \in Z$ while $m, k = 1,...,3$. For example, for operation a_2 function execution (7) allows you to create, supplement and

DOI 10.15588/1607-3274-2023-3-13

expand the database template of establishments that are promising for using in ENW. So, the implementation $\varphi(v_2, z_1)$ fulfills the requirement on the need to take into account information about the material base of the educational institution, the qualifications of its teaching staff, etc., the implementation of $\varphi(v_2, z_2)$ expands this template, supplementing it with information about the design capacity of the educational institution, age, etc., the implementation of $\varphi(v_3, z_2)$ requires taking into account the geospatial data of educational institutions, etc., in the database.

Summarizing the information flows, operations and functions of the model (5), in order to facilitate their perception while maintaining the rigor and formality of the representation, we depict it as an IDEF0-model (Fig. 2) [22, 23]. Based on the provisions of the functional modeling methodology, IDEF0-model determines the structure of IT of ENW territorial community formation. The implementation of proposed IT is possible by using the ArcGIS software suite by Esri.

Thus, the proposed IT, based on a consistent analysis of demographic, personnel, and infrastructural factors, will allow, when forming the ENW territorial community, to find a solution to problem (3), taking into account constraints (2) and (4), focusing on the real volumes of funding for the activities of educational institutions. The results obtained with the help of IT will make it possible to make informed decisions when choosing directions for optimization, for example, in conditions of limited financial support, when significant costs for maintaining schools with low occupancy can be reduced by reorganizing or reprofiling them [3, 15].

4 EXPERIMENTS

The possibility of using the proposed IT in the formation of a network of lyceums – institutions (structural divisions) that provide specialized secondary education (III level education) – is considered on the example of the communities of the Kharkiv region. At the same time, data on the city of Kharkiv and its educational institutions were excluded and were not considered when constructing ENW, which is associated with the specifics of the tasks of a large metropolis, which are not typical for other settlements [4, 8] of the region.

The purpose of the experiment was to assess the possibility of using spatial data to justify the choice of the location of an educational institution on the territory of the community in the formation of ENW. In particular, attention was focused on assessing the impact on the structure of the network element of the set Z – z_3 – criterion for choosing the location of the educational institution. In this case, such possible formulations were used z_3:

1. Lyceums are located in settlements with a population of at least 10,000 inhabitants;
2. Lyceums are located in the settlements of the districts of the territorial community, provided that the total population of the district is not less than 10,000 inhabitants.

Thus, according to the wording z_3 and taking into account the requirements of the Building Code 2.07.01–89, in expression (4) admissible value Λ for spatial accessibility was assumed to be 30 min. Due to the specificity of the information and the lack of accurate login data v_1 assessment of the demographic situation at the operation a_1 carried out using voluntary geographic information (VGI), the effectiveness of which for such tasks is confirmed in the works [12, 13, 23]. At the same time, the estimated number of lyceum students in the planning area, found by the formula [3, 12]:

$$N_{ENS} = N_{PA} \cdot \frac{97402}{2583141}, \tag{8}$$

is considered as a part of the number of residents in the planning area, taking into account the fact that the total population of the Kharkiv region as of January 1, 2022 is 2.583.141 people, including 15–18 years old (the age of applicants for specialized education) – 97.402 people.

In accordance with the requirements of The Law of Ukraine "On Complete General Secondary Education", lyceums must ensure the functioning of at least two classes in three areas of study at the level of specialized secondary education. Taking into account the cycles of the profile educational process and restrictions on the number of students in the class [1, 16], in expression (2) the value of N is taken equal to 500 people.

The following data were used as initial data:

– statistical data of the Main Department of Statistics of the Kharkiv region (http://kh.ukrstat.gov.ua/);

– data on educational institutions from the Education Management Information System of the Kharkiv region (https://kh.isuo.org/);

– VGI about the planning area from the OpenStreetMap (https://www.openstreetmap.org/) and Detsentralizatsiia (https://decentralization.gov.ua/) services.

As a result of the experiment, conclusions were drawn about the possibility of using geospatial analysis methods, as well as their effectiveness in the context of the reform of local self-government and the creation of new territorial communities, in particular, when solving problems:

– search for ways to improve ENW and possible directions of its development;

– analysis of the current state of ENW and assessment of decisions made related to spatial planning and the implementation of accessibility standards for specific places.

5 RESULTS

There are 19 settlements in the Kharkiv region (excluding Kharkiv) with a population of more than 10,000 people. Using VGI, according to formula (8), the estimated number of students was found and, taking into account the accepted value of N, the required number of lyceums was determined as 28. Their spatial distribution

DOI 10.15588/1607-3274-2023-3-13

on the territory of the Kharkiv region is shown in Fig. 3, while in the Bohodukhiv city there is 1 lyceum, in the Balakliia city – 2 lyceums, in the Izium city – 3 lyceums, in the Krasnohrad city – 1 lyceum, in the Slobozhanske urban-type settlement – 1 lyceum, in the Kivsharivka urban-type settlement – 1 lyceum, in the Kupiansk city – 2 lyceums, in the Lozova city – 4 lyceums, in the Pervomaiskyi city – 2 lyceum, in the Vysokyi urban-type settlement– 1 lyceum, in the Vovchansk city – 1 lyceum, in the Derhachi city – 1 lyceum, in the Liubotyn city – 1 lyceum, in the Merefa city – 1 lyceum, in the Nova Vodolaha urban-type settlement – 1 lyceum, in the Pisochyn urban-type settlement – 1 lyceum, in the Solonytsivka urban-type settlement – 1 lyceum, in the Zmiiv city – 1 lyceum, in the Chuhuiv city – 2 lyceums.

The spatial distribution of lyceums (Fig. 3) was found under the condition of uniform distribution of students throughout the territory of settlements. In case of their uneven settlement, the location of the lyceum is chosen in the places of maximum location of demand points D_i.

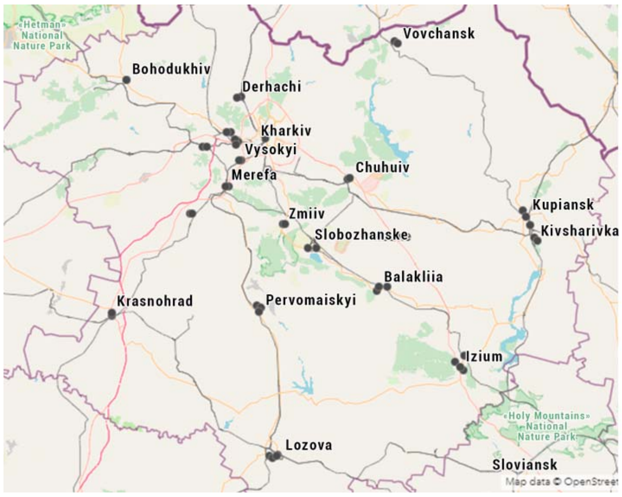


Figure 3 – A fragment of the distribution of lyceums across the territory of the Kharkiv region in settlements with a population of more than 10,000 people

In accordance with expression (3), for each lyceum, the distance to the expected demand points was found and the accessibility zones were determined (walking accessibility zone – 3 km, transport accessibility zone – 15 km and 30 min.) The results of the experiment are presented in Table 2.

Table 2 – Comparative results of lyceum accessibility assessments obtained using different placement criteria

Assessment parameter	Placement of lyceums in settlements with population		Comparison result, times
	More than 10.000 people	More and less 10.000 people	
Level of accessibility (%), including: walking distance (3 km) using transport distance (15 km) using transport time (30 minutes)	 0.95 16.46 47.6	 1.76 38.69 93.96	 ↑ 1.85 ↑ 2.35 ↑ 1.97
The area of the transport accessibility zone (30 min.), km^2	14 968.36	29434.36	↑ 1.97
Estimated number of lyceums in ENW	28	84	↑ 3.0

Taking into account the total number of inhabitants of the district (the second version of the wording) leads to the need to locate lyceums in settlements with a population of less than 10,000 people. In this case, the number of lyceums increases to 84. For example, in the Bohodukhiv district, instead of one lyceum in Bohodukhiv territorial community, 9 lyceums are created and operate, providing specialized secondary education in Bohodukhiv, Valky, Zolochiv, Krasnokutsk territorial communities. This allows you to increase the total area of the area of transport accessibility of the lyceums at the region to 29434,36 km^2, reaching the level of accessibility of specialized secondary education to almost 94 % (Table 2).

The final geospatial assessment of the accessibility zones of lyceums, obtained using the developed information technology for different formulations z_3, is presented in Fig. 4.

6 DISCUSSION

Analysis of statistical data on the distribution of the population of the Kharkiv region showed that the number of urban residents is more than 5 times higher than the population of rural areas. This confirms the correctness of the idea of locating educational institutions in urban areas of the region. However, the focus on placing lyceums only in settlements with a population of at least 10,000 people (and in the first edition of the law [16] – at least 50,000 people) leads to a significant violation of the requirement for the availability of specialized education. The zone of regulated transport accessibility covers only 47.6% of the Kharkiv region. (Table 2), which can lead to the problem of the lack of places in the created lyceums for all students (including those who are living in neighboring settlements) due to exceeding their design capacity (violation of constraint (2)).

Due to the significant distance between the recommended settlements (Fig. 5), areas with difficult access to specialized education are formed, which is especially noticeable in areas located closer to the borders of the region

DOI 10.15588/1607-3274-2023-3-13

(violation of the constraint (4)). In this case, the resulting economic effect from the reduction in the number of lyceums is leveled by the need to create and maintain boarding schools for students from remote areas. These problems explain the public outcry and negative attitude towards the first edition of the law "On Complete General Secondary Education" and the subsequent withdrawal of the discriminatory norm "on the placement of lyceums" in its new edition.

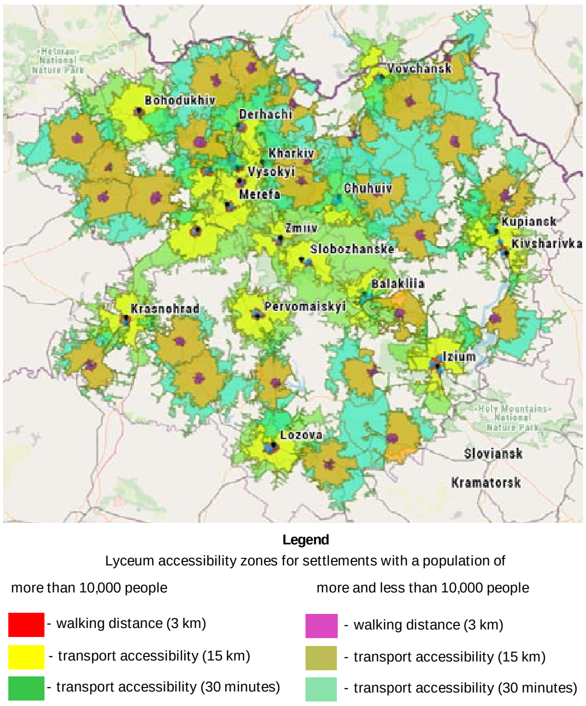


Figure 4 – An example of a geospatial assessment of the accessibility of lyceums obtained as a result of the application of the developed information technology

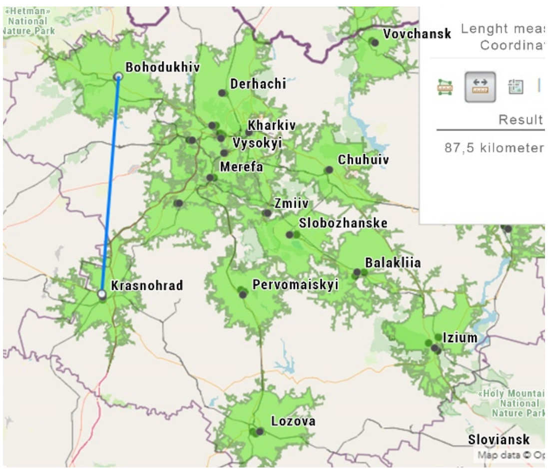


Figure 5 – Estimation of the distance between two neighboring lyceums in Bohodukhiv and Krasnohrad, Kharkov region

On the other hand, in cities located closer to Kharkiv, access zones overlap each other (Fig. 5). As a result, the problem of small-group classes arises, which, in addition to the emergence of financial support problems, is the cause of a decrease in the quality of education, a decrease in the number of education profiles, etc.

The placement of lyceums in the settlements of the districts of the territorial community in accordance with the second formulation of the criterion allows, on average, to increase the total accessibility zone by 2 times (Table 2), reduce the burden on cities, provide children with comfortable conditions and reduce the distance between lyceums so that students can choose the right lyceum which is closer to where you live. At the same time, if the idea of locating educational institutions in large settlements of the region's districts is observed, the recommended number of lyceums is increased by 3 times (Table 2).

CONCLUSIONS

The urgent problem of developing scientific and methodological support of information support for the process of forming the educational network of the community in order to find ways to improve it in the implementation of community development projects has been solved.

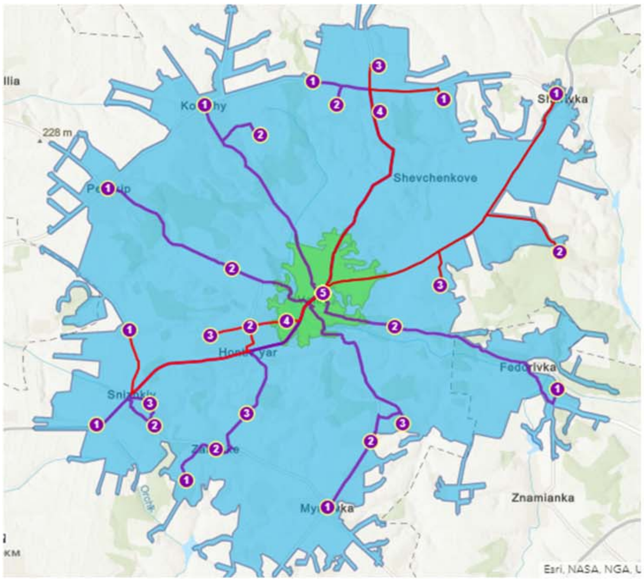
The scientific novelty of obtained results is that the adaptation of the p-median model to solve the problem of creating an ENW in the presence of constraints made it possible to combine demographic and infrastructural factors in making decisions about choosing the location of educational institutions. As a tool for solving the problem of choosing the location of educational institutions in ENW, the methodology for studying information processes was further developed by clarifying the set-theoretic model of information flows of the process. As a result of the clarification, an information technology for the formation of an ENW community was developed, which, based on an adapted p-median model and geospatial analysis methods, explains how a combination of various factors (demographic, infrastructural, personnel, economic) are processed and presented to support decision-making when formation of the educational network of the community and search for ways to improve it.

The practical significance of the obtained results is that the representation of the IT structure based on the IDEF functional modeling standard allows one to proceed to the creation of information systems for the formation of ENW based on spatial data. The conducted experiment on studying the capabilities of the developed IT showed its effectiveness in solving classical problems of accommodation, taking into account the accepted restrictions on the capacity of the educational institution and its spatial accessibility. At the same time, additional tools for solving the problems of ensuring the accessibility of education appear, in particular, the task of transporting students to the place of study and home. Using data about students, supplemented by geospatial information about their places of residence, and geospatial data about the locations of lyceums, the process implementation mechanism were proposed in the IDEF0-model – GIS – makes it possible to form student transportation routes, focusing on the al-

DOI 10.15588/1607-3274-2023-3-13

lowable value of Λ (Fig. 6). At the same time, all the necessary information for solving this problem is in the databases of outputs o_1 and o_3. The results of the experiment make it possible to recommend the proposed IT for the formation of a competitive educational network in accordance with the Laws of Ukraine, as well as to determine the effective conditions for its application.

Prospects for further research are in adjusting the data obtained in accordance with the actual occupancy of the classes of lyceums located in the planning territories. The use of actual data in the proposed IT will allow optimizing the network of lyceums, taking into account the possibility of organizing the functioning of parallel classes, transporting students from other settlements, etc., while the procedure for choosing the location of lyceums will remain unchanged.



N route	Start of the route (town)	End of the route (lyceum location)	Number of stops	Travel time, minutes	Route length, km
1	Perekip	Valky, Lyceum named after O. Maselsky	3	26	11,75
2	Hryntsiv Rih		4	34	16,19
3	Khvorostove		4	46	17,26
4	Koviahy		3	29	14,86
5	Sharivka		4	44	25,05
6	Fedorivka		3	24	13,12
7	Mynakivka		4	30	9,26
8	Buhaivka		4	30	13,19
9	Yaseneve		3	31	14,62
10	Kantakuzivka		4	46	17,36

Note: Routes are marked red, the implementation of which does not allow to achieve the value of spatial accessibility at the accepted (recommended) level without applying the additional organizational measures.

Figure 6 – An example of the routes for transporting students to the Valky lyceum of O. Maselsky obtained with the help of developed information technology

Author Contributions: Review and analysis of references, S. Danshyna, A. Nechausov; development of conceptual provisions and methodology of research, S. Danshyna; validation, A. Nechausov; analysis of research results, S. Danshyna, A. Nechausov; writing–original draft, S. Danshyna; writing–review and editing, A. Nechausov; project administration, S. Danshyna. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGEMENTS

The work is supported by the state budget scientific research project of National Aerospace University "KhAI" "Methodological bases of distributed systems for monitoring environmental objects creating" (state registration number 0122U002298) and with the support of the Regional Center of Space Monitoring of the Earth "Slobozhanshchina".

Authors express my special gratitude to Iryna Buhai for experimental confirmation of the effectiveness of the developed scientific-methodological basis.

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Received 06.03.2023.
Accepted 15.08.2023.

УДК 711.57:004.9

ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ ФОРМУВАННЯ ОСВІТНЬОЇ МЕРЕЖІ ТЕРИТОРІАЛЬНОЇ ГРОМАДИ

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АНОТАЦІЯ

Актуальність. Органам місцевого самоврядування надано значні повноваження щодо прийняття рішень у сфері освіти. Це потребує розроблення чітких і зрозумілих інструментів, які допоможуть сформувати мережу освітніх закладів для забезпечення якісного надання освітніх послуг. Об'єктом дослідження є процес формування освітньої мережі громади при реалізації проєктів розвитку під час здійснення реформи місцевого самоврядування. Метою роботи є підвищення об'єктивності рішень, що приймаються при формуванні освітньої мережі територіальної громади, узагальнюючи демографічні, кадрові, інфраструктурні, економічні чинники при виборі місця розміщення її об'єктів.

Метод. Дослідження класичної задачі про розміщення та її подальша адаптація до реальних завдань, що виникають при реалізації освітньої реформи, дозволили подати освітню мережу територіальної громади як сукупність незалежних повних дводольних графів. У цьому випадку для вирішення завдання вибору місця розміщення учбового закладу на мережі розроблено інформаційну технологію формування освітньої мережі громади. Ґрунтуючись на адаптованій *p*-медіанній моделі та методах геопросторового аналізу, узагальнюючи вимоги чинного законодавства, сформовано множину вхідних і вихідних параметрів інформаційної технології та множину її операцій. Подання структури IT у вигляді IDEF0-моделі наочно пояснює, як обробляють та узагальнюють сукупність різних факторів під час формування рішень при створенні освітньої мережі та пошуку шляхів її вдосконалення.

Результати. Розроблену інформаційну технологію досліджено під час вирішення завдання формування мережі ліцеїв у Харківській області з використанням геопросторової інформації, відкритих статистичних даних і даних про ліцеї. Запропо-

DOI 10.15588/1607-3274-2023-3-13

новані варіанти розміщення ліцеїв дають змогу досягти загального рівня доступності профільної середньої освіти майже 94%. У запропонованій ІТ є додаткові інструменти вирішення завдання підвезення учнів до місця навчання та додому.

Висновки. Проведені експерименти підтвердили працездатність запропонованої ІТ. Узагальнення отриманих результатів дає змогу рекомендувати її до використання на практиці при вирішенні завдань аналізу поточного стану освітньої мережі, пошуку шляхів її вдосконалення та можливих напрямів розвитку, а також оцінювання рішень, пов'язаних із просторовим плануванням мережі.

КЛЮЧОВІ СЛОВА: *р*-медіана модель, геопросторовий аналіз, модель інформаційних потоків процесу, IDEF0-модель, оцінки доступності.

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DOI 10.15588/1607-3274-2023-3-13