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STUDY OF THE ELEMENTARY BASE OF THE SETTLEMENT SYSTEMS

The article analyzes current changes that occur in the elementary structure of the settlement systems and also reflects the methodology of their study. Special attention is paid to the methodology of studying the directionality and intensity of relations between the settlements, dynamics of reciprocal development of the settlements in the system, homogeneity degree of the network of populated areas. All of the abovementioned provides an opportunity to establish the boundaries of the settlement system and allocate the nucleus of the system in the future. Investigation of the development level of the settlements' functions is the foundation for the establishment of their role in the settlement system, particularly the centrality or peripherality of the settlement.

Key words: *settlement system, nucleus of the settlement system, populated area, network of settlements, population of settlements, rank, graphical model.*

Леся Заставецька. ВИВЧЕННЯ ЕЛЕМЕНТАРНОЇ БАЗИ СИСТЕМ РОЗСЕЛЕННЯ. *У статті проаналізовано сучасні зміни, які відбуваються в елементарній структурі систем розселення, а також відображено методику їх вивчення. Особливу увагу приділено методиці вивчення спрямованості та інтенсивності зв'язків між поселеннями, динаміки взаємного розвитку поселень у системі, ступеня однорідності мережі населених пунктів. Все це дає змогу в подальшому встановити межі систем розселення, виокремити ядро системи. Дослідження рівня розвитку функцій поселень є основою для встановлення їх ролі у системі розселення, зокрема центральності чи периферійності поселення.*

Ключові слова: *система розселення, ядро системи розселення, населений пункт, мережа поселень, людність поселень, ранг, граф-модель.*

Леся Заставецкая. ИЗУЧЕНИЕ ЭЛЕМЕНТАРНОЙ БАЗЫ СИСТЕМ РАССЕЛЕНИЯ. *В статье проанализированы современные изменения, которые происходят в элементарной структуре систем расселения, а также отражено методику их изучения. Особое внимание уделено методике изучения направленности и интенсивности связей между поселениями, динамики взаимного развития поселений в системе, степени однородности сети населенных пунктов. Все это позволяет в дальнейшем установить границы систем расселения, выделить ядросистемы. Исследование уровня развития функций поселений является основой для установления их роли в системе расселения, в частности центральности или периферийности поселения.*

Ключевые слова: *система расселения, ядро системы расселения, населенный пункт, сеть поселений, население поселений, ранг, граф-модель.*

Setting of a problem in general terms. Nowadays social and economic processes have led to a change in the functions of the settlements in the settlement systems of different ranks, directionality and intensity of relations between the settlements in the systems, boundaries of the territorial settlement systems (especially at a grassroots level), to the disintegration of many grassroots systems, therefore, it is important to examine the entire set of populated areas of the territory under study, i.e. the network of settlements.

Analysis of the recent research and publications. Studies of the structure of settlement systems and problems of delimitation of their boundaries in the modern period are reflected in the works of K. Niemets, L. Niemets, K. Mezentsev, Yu. Pitiurenko, D. Tkach, O. Topchiiev, O. Shablii and etc.

Statement of the main investigation material. Territorial settlement systems of any taxonomic rank constitute an integral combination of populated areas and their territorial unities, which are united by means of settlement ties. One of the important features of these systems is the presence of the nucleus, which is the most developed in the socio-economic terms of the settlement, and also the existence of the so-called periphery.

The nuclei or the central settlements, due to their social and economic potential absorb the surrounding settlements to the area of their influence. And the more powerful the populated area is, the larger peripheral territory it has (settlements that are in the area of the influence of the nucleus). Thus, the capital covers by its organizational and economic, informational, cultural and educational and other ties all the populated areas of the country, interregional (regional) center – populated area of the vast region, regional center – populated areas of the administrative area, district center – populated areas of the administrative district. Territorial systems that are developed around the administrative centers, are being delimitated mostly by administrative boundaries.

Somewhat different situation is with the grassroots settlement systems, which are developed around the "local" centers – towns and large rural settlements. Area of their influence is being determined by the periodic and daily labour, production, social, informational and other ties. The lower the rank of the system is, the closer and more constant its ties with the periphery are.

The boundaries between the settlements are being established based on the study of the directionality and intensity of the ties between them. The important role in this plays the definition of the potential indicators of the settlement field, which characterize the attraction of the population within the certain territory. They are determined according to the Stewart's formula [4, p.30].

$$V_j = H_j + \sum_{i=1}^{n} \frac{H_i}{d_{ij}} \qquad (1)$$

where: V_j – potential of the settlement field for the j-settlement;
H_j – number of population of the j-settlement;
H_i – number of population of the i-settlement;
d_{ij} – distance between the j and i settlements;
n – number of settlements.

Calculated according to the separate populated areas indicators of their demographic potential are being mapped and joined by contour lines.

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"Statistical relief", which has been formed, reflects the potential territorial impact of the settlements and their engagement into the territorial settlement systems.

Taking into consideration the fact that besides the demographic potential, the nuclei have also industrial and social ones, K. Mezentsev suggests to use the method of superposition of maps of statistical surfaces of resettlement field potential, industrial activity field and public service field in order to allocate the nuclei of the macro regions.

For the delimitation of macro-regions (including the inter-regional settlement systems), K. Mezentsev applies the Thiessen polygons method [1, p.15-16], which can also be used in the process of regional settlement systems delimitation.

Since modern social and economic processes have led to a change in the boundaries of the territorial settlement systems (especially at the grassroots level), to the disintegration of many grassroots systems, therefore it is important to examine the entire set of populated areas of the territory under study, i.e. the network of settlements.

In order to begin the study of the settlement network, it is important to allocate the populated areas – "geospatial integrated and dense conglomeration of population together with its life-sustaining activities" [5, c.186], and only after that – their parameterization (quantitative and qualitative characteristics).

Main quantitative parameters of the populated areas include their population, size of the territory, they determine other quantitative and qualitative parameters of the settlements. Thus, according to the peculiarities of life activities one can distinguish rural and urban settlements. Rural settlements are divided into small (up to 500 inhabitants), medium (500-1000 inhabitants) and large (more than 1000 inhabitants); urban settlements are divided into small (up to 50,000 inhabitants), medium (50,000-100,000 inhabitants), large (100,000-500,000 inhabitants), extra-large (500,000-1000,000 inhabitants), cities with a million plus population (more than 1000,000 inhabitants). In each of these groups it is possible to distinguish subgroups, depending on the purpose of the study, thus, the group of small villages can be divided into isolated farmsteads (up to 100 inhabitants), and the group small towns can be divided into settlements with the level of population up to 10,000 inhabitants; 10,000-20,000 inhabitants and 20,000-50,000 inhabitants. All of them have a number of significant differences in the internal geospatial organization, functional structure, role in the settlement systems, which were formed during the settlement process. Factors, which determine the settlement processes, primarily the regional ones, have a significant influence upon the settlement network parameters.

One of the most important factors is the territorial community of people, which is revealed through the level and type of territory development. It determines the peculiarities of functioning of settlements, their system-forming ability. It is advisable to carry out the study of these features by the procedure of Yu. Pitiurenko (1977) and D. Tkach (1997), who have offered and used the score scale for the evaluation of the urban and rural settlement functions. Study of the development level of the settlements' functions is the foundation for the establishment of their role in the settlement system, particularly the centrality or peripherality of the settlement.

Dispersion of settlements and the average distance between the populated areas are among the significant factors for the analysis of the mutual arrangement of the settlements. These indicators characterize the location of the settlements on the territory, their mutual and topological parameters. Representing the measure of concentration of population, the dispersion is being determined from the following formula:

$$R = \frac{100 \times S}{d} \qquad (2)$$

where: R – index of dispersion;
S – number of settlements;
d – average level of population of the settlements.

This index can be determined both for all the settlements of the network and for the urban and rural settlements separately.

Average distance between the populated areas is being determined from the following formula:

$$S = \sqrt{\frac{2F}{\sqrt{3p}}} \qquad (3)$$

where: S – average distance between the settlements;
F – area of the territory;
p – number of population of the settlement.

For the calculation of the degree of homogeneity of the certain system populated areas network (district, regional) the indicator of entropy is also being used (Shannon's formula):

$$H = -\sum_{i=1}^{n} \log_2 p_i \qquad (4)$$

where: H – indicator of entropy;
p_i – possibility of the i-system status;
n – number of system statuses.

Clark's index is being used for the determination of the regularity of the settlements network (R):

$$R = \frac{R_A}{R_E} \qquad (5)$$

where: R_A – average distance between the populated area and its closest neighbor; $R_A = \frac{\Sigma A}{N}$, where: A- area of the territory, N- number of populated areas.
R_E – average distance between each populated area and its neighbor with the random distribution of populated areas at equal density:

$$R_E = \frac{1}{\sqrt{\frac{N}{A}}} \qquad (6)$$

Besides the abovementioned indicators, settlement and population density, level of urbanization, proportion of the nucleus in the population of the system, etc., are essential for the district and regional settlement systems. In order to establish the dynamics of reciprocal development of the settlement in the system, it is important to calculate the dependence between the rank of the populated area in the system and its population (it is preferable to take urban settlements for the calculation),

the so-called Zipf's formula:

$$\log \overline{H}_j = \log C - a \log j \quad (7)$$

where: C – coefficient, which is equal to the estimated population of the first city in the system;
a – slope ratio of the regression line in logarithmical coordinates;
j – rank of the city according to the actual population.

Calculations, carried out according to this formula at different periods, provide an opportunity to reveal the contrast ratio of the development of the nucleus and all other settlements of the system.

Since the separate parameters of the populated areas are connected by various links, in order to reveal them it is preferable to use correlation indexes, both parametric and rank (non-parametric). Parametric correlation indicator shows the relationship between the two quantitative parameters (for example, the dispersion of settlements and their density) or the state of the population at certain points in time (census), and is calculated using the following formula:

$$r = \frac{\Sigma_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{n \cdot \sigma_x \cdot \sigma_y} \quad (8)$$

where: r – correlation index ($1 > r > -1$);
x_i – meaning of the first phenomenon at the i-observation;
y_i – meaning of the second phenomenon at the i-observation;
$\bar{x}$, $\bar{y}$ – average value of the phenomena;
σ_x, σ_y – mean square deviation of the indexes x and y;
n – number of indexes.

Correlation for the indexes that are arranged according to the rank of quantitative character (for example, according to the population of systems and their territorial proportions) can be determined from the Spearmen's formula:

$$r = 1 - \frac{6\Sigma_{i=1}^{n}(x_i - y_i)^2}{n(n-1)(n+1)} \quad (9)$$

where: r – indicator of correlation;
x_i, y_i – rank of the i-indicator (i=1,2…n) of the first and second range of meanings;
n – number of indicators in a row (length of a row).

The important role in the study of territorial organization of the separate settlement systems and identification of the way of combining separate settlements in the systems plays the model development of these systems. The internal organization of the settlements in these systems is modeled by planar graphs, and the hierarchic structure – by the graph-trees.

Graphical model reflects linearly-nodal structure of the settlement (populated areas are the graph vertices, and the roads are the edges). Having simulated the district or regional system using the planar graph, we can determine which settlements occupy the most advantageous or the worst position in the system. For this we calculate the accessibility index of vertices (absolute index, König's, Bavelash's and Beachem's indexes) according to the methodology of A. Shablii (1984). Knowing these parameters, one can determine the way to improve the position of a particular area in the settlement system, optimization of the territorial organization of the entire settlement system as a whole.

The hierarchical structure of the settlement systems of different taxonomic ranks is being modeled using the graphs in which the root vertex is a center of the systems of higher rank. Using the indexes of the width and depth of the absolute and relative complexity of the graph, one can determine the structural complexity of such systems and compare them with each other. According to the theory of graphs, the degree of width is the minimal number of edges going out of one vertex, and the degree of depth is the maximum length of the chain from the root to the end vertex. Measure of the absolute complexity $\sigma(D)$ is determined as a sum of productions $d(y) \cdot k(y)$, where: $d(y)$- number of edges, going out of the root vertex of the subgraph; $k(y)$ – number of vertices of the subgraph, where y is the root vertex, that is:

$$\sigma(D) = \sum k(y) \cdot d(y) \quad (10)$$

Since graphs, which model regional, interregional and district systems have unequal number of edges, it is more appropriate to compare them upon the indicators of the relative complexity of the structure (O. Shablii, 1984):

$$S_0 = \frac{\sigma(D) - \sigma(n)}{\sigma_n} \quad (11)$$

where: S_0 – index of relative complexity;
$\sigma(D)$ – index of absolute complexity;
$\sigma(n)$ - index of minimal complexity ($\sigma_n = n \ln n$).

Based on the analysis of the given indexes, settlement systems of the same rank (for example, regional ones) can be compared with each other.

The fundamental problem of the settlement systems' study is the establishment of their development type of dynamics. There are three types of such dynamics: increasing centralization, stabilization and decentralization. An important heuristic means for determining the type of dynamics of the systems is the calculation of the contrast ratio of the urban settlements of the function system "rank-population" using the Zipf's formula (7). If the given ratio tends to increase, the centralization of the system is enhanced, if it doesn't change – there is the stabilization of a system, and if it is reduced – the decentralization of the system happens.

Quantitative parameters of the networks themselves do not make it possible to identify the peculiarities of combining settlements into settlement systems. Therefore parameterized objects should be systematized according to the quantitative and qualitative characteristics by means of distinguishing their certain kinds. And only after that it is possible to determine certain regularities and principles of the geospatial organization of the settlement systems of various taxonomic ranks.

The condition for the rational organization of territorial systems is the study of their structure and processes of development. Thus, it is necessary to proceed from the general theory of economic and geographical (economic) space. In the main economic works, where the rendering of such space is being singled out (R. Domanskyi, 1965; Yu. Lypets, 1971; M. Chyzhov, 1975; R. Tatevosov and L. Tatevosova, 1977; O. Topchiiev, 2000; O. Shablii, 2003; K. Niemets and

L. Niemets, 2013), it is considered as the repository of economic entities. Since the economic objects are always found in the settlements, then this space is a projection of populated areas on a plane. Such concept of populated areas as the elements of economic space provides great opportunity for the modeling of different kinds, primarily for the creation of structural and dynamic models. Since the economic space is multidimensional and it can be represented as an interaction field of populated areas, there are great opportunities for using interaction models (gravitational, diffusive) and methods of multidimensional mathematical analysis.

Among the models are those that characterize spatial interaction between the phenomena, those that can be represented by linear and non-linear (parabolic, logarithmic and others) dependencies. It is reasonable to apply models of spatial structure of the fields, which are the foundation for the IFI-modeling (integral function of impact) [2]. They include trend analysis, which requires the use of algebraic and trigonometric polynomials or linear differential equations in individual derivatives.

Based on the concept of the settlement system as the economic and geographical space and geographical field, it is possible to determine its characteristics (density, magnitude, potential and etc.), dynamics and thereby make their extrapolation for the future.

The structure of the settlement systems should also be considered in vertical aspect. To do this, it is necessary to study the ties between the nuclei of the system formation and the so-called "periphery" between the settlement systems of different taxonomic levels. The essential roles here play the cartographic, statistic and mathematical methods, and also the theory of graphs (creation of graphical models, the so-called "trees of combinations") and etc.

Conclusions. The application of the described set of methods and techniques gives the possibility to the fullest extent possible and with optimal efforts to carry out socio-geographical study of the modern elements of settlement systems, transformation and their functioning.

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Summary

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Nowadays social and economic processes have led to a change in the functions of the settlements in the settlement systems of different ranks, directionality and intensity of relations between the settlements in the systems, boundaries of the territorial settlement systems (especially at a grassroots level), to the disintegration of many grassroots systems, therefore, it is important to examine the entire set of populated areas of the territory under study, i.e. the network of settlements.

The boundaries between the settlements are being established based on the study of the directionality and intensity of the ties between them. The important role in this plays the definition of the potential indicators of the settlement field, which characterize the attraction of the population within the certain territory. They are determined according to the Stewart's formula.

In order to study the network of settlements it is necessary to investigate the indicators of settlement population, dispersion of settlements and average distance between the populated areas, density of settlements and population, level of urbanization, proportion of the nucleus in the population of the system and etc. In order to establish the dynamics of reciprocal development of the settlement in the system, it is important to calculate the dependence between the rank of the populated area in the system and its population.

The important role in the study of territorial organization of the separate settlement systems and identification of the way of combining separate settlements in the systems plays the model development of these systems. The internal organization of the settlements in these systems is modeled by planar graphs, and the hierarchic structure – by the graph-trees.

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