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Assessment of Transport Infrastructure Development Level of Ukraine

Abstract. The purpose of the article is to create a basic model of conducting an analytical assessment of infrastructure development efficiency. The basic model allows assessing the level of current infrastructure condition which provides production and social dimension of its stable development. The article substantiates the necessity of conducting an analytical assessment of infrastructure development level which identifies its weaknesses and determines the potential of improving its performance indicators. Integral estimation of road infrastructure efficiency is proposed. To assess the problems of infrastructure development provision the comparative analyses within the proposed model are made as well as with the Data envelopment analysis (DEA) method. The results of the research allow discovering the causes of harmful phenomena in the system of management and development, identifying major trends and prospects of development.

Keywords: transport infrastructure; development; efficiency; integral assessment; comparative analyses; DEA.

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Оцінка рівня розвитку транспортної інфраструктури України

Анотація. Підвищення ролі інфраструктури в інтенсивному розвитку світової економіки пов'язане зі збільшенням споживчого попиту на якісне транспортне сполучення. Розвиток транспортної інфраструктури сприяє торговельно-економічним відносинам, утворюючи канали виробничих комунікацій та соціальної мобільності як передумови до зростання рівня життя та добробуту, тому надзвичайно важливо виявити недоліки та запропонувати конструктивні рішення, які сприятимуть ефективному розвитку рівня транспортної інфраструктури, враховуючи наявні можливості. Метою дослідження є створення базової моделі для проведення аналітичної оцінки рівня розвитку транспортної інфраструктури, яка дозволяє визначити її поточний стан, відстежити напрями формування виробничого та соціального виміру стабільності регіонів України. Обґрунтовано необхідність проведення аналітичної оцінки рівня розвитку транспортної інфраструктури. Проведено аналіз останніх досліджень та публікацій, який демонструє плюралізм думок щодо методології проведення оцінки показників розвитку та водночас одностайність у необхідності забезпечення якісного рівня інфраструктури як передумову сталого розвитку. Визначено якісні та кількісні показники розвитку транспортної інфраструктури за даними 24 регіонів країни за допомогою моделі інтегральної оцінки. Проведено порівняльний аналіз розвитку інфраструктури в рамках запропонованої інтегральної моделі та аналіз з використанням методу Data envelopment analysis (DEA), який виявив розбіжності, що свідчить про варіативність методів оцінки. Результати дослідження дозволили виявити негативні тенденції, а також визначити перспективи розвитку транспортної інфраструктури, які мають бути спрямовані на активізацію залучення у сферу матеріального виробництва окремих регіонів, тим самим збільшуючи територіальну мобільність виробничих факторів, ефективність організації економічного простору та перспективне здійснення внутрішньо територіального поділу праці, забезпечення належних умов життя людей.

Ключові слова: транспортна інфраструктура; розвиток; ефективність; інтегральна оцінка; порівняльний аналіз; DEA.

Formulation of the problem. An excellent infrastructure level provides equally high opportunities both at the regional level and in the country as a whole. For many countries, transport infrastructure is one of the main sources of budget filling, so it should be given high priority. For Ukraine, which is in a very favorable geographical location, an appropriate level of transport infrastructure could play the same role in the country's economy as ports in Singapore. Assessment of the current state of the transport infrastructure of Ukraine will determine its potential and indicate its shortcomings.

Analysis of recent research and publications. The authors believe that having efficient and effective transport infrastructure (e.g. bridges, roads, railways, airways, and tunnels) in place is essential for supporting the economic and social well-being of an economy. Delivering, managing, and maintaining transport assets that are resilient and adaptive to changing environmental conditions have become a priority for many governments worldwide [1].

To support trade, stimulate economic growth, create jobs and conditions favorable to the economic situation to prosperity, Europe needs a well-developed transport

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network. Transport is the basis of the European integration process and is closely related to the creation of the internal market, which promotes employment and economic growth [2].

The paper Marzieh Reisi et al. highlights the role of spatial data infrastructures in decision support systems for uncertainty analysis and promoting smart cities and resilient environments [3].

Yang, L. et al. believe that it is necessary to examine the mechanism and conflicts of the complex transport, spaces, and humans system, to choose suitable strategies to design, and to critically assess the alternative plans for the sake of making sensible decisions [4].

The authors in their study seek to gain a better understanding of the interplay of transport pricing, transport service provision, cost recovery, together with explicit consideration of equity in a unified fashion. To do so, they carry out a simulation analysis, as theoretical results in second-best contexts are not clean and depend on assumptions on relevant parameters [5].

The vulnerability analysis of infrastructure exposed to natural hazards has become a key area of research due to the critical role that infrastructure plays for society and this topic has been the subject of significant advances from new data and insights following recent disasters. Transport systems, in particular, are highly vulnerable to natural hazards, and the physical damage of transport assets may cause significant disruption and socioeconomic impact [6].

Features of the socio-economic state depend on the basic characteristics of the country at the time of assessment, and the stage of its development. For Ukraine, the already existing asymmetry is an inhibiting factor, a characteristic feature of which is a different level of well-being, with the country's remoteness from assessment criteria, standards, and world average values, hyperbolized by the post-crisis state of the country [7].

Rapid response to the changeability of external factors is possible if independent infrastructure industries capable of their complex interrelationship to provide sustainable economic development of both particular regions and the whole country are available [8].

Formulation of research goals. The study's primary goal is to conduct the comparative analyses of road infrastructure objects by the method of integral assessment using of which will establish the basic model of sustainable infrastructure development's analytical assessment. The attainment of this goal determines the solution of the following issues:

– justification for the comparative analyses of infrastructure development as one of the problematic aspects and identifying competitive advantages of infrastructure in Ukraine;

– application of the method of integral assessment in determining qualitative indicators;

– application of the basic mode to map out trends and prospects of sustainable infrastructure development.

Outline of the main research material. A method of integral assessment created by Sazykin V. L. is considered for the best possible estimate of the comparable points [9]. This makes it possible not only to identify the best one in the group but also to estimate more accurate rating for each point.

The experts use various indicators that could cluster by certain criteria for analytical assessment of the infrastructure development level. The exclusivity of the assessment of transport infrastructure is that it analyzes diverse and interrelated indicators simultaneously. The basic model, in turn, reflects economic and social indicators. Applying the model of integral assessment is aimed at similar points.

Let's apply the method of integral assessment that allows a more accurate assessment of the best one among the compared objects on the example of road infrastructure.

Let's form the group of points serving as input data for further calculations (table 1).

Table 1 **A system of indicators reflecting the level of the road infrastructure development**

Indicator	Comparative review
P_1	Gas stations, un.
P_2	The length of public roads, thousand km
P_3	Road haulage, million ton-kilometres
P_4	Cargo transportation, million ton
P_5	Carriage of passengers by road transport (buses) inter-city, thousand
P_6	Carriage of passengers by road transport (buses) international lines, thousand

Source: compiled by author

It should be noted that data from 24 regions of Ukraine were used for comparative analyses of road infrastructure indicators (table 2).

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Table 2 **Objects for comparative analyses of road infrastructure indicators**

No	Regions	No	Regions
R_1	Vinnytsia region	R_{13}	Mykolaiv region
R_2	Volyn region	R_{14}	Odesa region
R_3	Dnipro region	R_{15}	Poltava region
R_4	Donetsk region	R_{16}	Rivne region
R_5	Zhytomyr region	R_{17}	Sumy region
R_6	Zakarpattia region	R_{18}	Ternopil region
R_7	Zaporizhzhia region	R_{19}	Kharkiv region
R_8	Ivano-Frankivsk region	R_{20}	Kherson region
R_9	Kyiv region	$R2_1$	Khmelnytskyi region
R_{10}	Kirovohrad region	R_{22}	Cherkasy region
R_{11}	Luhansk region	R_{23}	Chernivtsi region
R_{12}	Lviv region	R_{24}	Chernihiv region

Source: compiled by author

After forming the group of objects and the group of indicators that would be used for comparison, let's fill in the table of absolute deviations with the value of indicators necessary for the calculation. Since we chose the value reflecting the highest possible level for comparison, the unit of measurement called 'an average reference value' was introduced. It was obtained by dividing the indicator in Ukraine on the whole by the number of the regions researched, with the deletion of other segmentation (Table 3).

Table 3 **Absolute deviation of the logical group indicators from an average reference value (Ma), of road infrastructure in Ukraine**

Regions	Indicator					
	P_1	P_2	P_3	P_4	P_5	P_6
R_1	35,75	2,40	-1219,80	-21,03	2160,26	-77,05
R_2	-101,25	-0,80	-232,55	-36,83	4486,36	80,25
R_3	200,75	2,60	2135,15	274,17	2019,86	-78,25
R_4	-43,25	1,50	-877,25	62,47	-2238,34	-40,85
R_5	-41,25	1,80	-1885,2	-6,93	216,46	-72,75
R_6	-30,25	-3,20	2070,25	-41,43	-2494,84	6,75
R_7	19,75	0,20	-1503,30	-19,53	-947,94	-86,95
R_8	-96,25	-2,50	-1516,50	-38,23	275,06	55,95
R_9	192,75	2,00	3346,35	6,07	3396,86	-83,05
R_{10}	-77,25	-0,40	-1420,80	-1,03	-3300,84	-97,95
R_{11}	-175,25	-2,20	-2520,40	-45,53	-4266,44	-43,05
R_{12}	101,75	1,60	2314,75	-24,43	8357,86	306,75
R_{13}	-25,25	-1,80	-1346,10	-28,93	-1554,74	-71,55
R_{14}	133,75	1,50	825,95	-21,23	2055,26	13,75
R_{15}	22,75	2,30	-270,05	121,57	-2491,84	-79,35
R_{16}	-97,25	-1,50	-848,05	-33,13	3377,46	-37,35
R_{17}	-112,25	0,20	-2112,60	-37,53	-2013,94	-92,65
R_{18}	-84,25	-1,60	-1621,80	-31,83	1213,76	-64,45
R_{19}	232,75	2,80	1551,050	-17,43	-532,94	102,65
R_{20}	-61,25	-1,60	-1631,90	-36,23	-1054,04	-94,65
R_{21}	-30,25	0,50	-899,85	-16,73	-762,84	-93,05
R_{22}	-17,25	-0,60	478,05	-7,53	-2270,24	-97,95
R_{23}	-92,25	-3,70	-1577,40	-43,23	-2749,24	-55,85
R_{24}	-91,25	0,60	-1730,60	-38,33	-2692,94	-29,35
Ma	270,25	6,60	3002,85	50,23	4977,34	97,95

Source: calculated by author based on State Statistics of Ukraine [10]

The next stage of our calculation is to find the deviation of the comparative values from the average reference value, in percentage, in consideration of the sign, the value obtained on a formula:

$$Ri = \frac{Ma - Pi}{Ma} * 100,$$ (1)

where   Ri – the deviation when compared the average reference value to a selected indicator, in percentage;
Ma – an average benchmark;

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Pi – the value of an individual indicator.

In doing so, the calculated by us indicator Ma reflects the value of the highest level (the average reference value).

As there are indicators whose value is "less equal best" (for example, the number of accidents) for a particular group of objects considered while researching the road infrastructure, the formula would be as follows:

$$R_i = \frac{Pi - Ma}{Ma} * 100, \qquad (2)$$

After all values Ri was found, let's calculate the outcome indicator – the object's rating ®, on a formula:

$$R = \frac{1}{n}\sum_{i=1}^{n} Ri \qquad (3)$$

where n – is the number of objects in the group.

If the indicators in the group are not considered to be equal it is necessary to use the formula which has the form:

$$R = \sum_{i=1}^{n} Ri * Vi, \qquad (4)$$

where Vi is the normed values of all indicators, thus the sum of all values is 1.

After a comparison of the values obtained, we have the deviation from the average reference value, as a result of improvement or deterioration for each object (table 4).

Table 4 **Standardized deviations of indicators' values from the average reference value of the objects' ratings (Ma) of the road infrastructure in Ukraine, %**

Regions	The name of the criterion						The algebraic sum of standardized deviations	Benchmark
	P1	P2	P3	P4	P5	P6		
R1	13,2	36,3	-40,6	-41,9	43,4	-78,7	-68,2	-11,4
r2	-37,5	-12,1	-7,7	-73,3	90,1	81,9	41,4	6,9
R3	74,3	39,4	71,1	545,8	40,6	-79,9	691,3	115,2
R4	-16,0	22,7	-29,2	124,4	-45,0	-41,7	15,2	2,5
R5	-15,3	27,3	-62,8	-13,8	4,3	-74,3	-134,5	-22,4
R6	-11,2	-48,5	68,9	-82,5	-50,1	6,9	-116,4	-19,4
R7	7,3	3,0	-50,1	-38,9	-19,0	-88,8	-186,4	-31,1
r8	-35,6	-37,9	-50,5	-76,1	5,5	57,1	-137,4	-22,9
r9	71,3	30,3	111,4	12,1	68,2	-84,8	208,6	34,8
R10	-28,6	-6,1	-47,3	-2,1	-66,3	-100,0	-250,3	-41,7
R11	-64,8	-33,3	-83,9	-90,6	-85,7	-43,9	-402,4	-67,1
R12	37,7	24,2	77,1	-48,6	167,9	313,2	571,4	95,2
R13	-9,3	-27,3	-44,8	-57,6	-31,2	-73,0	-243,3	-40,6
R14	49,5	22,7	27,5	-42,3	41,3	14,0	112,8	18,8
r15	8,4	34,8	-9,0	242,0	-50,1	-81,0	145,2	24,2
R16	-36,0	-22,7	-28,2	-66,0	67,9	-38,1	-123,2	-20,5
R17	-41,5	3,0	-70,4	-74,7	-40,5	-94,6	-318,6	-53,1
R18	-31,2	-24,2	-54,0	-63,4	24,4	-65,8	-214,2	-35,7
R19	86,1	42,4	51,7	-34,7	-10,7	104,8	239,6	39,9
R20	-22,7	-24,2	-54,3	-72,1	-21,2	-96,6	-291,2	-48,5
R21	-11,2	7,6	-30,0	-33,3	-15,3	-95,0	-177,2	-29,5
R22	-6,4	-9,1	15,9	-15,0	-45,6	-100,0	-160,2	-26,7
R23	-34,1	-56,0	-52,5	-86,1	-55,2	-57,0	-341,0	-56,8
R24	-33,8	9,1	-57,6	-76,3	-54,1	-30,0	-242,69	-40,5
Ma	270,3	6,6	3002,8	50,2	4977,3	98,0	x	x

Source: compiled by author

The deviations are calculated to fulfill the function of standardization (rationing), since the calculations may use indicators different in meaning (intensive, extensive, absolute, and others). The algebraic sum of standardized deviations calculated for each object is the overall rating for this object. It characterizes to what percent the object deviates from the average, noting that the rating of the object for comparison is zero. The overall rating in the result of division into the number of the indicators makes it possible to calculate the average reference rating for each object.

Let's form a discrete vibrational range using the data obtained.

To that end, let's sort the range in ascending order (table 5).

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Table 5 **The calculation of the central points of analytical assessment of the road infrastructure efficiency in Ukraine**

x	|x - xj|	(x-xj²)
-67.07	57.47	3303.33
-56.83	47.23	2231.11
-53.1	43.5	1892.65
-48.53	38.93	1515.9
-41.72	32.12	1031.99
-40.55	30.95	958.19
-40.45	30.85	952.01
-35.7	26.1	681.45
-31.07	21.47	461.16
-29.54	19.94	397.79
-26.69	17.09	292.22
-22.91	13.31	177.28
-22.42	12.82	164.47
-20.53	10.93	119.57
-19.4	9.8	96.13
-11.36	1.76	3.11
2.53	12.13	147.03
6.9	16.5	272.1
18.8	28.4	806.3
24.2	33.8	1142.13
34.77	44.37	1968.29
39.93	49.53	2452.77
95.23	104.83	10988.37
115.22	124.82	15578.89
-230.29	828.69	47634.21

Source: compiled by author

Let's find out the indicators of the distribution center to assess the rage of distribution:

$$\bar{x} = \frac{\sum x_i + f_i}{\sum f_i}, \qquad (5)$$

Mode as the most common value of the sign of these data items, where x0 - is the beginning of the modal interval; h - is the value of the interval; f2 is the frequency respective to the modal interval; f1 is the pre-modal frequency; f3 is the after-modal frequency:

$$M_o = x_0 + h\frac{f_2 - f_1}{(f_2 - f_1) + (f_2 - f_3)}, \qquad (6)$$

The median divides the sample into two parts: one half is the variant less than the median, the other one is more. Let's calculate the median (Me) as the value of the sign for the middle of the ranked (structured) data:

$$M_e = x_0 + i + \frac{\frac{\sum f_i}{2} - S_{m-1}}{f_m}, \qquad (7)$$

Where Me is the required median; x0 is the lower limit of the interval, which contains the median; h - is the value of the interval; ∑fi is the sum of the frequencies or the number of members; Sm-1 is the sum of the accumulated intervals' frequencies before the median; ʃm is the frequency of the median interval.

Let's calculate the width of the variation as the difference between the maximum and minimum value of the primary data R=Xmax - Xmin

To take into account the differences in all these data items, let's calculate the average linear deviation.

$$d = \frac{\sum|x_i - \bar{x}| * f_i}{\sum f_i}, \qquad (8)$$

Using dispersion, we characterize the limits of spread about its mean:

$$D = \frac{\sum(x_i - \bar{x})^2 * F_i}{\sum f_i} \qquad (9)$$

The calculations made gives the following results: the weighted average is 9,6; the mode is absent as there are several indicators with the same value; the range comprises the even number of units, thus the median is identified as an average from two central values -22,6; the width of the variation is182,3; the average linear deviation is 34,53. Each value of the range differs from the other one by 34,5 on average; the dispersion is 1984,8; the average quadratic is 44,5, so each value of the range differs from the average value- 9,6 by 44,5 on average.

The analytical assessment of the researched objects of the road infrastructure in 24 regions of Ukraine illustrates the level of distribution of the sustainable development centers. Thus, by the results of the calculations Dnipro

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region, Lviv region, Kharkiv region, Kyiv region, Poltava region have entered the rating of Top-5 regions formed by us. They have the positive largest from the average reference value (table 6).

Table 6 **Top -5 regions leaders and outsider by the level of development of the road infrastructure in Ukraine**

Rating	Regions of Ukraine	Anti rating	Regions of Ukraine
1	Dnipro region	1	Lugansk region
2	Lviv region	2	Chernivtsi region
3	Kharkiv region	3	Sumy region
4	Kyiv region	4	Kherson region
5	Poltava region	5	Kirovograd region

Source: compiled by author

The leader of our rating is the Dnipro region, which claims to be the economic locomotive of Ukraine. The region has strong industrial and economic potential, high population rate which has caused the development of different types of transport communication. Lviv region is also the center of industrial and agricultural development. It is one of the most densely populated in Ukraine, has its recreation zones, borders on the Republic of Poland in the west. Kharkiv region and Poltava region also differ by the level of economic development and border on the Dnipro region on the north. Kyiv region is a large center of the development of industrial, economic, scientific progress with the administrative unit in the city of national importance, which is Kyiv (the capital of Ukraine).

The anti-rating is headed by the Lugansk region, which is located on the territory of the military actions since 2014. All the regions from the anti-rating have the same negative features, like narrow specialization or orientation of industry on imported raw materials; outdated technologies; dangerous production, and low demand as a result. The transport communication contains transit routes, unlike the top-5 leaders with the routes of national and international importance.

Subsequently, the methodology for applying (DEA) model may also be used to compare the level of development of several infrastructure industries to identify the most promising ones and to form the strategic objectives for sustainable development. In our study [8] the method of Data envelopment analysis (DEA) allowed a more accurate assessment of the best one among the compared objects on the example of road infrastructure. The analytical assessment of the researched objects of the road infrastructure in 24 regions of Ukraine by the method of Data envelopment analysis illustrates the level of distribution of the sustainable development centers (table 7).

Table 7 **Top regions leaders and outsider by the level of development of the road infrastructure in Ukraine CRS**

Rating	Regions of Ukraine	
	max Technical Efficiency CRS	min Technical Efficiency CRS
Road haulage	Zakarpattia region	Luhansk region
Cargo transportation	Dnipro region	Luhansk region
Carriage of passengers by road transport (buses) inter- city	Rivne region	Luhansk region
Carriage of passengers by road transport (buses) international lines	Lviv region	Cherkasy region

Source: compiled by author based on [8]

Thus, by the results of the calculations Zakarpattia region, Dnipro region, Rivne region, Lviv region have entered the rating of max TECRS regions formed by us those have the positive largest.

Despite the presence of the negative indicators which put regions into anti-rating, each of them has its features. At the same time with the critical assessment, the result may become the base for detecting the regions ready to develop towards unlocking its potential: recreation activities, green tourism, organic production, green energetics. Transport communication as a strategically necessary component able to provide a high level of development in any of the potential areas. As to ensure our conclusions, the Trans-European Transport Network

(TEN-T) policy addresses the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports, and railroad terminals. The ultimate objective is to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic, and territorial cohesion in the EU. Besides the construction of new physical infrastructure, the TEN-T policy supports the application of innovation, new technologies, and digital solutions to all modes of transport. The objective is improved use of infrastructure, reduced environmental impact of transport, enhanced energy efficiency, and increased safety [11].

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Conclusions. Thus, the proposed basic model has allowed allows assessing the level of current infrastructure condition, identifying the causes of negative phenomena in a region, indicating the activities to prevent them. The practical value of the research is that the given basic model can be used for analytical assessment of separate indicators and the groups of indicators but also the region as a whole. The use of the integral assessment method in identifying qualitative indicators allows further detailed indicators; their modification influences the total level of the object development. Only one element of the system of infrastructure provision was considered, which except road infrastructure also includes railway, air, river and sea transport, utilities infrastructure, electricity and water supply, information infrastructure (mobile communication and internet). To make strategic decisions it is necessary to conduct a complex assessment of all the above elements. This proves the relevance of the topic and defines the direction of our further researches.

Research is a conscious and directed effort to increase understanding and discover new and better ways to achieve goals. The implementation of innovation in an industry is determined by factors that accumulate internal and external capabilities. In turn, investments are considered to be the most important tool for creating conditions for economic development countries.

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