Assessment of Balanced Development of Kazakhstan's Regions in the Context of SDG Implementation

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Abstract: - In modern conditions, the implementation of a balanced regional policy is one of the key tasks for the Republic of Kazakhstan. The article discusses approaches to assessing the balanced development of Kazakhstan's regions, considering three dimensions (economic well-being, innovation and digitalization, environment). The purpose of this study is to develop a methodology for assessing regional development factors in the context of SDG implementation. The scientific novelty of the research lies in the use of a set of modern methods, including methods of retrospective analysis, logical and comparative analysis, analogies and generalizations, economic statistics, index, modified method of the principal components. The study uses not only existing methods, but also their modification. The research methodology is based on the sustainable development concept. The main focus of the study is on assessing the balanced development of the Kazakhstan regions. In conclusion, practical recommendations are proposed for regional government bodies aimed at improving the effectiveness of assessing the achievement of the SDGs at the regional level.

Key-Words: - Sustainable Development Goals (SDGs), economic well-being, environmental well-being, innovation, digitalization, regions, assessment, balanced development.

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1 Introduction

The 2030 Agenda for Sustainable Development and its goals should be used as a basis for defining policies and actions aimed at achieving sustainable development worldwide by 2030. The main feature of the 2030 Agenda for Sustainable Development is that it can be applied universally, considering regional, national, and local specifics, opportunities, levels of development, and specific challenges.

An analysis of the international experience of localization and implementation of the Sustainable Development Goals by the leading countries of the SDG index compiled by SDSN and Bertelsmann Stiftung shows that even this narrow group of countries has very different experiences both in the transition to sustainable development and directly in the implementation of the SDGs. Some countries adopted a national strategy for sustainable development as early as in 1997, while others adopted it only in the early 2000s. Also, countries are at completely different stages of implementing the SDGs in strategic documents – from the lack of such work to the localization of all 17 Sustainable Development Goals, [1].

The reasons for these differences are largely related to the specifics of managing the implementation process and the established models of the governmental organization. Nevertheless, these issues have not yet become the subject of active scientific discussions. So far, the greatest attention has been paid to the institutionalization of the SDGs at the national level and the assessment of the effectiveness of managing specific projects.

The concept of regional development of the Republic of Kazakhstan for 2025-2030 is aimed at solving these problems, considering account new challenges and using opportunities for sustainable growth, [2].

The priorities of the long-term territorial and spatial development of the Republic of Kazakhstan (until 2050) are set out in the General Scheme of Organization of the territory of the Republic of Kazakhstan, [3].

The National Development Plan of the Republic of Kazakhstan until 2030 sets two key tasks for the regions – to prevent critical gaps in the provision of social goods and services in accordance with the System of regional Standards and to promote a twofold economic growth.

According to the UN program in Kazakhstan, the share of the budget correlated with the SDGs averages 81% of the national budget, while 58.6% of the SDG targets received funding. This does not mean that 81% of expenditures were solely aimed at achieving the SDGs; it is about correlating budget programs with the SDGs using the coding methodology (SDG budget tagging).

Currently, the implementation of the SDGs at the regional level remains a serious challenge. Local executive authorities often face a shortage of analytical data, methodological tools, and personnel capable of integrating sustainable development goals into the budget planning system.

The Interparliamentary Commission of the Republic of Kazakhstan regularly reviews regional reports and develops proposals for adjusting indicators to increase their realism and practical applicability. Pilot projects are already being implemented in some regions of Kazakhstan to introduce the principles of sustainable development into regional programs. Thus, a system of "green budgets" is being formed in the East Kazakhstan region with an emphasis on energy efficiency and protection of water resources. In Qostanay region, the focus is on rational land use and processing of agricultural products, which is directly related to SDGs 2 and 12 ("hunger eradication" and "responsible consumption and production"). These practices show that the integration of the SDGs into regional policy is possible with coordination and analytical support.

Starting from the next budget period, Kazakhstan is implementing a new system of inter-budget transfers. Individual programs will be combined into a common pool of funds provided to the regions in the form of general transfers. This creates more autonomy for local governments and allows them to form investment plans focused on specific SDGs. At the same time, the responsibility of regional akims for the allocation of available financial resources is also increasing. This will require new approaches to management decision-making based on regional development assessment.

This issue is being considered by scientists from foreign countries and domestic researchers. For example, Italian scientists, [4], [5] have proposed an integrated analytical model for assessing the progress of Italian regions using social, economic, and environmental factors, as well as the role of green infrastructure in ensuring balanced territorial development around Milan. The article analyzes the risks and advantages of power centralization for the balanced development of regions using the example of Ireland. Using the example of the provinces of China, it has been proven that the development of digital infrastructure through technological innovation mechanisms contributes to the alignment of the development of urbanized provinces, [6], [7], [8].

In the works of scientists from Central Asian countries, much attention is paid to the implementation of the SDGs at the regional level. In particular, it is noted that in the Republic of Kazakhstan, the population places greater responsibility for implementing the Sustainable Development Agenda on local executive authorities. In Uzbekistan, the SDGs are integrated into strategic planning documents at the national and regional levels. In Kyrgyzstan, it remains important to ensure the equal economic development of all regions, create favorable living conditions for the population, and ensure that each region contributes to the overall economic development of the country, [9].

Within the framework of the SDGs for the CIS region, special attention is paid to the integration of socio-demographic structure factors into the process of developing and implementing political and economic strategies, [10]. This indicates the recognition of the importance of these factors for achieving sustainable development and improving the quality of population life, [11].

To assess the balanced development of the regions of Kazakhstan, it is proposed to expand the set of indicators used by indices characterizing digitalization and environmental well-being; structural shifts and dynamics of industrial indicators; indices "Regional Development Trap" and regional competitiveness; integral index of inclusive development; and an integrated approach is proposed, which includes an assessment of socio-economic and environmental indicators, [12], [13].

In the research of Kazakhstan scientists, the regional integrated SDI was calculated for 14 regions and 3 cities of Kazakhstan, cluster and factor analysis of regional groups was performed using key indicators (GRP, investment, employment, wage level, accessibility of infrastructure).

One of the widely used approaches is to calculate a composite index for each region, which is then compared with the indicators of other regions. This method is based on a statistical index approach that combines several indicators into one indicator, [14], [15], [16].

Despite the fact that a fairly large amount of information has been accumulated regarding methods for assessing regional development, at the same time, the methods used to assess balanced development serve as an important tool for determining the current state and prospects of territorial development in the context of the SDG implementation, [17], [18], [19], [20].

The authors of the article [21] analyze the publication activity on the SDGs in Kazakhstan, which is of interest for the methodological justification of the choice of indicators and data in assessing the rate of achievement of the SDGs.

2 Materials and Methods

The purpose of the study is to develop a methodology for assessing the factors of development of the Kazakhstan regions in the context of the implementation of the SDGs.

Two types of sources served as the information base for this study.

First, the state program documents reflecting the development of regions in the Republic of Kazakhstan have been studied.

Second, this study is based on statistical data obtained from the web portals of the statistical services of the Republic of Kazakhstan, as well as on forecast data from territorial development programs. In particular, the data for the analysis were obtained from the website of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

The scientific novelty of the research lies in the use of a set of modern methods, including methods of retrospective analysis, logical and comparative analysis, analogies and generalizations, economic statistics, index, modified method of the principal components

The research methodology includes an integrated approach to the analysis of socio-economic regions of Kazakhstan. To calculate the index of balanced development of regions, it is proposed to use three main dimensions: economic well-being, innovation and digitalization, and environment.

The following basic indicators were used to assess the economic component (economic well-being): GRP per capita, income per capita, unemployment rate.

The innovation component, considering the introduction of digital technologies, was assessed using the following indicators: the share of enterprises implementing innovations, the volume of innovative products in relation to the region's GRP, digital literacy, and Internet users.

The assessment of the environmental component was based on the use of the following basic indicators: the intensity of environmental protection costs (tenge per thousand tenge GRP), emissions of pollutants from stationary sources (per capita, kg), emissions of solid pollutants (per capita, kg), the intensity of emissions of solid pollutants (kg per GRP (million tenge)), the share of treated wastewater in % of the total wastewater flow.

The average values of the indicators for 3 years were used as basic indicators (to exclude the influence of individual fluctuations). Thus, the integral indicator and the 2022 rating calculated on its basis are based on the average values of the basic indicators for the period 2019-2021, the 2023 rating on the average values for the period 2020-2022, the 2024 rating on the average values, and the period 2021-2023. In addition, it was considered that in 2022 three new regions appeared in Kazakhstan: Abay, Zhetysu, and Ulytau. They were formed as a result of the administrative and territorial reform. As a result, the borders of the Almaty, East Kazakhstan, and Karaganda regions have also changed.

After initial data processing (in the absence of data for a number of regions, the 2023 value is assigned when calculating the average for 2022), the minimum and maximum values for each indicator are determined for the entire observation pool, and the indicators are normalized. The basic indicators $Xj.k$ are transformed to a unified (normalized) form $\tilde{X}j.k$ in accordance with the nature of the dependence of the basic indicator on the integral dimension index: if the growth of the indicator is interpreted as an improvement in the integral assessment, then the basic indicators are associated with an integral monotonically increasing dependence, in which

$$\tilde{X}j.k = \frac{Xj.k - min(Xj.k)}{max(Xj.k) - min(Xj.k)} \quad (1)$$

where the j index is the dimension number (1 - economic well–being, 2 - innovation and digitalization, 3 – environment);

The k index is the index number within the dimension.

If the growth of the base indicator is interpreted as a deterioration of the integral indicator, then the reverse normalization is carried out.

$$\tilde{X}j.k = \frac{max(Xj.k) - Xj.k}{max(Xj.k) - min(Xj.k)} \quad (2)$$

In this case, the minimum value of the normalized indicator is 0, and the maximum value is 1 in both cases.

The study uses a modified principal component analysis to construct indexes of individual dimensions and an integral index of balanced development, considering the interrelationships of the basic indicators.

For a group of indicators belonging to the same dimension, the modified index is constructed according to the following algorithm.

The eigenvalues λ of the covariance matrix of the $\mathbf{R}$ vector of unified indicators of this group are found, i.e. the characteristic equation ($\mathbf{I}$ - unit matrix) is solved

$$|\boldsymbol{R} - \lambda \boldsymbol{I}| = 0 \quad (3)$$

The eigenvalues λ are ordered in descending order, i.e. $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_p$, where p is the dimension of the vector of unified indicators for a given group (in this case, $p = 2 \div 4$ depending on the dimension under consideration).

The number m_0 of integral indicators for this group is determined based on the condition

$$m_0 = min\left\{m | \quad \frac{\lambda_1 + \lambda_2 + \ldots + \lambda_m}{\lambda_1 + \lambda_2 + \ldots + \lambda_p} > 0.55\right\} \quad (4)$$

(the resulting index should be responsible for a large proportion of the variance of the original indicators).

If $m_0 = 1$, the dimension index is constructed as a weighted sum of the unified basic indicators. The weights are determined based on the requirement that the integral index contains maximum information (in the sense of maximum variance) about the initial baselines.

Thus, after solving the characteristic equation (4) and identifying the largest eigenvalue, the components of the eigenvector $a = (a_1, a_2, .., a_p)^T$ of the covariance matrix $\boldsymbol{R}$ are determined as a solution to the system of equations

$$(\boldsymbol{R} - \lambda_1 \boldsymbol{I})\boldsymbol{a} = 0. \quad (5)$$

The value of the integral index of this dimension (Balanced Development Index) BDI_j is constructed as a modified first main component according to the formula

$$BDI_j = \sum a_k{}^2 \tilde{X}j.k \quad (6)$$

where j is the dimension number. The summation is carried out for all the basic indicators assigned to this dimension.

It follows from the properties of the principal component method that $\sum a_k{}^2 = 1$, i.e., the integral index is constructed as a weighted average of the unified basic indicators of a given group, the index values vary on the same scale as the values of the unified indicators, and the weights can be interpreted as the degree of indicator importance in constructing an integral index.

If the first main component does not describe a large proportion of the variance of the considered features, then the following calculation algorithm is used. The initial group is divided into two subgroups (basically, a subgroup can contain only one basic indicator). The affiliation of the basic indicators to a particular subgroup is determined by two requirements: they must characterize one aspect of the analyzed dimension and be sufficiently correlated.

The subindex of the subgroup $SubInd\_j.s$ (j - dimension number, $s = 1{,}2$ - subgroup number) is constructed according to formula (6), where not all the basic indicators of the dimension under consideration are summed, but only those included in subgroup s (the largest eigenvalue of the covariance matrix of the vectors of the subgroup and the eigenvector are preliminarily determined using formulas (3)-(5)). The subindexes of each group are combined into a single index using the formula

$$BDI_{j_n} = 1 - \rho_{j_n} \quad (7a)$$

where ρ_{j_n} is the "weighted" Euclidean distance from the n-th observation $(SubInd\_j_1, SubInd\_j_2)$ $(n = 1 \div N, N = 63)$ to the reference (1, 1) in the corresponding two-dimensional space:

$$\rho.j_n = \sqrt{v_1(SubInd\_j\_1_n - 1)^2 + v_2(SubInd\_j\_2_n - 1)^2} \quad (7b)$$

Non-negative normalized weights v_1, v_2 $(\sum_{p=1,2} v_p = 1)$ are determined in proportion to the variances of the subindexes:

$$\nu_s = \frac{Var(SubInd\_j.s)}{Var(SubInd\_j_1)+Var(SubInd\_j_2)}, \quad s = 1,2 \tag{13}$$

$$Var(SubInd\_j_s) = 1/N\sqrt{\sum(SubInd\_j\_s_n - \overline{SubInd_{j_s}})^2} \tag{7c}$$

The Integrated index of balanced development of the region (Summary Balanced Development Index) $SBDI$ is constructed from the indices of its dimensions according to formulas similar to (7a-7c)

$$SBDI = 1 - \sqrt{\sum_j \nu_j\,(BDI_j - 1)^2} \tag{8a}$$

$$\nu_{ij} = \frac{Var(SBI_j)}{\sum_j Var(SBI_{j)}} \tag{8b}$$

3 Results and Discussion

3.1 Assessment of the "Economic well-being" of the Regions

The "Economic well-being" dimension includes the following basic indicators: GRP per capita ($X_{1.1}$), income per capita ($X_{1.2}$), and unemployment (($X_{1.3}$). The first two indicators have a monotonously increasing relationship with the integral index, and therefore are normalized according to formula (1). The unemployment rate reduces the economic well-being of the region, and therefore normalization is applied to include this basic indicator in the integral index (2).

The first main component of this group of indicators reproduces almost 70% of the group's variance (condition (4) is satisfied), therefore, formula (6) is used to calculate the resulting indicator for this group.

As a result of this algorithm application, the following dependence was revealed:

$$BDI_1 = 0.44 \cdot \widetilde{X_{1.1}} + 0.42 \cdot \widetilde{X_{1.2}} + 0.14 \cdot \widetilde{X_{1.3}} \tag{9}$$

The sum of the weights, as follows from the calculation algorithm, is 1. The GRP per capita indicator has the greatest weight in determining this indicator, while the unemployment rate has the lowest.

The values of the resulting index of economic well-being, considering its dynamics, are shown in Figure 1 (Appendix).

The geo-codes of the regions are provided; the explanation is in the appendix.

The undisputed leader for the period under review is the region with geo-code KZ23 – Atyrau region, which is far ahead of other leaders of this dimension – KZ62 – Ulytau, KZ71 - city of Astana, and KZ75 - city of Almaty.

It should be noted that all regions show an increase in the index of economic well-being, although the dynamics of the leading regions and regions with a lower rating differ significantly. It should also be noted that the basic indicators of GRP per capita and income per capita are measured in current prices, respectively, the dynamics of nominal indicators are demonstrated.

The resulting indexes and ratings for each year are shown in Table 1 (Appendix).

Five leading regions (Atyrau region, city of Astana, Ulytau region, city of Almaty, and Karaganda region) saved their positions throughout the period under review, only city of Astana and Ulytau region changed places in the ranking in 2024.

Regarding the leading regions, it should be noted that the leadership of the listed regions in terms of economic well-being is explained by a combination of unique factors, including a favorable geographical location, resource potential, investment attractiveness, economic diversification, and government support.

This group includes the oil-producing Atyrau region, which provides 10% of Kazakhstan's GDP, 20% of industrial production, and 30% of investments due to the Kashagan deposit and ongoing petrochemical projects. This region is characterized by a high level of wages (the average salary is 1.6 times higher than the national level).

It is also necessary to note 2 regions where enterprises of the mining and metallurgical complex of the country operate: Ulytau region (Kazakhmys Corporation LLP) and Karaganda region (the industrial base of the region is formed by more than 100 enterprises and industries of mining, manufacturing, electricity, and water supply). In general, the mining and metallurgical complex is one of the most competitive and strategically significant sectors of the national economy, affecting all spheres, including the social one. Kazakhstan has 30% of the world's chromium ore reserves, 25% of manganese ores, and 10% of iron ores. Copper, lead, and zinc reserves account for 10% and 13% of the world's reserves, respectively. 32% of the enterprises of the mining and metallurgical complex are concentrated in the Karaganda region.

The group of leading regions includes 2 megacities: the city of Astana, where there is a high concentration of government agencies and international companies, which stimulates the growth of the service sector and construction, as well as city of Almaty, which is a financial and trade center, an international transport hub, and a center for the development of the tourism business.

The five regions that are the least economically prosperous (Turkestan region, city of Shymkent, Zhetisu region, Zhambyl region, Kyzylorda region) also did not change their positions relative to other regions in the ranking. The low rating of the economic well-being of the southern regions of Kazakhstan is due to a number of structural, geographical, and economic factors.

It should be noted that the strategic direction of increasing the competitiveness of the national economy is the development of agriculture and industry for processing agricultural products, primarily in the agro-industrial southern regions of Kazakhstan (Almaty, Zhambyl, Turkestan regions). The importance of this area for Kazakhstan is determined by the need to ensure the country's food security and the need to increase export products, which include not only grain, but also environmentally friendly food products. Low positions in the rating of the southern regions indicate the insufficient development of agricultural production and a serious lag in its technological equipment.

Demographic imbalances in the country are also one of the problems, so by 2050, with the current trend, the population of the northern regions of Kazakhstan will decrease by 0.9 million people, and the southern regions will increase by 5.2 million people. According to the forecast data, the density of settlement in the southern regions will be almost 4 times higher than in the northern regions.

3.2 Assessment of Innovation Activity and Digitalization at the Regional Level

In the modern world and in modern manufacturing, digital technologies play a leading role. Digitalization often acts as a catalyst for innovation, and the introduction of new digital technologies leads to the creation of new products and services. In turn, innovations stimulate the development of information technologies and their dissemination. Therefore, we have combined indicators related to the innovation activity of enterprises and indicators characterizing the penetration of the Internet and the ability to use digital technologies by the population into one dimension.

Table 2 (Appendix) shows a correlation matrix of indicators of the "*Innovation and digitalization"* dimension: the level of activity of enterprises in the field of innovation $X_{2.1}$; the proportion of Internet users aged 16-74 years $X_{2.2}$; the level of digital literacy of the population (the proportion of users aged 6 years and older who have the skills to use a personal computer, smartphone, tablet, laptop; standard programs; receiving services via the Internet) $X_{2.3}$; the volume of innovative products (goods, services) (per 100 GRP units) $X_{2.4}$

The level of innovative activity of enterprises is statistically significantly correlated only with the level of digital literacy of the population, which in turn correlates with the level of Internet penetration. At the same time, the volume of innovative products, although it characterizes the effectiveness of the innovation process, does not correlate with the rest of the indicators in this group. Therefore, we divided the group into two subgroups: the first subgroup included the first three basic indicators, and the second – only $X_{2.4}$. The subindex of the first subgroup is constructed according to the algorithm (3)-(6), then the resulting index BDI_2 of the *Innovation and digitalization* dimension is calculated using formulas (7a-7c).

If we decompose the index BDI_2 according to the unified basic indicators, using regression analysis, we get the following approximate decomposition:

$$BDI_2 \approx 0.11 \cdot \widetilde{X_{2.1}} + 0.14 \cdot \widetilde{X_{2.2}} + 0.17 \cdot \widetilde{X_{2.3}} + 0.54\widetilde{X_{2.4}} \quad (10)$$

Thus, it is the specific volume of innovative products that has the greatest weight in the formation of the resulting index of the *Innovation and digitalization* dimension.

Figure 2 (Appendix) shows the values of the volume of innovative products (goods, services) (per 100 GRP units). According to this indicator, the KZ39 region, Qostanay region, is a clear leader.

This region is in the middle of the ranking in terms of economic indicators, but it is increasing its innovation activity and has sharply increased the volume of innovative products in 2019-2023 (with an average growth rate of 45% per annum in nominal terms). At the same time, the level of innovation activity of enterprises in this area tended to decrease.

The resulting Innovation and digitalization dimension indexes and ratings for each year are shown in Table 3 (Appendix). Due to the algorithm of constructing the index, in which the production of innovative products has the greatest weight, Qostanay region has a leading position in the resulting ranking. The leading positions are explained by the implementation of a number of innovative projects in the region in recent years (construction of a plant for the production of main gear reducers for driving axles of trucks with a capacity of 86 thousand units per year with a growth potential of up to 180 thousand per year, of which 95% are planned for export; construction of a high-tech foundry with a capacity of 50 thousand tons of castings per year for production cylinder blocks, engine heads and gearbox housing of truck axles; construction of a plant for the production of special equipment based on the chassis of KAMAZ vehicles with a capacity of up to 1,500 units per year, followed by an increase to 5,000 units per year, including those produced for export; creation of an engineering and research center, etc.). At the same time, it should be noted that the region is experiencing a shortage of scientific potential. According to statistics, Qostanay region accounted for only 1.2% of all domestic R&D expenditures in 2024. The number of researchers per capita is 8 times lower than in the city of Almaty. Moreover, the average age of specialists with an academic degree reaches 54 years (compared to 50 years in the country). In this regard, it is necessary to modernize the scientific infrastructure and attract young researchers to the region, to involve more teachers of local universities in scientific work.

In second place is the Karaganda region, which, nevertheless, has significantly lower index values than the leader of the rating.

In general, the regions of Kazakhstan have a fairly low level of innovation activity.

It should be noted that assessments of the level of digital literacy in Kazakhstan differ from the EU methodology adopted in many countries. According to the Eurostat methodology, digital competencies are analyzed according to five main parameters (DigComp 2.0): information literacy, communication literacy, digital content creation, digital security, problem solving skills in a digital environment.

The calculation is made for people who have used the Internet in the last three months. The calculation uses information about more than 22 types of actions performed when working on a computer or in the Internet. The calculation is carried out in two stages: at the first stage, the level of proficiency in each group is assessed, and at the second stage, an integrated assessment is formed.

The level of proficiency in skills from a separate group is assessed on a three-point scale: "above basic" — having more than one skill / having an advanced skill; "basic" — having only one skill / having an entry-level skill; "no skills" - the absence of any skills from this group.

The integral assessment is based on the following scale: "above the basic level" — the presence of skills in all groups at the level "above the basic"; "basic level" — the presence of skills in all groups, provided that at least one group has a skill proficiency level of "basic"; "low level" — lack of skills in one, two, or three groups; "skills missing" — lack of skills in all four groups.

The statistics provided in the public domain contain only information about the proportion of users who have the skills to use a personal computer, smartphone, tablet, laptop; standard programs; receiving services via the Internet, without detailing the level of use, and the age group from 6 to 74 years is indicated. It is obvious that the basic level of digital literacy is not an active catalyst for innovation. The differences in this indicator between regions are not very large, as are the differences in Internet coverage among the population. Therefore, these indicators have little weight in the formation of the resulting index of Innovation and digitalization.

Most regions show an increase in the value of the resulting index (Figure 3, Appendix), although the position of the regions in the ranking is changing. Shymkent, East Kazakhstan region, Zhambyl region, and Abai region have worsened their positions in the rating. The following regions have risen by more than 5 positions in the rating: Akmola region, Aktobe region, Kyzylorda region, Pavlodar region, North Kazakhstan region. The average value of the resulting index increased by 22% in 2024 compared to the level of 2022, which shows a general trend of increasing digitalization and innovation processes.

Currently, digital technologies are being intensively introduced in the Republic of Kazakhstan, with an emphasis is on the development of artificial intelligence and the transformation of Kazakhstan into a full-fledged digital country within three years. Kazakhstan ranks 24th in the world in terms of e-government development and 10th in terms of online services. The government creates conditions for the free and productive work of AI and IT specialists. The digital infrastructure is expanding, educational centers are opening, and AI programs are operating in 20 universities. About 500 thousand citizens are trained in the basics of artificial intelligence through the programs AI Qyzmet, AI Sana, Tomorrow School, and QazCoders.

Of particular importance is the launch of Alem.ai – a key part of the digital infrastructure, which will become a platform for research, implementation of advanced solutions, and acceleration of startups.

Astana Hub plays an important role in the development of creative industries. Thanks to the accelerator in the form of a Venture Capital Fund, startups can apply for large-scale financing and enter the global market. A strategy is being implemented aimed at increasing exports of IT services to $1 billion by the end of this year. The world's leading technology companies, Playrix, Mytona, NetCracker and others, have already entered the Kazakh market, which indicates a high level of trust from international business and investors.

3.3 Assessment of the "Ecological well-being" of the Regions

The following basic indicators were selected: the intensity of environmental protection costs, which is calculated as the ratio of current environmental protection costs to the gross regional product ($X_{3.1}$), emissions of air pollutants from stationary sources (per capita kg) ($X_{3.2}$), emissions of solid pollutants (per capita kg) ($X_{3.3}$), emissions of solid pollutants per GRP unit ($X_{3.4}$), the share of treated wastewater in % of the total wastewater flow ($X_{3.5}$).

When constructing the resulting index, it is considered that an increase in environmental protection costs and an increase in the share of treated wastewater should lead to an increase in the index, and an increase in gaseous and solid pollutants (both per capita and per GRP unit) leads to a deterioration in the environmental situation, and hence to a decrease in the index. Therefore, the basic indicators $X_{3.1}, X_{3.5}$ are normalized according to formula (1), and the indicators $X_{3.2}, X_{3.3}, X_{3.4}$ are normalized according to formula (2).

The correlation of the basic indicators shows that the percentage of treated wastewater in % of the total wastewater flow ($X_{3.5}$) is weakly correlated with other indicators of this dimension. Therefore, just as for the dimension of Innovation and digitalization, the a priori set of basic indicators can be divided into two subgroups: the first is characterized by environmental protection costs and pollutant emissions, and the second consists of one indicator and includes only the indicator $X_{3.5}$.

A preliminary analysis of the basic indicators shows that the KZ55 region (Pavlodar region) is a distant outlier in the distribution of indicators $X_{3.3}$, $X_{3.4}$ - there are abnormally large emissions of solid pollutants in this region. And the KZ31 region (Zhambyl region) has an abnormally low proportion of treated wastewater. To avoid distortion of the results when calculating the weights in (6) and (7), these regions were removed from the data pool at the stage of calculating the weights. As a result, for the first subindex we have:

$$Subindex_{3.1} = 0.17\widetilde{X_{3.1}} + 0.27\widetilde{X_{3.2}} + 0.31\widetilde{X_{3.3}} + 0.24\widetilde{X_{3.4}} \quad (11)$$

(the sum of the weights is not equal to 1 due to round-off).

The second sub-index consists only of a unified basic indicator $\widetilde{X_{3.5}}$.

The weights for calculating the "weighted" Euclidean distance according to formula (7b) after eliminating the outliers turned out to be equal $\nu_1 = 0.59, \nu_1 = 0.41$. Thus, the weight of the indicator, the share of treated wastewater in% of the total *wastewater* flow, is slightly less when calculating the resulting index than the first subindex, reflecting, on the one hand, the amount of environmental pollution, and on the other hand, the costs of environmental protection. It should be noted that environmental protection costs positively correlate with the volume of emissions of gaseous and solid pollutants. Therefore, it should be expected that regions with harmful industries spend more on environmental protection than regions specializing in services or agriculture.

The resulting index of the Ecology dimension and the rating of regions is presented in Table 4 (Appendix).

The average value of the resulting *Ecology* dimension index has changed little over the period from 2022 to 2024, and the indicators of each region and the position in the rating have not changed (Figure 4, Appendix).

As can be seen from Figure 4 (Appendix), the regions vary greatly in the resulting index. Regions 31 and 55 have very low indicators and are clear outsiders, while regions 63, 71, 75, and 79 show consistently high index values.

To validate these results, a sensitivity analysis was performed by recalculating the index weights with the outliers included. The relative weights of the environmental dimension shifted. However, the overall regional rankings remained highly consistent (Spearman's rank correlation coefficient is about 0.92), indicating that the exclusion strategy effectively isolated the 'general trend' of development without unfairly penalizing or rewarding regions for extreme localized phenomena.

Figure 5 (Appendix) shows a diagram that makes it possible to compare the leading regions and the regions with the least environmentally friendly characteristics by basic indicators. In accordance with the rating of regions for 2024, presented in the Appendix in Table 4 and Table 5 leading regions are identified (West Kazakhstan region, Aktobe region, Kyzylorda region, city of Almaty, Mangystau region) and 5 outsider regions (Zhambyl region, Pavlodar region, Karaganda region, Ulytau region, Almaty region). For these regions, the unified basic indicators were averaged for each year. And the values of the average indicators for 2022 and 2024 are given. The diagram shows that regions that are ecologically prosperous spend little (and most likely not enough) on environmental protection. Most of all for environmental protection (per GRP unit) is spent by the Aktobe region, which is part of the group of leading regions. Nevertheless, other regions (in particular the city of Almaty) have a relatively low value of this indicator. The outsider regions have, on average, a high intensity of environmental costs, but also significantly higher emissions of air pollutants and emissions of solid pollutants. The percentage of treated wastewater in these regions is also significantly lower than in the leading regions.

The average values of the unified basic indicators remained virtually unchanged in 2024 compared to 2022. The changes are noticeable only in the unified indicator of emissions of solid pollutants per unit of GRP, which has increased, which means a decrease in emissions per unit of GRP in 2024 compared to 2022.

3.4 Calculation of the Integral Index of Balanced Development

The Integrated *index of balanced development of the region (Summary Balanced Development Index)* $SBDI$ is based on formulas (8). According to the methodology, the weights are calculated, and the integral index is calculated using the formula

$$SBDI = 0.41BDI_1 + 0.17BDI_2 + 0.41BDI_3 \tag{12}$$

Greater weight means greater variability of the feature: regions are more diverse among themselves and have changed over time in terms of economic and environmental indicators than in terms of *Innovation and digitalization* dimension.

Table 5 (Appendix) shows the resulting values of the integral index of balanced development, sorted by the values of 2024 to better represent the leading and outsider regions.

It should be noted that the integral index values are quite low even for the leading regions of the rating. This indicates an insufficiently balanced development of Kazakhstan's regions.

Figure 6 (Appendix) shows the value of the integral index components, averaged over 5 leading regions and 5 outsider regions. If the leading regions have high indicators of environmental well-being and above the national average in terms of economic well-being, then the leaders practically do not differ from outsiders in terms of Innovation and digitalization.

As a result of the analysis, regions can be classified according to the balanced development index. The profile of the regions is grouped based on three main dimensions: Economic well-being, innovation and digitalization, and environmental well-being are national security issues. The region profile considers trends for a specific region.

The leadership of a group of regions (Atyrau region, city of Astana, city of Almaty, Ulytau region, East Kazakhstan region) in economic well-being is explained by a combination of unique factors, including advantageous geographical location, resource potential, investment attractiveness, economic diversification, and government support

The geopolitical situation, including sanctions restrictions, has had a negative impact on the development of the following regions of Kazakhstan: Kostanay region, Mangystau region, Aktobe region, West Kazakhstan region, Akmola region, which does not allow them to enter a new, improved path of development. The low value of environmental well-being indicators also aggravates the situation. For example, Qostanay region was ranked last in the country in terms of providing residents of rural settlements with clean drinking water. This is an example of an erroneous prioritization. At the same time, the provision of water is one of the most important indicators of the SDGs.

5 regions occupy ambiguous positions in terms of economic and environmental well-being, innovation and digitalization, which indicates a weak balanced development of these regions. The above group includes industrial regions (Karaganda region, Abay region), the industrial base of which is formed by more than 100 enterprises and industries of mining, manufacturing, electricity and water supply, as well as agricultural regions (Qyzylorda region, Almaty region).

Low positions in the rating of mainly southern regions (Zhetisu region, city of Shymkent, Pavlodar region, Turkestan region, Zhambyl region) indicate the insufficient development of agricultural production, a serious lag in its technological equipment.

In addition, it should be noted that all regions of Kazakhstan have a fairly low level of innovation activity, which led to low indicators of the resulting index, despite the high percentage of Internet users and a fairly high percentage of digital literacy of the population.

3.5 Methodological Robustness and Data Limitations

The application of a modified Principal Component Analysis (PCA) and a distance-based integral index offers a more nuanced perspective on Kazakhstan's regional development than standard global methodologies. While ordinary PCA is frequently used to reduce dimensionality, its reliance on raw factor loadings can be problematic for SDG assessments. Standard loadings can be negative, making it difficult to interpret "progress." By using squared loadings, our BDI ensures that all weights are positive and sum to unity. The global SDG Index typically employs a simple arithmetic mean, assuming that all indicators are equally important. However, in the case of Kazakhstan, regional dependencies (such as the influence of the extractive sector on social indicators) suggest that indicators are highly correlated. Our modified PCA avoids the "double-counting" inherent in equal-weighting schemes by statistically assigning higher weights to indicators that capture the most unique information about regional imbalances. Most composite indices (like the Human Development Index) use geometric or arithmetic means, which can allow for "high substitution"—where a very high score in one goal masks a failure in another. By calculating the weighted Euclidean distance from an ideal point, our BDI and SBDI explicitly penalizes "unbalanced" development. A region only achieves a high SBDI if it performs consistently well across all dimensions, rather than excelling in one at the expense of others.

There are some data limitations of this study. First, it involves the measurement of digital literacy, which varies significantly between national and international standards. In Kazakhstan, digital literacy is primarily assessed through household surveys, which often define a "digitally literate" individual based on basic skills such as using a computer or accessing online services. Consequently, the high digital literacy scores reflected in our BDI may not be directly comparable to EU Digital Economy and Society Index (DESI) scores or other similar scores. This discrepancy suggests that while Kazakhstan has bridged the first-level digital divide (access), regional disparities in the second-level divide (sophisticated usage) may be masked by current reporting standards. Future research should aim to harmonize national data with international standards like DigComp to facilitate more accurate cross-country benchmarking.

To ensure the reliability of the regional rankings, this study utilizes three-year averages for all basic indicators. This approach is consistent with international practices to mitigate the impact of methodology changes or data reporting lags at the regional level. However, we acknowledge that this smoothing technique may partially overlook acute short-term shocks. SDG implementation is a long-term strategic goal, so a 3-year "stable" view is more relevant for policy-making than reacting to one-year outliers.

4 Conclusion

In modern conditions, the implementation of a balanced regional policy is one of the key tasks for the Republic of Kazakhstan. To achieve a sustainable socio-economic model of society and to recognize the inevitability of regional differences, it is necessary to minimize regional disparities. Socio-economic, demographic, and other differences between regions require constant improvement of approaches to the formation and implementation of regional policy, urban planning policy aimed at eliminating critical inequalities and unlocking the economic potential of each region.

To effectively assess the achievement of the SDGs at the regional level, it is necessary to develop and implement comprehensive and accessible tools for monitoring and analyzing the impact of factors that consider the multidimensional nature of this phenomenon, including social, economic, and environmental components.

In the context of globalization and urbanization, as well as increasing pressure on ecosystems, the integration of sustainable development principles into regional policies and economic practices is becoming a critical task.

The main directions of the proposals are the following:

– development and implementation of sustainable development indicator systems. The creation of integrated indicator systems is a key element in the formation of an effective monitoring system. These systems should be integrated into regional (akimats) information systems to ensure transparency and comparability of data. The use of international indicators, such as the SDGs, with their adaptation to regional specifics, helps to increase the reliability and validity of information.

– methodology of data collection and analysis. Regular data collection through multi-level approaches, including surveys, interviews, document analysis, statistical data, and the use of advanced analytical tools such as machine learning, artificial intelligence, and geographic information systems (GIS), is an integral part of the monitoring process. The use of standardized data collection techniques ensures the representativeness of the sample and the minimization of errors, which helps to improve the quality of analytical information.

– visualization and presentation of information. Creating interactive dashboards and reports based on the use of advanced data visualization technologies, such as GIS and digital platforms, makes information accessible and understandable to a wide range of users. This helps to increase the awareness and engagement of various stakeholders, including politicians, the business community, and public engagement mechanisms with stakeholders.

The organization of regular consultations and working meetings with representatives of business, government agencies, public organizations, and local communities contributes to the formation of consensus and coordination of actions within the framework of the implementation of sustainable development strategies. The formation of specialized working groups and committees makes it possible to integrate the efforts of various stakeholders and provide a systematic approach to solving complex problems.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

APPENDIX

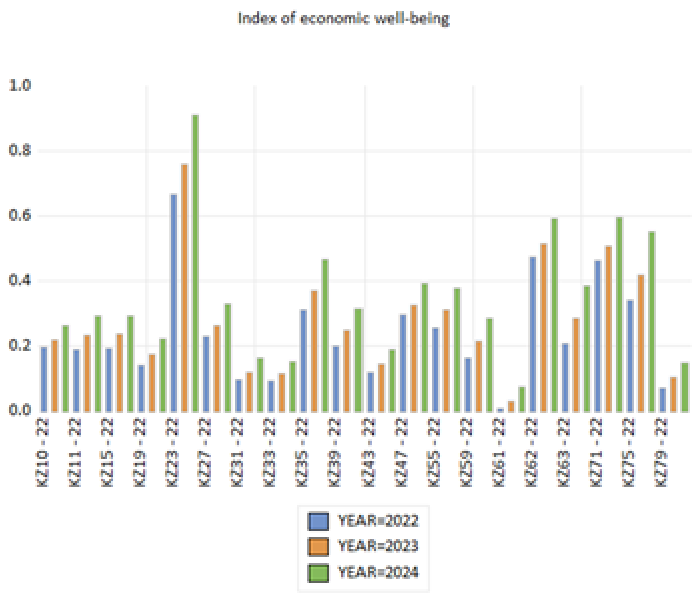

Fig. 1: Index of economic well-being of the Kazakhstan regions
Source: created by the authors

Table 1. Values of the resulting index of the dimension "Economic well-being" and the ranks of the regions

Geo-code	Region	2022	Region's rank	2023	Region's rank	2024	Region's rank
		BDI_1	**$RANK_1$**	**BDI_1**	**$RANK_1$**	**BDI_1**	**$RANK_1$**
KZ10	Abay region	0.196	11	0.218	13	0.262	14
KZ11	Akmola region	0.185	13	0.232	12	0.289	12
KZ15	Aktobe region	0.191	12	0.234	11	0.290	11
KZ19	Almaty region	0.137	15	0.171	15	0.219	15
KZ23	**Atyrau region**	0.666	1	0.759	1	0.908	1
KZ27	West Kazakhstan region	0.227	8	0.261	9	0.329	9
KZ31	Zhambyl region	0.096	17	0.118	17	0.161	17
KZ33	Zhetisu region	0.089	18	0.111	18	0.149	18
KZ35	**Karaganda region**	0.308	5	0.370	5	0.464	5
KZ39	Qostanay region	0.198	10	0.245	10	0.314	10
KZ43	Qyzylorda region	0.116	16	0.144	16	0.186	16
KZ47	Mangystau region	0.295	6	0.323	6	0.390	6
KZ55	Pavlodar region	0.254	7	0.310	7	0.375	8
KZ59	North Kazakhstan region	0.162	14	0.213	14	0.282	13
KZ61	Turkestan region	0.005	20	0.029	20	0.071	20
KZ62	**Ulytau region**	0.472	2	0.513	2	0.592	3
KZ63	East Kazakhstan region	0.205	9	0.284	8	0.384	7
KZ71	**city of Astana**	0.460	3	0.507	3	0.594	2
KZ75	**city of Almaty**	0.339	4	0.415	4	0.551	4
KZ79	city of Shymkent	0.069	19	0.101	19	0.148	19

Source: created by the authors

Table 2. Correlation of the basic indicators of the dimension "Innovation and digitalization"

Correlation t-Statistic Probability	$X_{2.1}$	$X_{2.2}$	$X_{2.3}$	$X_{2.4}$
$X_{2.1}$	1.000			

$X_{2.2}$	0.197	1.000		
	1.530	-----		
	0.131	-----		
$X_{2.3}$	0.404	0.533	1.000	
	3.361	4.796	-----	
	0.0014	0.000	-----	
$X_{2.4}$	0.071	-0.098	-0.060	1.000
	0.543	-0.747	-0.458	-----
	0.589	0.457	0.648	-----

Source: created by the authors

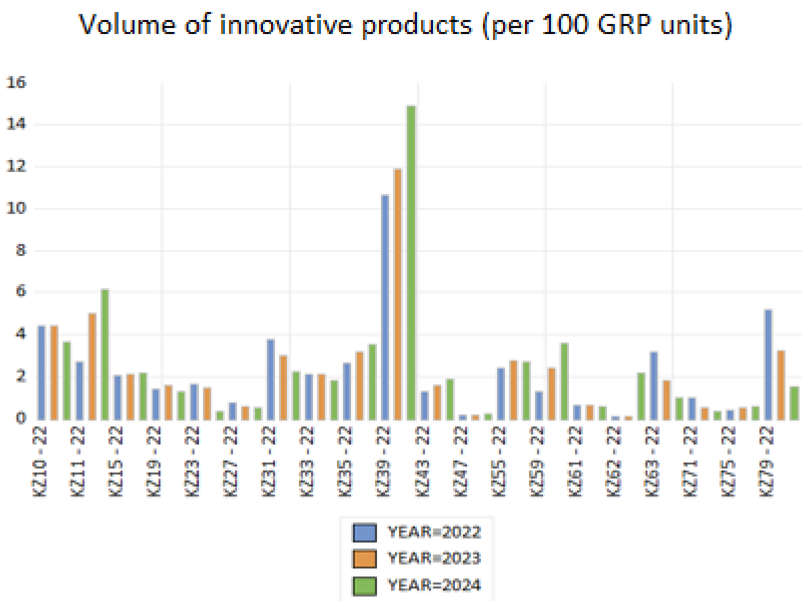

Fig. 2: Volume of innovative products
Source: created by the authors

Table 3. Values of the resulting index of the Innovation and digitalization dimension and the rank of the region

Geo-code	Region	2022		2023		2024	
		BDI_2	$RANK_2$	BDI_2	$RANK_2$	BDI_2	$RANK_2$
KZ10	Abay region	0.331	6	0.308	12	0.324	12
KZ11	Akmola region	0.123	19	0.270	17	0.383	4
KZ15	Aktobe region	0.283	12	0.345	4	0.391	3
KZ19	Almaty region	0.350	4	0.349	3	0.335	9
KZ23	Atyrau region	0.187	16	0.207	18	0.202	19
KZ27	West Kazakhstan region	0.066	20	0.116	20	0.161	20
KZ31	Zhambyl region	0.311	8	0.317	9	0.313	15
KZ33	Zhetisu region	0.294	10	0.310	11	0.315	13
KZ35	Karaganda region	0.405	3	0.430	2	0.461	2
KZ39	Qostanay region	0.616	1	0.689	1	0.766	1
KZ43	Qyzylorda region	0.219	15	0.296	13	0.357	7
KZ47	Mangystau region	0.133	18	0.205	19	0.245	18
KZ55	Pavlodar region	0.277	13	0.335	7	0.367	5
KZ59	North Kazakhstan region	0.179	17	0.290	14	0.350	8
KZ61	Turkestan region	0.248	14	0.290	15	0.314	14
KZ62	Ulytau region	0.290	11	0.271	16	0.361	6
KZ63	East Kazakhstan region	0.413	2	0.340	5	0.311	16
KZ71	city of Astana	0.346	5	0.337	6	0.334	10
KZ75	city of Almaty	0.298	9	0.320	8	0.333	11
KZ79	city of Shymkent	0.314	7	0.313	10	0.309	17

Source: created by the authors

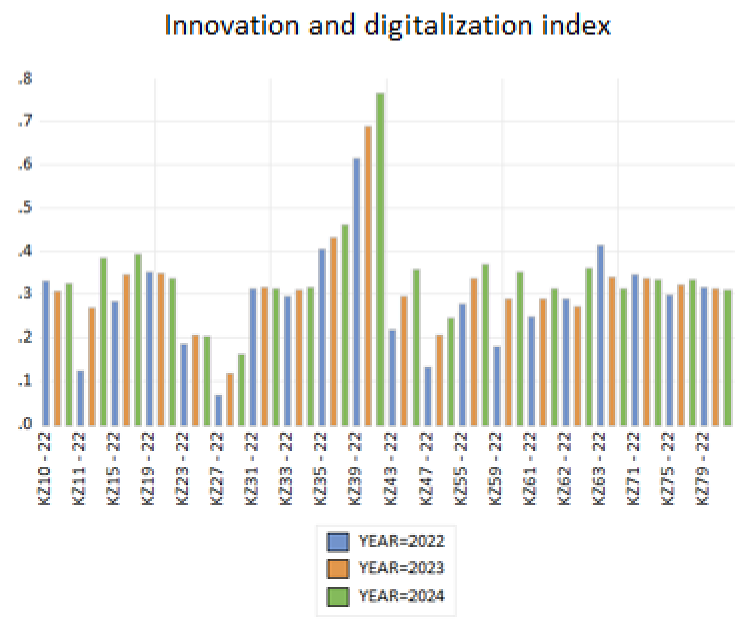

Fig. 3: Resulting index of the Innovation and digitalization dimension
Source: created by the authors

Table 4. Values of the resulting index of the *Ecological well-being* dimension and the rank of the region

Geo-code	Region	2022		2023		2024	
		BDI eco	Rank eco	BDI eco	Rank eco	BDI eco	Rank eco
KZ10	Abay region	0.749782	11	0.75882	11	0.76931	12
KZ11	Akmola region	0.635648	13	0.671574	12	0.690582	13
KZ15	Aktobe region	0.828932	6	0.848846	6	0.873985	2
KZ19	Almaty region	0.680608	12	0.649092	15	0.609995	16
KZ23	Atyrau region	0.557445	16	0.666941	13	0.771325	11
KZ27	West Kazakhstan region	0.898149	1	0.88897	1	0.883138	1
KZ31	Zhambyl region	0.331805	20	0.331727	20	0.339941	20
KZ33	Zhetisu region	0.819589	9	0.822099	10	0.827283	10
KZ35	Karaganda region	0.346649	19	0.375373	18	0.40145	18
KZ39	Qostanay region	0.501925	17	0.584109	17	0.652428	15
KZ43	Qyzylorda region	0.854551	5	0.861738	2	0.866085	3
KZ47	Mangystau region	0.858588	3	0.8551	4	0.85421	5
KZ55	Pavlodar region	0.349397	18	0.332539	19	0.351737	19
KZ59	North Kazakhstan region	0.628357	14	0.659566	14	0.683784	14
KZ61	Turkestan region	0.820218	8	0.830546	8	0.838738	9
KZ62	Ulytau region	0.611089	15	0.618881	16	0.60642	17
KZ63	East Kazakhstan region	0.803134	10	0.824502	9	0.850969	6
KZ71	city of Astana	0.827632	7	0.833453	7	0.840902	8
KZ75	city of Almaty	0.858521	4	0.861005	3	0.86244	4
KZ79	city of Shymkent	0.861581	2	0.852386	5	0.84435	7

Source: created by the authors

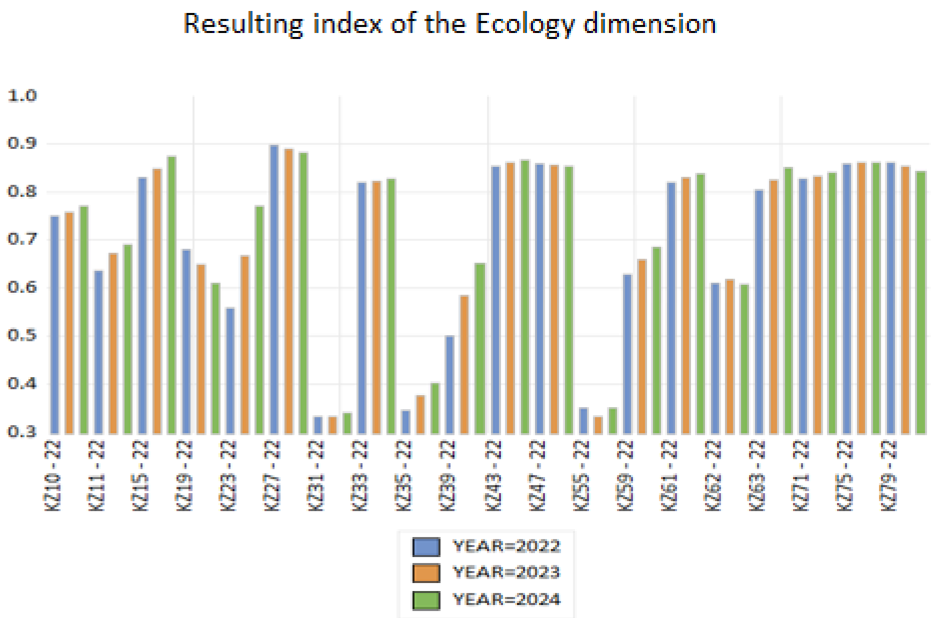

Fig. 4: Resulting index of the Ecological well-being
Source: created by the authors

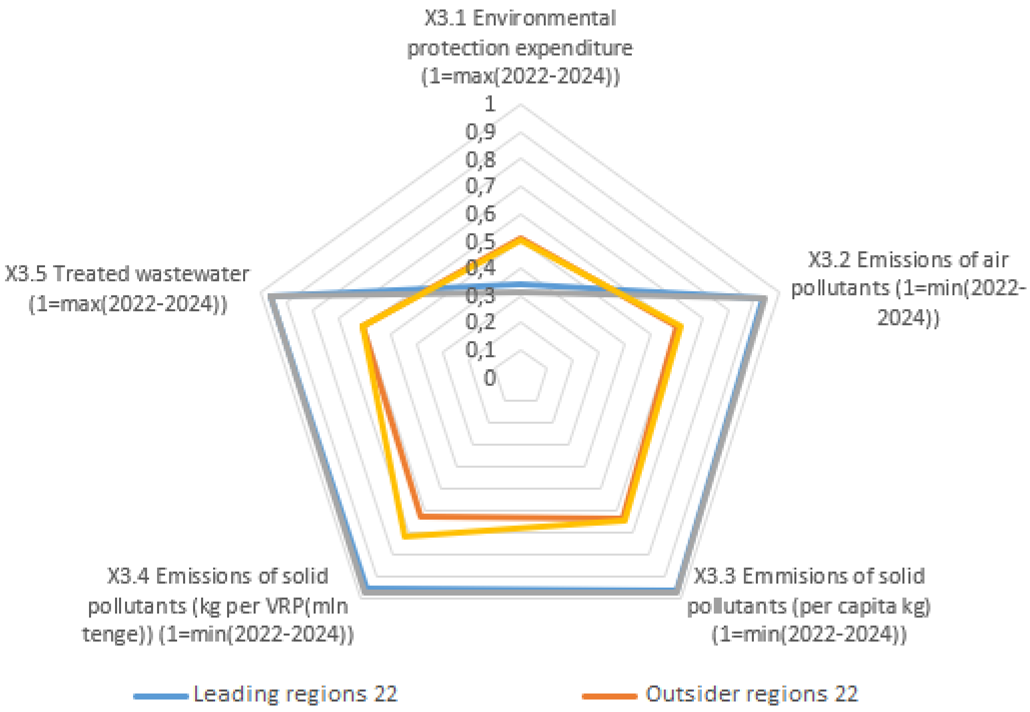

Fig. 5: Unified basic indicators of the Ecological well-being

Source: created by the authors

Table 5. Values of the Summary Balanced Development Index of the region (SBDI)

Geo-code	Region	2022		2023		2024	
		SBDI	Rank SBDI	SBDI	Rank SBDI	SBDI	Rank SBDI
KZ23	Atyrau	0.507837	2	0.576301	1	0.630959	1
KZ71	city of Astana	0.544973	1	0.565743	2	0.605362	2
KZ75	city of Almaty	0.476049	4	0.520792	3	0.589713	3
KZ62	Ulytau	0.485034	3	0.499437	4	0.548439	4
KZ63	East Kazakhstan	0.419261	5	0.452012	5	0.501383	5
KZ39	Qostanay	0.372531	9	0.431424	7	0.49612	6
KZ47	Mangystau	0.412954	6	0.445163	6	0.488497	7
KZ15	Aktobe	0.390161	8	0.428689	8	0.471738	8
KZ27	West Kazakhstan	0.365355	10	0.394369	10	0.439374	9
KZ11	Akmola	0.319753	16	0.382953	11	0.439334	10
KZ35	Karaganda	0.339766	12	0.382178	12	0.436989	11
KZ10	Abay	0.391075	7	0.399998	9	0.428545	12
KZ59	North Kazakhstan	0.318383	17	0.374282	13	0.427515	13
KZ43	Qyzylorda	0.338608	13	0.370226	14	0.405777	14
KZ19	Almaty	0.349717	11	0.361091	15	0.374159	15
KZ33	Zhetisu	0.334652	14	0.350348	16	0.373299	16
KZ79	city of Shymkent	0.331201	15	0.347965	17	0.373202	17
KZ55	Pavlodar	0.295946	18	0.323651	18	0.363876	18
KZ61	Turkestan	0.278621	19	0.300937	19	0.329806	19
KZ31	Zhambyl	0.22254	20	0.23408	20	0.256449	20

Source: created by the authors

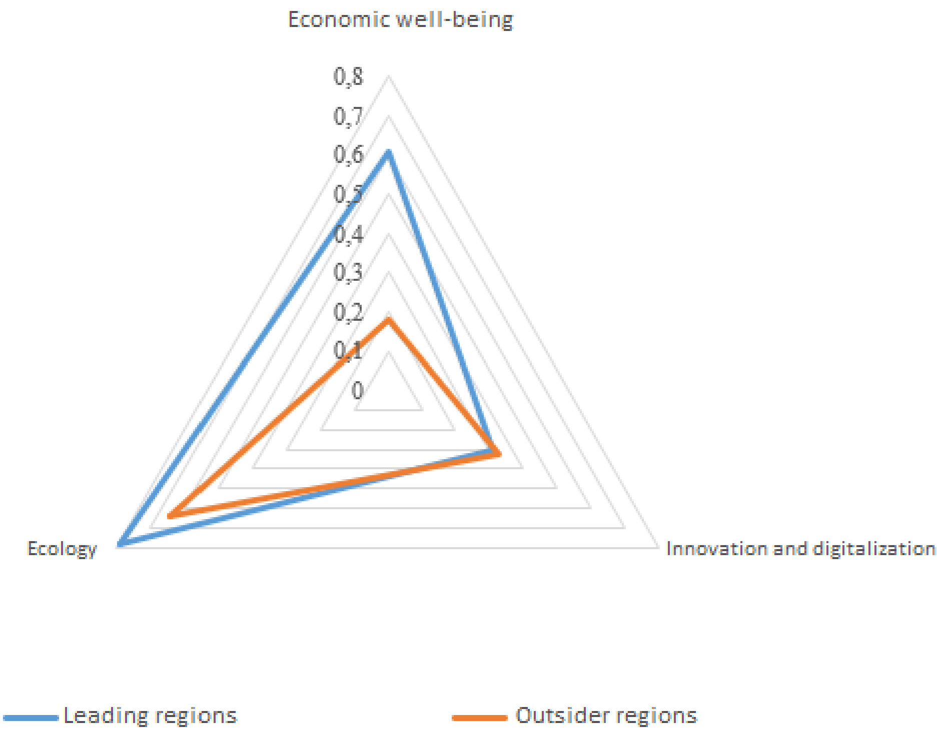

Fig. 6: Components of the balanced development index of the regions of Kazakhstan
Source: created by the authors