УДК 20.23.27
https://doi.org/10.47533/2020.1606-146X.170

A. G. OSPAN[1]*, M. E. MANSUROVA[1], YE. KH. KAKIMZHANOV[1], S. SH. IXANOV[1], V. B. BARAKHNIN[2,3]

[1]Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2]Federal Research Center for Information and Computing Technologies, Novosibirsk, Russia
[3]Novosibirsk State University, Novosibirsk, Russia

DEVELOPMENT OF A PROGRAM FOR THE INTEGRATION OF SOCIO-ECONOMIC INDICATORS WITH SPATIAL DATA TO ANALYZE THE STANDARD OF LIVING OF THE POPULATION OF KAZAKHSTAN

Up-to-date and reliable information is vital for assessing the socio-economic status of the population and effective decision-making. With the help of a spatial information base, social security and living standards data can be integrated to formulate strategic development plans and improve decision-making. This article presents the work on the integration of information about the standard of living and social security of the inhabitants of Kazakhstan with the display of data on the map. GIS tools were used for integration, as the latest technological advances in this field allow the manipulation of large amounts of geographic data and the creation of a spatial environment with socio-economic data. This work includes collecting unstructured data from the Bureau of National Statistics, reformatting the data into a structured database as an attribute-value pair, calculating important living standards indicators such as the real income index, the depth and severity of poverty and the social inequality index, and monitoring the results on the web map to compare regions based on the results obtained. It is also important to note the operation performed for the gridding of table attributes, since it was implemented automatically using the GIS tool. The results of the work are presented for three important indicators of the standard of living and displayed on a map using a heat map to visually show the changes in the indices for each region of Kazakhstan.

***Key words**: socio-economic information, living standards indicators, spatial data, GIS, map visualization, data extraction.*

Introduction. Economics professionals and governments need powerful tools to help them analyze, display and disseminate results, and make informed decisions about where to create new jobs or improve the quality of life in a given region [1]. Today, GIS technologies (such as ArcGIS Pro, QGIS, Google Earth Engine) are powerful and efficient in realizing these functions, helping economic professionals to support and control the change and growth of people's social life. A GIS facilitates the study of geographic distribution (single columns of an attribute table focusing on trends), geographic variation (single columns of an attribute table focusing on fluctuations), and geographic relationships (pairs of columns in an attribute table) [2].

Statistics are generally mathematical calculations such as mean, squared error, variance, correlation, and other mathematical statistics that support the scientific collection, organization, analysis, and interpretation of sample data to draw conclusions about their original population. Spatial statistical and econometric methods are broadly classified into three sub-domains based on the characteristics of spatial data: spatial point structures, geo-statistics, and attributes associated with discrete spatial units, mainly polygons [3].

* E-mail корреспондирующего автора: asselyaospan@gmail.com

The procedure for integrating socio-economic data and spatial reference of heterogeneous data is shown in Figure 1. This model was presented by the International Cartographic Association in its work "Cartography beyond the ordinary world" [4]. Using this model for statistical data associated with geographic features, one can obtain a spatial factor atlas about the main socio-economic indicators and convert the statistics into spatial data. Thus, the quantitative distribution in the cells of the spatial grid and integration with natural statistics data will be implemented.

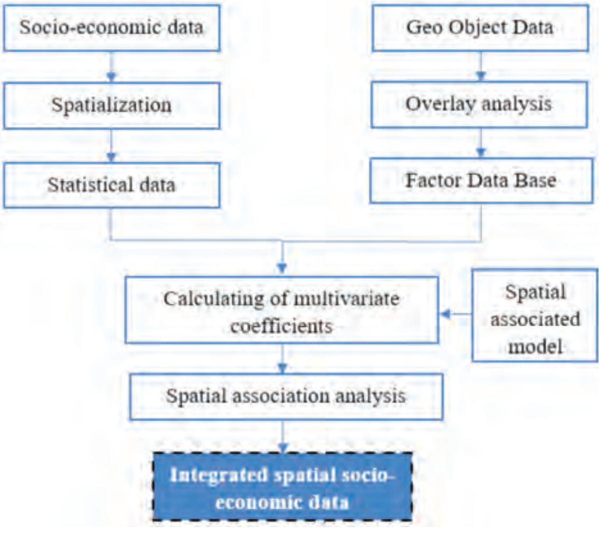

Figure 1 *– Diagram of a model for integrating socio-economic data with spatial data*

Based on this scheme, our tasks of integrating indicators of the level of social life of the people of Kazakhstan with a GIS-based spatial database with data visualization on a web map for a better understanding of the situation and comparison of results were completed.

Related work. Recent technological advances in GIS make it possible to manipulate large amounts of geographic data and create spatial environments with socioeconomic data. The creators of ArcGIS [5] have introduced a separate package called "GIS for Economic Development", where the thematic map has a table of contents that allows the reader to add layers of information to the base map. For example, a sociologist can use a base map of a particular country, and add datasets from the Bureau of Statistics to add layers of data to a map that shows the standard of living, age, and employment status of residents, thus combining multiple datasets in an infinite number of ways.

Recognizing the synergies (from the integration of GIS and spatial statistics/econometrics), spatial data scientists have proposed and made efforts to integrate the technical fields of the two disciplines [6]. Recent developments have resulted in greater availability of spatial statistics and econometrics tools on various platforms, including commercial GIS software (e.g. ArcGIS), statistical and mathematical software (e.g. Python), stand-alone packages and libraries in popular programming environments Spatial statistical and econometric methods are broadly classified into three sub-domains based on the characteristics of spatial data: structures, geo-statistics and attributes associated with discrete spatial units, mainly polygons [7]. Fischer, M.M., Getis, A. provide an extensive overview of spatial statistics and econometrics tools [8].

Griffith D.A. points out that one of the goals of spatial statistics is to provide a better understanding of how geographic landscapes function, some of which are economies of space [9]. It poses the following challenges for spatial econometricians, as suggested by contemporary spatial statistical work: (1) formulate efficient and efficient implementations of spatial autoregression for massive georeferenced datasets; (2) determining the usefulness of the main eigenvector of the geographic weights matrix for empirical analysis; (3) transformation of georeferenced data generation mechanisms in terms of mixed parametric models including spatial filters based on eigenvectors; and (4) improving our understanding of the terms spatially structured random effect (SSRE) and spatially unstructured random effect (SURE) that can appear in spatial statistical/ econometric model specifications.

Introducing the term "spatial econometrics", Paelinck, J. emphasizes the need to account for geographic dependence in spatial models, eliminate asymmetries in spatial relationships, recognize the importance of covariates located elsewhere, and include topological variables that explicitly span space. in the model specification [10].

Spatial statisticians often deal with observational data and therefore conduct correlation studies. Paelinck J. points out that one of the goals of spatial econometrics is to better understand how spatial economics works [10]. He discusses specification and multiple modes in the context of spatiotemporal representations. He concludes that partial difference equation models appear to be a suitable analysis tool for large sets of small spatial units. In conclusion, especially applied spatial statistics/econometrics has been made possible by the existence of GIS and other computer software packages. Let's take a look at the work done in this area.

In [11], the authors applied GIS to integrate social, economic and environmental factors to assess land vulnerability to degradation in the Pir Panjal Himalayas, Kashmir, India. In this work, a GIS tool was used to obtain information about irrigated lands and vegetation areas, as well as lands where degradation is high. The data obtained were compared with population density, age of residents, and economically important enterprises.

The authors of [12] present a GIS method for modeling ecosystem services by mapping socio-economic scenarios. As a result, the authors developed scenarios with the involvement of local stakeholders and experts to determine how major land cover classes might change under the influence of different sets of factors, formalized spatial rules such as agriculture can only occur on certain soil types, and created a future land cover map. cover, which can then be used to model ecosystem services.

The work [13] provides an analysis of the human resources of Kazakhstan based on GIS. Demographic, social, economic and environmental indicators were used to calculate human resources. Here, the results of the calculation of human resources are displayed on a map of Kazakhstan, where cities are identified as a "talent magnet", industrial areas and peripheral regions with the lowest rates, and an analysis of the reasons for such results is also made.

Based on the above works, it can be concluded that the integration of socio-economic data with GIS is an effective method and gives a positive result in the course of analysis and research.

If we turn to the implementation of our program, then different methods and tools were used here. For example, for our work, all tabular data are taken from the Bureau of National Statistics [14] and they are in the form of unstructured data. To solve this problem, the article [15] provides a CRL (Cells Rule Language) method that extracts data from arbitrary semi-structured tables (in text formats, spreadsheets and web tables) and transforms them into a structured form from which they can be loaded to the database using standard ETL tools (Extract, Transform, Load). A formal language of rules for the analysis and interpretation of tables, called CRL (Cells Rule Language), has been proposed. The execution of such rules allows you to restore the semantics of the table, which was originally absent, but necessary for extracting and transforming tabular information. The complete implementation algorithm is given in [16].

As soon as our tables are brought into a structured database, and are ready for manipulation for calculation, an economic model will be built to assess the standard of living of the population of Kazakhstan. In [13], four indicators are used to calculate human resources, and the results are successful, therefore, a similar model will be used for our economic model, only indicators for the standard of living of the population.

Materials and methods. To accomplish our tasks, the following steps will be performed:

1. Collection of data from the Bureau of National Statistics.
2. Converting unstructured tabular data to structured databases using SQL.
3. Selection of living standards indicators based on the UN guidelines for measuring poverty: the index of real money incomes of the population, the severity of poverty, the depth of poverty and the inequality index (Gini coefficient)).
4. Construction of an economic model for effective analysis of the standard of living of the population.
5. Performing coordinate referencing of all regions of Kazakhstan and visualizing the results on a web map for comparison and analysis.

The definition of the term poverty is described in the guidelines on measuring poverty by the United Nations Economic Commission for Europe [17]. This guide notes the concept of inequality, which is measured by the Gini coefficient, as well as the monetary approach to poverty, including in terms of income and consumption spending, most commonly used to measure poverty in monetary terms. It is now widely recognized that the concept of poverty goes beyond the material conditions of people’s lives and is also expressed in ill health, job insecurity, social exclusion, malnutrition, and personal insecurity.

Based on UN information, for the study of the living standards of Kazakhstan, indicators such as the index of real money incomes of the population, the severity of poverty, the depth of poverty and the inequality index (Gini coefficient) from the Bureau of National Statistics of Kazakhstan (1) were selected.

The depth of poverty index shows how far people have fallen below the poverty line (depth of poverty) as a percentage of the poverty line. The depth of poverty index can be expressed as follows (formula 1):

$$P_0 = \frac{1}{N}\sum_{i=1}^{N}\frac{G_i}{z} \quad (1)$$

where the poverty gap (G_i) is equal to the poverty line minus actual (equivalent) income or expenditure for those living in poverty and zero for those who are not.

The following formula (2) also calculates the poverty depth coefficient (P1), which characterizes the average distance of the poor from the poverty line:

$$P_1 = \frac{1}{n}\sum_{i=1}^{n}\left[\max\left(\frac{z-x_i}{z};0\right)\right]^1 \tag{2}$$

where z is the average subsistence minimum for one member of the household; xi is the indicator of the per capita income index of person i covered by the survey; n is the total surveyed population.

The poverty severity coefficient (P2), which characterizes the degree of inequality among the poor, is calculated using formula (3):

$$P_1 = \frac{1}{n}\sum_{i=1}^{n}\left[\max\left(\frac{z-x_i}{z};0\right)\right]^2 \tag{3}$$

The difference between the poverty depth ratio and the poverty severity ratio is that the latter is calculated more heavily by households that are severely underfunded.

The Gini coefficient (Income Concentration Index) is a statistic for assessing economic equality. It was invented by the economist Gini Corrado [17]. It shows the even distribution of income or wealth among the members of society. The coefficient is measured using a graphical method - the Lorentz curve. To get the Gini coefficient, you need to: a) calculate the area of the figure (T), which is formed by the line of absolute equality and the Lorentz curve; b) calculate the area of triangle OFE; c) divide the area T by the area OFE: Gini coefficient = T / OFE.

As a result, we get a number from 0 to 1. If incomes are evenly distributed, then the indicator will be 0, if everything belongs to one person, then - 1. In general, the lower the Gini coefficient, the better, the less economic inequality in the country.

After receiving the results of the above indicators of the standard of living, it is necessary to perform a spatial reference to the regions of Kazakhstan. To perform this task, the ArcGIS tool will be used, since there is a tool that automatically determines vector x, y coordinates from the names of areas, without adding extra attributes to the tables. For the best understanding and analysis of the results, a heat map will be applied, which will highlight the regions in comparison with each other.

Results and discussion. Based on the above calculations, results were obtained from 2001 to 2021 for the regions of Kazakhstan. To visualize and compare the results, the data will be displayed on a map using a heat map, where the colors change from the minimum to the maximum value. The convenience of using a web map is that the user himself can choose the colors he needs, thus making it easier to read the results on the map.

Using formulas (1), (2) and (3), we have obtained indicators of the depth and severity of poverty from 2001 to 2021. (Table 1) life of the population over the past 10 years.

Table 1 **–** Indicators of the depth and severity of poverty in the regions of Kazakhstan from 2001 to 2021.

Regions of Kazakhstan										
Akmola Region	12,2	8,5	1,3	0,5	1,2	5,0	3,2	0,5	0,1	0,4
Aktobe Region	15,0	8,0	0,5	0,3	0,6	7,1	3,0	0,1	0,1	0,1
Almaty	3,9	1,4	0,2	0,1	1,0	1,2	0,3	0,0	0,0	0,3
Almaty Region	20,8	6,7	0,3	0,3	0,7	9,5	2,1	0,1	0,1	0,2
Atyrau Region	20,6	14,7	0,5	0,1	0,2	10,2	5,4	0,1	0,0	0,0
East Kazakhstan Region	12,3	6,6	1,5	0,5	0,9	5,5	2,4	0,5	0,2	0,2
Jambyl Region	24,0	9,4	0,6	0,5	0,5	10,3	3,0	0,1	0,1	0,1
Karaganda Region	11,3	5,0	0,6	0,3	0,5	4,7	1,8	0,2	0,1	0,1
Kostanay Region	15,0	9,7	0,9	0,5	0,5	7,3	3,8	0,3	0,1	0,1
Kyzylorda Region	17,8	10,5	0,8	0,4	0,7	6,8	3,2	0,2	0,1	0,2
Mangystau Region	23,2	7,5	1,1	0,4	1,6	11,4	2,2	0,2	0,1	0,5
North Kazakhstan Region	6,3	7,1	1,8	0,8	0,8	2,4	2,5	0,6	0,3	0,2
Nur-Sultan	1,6	0,8	0,4	0,1	0,3	0,5	0,3	0,1	0,0	0,1
Pavlodar Region	9,3	4,5	0,9	0,2	0,6	3,8	1,5	0,3	0,1	0,1
South Kazakhstan Region	19,0	10,0	1,8	0,4	0,9	8,0	3,0	0,5	0,1	0,2
West Kazakhstan Region	13,9	8,3	0,9	0,5	0,7	5,6	2,9	0,2	0,1	0,1

– max indicators, – min indicators.

In this Table 1, the regions marked in orange and green have the highest depth of poverty and the lowest. In Mangistau and North Kazakhstan regions, the depth of poverty is higher than in other cities, which indicates an unsatisfactory standard of living in these regions. Below are graphs for a better comparison of results over the past 10 years. (Figure 2, 3)

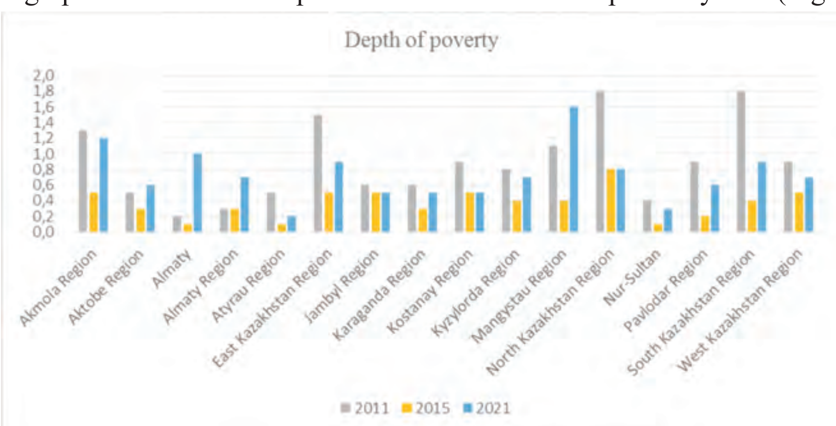

Figure 2 **–** Indicators of the depth of poverty of the regions of Kazakhstan from 2011 to 2021

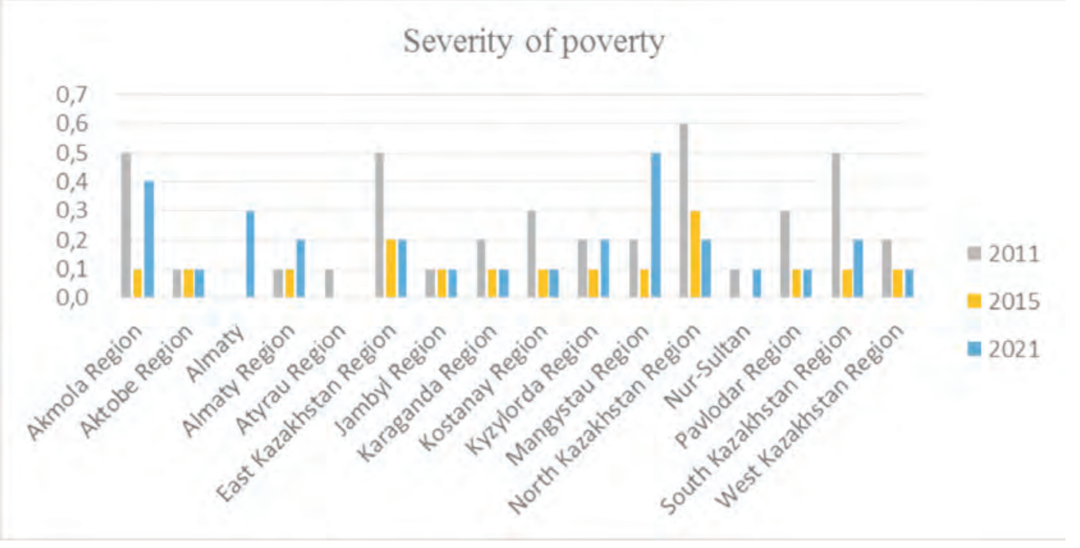

Figure 3 – Poverty severity rates of the regions of Kazakhstan from 2011 to 2021

The depth and severity of poverty indicators for 2021 were displayed on a web map using a regional and heat map, where the color changes depending on the value of the coefficient. (Figure 4). Here we can see that two layers are used. The first layer displays tabular data for the depth of poverty, and colors from light blue to dark blue. The second layer is a heat map for poverty severity, in red and green circles.

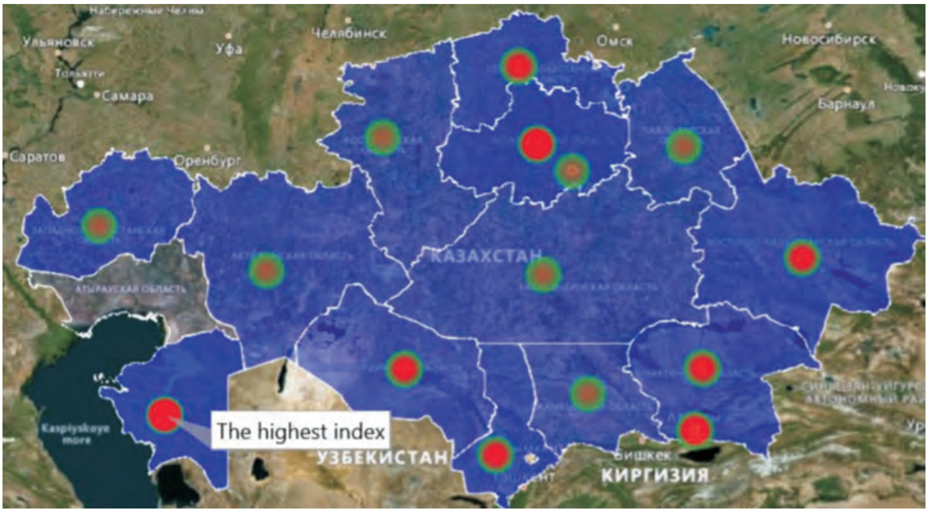

Figure 4 – Displaying data of depth and severity of poverty for regions of Kazakhstan for 2021 on the web map

Table 2 shows the performance of the Gini coefficient from 2001 to 2021, as mentioned above, the lower the Gini index and close to zero, the more equal the region is and vice versa.

Table 2 **–** Indicators of the Gini coefficient for the last 20 years in all regions of Kazakhstan.

Regions of Kazakhstan	2001	2005	2011	2015	2021	Regions of Kazakhstan	2001	2005	2011	2015	2021
Akmola Region	0,344	0,297	0,284	0,270	0,287	Kostanay Region	0,370	0,310	0,258	0,254	0,256
Aktobe Region	0,382	0,296	0,278	0,269	0,285	Kyzylorda Region	0,280	0,248	0,255	0,210	0,230
Almaty	0,309	0,233	0,259	0,271	0,321	Mangystau Region	0,385	0,284	0,180	0,210	0,188
Almaty Region	0,331	0,267	0,246	0,255	0,280	North Kazakhstan Region	0,295	0,271	0,296	0,269	0,298
Atyrau Region	0,372	0,309	0,234	0,219	0,222	Nur-Sultan	0,345	0,306	0,272	0,224	0,259
East Kazakhstan Region	0,348	0,296	0,285	0,284	0,319	Pavlodar Region	0,318	0,263	0,266	0,226	0,312
Jambyl Region	0,310	0,222	0,248	0,221	0,220	South Kazakhstan Region	0,313	0,242	0,213	0,194	0,188
Karaganda Region	0,333	0,303	0,291	0,292	0,309	West Kazakhstan Region	0,321	0,276	0,255	0,263	0,249

Here you can see that social inequality for 2021 is more pronounced in the largest city of Kazakhstan - Almaty, where the incomes of the population are very different from each other. Also, the North Kazakhstan region showed the best results for 2015 and 2021, which indicates that the incomes of the population are close to each other. The developed countries of the world practice economic models that help bring the Gini coefficient closer to 0 [16]. In Figure 5, one can observe the declining dynamics for all regions, here the conclusion is that the country has improved its social condition over the past 20 years. On the one hand, it is necessary to take into account both devaluation and other categories that mainly describe economic development and the standard of living of the population. However, these tasks are outside the scope of our work.

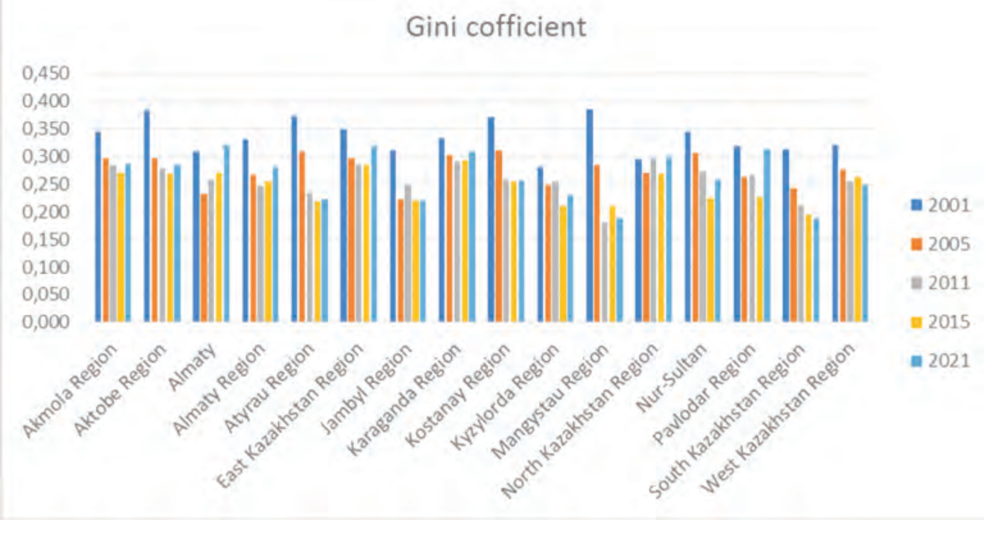

Figure 5 **–** Graph of Gini coefficient indicators from 2001 to 2021 for the regions of Kazakhstan

Below the data display of the Gini coefficient is shown in Figure 6, where a heat map is used, which highlights areas by their values: red - maximum, yellow - average, green - minimum. There is also a sheet map displaying tabular data for 20 years of the geoobject to which the coordinate referencing is performed.

Figure 6 – Heatmap of Kazakhstan with Gini coefficient indicators for 2021

In the future, the establishment of such tasks as finding the causes of poverty, identifying the stability of variability is to be set. For example, a significant number of employed population on life indices, between such indicators of labor/employment and acute poverty, a direct or inverse correlation, and whether there is a relationship between fast working youth and the level of income in the region. That is, it requires a thorough analysis of all indicators that are relevant to the socio-economic life of the population. All these works will be carried out in anticipation of our research.

Conclusion. Our main goal in this work was to integrate socio-economic indicators with the map for better monitoring and comparison of results. To accomplish these tasks, a collection of unstructured tabular data was made, consisting of indicators describing the socio-economic condition of the population. Since there are many indicators, it was important to choose the most important 3-4 indicators. Moreover, the choice was made in favor of such indicators as the severity of poverty, the depth of poverty and the inequality index (Gini coefficient). Mean income measures were used to calculate the Gini coefficient. All calculations were made in ArcGIS Analytics, it is important to properly prepare the incoming data.

After receiving the results, the regions were coordinated to the map, where the program automatically recognized the vector coordinates of all regions of Kazakhstan. Here it should be taken into account that today the ArcGIS program recognizes names only in English.

Since, now we are interested in automatically displaying attribute values on a map, only a vector map was used, where raster data is not specified. In addition, for the best understanding, a heat map layer has been added where the color changes depending on the value.

Based on the results obtained, we can say that all our tasks that we set at the beginning have been completed, there are also new tasks that, based on this work, we will continue in the future.

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Ә. Ғ. ОСПАН[1], М.Е. МАНСУРОВА[1], Е.Х. КАКИМЖАНОВ[1], С.Ш. ИКСАНОВ[1], В.Б. БАРАХНИН[2,3]

[1] Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан
[2]Ақпараттық және есептеуіш технологиялар федералды зерттеу орталығы, Новосибирск, Ресей
[3]Новосибирск мемлекеттік Университеті, Новосибирск, Ресей

ҚАЗАҚСТАН ХАЛҚЫНЫҢ ӨМІР СҮРУ ДЕҢГЕЙІН ТАЛДАУ ҮШІН ӘЛЕУМЕТТІК-ЭКОНОМИКАЛЫҚ КӨРСЕТКІШТЕРДІ КЕҢІСТІКТІК ДЕРЕКТЕРМЕН ИНТЕГРАЦИЯЛАУ БАҒДАРЛАМАСЫН ӘЗІРЛЕУ

Халықтың әлеуметтік-экономикалық жағдайын бағалау және тиімді шешімдер қабылдау үшін өзекті және сенімді ақпарат қажет. Кеңістіктік ақпараттық базаның көмегімен әлеуметтік қамсыздандыру мен өмір сүру деңгейі туралы деректерді стратегиялық даму жоспарларын әзірлеу және шешім қабылдау процесін жақсарту үшін біріктіруге болады. Бұл мақалада Қазақстан тұрғындарының өмір сүру деңгейі мен әлеуметтік қамтамасыз етілуі туралы ақпаратты картада көрсете отырып интеграциялау бойынша жұмыстар ұсынылған. Интеграция үшін ГАЖ құралдары қолданылды, өйткені осы саладағы соңғы технологиялық жетістіктер географиялық деректердің үлкен көлемін басқаруға және әлеуметтік-экономикалық деректермен кеңістіктік орта құруға мүмкіндік береді. Бұл жұмыс Ұлттық статистика бюросынан құрылымданбаған деректерді жинауды, деректерді атрибуты-мәні жұбы ретінде құрылымдалған дерекқорға қайта форматтауды, нақты табыс индексі, кедейліктің тереңдігі мен ауырлығы және әлеуметтік теңсіздік индексі сияқты өмір сүру деңгейінің маңызды көрсеткіштерін есептеуді қамтиды. Интернеттегі нәтижелерді бақылау, алынған нәтижелер негізінде аймақтарды салыстыруға арналған карта. Сондай-ақ, кесте атрибуттарының торын құру үшін жасалған операцияны атап өту керек, өйткені ол автоматты түрде ГАЖ құралының көмегімен жүзеге асырылды. Жұмыс нәтижелері өмір сүру деңгейінің үш маңызды көрсеткіші бойынша ұсынылған және Қазақстанның әрбір өңірі бойынша көрсеткіштердің өзгергенін көрнекі көрсету үшін жылу картасының көмегімен картада көрсетілген.

***Түйін сөздер**: әлеуметтік-экономикалық ақпарат, өмір сүру деңгейінің көрсеткіштері, кеңістіктік деректер, ГАЖ, картографиялық визуализация, деректерді шығару.*

А.Г. ОСПАН[1], М.Е. МАНСУРОВА[1], Е.Х. КАКИМЖАНОВ[1], С.Ш. ИКСАНОВ[1], В.Б. БАРАХНИН[2,3]

[1] Казахский национальный университет им. аль-Фараби, Алматы, Казахстан
[2]Федеральный исследовательский центр информационных и вычислительных технологий, Новосибирск, Россия
[3]Новосибирский государственный университет, Новосибирск, Россия

РАЗРАБОТКА ПРОГРАММЫ ИНТЕГРАЦИИ СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ ПОКАЗАТЕЛЕЙ С ПРОСТРАНСТВЕННЫМИ ДАННЫМИ ДЛЯ АНАЛИЗА УРОВНЯ ЖИЗНИ НАСЕЛЕНИЯ КАЗАХСТАНА

Актуальная и достоверная информация необходима для оценки социально-экономического положения населения и принятия эффективных решений. С помощью пространственной информационной базы данные о социальном обеспечении и уровне жизни могут быть интегрированы для разработки стратегических планов развития и улучшения процесса принятия решений. В данной статье представлены работы по интеграции информации об уровне жизни и социальной обеспеченности жителей Казахстана с отображением данных на карте. Для интеграции использовались инструменты ГИС, поскольку последние технологические достижения в этой области позволяют манипулировать большими объемами географических данных и создавать пространственную среду с социально-экономическими данными. Эта работа включает в себя сбор неструктурированных данных из Бюро национальной статистики, переформатирование данных в структурированную базу данных в виде пары атрибут-значение, расчет важных показателей уровня жизни, таких как индекс реального дохода, глубина и серьезность бедности и индекс социального неравенства, отслеживание результатов в Интернете, карта для сравнения регионов на основе полученных результатов. Также важно отметить операцию, выполненную для построения сетки атрибутов таблицы, так как она была реализована автоматически с помощью инструмента ГИС. Результаты работы представлены по трем важным показателям уровня жизни и отображены на карте с помощью тепловой карты, чтобы наглядно показать изменение показателей по каждому региону Казахстана.

Ключевые слова*: *социально-экономическая информация, показатели уровня жизни, пространственные данные, ГИС, картографическая визуализация, извлечение данных.