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MODELING OF TERRITORIAL DIFFERENTIATION BY TRANSPORT INFRASTRUCTURE LEVEL OF DEVELOPMENT

Cherednichenko Kostiantyn, Miroshnikova Julia. *«Modeling of territorial differentiation by transport infrastructure level of development».* The research paper presents theoretical and practical aspects of differentiation of territories according to the level of transport infrastructure development. The purpose of the research is to develop a formalized approach to territorial differentiation according to the level of transport infrastructure development on the example of Ukrainian regions. The issues with the term of "transport infrastructure" are defined. Classical methodological approaches to transport infrastructure level of development assessment are described. The essence of the concept of "differentiation" and its meaning in the transport industry are revealed. The coefficients for assessing the provision of regions with transport infrastructure, transport network density coefficient and the assessment of transport network safety indicator are considered. On the basis of the considered coefficients and initial statistical data, the analysis of regions of Ukraine, based on a level of development of a transport infrastructure, was conducted. The inequality of transport infrastructure level of development (even within one country) is caused due to both objective (geographical location, resource potential) and subjective reasons (efficient use of resources, effectiveness of regional management). An integrated assessment in order to solve this task was formed. It is based on the apparatus of the methodology of decision-making in conditions of uncertainty. For the practical demonstration, the regions of Ukraine were differentiated, according to the level of transport infrastructure development. During the evaluation, it is possible to determine the factor with the greatest impact on the overall result by region. Improving the quantitative indicators that form the most influential qualitative assessment would lead to an increase of the overall assessment. Thus, using the developed algorithm, it becomes possible to optimize the management of transport infrastructure development of a particular territory.

Keywords: transport infrastructure, territorial differentiation, mathematical modeling, integrated assessment, transport safety, transport network density, carrying capacity.

Чередніченко Костянтин, Мірошнікова Юлія. *«Моделювання диференціації територій за рівнем розвитку транспортної інфраструктури».* У статті викладені теоретичні та

практичні аспекти диференціації території за рівнем розвитку транспортно інфраструктури. Метою даної роботи є розробка формалізованого підходу територіальної диференціації за рівнем розвитку транспортної інфраструктури на прикладі регіонів України. Розкрито проблематику та визначено термін «транспортна інфраструктура». Описано класичні методичні підходи до формування оцінок рівня транспортної інфраструктури та їх недоліки. Розкрито сутність поняття «диференціація» та її значення у транспортній галузі. Розглянуто коефіцієнти оцінки забезпеченості регіонів транспортною інфраструктурою. На базі розглянутих коефіцієнтів та вихідних статистичних даних був проведений аналіз регіонів України за рівнем розвитку транспортної інфраструктури. Нерівність рівня розвитку транспортної інфраструктури (навіть у межах однієї країни) обумовлена як об'єктивними (географічне розташування, ресурсний потенціал), так і суб'єктивними причинами (ефективне використання ресурсів, ефективність регіонального управління). Для вирішення даної проблеми була розрахована інтегральна оцінка. Базуючись на даній оцінці для практичної демонстрації розробленого алгоритму, було продиференційовано регіони України за рівнем розвитку транспортної інфраструктури. Використовуючи розроблений алгоритм, стає можливим оптимізувати управління розвитком транспортної інфраструктури певної території.

Ключові слова: транспортна інфраструктура, диференціація територій, щільність транспортної мережі, транспортна безпека, пропускна здатність, математична модель, інтегральна оцінка.

Чередниченко Константин, Мирошникова Юлия. «Моделирование дифференциации территорий по уровню развития транспортной инфраструктуры». В статье изложены теоретические и практические аспекты дифференциации территорий по уровню развития транспортной инфраструктуры. Целью данной работы является разработка формализованного подхода территориальной дифференциации по уровню развития транспортной инфраструктуры на примере регионов Украины. Раскрыто проблематику и определение термина «транспортная инфраструктура». Описаны классические методические подходы к формированию оценок уровня транспортной инфраструктуры и их недостатки. Раскрыта сущность понятия «дифференциация» и его значение в транспортной отрасли. Рассмотрены коэффициенты оценки обеспеченности регионов транспортной инфраструктурой. На базе рассмотренных коэффициентов и исходных статистических данных был проведен анализ регионов Украины по уровню развития транспортной инфраструктуры. Неравенство уровня развития транспортной инфраструктуры (даже в пределах одной страны) обусловлена как объективными (географическое положение, ресурсный потенциал), так и субъективными причинами (эффективное использование ресурсов, эффективность регионального управления). Для решения данной проблемы была рассчитана интегральная оценка. Основываясь на данной оценке для практической демонстрации разработанного алгоритма, были оценены регионы Украины по уровню развития транспортной инфраструктуры. Используя разработанный алгоритм, становится возможным оптимизировать управление развитием транспортной инфраструктуры определенной территории.

Ключевые слова: транспортная инфраструктура, дифференциация территорий, плотность транспортной сети, транспортная безопасность, пропускная способность, математическая модель, интегральная оценка.

Introduction. The transport system has significant importance for the modern economy, because other industries productivity and, as a consequence, the financial welfare of the state depends on it. The role of transport systems is constantly growing, especially during the implementation of large-scale international integration plans.

Transport infrastructure refers to the framework that supports transport system. This includes roads, railways, ports and airports. The inequality of transport infrastructure level of development (even within one country) is caused due to both objective (geographical location, resource potential) and subjective reasons (efficient use of resources, effectiveness of regional management).

Literature review and problem statement. In modern scientific researches, "transport infrastructure" is interpreted in several aspects [1-5]. However, none of the considered approaches takes into account the impact of integration processes on transport infrastructure.

A general definition of transport infrastructure is formulated as a connecting element between production and consumption, which includes networks of connections of all modes of transport and facilities serving vehicles and communications (stations, airports, ports, etc.). It is also recommended to consider the transport infrastructure as a system of infrastructure by types of transport. Analysis of scientific research about transport infrastructure showed a variety of approaches to the assessment of its development level. Namely: the concepts of "transport network density" [6], "carrying capacity" [7], "transportation timing" [8] and "transport infrastructure provision". Most of the modern methods of transport infrastructure assessment, however, do not include transport safety and geographical location indicators.

Unfortunately, each approach analyzes only one factor, ignoring other indices that could potentially affect the overall level of transport infrastructure. The lack of integrated assessment could lead to a misinterpretation of the real level of development and, as a consequence, inefficient management of transport system.

The aim and objective of research. The aim of the study is to develop a formalized approach of territorial differentiation by transport infrastructure level of development on the example of Ukrainian regions.

Presentation of the main material. The differentiation of transport infrastructure (TI) should be considered as a process of distribution of transport infrastructures on the basis of integrated quantitative assessments of their level of development.

The classic approach to transport infrastructure assessment is the analysis of

regions provision with transport infrastructure, which is based on coefficients of Engel, Goltz, Uspensky, Vasilevsky [8]:

$$K_E = \frac{L}{\sqrt{S * H}}, \quad (1)$$

$$K_G = \frac{L}{\sqrt{S * N}}, \quad (2)$$

$$K_U = \frac{L}{\sqrt[3]{S * H * t}}, \quad (3)$$

$$K_V = \frac{L}{\sqrt[3]{S * H * Q}}, \quad (4)$$

where K_E – Engel coefficient;

K_G - Goltz coefficient;

K_U - Uspensky coefficient;

K_V - Vasilevsky coefficient;

L – the length of roads in the region;

S – area of region;

H – population;

N – number of settlements;

t - the total weight of freights transported to the territory;

Q - total weight of products produced on the territory.

However, this method has disadvantages, such as: a region with a large area loses to a country with a smaller area in advance; the geographical factor is not taken into account; etc. Therefore, during territorial analysis, these coefficients must be supplemented. It is recommended to take into account transport network density coefficients [8].

Transport network density coefficient is the ratio of total roads length in the region to the area of region (formula 5) and population (formula 6):

$$d_S = \frac{1000L}{S}, \quad (5)$$

$$d_H = \frac{1000L}{H}, \quad (6)$$

Density of roads in relation to: the area of region and population (formula 7), density of

cargo transportation by road (formula 8), GBP (formula 9):

$$d_{SAT}^A = \frac{S^{AT}}{\sqrt{S^R A^R}} \quad (7)$$

$$d_{SAT}^{S^R A} = \frac{S^{AT}}{\sqrt{S^R * N_A^R}} \quad (8)$$

$$d_{SAT}^{S^R V^R} = \frac{S^{AT}}{\sqrt{S^R V^R}} \quad (9)$$

where S^{AT} - density of highways;
 S^R – area of region;
 A^R – population;
 N_A^R - range of transportation of goods by road;
 V^R - GDP.

Then the formula of integral assessment of road density:

$$d_{SAT} = \frac{S^{AT}}{\sqrt[4]{S^R A^R N_A^R V^R}}, \quad (10)$$

It is worth to be included another approach to transport infrastructure level assessment, which is based on traffic safety index in transport network [9].

Accident rate:

$$I = \frac{10^6 z}{365 * L * N}, \quad (11)$$

where z - number of accidents per year;
 N - average daily traffic intensity in both directions;
 L - the road length.

Using formulas (1-11) and statistical data [11-15], the coefficients of transport infrastructure level of development of Ukrainian regions were calculated:

Table 1. Transport infrastructure level of development assessment

Criterion	Region								
	Donetsk region	Prydniprovsky region	Northeastern region	Central region	Northwestern region	Podilsky region	Black Sea region	Carpathian region	Capital region
K_E	0,0242	0,0348	0,0439	0,0446	0,0424	0,0498	0,0328	0,036	0,047
K_G	1,1831	1,4694	1,3309	1,4903	1,297	1,0768	1,2999	1,386	1,395
K_U	0,9045	1,174	1,6462	1,5807	1,6521	1,8136	1,134	1,146	1,495
K_V	1,1095	1,1228	1,4768	1,0877	0,8555	1,4537	1,4434	1,273	1,374
d_S	262203	317140	343750	305006	312 750	395051	234981	381084	309524
d_H	2225,5	3810,8	5618,5	6531,0	5734,8	6271,9	4587,8	3571,6	6987,2
d_{SAT}^A	1,1	1,3	1,4	1,9	2,0	2,3	1,1	2,3	1,4
$d_{SAT}^{S^R A}$	23,9	23,2	27,4	30,2	38,2	42,4	17,0	38,8	20,2
$d_{SAT}^{S^R V^R}$	0,06	0,09	0,09	0,16	0,19	0,18	0,08	0,17	0,07
d_{SAT}	0,35	0,49	0,56	0,85	0,99	0,98	0,43	0,80	0,45
I	0,03	0,09	0,09	0,06	0,05	0,08	0,15	0,12	0,11

The next step is the formation of an integrated assessment of transport

infrastructure level of development for territorial differentiation. It is possible to use

the apparatus of decision-making theory in conditions of uncertainty in order to conduct this procedure. It is recommended to use Savage's criterion (C_S). In this case, by

"alternatives" should be understood "certain regions" (table 1), the calculated coefficients (formulas 1-11) – as expert assessments.

$$r_{ij} = \max_{1 \leq i \leq m} a_j - a_{ij} \quad (12)$$

$$\bar{F} = \min_{1 \leq i \leq m} \max_{1 \leq j \leq n} r_{ij} = \min_{1 \leq i \leq m} \max_{1 \leq j \leq n} (\max_{1 \leq i \leq m} a_j - a_{ij}) \quad (13)$$

To conduct the assessment, it is necessary to develop a table (table 2) of relative values from table 1.

Table 2. Relative values of transport infrastructure level of development

Region	Assessment					
	K_E	K_G	K_U	K_V	d_{SAT}	I
Donetsk region	0,4859	0,7941	0,4983	0,5796	0,3535	0,2000
Prydniprovskiyi region	0,6988	0,9873	0,6472	0,7603	0,4949	0,6000
Northeastern region	0,8815	0,8938	0,9074	0,8626	0,5657	0,6000
Central region	0,8956	1,0000	0,8716	0,9844	0,8586	0,6000
Northwestern region	0,8514	0,8705	0,9107	1,0000	1,0000	0,4000
Podilsk region	1,0000	0,7240	1,0000	0,9303	0,9899	0,3333
Black Sea region	0,6586	0,6964	0,6251	0,6811	0,4343	1,0000
Carpathian region	0,7410	0,7834	0,6318	0,8125	0,8081	0,8000
Capital region	0,9337	0,9873	0,8241	0,9770	0,4545	0,7333

According to formulas (12-13) a table of r_{ij} was formed (table 3):

Table 3. Table of r_{ij}

Region	Assessment					
	K_E	K_G	K_E	K_V	K_E	I
Donetsk region	0,5141	0,2059	0,5017	0,4204	0,6465	0,8000
Prydniprovskiyi region	0,3012	0,0127	0,3528	0,2397	0,5051	0,4000
Northeastern region	0,1185	0,1062	0,0926	0,1374	0,4343	0,4000
Central region	0,1044	0,0000	0,1284	0,0156	0,1414	0,4000
Northwestern region	0,1486	0,1295	0,0893	0,0000	0,0000	0,6000
Podilsk region	0,0000	0,2760	0,0000	0,0697	0,0101	0,6667
Black Sea region	0,3414	0,3036	0,3749	0,3189	0,5657	0,0000
Carpathian region	0,2590	0,2166	0,3682	0,1875	0,1919	0,2000
Capital region	0,0663	0,0127	0,1759	0,0230	0,4455	0,2667

Then the territorial differentiation of regions (table 4):

Table 4. Territorial differentiation of Ukrainian regions

Place	Region	Integrated assessment (1 - C_s)
1	Carpathian region	0,6318
2	Central region	0,6000
3	Northeastern region	0,5657
4	Prydniprovskiyi region	0,4949
5	Capital region	0,4545
6	Black Sea region	0,4343
7	Northwestern region	0,4000
8	Podilsk region	0,3333
9	Donetsk region	0,2000

According to the results, the Carpathian region is the most developed region of Ukraine, and the Donetsk region is the least developed.

Conclusions. The developed algorithm allows to estimate the level of transport infrastructure by integrated assessment. During the evaluation, it is possible to

determine the factor with the greatest impact on the overall result by region. Improving the quantitative indicators that form the most influential qualitative assessment would lead to an increase of the overall assessment. Thus, using the developed algorithm, it becomes possible to optimize the management of transport infrastructure development of a particular territory.

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