“Assessment of the development level of information and communication infrastructure in the regions of Ukraine”

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ARTICLE INFO	Oleh Kolodiziev, Viktoriia Tyschenko, Viktoriia Ostapenko and Tetiana Kolodizieva (2018). Assessment of the development level of information and communication infrastructure in the regions of Ukraine. *Problems and Perspectives in Management*, *16*(2), 134-144. doi:10.21511/ppm.16(2).2018.12
DOI	http://dx.doi.org/10.21511/ppm.16(2).2018.12
RELEASED ON	Tuesday, 08 May 2018
RECEIVED ON	Thursday, 23 November 2017
ACCEPTED ON	Tuesday, 24 April 2018

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JOURNAL	"Problems and Perspectives in Management"
ISSN PRINT	1727-7051
ISSN ONLINE	1810-5467
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
23	2	2

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BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10, Sumy, 40022, Ukraine

www.businessperspectives.org

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ASSESSMENT OF THE DEVELOPMENT LEVEL OF INFORMATION AND COMMUNICATION INFRASTRUCTURE IN THE REGIONS OF UKRAINE

Abstract

The influence of information is the main productive force and the subject of production for the economic systems development. Information services contribute to the competitive economy, to the provision of optimal conditions for human development, and the implementation of effective democratic procedures. The results of the socio-economic development of Ukraine testify to the growing lag of the parameters of its competitiveness from many countries of the world and to the strengthening of differentiation in the regional development. Since the regional environment today largely determines the competitiveness of the entire national economy, it becomes important to discuss the appropriate methodological tools for assessing the development level of information and communication infrastructure (ICI) in the regions of Ukraine.

Given the necessity of solving a specific problem, a methodological approach to assessing the development level of ICI is proposed, which is based on the calculations of integral indicators by the entropy method and aimed at the implementation of a group of economic regions in accordance with its defined parameters. The improved methodical toolkit takes into account consistent stages of the system for estimating indicators, which allows to analyze and evaluate the levels of ICI regions development and to obtain the value of specific digital divisions between individual regions.

The implementation of the proposed scientific and methodological approach allowed to obtain the results of the assessment of the ICI development level, to allocate regional clusters depending on the ICI development levels, to identify factors that restrain the ICI development in the regions and to propose recommendations for their elimination.

Keywords infrastructure, region, integral assessment, clusterization, information service, communication service

JEL Classification O14, R11

Received on: 23rd of November, 2017
Accepted on: 24th of April, 2018

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INTRODUCTION

One of the decisive factors in the socio-economic growth of any economy is a significant increase in demand for information in the economic sphere. Those countries that specialize in high technology have higher rates of economic growth compared to other states. Thanks to the use of information and communication infrastructure (ICI), new environment for the activity and development of society in the economic, social and politic spheres is created. At the forefront today is the need to address the high-quality information and communication provision of economic processes, which is carried out through information technology and communication services, including information products. Thus, mobile telephony has become the most affordable service along with the positive dynamics of increasing the number of

Internet users in Ukraine. Understanding the importance of information and communication infrastructure for the development of the country's economy has sharpened the problem of creating a qualitative and adequate mechanism for its assessment and analysis both in Ukraine as a whole and in the context of its regions.

There are more than 20 different international e-indices in the world, but the most commonly used are as follows: the Information and Communication Technologies Development Index (IDI), which is calculated by the United Nations specialized agency in the field of global telecommunication – the International Telecommunication Union (ITU); The Digital Opportunity Index (DOI), developed by the ITU within the WPIIS; Digital Access Index (DAI), ITU; The Information Society Index (ISI), presented by IDC research. There are also several world-recognized indices that are calculated by organizations in different ways: the International Telecommunication Union – the ICT Development Index, the World Wide Web Development Index (The Web Index), the World Economic Forum – Networked Readiness Index.

According to the ITU report "Measuring Information Society 2017", which contains the development ratings in the IC sector of 176 countries, Ukraine ranks 79th with the index of 5.62. At the same time, the values of subindices vary considerably: the subindex of access to basic information resources is 6.60; the subindex of the intensity of information use is 3.17, and practical skills in the information and communication technologies – 8.56. That is, in Ukraine, the most problematic link in the development of information and communication infrastructure is the inadequate use of its potential by the state, organizations and citizens.

1. LITERATURE REVIEW

Scientists from different countries devoted their works to individual aspects of the ICI development as a component of the information society. Bell (2004) and Adamczewski (2016) explore the development of the information society. In particular, Adamczewski (2016) considers the economic essence and explores the reasons for the growth of the third information platform in the digital transformation of business organizations. The author notes that the ICT dynamic development has led to the development of a new technological standard that allows to introduce new business models. They are based on four components, namely social media, mobile devices, customer behavior and customer preferences, using analytical tools, as well as computer tools. Shumayeva (2014) offers an index model for assessing the information society development in Ukraine based on the survey methods for building the most popular ICT indices. The results of the comparative analysis of assessing the information society development of the world according to the chosen ICT indices are presented. It is through the composition indicator, which includes a number of basic indicator sectors (potential, ICT use, management and availability, infrastructure, innovation and investment) to assess the current trends in the information society in Ukraine and to predict the parameters of the society's informatization for the near future. Mikhaylovska (2009) considers the degree of the information society development in Ukraine in comparison with other countries, the rating of Ukraine according to the main international indices, which are used to measure the degree of the information society development, and outlines the main problems that arise during the information society development in Ukraine.

Nord, Riggio, and Paliszkiewicz (2017) studied the use of information technologies and their impact on socio-economic development. These authors state that information and communication technologies (ICTs) provide global connections, communication and empowerment of participants. Practical experience is presented when the strengthening of authority leads to the socio-economic development of Italy. The results are useful for companies in Italy and other countries, especially developing ones. It is proved that awareness of the need for education and the use of social technologies, equality of gender incomes can be achieved as a result of socio-economic development.

Seeletse (2016) points out that information and communication technologies as a learning resource should be used by lecturers who want to embrace technologies and innovations and to be competitive both at the regional and global levels.

Sutman and Dadang Prasetyo Jatmiko (2016) determine the need for information technology in any enterprise activities.

Frolov, Hovorun, and Ostapenko (2017) considered communication technologies in the context of human resources management. They point out that as a result of the development of new communication technologies in the near future, there will be a lot of changes in the labor market models and the needs of personnel in terms of requirements to employees. At the same time, a new generation of workers will emerge on the labor market, which has grown with the development of communication technologies. Some of them will become employers and introduce new approaches to employing people that are different from traditional labor market models.

Kozhukhivska (2009) discloses the essence of the "information technology" concept, and describes the stages of its development and types of information technology. The main components of information technologies are considered, and prospects of their use in firms and in the financial sphere are determined. The problems and threats to business related to the use of information technologies are highlighted. Informational computer technologies in Ukraine, which work on micro, meso (firms, enterprises), and macroeconomic level (the system of national security and its components, "Budget of Ukraine", "GDP forecast", etc.) are systematized.

Morgado, Pazotto, and Amorim (2014) evaluate ICD and ICT assessments. It is taken into account that the percentage of Internet use in households can be considered as the determining factor. Internet usage percentages in Brazil and countries where this percentage reaches 100% are compared. Emphasis was placed on the importance of the digital inclusion measures taken by the government, companies and non-governmental organizations to increase the efficiency of the labor factor in the implementation of the Brazilian production unit.

Kaidi (2016) considers the main features of the ICI development in the global electronic space at the present stage. The author states that the global information infrastructure necessary for the GIS development implies an adequate technological, economic, organizational, production and structural development of the sphere of infocommunications.

Volokh (2014) explores the role of ICI in the development of e-government. The approaches to the nature of the ICI and its individual components are determined. The main provisions of the concept for the creation of a national ICI in Ukraine are proposed.

The purpose of the study is to improve the scientific and methodological support for assessing the ICI development level and its testing using the example of the Ukrainian regions.

2. METHODS

In order to determine the parameters of the ICI development level in the regions of Ukraine, the following research methods were used:

1) The method of a priori ranking to form a system of evaluation indicators. It is proved that a large number of indicators does not guarantee better results, and, conversely, increases the likelihood of a significant error, which leads to the results distortion. The results of systematizing the views of scientists, obtained based on the use of the priori ranking method, which allowed to select most important features for the next stages of the study, as well as the justified exclusion of some of the indicators for further research, are shown in Figure 1.

At the stage of forming a system of indicators characterizing ICI, the following aspects were taken into account:

- economic conditions for development, which are specific for the regions of Ukraine and their geographical location;
- availability of official statistical information for a certain period of time (for building dy-

namics series), ensuring comparability of indicators;

- indicators used by the State Department of Communications and Informatization of the Ministry of Transport and Communications of Ukraine;
- the possibility of using indicators applied by international organizations (World Bank, European Commission, International Telecommunication Union, Regional Telecommunication Union, Organization of Black Sea Economic Cooperation);
- approaches of the authors concerning the evaluation of the information society development in general and communication technologies in particular.

Basic formulae for calculations:

a. determining the sum of the ranks for the indicators selected:

$$R_i = \sum_{j=1}^{m_r} a_{ij}, \tag{1}$$

R_i is a rank sum; a_{ij} – rank of each *i*-th indicator; n_r – number of alternatives; m_r – number of experts' (scholars) opinions; $i = 1,\ n;\ j - 1,\ m;\ j \neq I;$

b. determining the difference between the sum of ranks of each indicator and the average sum of ranks:

$$\Delta_i = R_i - \frac{1}{n_r} \sum_{i=1}^{n_r} \sum_{j=1}^{m_r} a_{ij}, \tag{2}$$

$$i = \left(\overline{1,\ n_r}\right),\ \ j = \left(\overline{1,\ m_r}\right),$$

where a_{ij} – rank of each *i*-th indicator; n_r – number of alternatives; Δ_i – average sum of ranks; m_r – number of expert points of view; $i = 1,\ n;\ j - 1,\ m;\ j \neq I;$

c. estimating the degree of consistency of expert opinions on the importance of each of the evaluated objects (using the concordation coefficient):

$$\omega_i = \frac{12 s_i}{m_r^2 \left(n_r^3 - n_r\right) - m_r \sum_{j=1}^{m_r} T_j}, \tag{3}$$

$$T_j = \sum_{i=1}^{n_r} \left(t_j^3 - t_j\right), \tag{4}$$

$$s_i = \sum_{i=1}^{n_r} \left(\Delta_i\right)^2, \tag{5}$$

where ω_i – concordation coefficient; s_i – dispersion of expert opinions consensus; n_r – number of alternatives; m_r – number of expert points of view; T_j – a term that is entered if there are fractional ranks in the ranking of experts; t_j – number of identical ranks; $i = 1,\ n;\ j - 1,\ m;$ $1 \leq \omega_i \leq 0;$

d. estimating the probability of the concordation coefficient by the Pearson criterion. For the investigated case, when $n \geq 7,$ the hypothesis is tested according to the following formula:

$$\Phi = m \cdot \left(n - 1\right) \cdot W_q. \tag{6}$$

If $\Phi > 0\ \ \left(f,\ \gamma\right),$ then the expert opinions are considered to be consistent with the significance level.

That is, it can be argued that there is a non-random coherence of expert opinions and it is possible to remove the most significant indicators.

2) Integral assessment by the entropy method to compare the values of the indicators according to the determined features:

c. normalization of the output data of the matrices formed in accordance with substage 3.1 (see Figure 1) with the formula (Malaryts, 2006):

$$d_{norm} = \frac{x_i - x_i^{\min}}{x_i^{\max} - x_i^{\min}}, \tag{7}$$

where d_{norm} – the normalized values of the indices [0…1] according to the matrix: $X_{ntr} = \left\{x_{ij}\right\};$ $x_i^{\max},\ x_i^{\min},\ y_i^{\max},\ y_i^{\min}$ – the maximum and the minimum value of the indicators, respectively, for the entire period of observations;

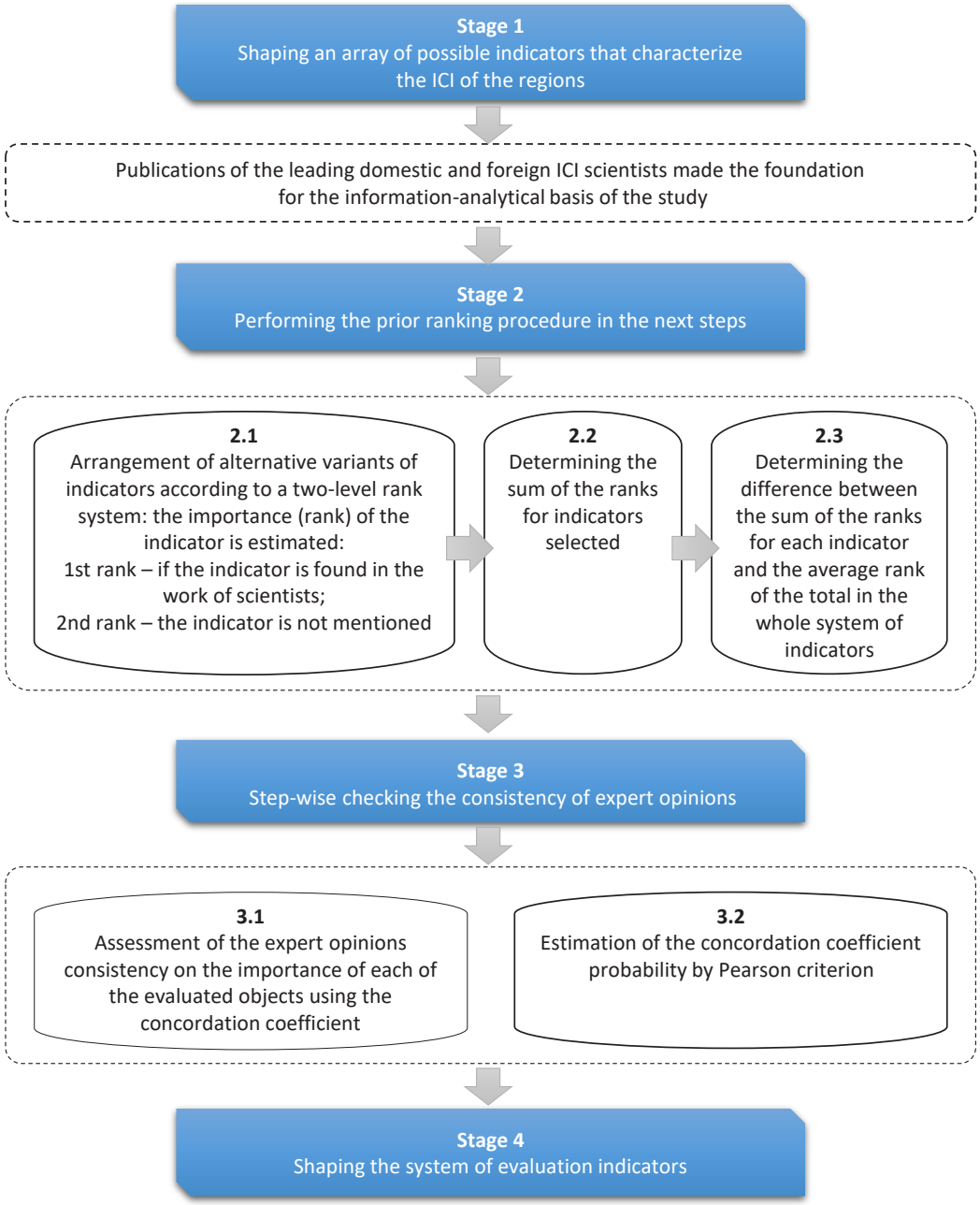

Figure 1. Consistent stages of shaping the system of estimated figures that characterize the ICI development level in the regions

d. exclusion of semi-permanent features from the previous list using the coefficient V_j, which is determined by the formula:

$$V_j = \frac{S_j}{\overline{x_j}}, \quad \text{where} \quad S_j = \left[\frac{1}{m}\sum_{i=1}^{m}\left(x_{ij} - \overline{x_j}\right)^2\right]^{1/2};$$

$$\overline{x_j} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}, \qquad (8)$$

where V_j – coefficient of semi-permanent features; S_j – standard deviation of the j-th indicator; $\overline{X_j}$ – sample average of one j-th indicator; x_{ij} – value of j-th fractional indicators for the i-th region of the country; $i = \overline{1,\ m}$, $j = \overline{1,\ n}$, $j \neq i$.

If $V_j \leq \varepsilon$, where ε is some given small value (for example, $V_j \leq 0{,}1$), then the indicator is semi-constant and excluded from the further research.

e. calculation of the integral index. The complexity of determining the integral indicator is due to the following factors: the choice of

the method for calculating the integral indicator, the choice of the optimal number of valuation indicators that characterize the research object (in our case, the region), the economic disproportions in regional development. Given that the regions are characterized by an indeterminate (entropy) nature of development, the entropy method (Malaryts, 2006) was chosen among the methods of calculating integral indicators (Kizim & Geymn, 2008) to construct integral indicators:

$$I_{Si} = \sum_{j=1}^{n} E_j b_{ij}, \ i = 1, \ m, \tag{9}$$

where I_{Si} – integral value of the S_i object; E_i – the *j*-th feature entropy; b_{ij} – estimate of the *j*-th feature for the *i*-th object; n – number of features; m – number of objects.

The choice of the method for calculating the integral index of development is due to the conditions for achieving the goal of an analysis: the ability to monitor trends in regional dynamics, to identify regions that find their place in the market, to manage the processes of regional asymmetries bringing to numerical calculations. A characteristic feature of integrated indicators is that their values vary between 0 and 1, which allows to describe the impact factors studied and interpret economic understanding the valuation inputs.

3) Cluster analysis is used at the stage of shaping homogeneous clusters, for which unified methodological rules and procedures for organizing the managing ICI development were used. An agglomeration cluster analysis is one of the most common instruments for grouping regions. In the course of clustering of regions as a measure of the distance between objects, the Euclidean distance was chosen, and for the distance between clusters the Ward principle was adopted. The grouping is carried out based on the gradual minimum growth of the criterion value (in our case, it is the Euclidean distance).

It is necessary to note that the purpose of the analysis is to classify typical objects in a set of similar features (in our case, regional systems), therefore, Kyiv which is the city of republican subordination was not included in the list of objects for clusterization (in the analysis of statistical data of the Kyiv region, the city of Kiev is not taken into account. Directly the city itself is the undisputed leader for all indicators, including ICI). Due to the lack of data, Donetsk and Luhansk regions, and the Autonomous Republic of Crimea were excluded from the general list of regions at the calculations stage.

3. RESEARCH FINDINGS

Estimation of the ICI development in the regions of Ukraine consists of three interrelated stages of implementing specific organizational procedures. Their content and consistency of the implementation are detailed in Figure 2. The results of the approbation of the proposed methodological approach to assessing the ICI development level in the regions were conducted based on the data of the State Statistics Committee of Ukraine in the dynamics of 5 years (2012–2016).

In the first stage (see Figure 2, Module 1), the following aspects are taken into account: information accessibility; possibility of using an appropriate mathematical apparatus; proposals of scientists on the list of indicators of the ICI regional development (Amosha & Nikolayenko, 2015; Kalyuzhna, Nord, Riggio, & Paliszkiewicz, 2017; Malaryts, 2006); official data of the State Statistics Service of Ukraine (Bell, 2004; Fedulova & Kornieieva, 2009; Viera, Foresti, & da Rosa, 2016). The system of indicator is formed characterizing the ICI regional development in Ukraine by two groups, which are the latest:

- a group of indicators characterizing information services of ICI (provision of communication facilities (level of penetration of fixed telephone, mobile communication and the Internet), volume of realized communication services and in the field of informatization, level of penetration of computer equipment, investments in the basic capital of telecommunications companies);

- a group of indicators characterizing the communication services of the ICI (sending newspapers and magazines, sending letters, telegrams, parcels, intercity telephone calls, subscribers of mobile communication, cable television, Internet).

Source: Elaborated by the authors.

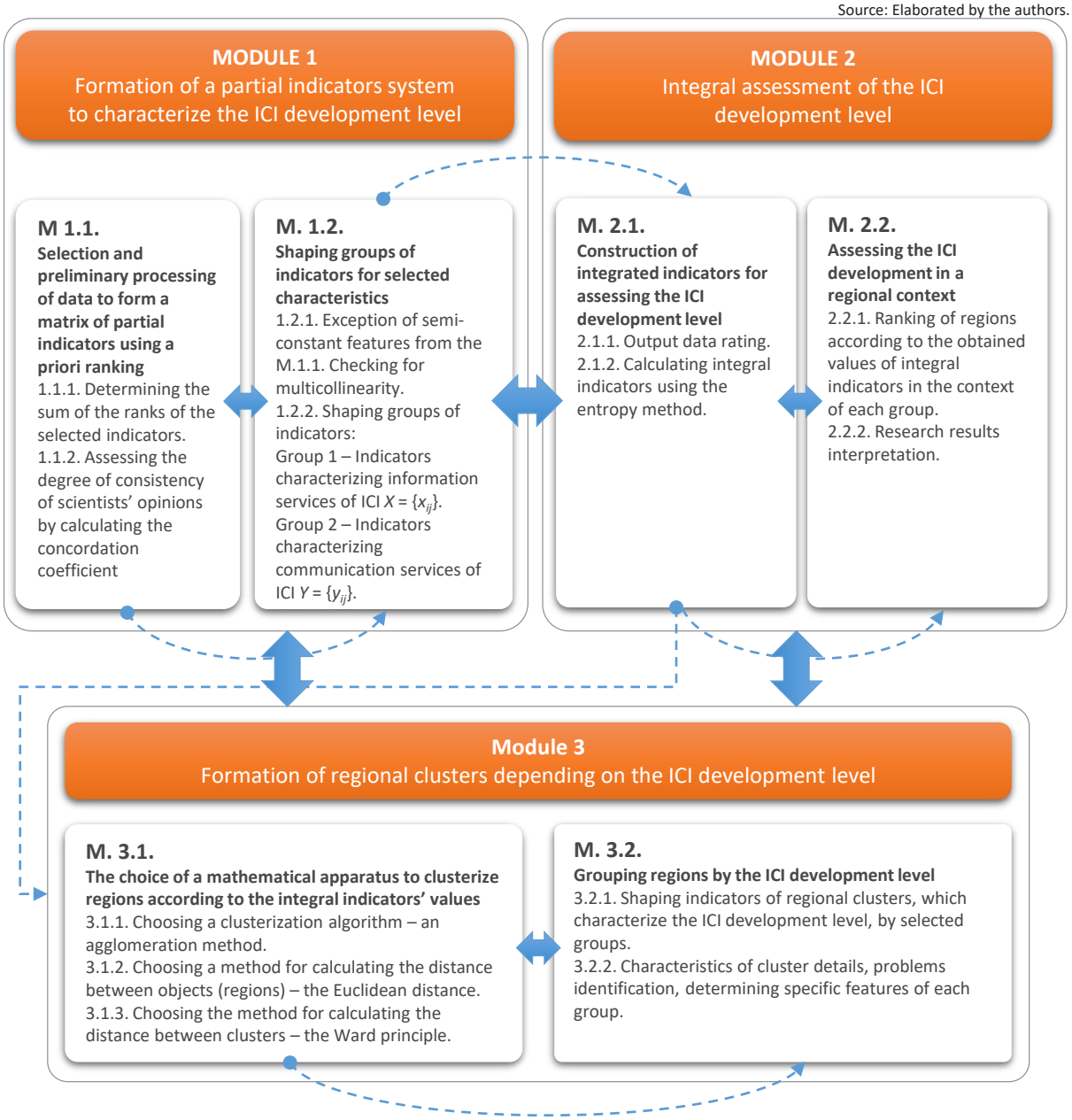

Figure 2. Scheme for the estimating the ICI development level in terms of regions

Calculated values of integral indicators in the dynamics over 5 years (Table 1) are the result of the second stage implementation (see Figure 2, Module 2). The analysis of indicators showed that the industrialized and most promising regions occupy the first positions in the ICI rating. Kyiv and Kyiv region is the undisputed leader – the 1st rank during the whole period under study. Kharkiv (change of ranks: from 2nd to 4th), Dnipropetrovsk (change of ranks: from 2nd to 3rd), Odesa (change of ranks: from 2nd to 5th), and Lviv (change of ranks: from 3rd to 5th) regions.

Despite the fact that in recent years, the volume of investments in communication activity has increased and the costs of informatization are increasing each year, this is clearly not enough to achieve such a level of the ICI development, that it became a driving force and an assistant to the country's economic growth.

The third stage (see Figure 2, Module 3) contains the results of the distribution of Ukrainian regions by clusters, depending on the values of integral indicators, between which there are significant differences in the trends of ICI development (Table 2).

Table 1. Integral indicators and ranks of ICI development in the Ukrainian regions

Regions	ICI information services										ICI communication services									
	2012		2013		2014		2015		2016		2012		2013		2014		2015		2016	
	Iis	Rank	Iis	Rank	Iis	Rank	Iis	Rank	Iis	Rank	Ics	Rank	Ics	Rank	Ics	Rank	Ics	Rank	Ics	Rank
Kharkiv	0.53	4	0.55	4	0.55	4	0.62	4	0.65	3	0.72	3	0.71	2	0.67	2	0.6	2	0.65	2
Dnipropetrovsk	0.63	2	0.65	3	0.67	3	0.73	2	0.77	2	0.72	2	0.68	3	0.59	3	0.58	3	0.57	3
Odesa	0.62	3	0.68	2	0.7	2	0.69	3	0.62	4	0.4	4	0.38	5	0.47	5	0.56	4	0.56	4
Lviv	0.47	5	0.51	5	0.52	5	0.6	5	0.61	5	0.48	3	0.51	4	0.52	4	0.54	5	0.54	5
Zaporizhzhia	0.27	8	0.28	8	0.27	8	0.3	8	0.32	7	0.27	5	0.26	7	0.25	6	0.24	6	0.31	6
Vinnytsia	0.35	6	0.34	6	0.34	6	0.37	6	0.37	6	0.22	7	0.28	6	0.24	7	0.22	7	0.29	7
Kyiv and the city of Kyiv	0.85	1	0.89	1	0.89	1	0.96	5	0.96	1	0.95	1	0.89	1	0.87	1	0.93	1	0.91	1
Poltava	0.23	11	0.21	11	0.21	11	0.2	11	0.23	11	0.23	6	0.23	8	0.21	9	0.2	8	0.22	8
Chernihiv	0.25	10	0.26	10	0.26	9	0.29	10	0.27	10	0.18	8	0.18	9	0.19	8	0.18	9	0.19	11
Mykolaiv	0.17	12	0.17	12	0.17	12	0.19	12	0.22	12	0.16	13	0.16	12	0.16	12	0.17	10	0.18	12
Cherkasy	0.28	7	0.28	7	0.28	7	0.31	7	0.3	8	0.17	10	0.17	11	0.17	11	0.16	11	0.2	10
Kropyvnytskyi	0.1	21	0.09	22	0.08	22	0.08	22	0.08	22	0.18	9	0.18	10	0.18	10	0.15	12	0.15	14
Volyn	0.11	19	0.11	20	0.1	20	0.12	19	0.11	18	0.15	15	0.15	16	0.15	13	0.15	13	0.21	9
Zhytomyr	0.27	9	0.27	9	0.26	10	0.3	9	0.3	9	0.15	16	0.15	17	0.15	14	0.15	14	0.16	13
Kherson	0.11	17	0.11	18	0.1	18	0.12	17	0.11	19	0.14	17	0.15	14	0.14	15	0.14	15	0.14	15
Ivano-Frankivsk	0.14	14	0.14	14	0.13	14	0.15	13	0.14	14	0.11	18	0.11	18	0.12	18	0.13	16	0.1	19
Khmelnytskyi	0.15	13	0.15	13	0.14	13	0.15	14	0.18	13	0.15	14	0.15	15	0.13	16	0.13	17	0.12	17
Sumy	0.13	15	0.12	15	0.11	15	0.11	21	0.10	20	0.17	12	0.16	13	0.13	17	0.13	18	0.13	16
Rivne	0.11	18	0.11	19	0.1	19	0.12	18	0.12	17	0.11	19	0.11	19	0.11	19	0.11	19	0.11	18
Zakarpattia	0.11	20	0.12	17	0.11	17	0.14	15	0.13	15	0.1	21	0.1	21	0.1	22	0.11	20	0.07	22
Chernivtsi	0.09	22	0.1	21	0.09	21	0.11	20	0.09	21	0.09	22	0.09	22	0.1	20	0.1	21	0.9	20
Ternopil	0.12	16	0.12	16	0.11	16	0.13	16	0.13	16	0.1	20	0.1	20	0.1	21	0.1	22	0.9	21
Donetsk	Not available																			
Luhansk	Not available																			

Note: Iis – integral indicator characterizing the ICI information services; Ics – integral indicator characterizing the ICI communication services.

The fact that Kharkiv, Lviv, Odesa and Dnipropetrovsk regions were included in the second cluster during the whole period under study, which is characterized by high indicators of ICI development, is expected. This suggests that the regions are similar in their economic development, are industrialized regions with strong scientific and technical potential and domination of large enterprises of the real economy.

The third cluster (includes 31.8% of the total population of the studied regions) is characterized by the average values of the calculated integral indicators. The values of the integral indicators of ICI communication services are somewhat lower than those of the second cluster. This is logical and due to changes in the toolkit for communication, creation, distribution, storage, receipt and management of information.

In addition, the expected result is motivated by the presence of a wide range of research and education institutions in the regions, access to the Internet, and a high proportion of the population who receive higher education in general. In addition, the regions are represented by all key branches and locomotives of the economy's growth – aviation, metallurgy, mechanical engineering, and agro-industrial complex.

All other regions fall into the fourth cluster (50% of the total population of regions), which is characterized by low values of calculated integral indicators. These are agro-industrial and underdeveloped regions that need government support to increase their level of development and attract investment funds to support existing business.

It should be noted that the third and fourth clusters are characterized by a higher level of development of ICI information services, and slowdown of indicators, characterizing the development of communication services of ICI. The slowdown in growth dynamics is explained by features such as reduction of corporate and individual consumers' expenses for telecommunication services over the last five years, and, first of all, for mobile communication services; high degree of saturation of mobile communication services, which, in recent years, was the main factor in the growth of revenues in the telecommunications sector.

Table 2. Structure of the aggregate of the Ukrainian regions according to the clusters formed depending on the values of the ICI components

1st cluster	2nd cluster	3rd cluster	4th cluster
Gradation of distribution into clusters			
Iis – 0.85:0.97; Ics – 0.87:0.95	Iis – 0.73:0.47; Ics – 0.72:0.38	Iis – 0.56:0.17; Ics – 0.27:0.16	Iis – 0.08:0.30; Ics – 0.09:0.18
Regions distribution			
Kyiv and the city of Kyiv	**Dnipropetrovsk**	**Vinnytsia**	**Volyn**
–	Lviv	Zhytomyr	Zakarpattia
–	Odesa	Zaporizhzhia	Ivano-Frankivsk
–	Kharkiv	Kyiv	Kropyvnytskyi
–	–	Poltava	Mykolaiv
–	–	Chernihiv	Rivne
–	–	Cherkasy	Sumy
–	–	–	Ternopil
–	–	–	Kherson
–	–	–	Khmelnytskyi
–	–	–	Chernivtsi

CONCLUSION

According to the study results, the following conclusions can be drawn.

1. The proposed scientific and methodological support for assessing the ICI development level in the economic regions of the country made it possible to obtain the necessary methodological tools for clustering the regions with a view to their further evaluation and implementation of the diagnostics of the ICI development level.

2. An improved methodological approach takes into account the sequence of stages of shaping the system of assessment indicators based on a priori ranking and allows to justify the division of indicators into groups. The system of indicators allows to perform a comparison and an analysis at different levels of structural elements specification and to obtain specific digital values of characteristics breaks between regions.

3. The feasibility of the proposed methodological support for assessing the ICI development level is justified, which made it possible to identify powerful and most promising regions of the leadership (the city of Kyiv and Kyiv region, Dnipropetrovsk, Lviv, Odesa and Kharkiv regions). Overtaking regions (the second cluster) are emphasized, which have a potential opportunity to get to the first cluster. The existence of several problem regions has been proved, which lag behind other territories by certain features and require special attention from the part of the public and the private sectors.

4. Significant regional socio-economic disproportions of development and territorial disintegration have been proved, which testifies to:

- the inability of public authorities to conduct systematic and effective macroeconomic regulation;
- inhibition of territorial diffusion of resources, which means the weakened effect of intensive (innovative) factors of economic growth and intensification of extensive ones;
- the dominance of extensive factors of economic growth, which, in turn, worsens macroeconomic imbalances, the manifestation of which is the inflationary processes acceleration.

Objective conditions for the economy functioning require introducing an effective state support and stimulation of socio-economic development of problem regions, primarily through the development and implementation of state target programs in those areas where state intervention is required.

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