American Journal of Social and Humanitarian Research

Vol. 7 Issue 1 **| pp.** 200-207 **| ISSN:** 2690-9626

Available online @ https://globalresearchnetwork.us/index.php/ajshr

Article

Evaluation of the Social Potential of the Districts of Kashkadarya Region Based on Integral Indices and Cluster Analysis

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Abstract: The paper assesses the social availability presented by the integral index method with cluster analysis regarding the social potential of the districts of Kashkadarya region. Perceived social potential is a multidimensional trait indicating social security, economic well being and provision of infrastructure that together form human development chances especially of childhood social potential. The knowledge gap for region level empirical assessments by quantitative methods in social potential in Uzbekistan have been targeted.

It employs Z standardization of socio-economic indicators, composite indices related to economic development, security and infrastructure provisioning, and multivariate clustering using the Expectation Maximization algorithm. Districts are being classified based on normalized indicators obtained from the official statistical data, which means that districts are compared based only on normalized indicators due to the fact that those indicators relate to structural characteristics of the territory, which are not very comparable.

These findings show the substantial differences in social potential across regions. These clusters stretch from the most economically and infrastructurally developed districts to those underperforming on all dimensions. The results show that economic growth per se does not provide the base for high social potential: security and infrastructure factors are decisive for regional development.

Findings highlight the need for differentiated regional social policies. This suggests that there are important policy implications such as favouring investments in infrastructure and social security at the level of low potential clusters and changing economic indicators, as they are currently having no meaning in describing how household well being is. Such tool created with the help of proposed approach provides a solid analytical foundation for enabling regional diagnostics and can be used to implement it for other regions of Uzbekistan, further allowing for factual territorial development planning.

Keywords: regional development, social potential, social potential of childhood, integral indices, cluster analysis, Z-standardization, EM clustering, infrastructure, social security, economic well-being.

Citation: Zoirov G'. Evaluation of the Social Potential of the Districts of Kashkadarya Region Based on Integral Indices and Cluster Analysis. American Journal of Social and Humanitarian Research 2026, 7(1), 200-207.

Received: 10th Oct 2025
Revised: 11th Nov 2025
Accepted: 24th Dec 2025
Published: 28th Jan 2026

INTRODUCTION

What we highly appreciate about socio-economic development of regions defines a definite limit of their sustainable development, however the paradox is that the social inequality in the distribution of resources and social opportunities is growing, which increases the unevenness of territorial development [1]. These differences, as well as the demand for a differentiated approach to regional social policy, have become more pronounced in Uzbekistan, where regional administration has recently begun to gain governance functions.

The social potential of a territory, such as the social potential of childhood—is one of the main factors determining access to education, health care and overall human development opportunities; at the same time, its low formation enhances regional inequality. Methods. A clustering method is used to address the problems observed in the social potential spread in the districts and cities of Kashkadarya region which are different because of their nature, lands, population and regions, and to scientifically substantiate the improvement of regional social policy [2].

While regional studies may understand the social potential of childhood primarily as a secondary element of demographic theory, it must be understood comprehensively as a potential strategic resource that shapes human capital in regional, national, and global contexts. The social potential of childhood depicts a connected cycle of conditions, assets, and results that impact the well-being and growth of kids.

This potential is significant only in its interaction with the level of economic development, the status of social infrastructure, education and healthcare systems, and the institutional environment, as all this determines the formation of human capital in the region in question (Kashkadarya region) as well. Therefore, clustering territorial units based on social potential indicators is of significant importance for the systematic assessment of children's development conditions and for the scientifically grounded improvement of regional social policy [3].

Literature Review. Issues of regional social potential and socio-economic development have been established as an important research direction in economic and social sciences. In the scholarly literature, social potential is interpreted as one of the key resources determining the sustainability and competitiveness of regions. In particular, Kalmuratov B.S. and co-authors conceptualize regional social potential as a management object that reflects complex socio-economic processes, emphasizing its systemic nature and its role in shaping regional development outcomes. According to their approach, social potential integrates economic, social, demographic, and institutional factors, making it a critical component of evidence-based regional policy formulation.

In international research, the relationship between regional development and social factors is commonly examined through the concept of social capital. Empirical studies conducted by Nan Lin and B. H. Erickson demonstrate, using statistical models, that social capital has a significant impact on education, cultural development, and regional economic growth, confirming its role as an important driver of socio-economic progress.

The cluster approach is regarded as an important methodological tool for grouping regions according to their level of development [4]. In the *Cluster Initiative Greenbook* report, clustering is interpreted as an effective mechanism for improving regional policy, stimulating innovation activity, and enhancing territorial competitiveness.

Multidimensional statistical methods, including cluster analysis, are widely applied to identify socio-economic disparities among regions. Everitt and co-authors substantiate the methodological advantages of cluster analysis in socio-economic research, highlighting its effectiveness in revealing structural heterogeneity and grouping territories based on complex, interrelated indicators.

In the context of Uzbekistan, issues of regional social potential have also been addressed in national research. X. F. Akramov examines how social capital resources embedded within the *mahalla* institution contribute to the functioning and effectiveness of social protection mechanisms, highlighting the role of local the role of social networks and trust in facilitating social welfare outcomes [5].

Moreover, the role of social capital in the family and education is the subject of research by M. J. Norqobilov, who notes that education and family as the main institutions have traditionally formed social values, norms, and human development potential and have been the means of transferring these values from one generation to another.

In summary, the prevalence of theoretical and empirical connections between social potential and cluster research at the regional level are indeed supported by the academic literature. These methods offer a strong scientific basis for why the current research was designed in the way that it was, including the chosen statistical approaches preference in this study.

Research Methodology. The study approximates social landfund and divide districts of the Kashkadarya region by social potential of childhoods in complex approach. Methodologically, it is based on systemic and regional analysis, used statistical standardization of data (Z-standardization), the integral index method, and multivariate cluster analysis [6]. The EM clustering algorithm is used to group territorial units, and the results provide a scientifically substantiated foundation for the intact differentiation of regional social policy Directions.

Analysis and Results. Cluster analysis facilitated objective grouping of territories based on multidimensional indicators and allowed for a multi-faceted evaluation of social processes in the study. For this clustering some basic comprehensive indices which reflected economic development, social security and infrastructure supply were used, and these indices are relative ones, which means these indices are comparable ones that calculated with respect to other indices in each region.

This took place in two steps: the indicators first turned into relative indicators and then standardized to the single measurement scale. This methodological approach, firstly, laid the scientific foundation for the objectivity of the assessment of the social potential of the districts of Kashkadarya region using cluster analysis, and, secondly, was used to form a targeted improvement of social policy in the region [7].

The common Z-standardization method in statistical analysis was used to normalize the indicators. This would enable the assessment of each territorial indicator with respect to the entire distribution and to convert variables measured in different units into a unique one. The standardized value was calculated using the following formula:

$$I_{norm} = \frac{x - \bar{x}}{\sigma} \qquad (1)$$

where: I_{norm} - normalized (standardized) value of the indicator; x - actual value of the indicator for a specific territory (district or city); $\bar{x}$ - arithmetic mean of the indicator across all territories; σ - standard deviation of the indicator across territories.

This formula measures the deviation of a territorial indicator from its mean value: positive values indicate above-average levels, negative values reflect below-average levels, and values close to zero correspond to the average. Z-standardization converts any indicator with unit of measure into a common statistical scale, allowing equal contribution of each indicator to the cluster analysis outcomes, thus increasing their precision and reliability.

This method provided adequate reliability of territorial modeling and stability of obtained data, clustering results, in revealing real territorial differences in social potential within the Kashkadarya region [8]. The normalized indicator values were calculated without applying weighting coefficients to the indicators; thus, all indicators are considered equally important; the integral indices for the EU countries were constructed using official and comparable statistical data.

The economic development index was calculated based on gross regional product per capita, unemployment rate, and the share of low-income population, with negative factors incorporated using inverse signs. This approach enabled an objective and balanced assessment of regional economic development.

Consequently, the economic development index was defined as the arithmetic mean of the three standardized indicators and calculated using Formula (2). The index serves as an important analytical tool for evaluating the overall economic condition of the region, conducting interregional comparisons, and informing socio-economic policy priorities:

$$I_{edi} = \frac{I_{GRP}+I_{nempt}+I_{subs}}{3} \qquad (2)$$

where: I_{edi}- economic development index; I_{GRP} - standardized value of gross regional product per capita; *Iunemp* - standardized unemployment rate (included with a negative sign); I_{subs} - standardized share of population with income below the subsistence minimum (included with a negative sign).

The selected indicators are integrated with the help of the arithmetic mean, which allows to obtain a classical approach to the assessment of the economic development level of the Kashkadarya region, since the above formula is quite universal [9]. The measures are shown in four different forms and reflect crime rates, road traffic accident statistics, air pollution measures and volumes of contaminated wastewater, thus the regional security index is created out of standardised values of these indicators. Every constituent of the security index is considered a negative factor, each with equal weight, providing harmonised and holistic data on safety conditions of the territory. As a result, the regional security index is calculated based on the following formula:

$$I_{risk}=\frac{I_{crime}+I_{RTA}+I_{air.poll}+I_{wastew.poll}}{4} \qquad (3)$$

where: I_{risk} *- regional security (risk) index;* I_{crime} *- normalized value of the number of crimes per 100,000 population;* I_{RTA} *- normalized value of the number of road traffic accidents per 100,000 population;* $I_{air.poll}$ *- normalized value of the volume of harmful substances emitted into the atmosphere per capita;* $I_{wastew.poll}$ *- normalized value of the volume of polluted wastewater per capita.*

It enables the implementation of comprehensive analysis of the security status of the population of the Kashkadarya region, identification of problem areas, and development of the regional development strategy based on a scientific basis [10]. The scope of infrastructure supply is evaluated through a third composite (integrational) index—integral as the generalized integral value of several scalar indexes.

Well-known indicators of housing and communal services, transport, communications, healthcare and educational infrastructure are included in the index. These indicators are calculated using appropriate formulas and normalized according to a unified methodology. This approach enables the comparison of indicators with different units of measurement and provides a comprehensive assessment of the level of infrastructure development. As a result, the infrastructure provision index is determined based on the following formula:

$$I_{infra}=\frac{I_{housing}+I_{comm}+I_{health}+I_{edu}+I_{transport}}{5} \qquad (4)$$

where: I_{infra} *- is the infrastructure provision index;* $I_{housing}$ *- is the normalized value of the housing and communal services infrastructure index;* I_{comm} *- is the normalized value of the communication and telecommunications infrastructure index;* I_{health} *- is the normalized value of the healthcare infrastructure index;* I_{edu} *- is the normalized value of the education infrastructure index;* $I_{transport}$ *- is the normalized value of the transport infrastructure index.*

This approach makes it possible to comprehensively and scientifically assess the level of infrastructure development in the Kashkadarya region and to identify priority directions for regional development [11]. The housing infrastructure provision index is calculated based on Formula (5) and provides a comprehensive assessment of the quantitative and qualitative condition of the housing stock in the region through the normalized values of two key indicators reflecting the population's living conditions. The housing infrastructure index is expressed by the following formula:

$$I_{housing}=\frac{I_{area}+I_{dilapidated}}{2} \quad (5)$$

where: $I_{housing}$- is the housing infrastructure provision index; I_{area} - is the normalized value of the average housing area per capita; $I_{dilapidated}$ - is the normalized value of the share of dilapidated and emergency-condition housing in the total housing stock.

Since an increase in the share of dilapidated and emergency-condition housing indicates a deterioration in living conditions, this indicator is treated as a negative factor in the normalization process. The housing infrastructure index possesses high scientific and practical feasibility in the measurement of home sufficiency level of people residing in the Kashkadarya region, determination of the existing issues, improving housing policy.

Communication infrastructure index is computed according to the formula and represents the degree of development of modern infrastructure of the region (normalized indicators expressing access to transport (including roads, railways, and airports) and information and communication services) [12]. The communication infrastructure index is expressed by the following formula:

$$I_{comm}=\frac{I_{bus}+I_{internet}}{2} \quad (6)$$

where: I_{comm} - is the communication infrastructure provision index; I_{bus} - is the normalized value of the number of public buses per 100,000 population; $I_{internet}$ - is the normalized value of the number of Internet subscribers per 100 population.

An increase in the number of public transport vehicles and the share of Internet subscribers reflects expanded mobility and access to information for the population, thereby enabling a comprehensive assessment of the level of communication infrastructure development in the Kashkadarya region.

The healthcare infrastructure provision index is calculated based on Formula (7) and provides a comprehensive assessment of the population's access to medical services through normalized indicators reflecting the capacity of healthcare service delivery. The healthcare infrastructure index is expressed by the following formula:

$$I_{health}=\frac{I_{\text{physicians}}+I_{medstaff}+I_{beds}+I_{outpatient}}{4} \quad (7)$$

where: I_{health} - is the healthcare infrastructure provision index; $I_{physicians}$ - is the normalized value of the number of physicians per 10,000 population; $I_{medstaff}$ - is the normalized value of the number of mid-level medical personnel per 10,000 population; I_{beds} - is the normalized value of the number of hospital beds per 10,000 population; $I_{outpatient}$ - is the normalized value representing the service capacity of outpatient clinics and polyclinics per 10,000 population.

This index is of great importance for assessing the level of development of the healthcare system in the Kashkadarya region, identifying disparities in the provision of medical services across different areas, and making scientifically grounded decisions for the further development of the sector.

The education infrastructure provision index is calculated based on Formula (8) and enables a comprehensive assessment of the level of development of the education system in the region by relying on the normalized values of key indicators covering all stages of education [13]. The education infrastructure index is expressed by the following formula:

$$I_{edu}=\frac{I_{preschool}+I_{shift}+I_{class\_sizc}+I_{secondary}\ +I_{higher}}{5} \quad (8)$$

where: I_{edu} - is the education infrastructure provision index; $I_{preschool}$ - is the normalized value of the preschool education coverage rate of children (%); I_{shift} - is the normalized value of the share of students studying in second and third shifts; I_{class_sizc} - is the normalized value of the average class occupancy level; $I_{secondary}$ - is the normalized value of the number of students in secondary (vocational and professional) education institutions per 10,000 population; I_{higher} - is the normalized value of the number of students in higher education institutions per 10,000 population.

A greater share of students in second and third shifts, as well as higher class occupancy rates, suggests increasing strain on education infrastructure and is, therefore, treated as a dis-facilitator in the assessment process. Index of education infrastructure to investigate the

educational system in the Kashkadarya region, to find the problems that exist, and to develop scientifically based conclusions about how to improve the condition of the sector [14].

This objective access to the activities of key institutions reflecting the population's participation in cultural life, as well as access to cultural and educational resources is expressed in the cultural infrastructure provision index, calculated based on Formula (9). The cultural infrastructure index is expressed by the following formula:

$$I_{culture}=\frac{I_{theatre}+I_{museum}+I_{library}+I_{press}}{4} \quad (9)$$

where: $I_{culture}$ - is the cultural infrastructure provision index; $I_{theatre}$ - is the normalized value of the number of theatre visitors per 1,000 population; I_{museum} - is the normalized value of the number of museum visits per 1,000 population; $I_{library}$ - is the normalized value of the size of library collections per 1,000 population; I_{press} - is the normalized value of the circulation of newspapers and periodicals per 1,000 population.

High values of these indicators reflect a well-developed cultural environment in the region and a high level of the population's spiritual and educational engagement. Therefore, the cultural infrastructure index is of significant importance for assessing the state of the cultural sector and identifying regional disparities in the Kashkadarya region.

As a result of the calculations, the composite (integral) indices of economic development, security, and infrastructure provision were adopted as the main information base for clustering regional units and were processed using the Deductor software platform. We handled data quality and outliers, which let to more robustliers, which translates to more reliable clustering results.

The clustering were performed with k-means, g-means and Kohonen maps on the first stage and the EM clustering algorithms were used as they fit best based on statistical criteria. EM algorithm attested that there were seven clusters optimal for the number of clusters and these clusters had a pronounced difference in socio-economic development levels of the regions that was expressed in the indices [15]. The average values and dispersion of the composite indices by cluster are presented in Table 1.

Table 1

Descriptive statistical indicators of the composite indices by clusters

Indicators / Clusters	0	1	2	3	4	5	6
Economic Development Index (I< sub >econ</sub>)							
Average value	1,54	–1,00	0,13	0,02	–0,05	0,97	–0,80
Standard deviation	0,34	0,51	0,30	0,23	0,28	0,21	0,66
Security Index (I_{risk})							
Average value	–0,97	1,19	0,24	–0,59	0,40	0,29	–0,24
Standard deviation	0,34	0,47	0,13	0,34	0,30	0,50	0,16
Infrastructure Index (I_{infrastructure})							
Average value	–0,50	–0,75	0,06	0,12	0,16	0,56	–0,16
Standard deviation	0,41	0,22	0,19	0,23	0,19	0,37	0,33

The social potential of the clusters was qualitatively assessed using the categories "very high," "high," "medium," "low," and "very low." For this purpose, the range between the maximum and minimum values of the composite indices was divided into five equal parts. Accordingly, the assessment step was set at 0.68 for the economic development index, 0.63 for the security index, and 0.39 for the infrastructure index.

This approach provides a methodological basis for a comprehensive quantitative and qualitative assessment of clusters, comparing the social potential of the districts of the Kashkadarya region, and scientifically substantiating regional development strategies. The assessment intervals are presented in Table 2.

Table 2

Intervals of index values characterizing the levels of social potential development of regions

Indices	Very high	High	Medium	Low	Very low
Economic development Index (I< sub >econ</sub>)	[+1,74; +1,07]	[+1,06; +0,39]	[+0,38; -0,29]	[-0,30; -0,97]	[-0,98; -1,65]
Security Index (I_{risk})	[+1,74; +1,11]	[+1,10; +0,48]	[+0,47; -0,15]	[-0,16; -0,78]	[-0,79; -1,41]
Infrastructure Index (I_{infrastructure})	[+1,00; +0,61]	[+0,60; +0,22]	[+0,21; -0,17]	[-0,18; -0,56]	[-0,57; -0,95]

Based on the established intervals, the social potential of the clusters was qualitatively assessed. Cluster 0 is characterized by a high level of economic development and low security, while Cluster 1 features low economic and infrastructure development combined with high security. Clusters 2 and 4 demonstrate medium levels across all indices and thus represent relatively stable territories.

Cluster 3 is distinguished by low security, Cluster 5 by high economic development and infrastructure provision, and Cluster 6 by low values across all three indices, bringing together the regions with the weakest social potential. This classification helps identify regional disparities and provides a scientific basis for the formulation of regional development policies.

Table 3

Significance of indices in the clustering process, %

Indices / Clusters	0	1	2	3	4	5	6
Economic development Index	100,0	100,0	80,7	4,7	21,8	99,9	99,9
Security Index	99,4	100,0	99,9	100,0	92,3	70,5	73,2
Infrastructure Index	98,4	100,0	62,1	80,7	69,6	99,8	81,6

The analysis of the table 3 shows that in some clusters the influence of the economic development index on the clustering process is low, which indicates the need to revise its methodology. This situation can be explained by deviations of gross regional product per capita from a normal distribution and by the fact that the income generated in the region is not fully reflected in the population's well-being.

Therefore, it is proposed to use an income index-expressing the ratio of average per capita monetary income to the subsistence minimum-instead of gross regional product in the economic well-being index. This approach increases the reliability of the clustering results and contributes to a more objective assessment of the social potential of the territories of the Kashkadarya region.

Clustering results showed differences in social potential between regions. In Cluster 0 there is high economic advancement but low at security and infrastructure, while in Cluster 1 economic and infrastructural development are low with relatively high security. Cluster two, is the most populous cluster with respect to the number of regions, is characterized by average level of development but also imbalance within.

The third cluster has a low level of security and social and infrastructural factors are of a greater importance than economic factors. Cluster four is a fairly average cluster with characteristics close to cluster two. The fifth cluster unites the regions with the greatest social potential and is characterized by the balanced nature of development of economic and infrastructural factors. Conversely, the sixth cluster is a group of regions with the weakest social potential and the most intra-clock differences, being marked with a low value on all three indices.

This classmate highlights the need for a holistic approach where analysis of regional modernisation should be focused on economic, security, and communication aspects. This also indicates possible setup of clusters which might be optimized in the future and identify similar clusters getting merged.

Conclusions. Next, the comparison of the clustering results with traditional grouping methods and the results of regional clustering obtained by other researchers help to verify the found conclusions, which increases the reliability of results. Future research will involve fine-tuning social potentials classifications of clusters for assessment, enhancement of evaluation scales, and a more profound analysis of relationships between the composite indices.

Also, in 2024, it is planned to create clustering maps on the basis of GIS technologies and to analyze the dynamics of regional social potential by comparing the results with the previous periods. Such an approach will enable the regional development trends identification and targeted regional policy formulation based on scientifically sound policies.

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