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METHODOLOGY FOR ANALYSIS OF THE LEVEL OF FINANCIAL SOLVENCY OF THE UNITED TERRITORIAL COMMUNITIES OF UKRAINE

The article is focused on the research of methods for analyzing the level of financial solvency and the development of united territorial communities (UTCs). The authors, using taxonomic and cluster analysis to determine the level of development and financial solvency of the UTCs, proved their hypothesis and denied the impact of population and area indicators on the development and financial solvency of UTCs. The taxonomic indicator of the level of financial solvency was calculated on the basis of the indicators-stimulants, which have a positive impact on the resulting indicator, as well as two indicators-destimulators, which have a negative impact on the resulting indicator. Based on taxonomic and cluster analysis, all UTCs are divided into three groups according to the level of development and financial solvency.

The results of the cluster analysis, as well as the taxonomic analysis, indicate the importance of stable centroids and clusters among which there is no area and population of UTCs.

Keywords: taxonomic analysis, cluster analysis, financial solvency of the UTCs.

Problem statement. In the process of implementing the decentralization reform in Ukraine, various methodologies are used to analyse the financial solvency of united territorial communities (UTCs). This will enable to determine the key input indicators that affect the level of financial solvency of the UTCs, as well as the factors that influence these changes. The majority of the developed methods highlight the significance of two input indicators: the area and population of the UTCs, which, in the authors' opinion, affect the financial solvency of the UTCs, and are grouped according to these indicators. In our view, this approach is one-sided and requires confirmation or denial of the significance of the area and population of the UTCs, which are used in the analysis of the level of financial viability of the UTCs. For this reason, the methodology of cluster and taxonomic analysis will be used to determine the level of financial solvency of the Ukrainian UTCs and to determine the significant input factors of the analysis.

Analysis of recent research and publications. Financial monitoring experts from the Central Reform Office of the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine (with the support of the U-LEAD Programme with Europe and SKL International) carried out a comparative assessment model, which provides an ongoing analysis of the UTCs budgets of all 24 regions. In this model, they used four main indicators: own revenues per inhabitant (ratio of own revenues to the number of residents of the respective UTC), the level of budget subsidy (ratio of the volume of basic / reverse subsidies to the total amount of UTC revenues, excluding subventions from the state budget), a share of costs on maintenance of the administrative personnel in the revenues of the UTCs (ratio of costs on maintenance of the administrative personnel of local self-government bodies to the amount of revenues without taking into account transfers from the state budget), capital expenditures per capita (ratio of incurred capital expenditures without taking into account own receipts of budget-funded entities with the number of residents of a certain UTC)[1]. On the basis of the same methodology, the coordinator of financial decentralization J. Kazyuk stated that the smallest in terms of territory and population UTCs have a low financial solvency in the majority of cases. These communities also have insufficient labour capacity for their development and quality management. The only exception is the individual communities where budget forming enterprises and large enterprises of the real sector of the economy are located[2].

[1] Press center of the Decentralization initiative, results of financial decentralization over 10 months of 2018 – expert analysis. < https://decentralization.gov.ua/news/10197 (2019, January, 19).
[2] Kazuk, J. (2017). *Larger communities have more opportunities: experts analyzed the budgets of 665 UTCs in 2018*. <https://decentralization.gov.ua/news/10649?page=3> (2019, February, 09).

Formulation of a task. In the course of the study, it is necessary to conduct a cluster and taxonomic analysis of the level of financial solvency of the Ukrainian UTCs, which will allow to determine significant indicators of impact on the change in the level of financial solvency of the united territorial communities.

Presentation of the research material. In the context of the assumption that other input indicators have an impact on the financial solvency of the Ukrainian UTCs, initially we assessed the average performance of 665 UTCs by the groups identified by experts. After that, we conducted taxonomic and cluster analyses of all UTCs in 2018 based on four main indicators defined by experts.

On the basis of official statistics from the website Public space, as well as official statistics on the implementation of state and local budgets 665 UTCs for 2017-2018 years of the Ministry of Finance of Ukraine, we conducted an in-depth statistical analysis of the financial activities of UTCs in Ukraine in 2018. We summarize the average values of the key financial performance indicators for different groups in Table 1.

Based on the data, it is clear that the first group of UTCs, in which the average population of 1 UTC is more than 20 thousand people, in comparison to the following three groups, in terms of overall financial indicators, shows a much better position in terms of their own local income budgets, capital expenditures, management expenditures and grants.

Table 1

Indicators of 665 UTCs of Ukraine depending on group membership in 2018[1] [2]

Indicator	1 Group	2 Group	3 Group	4 Group
Number of UTCs	87	103	227	248
Population in the group, thousand people	1866,2	1267,3	1596,5	863,3
The average population within one UTC, thousand people	21,451	12,304	7,033	3,481
Group's own income, thousand UAH	6678,10	4711,63	6012,78	3605,92
The average value of own income per inhabitant, UAH	3578,45	3717,85	3766,22	4176,90
Capital expenditures of the group, thousand UAH	1960,66	1607,95	2188,51	1242,23
The average value of capital expenditures per inhabitant, UAH	1050,62	1268,80	1370,82	1438,93
Management expenses (group), thousand UAH	1355,50	1201,00	1789,90	1181,97
The average cost of management per capita, UAH	726,34	947,69	1121,14	1369,13
Government subsidies (group), thousand UAH	544,53	587,15	817,88	358,61
The average value of state subsidies per inhabitant, UAH	291,79	463,31	512,30	415,39

However, when comparing the indicators of the first group of UTCs with the next three in terms of indicators per 1 person of the UTC's population, we observe trends that do not fully confirm the findings of the expert group. Thus, the average of own revenues of local budgets per person in the second, third and fourth groups is higher than in the first group. In particular, this indicator in the fourth group is higher by UAH 598,45 compared to the first group. Also, considering the maintenance needs of the industries funded by the local budgets of the first group of UTCs, we conclude that they are much larger because there are more consumers of these services. And this has not yet been taken into account: in the process of reorganization in the educational sector, health care support schools, health institutions do not restrict the provision of services to consumers who are residents of other UTCs, but their settlements are closer to these institutions.

[1] Regionet (2018). *Monitoring of the process of decentralization of power and reform of local self-government as of January 10, 2018 (until December 2017).* <http://regionet.org.ua/files/10-2018.pdf> (2019, April, 18).
[2] Storage (2019). *Monitoring of the process of decentralization of power and local self-government reform as of 10 February 2019*. <https://storage.decentralization.gov.ua/uploads/library/file/378/10.02.2019_ukr.pdf> (2019, April, 19).

Therefore, we assume that, at present, the financial capacity of UTCs depends, first of all, on the active and effective actions of its self-government bodies. First of all, to what extent these bodies contribute to the development of the business environment in their locality, develop attractive investment projects or seek out for investors who will provide creation of a really viable business entity, develop projects to attract funds from the State Regional Development Fund, take measures to reduce the income of households. All of these actions can have a greater impact on the accumulation of additional revenues to the UTC budgets, which will increase their financial solvency.

In order to analyze the UTCs grouping by the four indicators proposed by the experts, we conducted taxonomic and cluster analyses of UTCs in 2018. These methods of analysis should be used in assessing the level of development and financial solvency of UTCs.

It is advisable to use taxonomic procedures to compare objects characterized by a large number of features. One method of exploring multidimensional objects is the taxonomic measure of the level of development proposed by Z. Helvig [1]. This metric is a synthetic value that is *equivalent* to all the features that characterize the objects. It allows to organize the elements of the study population by setting the relative position of each unit of the statistical population in a multidimensional space of features.

The first step in the process of building a taxonomic indicator of the level of development is to build a matrix of observations:

$$X = \begin{pmatrix} x_{11} & \dots & x_{1k} & \dots & x_{1m} \\ \dots & \dots & \dots & \dots & \dots \\ x_{i1} & \dots & x_{ik} & \dots & x_{im} \\ \dots & \dots & \dots & \dots & \dots \\ x_{n1} & \dots & x_{nk} & \dots & x_{nm} \end{pmatrix}, \quad (1)$$

where:

n – the number of objects being studied;

m – the number of features;

x_{ij} – the value of the j-th attribute for the i-th object.

The next step in the procedure under consideration is to differentiate the features of the observation matrix. All variables are divided into stimulants and destimulators. The reason for the division of features into two groups is the nature of the influence of each of them on the level of development of the studied objects. Signs that have a positive, stimulating effect on the level of development of objects are called stimulants, in contrast to the features of destimulators (Table 2).

Table 2

Separation of features into stimulants and dis-stimulants

Symbols	Name of indicator	The nature of the impact on financial capacity	Group
X1	Own income per 1 resident for 2018 (UAH)	Positive	Stimulant
X2	Budget subsidy level (share of base / reverse subsidies in revenues)	Negative	Destimulator
X3	Share of expenses on maintenance of the management system in own revenues (without transfers) (%)	Negative	Destimulator
X4	Capital expenditures per 1 inhabitant (without own revenues of budgetary institutions) (UAH)	Positive	Stimulant

[1] Plutta, B. (1980). *Comparative multivariate analysis in economic research. Methods of taxonomy and factor analysis*. Moscow: Statistics.

Using this features' separation, we calculated all four metrics listed in the previous table for all 665 UTCs by applying Excel.

In the third step, since the features included in the observation matrix are heterogeneous, standardization of their values is carried out and a matrix of standardized output data is constructed (Fig. 1). In a nutshell, standardization is the transition to some single form of description of all features, the introduction of a new conditional unit, which allows the formal comparison of heterogeneous objects.

When solving practical problems, the most widespread standardization methods based on the statistical standardization procedure have been applied, in which all indicators describing the object of clustering are reduced to the form when their average value is 0 and the variation around the mean (variance) is equal to 1:

$$z_{ij} = \frac{x_{ij} - \bar{x_j}}{\sigma_j}, \quad (2)$$

where z_{ij} – the normalized j-th index of the i-th object;

x_{ij} – the value of the j-th attribute for the i-th object;

$\bar{x_j}$ – the average value of the j-th sign across the entire set of classified objects;

σ_j – the root mean square deviation of the j-th sign.

Standardization is a necessary procedure that eliminates the impact of multifaceted metrics on the degree of similarity between objects. As a result of the normalization, the transition from the input matrix X to the standardized data matrix X^{norm}.

Next, we build a reference point Z0 (development standard) – an artificial point with coordinates (z01, z02,… z0m), characterized by the best values for each of the signs *x1, …, xm*. The reference point values are calculated as *max(zij)* (for stimulants) and *min(zij)* for dis-stimulants, *zij* – the standardized value of the j-th feature for the i-th object.

The distances in the multidimensional feature space are determined between the individual points (objects) and the reference point Z0 (the development standard). The smaller this distance is, the closer the object is to the standard.

The distance is calculated based on the Euclidean distance by the formula:

$$d_0 i = \sqrt{\sum_{j=1}^{m} \left(x_{ij} - x_{0j}\right)^2}, \quad (3)$$

where: *m* – the number of variables (attributes) that describe the objects;

x_{ij} – measure the distance to which we are trying to calculate;

x_{0j} – the index from which we calculate the distance.

The calculated distances are the initial values when calculating the taxonomic indicator of the level of development:

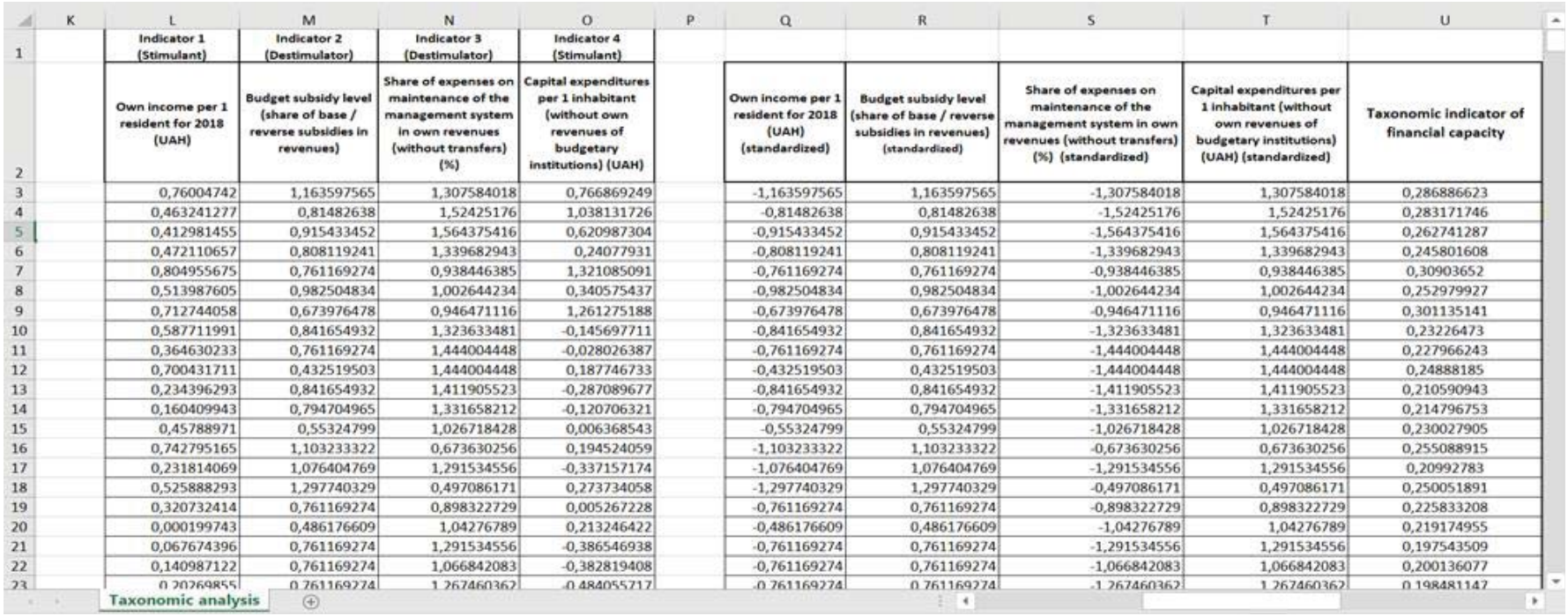
$$k_i = 1 - \frac{d_{0i}}{d^1}, \quad (4)$$

where $d = \underline{d}_0 + 2\sigma_0$,

$\underline{d}_0 = \frac{\Sigma \cdot a_0 i}{n}$ – the arithmetic mean of Euclidean distances between objects and the n standard,

σ_0 – the mean square deviation of the Euclidean distances between objects and the standard.

The values of the taxonomic indicator of the level of development should be interpreted in the way if the value of the indicator is closer to 1, the higher the level of development is the object, and the closer to 0 – the lower (Table 3).



	K	L	M	N	O	P	Q	R	S	T	U
1		Indicator 1 (Stimulant)	Indicator 2 (Destimulator)	Indicator 3 (Destimulator)	Indicator 4 (Stimulant)						
2		Own income per 1 resident for 2018 (UAH)	Budget subsidy level (share of base / reverse subsidies in revenues)	Share of expenses on maintenance of the management system in own revenues (without transfers) (%)	Capital expenditures per 1 inhabitant (without own revenues of budgetary institutions) (UAH)		Own income per 1 resident for 2018 (UAH) (standardized)	Budget subsidy level (share of base / reverse subsidies in revenues) (standardized)	Share of expenses on maintenance of the management system in own revenues (without transfers) (%) (standardized)	Capital expenditures per 1 inhabitant (without own revenues of budgetary institutions) (UAH) (standardized)	Taxonomic indicator of financial capacity
3		0,76004742	1,163597565	1,307584018	0,766869249		-1,163597565	1,163597565	-1,307584018	1,307584018	0,286886623
4		0,463241277	0,81482638	1,52425176	1,038131726		-0,81482638	0,81482638	-1,52425176	1,52425176	0,283171746
5		0,412981455	0,915433452	1,564375416	0,620987304		-0,915433452	0,915433452	-1,564375416	1,564375416	0,262741287
6		0,472110657	0,808119241	1,339682943	0,24077931		-0,808119241	0,808119241	-1,339682943	1,339682943	0,245801608
7		0,804955675	0,761169274	0,938446385	1,321085091		-0,761169274	0,761169274	-0,938446385	0,938446385	0,30903652
8		0,513987605	0,982504834	1,002644234	0,340575437		-0,982504834	0,982504834	-1,002644234	1,002644234	0,252979927
9		0,712744058	0,673976478	0,946471116	1,261275188		-0,673976478	0,673976478	-0,946471116	0,946471116	0,301135141
10		0,587711991	0,841654932	1,323633481	-0,145697711		-0,841654932	0,841654932	-1,323633481	1,323633481	0,23226473
11		0,364630233	0,761169274	1,444004448	-0,028026387		-0,761169274	0,761169274	-1,444004448	1,444004448	0,227966243
12		0,700431711	0,432519503	1,444004448	0,187746733		-0,432519503	0,432519503	-1,444004448	1,444004448	0,24888185
13		0,234396293	0,841654932	1,411905523	-0,287089677		-0,841654932	0,841654932	-1,411905523	1,411905523	0,210590943
14		0,160409943	0,794704965	1,331658212	-0,120706321		-0,794704965	0,794704965	-1,331658212	1,331658212	0,214796753
15		0,45788971	0,55324799	1,026718428	0,006368543		-0,55324799	0,55324799	-1,026718428	1,026718428	0,230027905
16		0,742795165	1,103233322	0,673630256	0,194524059		-1,103233322	1,103233322	-0,673630256	0,673630256	0,255088915
17		0,231814069	1,076404769	1,291534556	-0,337157174		-1,076404769	1,076404769	-1,291534556	1,291534556	0,20992783
18		0,525888293	1,297740329	0,497086171	0,273734058		-1,297740329	1,297740329	-0,497086171	0,497086171	0,250051891
19		0,320732414	0,761169274	0,898322729	0,005267228		-0,761169274	0,761169274	-0,898322729	0,898322729	0,225833208
20		0,000199743	0,486176609	1,04276789	0,213246422		-0,486176609	0,486176609	-1,04276789	1,04276789	0,219174955
21		0,067674396	0,761169274	1,291534556	-0,386546938		-0,761169274	0,761169274	-1,291534556	1,291534556	0,197543509
22		0,140987122	0,761169274	1,066842083	-0,382819408		-0,761169274	0,761169274	-1,066842083	1,066842083	0,200136077
23		0,20269855	0,761169274	1,267460362	-0,484055717		-0,761169274	0,761169274	-1,267460362	1,267460362	0,198481147

Taxonomic analysis

Fig. 1. Matrix of calculated standardized data according to stimulants and destimulators for 665 UTCs of Ukraine in 2018

Table 3

Interpretation of the values of the taxonomic indicator of the level of development

Level of development	The value of the taxonomic indicator of the level of development
Highest	0,8–1
High	0,6–0,79
Average	0,4–0,59
Low	0,2–0,39
Lowest	0,0001–0,19

Based on the above methodology, we conducted a taxonomic analysis of the financial capacity of the united territorial communities. At the same time, a taxonomic indicator of the level of development was calculated for all 665 UTCs of Ukraine in 2018.

The calculation of the taxonomic indicator of the level of development was made on the basis of stimulus indicators that have a positive impact on this result, namely own income per 1 inhabitant and capital expenditures per 1 inhabitant (excluding own revenues of budgetary institutions) in 2018, as well as two stimulus indicators, the level of budget subsidization (the share of base / reverse subsidies in revenues) and the share of expenditures for the maintenance of the management system in own revenues (excluding transfers) (%)), which have a negative impact on the resultant indicator. On the basis of taxonomic analysis, all UTCs are divided into three groups by level of development, some of the results are shown in Table 4.

Table 4

An extract of the grouping of Ukrainian UTCs by the level of development based on taxonomic analysis

Level of development	Region	Name of UTC	Population as of 01.01.2018 (thousand)	Taxonomic indicator of financial capacity
Highest	Dnipropetrovsk	Slobozhanska	14,6	0,8594773
High	Poltava	Senchanska	3	0,729411885
	Dnipropetrovsk	Hrechanopodivska	3,6	0,696297067
	Dnipropetrovsk	Troitska	2,7	0,685771838
	Dnipropetrovsk	Verbkivska	7,5	0,63937722
	Zhytomyr	Oliivska	5,3	0,623558969
	Odessa	Avanhardivska	10,5	0,618794511
	Donetsk	Shakhivska	2,9	0,602456664
Average	Kharkiv	Natalynska	6,4	0,558921215
	Donetsk	Andriivska	2,4	0,548674259
	Poltava	Pryshybska	2	0,520404373
	Dnipropetrovsk	Bohdanivska	6,8	0,516669523
	Cherkasy	Stepanetska	5,3	0,511248699

As it can be seen from Table 4, the results of taxonomic analysis completely deny the experts' assertion that the financial capacity is affected by the area and population of the territorial community. Thus, only one Slobozhany UTC with a population of significantly less than 20 thousand people has a high level of development, enabling its financial solvency. The following in terms of taxonomic development, seven UTCs, which have a high level of development, have a population of less than 3 thousand people.

The second method, which also provides a more detailed assessment of the level of development and financial capacity of the UTCs, is cluster analysis.

K-means clustering is a popular clustering method. It is a method of organizing many objects into relatively homogeneous groups, invented in the 1950s by the mathematician Hugo Steinhaus[1] and almost simultaneously by Stuart Lloyd[2]. This method became especially popular after McQueen's work[3].

The purpose of the method is to divide n observations into k clusters so that each observation belongs to the cluster with the mean closest to it. The method is based on minimizing the sum of squares of distances between each observation and the center of its cluster, that is, the function:

$$\sum_{i=1}^{N} d(x_i, m_j(x_i))^2, \tag{5}$$

where: $d -$ the metric, in our case, the square of Euclidean distance, which is calculated by the formula:

$$d_{0i} = \sqrt{\sum_{j=1}^{m} (x_{ij} - x_{0j})^2}, \tag{6}$$

where: m – the number of variables (attributes) that describe the objects, x_{ij} – measure the distance to which we are trying to calculate,

x_{0j} – an indicator from which distance is calculated,

x_i – the i-th data object, while $m_i(x_i)$ – the center of the cluster to which the x_i element is assigned at the j-th iteration.

The implementation of this method requires step by step application.

The first step is to have an array of observations (objects), each of which has definite values on a number of grounds. According to these values, the object is located in a multidimensional space:

$$X = \begin{pmatrix} x_{11} & \dots & x_{1k} & \dots & x_{1m} \\ \dots & \dots & \dots & \dots & \dots \\ x_{i1} & \dots & x_{ik} & \dots & x_{im} \\ \dots & \dots & \dots & \dots & \dots \\ x_{n1} & \dots & x_{nk} & \dots & x_{nm} \end{pmatrix}, \tag{7}$$

Table 5 provides an explanation of the indicators used in the cluster analysis.

Table 5

The interpretation of indicators used in cluster analysis

Symbol	Name of indicator
X1	Own income per 1 resident for 2018 (UAH)
X2	Budget subsidy level (share of base / reverse subsidies in revenues)
X3	Share of expenses on maintenance of the management system in own revenues (without transfers) (%)
X4	Capital expenditures per 1 inhabitant (without own revenues of budgetary institutions) (UAH)

[1] Steinhaus, H. (1957). Sur la division des corps matériels en parties. *Bull. Acad. Polon. Sci, 4 (12)*, 801-804.
[2] Lloyd., S. P. (1957). Least square quantization in PCM". *Bell Telephone Laboratories Paper*. <http://www-evasion.imag.fr/people/Franck.Hetroy/Teaching/ProjetsImage/2007/Bib/lloyd-1982.pdf> (2019, November, 15).
[3] Proceedings of 5th Berkeley Symposium on Mathematical Statistics and Probability (2018). *Some Methods for classification and Analysis of Multivariate Observations*. University of California Press, 281-297.

In the second step of the analysis, researchers determine the number of clusters to be created. To do this, the Elbow method was applied in the paper.

The Elbow method is a heuristic method of interpretation and validation of consistency within cluster analysis designed to help finding the appropriate number of clusters in a dataset. (Fig. 2).

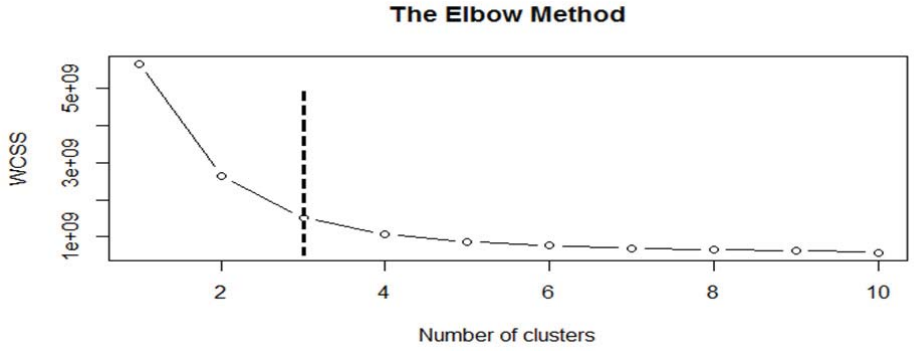


Fig. 2. Graphical interpretation of the Elbow method

Following the figure 2, the vertical dotted line is referred to as the *elbow*.

Upon testing with the K-means method in both cases, we determined that the number of clusters selected should be 3. This method considers the percentage of variance explained as a function of the number of clusters. In means that the number of clusters should be chosen so that the addition of another cluster does not give much better data modeling. More precisely, if you plot the percentage variance explained by clusters against the number of clusters, the first clusters will add a lot of information (the lines on the graph are descending), but at some point the lines will begin to smooth out, creating an angle in the graph. The number of clusters is selected at this point, hence the Elbow criterion. This *elbow* cannot always be uniquely identified. The percentage of variance explained is the ratio of variance between groups to the total variance; also known as the F-test. A slight variation of this method builds the intra-group variance distortion.

According to this method, the following steps occur:

1. k observations are randomly selected, which in this step are considered to be centers of clusters.

2. Each observation is *attributed* to one of n clusters, typically the one to which the distance is shortest.

3. The new center of each cluster is calculated as an element, the signs of which are calculated as the arithmetic mean of the objects included in this cluster.

4. The number of iterations occurs (steps 3-4 are repeated) until the cluster centers become stable (i.e. each object will have the same objects in each iteration), the variance inside the cluster will be minimized and between clusters maximized.

The cluster analysis was performed in an integrated RStudio development environment using a programming language for statistical computing and R data analysis.

On the basis of the cluster analysis, all 665 UTCs of Ukraine studied were also divided into 3 clusters (Table 6). The results of the cluster analysis, as well as the taxonomic analysis, indicate the importance of stable centroids and clusters, among which area and population of UTCs are not listed. It means that these two attributes are not significant in these two methods of analysis.

The number of clusters is selected based on the research hypothesis. In this paper, the analysis is based on the Elbow method. If not, it is recommended to create 2 clusters, then 3, 4, 5, comparing the results.

Conclusions. Thus, in practice, different methods of analysis should be used to determine the level of development of united territorial communities and their financial solvency. Based on the greater variability of methods of analysis, we can more objectively draw conclusions about significant indicators that affect the development of territorial communities and their financial solvency. The analysis makes it possible to say that no matter how many people live in a territorial community and what its area is, the development of this community depends, first of all, on the effective formation of financial potential within its territory, which will increase the level of community development and provide its financial solvency.

Table 6

Steady centroids of clusters 665 UTCs of Ukraine in 2018

Centroid	Own income per 1 resident in 2018 (UAH)	Budget subsidy level (share of base / reverse subsidies in revenues) (%)	Share of expenses on maintenance of the management system in own revenues (without transfers) (%)	Capital expenditures per 1 inhabitant (without own revenues of budgetary institutions) (UAH)	Cluster
1	2644,016	0,178673516	0,3279909	929,3352	1
2	5485,566	-0,004451923	0,2231827	1818,0404	2
3	15559,783	-0,109888889	0,1356111	5734,4	3

References:

1. Decentralization (2019). *Rezultaty finansovoyi detsentralizatsiyi za 10 misyatsiv 2018 roku – ekspertnyy analiz* [Results of financial decentralization over 10 months of 2018 – expert analysis]. <https://decentralization.gov.ua/news/10197> (2019, January, 19). [in Ukrainian].
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