

Geometric Approach for Assessing the Sustainable Development of Territories

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Abstract: In this paper, we delve into a groundbreaking methodology that evaluates the sustainable development of territories through a geometric approach. We explore

novel approaches to assess sustainable development by constructing geometric figures that represent economic, social, and environmental levels of development. This innovative approach enables the evaluation of the balance between these spheres by determining the areas of the inscribed figures and examining their ratios. Through this geometric framework, a comprehensive understanding of the sustainable development landscape can be obtained.

Keywords: Sustainable Development, Balanced Development, Sustainable Development Assessment, Sustainable Development Index, Geometric Approach to Assessment.

1 Introduction

The imperative of sustainable development (SD) stands as one of the utmost priorities in today's world [2]. It commands the attention of global leaders, drives the implementation of numerous governmental and intergovernmental programs, and serves as the focal point for countless scientific studies. By aligning OBQ and SD, businesses can achieve a competitive advantage, attract and retain top talent, and build a reputation as a responsible corporate citizen [1]. Prominent international organizations have long recognized SD significance [3]. At its core, the concept of sustainable development strives to forge a comprehensive connection between three vital components: the economy, society, and the environment. It endeavors to foster collaboration among developed nations, governments, businesses, civil society, scientific expertise, governmental policies, urban and rural communities, and both present and future generations [4].

To effectively tackle the pressing challenges confronting nations across the globe, the concept of sustainable development should serve as the foundation for devising solutions. This paradigm, recognized as the most promising ideology of the 21st century, transcends the limitations of fragmented existing worldview ideologies, rendering them insufficient for guiding civilization toward balanced development. Assessing the level of sustainable development holds paramount importance within the field of sustainable development research. This evaluation is crucial for comprehending the current state of affairs, pinpointing problems and imbalances, delving into their root causes, and substantiating the implications and remedies for achieving sustainable development goals.

Within the scope of this work, we will focus on the study of the level of sustainable development of the country in the regional aspect. The regional aspect of sustainable development research is important for sufficiently large countries with a significant level of regional asymmetries [5].

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2 Methodologies

Currently, there are many approaches to assessing the integral levels of development of countries and their regions from different positions and according to different parameters. All of them involve the selection of a system of quantitative parameters (indicators), which in practice are determined by the availability, accessibility, objectivity, efficiency, and meaningfulness of the existing statistical base.

International organizations, foreign and domestic scientific institutes have proposed approaches to assessing the level of sustainability of development of territorial systems at different levels (macro-, meso- and micro-levels). The methods of assessing sustainability of development, which are based on the index approach of determining the integral level of social, economic and ecological development and summing them up into a generalizing index of sustainable development of a certain territorial system, have gained the greatest recognition. The most common methods of assessing the level of sustainable development of territories, which have become widely used in world practice, are presented in the table 1.

3 Discussions

These approaches have important methodological and applied value for the assessment of sustainable development of the regions of Ukraine and allow to identify indicators that reflect the initiatives of countries and international organizations in approaches to the assessment of sustainable development issues related to integration policy in the economic, social and environmental spheres 0.

However, certain approaches may not provide a comprehensive examination of balanced development across social, economic, and environmental dimensions. Instead, they tend to focus on specific areas or aspects. For instance, the United Nations Development Program (UNDP) and the United Nations Department for Economic and Social Affairs (UNDESA) concentrate on the social dimension. On the economic front, the World Economic Forum and the Intellectual Center of the Foundation (Heritage Foundation) play key roles in assessment. Meanwhile, the methodology employed by Yale and Columbia Universities in the United States is used by the World Economic Forum to evaluate the Environmental Sustainability Index. The World Bank, in collaboration with the United Nations Environment Program (UNEP) and the International Center for Tropical Agriculture (CIAT), contributes to the assessment of environmental factors.

4 Results

In addition, a significant number of indicators are adapted for use only at the national level. Therefore, taking into account world developments, we will determine the directions of evaluation of sustainable development for the regions of Ukraine. In order to achieve this, our assessment methodology will incorporate a set of indicators that capture the volume, structure, quality, and efficiency of resource utilization. These indicators will be derived through mathematical analysis of primary data from official statistical sources such as the State Statistics Service of Ukraine, ministries and agencies, research institutes, the National Bank of Ukraine, as well as our own observations.

Figure 1 illustrates the different dimensions of the integrated assessment of regional sustainable development. The specific indicators within each dimension may vary depending on the statistical data available and the unique characteristics of each country's development. To determine the overall level of sustainable development in the region, we propose a comparative analysis of two triangles, ABS and $A'B'C'$, with a shared center point O (as shown in Figure 2) 0. The triangle ABC represents the reference level of sustainable development and is characterized by segments that reflect the equidistant distances of the triangle's vertices from its center, namely AO , BO , and OC . On the other hand, the triangle $A'B'C'$ corresponds to the calculated level based on three values, represented by segments that measure the distances from the triangle's vertices to point O – specifically, $A'O$, $B'O$, and $C'O$.

By comparing the areas of these two triangles, we can assess the integral level of sustainable development in the region. This approach allows us to quantify the progress made in achieving sustainable development goals and identify areas that require further attention and improvement.

Table 1: Some methods of assessing the level of sustainable development.

| Developers | Calculation method | System of indicators | Practical implementation | Comment |
|---|--|---|--|--|
| 1 | 2 | 3 | 4 | 5 |
| World Economic Forum [www.weforum.org] | The methodology provides for the calculation of the index of competitive development | Includes indicators: - technological development; - public institutions; - macroeconomic environment | Annual calculations are made for 117 countries of the world and published in the Global Competitiveness Report | Allows to take into account the level of economic development, the role of the institutional component, but does not take into account other areas of sustainable development |
| Heritage Foundation [https://web.archive.org/web/20080227044144/http://www.heritage.org/research/features/index/chapters/pdf/index2008_execsum.pdf https://www.heritage.org/] | The methodology provides for the calculation of the index of economic freedom | The 10 Economic Freedoms: Business Freedom; Trade Freedom; Fiscal Freedom; Government Size; Monetary Freedom; Investment Freedom; Financial Freedom; Property Rights; Freedom from Corruption; Labor Freedom | Based on the calculations, countries are rated by the level of economic freedom | The methodology is aimed at assessing economic development and the financial capacity of countries |
| Yale and Columbia Universities, USA, for the World Economic Forum in Davos [https://www.yale.edu/about-yale] | The methodology provides for the calculation of the environmental sustainability index ESI (Environmental Sustainability Index) | Contains indicators: Characteristics of the environment; Level of pollution and impact on the environment; losses to society from pollution in the form of product losses, diseases, etc.; Social and institutional capacity to counter environmental impacts; Reducing the population's dependence on environmental influences; Opportunities to solve global environmental problems by consolidating efforts to preserve nature | The Environmental Sustainability Index (ESI) is a measure of overall progress towards environmental sustainability. The index provides a comprehensive profile of national environmental protection based on a composite of indicators derived from underlying data sets | The methodology allows for detailed monitoring of the ecological development of the country and regions, which can be used to assess the ecological sphere of sustainable development of regions |
| United Nations Development Program [www.hdr.undp.org/reports/global] | The methodology involves the calculation of the human development index | Contains indicators: - the average life expectancy of the population; - level of education of the population; - standard of living according to GDP per capita according to purchasing power parity | Annual calculations are made for 117 countries of the world | The indicators of this methodology should be included in the methodology for assessing the level of sustainable development of the region |

Continuation of the table. 1

| 1 | 2 | 3 | 4 | 5 |
|---|---|--|--|---|
| Economist Intelligence Unit [https://www.economist.com/media/pdf/QUALITY_OF_LIFE.pdf] | The methodology provides for the calculation of the quality and safety of life index | Contains indicators: - GDP per capita; - the average life expectancy of the country's population; - rating of political stability and security of the country; - number of divorced families per 1000 population; - the level of public activity; - climatic conditions of the population; - the level of unemployment in the country; - the level of political and social freedoms in the country; - the ratio between the average salary of men and women | Annual calculations are made | The proposed indicators should be used when assessing the level of financial security in the areas of sustainable development of the region, when determining the level of social development of the region |
| The International Bank for Reconstruction and Development [https://www.worldbank.org/en/who-we-are/ibrd] | The methodology involves taking into account indicators characterizing the economic situation, the state of the environment, the level of human development for industrially developed countries and developing countries | Contains indicators: - macroeconomic situation; - population development; - working conditions of enterprises; - integration into the world economy; - state policy | Annual calculations are made for different groups of countries and territories and published in the World Development Report | To assess the level of sustainable development of regions, it is advisable to use the indicators proposed in the methodology, grouping them by areas of sustainable development |
| Redefining Progress [https://gnhusa.org/genuine-progress-indicator/ ; https://en.wikipedia.org/wiki/Genuine_progress_indicator#] | The methodology involves the calculation of the Genuine Progress Indicator (GPI), the Index of Sustainable Economic Welfare (ISEW) or the index of the level of environmental impacts | The proposed index acts as an alternative to GNP, which takes into account, in addition to economic benefits, environmental losses, and evaluates the relative efficiency of the economy over a certain period of time | Annual calculations are carried out both for countries and their individual regions | The main emphasis in the methodology is focused on the assessment of social and ecological development, somewhat indirectly - on the economy |
| United Nations Commission on Sustainable Development (UNCSD) [https://www.un.org/esa/sustdev/csd/csd9_indi_bp3.pdf] | The methodology involves determining the integral level of sustainable development | 4 main groups of indicators: - indicators of social aspects of sustainable development - indicators of economic aspects of sustainable development - indicators of ecological aspects of sustainable development - indicators of institutional aspects of sustainable development (policy planning, scientific developments, international legal instruments, information support, strengthening the role of the main population groups). | A set of indicators is offered to countries for testing and preparation of national programs | The methodology allows for a comprehensive approach to the assessment of the issues of sustainable development. It is rather difficult to quantify and compare the institutional aspects of sustainable development |

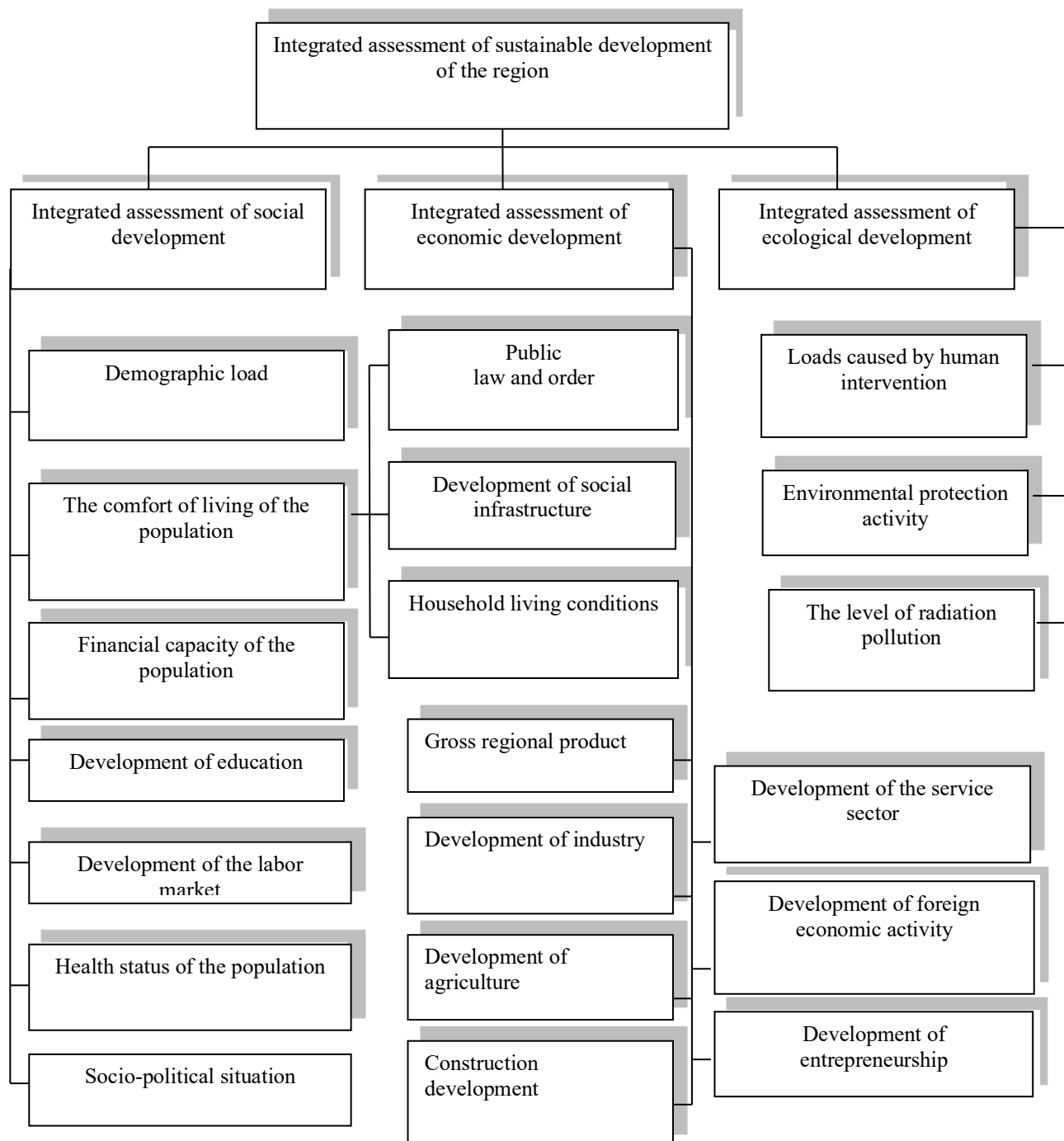


Fig. 1. Areas of assessment of sustainable development of the region.

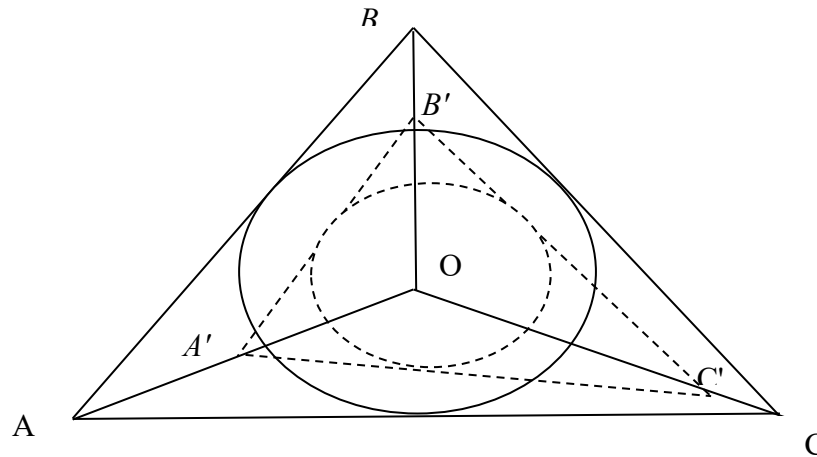


Fig. 2. Graphic representation of the levels of sustainable development of the region.

AO – segment corresponding to the maximum level of economic development of the region;

BO – segment corresponding to the maximum level of social development of the region;

CO – segment corresponding to the maximum level of ecological development of the region;

A'O - segment corresponding to the estimated level of economic development of the region;

B'O - segment corresponding to the estimated level of social development of the region;

C'O - segment corresponding to the estimated level of ecological development of the region.

The common property of two triangles is the equality of all internal angles with the vertex at point O, i.e.:

$$\angle AOC = \angle A'OC' = \angle AOB = \angle A'OB' = \angle BOC = \angle B'OC' \quad (1)$$

The level of development in three spheres will be characterized by an appropriate indicator - the index of socio-ecological and economic development of the region, which we propose to calculate as the ratio of the areas of triangles ABC and A'B'C':

$$I_{see} = \frac{S_{\Delta A'B'C'}}{S_{\Delta ABC}}, \quad (2)$$

where Isee - is the index of socio-ecological and economic development of the region;

$$S_{\Delta A'B'C'} - \text{area of triangle } A'B'C'; \quad (3)$$

$$S_{\Delta ABC} - \text{area of triangle } ABC. \quad (4)$$

The initial data for determining this index are the lengths of the segments characterizing the distance of the vertices of the triangles from their common center (point O). Calculation formula for calculating the area of a triangle:

$$S_{\Delta} = \sqrt{p(p-a)(p-b)(p-c)}, \quad (5)$$

where p is the semi-perimeter of triangle ABC;

a, b and c are the lengths of the sides of the triangle.

The semi-perimeter p will be determined:

$$p = \frac{\sqrt{AO^2 + BO^2} + \sqrt{BO^2 + CO^2} + \sqrt{AO^2 + CO^2}}{2}, \tag{6}$$

accordingly, the socio-ecological-economic development index of the region will be calculated:

$$I_{see} = \frac{\sqrt{p(p-A'O)(p-B'O)(p-C'O)}}{\sqrt{p(p-AO)(p-BO)(p-CO)}} \tag{7}$$

Since in our case, the lengths of the segments AO , BO , and CO are understood as the reference (maximum) values of the indices of economic, social, and ecological development, we can write the following equivalent designations for the lengths of the segments:

$I_e^{max} = AO = I$ – maximum index of economic development of the region;

$I_s^{max} = BO = I$ – maximum index of social development of the region;

$I_{ek}^{max} = CO = I$ – the maximum index of ecological development of the region.

For the lengths of segments $A'O$, $B'O$, $C'O$, you can write down the values of the calculated indices:

$I_e = A'O$ - estimated index of economic development of the region;

$I_s = B'O$ - calculated index of social development of the region;

$I_{ek} = C'O$ - calculated index of ecological development of the region.

Accordingly, the formula for determining the socio-ecological-economic development index of the region will take the following form:

$$I_{see} = \frac{\sqrt{p(p-I_e)(p-I_s)(p-I_{ek})}}{\sqrt{2,12(2,12-1,41)(2,12-1,41)(2,12-1,41)}} = \frac{\sqrt{p(p-I_e)(p-I_s)(p-I_{ek})}}{0,866} \tag{8}$$

At the same time, the proposed method does not allow taking into account the level of development disparities in areas of sustainable development. In order to take into account the level of balance of the spheres of sustainable development, it is proposed to compare the area index of the circle inscribed in the triangle $A'B'C'$ (relative to the reference value) with the area index of this triangle, which will allow to determine the level of balance between each of the spheres, because the increase in the area of the circle will indicate about high values of development levels in each of the spheres and vice versa.

The level of balance will be determined by:

$$P_{bal} = \left(\frac{S_{oA'B'C'} \div S_{\Delta A'B'C'}}{S_{oABC} \div S_{\Delta ABC}} - \varphi \right) \cdot 100\%, \tag{9}$$

where $P_{3\sigma}$ – level of balanced development of the region;

$S_{oA'B'C'}$ - area of a circle inscribed in a triangle $A'B'C'$;

S_{oABC} - area of a circle inscribed in a triangle ABC ;

Φ - is a quasi-constant value obtained during calculations.

The balance index is equal to:

$$I_{bal} = \frac{S_{oA'B'C'} \div S_{\Delta A'B'C'}}{S_{oABC} \div S_{\Delta ABC}}, \tag{10}$$

where I_{bal} – is the regional development balance index.

The area of the circle inscribed in the triangles ABC and A'B'C' is determined using the formula:

$$SO_{ABC} = \pi r^2 = \pi \cdot \frac{S\Delta_{ABC}}{p}; SO_{A'B'C'} = \pi r'^2 = \pi \cdot \frac{S\Delta_{A'B'C'}}{p}. \quad (11)$$

The application of the measure of balance of each of the spheres in the method of assessing the level of sustainable development of the region will allow taking into account the level of their proportionality and uniformity of development. According to this, the sustainable development index of the region will be determined: $I_{SD} = I_{see} \times I_{bal}$.

The authors' methodology for assessing the level of sustainable development of countries and territories has been developed, which, unlike the existing ones, allows taking into account the level of balance in its social, economic and environmental spheres. On the other hand, recently, the COVID-19 pandemic has highlighted the importance of sustainable development 00. The authors' methodology for assessing sustainable development considers the balance between social, economic, and environmental spheres. This methodology can be used to track progress towards sustainable development goals and inform policy decisions.

5 Conclusions and recommendation

Drawing on an analysis of methodological approaches adopted in global practices, this study presents a novel methodology for evaluating the level of sustainable development in regions. This methodology entails the establishment of assessment directions and a comprehensive system of indicators. In contrast to existing methods, the proposed approach enables the determination of a region's level of balanced development across its various spheres.

The research emphasizes the need for further investigations into sustainable development and strongly recommends the adoption of the proposed methodology by countries and regions. By doing so, it becomes possible to identify regional disparities in the levels of sustainable development, specifically in terms of the equilibrium among social, economic, and environmental dimensions. By utilizing this methodology, policymakers and researchers can gain valuable insights into the regional dynamics of sustainable development and make informed decisions to foster more balanced and inclusive growth.

Conflicts of Interest Statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

References

- [1] Le Blanc, D. Towards integration at last? The Sustainable Development Goals as a network of targets. *Sustainable Development*, Vol. 23 No. 3 (2015) PP. 176-187.
- [2] World Bank. World Development Indicators 2021. Retrieved from <https://databank.worldbank.org/reports.aspx?source=world-development-indicators>
- [3] Hamed Fazlollahtabar, Online Business Quality of Service Information Analytics using Artificial Intelligence, *Inf. Sci. Lett.* Vol. 10, No. 1 (2021), PP:93-100 doi:10.18576/isl/100111
- [4] Ammar Al-Sammarrace and Nadya Alshareeda, The Role of Artificial Intelligence by Using Automatic Accounting Information, System in Supporting the Quality of Financial Statement, *Inf. Sci. Lett.* Vol. 10, No. 2 (2021), PP:223-254, doi:10.18576/isl/100208
- [5] Eman Wadie Abdel Halim, The Influence of University Students Inclination and Their Intentions towards Self-Employment Decision: Applied to Students of Entrepreneurship Clubs, *Inf. Sci. Lett.* Vol. 10, No. 2 (2021), PP:341-376, doi:10.18576/isl/100215
- [6] Alaa Zuhir Al Rawashdeh, Asma Rebhi Al Arab, Noura Nasser Alqahtani and Zineb Hadmer, The Sociological Understanding, for Corona Crises and its Reflections on Society: An Inductive Analytical Vision, *J. Stat. Appl. Prob.* Vol. 10, No. 1 (2021), PP:267-286 doi:10.18576/jsap/100123

- [7] Official Documents System of the United Nations. <https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/92/PDF/N1529192.pdf?OpenElement>
- [8] 17 Goals to Transform Our World. <https://www.un.org/sustainabledevelopment/>
- [9] Ruggerio, Carlos Alberto. Sustainability and sustainable development: A review of principles and definitions. *Science of the Total Environment*, Vol. 786 (2021): PP. 147481.
- [10] Rasulov, Anvar, Nusratulla Alimkulov and Ural Safarov. The role of geocological indicators in the sustainable development of areas, *Journal of Pharmaceutical Negative Results*, Vol. 3 No. 12 (2022) PP. 6498-6501 DOI: 10.47191/ijmra/v3-i12-16.
- [11] Kirkby, John, Phil O'Keefe, and Lloyd Timberlake. *Sustainable Development: An Introduction*. The Earthscan reader in sustainable development. Routledge, 2023. PP. 1-14.
- [12] Wallaa M. Al-Shakhis and Dr.Linda Banks-Santilli, Promoting Critical Thinking Skills in Students in Middle and High School to Achieve the Kingdom of Saudi Arabia's National Vision 2030, *World Research of Political Science Journal*, Vol. 6, No. 1, (2022) PP. 55-72 <http://dx.doi.org/10.18576 /WRPSJ/060105>
- [13] Sachs, Jeffrey D., et al. *Sustainable development report 2022*. Cambridge University Press, 2022.
- [14] Progress to date and remaining gaps in the implementation of the outcomes of the major summit s in the area of sustainable development and analysis of the themes for the Conference. Report of the Secretary-General. The Preparatory Committee for the United Nations Conference on Sustainable Development 17–19 (2010) Retrieved from http://www.undpcc.org/undpcc/files/docs/publications/submitted/SGReport_on_UNCSD_final-1April2010.pdf
- [15] Vakhovych, I., Satyvaldieva, B., Dooranov, A., Marchenko, O., Salivonchik, I. Smart specialization of the region as a tool for modernizing innovative development, *Estudios de Economia Aplicada*, Vol. 39 No. 5, (2021) PP. 4800
- [16] Vakhovych, I. Financial policy of sustainable development of the region: formation methodology and implementation mechanisms. Lutsk: Nadstyr'ya. 496 (2007).
- [17] A. A. M. Teamah, W. A. Afifi, Javid Gani Dar, Abd Al-Aziz Hosni El-Bagoury, Sndus Naji Al-Aziz, Optimal Discrete Search for a Randomly Moving COVID19, *J. Stat. Appl. Prob.* Vol. 9, No. 3 (2020), PP:473-481: doi:10.18576/jsap/090304
- [18] Abdullah Ali H. Ahmadini, Nitesh K. Adichwal, Mutum Zico Meetei, Yashpal Singh Raghav, Mohammed Ali H. Ahmadini, Ahmed Msmali, Neha Seth, Knowledge, Awareness and Practices (KAP) about COVID-19 in Jazan, *J. Stat. Appl. Prob.* Vol. 10, No. 2 (2021), PP:487-497: doi:10.18576/jsap/100217
- [19] Hamid El Maroufy, Adil Lahrouz, PGL Leach, Qualitative Behaviour of a Model of an SIRS Epidemic: Stability and Permanence, *Appl. Math. Inf. Sci.* Vol. 5, No. 2 (2011) PP: 220-238
- [20] H. A. A. El-Saka, The Fractional-order SIR and SIRS Epidemic Models with Variable Population Size, *Math. Sci. Lett.* Vol. 2, No. 3 (2013) PP: 195-200
- [21] Ahmed M. Yousef, Saad Z. Rida, Yassein Gh. Gouda, Asmaa S. Zaki, On Dynamics of a Fractional-Order SIRS Epidemic Model with Standard Incidence Rate and its Discretization, *Prog. Frac. Diff. Appl.* Vol. 5, No. 4 (2019) PP: 297-306 : doi:10.18576/pfda/050405