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EVALUATING THE SUSTAINED DEVELOPMENT OF SOCIO-ECONOMIC SYSTEMS

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ABSTRACT. The conventional approach to assessing the developmental level of any socioeconomic system (SES) is to consider only its state in a given year. However, this approach does not adequately reflect the dynamic and complex nature of SES, which are inherently unstable due to their inertia. In other words, the development indicators at any point in time (year) of the considered period (CP) largely depend on the results of the development that occurred in the previous periods. This makes it difficult to adequately quantify the development of SES over a specific period. This paper presents a novel methodology for obtaining the SES sustained development index by combining the values of two parameters – intensity and uniformity. Since the former must take into account the totality of both positive and negative changes that occurred during the CP, correlation regression analysis is used to calculate the values. The latter is reflected by the value relationships of actual changes in individual periods of CP with SES development taking place without any deviations. Given that the importance of intensity and uniformity for sustained development is not the same, multi-criteria method is used to combine the values in a representative manner.

JEL Classification: O01, O11, O47

Keywords: development of socioeconomic systems, development intensity, uniformity, sustainedly

Introduction

Quality of life depends on the functioning of interconnected socioeconomic systems (SES) of various types and levels. The social system, as an essential part of SES, makes them active by nature and precipitates the circumstances that determine their functioning and survival. Consequently, all socioeconomic systems are open, i.e., they maintain a constant relationship with the surrounding environment. This means that an SES can only achieve its goal with the use of various resources obtained from the outside. In turn, it must meet external needs – supply products, services, etc. Since SES are naturally expansive and complex, their purposeful management is complicated and contingent on very specific circumstances. Thus, quantitative assessment of their condition at a desired moment in time is a crucial task and this topic has, accordingly, been under intense scrutiny for many years. While there are various ways of accomplishing this, multi-criteria methods have been primarily used for this purpose in recent times (Lisiński et al., 2020; Boggia & Cortina, 2010; Volkov, 2018; Oželienė, 2019; Gedvilaitė, 2019; Mammela et al., 2019). Such preference can be explained by the complexity and intricacy of SES. The numerous criteria and indicators used to evaluate an SES are interrelated as elements of the same system. However, they have unequal importance in relation to the considered phenomenon, can be expressed in different dimensions, and can change in different directions. That is why multi-criteria methods are employed to combine these indicators into a single measure capable of quantitatively reflecting the state of SES development.

Generally, multi-criteria evaluation is used to achieve two main goals: rank the options under consideration and assess the state of SES taken separately. The pursuit of the first objective, also called a decision-making support system as it provides the necessary information for the decision-maker, is much more common. It is particularly useful when addressing production, technological, and organizational problems. For example, this method has gained a wide application in construction (Khoso et al., 2021; Bana e Costa et al., 2012; Birjandi et al., 2019; Chen et al., 2020; Chen et al., 2021; Marović et al., 2021; Sutthichaimethee et al., 2024).

The objective of this multi-criteria assessment relies on the normalization of multidimensional indicator values, which determines the sequence of their transformation into comparable forms. In this context, the normalized value of an individual indicator is derived in relation to the values of all other alternatives for the same indicator (Hwang & Yoon, 1981).

If the aim of the multi-criteria evaluation is to assess the development level of an SES independently, this method of normalizing indicator values is unsuitable. In such a case, the normalized value of each indicator should be determined independently of the values of other potential related alternatives (Ginevičius, 2008; Golusin, Munitlak, 2009). The state of SES development is typically evaluated at a specific point in time-usually the current year. However, these systems have been operating for many years. As large-scale systems, they exhibit inertia, meaning that development outcomes in the current period are significantly influenced by the extent of development in previous periods. In other words, the development status in the present period is shaped by the developmental context established during earlier periods (Ginevičius et al., 2018). This observation is substantiated by an analysis of renewable energy development in European Union countries using a correlation-regression analysis model $Y_p = f(\bar{X}^t)$, where Y_p – represents the percentage of renewable electricity in the total electricity production during the final year of the assessed period; $\bar{X}^t$ – denotes the average renewable energy development values (percentages) for the years preceding the final year. The correlation coefficient was determined to be 0.74, highlighting the need to address a critical issue in both scientific and practical contexts: how to adequately evaluate SES development during the assessed period. The argument value used in the correlation model $\bar{X}$ in the correlation model is unsuitable for several reasons. Firstly, it fails to account for developmental changes within the assessed period influenced by random factors. Secondly, it does not capture the fundamental aspects of SES functioning as dynamic processes, such as development, intensity, uniformity, and sustained development, nor does it address the category of dynamics, which is inherently distinct from the aforementioned SES functioning parameters. While these parameters are interconnected as reflections of SES processes, dynamics focus solely on the trajectory of changes and the development of isolated phenomena or processes over time. Consequently, it is appropriate to discuss the intensity, uniformity, and sustained development of SES development, but not the dynamics of development. The latter pertains exclusively to the temporal changes of individual phenomena or processes. The interrelationships among these categories are summarized in (Table 1).

Table 1. Characteristics of SES functioning and individual phenomena and processes

Categories of the phenomenon under consideration	Category description	The essence of the category
Development	SES functioning	Positive quantitative changes in SES functioning
Intensity	Development characteristic of SES	Positive changes in SES development
Evenness	Characteristics of SES development	SES development while maintaining positive changes of equal magnitude
Dynamics	a separate socioeconomic phenomenon	of a separate socio-economic phenomenon, process

Source: compiled by the author

Based on Table 1, the SES functioning category interfaces will look like this (Figure 1).

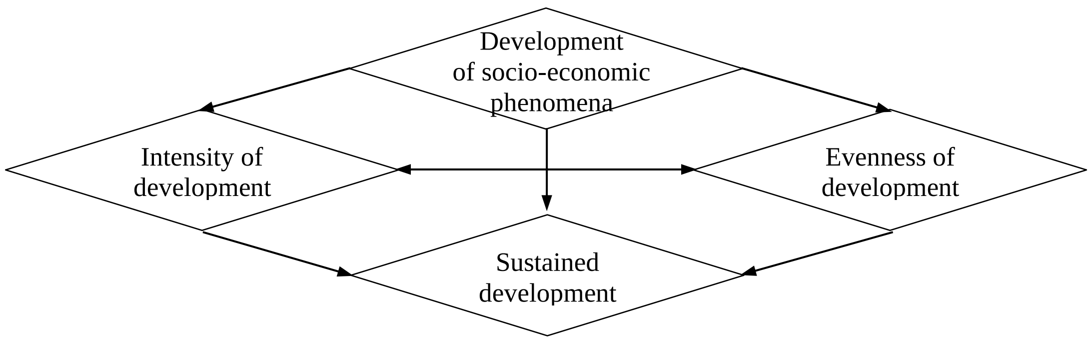

Figure 1. SES functioning diamond
Source: compiled by the author

Table 1 and Figure 1 illustrate that the fundamental characteristic of SES functioning is development, with sustained development being its integral aspect. Sustained development represents long-term progress, emphasizing development as an ongoing process. It is insufficient to determine whether SES sustained development is based solely on data from a single year. SES development is influenced by various destabilizing factors, both objective and subjective, leading to fluctuations that impact outcomes.

Furthermore, Figure 1 highlights that to quantify sustained development, it is essential to evaluate its evenness and intensity, subsequently integrating these indicators into a composite sustained development index. At present, methodologies to achieve this are largely undeveloped, with only a few attempts documented (Ginevičius et al., 2018; 2021). The aim of this article is to propose a methodology for evaluating sustained development within socioeconomic systems (SES) and to validate it through.real-world examples.

1. Literature review

Socio-economic systems are often examined within the context of their sustainable development (SD), as sustained development is implicitly regarded in the literature as a prerequisite for SD. For instance, it is noted that the concept of sustainability may overlook evolving, unidentified needs over time. Numerous studies highlight that sustainable development is an ongoing, long-term process, continuously adapting to changing circumstances (Bartelmus, 2003; Baumgartner, Korhonen, 2010; Mishchuk et al., 2023; Morse, 2008; Pânzaru, Dragomir, 2012). It is highlighted that sustainability inherently assumes the presence of stable growth (Čiegis et al., 2011; Tjahjanto et al., 2023; Švažas et al., 2023). The long-term viability of SES is sustained solely through continuous development and growth (Ginevičius et al., 2016; Volkov, 2018; Pânzaru, Dragomir, 2012; Oželienė, 2019). The fact that SD is inseparable from stability and long-term development is also written in other literature sources (Mines, 2010). A sustainable interpretation of the concept of development arises from the understanding that SD involves a stable pursuit of a dynamic and evolving objective (Volkov, 2018).

Other literature sources also highlight SES development, particularly in the context of achieving financial stability in banking institutions (Podvezko, 2013; Laeven, Valencia, 2010; Kakes, Ullersma, 2003) and the overall country's financial model (Streimikiene et al., 2023; Dong & Bilan, 2024) and financial security (Dankiewicz et al., 2022). The significance of maintaining stable economic performance is also underscored (European Central Bank ..., 2012).

Stability, at its core, signifies consistent, firm, and unaltered development. It is defined by two fundamental dimensions: the quantitative aspect, which represents the extent of SES development during the CP, and the qualitative aspect, which reflects the magnitude of changes that occurred within this timeframe. Effective management of development requires the ability to quantitatively assess these parameters. However, current practices are largely confined to verbal descriptions or graphical representations of development changes across different periods (Volkov, 2018; Molendowski, Petraškevičius, 2020; Qin et al., 2020; Niu et al., 2021). This is commonly referred to as the dynamics of change. However, it serves merely as a textual illustration and does not offer any quantitative evaluation of the situation. This limitation is not coincidental, as only a limited number of studies have addressed this aspect (Ginevičius et al., 2018). All existing studies evaluate the intensity and uniformity of development within the considered period, summarizing these aspects under the term „development dynamics"." However, the question arises as to whether this metric can accurately be labeled an index of dynamics. According to dictionary definitions, dynamics refers to the progression or course of a phenomenon. This interpretation suggests that the trends of change may be undervalued. At best, the evenness of development can be inferred from the dynamics, albeit without quantitative representation. It is understood that the natural state of SES functioning is development, which fundamentally involves progression from a less advanced (lower) state to a more advanced (higher) state. Consequently, the parameters of intensity and evenness do not fully encapsulate the dynamics of the process but rather represent specific aspects of development and sustained development as a whole. To quantify development comprehensively, both intensity and evenness must be appropriately evaluated. Currently, two approaches have been proposed to assess intensity (Ginevičius et al., 2018):

$$I_p = \frac{Q_f}{Q_b}; \quad (1)$$

$$I_p = \frac{Q_f - Q_b}{Q_f}, \quad (2)$$

where I_p– represents the intensity of SES development during the considered period; Q_f– denotes the significance of SES development at the end of the CP and Q_b – refers to its significance at the beginning of the period.

From formulas (1) and (2), it is evident that the metric I_p does not account for developmental changes during the CP and thus requires refinement. Another parameter, evenness, is addressed in the literature by comparing the ideal trajectory of SES development, represented by NL with its actual trajectory. The ideal trajectory represents SES development without deviations, while the actual trajectory is calculated by summing the lengths of the diagonals of right triangles that depict SES development across separate periods within the CP (Ginevičius, 2018). It is prudent to explore alternative methods for the quantitative assessment of the evenness of SES development, including analytical approaches. A review of the literature reveals a notable lack of methodological frameworks for evaluating sustained SES development as a critical condition for its coherence, particularly in terms of comprehensive quantitative assessment techniques.

2. Research methodology

The literature review suggests that the quantitative assessment of sustained SES development as a process is best conducted in two stages. First, the values of the indicators reflecting sustained development are determined. Second, these values are integrated into a single composite measure, referred to as the sustained development index.

Given the inherent complexity of socio-economic systems, their development state can be evaluated using either a single comprehensive indicator or a system of multiple indicators (Radovanović et al., 2017; Bolcarova, Kološta, 2015; Babu, Datta, 2015; Gedvilaitė, 2019; Moldan et al., 2012; Kozyreva et al., 2017; Jędrzejczak, Barska, 2019; Sytnik et al., 2023; Termosa, 2017).

For instance, it is widely recognized today that a country's economic development is adequately represented by its Gross Domestic Product (GDP) per capita. Despite its limitations, GDP per capita is universally applicable due to its standardized calculation methodology, enabling cross-country comparisons and ease of access to relevant data.

Using a system of indicators to assess a country's economic development offers more nuanced insights, as it allows for a more detailed representation of the phenomenon under analysis. However, this approach has not gained widespread adoption, primarily because countries employ indicator systems that vary significantly in both calculation methods and structural composition (Ginevičius et al., 2022; Trišč et al., 2023).

Sustained development of SES based on a single indicator. In this approach, a single-row matrix is constructed (Table 2).

Table 2. Matrix for quantifying the sustained SES development based on a single indicator

Year	t_1	t_2	t_3	...	t_j	...	t_m
Indicator value	q_1	q_2	q_3	...	q_j	...	q_m

Source: compiled by the author

Referring to Table 2, the calculations commence by determining the values of the partial dimensions of sustained development, namely intensity and evenness. The extent of development is represented by the difference between the values at the beginning and end of the CP.

$$\Delta Q = Q_f - Q_b; \quad (3)$$

where ΔQ representsthe extent of SES development during the CP.

Developmental changes of varying magnitudes and types occur during the CP due to both objective and subjective factors. This raises the question of which measure most effectively represents the intensity of these changes. In the context of actual development, analysis facilitates the exploration of potential characteristic scenarios (Figure 2).

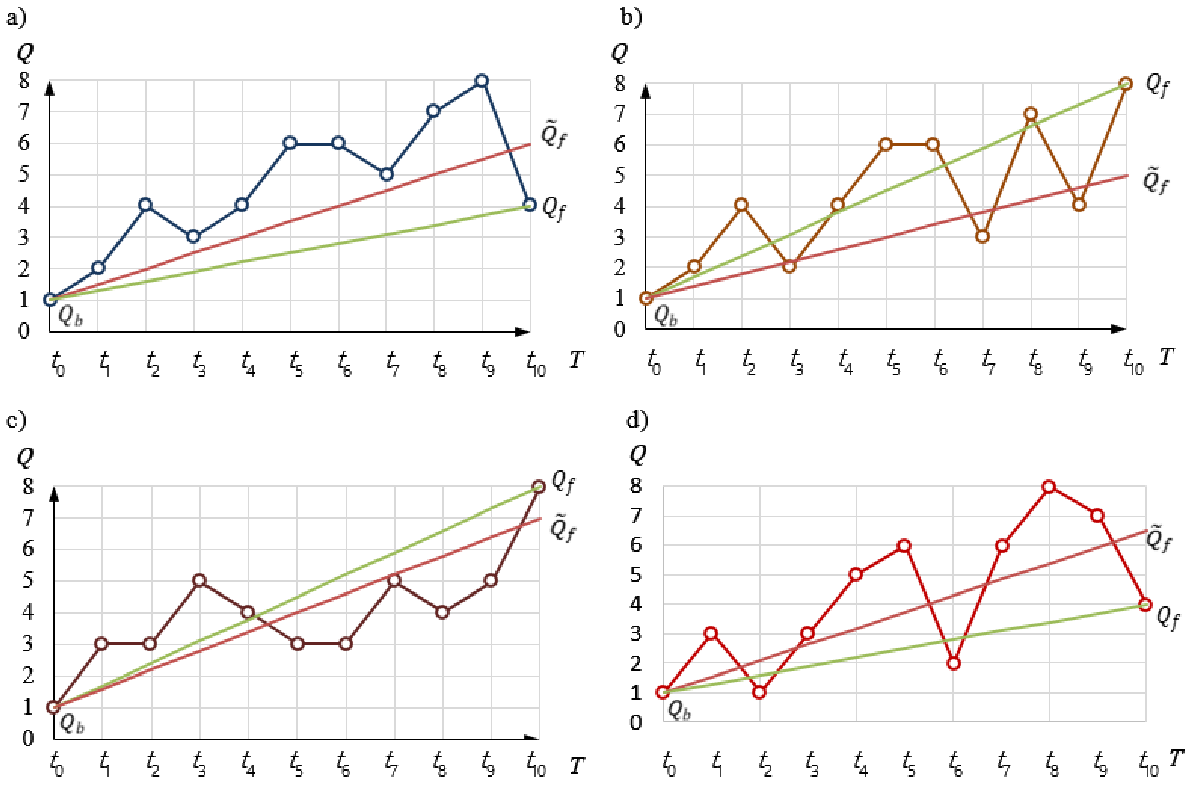

Figure 2. Typical situations of SES development
Source: compiled by the author

Figure 2 illustrates that the valueQ_f does not accurately represent the actual development situation, as it fails to account for changes occurring during theCP. Currently, the development situation is typically evaluated based solely on the significance of development over the past few years.

To adequately reflect the intensity of development, it is essential to derive a comprehensive view of the extent of changes that occurred during the CP. This can be achieved through correlation-regression analysis, which determines the statistical dependence between a dependent variable and an independent variable. In practice, this relationship is expressed as a function $y = f(x)$, where y is the dependent variable and$x$ is the independent variable. For a linear relationship, this dependence is expressed as:

$$y = ax + b, \tag{4}$$

where a and b are unknown parameters of the line.

The parameters a and b are calculated using the least squares method. The empirical function of the variable y is expressed as:

$$\tilde{y} = ax + b.$$

here $\tilde{y}$ is the dependent variable of the empirical function.

In this context, the independent variables represent the sequence of CP time periods, with the first period assigned a value of 1 and the final period assigned a value of m. These variables are mutually independent. The dependent random variables correspond to the expansion values observed at the end of each time period. Accordingly, the regression equation can be expressed as:

$$\tilde{Q}_f = at_j + b + \varepsilon, \tag{5}$$

where $\tilde{Q}_f$ represents the value of Q_f which evaluates the extent of development changes during the CP; t_j CP j-th time period number $j = \overline{1,m}$; ε – random error.

To ensure that the measure ΔQ is informative, it should be expressed as a relative value (coefficient) rather than an absolute value. In this case, it becomes an indicator of the intensity of SES development throughout the CP:

$$K_I = \frac{\tilde{Q}_f - Q_b}{\tilde{Q}_f}, \tag{6}$$

where K_I is the intensity index of SES development during the CP.The evenness of SES sustained development is determined by comparing the actual development changes in individual CP time periods to the scenario in which the development occurs without deviations, meaning the expansion value increases uniformly across each period:

$$\Delta q_j = \frac{Q_f - Q_b}{T-1}, \tag{7}$$

where Δq_j – represents the change in the development of the phenomenon during the j-th period under ideal conditions (without deviations), and T – number of CP years.

From formula (7), it is evident that the first CP period is excluded from the calculations, as development changes are assessed starting from the second period. In the case of ideal SES development, $\Delta q_j = \Delta q_{j+1}$. Using formula (7), the ideal development value at the end of each CP time period can be determined as:

$$\Delta\tilde{p}_j = Q_b + (j-1)\Delta q_j, \tag{8}$$

where $\Delta\tilde{p}_j$ represents the value of the ideal SES development at the end of the j-th time period.

A specific example is provided for illustration (Figure 3).

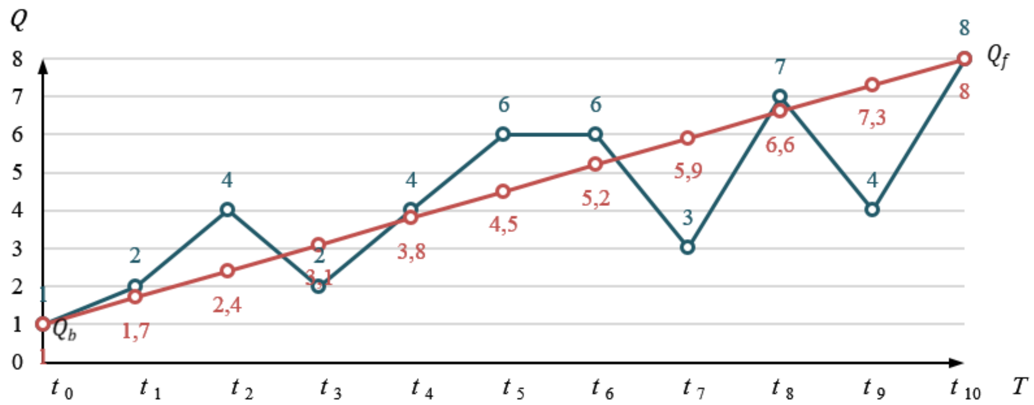

Figure 3. Actual and calculated (ideal) values of SES development across individual periods within the CP
Source: compiled by the author

To determine the evenness of SES development throughout the CP, it is necessary to compare the actual development value with its maximum possible value. The actual value is calculated as follows:

$$P_T^f = \sum_{j=1}^{m} k_j, \tag{9}$$

where P_T^f is the actual change value k_j of SES expansion through CP; – coefficient.

The magnitude k_j represents the deviation of actual development from ideal development at the end of the j – time period. It is determined as the ratio q_j a $\tilde{q}_j$. The calculation method depends on which value is greater::

$$\text{if } q_j > \tilde{q}_j, \text{ then } k_j > \frac{q_j}{\tilde{q}_j}; \tag{10}$$

$$\text{if } q_j < \tilde{q}_j, \text{ then } k_j > \frac{\tilde{q}_j}{q_j}. \tag{11}$$

For the first and last periods of the CP, this ratio will always equal one, as $q_j = \tilde{q}_j$ in these instances. Consequently, these periods may be underestimated. The maximum possible deviation value is obtained when $k_j = 1.0$ for all time periods. In this case:

$$P_T^{\max} = N - 2, \tag{12}$$

where $P_T^{\max}$ is the maximum possible change value of SES development through PC; N is the number of CP periods.

Using formulas (8) and (9), the uniformity indicator of SES development is calculated as follows:

$$K_T = \frac{P_T^{\max}}{P_T^f} = \frac{N-2}{P_T^f}, \tag{13}$$

where K_T represents the indicator of SES development evenness.

To derive the SES sustained development index, the partial indicators—intensity and evenness-must be combined into a single comprehensive measure. This can be achieved through multi-criteria evaluation, as the relative importance of these indicators for sustained development is not identical (Ginevičius et al., 2018). The relative importance of these indicators varies depending on the phenomenon under consideration. Regardless, the following condition is always satisfied: $\sum_{i=1}^{2} \omega_i = 1.0$. The SES sustained development index is then calculated as follows:

$$K_T = R_I \omega_I + R_T \omega_T, \tag{14}$$

where K_T – SES sustained development index; ω_I – indicator of the importance of SES development intensity; ω_T – the same, development uniformity.

SES sustained development assessment indicator system. In approach, the calculations are conducted usinga matrix encompassing all relevant indicators (Table 3).

Table 3. Quantitative Assessment Matrix for SES Sustained Development Based on the Indicator System

Indicators	Periods of the period under review						
	t_1	t_2	t_3	...	*i.e*	...	*i.e*
	indicator values						
1	q_{11}	q_{12}	q_{13}	...	q_{1j}	...	q_{1m}
2	q_{21}	q_{22}	q_{23}	...	q_{2j}	...	q_{2m}
3	q_{31}	q_{32}	q_{33}	...	q_{3j}	...	q_{3m}
⋮	⋮	⋮	⋮	...	⋮	...	⋮
i	q_{i1}	q_{i2}	q_{i3}	...	q_{ij}	...	q_{im}
⋮	⋮	⋮	⋮	...	⋮	...	⋮
n	q_{n1}	q_{n2}	q_{n3}	...	q_{nj}	...	q_{nm}

Source: compiled by the author

The SES development intensity index is calculated as follows:

$$\widetilde{K}_I = \frac{\tilde{\tilde{Q}}_{fi} - \tilde{Q}_{bi}}{\tilde{Q}_{fi}^{T}}, \tag{15}$$

where $\widetilde{K}_I$ – denotes the coefficient of development intensity for the *i*-th indicator; $\tilde{\tilde{Q}}_{fi}$ – represents the value of the *i*-th indicator at the end of the CP, reflecting the changes that occurred during the period, and $\tilde{Q}_{bi}$ – is the value of the *i*-th indicator at the beginning of the CP.

To perform calculations using formula (15), it is necessary to establish the aggregate values of all indicators at both the beginning and end of the CP. These indicators may differ significantly in various aspects: they might be expressed in different dimensions, change in opposite directions (e.g., some increase improves the situation while others worsen it), or carry unequal importance with respect to the CP. In such conflicting situations, multi-criteria methods are well-suited for combining these indicators (Hwang, Yoon, 1981).

However, analysis reveals that these methods are primarily designed for evaluating and ranking options, which involves normalizing multidimensional indicators to transform them into dimensionless, comparable values:

$$\tilde{q}_{ij} = \frac{q_i}{\sum_{j=1}^{m} q_i}, \tag{16}$$

where $\tilde{q}_i$ is the normalized value of the *i*-th indicator ($j = \overline{1, m}$, m represents the number of time periods).

Formula (16) shows that this normalization method is unsuitable for cases where the objective is to assess the development state of specific CP periods (years). In such cases, the normalized value of the *j*-th indicator cannot depend on the values of other indicators, as in formula (14). To address this, the indicators' values are divided by their maximum possible value expressed in the same dimension (Ginevičius, 2008; Golusin, Munitlak, 2009). In this approach, it is crucial to identify such a maximum value while ensuring the condition $q_i^{\max} > q_i$, is met, where $q_i^{\max}$ is the sought maximum value of the *i*-th indicator. Various methods, including expert judgment, literature references, statistical databases, or official documents, can be used to determine this maximum value (Ginevičius, 2008; Podvezko, 2013; Gedvilaitė, 2019). In this study, the maximum value is taken as the highest value of the indicator across all considered options (regions, countries, companies) and CP periods (years) (Table 3).Once the maximum values for all SES development indicators are determined, normalization is performed as follows:

$$\tilde{q}_i = \frac{q_{ij}}{q_i^{\max}}, \tag{17}$$

where $\tilde{q}_i$– the normalized value of the *i*-th indicator; $q_i^{\max}$ – is the maximum value of the *i*-th indicator.

With normalized values, multi-criteria assessments of SES development for the first and last periods (years) of the CP can be conducted using methods such as SAW, TOPSIS (Hwang, Yoon, 1981); ELECTRE (Roy, 1991); PROMETHEE (Brans et al., 1986; Zahedi, 1986); VIKOR (Opricovic, 1998; Cherniak et al., 2024). The SAW method is represented as:

$$Q_{1,i} = \sum_{i=1}^{n} \omega_i \tilde{q}_{1i} (\, i = \overline{1,n}; \, j = \overline{1,m}); \tag{18}$$

$$Q_{mi} = \sum_{i=1}^{n} \omega_i \tilde{q}_{mi}, \tag{19}$$

where Q_{i1} – is the multi-criteria assessment value of the *i*-th indicator for the first CP time period,; Q_{im} – is the corresponding value for the last CP period; $\tilde{q}_{1i}$ – is the transformed value of the *i*-th indicator for the first CP period $\tilde{q}_{mi}$ is the transformed value for the last CP period, and; ω_i– is the weight of the *i*-th indicator ($i = \overline{1,n}$).

Using Q_{i1} and Q_{im}, the development intensity index is calculated as:

$$\widetilde{K}_I = \frac{Q_{im} - Q_{i1}}{Q_{im}}, \tag{20}$$

where $\widetilde{K}_I$ – is the SES development intensity index for the *i*-th indicator over the CP.

The evaluation of SES sustained development evenness is analogous to the single-indicator case. However, based on formulas (8)–(11), the evenness values for each indicator are calculated first, then aggregated:

$$P_T^f = \sum_{i=1}^{n} P_{Ti}, \tag{21}$$

where P_T^f represents sum of SES development evenness values .

The overall SES development evennes $\tilde{P}_T$ is then determined as:

$$K_T = \frac{(N-2)}{P_T^f}. \tag{22}$$

In the second stage, the SES development intensity and uniformity indices are combined using formula (18) to form a single sustained development index.

The third parameter in SES sustained development is the duration of the CP. This issue remains unresolved. If the CP is too short, the evaluation may lack accuracy. Conversely, extending the CP beyond an adequate duration adds no value. This relationship can be represented as shown in (Figure 4).

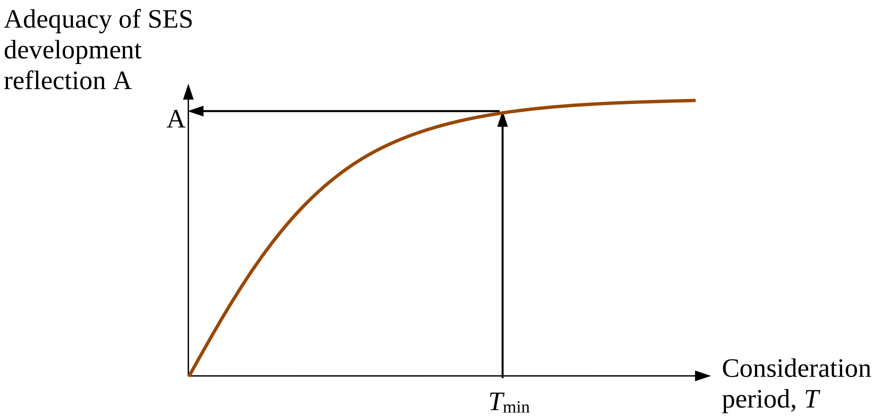

Figure 4. Relationship Between the Adequacy of Quantitative Assessment of SES Sustained Development and the CP (T_{min} – Minimum Considered Period)
Source: compiled by the author

T_{min} in both scientific and practical terms, T_{min} represents the minimum duration required for an adequate assessment. Currently, discussions on SES sustained development are limited to periods chosen subjectively, allowing for flexibility in determining the CP.

3. Empirical study

The verification of SES sustained development has been conducted in two scenarios: one where development is represented by a single indicator and another where it is reflected through a system of indicators. In the first scenario, the focus is on changes in population growth in Czech cities, while in the second, the emphasis is on the economic development of a specific region in Lithuania.

Assessment of Sustained Urban Population Growth in the Czech Republic. This assessment is based on population growth changes observed over a 10-year period (Table 4).

Table 4. Increase in the population of Czech cities 2011–2020, percent (base – 2010)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Meaning	0.11	0.16	0.16	0.23	0.32	0.32	0.41	0.49	0.57	0.44

Source: Eurostat, 2022

Table 4, along with the graphical representation of its data, demonstrates that SES sustained development is characterized by three fundamental parameters: intensity, uniformity, and the duration of the CP (Figure 5).

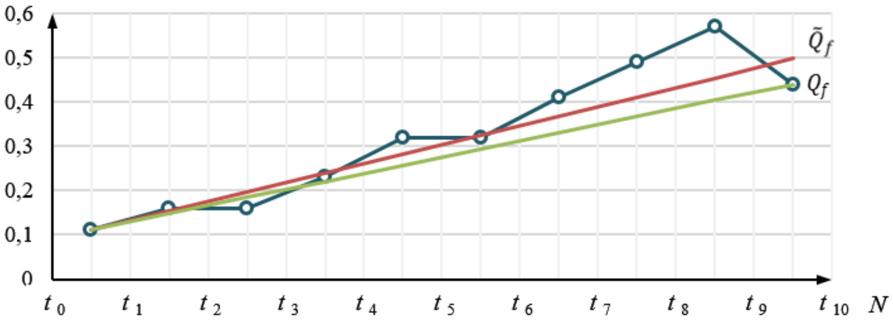

Figure 5. Population growth in Czech cities, percent
Source: compiled by the author based on (Eurostat, 2022)

Figure 5 illustrates that the intensity of development during the CP cannot be accurately assessed solely based on the results of the final year. Using Table 4 and formula (5), the transformed Q_f value $\tilde{Q}_f$ was calculated to be0.543 ($Q_f = 0.44$). Accordingly, the intensity of population growth in Czech cities during the period 2009–2018 is determined as follows:

$$P_I = \frac{0.543-0.11}{0.543} = 0.8.$$

To evaluate the evenness of development, the increase in development for each CP time period was calculated under the assumption of no deviations, as specified by formula (7):

$$\Delta q_j = \frac{0.44-0.11}{9} = 0.037.$$

Using this value and formula (8), the development values for the CP at the end of each period were determined (Table 5).

Table 5. Results of the Sustained Population Growth Calculation in Czech Cities

Indicators	Year										Everything
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
q_j	0.11	0.16	0.16	0.23	0.32	0.32	0.41	0.49	0.57	0.44	–
Δq_j	0.11	0.15	0.18	0.22	0.26	0.30	0.33	0.37	0.41	0.44	–
k_j	1	1.067	1.125	1.045	1.231	1.067	1.242	1.324	1.390	1	9.491

Source: compiled by the author

Using formula (21), the uniformity coefficient value was calculated as follows: K_T:

$$K_T = \frac{8}{9.491} = 0.84.$$

o derive a summary estimate of sustained development, it is essential to determine the relative importance of evenness and intensity for sustained development. Expert evaluations revealed that the importance of development evenness is 0.4, while the importance of intensity is 0.6. With these weights, the sustained development index can now be calculated using formula (14):

$$K_T = 0.84 \cdot 0.4 + 0.80 \cdot 0.6 = 0.72.$$

From the calculated K_T value, it can be concluded that the population growth in Czech cities is sufficiently sustained development.

Calculation of SES Sustained Development Using a System of Indicators In this case, the economic sustained development of a specific region in Lithuania was analyzed for the period preceding the COVID-19 pandemic, specifically from 2009 to 2018 (Table 6).

Table 6. Economic Development of the Lithuanian Region 2009–2018 the values of the indicators

Row No.	Indicators	Unit of measure	Year									
			2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Unemploymen t	percent	6.0	17.0	21.2	14.3	12.8	9.7	8.5	7.6	5.6	4.8
2	Employment	percent	67.7	62.6	61.9	64.7	65.8	68.1	70.2	70.9	74.7	76.3
3	Operating business entities	pcs	28147	29670	29347	30887	30055	32073	34419	38033	40549	410909
4	Material investments per inhabitant.	Eur	3886	4126	2156	1436	2675	2937	3069	3378	2824	3256
5	Avg . gross wages	Eur	710	676	705	678	704	733	768	804	864	891
6	Turnover of one economic entity	thousand Eur	1128.2	895.2	651.1	763.9	831.9	852.5	840.2	803.1	761.6	803.4
7	FDI per inhabitant	thousand Eur	7.2	7.1	7.5	8.6	9.6	10.8	11.2	11.8	12.3	12.4

Source: Lietuvos apskritys, 2023

The annual indicator values do not adequately capture the development changes that occurred during theCP. Therefore, it is necessary to calculate summary measures. Using the regression model (5), the following results were obtained (Table 7).

Table 7. Size $\tilde{Q}_f$calculation results

Indicator no.	1	2	3	4	5	6	7
$\tilde{Q}_f$meaning	4.8	74.5	40492	2878	855	755.4	13.2

Source: compiled by the author

To calculate the development intensity index, it is first necessary to determine the economic development status values for the period 2009–2018. Table 8 illustrates that the economic development indicators are expressed in different dimensions. For normalization, the maximum values of the indicators$q_i^{\max}$ are derived from Table 6 (as shown in Table 8). The normalized values are then calculated using the following formula:

$$\tilde{q}_{i2009} = \frac{q_{2009}}{q^{\max}}, \tag{23}$$

$$\tilde{q}_{i2018} = \frac{\tilde{Q}_{2009}}{q^{\max}}, \tag{24}$$

here $\tilde{q}_{i2009}$ – the normalized value of the *i*-th indicator in 2009; $\tilde{q}_{i2018}$ – same, 2018.

The results of calculations based on formula (17) are given in Table 8.

Based on expert evaluations, the weights assigned to the economic development indicators for the region under consideration were determined (Table 8). The economic development status for the first and last years of the reviewed period was calculated using the SAW multi-criteria evaluation model (18)–(19) (Hwang, Yoon, 1981):

$$K_i = \sum_{i=1}^{n} \omega_i \tilde{q}_i, \tag{25}$$

where K_i represents the significance of the multi-criteria assessment of the economic development status of the *i*-th region, calculated using the SAW method.

Table 8. Economic Development of Lithuanian Regions 2009–2018 maximum and normalized values of indicators

Indicators	Unemployment, percent	Employment, percent	Operating economic entities, units	Material investments per inhabitant. Eur	Avg . gross salary, EUR	Turnover of one economic entity, a thousand Eur	FDI per inhabitant
Size $q_i^{\max}$values	21.2	76.3	410909	4126	891	1128.2	12.4
Normalized values,$\tilde{q}_{i(2009)}$	0.28	0.89	0.68	0.94	0.80	1.00 a.m	0.58
Normalized values,$\tilde{q}_{i(2018)}$	0.23	1.00 a.m	1.00 a.m	0.79	1.00 a.m	0.71	1.00 a.m
Indicator weightsω_i	0.15	0.10	0.15	0.10	0.15	0.25	0.10

Source: Lithuanian counties

Using formulas (18)–(19), the K value was determined to be 0.76 for 2009 and 0.79 for 2018. The regional economic development intensity index was then calculated using formula (14):

$$K_I = \frac{0.79-0.76}{0.79} = 0.04.$$

From the K_I value, it can be concluded that the economic development of the region during the 2009–2018 period was low.The uniformity of the region's economic development indicators was evaluated using formulas (9)–(11), resulting inK_T= 0.77.

Using formula (13), the sustained development index for the economic development of the region under consideration was calculated. Experts assigned a weight of 0.7 to development intensity and 0.3 to uniformity. The resulting value of the sustained development index is 0.37. This indicates that the region's economic development is relatively consistent but lacks intensity, and as a result, does not exhibit a high level of sustained development.

This indicates that while the economic development of the region exhibits relatively consistent growth, it lacks intensity. Consequently, the region does not demonstrate a high level of sustained economic development.

Conclusions

A fundamental prerequisite for SES sustained development is the continuity of development, characterized by consistency, stability, and resilience to adverse conditions. As a process, sustained development is represented by two key parameters: intensity and uniformity.

To accurately assess development intensity, it is essential to account for changes occurring in individual periods within the considered timeframe. The correlation-regression analysis model facilitates this by treating the value of SES development at the end of the CP as the dependent variable and the number of periods within the timeframe as the independent variable.

SES development is defined as the ratio of actual development changes during specific periods to ideal development, i.e., development without any deviations.

The generalized SES sustained development index is derived by combining the intensity and uniformity indicators into a single value. Since the relative importance of these indicators for sustained development is unequal, their weights are evaluated. The index is calculated using the multi-criteria evaluation SAW model.

The proposed methodology has been validated through two real-world examples: one involving a single indicator representing SES development and another using a system of indicators. The calculations confirmed the methodology's reliability and applicability.

Further research on the quantitative assessment of SES sustained development should focus on determining the minimum duration of the CP. This would strike a balance between minimizing computational effort and ensuring the adequacy of the results obtained.

References

Babu, S., & Datta, S. (2015). Revisiting the link between socio-economic development and environmental status indicators focuses on panel data. *Environment Development and Sustainability, 17*(3), 567–586. 10.1007/s10668-014-9561-6

Bana e Costa, C.A., Carnero, M.C., Oliveira, M.D. (2012). A multi-criteria model for auditing a Predictive Maintenance Programme. *European Journal of Operational Research, 217*(2), 381-393. https://doi.org/10.1016/j.ejor.2011.09.019

Bartelmus, P. (2003). Dematerialization and capital maintenance: two sides of the sustainability coin. *Ecological Economics, 46*(1), 61-81. https://doi.org/10.1016/S0921-8009(03)00078-8

Baumgartner, R.J., Korhonen, J. (2010). Strategic Thinking for Sustainable Development. *Sustainable Development, 18*(2), 71-75. 10.1002/sd.452

Birjandi, A.K., Akhyanu, F., Sheikh, R., Sana, S.S. (2019). Evaluation and selecting the contractoe in bidding with incomplete information using MCGDM method. *Soft Computering*, 10569-10585. https://doi.org/10.1007/s00500-019-04050-y

Boggia, A., & Cortina, C. (2010). Measuring sustainable development using a multi-criteria model: A case study. *Journal of Environmental Management , 91*(11), 2301-2306.

Bolcarova, P., & Kološta, S. (2015). Assessment of sustainable development in the EU27 using aggregated SD index. *Ecological Indicators, 48*, 699–705. https://doi.org/10.1016/j.ecolind.2014.09.001

Brans, J. P., Vincke, Ph., & Mareschal, B. (1986). How to select and how to rank projects: The Promethee method. *European Journal of Operational Research, 24*(2), 228–238. https://doi.org/10.1016/0377-2217(86)90044-5

Chen, Z.S., Zhang, X., Pedrycz, W., Wang, X.J., Skibniewski, M.J. (2020). Bild evaluation in civil construction under uncertainty: A two-stafe LSP-ELECTRE III-based approach. *Engineering Applications of Artificial Intelligence, 94,* 103835. https://doi.org/10.1016/j.engappai.2020.103835

Chen, Z.S., Zhang, X., Rodríguez, R.M., Pedrycz, W., Martínez, L. (2021). Expertise-based bid evaluation for construction-contractor selection with generalized comparative linguistic ELECTRE III. *Automation in Construction, 125,* 103578. https://doi.org/10.1016/j.autcon.2021.103578

Cherniak, O., Trishch, R., Ginevičius, R., Nechuiviter, O., Burdeina, V. (2024). Methodology for Assessing the Processes of the Occupational Safety Management System Using Functional Dependencies. 996 LNNS. *Lecture Notes in Networks and Systems*, 3-13. https://doi.org/10.1007/978-3-031-60549-9_1

Čiegis, R., Dilius, A., Mikalauskienė, A. (2011). Darnaus vystymosi sričių dinamikos vertinimas Lietuvoje. *Regional Formation and Development Studies, 1* (11), 45-59.

Dankiewicz, R., Balawejder, B., Chudy-Laskowska K., & Britchenko I. (2022). Impact factors and structural analysis of the state's financial security. *Journal of International Studies, 15*(4), 80-92. https://doi.org/10.14254/2071-8330.2022/15-4/5

Dong, Q., & Bilan, Y. (2024). Effect of Free Trade Area Policy on Innovation Capability in the Service Industry. *Amfiteatru Economic*, 26(66), 589-589.

European Central Bank. (2012). *Financial Stability Review*. London: European Central Bank.

European Environment Agency. (2019). *The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe*.

Eurostat. (2021). At-risk-of-poverty thresholds - EU-SILC and ECHP surveys: https://ec.europa.eu/eurostat/databrowser/view/ILC_LI04/default/table?lang=en

Gedvilaitė, D. (2019). *The assessment of sustainable development of a country's regions. Doctoral dissertation [Šalies regionų darnios plėtros vertinimas. daktaro disertacija].* Vilnius: Technika. https://etalpykla.vilniustech.lt/handle/123456789/59423

Ginevičius, R., Gedvilaitė, D., Stasiukynas, A., & Šliogerienė, J. (2018). Quantitative Assessment of the Dynamics of the Economic Development of Socioeconomic Systems Based on the MDD Method. *Inzinerine Ekonomika-Engineering Economics, 29*(3), 264–271. https://doi.org/10.5755/j01.ee.29.3.20444

Ginevičius, R., Trishch, R, Bilan, Y., Lis, M., & Pencik, J. (2022). Assessment of the Economic Efficiency of Energy Development in the Industrial Sector of the European Union Area Countries. *Energies, 15*(9), 3322. https://www.mdpi.com/1996-1073/15/9/3322

Ginevičius, R., Trishch, R, Remeikienė, R., & Gasparėnienė, L. (2021). Complex evaluation of the negative variations in the development of Lithuanian municipalities. *Transformations in Business &Economics, 20*(2A(53A)), 635-653.

Ginevičius, R., Visokavičienė, B.T., Bilan, Y., & Lisiński, M. (2024). Quantitative assessment of the financial hardship in the euro area countries. *PLoS ONE: Public Library of Science (PLoS), 19*(4), 1-15. 10.1371/journal.pone.0294886.s001

Golusin, M., & Munitlak, I.O. (2009). Definition, characteristics and state of the indicators of sustainable development in countries of Southeastern Europe. *Agriculture, Ecosystems & Environment, 130*(1-2), 67–74. https://doi.org/10.1016/j.rser.2010.07.064

Hwang, C. L., & Yoon, K. (1981). *Multiple Attribute Decision Making. Methods and Application a State-of-the-Art Survey. Lecture Notes in Economics and Mathematical Systems 186.* Berlin, Heidelberg: Springer.

Jędrzejczak-Gas, J., & Barska, A. (2019). Assessment of the Economic Development of Polish Regions in the Context of the Implementation of the Concept of Sustainable Development - Taxonomic Analysis. *European Journal of Sustainable Development, 8*(5), 222–233. https://doi.org/10.14207/ejsd.2019.v8n5p222

Kakes, J., & Ullersma, C. (2003). Financial stability in low-inflation environments. *BIS Papers chapters, in: Bank for International Settlements (ed.), Monetary policy in a changing environment, 19*, 355-367.

Khoso, A.R.,Yusof, A.M, Khahro, S.H., Abidin, N.I.A.B., & Memon, N.A. (2021). Automated two-stage continuous decision support model using exploratory factor anaysis-MACBETH-SMART: an application of contractor selection in public sector construction. *Journal of Ambient Intelligence and Humanized Computing*. https://doi.org/10.1007/s12652-021-03186-w

Kozyreva, O., Sagaidak-Nikituk, R., & Demchenko, N. (2017). Analysis of the socio-economic development of Ukrainian regions. *Baltic Journal of Economic Studies, 3*(2), 51–58. https://doi.org/10.30525/2256-0742/2017-3-2-51-58

Laeven, L., & Valencia, F. (2010). Resolution of banking crises: The good, the bad, and the ugly. *IMFWorking Paper, 146*, 1-35.

Lietuvos apskritys. (2023 m. April 3 d.). Vikipedija Laisvoji enciklopedija: https://lt.wikipedia.org/wiki/Lietuvos_apskritys

Lisiński, M., Augustinaitis, A., Nazarko, L., Ratajczak, S. (2020). Evaluation of dynamics of economic development in Polish and Lithuanian regions. *Journal of Business Economics and Management, 21*(4), 1093-1110. https://doi.org/10.3846/jbem.2020.12671

Main GDP aggregates per capita. (2022). Nuskaityta iš Eurostat.

Mammela, J., Juuti, T., & Julkunen, P. (2019). Technology Valuation Method for Supporting Knowledge Management in Technology Decisions to Gain Sustainability. *Sustainability, 11*, 3410. https://doi.org/10.3390/su11123410

Marović, I., Perić, M., Hanak, T. (2021). A multi-criteria decissionsupport concept for selecting the optimal contractor. *Applied Sciences, 11*(4), 1660. https://doi.org/10.3390/app11041660

Mines, C. (2010). *Will it firms drive the sustainable wave of corporate evolution?* https://trellis.net/article/will-it-firms-drive-sustainable-wave-corporate-evolution

Mishchuk, H., Czarkowski, J. J., Neverkovets, A., & Lukács, E. (2023). Ensuring Sustainable Development in Light of Pandemic "New Normal" Influence. *Sustainability, 15*(18), 13979. https://doi.org/10.3390/su151813979

Moldan, B., Janoušková, S., Hák, T. (2012). How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators, 17*, 4–13. https://doi.org/10.1016/j.ecolind.2011.04.033

Molendowski, E., Petraškevičius, V. (2020). International competitive positions of the Baltic States – changes and determinants in the post-accession period. *Journal of Business Economics and Management, 21*(3), 706-724. https://doi.org/10.3846/jbem.2020.11983

Morse, S. (2008). Post-sustainable development. *Sustainable Development, 16*(5), 341-352.

Niu, Z., Zhang, Y., Li, T., Baležentis, T., Štreimikienė, D., Shen, Z. (2021). Total factor productivity growth in China's corn farming: an application of generalized productivity indicator. *Journal of Business Economics and Management, 22*(5), 1189-1208. https://doi.org/10.3846/jbem.2021.15105

Opricovic, S. (1998). *Multicriteria Optimization of Civil Engineering Systems.* Belgrade, Serbia: Faculty of Civil Engineering.

Oželienė, D. (2019). *Modelling the factors of a company's sustainable development. Doctoral dissertation.* Vilnius: Technika.

Păcurari, D. (2012). Models for Assessing the Profitability and Sustainable Growth of the Enterprise. *Economy Transdisciplinarity Cognition, 15*(1), 112-118.

Pânzaru, S., Dragomir, C. (2012). The Considerations of the Sustainable Development and Eco-Development in National and Zonal Context. *Revista de management comparat international/Review of international comparative management, 13*(5), 823-831.

Podviezko, A. (2013). *Evaluation of financial stability of commercial banks. Doctoral dissertation.* Vilnius: Technika.

Qin, M., Su, C.-W., Xiao, Y.-D., Zhang, S. (2020). Should gold be held under global economic policy uncertainty? *Journal of Business Economics and Management, 21*(3), 725–742. https://doi.org/10.3846/jbem.2020.12040

Radovanović, M., & Lior, N. (2017). Sustainable economic–environmental planning in Southeast Europe – beyond-GDP and climate change emphases. *Sustainable Development, 25*(6), 580–594. https://doi.org/10.1002/sd.1679

Roy, B. (1991). The outranking approach and the foundations of ELECTRE methods. *Theory and Decision, 31*, 49–73. https://doi.org/10.1007/BF00134132

Streimikiene, D., Mikalauskiene, A., & Burbaite, G. (2023). The role of sustainable finance in achieving sustainable development goals. *Economics and Sociology, 16*(1), 271-298. https://doi.org/10.14254/2071-789X.2023/16-1/17

Sutthichaimethee, P., Mentel, G., Voloshyn, V., Mishchuk, H., & Bilan, Y. (2024). Modeling the Efficiency of Resource Consumption Management in Construction Under Sustainability Policy: Enriching the DSEM-ARIMA Model. *Sustainability*, 16 (24), 10945. https://doi.org/10.3390/su162410945

Švažas, M., Navickas, V., Paškevičius, R., Bilan, Y., & Vasa, L. (2023). Renewable energy versus energy security: The impact of in-novation on the economy. R*ynek energii*, (1 (164)), 60-71.

Sytnik, I., Stopochkin, A., Wielki, J., Edaich, S., & Sytnik, B. (2023). Prerequisites and scenarios for the EU economy transformation inlight of Industry 4.0 development. *Journal of International Studies, 16*(2), 85-101. https://doi.org/10.14254/20718330.2023/16-2/5

Termosa I. (2017). The ways of forming the sustainable development of rural areas of Ukraine. *Economics, Management and Sustainability, 2*(1), 76–82. https://doi.org/10.14254/10.14254/jems.2017.2-1.7

Trishch, R.M., Sichinava, A., Bartoš, V., Stasiukynas, A., Schieg, M. (2023). Comparative assessment of economic development in the countries of the European Union. *Journal of Business Economics and Management, 24*(1), 20-36. https://doi.org/10.3846/jbem.2023.18320

Tjahjanto, H., Tuhana, T., Mafruhah, I., Istiqomah, N., & Ismoyowati, D. (2023). High unemployment, disrupted economic growth and sustainable development goals: Analyzing unemployment reduction. *Economics and Sociology, 16*(1), 106-120. https://doi.org/10.14254/2071-789X.2023/16-1/7

Volkov, A. (2018). *Assessment of the impact of the common agricultural policy direct payments system on agricultural sustainability. Doctoral dissertation.* Vilnius: Technika. https://vb.lcss.lt/object/elaba:30829704/index.html

Zahedi, F. (1986). The Analytic Hierarchy Process: A Survey of the Method and Its Applications Interfaces. *INFORMS, 16*(4), 96–108. https://www.jstor.org/stable/25060854