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A STUDY ON DATA NORMALIZATION AND AGGREGATION METHODS FOR MONITORING QUALITY OF LIFE IN THE REGIONS OF UKRAINE BASED ON OPEN STATISTICAL DATA

Lukianchuk Iu., Tulashvili Yu., Onishchenko D. A study on data normalization and aggregation methods for monitoring quality of life in the regions of Ukraine based on open statistical data. The article examines modern approaches to assessing the quality of life of the population in the regional context. Open sources of statistical data suitable for regional analysis are analyzed. A comparative analysis of existing data visualization tools is conducted. The choice of the Rational Unified Process (RUP) design methodology and the MERN technology stack for creating a web monitoring platform is substantiated. The platform architecture, UML models and algorithms for data normalization and calculation of integral quality of life indices are developed. The results of an experimental study for five regions of Ukraine are presented. Based on the analysis, it was found that the highest integral quality of life index is in Kyiv city, the lowest -- in Dnipropetrovsk region due to critical environmental problems. The proposed web platform can be used by local governments, research centers and public organizations to monitor regional development.
Keywords: web analytics, quality of life, regional analysis, open statistical data, data normalization methods, integral index, MERN, React, Node.js, MongoDB, RUP, UML.

Лук'янчук Ю.А., Тулашвілі Ю.Й., Оніщенко Д.Т. Дослідження методів нормалізації та агрегації даних для моніторингу якості життя в регіонах України на основі відкритих статистичних даних. У статті досліджуються сучасні підходи до оцінювання якості життя населення в регіональному розрізі. Проаналізовано відкриті джерела статистичних даних, придатні для регіонального аналізу. Проведено порівняльний аналіз існуючих інструментів візуалізації даних. Обґрунтовано вибір методології проєктування Rational Unified Process (RUP) та технологічного стеку MERN для створення веб-платформи моніторингу. Розроблено архітектуру платформи, UML-моделі та алгоритми нормалізації даних і розрахунку інтегральних індексів якості життя. Представлено результати експериментального дослідження для п'яти регіонів України. На основі проведеного аналізу встановлено, що найвищий інтегральний індекс якості життя має м. Київ, найнижчий – Дніпропетровська область через критичні екологічні проблеми. Запропонована веб-платформа може бути використана органами місцевого самоврядування, дослідницькими центрами та громадськими організаціями для моніторингу регіонального розвитку.
Ключові слова: веб-аналітика, якість життя, регіональний аналіз, відкриті статистичні дані, методи нормалізації даних, інтегральний індекс, MERN, React, Node.js, MongoDB, RUP, UML.

Statement of the scientific problem.

In today's digital society, the ability to effectively collect, process and visualize large volumes of statistical data is becoming a decisive factor for making informed management decisions. This is particularly relevant in the context of assessing the quality of life of the population in the regions of Ukraine, which faces unprecedented challenges related to military aggression, internal migration and the need to restore affected territories [1]. Despite the significant amount of open data published by the State Statistics Service, international organizations and sociological institutions, there is a substantial gap between the availability of this information and its accessible, visualized presentation that would allow quick comparison of regions with each other [2]. Thus, the scientific problem lies in the need to develop scientifically grounded methods for normalizing heterogeneous indicators and calculating integral indices that enable objective regional comparison.

Analysis of research.

The concept of quality of life is complex and multidimensional. In [1], it is proposed to consider it as a basic indicator of socio-economic development of a region, which includes both objective living conditions (income level, access to services, environmental condition) and subjective feelings of the population (life satisfaction, sense of security, social optimism). This approach allows obtaining a more complete picture of well-being than using only material indicators. Methodologically, this work builds on recent advances in multi-criteria decision analysis (MCDA) for regional comparisons [3, 4], as well as on research into methods for constructing composite indices [5].

According to monitoring data [2], conducted by the World Bank in Ukraine, the period 2023-2025 was characterized by significant shifts in economic activity and population size. The frontline regions suffered the greatest losses: almost half of households in these areas reported damage to housing, and food security indicators there are significantly worse than in the west of the country. At the same time, western regions and the city of Kyiv became centers of attraction for internally displaced persons, which created additional pressure on local infrastructure, but at the same time stimulated economic activity. The Gini coefficient, which measures income inequality, increased from 0.41 to 0.50, indicating a widening gap between rich and poor populations.

The international crowdsourcing platform Numbeo [6] offers an alternative approach to assessing quality of life, based on data provided directly by users. According to its rating, Ukraine ranks 68th in the world with an index of 115 (while the leader Luxembourg has a score of 220). Interestingly, even within the same country, there are significant differences: Lviv receives a score of 135.80, while Dnipro receives only 99.67. This difference is explained by various factors: Lviv has a better environmental situation and higher level of security, while in Dnipro these indicators are significantly worse due to proximity to the combat zone and concentration of heavy industry.

Fig. 1. Diagram of the structure of quality of life indicators [developed by the author]

Sociological research [7] adds a subjective component to objective statistics. It turned out that despite all the difficulties of wartime, 58% of Ukrainians consider themselves happy. However, this indicator significantly depends on material well-being: among affluent segments it reaches 77%, while among low-income groups it is only 38%. The research also confirmed a linear relationship between the level of happiness and an optimistic view of the country's future.

Regarding technical means of data visualization, analysis of modern tools shows that each has its own strengths and weaknesses. Tableau Public [8] is a powerful business analytics solution, allowing the creation of complex dashboards without programming, but its free version requires public access to all created visualizations, which is not always acceptable for research projects. Plotly [9] supports multiple

programming languages (Python, R, JavaScript) and uses modern SVG and WebGL technologies, ensuring high performance even with large datasets. D3.js [10] provides maximum flexibility, allowing any visualization to be implemented, but requires deep knowledge of JavaScript and significant development time. Chart.js [11] is the easiest to use, ideal for basic charts, but has a limited number of visualization types. Leaflet [12] specializes in cartography and integrates well with OpenStreetMap, making it indispensable for geospatial analysis.

Presentation of the main material and substantiation of the research results.

To create a web platform for monitoring the quality of life, the Rational Unified Process (RUP) methodology was chosen [13], which has proven itself as an effective approach for developing complex software systems. RUP is based on an iterative model that allows breaking a large project into several manageable parts, each of which ends with the creation of a working version of the product. This approach reduces risks because the customer can see intermediate results and make adjustments at early stages. In addition, RUP involves the use of the Unified Modeling Language (UML) for visualizing system architecture, which facilitates communication among all project participants.

Within the scope of the work, three key types of UML diagrams were developed. The use case diagram identified two main actors of the system: the Visitor (Analyst), who gains access to public analytics, can filter data by regions and years, compare indicators of different regions and export results to external formats, and the Administrator, who is responsible for populating the system with data and managing sources and metadata. The activity diagram describes in detail a typical user workflow: from opening the main page with a general dashboard to selecting regions for comparative analysis and obtaining visualized results in the form of charts and tables. The class diagram captures the static data structure, defining the main entities of the subject area: regions, indicators, indicator values, categories, data sources and users.

The MERN stack [14] was chosen as the technological foundation for implementing the platform, which includes MongoDB (non-relational database), Express.js (server framework), React (client library) and Node.js (server environment). The main advantage of this stack is the use of a single programming language (JavaScript) at all levels, which significantly simplifies development and code maintenance, since the developer can freely move between the server and client parts without needing to change the mental context [14]. In addition, all MERN components are open-source, well-documented and have large communities, guaranteeing the availability of ready-made solutions for typical tasks.

Node.js [15] provides an asynchronous, event-driven architecture that allows the server to handle thousands of simultaneous connections without blocking execution threads. This is critically important for an analytical platform that may be accessed by many users simultaneously. Express.js [16] simplifies the creation of RESTful APIs, providing convenient mechanisms for routing HTTP requests, handling middleware and working with request and response bodies. MongoDB was chosen for its flexibility: data from different sources (State Statistics Service, World Bank, Numbeo, KIIS) have different structures, and the NoSQL approach allows storing them without the need to pre-coordinate a rigid schema. Mongoose [17] is used for convenient work with MongoDB -- a library that adds typing and data validation. React [18] ensures fast interface updates thanks to the virtual DOM: instead of directly manipulating the browser's DOM tree, React creates a lightweight virtual copy, compares it with the previous state and applies only the necessary changes, which significantly increases performance.

To calculate generalized quality of life indicators, algorithms for data normalization and aggregation were developed. Since the initial indicators have different units of measurement (hryvnias, percentages, number of people per 1000 population, etc.) and different ranges of values, they need to be brought into a comparable form. For this purpose, the min-max normalization method is used, which converts each value into a number from 0 to 1. The type of indicator is taken into account: for stimulants (higher value corresponds to better quality of life, e.g., salary or life expectancy) a direct transformation is used, while for destimulants (higher value worsens quality of life, e.g., unemployment rate or pollutant emissions) an inverse transformation is used. After normalization, indices for each of the five categories (economy, education, healthcare, ecology, infrastructure) are calculated as the arithmetic mean of the corresponding indicators. The overall integral quality of life index for a region is calculated as the arithmetic mean of the five category indices, ensuring equal weighting of all components.

Formally, the proposed method can be described as follows. Let x_{ij} be the value of indicator j for region i. For stimulants:

$$x'_{ij} = \frac{x_{ij} - \min\limits_j}{\max\limits_j - \min\limits_j} \quad (1)$$

For destimulants:

$$x'_{ij} = \frac{\max\limits_j - x_{ij}}{\max\limits_j - \min\limits_j} \quad (2)$$

The category index C_{ik} for category k is:

$$C_{ik} = \frac{1}{n_k} \sum_{j \in category_k} x'_{ij} \quad (3)$$

The overall integral index Q_i is:

$$Q_i = \frac{1}{5} \sum_{k=1}^{5} C_{ik} \quad (4)$$

Table 1. Integral quality of life indices by region (2025)

Indicator / Region	Kyiv city	Lviv region	Dnipropetrovsk region	Kyiv region	Odesa region
Economy	0.92	0.68	0.75	0.70	0.65
Education	0.88	0.85	0.70	0.65	0.68
Healthcare	0.85	0.80	0.72	0.60	0.62
Ecology	0.65	0.78	0.25	0.60	0.55
Infrastructure	0.90	0.65	0.75	0.72	0.68
Overall index	0.84	0.75	0.63	0.65	0.64

The experimental study was conducted based on data for the period 2022-2025 for five regions of Ukraine representing different geographical macro-regions: the capital region (Kyiv city), central (Kyiv region), western (Lviv region), southern (Odesa region) and eastern (Dnipropetrovsk region). This selection allows identifying regional characteristics and trends.

As shown in Table 1, the highest overall quality of life index is found in the city of Kyiv (0.84). This is explained by several factors: firstly, the capital has the highest average monthly salary (UAH 22,450), which is almost 20% higher than indicators in other regions; secondly, it has the largest number of higher education institutions and research facilities; thirdly, the accessibility and quality of medical services in Kyiv are the best in the country. However, the environmental situation in the capital (0.65) is problematic due to high anthropogenic pressure and traffic congestion.

Lviv region ranks second with an overall index of 0.75. The strengths of this region are ecology (0.78) due to significant forest areas and the absence of heavy industry, as well as education (0.85) and healthcare (0.80). Notably, according to the results of external independent assessment, graduates of Lviv region schools traditionally demonstrate some of the highest scores in Ukraine, indicating the high quality of secondary education. The disadvantage is the relatively low housing provision (0.65), which is associated with historical development and high population density.

Dnipropetrovsk region, despite high economic indicators (0.75) and developed infrastructure (0.75), has the lowest overall index (0.63). The main problem is the catastrophic environmental situation (0.25). This region is the center of Ukraine's mining and metallurgical complex, housing such giants as the Kryvyi Rih Iron Ore Plant, the Marhanets and Ordzhonikidze mining and processing plants. Pollutant

emissions into the atmosphere per capita here are several times higher than the Ukrainian average, which negatively affects public health and life expectancy.

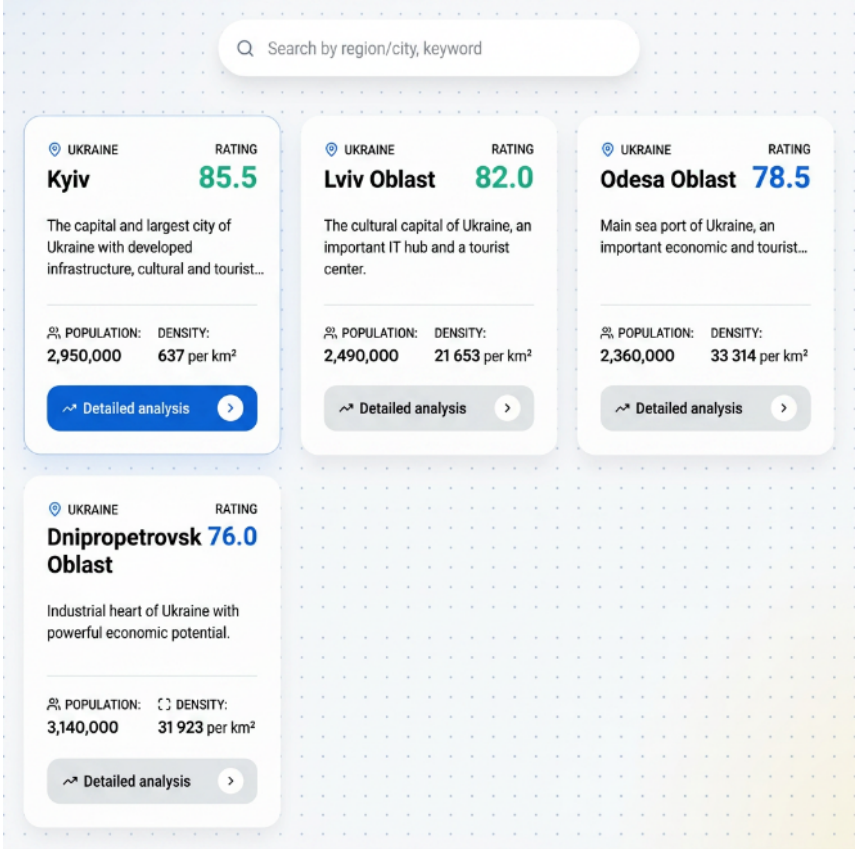

Fig. 2. Visualization of indicators for the studied regions [developed by the author]

Kyiv and Odesa regions show similar overall index values (0.65 and 0.64 respectively). Kyiv region has better economic indicators (0.70) and higher housing provision (0.72) due to active suburban construction. Odesa region, in turn, has a slightly better environmental situation (0.55) and higher education indicators (0.68), but suffers from the seasonal nature of employment in tourism and logistics, which leads to a higher unemployment rate (8.5% versus 6.8% in Kyiv region).

Analysis of dynamics over the period 2022-2025 reveals an interesting pattern. In 2022, after the start of the full-scale invasion, a sharp decline in indicators was observed in all regions. However, Dnipropetrovsk (due to proximity to the combat zone) and Odesa (due to port blockade) regions suffered the most. In 2023-2024, gradual recovery occurred, with the fastest recovery taking place in Lviv region (due to the influx of internally displaced persons and relocation of enterprises) and the city of Kyiv (due to active adaptation of the economy to new conditions). By 2025, most regions had reached pre-war levels or even exceeded them in some categories, indicating the high adaptability of the Ukrainian economy.

Conclusions and prospects for further research.

As a result of the conducted research, a method for normalizing heterogeneous regional indicators (stimulants and destimulants) using min-max normalization was proposed and experimentally validated. An aggregation approach based on equally weighted category indices was formulated. The method was experimentally validated on real data from five regions of Ukraine (2022–2025). It was found that the highest integral quality of life index is in Kyiv city (0.84) and the lowest in Dnipropetrovsk region (0.63), which is primarily due to environmental factors. An experimental web platform based on RUP and MERN was implemented as a validation environment for the proposed method.

The created platform has practical value for local governments (who can use it to monitor the effectiveness of their activities), research centers (who gain a convenient tool for analyzing regional data) and public organizations (who can use the platform for government oversight and advocacy of changes).

Prospects for further research include expanding geographical coverage to all 24 regions of Ukraine and the possibility of detailing to the level of individual territorial communities (after the administrative-

territorial reform this is particularly relevant). It is also planned to add new categories of indicators, including digitalization (access to broadband internet, level of digital literacy), security (crime rate, trust in law enforcement) and cultural development (availability of theaters, museums, libraries). In addition, the implementation of predictive models based on machine learning methods is envisaged, which will allow predicting changes in quality of life based on historical data and current trends, as well as integration with APIs of international organizations to compare Ukrainian regions with regions of neighboring EU countries. A separate direction is the creation of a native mobile application for iOS and Android, which will provide access to the platform from any device

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