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Assessment of Regional Readiness for Smart City Policy Implementation in Kazakhstan.

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Abstract— **The purpose of the research is to assess the level of readiness of the regions of Kazakhstan to implement the "smart city" policy. The research is aimed at identifying regions with the greatest potential for the development of smart cities. The research methodology includes conducting a cluster analysis to assess the level of readiness of the regions of Kazakhstan to implement the "smart city" policy. The methodology included the analysis of three groups of factors, such as the social, economic, and scientific environment, which determine the readiness of regions for a smart city policy. The analyzed period included data from 2010 to 2022. The results of the study allowed us to identify the leading regions with a high level of readiness for smart cities and regions that require additional attention and resources to improve their infrastructure and stimulate economic growth. The study showed that the division of regions of Kazakhstan into two clusters according to the value of the Gap Statistic (~0.6 at k=2) is optimal. The first cluster was distinguished by a developed economic and social infrastructure, high indicators in education and health care. The second cluster showed lower indicators, reflecting a lag in development. Almaty and Astana were identified as leader, emphasizing their positions in development among other regions.**
Index Terms—cluster analysis , Kazakhstan, regional economy, smart cities.

I. INTRODUCTION

In the modern world, digital technologies play an increasingly important role in the development and development of the urban environment. The concept of smart cities, based on the use of digital technologies to optimize management, increase the efficiency of public services and improve the quality of life of citizens, is becoming increasingly relevant and widely discussed. However, the introduction of digital technologies into urban environments has the potential to strengthen democratic processes, and also carries the risk of centralizing power and increasing the number of colors.

The purpose of these articles is to observe the region of policy implementation in smart cities. The study examines various aspects of smart city concepts, including their role in ensuring transparency and citizen participation in city governance, as well as the influence of economic, social and economic factors on the development of smart cities.

To achieve this goal, the article analyzes existing theoretical approaches to understanding smart cities, as well as the experience of various countries in implementing smart initiatives. Additionally, apply cluster analysis techniques to target groups of regions with similar weather conditions and observe their approach to implementing smart city policies.
The results of the study show the main factors determining the readiness of regions for smart cities, and the results of the study can be used for the further development and implementation of smart trends.

II. BACKGROUND

The digital infrastructure of smart cities can either strengthen or undermine democratic processes, depending on how it is used. Technology can provide platforms for civic participation and co-optation of ideas in the urban planning process, but without adequate transparency and equal access to these technological resources, the risk of centralizing power and increasing inequality remains high [1]. Cities are developing smart initiatives to attract international investment and technology companies, often at the expense of local needs and interests. Decisions about smart city development are often made by authorities and corporate leaders without much public consultation, which can lead to a lack of transparency and accountability. The main areas of the smart city concept include optimizing transport systems, using renewable energy, monitoring air and water quality, developing modern educational technologies, using telemedicine, ensuring security through intelligent monitoring and control systems, and increasing the efficiency and accessibility of city services through Internet of Things technologies (IoT) [2].
In the context of smart cities, Foucault views technology as a feature of monitoring, data collection and analytics for the management of urban populations [3]. He emphasizes that power is oriented toward the population as a whole and uses statistics, medical records, and other forms of data collection to govern and regulate populations [4]. In this way, technology in smart cities can function as means of disciplinary power, allowing for more nuanced and comprehensive governance of citizens' daily lives.
The concept of planetary urbanization, in the context of smart cities, also considers the impact of technology and digital infrastructure on the standardization of urban practices. Subsequently, cities turn into nodes of a global network, where each node contributes to the unification of the global urban experience through the exchange of data, technologies and management practices [5]. Unlike Foucault, Lefebvre's approach addresses opportunities for civic participation. The author emphasizes that smart technologies contribute to the formation of a “global city” through both physical infrastructure and digital spaces. It creates new forms of power and governance, whereas simultaneously providing tools for participation and interaction between city authorities and the population [6]. Technology can enhance surveillance and control, but it also creates channels for civic participation and dialogue with authorities. The political economy model of smart cities examines how economic interests, corporate governance, and political structures shape the development of smart cities. She views smart cities not simply as technological projects, but as complex socio-economic and political enterprises that embody and reproduce certain types of power and control [7].
Smart cities are becoming an arena for competition for resources, power and control, with multinational corporations, tech giants and government agencies playing key roles. Kuecker and Hartley [8] highlighted the role of multinational corporations, government agencies and international organizations in promoting the smart cities agenda. Large corporations may benefit greatly from contracts to develop and implement technology solutions, whereas local communities may face risks associated with loss of privacy, increased social control, and increased inequalities in access to city services. The introduction of smart technologies can exacerbate already existing inequalities, creating a “digital divide” between those who have access to the latest technologies and those who remain outside this digital ecosystem [9].
Chang et al. [10] approach the analysis of smart urbanism through the lens of “provincialization”, focusing on the broader and more diverse factors influencing smart urbanism. In Taipei, smart city initiatives have been refocused on strengthening the local economy and supporting local start-ups and ICT enterprises, fostering the development of a unique ecosystem of innovation that reflects local economic

strategies and policy priorities. In Taipei, the focus on smart initiatives has shifted towards improving governance transparency and citizen participation through platforms such as i-Voting and smart budget participation, promoting a more democratic and inclusive decision-making process.

There are, diverse development pathways of smart cities, though there are common characteristics as sustainability, environmental concern, attraction of external investments, and the development of platforms supported by local political and administrative power, they also contribute to the sustainability of the labor market [11]. However, each urban area of smart city initiatives are context-specific [12]. In the work of Noori, Hoppe and de Jong [13] there were analyzed four cities examplifying unique approach to smart urban development, reflecting cultural, economic, and political context of regions. Amsterdam is characterized as a business-oriented city and employs a bottom-up approach to stimulate entrepreneurship and innovation with a strong emphasis on innovation and competition. Barcelona, on the other hand, prioritizes participation and social inclusion, emphasizing democracy, citizen empowerment through technology, and data sovereignty. Dubai is marked by visionary and ambitious leadership, with a state-driven and service-oriented approach that values innovation, state supremacy and branding. Masdar's approach is defined by technological optimism and an investment-driven strategy focused on branding and visibility. The city aims to set benchmarks in sustainable urban development through flagship projects and strong branding efforts.

China on the contrary adopted a pilot smart city policy in 2012, seeking to use digital technologies to collect and analyze data that can inform government and business decisions [14], [15]. The main goal was to create a public digital infrastructure that would support sustainable growth and environmental sustainability, integrating technologies such as artificial intelligence (AI) and the Internet of things (IoT) to stimulate environmental innovation and the development of green patents. Thus, that approach was focused as a mechanism for regional development and environmental sustainability and was integrated in more than 100 cities [16].

III. METHODOLOGY

Implementation of a smart city policy depends on the level of the readiness of a region. Based on the conducted literature review there can be identified main factors which contribute to the possibility of a smart city development (Figure 1).

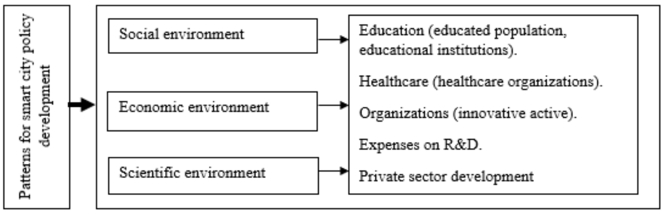

Fig. 1. Factors of regional development. This figure reflects the structure of patterns for smart cities development, which is also the condition for development of urban area, specific to countries as Kazakhstan based on regional development.

Factors selection is explained by the fact that Kazakhstan is socially oriented country. Thus, main goal of the country is to improve the well being of population. Selected variables stand out as main directions in the road map of the development of regions. Existing studies have given the clear idea that developing countries or countries with mixed economies are more inclined to follow regional policy development. Therefore, urbanization process or smart city policy implementation requires adjustment in various factors beforehand.

Thus, it is important to identify regions well prepared to urbanization process. In order to analyze current state of regional development in Kazakhstan it is required conduct cluster analysis based on selected factors and identify strong regions. The analysis includes regions which have ben established since 2010, and in 2017 Shymkent and Turkestan were given the status of separate regions (not part of South Kazakhstan region). Regions which were identified in 2022 were not included in the analysis. The data was collected from official source of information for the period 2010-2022. JAMOVI software was used for clustering of the regions.

IV. Results

The process of regions clustering is usually based on specific characteristics as high indicators of economy development or labor force potential. As there are three groups of factos selected for the analysis. First, clustering of regions of Kazakhstan is implemented. In order to identify leading regions clustering was included to methods.

In Figure 1 there are provided results of K-means clustering.

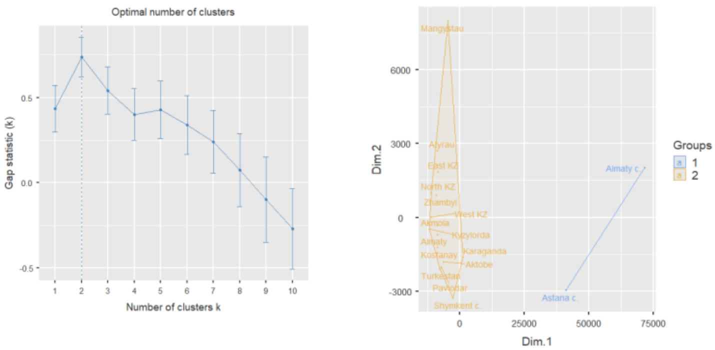

Fig. 2. K-means clustering. This figure reflects the number of clusters identified through K-means clustering approach and regions included into Cluster-1 and Cluster-2.

The highest Gap Statistic value is observed at k=2, which indicates that two clusters are optimal for this dataset according to this method. This peak suggests that the data is best summarized by two distinct groups. At k=2, the Gap Statistic value appears to be approximately 0.6, with error bars extending from about 0.45 to 0.75. The small error bars here show that there's a high level of confidence in this value of the Gap Statistic. As we move to k=3, the Gap Statistic value decreases, which indicates that the quality of the clustering solution gets worse. At k=3, the Gap Statistic value drops to around 0.3 with error bars ranging from roughly 0.2 to 0.4. The decline in the Gap value and the overlap of error bars between k=2 and k=3 suggest that increasing the number of clusters from two to three does not provide a statistically significant improvement in clustering quality. For k greater than 3, the Gap Statistic continues to decline, and the confidence in the estimates decreases as shown by the increasing length of the error bars.

Since the Gap Statistic peaks at k=2 and then significantly declines, dividing the dataset into three clusters would not capture the inherent structure as effectively as two clusters, according to this method. The numbers suggest that whereas two clusters are distinctly different from each other, a third cluster would not represent a significant departure from the variation expected by random chance.

The displayed graph illustrates the segregation of regions into two distinct groups based on principal components Dim1 and Dim2, elucidating variances in their characteristics. Group 1 is delineated by a dense clustering of points in the domain of negative to near-zero values on Dim2 and low values on Dim1, with the extremities reaching approximately -30,000 on Dim1 and about -90,000 on Dim2, indicative of a homogeneity within these regions with respect to the studied indicators. In stark contrast, Group 2 is distinguished by the pronounced divergence of one region — Almaty c., peaking at a value of 70,000 on Dim1, implying its exclusivity in certain economic or social metrics. Astana c. also exhibits elevated values on Dim1 relative to the first group, albeit to a lesser extent than Almaty c. This bifurcation corroborates the existence of two principal groupings; however, the Mangystau region is marked by an exceptional value on Dim2, transcending the common pattern and presumably reflecting unique regional attributes. Such a significant deviation could be associated with exclusive economic, social, or other factors inherent to this specific region. Given the distribution in the graph, two clusters seem to be a reasonable choice, since Almaty c. and Astana c. really stand out from other regions, and these two cities may differ greatly in terms of development from the rest of the regions of Kazakhstan. However, if we considered the possibility of a more fine-grained division within the main group (Group 1), we might find subgroups that could be formed on the basis of more subtle differences, leading to the use of three or more clusters.

These centroids represent the mean value of each attribute for the regions grouped within the respective clusters and provide a profile of the typical characteristics within each cluster (Table 1).

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TABLE I

CENTROIDS FOR CLUSTERS 1 , 2

Predictors	1	2
Education	2.758	-0.172
#Hospitals	2.350	-0.147
#HEI	3.623	-0.226
#Schools	2.734	-0.171
#Private Enterprises	3.193	-0.200
#Laqrge Enterprises	3.357	-0.210
#EntR&Dactivity	3.377	-0.211
R&D expenses	3.317	-0.207

Cluster 1 is characterized by positive normalized values across all indicators, suggesting that regions within Cluster 1 is characterized by notably robust positive normalized values across all listed indicators, implying that regions within this cluster significantly outperform the mean of the dataset. Education exhibits a high value at 2.758, suggesting a strong emphasis on academic facilities. Hospitals and higher education institutions (HEI) follow suit with values of 2.350 and 3.623 respectively, indicating a considerable presence of healthcare and tertiary education facilities. The number of schools, at 2.734, further supports the concentration of educational resources. The business environment is reflected in high scores for private enterprises (3.193) and large enterprises (3.357), denoting an abundance of corporate establishments. Furthermore, entertainment-related research and development activity, along with R&D expenses, score 3.377 and 3.317 respectively, underscoring significant investment in innovation and development.

Cluster 2, in contrast, displays negative normalized values for all indicators, which suggests that regions in this cluster are characterized by lower-than-average performance in these domains. The education level, with a score of -0.172, and the number of hospitals, at -0.147, indicate a relative scarcity in educational and health facilities. HEIs and schools have values of -0.226 and -0.171, further pointing to limited educational infrastructure. Scores for private enterprises (-0.200) and large enterprises (-0.210) reflect a less vibrant commercial sector. Similarly, a restrained engagement in innovation is evident from the scores for entertainment R&D activity (-0.211) and R&D expenses (-0.207).

In essence, the profiles of the two clusters are in stark contrast: Cluster 1 regions display a strong presence across all measured socioeconomic factors, whereas Cluster 2 regions appear to lag behind across these same dimensions. The 'Note: compiled by authors' indicates that the data in the table has been curated and calculated by the authors of the report or study, signifying that these figures are the result of their analytical methods applied to the underlying data.

Further, heat map clustering was conducted to check the assumption if 2 cluster is appropriate number of clusters in Figure 3.

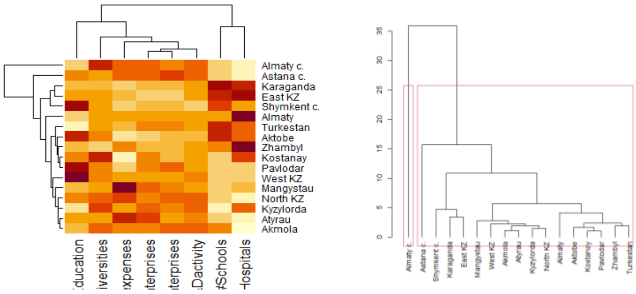

Fig. 3. Heatmap and Ward Dendrogram clustering. This figure reflects the number of clusters identified through Heatmap and Ward Dendrogram clustering approach and regions included into Cluster-1, Cluster-2 and Cluster-3.

The first large cluster consists of regions that have similar high indicator values, as indicated by the dark red color on the heat map, including Almaty and Astana. These regions perform well in most categories as education, R&D spending, large enterprises, and science and technology activity.

The second cluster includes regions that generally have average indicators (orange color on the map), such as Karaganda and East Kazakhstan. These regions show average levels for most indicators.

The third cluster can be identified as a group of regions with low scores in most categories (yellow), for example, Mangistau and Western Kazakhstan. These regions show themselves to be less active in the fields of education, science and economic activity.

There also could be identified the relative similarity between metrics within regions. Regions with high scores in education also score high in R&D spending. There is a correlation between the presence of large enterprises and overall activity in Science and Technology. These correlations may reflect general trends in regional development, where regions with developed infrastructure and investments in education and R&D tend to have higher economic activity and scientific development. In Table 2 there are results for cluster centroids.

TABLE II
CENTROIDS FOR CLUSTERS 1 , 2, 3

No	1	2	3
Education	2.758	-0.422	0.909
#Hospitals	2.350	-0.257	0.331
#HEI	3.623	-0.371	0.401
#Schools	2.734	-0.418	0.900
#Private	3.193	-0.396	0.650
#Laqrge Enterprises	3.357	-0.379	0.525
#EntR&Dactivity	3.377	-0.375	0.499
R&D expenses	3.317	-0.327	0.312

Cluster 1 exhibits notably high positive values across all indicators, strongly suggesting that regions within this cluster exceed the average on these socioeconomic dimensions. Education has a high value of 2.758, indicating a significant emphasis on educational facilities. Hospitals and higher education institutions (HEI) have scores of 2.350 and 3.623, respectively, denoting a high presence compared to other clusters. The number of schools is also well above the mean at 2.734. In terms of business and economic activity, private enterprises and large enterprises score 3.193 and 3.357, respectively, indicating a robust business environment. Entertainment R&D activity and R&D expenses are high as well, with scores of 3.377 and 3.317, highlighting the importance of research and development in these regions.

Cluster 2 is characterized by negative values for all indicators, pointing to below-average metrics in these regions. Education shows a value of -0.422, and the number of hospitals is at -0.257, both suggesting fewer educational and healthcare facilities. The negative scores extend to HEIs (-0.371), schools (-0.418), private enterprises (-0.396), and large enterprises (-0.379). Similarly, entertainment R&D activity and R&D expenses are low, with values of -0.375 and -0.327, respectively, indicating less activity in these sectors.

Cluster 3 presents moderate positive values, suggesting that regions within this cluster are somewhat above average in socioeconomic aspects but do not reach the high levels of Cluster 1. The education score is 0.909, and the number of hospitals is at 0.331, which are modestly above the mean. HEIs and schools have scores of 0.401 and 0.900, indicating a reasonably good educational infrastructure. Private enterprises and large enterprises score 0.650 and 0.525, respectively, reflecting a healthy economic environment but not as strong as Cluster 1. Entertainment R&D activity and R&D expenses have values of 0.499 and 0.312, pointing to a fair level of research and development engagement.

In summary, Cluster 1 is distinguished by its significantly high positive values, indicating a strong presence of all studied socioeconomic factors. Cluster 2, on the other hand, stands out for its lower-than-average values across the board, whereas Cluster 3 occupies a middle ground, with moderately positive values that suggest it fares better than Cluster 2 but is not as affluent as Cluster 1. The note "complied by authors" implies that these findings are the authors' own constructions based on their analysis.

CONCLUSION

This dichotomous division of clusters allows for a clear distinction between regions requiring developmental focus and those that can be considered models of socio-economic success. Thus, this approach provides analysis or raw data based on the readiness of regions for qualitative improvement of existing policies. Therefore, main conclusions of current state of regional development and readiness for urban and smart cities policy implementation are the following.

The Cluster-1 has high positive values across all the indicators, suggesting these regions are well-developed with strong education systems (as indicated by the number of schools and higher education institutions), healthcare facilities (number of hospitals), and robust economic activity (number of private and large enterprises, entertainment R&D activity, and R&D expenses). The regions in this cluster are likely the economic and social leaders, showcasing higher investment and focus on development across various sectors.

The Cluster -2 regions show negative values for all indicators, suggesting they are underdeveloped relative to the dataset's mean. They have fewer educational institutions, hospitals, and lower business activity, which positions them as the laggards in this socio-economic framework. These regions may require more attention and resources to enhance their infrastructure and stimulate economic growth.

The analysis revealed that regional policy causes loop sided development, suggested by the overall development of entrepreneurship environment across the country and industrial production as well. However, this approach results in major issues as high emission and environment pollution. At the same time the ecological issue affect the quality of life and impacts on the economic activity of the population.

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