13. Krchova, Z. Aggressive behavior of drivers in Slovakia affecting road safety [Text] / Z. Krchova // Transport problems. – 2012. – Vol. 7, Issue 2. – P. 111–116.
14. Oven, S. Survey and evaluation of fatigue assessment software [Electronic resource] / S. Oven // Project, Fall. – 2009. – P. 30. – Available at: http://www.utmis.org/sv/aktuellt/Documents/Oven_Project(2).pdf
15. Guzek, M. Research on behaviour of drivers in accident situation conducted in car driver simulator [Text] / M. Guzek, R. Jurecki, Z. Lozia, T. Stanczyk, P. Zdanowicz // Journal of KONES. Powertrain and transport. – 2009. – Vol. 16. – P. 173–184.
16. De Winter, J. C. F. Relationships between driving simulator performance and driving test results [Text] / J. C. F. de Winter, S. de Groot, M. Mulder, P. A. Wieringa, J. Dankelman, J. A. Mulder // Ergonomics. – 2009. – Vol. 52, Issue 2. – P. 137–153. doi: 10.1080/00140130802277521
17. Zhuk, M. Metodyka doslidzhen vplyvu psykhofiziolohichnykh osoblyvostei vodiia na chas yoho reaktsii u realnykh umovakh [Text] / M. Zhuk, V. Kovalyshyn // Komunalne hospodarstvo mist. – 2012. – Issue 103. – P. 479–484.
18. Dolya, V. Influence of information load on the basic parameters of drivers activity (exciting process) [Text] / V. Dolya, I. Enhlezi, I. Afanasieva // Eastern-European Journal of Enterprise Technologies. – 2011. – Vol. 1, Issue 2 (49). – P. 65–68. – Available at: http://journals.uran.ua/eejet/article/view/1887/1782
19. Havrylov, E. V. Systematolohiya na transporti [Text]: pidr. / E. V. Havrylov, M. F. Dmytrychenko, V. K. Dolya et. al.; M. F. Dmytrychenko (Ed.) // Erhonomika. – Kyiv: Znannya Ukrayiny, 2008. – 256 p.
20. Jamraz, K. Macro model of seat belt use by car drivers and passengers [Text] / K. Jamraz // Transport problems. – 2013. – Vol. 8, Issue 4. – P. 103–114.

UDC 656.025.2: 519.852.35
DOI: 10.15587/1729-4061.2017.98118

ESTIMATION OF TRANSPORT ACCESSIBILITY OF THE CAPITAL ECONOMIC REGION

O. Matiychyk
Senior Lecturer*
E-mail: matiychykalyona1983@gmail.com
A. Babenko
PhD**
E-mail: ababenko@nau.edu.ua
P. Yanovsky
PhD, Associate Professor*
E-mail: niklu@ukr.net
L. Sulyma
PhD, Associate Professor*
E-mail: m1la1@mail.ru
*Department of Air Transportation***
**Center of Advanced Technologies
***National Aviation University
Kosmonavta Komarova ave., 1,
Kyiv, Ukraine, 03058

Визначено методику для обчислення транспортної доступності регіону. Обґрунтовано вибір Столичного економічного району як регіону для визначення транспортної доступності. Адаптовано іноземний підхід до обчислення транспортної доступності Столичного економічного району України. Формалізовано вираз для обчислення потенційної транспортної доступності. Розроблено шкалу рівнів доступності. Проведено кількісну оцінку значень транспортної доступності міст регіону відносно столиці

Ключові слова: транспортна доступність, транспортне планування,транспортна мережа, автомобільний транспорт

Определена методика измерения транспортной доступности региона. Обоснован выбор Столичного экономического района как региона для определения транспортной доступности. Был адаптирован иностранный подход к измерению транспортной доступности Столичного экономического района Украины. Формализовано выражение для измерения потенциальной транспортной доступности. Разработана шкала уровней доступности. Проведена количественная оценка значений транспортной доступности городов региона относительно столицы

Ключевые слова: транспортная доступность, транспортное планирование, транспортная сеть, автомобильный транспорт

1. Introduction

Modern researchers utilize various approaches and indicators for analyzing the state of transport systems development. Among other indicators that combine technical and economic influence, the indicator of transport accessibility should be highlighted.

Transport accessibility (TA) as the indicator of efficient functioning of transport systems is used to define the attractiveness of the region for passengers with regard to location of main transport nodes. The given indicator reveals the efficiency of capital investment into transport infrastructure projects. TA is an essential element of planning and development of the national transport system (TS).

Transport systems should provide equal opportunity for movement to all social groups for various distances and under the condition of satisfying different activity needs. Still, this fact is often overlooked by transport industry managers in Ukraine.

Theoretically, the effect from improved transport accessibility allows implementation of more efficient solutions to transport problems, and so enables efficiency improvement of the Ukrainian transport system [1].

Agreeable level of accessibility to transport services in the country demonstrates the level of integration of the national transport system. The indicators of transport accessibility are composed of several elements and can be estimated in many ways. TA can be employed in evaluation of transport system efficiency [2].

Revealing the shortcomings in the operation of transport systems facilitates designing the sum of such actions of coordination, management and organization of the elements of a transport system that will improve transport system efficiency [3].

To carry out research of TA of the individual region of Ukraine, the Capital Economic Region as the region with the highest potential of export-import services was chosen. In contrast, the Donetsk Economic Region by 2012 was characterized by the highest indicators of economic development of the country. In the face of the challenging geopolitical situation in the region since early 2013, today the Capital Economic Region shows the highest competitiveness and economic efficiency among all economic regions of Ukraine. However, problems of transport infrastructure development may become the cause of slowing down the sustainable development of the Capital Economic Region [4].

Current scientific research does not propose such a methodology of estimating TA of the region that allows evaluation of efficiency of transport operation from the user's point of view. Using the case of the Capital Economic Region, it is necessary to estimate the transport accessibility of the region by road passenger transport and validate the applied methodology.

2. Literature review and problem statement

Present direction in research of TA is primarily focused on urban transport systems. The given city acts as the subject of investigation, whereas the urban transport system becomes the object of research like, for instance, in the paper [5]. A typical case is evaluation of accessibility based on the study of urban public transport. In particular, in the study [6] the authors performed evaluation of TA for the city of Riga. In the paper [7] modeling of TA was conducted to forecast the effects from the future infrastructure on accessibility in Edinburg, United Kingdom. The aim of the authors in the work [8] is the study of the level of potential TA for various social groups in relation to the possibility of travel for education and work in the city-region of Bogota, the capital of Colombia.

Besides, some authors offer adapted models of TA indicators. Namely, in the paper [9] validation and comparison of two accessibility indicators (potential and adapted) were suggested to evaluate different policy scenarios in the context of TA research for the city of Madrid (Spain).

It is also determined that research of TA is performed for individual countries. Thus, in the paper [10] the researchers modeled and evaluated accessibility for the Netherlands based on the land use and transport interaction model TIGRIS XL.

It should be noted that in some of the given studies the network of high-speed railways was chosen as the subject of research. In particular, in the paper [11] the impact from high speed railway network development in urban areas of Spain on transport accessibility and efficiency was studied. In the paper [12] assessment of the influence of the high-speed railway connections development on the accessibility of South Korea over the period from 2004 to 2018 was performed. In the work [13] the investigation of the impact of high-speed railways on railway transport accessibility in China was carried out.

The paper [14] explains how the level of development of the transport systems of the given country in the given region performs a “spillover effect” on TS of neighboring countries and promotes their mutual integration of transport systems of these states.

Several studies are devoted to investigation of transport accessibility of the given transport mode without linking it to the specific city, region or country. Thus, in the paper [15] the problem of improving the accessibility of public transport was solved through development of the concept of universal accessibility. The results of the research into the potential influence on accessibility by way of improvement and development of European railway transport are presented in the work [16]. Analysis of air transport accessibility based on economic indicators of the studied regions is suggested in the paper [17].

Some researchers develop new concepts of transport accessibility evaluation and/or improve the existing concepts. In this way, the study [18] offers a new approach to modeling the functions of distant interaction for evaluation of transport accessibility. The authors of the paper [19] designed a new concept of digital city accessibility based on the potential measure of accessibility.

Regional level of passenger transport operation was considered in the paper [20]. The need for using the “minimal transport standard” as the instrument for evaluation and management of regional transport infrastructure development was justified.

Improvement of transport infrastructure was studied in the work [21] as the factor of change in management of the regional economic activity. The paper [22] investigated the effect of transport networks in the region on the spatial distribution of economy. The majority of research papers was published before 2002, or studied the matter of transport accessibility in the context of high speed railways.

Therefore, a need arose to improve the methodology of estimating road TA of the region with application of the selected methodology of evaluating TA of regions of Ukraine.

3. The aim and objectives of the research

The aim of the given study is estimation of potential transport accessibility by road passenger transport.

To attain the aim, the following objectives were identified:

– to define the methodology of estimating transport accessibility of the region by road passenger transport and its applicability to the Capital Economic Region of Ukraine;

– to calculate potential transport accessibility the Capital Economic Region of Ukraine;

– to validate and develop the scale of evaluating TA of the Capital Economic Region of Ukraine by road passenger transport based on the suggested methodology.

4. Economic and activity characteristics of the Capital Economic Region

4. 1. Potential of the Capital Economic Region for generation of passenger transportation demand

Approach to the economic and geographic zoning of Ukraine in [23] allows separating the region for performing the investigation, namely the Capital Economic Region, which Zhytomyr, Chernihiv and Kyiv oblasts.

The Capital Economic Region with the center located in the city of Kyiv is the region with varied innovative types of economic and social activities, with a high rate of labor migration, and solid socio-cultural relations [24].

According to informational data in open access, we will consider the economic potential of every oblast, which is included into the region under study (Fig. 1).

Zhytomyr Region

Geographically, Zhytomyr region is a border region, which neighbors to the north with the Republic of Belarus. Zhytomyr region includes 23 administrative districts, 12 cities, 5 of which are of district significance.

Zhytomyr region has a forked network of state and local road levels with a total length of 8.5 ths km.

The areas of international road transport corridors pass through the territory of the region. International Automobile path Kyiv-Chop (M-06) of 846.2 km length is an important part of the Ukrainian road network and several key international transport corridors. The road Kyiv-Chop is included in the Pan-European Corridor № 3 and № 5, the transport corridor Europe – Asia and European routes E-40, E-50 and E-573.

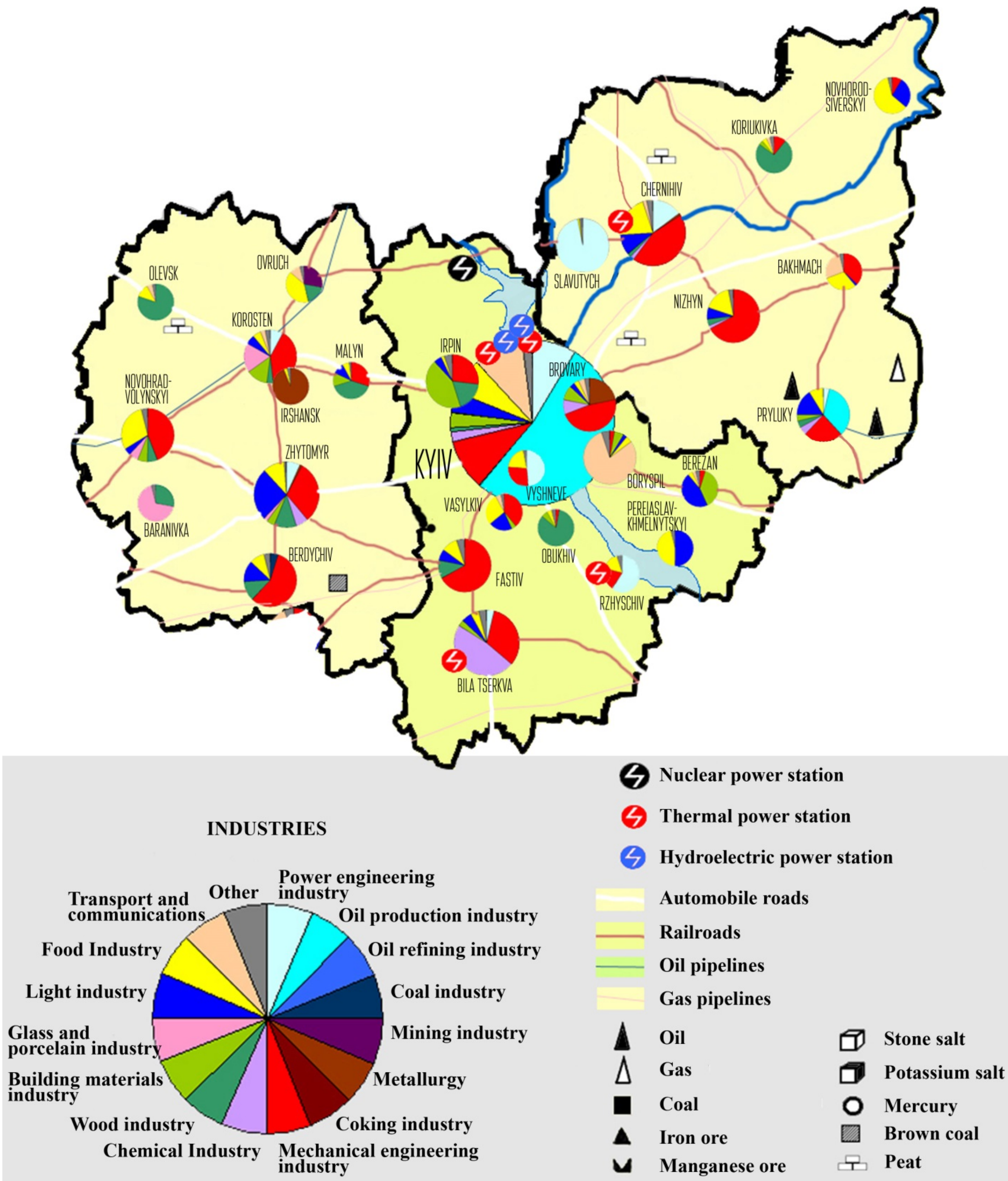

Fig. 1. Economic map of the Capital Economic Region

According to the State Statistics Service of Ukraine, as of 2016 the population of Zhytomyr region amounted to 1243 ths persons and net migration amounted to 1.8 ths persons.

In 2016, about 400 companies with foreign capital were formed and function in Zhytomyr region.

Zhytomyr region possesses a great cultural heritage. The region employs more than 3000 cultural institutions. General secondary education is represented by 805 secondary schools.

Kyiv Region

Kyiv region consists of 26 cities, including 13 regional centers and 13 of district significance. The peculiarity of Kyiv region is that Kyiv city, with the main authorities, is not included as administrative part of the region. In 2016 the population amounted to 1734 ths persons.

According to 2016, industrial complex of Kyiv region consisted of 22 large companies, 354 medium and 2.391 small.

The international transport corridors № 3, № 7 and № 9, railroads by 5 trunk routes and other state and regional networks of transport routes pass through the territory of Kyiv region.

The region has the largest in Ukraine International Airport State Enterprise "Boryspil International Airport".

The length of railways of Kiev region, without taking into account access roads equals 794 km and the total operational length – 1100 km.

Trypilska TPP, Kyiv HPP, Kyiv PSPP are located in the region.

Higher education in the Kiev region can be received in 29 universities of different types and levels of accreditation.

The best tourist and cultural centers of Kyiv region are the city of Bila Tserkva, Boryspil, Pereyaslav-Khmelnytsky and Rzhyschiv.

Chernihiv Region

Chernihiv region consists of 16 cities (4 of regional and 12 of regional significance) and is located in the northeastern part of Ukraine.

The population of Chernihiv region in 2016 amounted to 1036 ths persons.

The length of public roads in 2016 amounted to 7.722.0 km. The main transport hub of Chernihiv region is the Chernihiv city, with the main international railways and trunks.

63 state highways pass the territory of the region, two of which (M-01 and M-02) are a part of the international transport corridor №9 and European highways E-95 and E-101.

On the territory of Chernihiv region, there are 4 reserves, 32 museums of different ownership, 6 sanatoriums and treatment and rehabilitation centers and about 20 institutions of rehabilitation and recreation for children.

Industrial centers of the region are the cities of Chernihiv, Pryluky and Nizhyn.

The higher education system in the region is represented by 23 state universities of different levels of accreditation, and single private institution of higher education – Pryluky financial and legal college.

Consequently, based on the analysis of potential of the studied region, we assume that the demand for regional passenger services is generated only by cities of regional and district significance.

4. 2. Activity types of the population of the Capital Economic Region

From the characteristics of economic potential of the Capital Economic Region, it can be asserted that the region offers differentiated activities that can be performed by its population: work, education, recreation, etc.

These activity types serve the foundation for the choice of the type of TA indicator for the given regional TS. All activity types of the population were grouped for further usage on the stage of calculating the activity function.

Classification of the activity types that generate demand for travel includes:

1) tourist needs (number of parks, wildlife reserves, architectural sites, recreational areas, holiday camps);

2) cultural needs (number of theaters, libraries, museums, exhibitions, galleries, philharmonics);

3) needs related with labor activity (number of enterprises in the region);

4) educational needs (number of higher educational institutions, secondary schools, out-of-school educational institutions);

5) administrative and social needs (administrative bodies, public organizations, local social service centers);

6) medical service needs (public health care centers).

The following stage of accessibility estimation lies in the researcher's choice of the type of regional transport accessibility indicator and formalization of the activity function and the impedance function for performing evaluation of TA. The most applicable, from the point of open access data collection and interpretation of findings, can be the indicator of potential transport accessibility. According to the proposed approach, Euclidean distance is designated as the impedance function.

5. Research findings on potential transport accessibility of the Capital Economic Region

5. 1. Classification of accessibility indicators for regional transport systems

Creation of a comprehensive classification of transport accessibility indicators for regional transport systems is a prerequisite to the choice of the methodology for estimation of TA of the region.

Different indicators are used to obtain results of TA calculations for urban and public passenger transport. Indicators of TA ensure evaluation of various parameters of the state of transportation network and drawing conclusions on the shortcomings of the TS based on the given parameters.

There are several approaches to breakdown of TA indicators. In particular, the indicator of integral transport accessibility (ITA) in the work [25] reflects the level of transport supply in the given region. Thus, integral transport accessibility is perceived as the degree of coverage of the given territory by the transportation network disregarding the accessibility of particular destinations. According to another approach in the work [26], transport accessibility is grouped into temporal and metrical transport accessibility. These types of TA allow estimating the number of people who are able to satisfy their need for passenger travel over a definite interval of time or within the zone under study (within an isochrone).

Given the limitations of the above classifications and based on the analyzed papers, the classification of TA indicators for regional transport systems was organized. TA was categorized into relative TA, integral TA, travel cost, potential TA and daily TA (Fig. 2).

Relative TA shows how good is the connection between any two transport nodes within the region under study. It can be calculated according to the formula suggested in the paper [27]:

$$A_i = C_{ij}, \qquad (1)$$

where C_{ij} is the degree of spatial separation of the connection between i and j transport nodes.

The concept of relative TA can be defined as the cost and effort required to perform the given travel.

There is the principal difference between relative and integral TA. Integral TA reveals the relation between the given node and other relative nodes within a spatial set. Therefore, integral TA accounts for the opportunities of travel for users of the transportation network. The formula of integral TA for the node proposed by the authors in the paper [27] can be represented as:

$$A_i = \sum C_{ij}. \qquad (2)$$

Different types of accessibility indicators can be built through identification of various forms of activity functions $g(W_j)$ and impedance functions $f(c_{ij})$.

Travel cost is based on the assumption that not all transport nodes in the region contribute to the degree of accessibility of the region. For example, the set of the cities that form attractiveness of the given region can be limited by the indicator of size of destination $W_j$or level of its attractiveness W_{min}.

Travel cost estimates the accumulated total cost required for travel to the given set of transport nodes. In simple expression, estimation of travel cost does not depend on the size of the transport node.

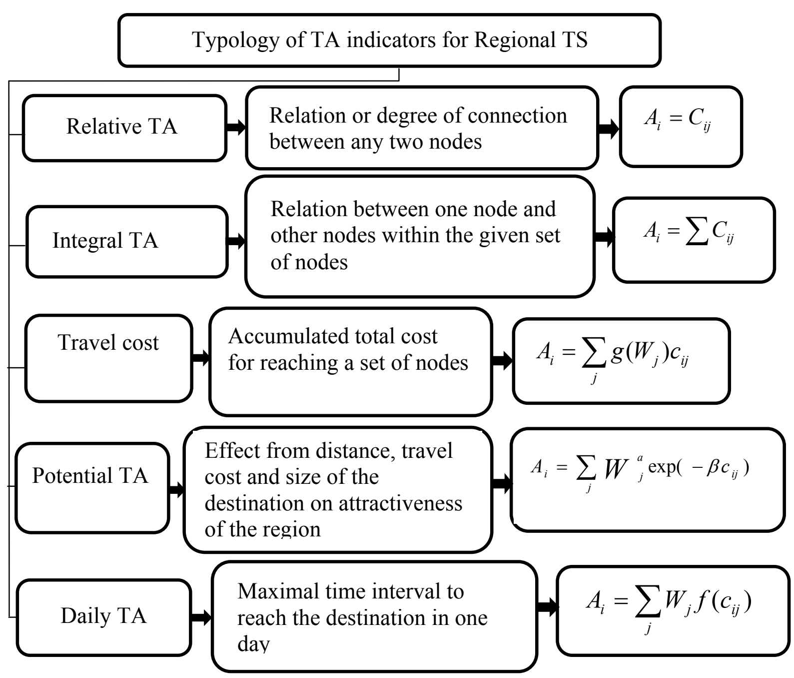

Fig. 2. Classification of transport accessibility indicators for regional transport systems

In the paper [28] the formula of calculating the travel cost is represented as:

$$A_i = \sum_j g(W_j) \times c_{ij}. \qquad (3)$$

The impedance function is defined in the following way:

$$g(W_j) = \begin{cases} W_j \,|\, 1, & \text{if } W_j \geq W_{min}, \\ 0, & \text{if } W_j < W_{min}. \end{cases} \qquad (4)$$

According to the formula (3), the lower is the value of attractiveness of the transport node, the higher is the degree of accessibility of the region.

The foundation for estimation of potential TA was the assumption that the attractiveness of the destination increases with the increase in size and decreases as the distance from it increases. The size of destination depends on economic indicators of regional development, like GDP, population, income, etc.

The activity function can be linear or non-linear. The general representation of the activity function is [28]:

$$A_i = \sum_j W_j^a \exp(-\beta c_{ij}). \qquad (5)$$

The agglomeration effect is considered in the given type of TA and is signified in the formula by parameter a. Parameter β indicates that the neighboring destinations exercise a larger influence than the destinations which are separated.

Daily TA shows the maximum time that is required to reach the given destination and return to the point of origin in one day. A business trip with the necessity to start off in the morning and come back in the evening serves a perfect illustration of daily TA.

The suggested classification of TA indicators in the given investigation is used as the foundation of the methodology of estimating the potential TA of the Capital Economic Region.

5. 2. Formalized model for estimation of potential transport accessibility

In general, the aim of evaluating TA is reduced to solution of the accessibility function. The accessibility function is a construct of two functions. The first function is the activity function. The activity function describes those activities and opportunities that can be reached within the destination node. This function represents for the goals possible to be attained in relation to the destination node. The second function is called an impedance function that refers to particular cost necessary to reach the goals of travel [29]:

$$A_{gen\_i}(g(O_j), f(c_{ij})) = g(O_j) \cdot f(c_{ij}), \qquad (6)$$

where g (O_j) refers to the activity function; O_j are the aims of travel in relation to the destination node j; f (c_{ij}) is the impedance function; c_{ij} is the impedance (constraint) parameter, i. e. the cost, for instance, travel cost, time, expenses, distance between the nodes, etc.

The prerequisite to gravity of passenger traffic between the nodes is:

$$A_{gen\_i}(g(O_j),f(c_{ij}))>0.$$

Based on the mathematical expression of the generalized TA, we can formalize the equation for calculation of potential TA for the region by road transport in relation to one of the objectives of the given research.

5. 3. Potential transport accessibility of the Capital Economic Region (road transport)

Numerical (quantitative) estimation of potential transport accessibility can be performed based on the formula (1). To carry out numerical estimation of potential transport accessibility, data availability is the necessary condition. Thus, we will enter the following notation: S_f – a set of data available in open access.

The function of potential TA by road transport for every oblast in the Capital Economic Region shall be estimated. To accomplish this objective, the activity function is defined as the sum of all activities that generate travel demand to the destination node j:

$$g(O_j)=\sum_{\forall j} O_j=\sum_{b=1}^{n}\sum_{m=1}^{k} D_{pj},\ \forall D_p \in S_f, \tag{7}$$

where D_{pj} is the classified aim of travel; m=1,...,k – the number of identified classes of travel; b=1,...,n – the number of the objects that generate the given class of travel.

The impedance function c_{ij}will be represented as the Euclidean distance between i and j:

$c_{ij}=e_{ij}=e(i, j)$;

$e_{ij}=e(i, j)$ is the Euclidean distance (graph edge) between the regional center and the satellite city.

Then the impedance function can be written as [29]:

$$f(c_{ij})=f(e_{ij}(i,j))=\exp\left(-\beta\cdot e_{ij}(i,j)\right). \tag{8}$$

The final formula of potential transport accessibility by road transport based on the developed classification of travel demand for the oblast in relation to the center of oblast and to the satellite cities will be written as:

$$A_{pot\_i}\left(D_{Tj},D_{Cj},D_{Lj},D_{EDj},D_{ADj},D_{Mj},e_{ij}(i,j)\right)=$$
$$=\left(\sum_{\forall Tj} D_{Tj}+\sum_{\forall Cj} D_{Cj}+\sum_{\forall Lj} D_{Lj}+\right.$$
$$\left.+\sum_{\forall EDj}+D_{EDj}+\sum_{\forall ADj} D_{ADj}+\sum_{\forall Mj} D_{Mj}\right)\times\exp\left(-\beta\cdot e_{ij}(i,j)\right),$$
$$\forall D_{Tj},D_{Cj},D_{Lj},D_{EDj},D_{ADj},D_{Mj},e_{ij}(i,j)\in S_f,\ i\neq j, \tag{9}$$

where D_{Tj}, D_{Cj}, D_{Lj}, D_{EDj}, D_{ADj}, $D_{Mj}$are the activity types available in node j.With regard to the following classification of activities, such needs generate travel demand:

D_{Tj} – tourist needs (number of parks, wildlife reserves, architectural sites, recreational areas, holiday camps);

D_{Cj} – cultural needs (number of theaters, libraries, museums, exhibitions, galleries, philharmonics);

D_{Lj} – needs related with labor activity (number of enterprises in the region);

D_{EDj} – educational needs (number of higher educational institutions, secondary schools, out-of-school educational institutions);

D_{ADj} – administrative and social needs (administrative bodies, public organizations, local social service centers);

D_{Mj} – medical service needs (public health care centers);

β refers to the parameter that reveals the sensitivity to spatial disintegration of the regional center and the satellite cities. During the work on the European project SASI [29], the researchers calculated the value of β parameter for the road transport β=0.007;

$e_{ij}=e(i, j)$ is the Euclidean distance (graph edge) between the regional center and the satellite city.

Parameter β is crucially important for estimation of potential TA. While calibrating the parameter β, researchers in the paper [29] summarized that the obtained values of the parameter β for road transport exhibited the following principle.

The more distant is the satellite city from the regional center, the less it contributes to the accessibility of the center. On par with that, the parameter β is measured in 1/km. Thus, potential TA is a non-dimensional value.

On the following stage of estimations, calculation of the Euclidean distance for connections of the district cities and regional cities with the regional center of the Capital Economic Region is absolutely necessary.

The choice of Euclidean distance as the impedance function for estimation of potential TA is motivated by the fact that Euclidean distance is the most widely used measure of distance between the objects. Euclidean distance is the geometrical distance between the objects in the multidimensional space (Fig. 3).

The formula of calculation of the Euclidean distance is written as:

$$ED=\sqrt{\sum_i (x_i-y_i)^2}, \tag{10}$$

where x_i, y_i are the geographic coordinates of the destinations i and j.

Therefore, using the formula (9), potential road transport accessibility of the satellite cities related to the regional center and the accessibility of the regional center related to the satellite cities can be calculated.

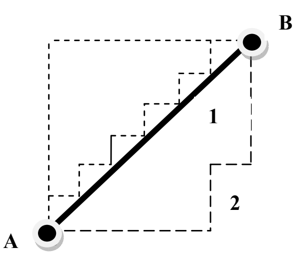

Fig. 3. Euclidean distance on a spatial scheme of distances between objects of the network: 1 – Euclidean distance by straight line; 2 – Manhattan distance or "city block distance"

The Euclidean distance is calculated by the formula (10) based on the initial data about the coordinates of the cities in connection with the regional center of Kyiv, Chernihiv and Zhytomyr regions. The data on Euclidean distance for every connection is necessary to estimate the potential transport accessibility of the district and regional cities in the relevant region of the Capital Economic Region.

The calculations were performed according to the formula (9). Using the initial data, the estimations of potential road TA for the cities of the region in relation to the regional center were carried out.

Consistent with the provisions of the "State Strategy of Regional Development for Ukraine for the period till 2020", the city of Kyiv acts as the generator of "gravity" for the entire country. So, for the Capital Economic Region, the calculations were done under the condition that Kyiv is the gravity center, instead of the regional centers of Kyiv, Chernihiv and Zhytomyr regions.

The research findings on the potential accessibility for the cities of the Capital Economic Region are presented in Fig. 4. To interpret the results of estimations of potential TA, it should be noted that this indicator is better as its numerical value increases.

Analysis of the results of TA calculations presented in Fig. 4 showed that the highest numerical values of potential TA in relation to the city of Kyiv are characteristic of Vyshneve and Vyshhorod (134013 and 132500, respectively). The lowest potential TA related to Kyiv is exhibited by Novhorod-Siverskyi (Chernihiv region) – 22212 and Olevsk (Zhytomyr region) – 24491.

Based on the obtained results of calculations, the scale for TA evaluation of the investigated region was developed. The scale consists of seven levels:

1) very low;
2) low;
3) medium-low;
4) medium;
5) medium-high;
6) high;
7) the highest.

The range of values for the mentioned above levels is shown in Table 1.

Table 1

Scale for the estimation of the level of potential transport accessibility in the Capital Economic Region

Range of Values	Level of Potential TA
0–19000	Very low
20000–39999	Low
40000–59999	Medium-low
60000–79999	Medium
80000–99999	Medium-high
100000–119999	High
120000–140000	The highest

It is considered that potential TA of the region is higher when the number of peripheral cities is low. Cities which are geographically separated from the center or have a limited number of available activities can be called peripheral.

Analysis of the potential transport accessibility calculations for the cities of the Capital Economic Region revealed more and less accessible cities by road transport.

Based on the developed scale for potential TA evaluation of the Capital Economic Region, the map of potential transport accessibility for the cities of the Capital Economic Region was created (Fig. 5).

There are six cities with the highest level of potential TA in the investigated region, which can be emphasized: Irpin – 127025, Brovary – 126572, Vyshneve – 134013, Vyshhorod – 132520, Boiarka – 125883.

Cities with a high level of potential TA are the following: Vasylkiv – 116317, Obukhiv – 111580, Boryspil – 116889 and Ukrainka with the value of 112514.

Such cities of the Capital Economic Region as Berezan, Fastiv, Bila Tserkva have medium-high potential TA with the range of values from 80000 to 99999.

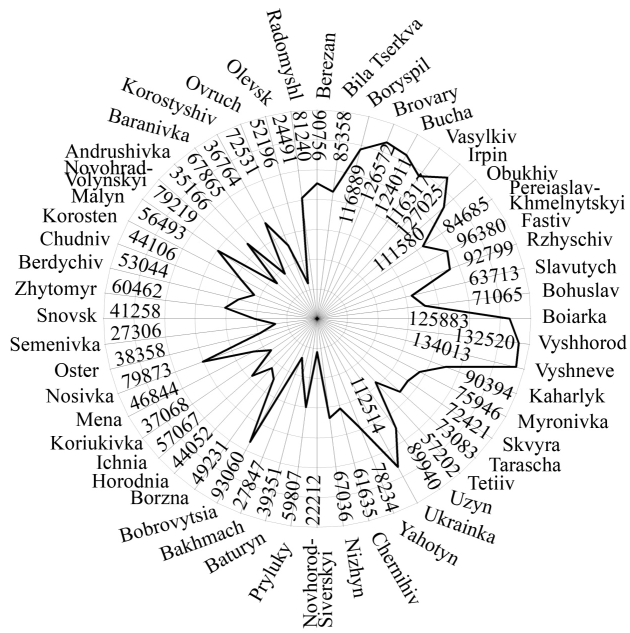

Fig. 4. Numerical values of potential transport accessibility for the cities of the Capital Economic Region

The most numerous group of cities with a medium level of potential transport accessibility includes ten cities, such as: Myronivka, Bohuslav, Tarascha, Skvyra, Andrushivka, Zhytomyr, Chernihiv, Slavutych, Nizhyn and Nosivka.

Potential TA with the medium-low level is characteristic of the following cities: Korosten – 56493, Snovsk – 41258, Malyn – 56493 and Ovruch – 52196.

Although the cities with a very low level of potential transport accessibility were not revealed in the investigated region, cities Olevsk, Baranivka, Novhorod-Siverskyi, Baturyn, Bakhmach, Oster, Koriukivka, Novohrad-Volynskyi and Semenivka have the range of values from 20000 to 39999. They are considered to be peripheral in relation to the center of the Capital Economic Region – Kyiv.

Summarizing, it can be stated, that cities with the highest level of potential transport accessibility have a high level of economic development. The population of such cities is closely connected with the center of the region and has ample opportunities for realizing various activities in the region.

Due to the spatial apartness from the center of the region, the share of peripheral cities in the Capital Economic Region equals 46 %, incorporating cities with low and medium-low levels of potential TA.

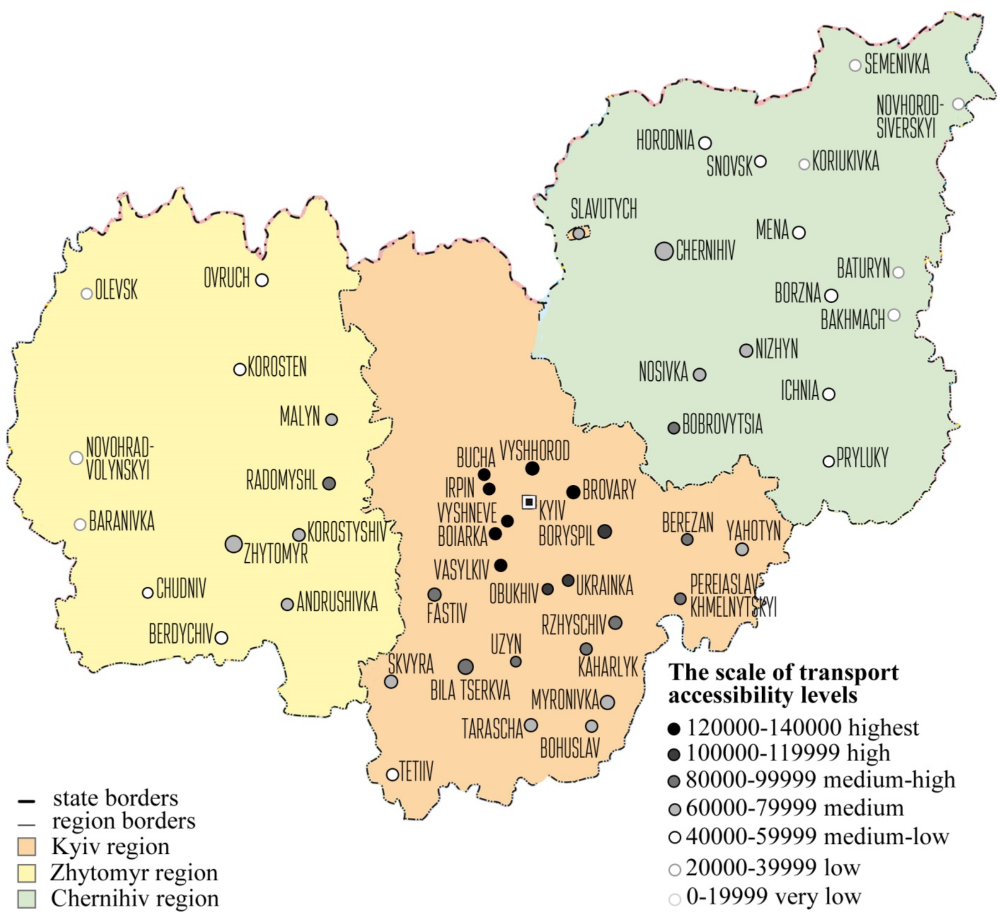

Fig. 5. Map of potential transport accessibility for the cities of the Capital Economic Region

6. Discussion of research findings

The conducted research and the proposed methodology can be applied for any country, but they are characterized by significant limitations. As the authors suggest, the performed research possesses the following shortcomings:

– studies of TA were not performed for the whole of Ukraine, as this is reasoned by significant labor intensity of the processes of data collection and data processing that are required for some calculations;

– studies of TA of the Capital Economic Region for every node on the network were not carried out, but only for satellite cities in relation to Kyiv. This is motivated by, first, the fact that Kyiv is the city-center of gravity due to its high initial indicators; and, second, by the labor intensity of data collection and processing;

– the study does not account for the quality of the road pavement. In the subsequent investigations, it would be relevant to expand the concept of TA to the timeframe of the travel, i.e. to evaluate TA using the relation of real and ideal time of travel (under the condition of unhindered movement at stable speed).

All the above-mentioned drawbacks can form the direction of further studies.

Application of the proposed methodology of TA evaluation for road transport network can serve well in revealing weaknesses of regional transport infrastructure. The given methodology can be used for other regions of Ukraine to evaluate the current efficiency of the road transport network. The methodology can be employed in urban development, transport planning and establishment and/or development of regional transport system.

The study conducted is an independent research and is not a continuation of any previously conducted research. In the future, development and deepening of the scientific research into TA, namely, adaptation or development of aggregated TA indicator with regard to a spectrum of influence factors. Expansion and adaptation of the proposed methodologies of TA evaluation for other transport modes are planned.

7. Conclusions

1. It has been identified that the majority of methodologies for TA estimation cannot be applied to quantitative evaluation of TA due to the absence of open access data. These methodologies for TA estimation need extended statistical data, like: GDP of the oblast or region, employment rate with distribution of employed population by occupation in the oblast or region, the number of cars per capita of the oblast or region, etc.

2. The assignment of adapting the western approach of potential TA estimation was solved by way of developing the methodology for potential TA estimation. For the model of road TA, it was suggested to use such initial data: Euclidean distance and real distance between the cities (nodes), and the number of different activities available at the destination. Based on the analysis of findings on TA, it was discovered that the highest values of potential TA in relation to

Kyiv are characteristic of the satellite cities Vyshneve and Vyshhorod (with TA values 134013 and 132500, respectively). Novhorod-Siverskyi (Chernihiv region) – 22212 and Olevsk (Zhytomyr region) – 24491 have the lowest potential TA in relation to Kyiv.

3. The scale of transport accessibility evaluation was developed. The scale included 7 levels, such as:

1) very low;
2) low;
3) medium-low;
4) medium;
5) medium-high;
6) high;
7) the highest.

In order to improve perception of the research outcomes, the numeric data on TA was visualized.

Comparison of the numeric data on TA for one city related to the whole of other cities will enable identification of the cities that should be considered, for one, as improvement of efficient functioning of the regional TS.

Thus, the given methodology can be used as one of the additional criteria for decision-making in transport planning.

References

1. Matiychyk, O. Accessibility of transport systems in passenger transportation [Text] / O. Matiychyk, K. Kryshkevych // Science-based technologies. – 2013. – Vol. 18, Issue 2. doi: 10.18372/2310-5461.18.4984
2. Yanovsky, P. Infrastructure approach to measuring passenger transport accessibility [Text] / P. Yanovsky, O. Matiychyk // Railway Transport of Ukraine. – 2014. – Issue 6 (109). – P. 14–18.
3. Yanovsky, P. Otsinka dostupnosti pasazhirskogo transportu na regionalnomu rivni [Text] / P. Yanovsky, O. Matiychyk // Science-based technologies. – 2013. – Issue 3 (19). – P. 345–349.
4. Dubel, V. Osoblyvosti ekologo-ekonomichnogo rozvytku regioniv Ukrayiny [Text] / V. Dubel // Bullein of Donetsk National University. Series C. Economics and Law. – 2014. – Issue 1. – P. 52–56.
5. Litman, T. Evaluating Accessibility for Transport Planning: Measuring People's Ability to Reach Desired Goods and Activities [Text] / T. Litman. – Victoria Transport Policy Institute, 2012. – 56 p.
6. Yatskiv (Jackiva), I. Evaluating Riga Transport System Accessibility [Text] / I. Yatskiv (Jackiva), E. Budilovich // Procedia Engineering. – 2017. – Vol. 178. – P. 480–490. doi: 10.1016/j.proeng.2017.01.091
7. Karou, S. Accessibility modelling: predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK [Text] / S. Karou, A. Hull // Journal of Transport Geography. – 2014. – Vol. 35. – P. 1–11. doi: 10.1016/j.jtrangeo.2014.01.002
8. Guzman, L. A. Assessing equity in transport accessibility to work and study: The Bogot region [Text] / L. A. Guzman, D. Oviedo, C. Rivera // Journal of Transport Geography. – 2017. – Vol. 58. – P. 236–246. doi: 10.1016/j.jtrangeo.2016.12.016
9. Wang, Y. Assessing the accessibility impact of transport policy by a land-use and transport interaction model – The case of Madrid [Text] / Y. Wang, A. Monzon, F. D. Ciommo // Computers, Environment and Urban Systems. – 2015. – Vol. 49, Issue 126–135. doi: 10.1016/j.compenvurbsys.2014.03.005
10. Zondag, B. Accessibility modeling and evaluation: The TIGRIS XL land-use and transport interaction model for the Netherlands [Text] / B. Zondag, M. de Bok, K. T. Geurs, E. Molenwijk // Computers, Environment and Urban Systems. – 2015. – Vol. 49. – P. 115–125. doi: 10.1016/j.compenvurbsys.2014.06.001
11. Monzon, A. Efficiency and spatial equity impacts of high-speed rail extensions in urban areas [Text] / A. Monzon, E. Ortega, E. Lopez // Cities. – 2013. – Vol. 30. – P. 18–30. doi: 10.1016/j.cities.2011.11.002
12. Kim, H. The impacts of high-speed rail extensions on accessibility and spatial equity changes in South Korea from 2004 to 2018 [Text] / H. Kim, S. Sultana // Journal of Transport Geography. – 2015. – Vol. 45. – P. 48–61. doi: 10.1016/j.jtrangeo.2015.04.007
13. Shaw, S.-L. Impacts of high speed rail on railroad network accessibility in China [Text] / S.-L. Shaw, Z. Fang, S. Lu, R. Tao // Journal of Transport Geography. – 2014. – Vol. 40. – P. 112–122. doi: 10.1016/j.jtrangeo.2014.03.010
14. Lopez, E. Assessment of Cross-Border Spillover Effects of National Transport Infrastructure Plans: An Accessibility Approach [Text] / E. Lopez, A. Monzon, E. Ortega, S. Mancebo Quintana // Transport Reviews. – 2009. – Vol. 29, Issue 4. – P. 515–536. doi: 10.1080/01441640802627974
15. Zajac, A. P. City Accessible for Everyone – Improving Accessibility of Public Transport Using the Universal Design Concept [Text] / A. P. Zajac // Transportation Research Procedia. – 2016. – Vol. 14. – P. 1270–1276. doi: 10.1016/j.trpro.2016.05.199
16. Rotoli, F. Potential Impacts on Accessibility and Consumer Surplus of Improvements of the European Railway System [Text] / F. Rotoli, P. Christidis, L. Vannacci, H. G. Lopez-Ruiz, C. E. Navajas, R. N. Ibanez // Transportation Research Procedia. – 2014. – Vol. 3. – P. 319–328. doi: 10.1016/j.trpro.2014.10.012
17. Yamaguchi, K. Inter-regional air transport accessibility and macro-economic performance in Japan [Text] / K. Yamaguchi // Transportation Research Part E: Logistics and Transportation Review. – 2007. – Vol. 43, Issue 3. – P. 247–258. doi: 10.1016/j.tre.2006.10.004
18. Martinez, L. M. A new approach to modelling distance-decay functions for accessibility assessment in transport studies [Text] / L. M. Martinez, J. M. Viegas // Journal of Transport Geography. – 2013. – Vol. 26. – P. 87–96. doi: 10.1016/j.jtrangeo.2012.08.018
19. Tranos, E. Accessibility of cities in the digital economy [Text] / E. Tranos, A. Reggiani, P. Nijkamp // Cities. – 2013. – Vol. 30. – P. 59–67. doi: 10.1016/j.cities.2012.03.001
20. Zadvornyj, Ju. V. Kriterii ocenki razvitija transportnoj infrastruktury regiona [Text] / Ju. V. Zadvornyj // Rossijskoe predprinimatel'stvo. – 2011. – Issue 1 (175). – P. 168–168.
21. Melendez, J. H. On the change in surpluses equivalence: measuring benefits from transport infrastructure investments [Text] / J. H. Melendez, P. Rietveld, E. Verhoef // European Transport. – 2007. – Vol. 36. – P. 107–140.
22. Johansson, B. Transport Infrastructure Inside and Across Urban Regions [Text] / B. Johansson // OECD/ITF Joint Transport Research Centre Discussion Papers. – 2007. doi: 10.1787/234705655722

23. Mezentseva, N. Ekonomichna i sotsialna geografIya Ukrainy [Text]: navch.-metod. pos. / N. Mezentseva, K. Mezentsev. – Kyiv: Vydavnycho-polihrafichnyy tsentr „Kyyivs'kyy universytet", 2010. – 239 p.
24. Ischuk, S. Kyivskiy stolychniy region: yogo mezhi, funktsiyita napryamy rozvitku [Text] / S. Ischuk, A. Gladkyy // Economic and social geography. – 2013. – Issue 1 (66). – P. 21–31.
25. Doroshenko, V. Osnovni pokaznyky ta indikatory funktsionuvannya pasazhirskoyi avtotransportnoyi systemy [Text] / V. Doroshenko, K. Didenko // Bulletin of Taras Shevchenko National University of Kyiv. – 2005. – P. 35–36.
26. Agasyants, A. Razvitie seti avtomobilnyih magistraley v krupneyshih gorodah. Transportno-gradostroitelnyie problemyi [Text]: Monograph / A. Agasyants. – Moscow: ACB, 2010. – 248 p.
27. Morris, J. M. Accessibility Indicators For Transport Planning [Text] / J. M. Morris, P. L. Dumble, M. R. Wigan // Transportation Research Part A: General. – 1979. – Vol. 13, Issue 2. – P. 91–109. doi: 10.1016/0191-2607(79)90012-8
28. Schurmann, C. Towards a European Peripherality Index Final Report. Report for General Directorate XVI Regional Policy of the European Commission [Text] / C. Schyrmann, A. Talaat. – Institut fur Raumplanung Fakultat Raumplanung, Universitat Dortmund, 2000. – 48 p.
29. Spiekermann, K. TRACC Transport Accessibility at Regional/Local Scale and Patterns in Europe [Text] / K. Spiekermann, M. Wegener, V. Kveton, M. Marada, C. Schurmann, O. Biosca et. al. // Applied Research 2013/1/10. ESPON. – 2013. – 164 p. – Available at: http://www.espon.eu/export/sites/default/Documents/Projects/AppliedResearch/TRACC/TRACC_Interim_Report_210211.pdf

Проведено комплексну оцінку зв'язків критеріїв оптимальності процесу буріння свердловин (мінімумів собівартості 1 м проходки і питомих витрат енергії) за допомогою методу Фаррара-Глобера. Визначено, що спостерігається повна мультиколінеарність між досліджуваними критеріями при зміні осьової сили на долото і частоти його обертання. Запропоновано дуалістичний підхід до вирішення задачі оптимального управління процесом буріння і формування критерію оптимальності на засадах енергоінформаційного підходу

Ключові слова: оптимальне управління, процес буріння, критерії оптимальності, взаємозв'язки, метод Фаррара-Глобера

Проведена комплексная оценка связей критериев оптимальности процесса бурения скважин (минимумов себестоимости 1 м проходки и удельных расходов энергии) с помощью метода Фаррара-Глобера. Определено, что наблюдается полная мультиколлинеарность между исследуемыми критериями при изменении осевой силы на долото и частоты его вращения. Предложен дуалистический подход к решению задачи оптимального управления процессом бурения и формирования критерия оптимальности на основе энергоинформационного подхода

Ключевые слова: оптимальное управление, процесс бурения, критерии оптимальности, взаимосвязи, метод Фаррара-Глобера

UDC 681.514.685:622.24
DOI: 10.15587/1729-4061.2017.97934

ANALYSIS OF INTERRELATIONS BETWEEN THE CRITERIA OF OPTIMAL CONTROL OVER THE PROCESS OF DRILLING THE WELLS

L. Kopystynskyy
Postgraduate student*
E-mail: kopystynskyy@gmail.com

V. Kropyvnytska
PhD, Associate Professor**
E-mail: vita103k@mail.ru

A. Lagoyda
Assistant*
E-mail: lahoidaandrii@gmail.com

G. Sementsov
Doctor of Technical Sciences, Professor*
E-mail: kafatp@ukr.net

*Department of automation computer-integrated technologies***
Department of computer systems and networks*
***Ivano-Frankivsk National Technical University of Oil and Gas
Karpatska str., 15, Ivano-Frankivsk, Ukraine, 76019

1. Introduction

One of the key technologies in the extraction of hydrocarbons is the process of drilling wells. This is an irreproducible non-stationary non-linear stochastic-chaotic process that evolves over time under the influence of disturbances, which requires making optimal control decisions under conditions of a priori and current uncertainty about the parameters and structure of the object. The object is related to the class of MI-MO (multiple input-multiple output).

The basic optimality criterion of the well drilling process is the cost per meter – C-criterion. The models of C-criterion