IMPACT OF ECONOMIC DEVELOPMENT ON THE ECOLOGY IN THE REGIONS OF LITHUANIA

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Introduction

Today, when we talk about development, irrespective of the level of the analysed subject – a state, a sphere of economic activity, a region or a company – first of all we think about sustainable development. The following concept of sustainable development has been formed in the global environmental and in economic development forums, and has become the classic definition: it is development that meets the current needs of a society without compromising the ability of future generations to meet their own needs. This concept is based on three components – environmental, economic and social development.

The definition of sustainable development allows for the conclusion that it is a compromise between the environmental, economic and social objectives of a society. It involves a process of transformations when economic advancement is coordinated with environmental, social and cultural changes. On the other hand, it must always be stressed that the main basis for both social and environmental development is economic development. However, the economic objectives should not be maximized without observing the environmental and social limitations. Such limitations shape a reverse effect on the economic development. The social and ecological developments have a similar interrelationship.

Sustainable development (SD) is especially relevant when we talk about regional politics, the objective of which is to reduce the differences in economic development between individual states or regions within a country. Where regional politics are ineffective, social tensions grow and this is expressed through the amount of emigration, criminality, higher death-rates, lower birth rates, etc. Besides this, the ecology of the region suffers: water and air pollution increases, and the natural resources are used inefficiently. Therefore, sustainable development in a region can be seen as a critical condition for effective regional policies.

In order to better understand the phenomenon of sustainable development and to manage it purposefully, two tasks need to be performed: first, a quantitative assessment of the state of the components for sustainable development at a certain time; and second, their interrelationship needs to be determined. In the general process of development, the main role is played by economic development; therefore, it is important to determine its impact on the other two components of sustainable development and especially on the environment.

Economic and social, as well as environmental development, is a complex phenomenon that is expressed by many aspects. The criteria reflecting the development are expressed by different dimensions, besides which their directions of impact can be different, i.e. some of them may be maximizing (the situation improves when the value of the indicator increases), while the others are minimizing (the situation is deteriorating when the value of the indicator increases). Given this contradictory situation, multicriteria methods are best suited for the quantitative assessment of the state of a complex phenomenon, and in recent years these methods have been applied more widely for solving various tasks due to their universality (Ginevičius et al., 2011; Ginevičius & Podvezko, 2012; Mardani et al., 2015; Mardani et al., 2016; Zolfani et al., 2015).

This article attempts to analyze how to calculate the indexes of economic and ecological development based on multicriteria methods in a manner that will allow for an analysis of their interrelationships.

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1. Formation of the Index of Ecological Development in Regions

We will attempt to assess ecological development in two ways: through ecological development indexes; and through indicators directly reflecting such development. Bearing in mind the objective of our research, the existing ecological development indexes are not suitable. They have been formed in the context of sustainable development; thus, besides the indicators that immediately reflect the state of the environment, they include, for example, indicators of the efficiency of environmental policies, indicators forecasting of the state of the environment, economy and social impact, and many other indicators of various natures. These indexes are also very complex, covering hundreds of aspects affecting the environment at a large or smaller rate (Čiegis et al., 2010).

We are more interested in suggestions of how to form an index that exclusively reflects the ecological development in a region. Many (very different) approaches can be found, which also differ in the number of indicators suggested for inclusion into the system. Some suggestions for the assessment of ecological development are presented below.

All of the approaches can be divided into two groups. Those that suggest forming index models from a different number of indicators and indicators with different content are attributed to the first group. Meanwhile, the second group covers those suggestions which, besides suggesting a list of indicators, indicate the manner of integrating the indicators into the index. The number of indicators listed by the sources included in the first group varies from several to a dozen.

Kondyli (2010) provides the following indicators for the assessment of ecological development: quantity of the available water resources per resident; percentage of samples that are compatible with the established quality standards; number of species per km^2; and a pressure-based assessment index.

Boggia and Cortina (2010) distinguish eight indicators of ecological development: CO_2 emissions; artificial surface areas (urbanized areas of a municipality in relation to the total area); fragmentation index (level of fragmentation in a territory due to infrastructures and urbanization; electric power use (consumption rate of electricity for domestic use per consumer); waste separation (percentage of differentiated waste collection); drinking water use (amount of water used per capita per municipality); certified firms (the ratio between the number of companies with an environmental certification (ISO 14001 and EMAS) and the other companies); and certified public institutions.

Golusin et al. (2011) suggest the following indicators for the assessment of ecological development: fertile ground (%); ploughed ground (%); irrigation (km^2); usage of fertilizers (kg/ha/yr); organic agriculture (% of the ploughed ground); usage of pesticides (kg/ha/yr); emissions of methane (1,000 metric tons); emissions of carbon dioxide (metric tons); forestation (km^2); and usage of energy equiv.

Babu and Datta (2015) present seven indicators for ecological development: greenhouse gas emissions; consumption of ozone depleting substances; number of globally threatened species; deforestation rate; rural population density; and population with access to improved water sources.

Wallis et al. (2011) distinguish the following indicators for ecological development: dryland pastures, dryland salinity, remnant vegetation, wind erosion, pine plantations, soil structure decline and water erosion.

The research attributed to the second group suggests that the index of ecological development in a region should be expressed using three indicators: forested areas in relation to the area of the region (as a percentage); amount of emitted pollutants (in tons); and amount of polluted and insufficiently treated waste water (thou. m^3) (Čiegis et al., 2010).

Thus, the suggested ecological development systems differ not only in their number of indicators, but also in their composition. A common feature is that all of them – some to a higher degree, others to a lesser degree – reflect non-renewable resources that include water, air and land. In other words, each system includes the factors that have a long-term impact on the environment. This approach is methodically correct, as it echoes the classic concept of sustainable development – meeting the current needs of a society without compromising the ability of future generations to meet their own needs. Therefore, the principal system of ecological development should cover at least several critical indicators reflecting the above resources (Fig. 1).

Fig. 1: Essential composition of the ecological development index

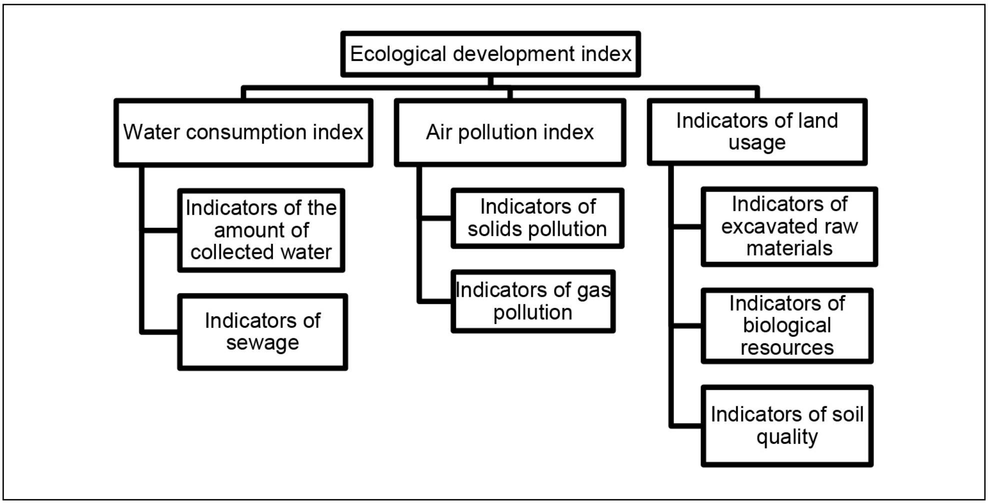

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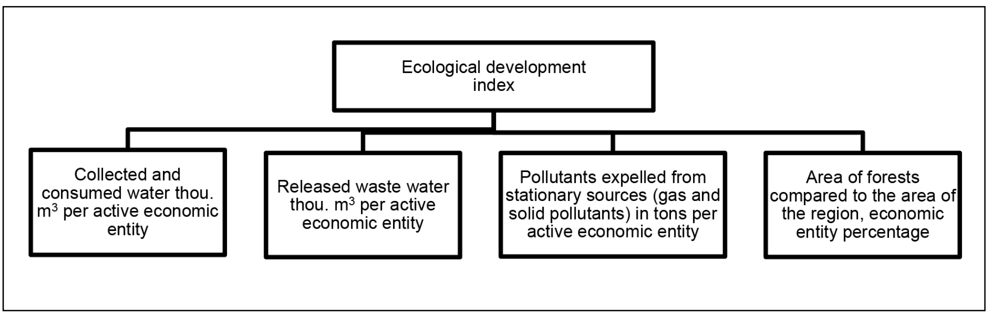
Fig. 2: Composition of the indicators for the index of ecological development in a region



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Bearing in mind that the objective of the research is to assess the impact of economic development in a region on the ecology, water consumption may be reflected by at least two indicators that also show the size of the region – amount of collected and consumed water per one economic entity (thou. m^3). The air pollution may also be described by two indicators – the amount of gas and solid pollutants emitted from stationary sources of pollution per one economic entity (in tons). The state of the land in a region may be described using three indicators: amount of excavated raw materials, and quality of the biological resources and soil. Statistics Lithuania provides information according to all of the listed indicators except for the raw materials and soil (these indicators are not typical to Lithuania because of the near absence of minerals, and the soil is rather ecological). Of course, all of the basic indicators may be elaborated, if necessary. On the other hand, an analysis of the sources of literature shows that the possibilities and scope of the research is often limited by the availability of reliable data.

Thus, our further research will be based on a system of four indicators (Fig. 2).

As you can see in Fig. 2, the first three indicators are minimizing, i.e. the situation deteriorates when their value increases; and the fourth one is maximizing – the situation improves when its value grows.

2. Formation of the Index of Economic Development in a Region

Similarly to the case for ecological development, the economic development is also assessed in two ways: by using indexes and by using the criteria of economic sustainability that directly reflects such development. Just like in the first instance, and bearing in mind the objectives of this research, the available indexes for economic sustainability are not suitable. They are global, and generally reflect not only economic development itself, but also other aspects of development such as: sustainable economic welfare; progress covering social, economic and ecological realities, etc. (Čiegis et al., 2010).

The research will therefore be based on the existing suggestions for the formation of an index exclusively examining the economic development in a region. An analysis of the sources of literature shows that the available systems differ greatly both terms of the number and the composition of the indicators.

Also, as in the case of ecological development, all of the approaches can be divided into two groups: those composed of the formation of indexes from a different number of indicators and the formation of indicators and indexes with different content; and those where the list of suggested indicators is complemented by the manner of integrating those indicators into one aggregate value.

The number of different indicators suggested by the sources included in the first group varies from several to a dozen.

Kondyli (2010) suggests the following indicators for the assessment of economic development: percentage of employed in the active population; percentage of employed in the competitive economic sub-sectors; and specialization coefficient of the economic sub-sectors.

Boggia and Cortina (2010) distinguish nine indicators for socio-economic development: population density; overall unemployment rate; women's unemployment rate; work-related accidents; index of higher education; index of tourist attractions; index of demographic dependence; number of active businesses and available income.

Wallis et al. (2011) suggest the following indicators for the assessment of economic development: medium household income; unemployment rate; and employment diversity.

Babu and Datta (2015) describe economic development using three indicators (GDP per capita, economic growth rate per capita, and economic structure). Finally, Golusin et al. (2011) present the following indicators for economic development: GDP; debt (% of the GDP); road infrastructure (1,000 km); inflation (%); Gini coefficient index; growth of the GDP (%); investments as part of the GDP (%); industrial growth (%); external debts (bln $); and exports (bln $).

The review of the above suggestions shows that a methodical basis is lacking for the formation of the economic development index. The list of indicators covers indicators that reflect the social development in a region (indicators of university education, demography, household income, etc.), as well as the general economic development in a region, unemployment rate in both the economic and the social sector, etc. It is therefore difficult to determine the impact of the economic development in a region on its ecological situation on the basis of such indexes. The index of economic development should cover only the indicators that reflect such development directly, in various aspects.

One research study attributed to the second group of sources (Čiegis et al., 2010) suggests describing the economic development of regions using three indicators, and then integrating them into one aggregate value by adding up the values of these indicators. The indicators are as follows: gross domestic product (GDP) per one resident in the region; foreign direct investment (FDI) per one resident in the region; as well as the rate of unemployment in the region, as a percentage.

The authors maintain that the GDP per capita reflects the general level of economic development and is a reliable indicator of economic success. The FDI indicator is included because it creates the conditions for faster technological progress and is thereby a source for increased economic potential. The rate of unemployment reflects the possibilities of economic development that creates new jobs.

Nonetheless, some doubts remain: first of all, whether the economic development indexes for the regions formed in this manner adequately reflect the current situation; and secondly, whether the number of indicators included in the index is sufficient. A correlation analysis of the interrelationship of the GDP with the FDI and the rate of unemployment shows that the GDP integrates in itself both the results of technological development and the rate of unemployment, i.e. both the FDI and the rate of unemployment in the region are partial indicators of the GDP. Thus, if we take this road, the economic development in a region should be reflected by the gross domestic product alone.

On the other hand, the determination of the GDP and its change is based on the annual results of businesses in the region. Therefore, besides those activities directly associated with economic development (industry, construction, agriculture and transport, etc.), the GDP is influenced by certain aspects of social development (trade, organization of working hours, etc.). As a result, taking the GDP exclusively as the indicator to summarize economic development would give us a distorted image.

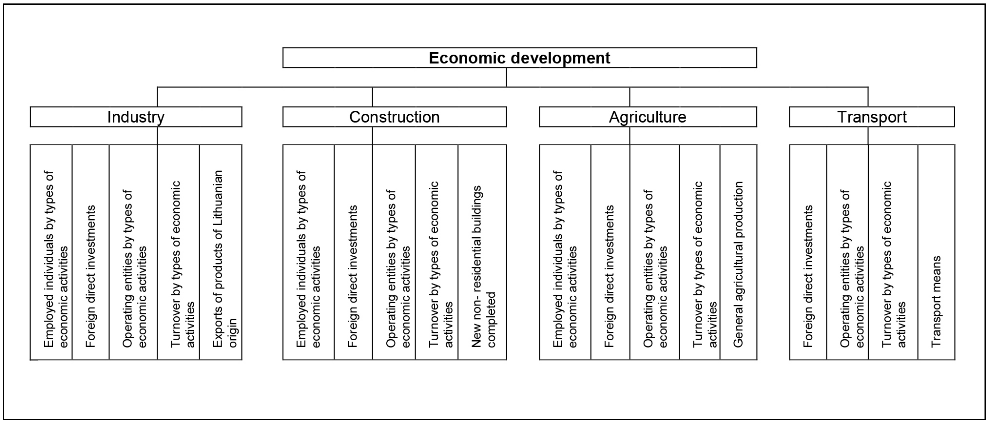
Additionally, the number of employed people in the region covers all of the people employed in administration, the social insurance sector, education, health care institutions, etc. These are not exclusively economic activities as they do not create a material product; thus, the general rate of unemployment cannot fully reflect this aspect of economic development.

The main conclusion that can be drawn from this research is that the indexes should be formed from indicators at the same level, i.e. we cannot integrate the indicators for summarizing and directly reflecting the analysed phenomenon into one whole. The system of indicators should also be more detailed, as this will allow us to: cover all of the essential aspects of economic development in a region; obtain 'pure' indicators that directly reflect a certain aspect of development; and assess the actual situation more accurately thanks to detailed indicator weights.

In reality, the economic development in a region is a complex process that is expressed by many aspects. In turn, every one of these aspects can be described by a certain number of indicators. We can distinguish the following characteristic components of economic development in a region: industry, construction, agriculture and transport, i.e. the spheres of activity which create a material product or that provide services for such products. Based on this, the index should not include activities that use the products created by economic activities or that create conditions for their use, for example, foreign and domestic trade, investments, etc.

Based on such reasoning, the following structure of the economic development index for a region was formed (Fig. 3) (Ginevičius et al. 2015).

Fig. 3: System of indicators of the economic development in the regions of a country



Source: Ginevičius et al., 2015

As can be seen from Fig. 3, all of the economic development indicators are maximizing, i.e. the situation improves when their value increases.

3. Aggregation of the Ecological and Economic Development in a Region into Indexes

Based on suggestions from the sources of literature, all of the development indexes can be divided into two groups: non-integrated and integrated assessments (Čiegis et al., 2010). The majority of the indexes from the first group are intended for the assessing sustainability of development at the national level (Hamilton, 2001; Lange, 2003; Ness et al., 2007; Roshen & Dincer, 2007; Bolcárová & Kološta, 2015; Chansarn, 2013; Jia et al., 2007; Zinatizadeh et al., 2017; Radovanović & Lior, 2017). Nearly all of them are intended for the assessment of the impact of manufactured products or provided services on the environment. Such indexes include the already mentioned indexes for sustainable economic welfare, corrected net savings, true human development, progress, life cycle assessments, calculation of the living expenses, flow of the product materials, analysis of the product energy, etc.

The integrated assessment methods include conceptual modelling, environmental impact assessments, strategic environmental, sustainability impact, monetary and multicriteria assessment methods. A review of these methods allows us to reach several conclusions. First of all, the majority of the suggested indexes are intended for the analysis of various aspects of sustainable development at the national level; while for the analysis of the conditions for development in a country, it is important to have the possibility to also assess these processes at the regional level. Secondly, attempts have been made to integrate all three components of sustainable development (economic, social and environmental) into one assessment system. Third, although we have observes a shift in the sustainable development methods towards integrated approaches, these are not yet generally applied.

4. Application of Multicriteria Methods in the Formation of Regional Development Indexes

Lately, multicriteria methods have been applied more and more often (as universal methods) for the assessment of complex phenomena (Ginevičius et al., 2011; Ginevičius & Podvezko, 2012). These methods allow the people making decisions to take into account the relative importance of the criteria. They can also be a basis for the assessment of both individual components in sustainable development and the regional sustainable development as a whole.

The nature of the application of multicriteria methods and the method of calculation depends on the objectives of the assessment. The main two objectives are the determination of the priority ranking of the variants in the analysed phenomenon, according to the criterion of the choice and the quantitative assessment of the state of an individual phenomenon at the desired point in time. In the first case, multicriteria methods can help solve the problems that arise due to the people making decisions having different priorities, i.e. when some people stress one criterion and others emphasize another criterion. In this situation, such methods allow for a rational decision to be made in a situation with contradictory criteria (Belton & Stewart, 2002).

Furthermore, the determination of the state of an individual phenomenon at a certain point in time creates possibilities for the correlation-regression analysis of the interrelation of the components involved in the sustainable development of regions.

Multicriteria methods can be grouped into two categories, where the approaches differ in the method of establishing the preferences and the aggregation of information about the criteria (Čiegis et al., 2010). The first group can be relatively called the methods of compensated value. They are based on the assumption of compensation, i.e. that the advantages of one criterion can be counterweighed by the drawbacks of another criterion. In other words, it is considered that the maximizing criteria may counter the minimizing ones. The other group of methods can be relatively called the methods of non-compensated value. They are based on the concept of a non-compensated value and negate the possibility of compensation between the indicators.

Ecological and economic development in regions is described by many indicators of various dimensions, besides which some of them are maximizing and others are minimizing. Irrespective of the objective of the assessment

– be it a priority ranking of the variants or an assessment of the state – all of these contradictory indicators need to be integrated into one summarizing value. Such tasks can very well be solved by applying multicriteria methods (Ginevičius et al., 2011; Ginevičius & Podvezko, 2012).

Before proceeding to the immediate assessment of ecological and economic development in a region, we need to substantiate which model of multicriteria assessment we will take as our basis – a compensated or a non-compensated value method.

The mathematical expression of the multicriteria compensated value theory method, which can be relatively called the MDE (Multicriteria Different Evaluation) method, is as follows (Golusin et al., 2011):

$$K_l^{KV} = \sum_{i=1}^{m} w_{li}^{+} \tilde{q}_{li}^{+} - \sum_{i=1}^{n} w_{lj}^{-} \tilde{q}_{lj}^{-}, \qquad (1)$$

where K_l^{KV} – value of the analyzed phenomenon l (variant of phenomenon) applying a multicriteria compensated value assessment; w_i^{+} – weight of the indicator i improving the situation of the analyzed phenomenon l (variant of phenomenon);

$(i = \overline{1,m})$; w_j^{-} – weight of the indicator j showing a deterioration of the situation of the analyzed phenomenon l (variant of phenomenon);

$(j = \overline{1,m})$; $\tilde{q}_i^{+}$ – normalized value of the indicator i showing an improvement of the situation of the analyzed phenomenon l (variant of phenomenon); and $\tilde{q}_j^{-}$ – normalized value of the indicator j showing a deterioration of the situation of the analyzed phenomenon l (variant of phenomenon).

On the condition that $\sum_{i=1}^{n} w_i^{+} + \sum_{i=1}^{m} w_j^{-} = 1.0$.

The mathematical expression of the multicriteria non-compensated value method is as follows:

$$K_l^{NV} = \sum_{i=1}^{n} w_i \tilde{q}_i, \qquad (2)$$

where K_l^{NV} – value of the analyzed phenomenon l (variant of phenomenon) applying a multicriteria non-compensated value assessment method; w_i– weight of the indicator i of the analyzed phenomenon l (variant of phenomenon) $(i = \overline{1,n})$; and $\tilde{q}_i$ – normalized value of the indicator i of the analyzed phenomenon l (variant of phenomenon).

On the condition that $\sum_{i=1}^{n} = 1.0$.

It is not difficult to notice that when model (1) is $\sum_{i=1}^{n} w_j^{-} \tilde{q}_j^{-} = 0$, we have model (2). This is the multicriteria assessment SAW (Simple Additive Weighting) method (Hwang & Yoon, 1981).

We can see from the formula (1) that the impact of the indicators improving the situation compensates for the impact of the indicators showing a deterioration of the situation. The question that arises is how correct is it to use such a model for the assessment of the ecological development of regions? And what ecological situation is reflected when we have $\sum_{i=1}^{m} w_i^{+} \tilde{q}_i^{+} > \sum_{i=1}^{n} w_j^{-} \tilde{q}_j^{-}$? It would seem that the ecological situation has improved. However, even in this case water was consumed, waste water was released, the air was polluted, and areas may have been deforested. If a region is developing quickly, then the factors improving the situation may 'cover' for the significant impact of the factors that are irreversibly deteriorating the situation at the same time. Is this reason enough to state that there are no problems with the ecological situation in the region?

All of these questions are answered by one research study on this topic that used a multicriteria compensated value method (Golusin et al., 2011). This study analyzed the impact of economic development in Southeast European countries on their ecological development. In some countries (Albania, Bosnia and Herzegovina), the ecological situation was assessed as being positive, i.e. it improved. This happened because the areas of fertile and arable land and forests, the scope of irrigation, and the ecological agriculture may have increased there. In other words, the factors whose proportions vary from year to year, such as areas of useful land, scope of the ecological agriculture, forested areas, etc. may decrease due to various reasons that are attributed to factors improving the situation. All of these results can be ascribed to restorable factors.

However, bearing in mind the universally accepted concept of sustainable development, these factors may not ensure the quality of life for future generations if non-renewable resources like the water, air, land cannot be used accordingly. This allows us to maintain that the multicriteria compensated value theory methods are not suitable for the correct assessment of the ecological development in a region, as in the context of sustainable development they present a misleading image. In this case, it is more suitable to apply a multicriteria non-compensated value method which does not provide for compensation between the criteria, i.e. the ecological development in a region should be assessed by applying the model (2). Based on Fig. 3, we can state that the system of indicators for ecological development in a region should consist only of the minimizing indicators reflecting the non-renewable resources.

Similar reasoning can be applied to the economic development in a region. In this case, only the maximizing indicators should be included in the system of indicators. This is also confirmed by the aforementioned research (Golusin et al., 2011). Factors improving both the ecological and the economic situation should be viewed as certain unavoidable daily activities of people that are dictated by the objective requirements ensuring the normal satisfaction of the needs of the current society for development in a region as a socio-economic system.

The MDE multicriteria assessment method differs from the SAW method in the order of normalization of the value of the indicators. The following method of normalization is applied (Ginevičius, 2009; Ginevičius et al., 2011):

$$\tilde{q}_{il} = \frac{q_i}{\max\{|q_{il}|\}}, \qquad (3)$$

where $\max\{|q_{il}|\}$ – highest value of all values of the indicator i of variant l.

As can be seen from the formula (3), both positive and negative normalized values are obtained in this case.

The SAW method states that the nature of the change of the values of all indicators is the same, i.e. all of them are either maximizing or minimizing. The maximization of the values of the indicators is done in the following manner (Hwang & Yoon, 1981):

$$\tilde{\tilde{q}}_{il}^{\max} = \frac{\min\{|q_{il}|\}}{q_{il}}, \qquad (4)$$

where $\tilde{\tilde{q}}_{il}^{\max}$ – maximized value of the indicator i of variant l; and $\min\{|q_{il}|\}$ – lowest value of all values of the indicator i of variant l.

The minimization of the values of the indicators is carried out in the following manner (Hwang & Yoon, 1981):

$$\tilde{\tilde{q}}_{il}^{\min} = \frac{q_{il}}{\max\{|q_{il}|\}}, \qquad (5)$$

where $\tilde{\tilde{q}}_{il}^{\min}$ – minimized value of the indicator i of variant l.

If the objective of the multicriteria assessment is to determine the state of an individual phenomenon (region), then the normalization is done by applying the formula (4) when using the SAW method. If the objective is to determine the priority ranking of the variants, then the values of the indicators are normalized in the following manner (Ginevičius & Podvezko, 2007):

$$\tilde{q}_{il} = \frac{q_{il}}{\sum_{i=1}^{n} q_{il}}, \qquad (6)$$

where $\tilde{q}_{il}$ – value of indicator the i of the analyzed phenomenon l.

Our objective is to determine the impact of the economic development in a region on its ecological development. Thus the procedure for the assessment of the state of the ecological development has to be coordinated with the procedure for the quantitative assessment of the economic development. Fig. 3 shows that this is reflected by exclusively maximizing the indicators; therefore, the minimizing indicators for ecological development needs to be maximized. All of the calculations are done using formulas (2) and (4).

5. Multicriteria Assessment of the Ecological and Economic Development in the Regions of Lithuania

The multicriteria assessment of the ecological and economic development in the regions of Lithuania was carried out on the basis of information provided annually by Statistics Lithuania (Counties of Lithuania 2010, 2011, 2012). The most recently published data are for 2012; thus, to reflect the changes all of the calculations are performed for 2010-2012.

Based on formula (2), the following results of the multicriteria assessment of the economic and ecological development in the regions of Lithuania were obtained (Tabs. 1 and 2).

As was already mentioned, the quantitative assessment of the economic and ecological state of an individual region allows for an analysis of the interrelationship of these factors.

6. Correlation-Regression Analysis of the Impact of Economic Development on Ecological Development in the Regions of Lithuania

A correlation-regression analysis was used for the analysis of interrelationship of the economic and environmental state existing in the regions of Lithuania.

The aim of the correlation analysis is to determine the impact of an independent variable (X) on a dependent variable (Y). In our case, the economic development in the region is expressed as a complex indicator (X_{ek}), with

Tab. 1: Results of the multicriteria assessment of the ecological development in the regions of Lithuania

No.	Name of the region	2010	2011	2012
1	Vilnius	0.629329	0.648033	0.637504
2	Kaunas	0.263273	0.247726	0.243366
3	Klaipėda	0.508710	0.548255	0.516819
4	Alytus	0.586622	0.607345	0.570716
5	Marijampolė	0.409600	0.370946	0.357412
6	Panevėžys	0.599565	0.587119	0.519884
7	Šiauliai	0.530188	0.482941	0.372684
8	Telšiai	0.285590	0.268932	0.266211
9	Utena	0.265350	0.290487	0.256393
10	Tauragė	0.811144	0.754673	0.720749

Source: own

Tab. 2: Results of the multicriteria assessment of the economic development in the regions of Lithuania – Part 1

No.	Name of the region	2010	2011	2012
	Industry			
1.	Vilnius	0.3520	0.4718	0.3858
2.	Kaunas	0.4108	0.5968	0.4382
3.	Klaipėda	0.3980	0.5600	0.4352
4.	Alytus	0.2856	0.4652	0.2994
5.	Marijampolė	0.8160	0.4478	0.2931
6.	Panevėžys	0.3486	0.6116	0.3942
7.	Šiauliai	0.3034	0.4918	0.3478
8.	Telšiai	0.5054	0.7996	0.6450
9.	Utena	0.3214	0.5728	0.3240
10.	Tauragė	0.2714	0.4540	0.2910

Tab. 2: Results of the multicriteria assessment of the economic development in the regions of Lithuania – Part 2

No.	Name of the region	2010	2011	2012
		Construction		
1.	Vilnius	0.5741	0.6901	0.5287
2.	Kaunas	0.2934	0.5535	0.3649
3.	Klaipėda	0.3662	0.5874	0.3626
4.	Alytus	0.3061	0.6896	0.2685
5.	Marijampolė	0.1466	0.2854	0.1891
6.	Panevėžys	0.2367	0.3056	0.3195
7.	Šiauliai	0.2541	0.3703	0.2989
8.	Telšiai	0.4297	0.8627	0.4361
9.	Utena	0.3627	0.5960	0.3608
10.	Tauragė	0.1913	0.3053	0.2369
		Agriculture		
1.	Vilnius	0.1211	0.1403	0.1642
2.	Kaunas	0.1935	0.2640	0.2786
3.	Klaipėda	0.2811	0.3350	0.2560
4.	Alytus	0.2394	0.3651	0.3789
5.	Marijampolė	0.3860	0.5747	0.5318
6.	Panevėžys	0.3168	0.4948	0.2935
7.	Šiauliai	0.5397	0.6899	0.7223
8.	Telšiai	0.3196	0.4823	0.4224
9.	Utena	0.2584	0.3765	0.2661
10.	Tauragė	0.4019	0.6317	0.5020
		Transport		
1.	Vilnius	0.4118	0.4586	0.5318
2.	Kaunas	0.2966	0.3182	0.3460
3.	Klaipėda	0.8044	0.8996	0.9870
4.	Alytus	0.2576	0.2558	0.2840
5.	Marijampolė	0.3455	0.2725	0.2922
6.	Panevėžys	0.1512	0.2722	0.3012
7.	Šiauliai	0.2748	0.3150	0.3470
8.	Telšiai	0.2495	0.1090	0.2904
9.	Utena	0.2048	0.1985	0.2204
10.	Tauragė	0.2391	0.2449	0.3118

Source: own

its components of industry (X_{ep}), construction (X_{es}), agriculture ($X_{ež}$) and transport (X_{et}) as the independent variables. The dependent variables are the ecological development in the region expressed as a complex indicator (Y_{ak}) with its individual indicators being the amount of collected and consumed water, per thou. m^3, for one operating economic entity (Y_{vp-s});

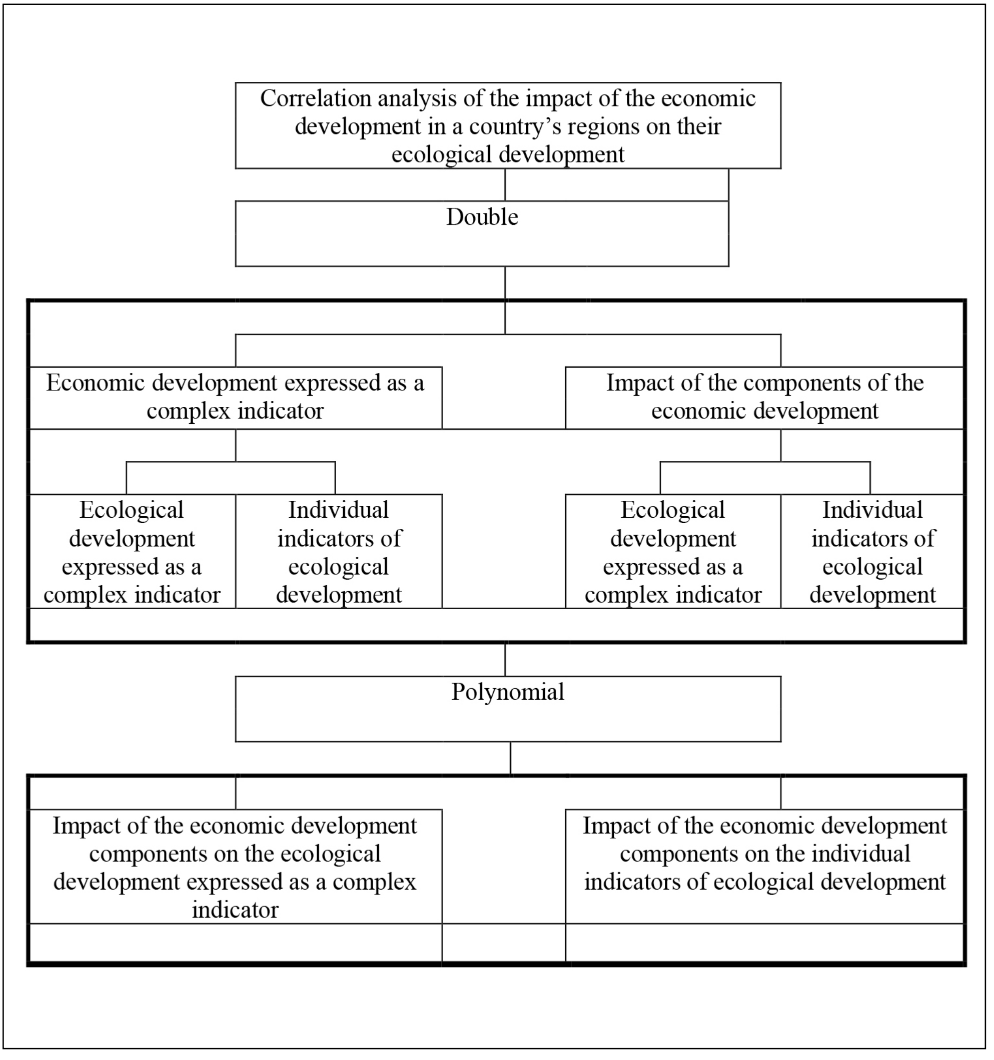
the amount of pollutants emitted by stationary sources of pollution, in tons, for one operating economic entity (Y_{ta}); the amount of released waste water, per thou. m^3, for one operating economic entity (Y_{in}); and the forested areas in comparison to the whole area of the region, in km^2 (Y_{mp}).

In order to thoroughly analyze the impact of the economic development in a region on its ecology, the following cross-sections were analyzed (Fig. 4)

The results of the correlation analysis carried out by applying the structure provided in Fig. 4 are presented in Tabs. 3 and 4.

Before analyzing the results of the correlation analysis, the meaning of the signs and values of the obtained correlation coefficients need to be discussed.

Fig. 4: Structure of the correlation-regression analysis of the impact of the economic development in a country's regions on their ecological development



Source: own

The multicriteria assessment of the indicators of both economic and ecological development was based on maximized values of the minimizing indicators. This means that the higher the normalized value of such an indicator, the lower the non-normalized or real value becomes, indicating that the situation is better and vice versa. The value of r ranges within the limits $0 < r < 1.0$ or $0 > r > -1.0$. So if the value of the correlation coefficient r is positive, it means that the economic development has improved the ecological situation, i.e. the negative impact on the environment decreases. Such a situation is impossible, as economic development cannot happen without the consumption of resources such as water, air and land; thus, pollution of various natures cannot be avoided. However, maybe the positive impact of an individual component of economic development on an individual indicator of ecological development is possible. Therefore, the real value of the correlation coefficient may vary within the limits from 0 to -1 ($0 < r < -1.0$). The higher the value, the higher is the negative impact of the economic development on the ecology. So to achieve sustainability, the value of r should be near to 0 ($-r \rightarrow 0$).

Results of the double correlation analysis. The impact of the economic development in the regions (X_{ek}) on their ecological development (Y_{ak}) is shown by the values of the coefficient r (Tabs. 3-4). In 2010-2012 these values ranged from 0.7 to 0.77. This indicates a very strong negative impact of economic development on the ecological development.

For instance, the negative impact of economic development on the amount of emitted pollutants is increasing. The same can be said about the released waste water. On the other hand, the negative impact of economic development on forestation is consistently decreasing. A gratifying result is that the economic development is not increasing the amount of collected and consumed water. This attests to positive structural and technological changes.

Out of the four components of economic development, construction has the biggest negative impact. Industry and transport have a smaller negative impact; while the development of agriculture improves the ecological situation in the regions. This situation remained unchanged throughout the examined years.

The components of economic development have a different impact on the amount of pollutants that are emitted from stationary sources of pollution. Here, the biggest pollutant is industry, followed by construction and transport, and then agriculture. Positive values for the impact of transport were also obtained, most probably due to the fact that it is not a stationary source (indicating that this phenomenon needs a separate and more detailed analysis).

Both industry and construction release almost the same amount of waste water. They are followed by transport; while the development of agriculture does not increase the amount of waste water in the regions.

The components of economic development have an interesting impact on forested areas. Industry has the biggest negative impact, followed by agriculture and transport; while the development of construction does not have any impact on the forested areas. This means that construction is not being carried out in forested areas.

With several exceptions, the values of the double correlation coefficients provided in Tab. 3 testify to a rather big negative impact of economic development on the ecological development in the regions.

Results of the polynomial correlation analysis. The aim of the polynomial correlation analysis is to determine the scope of the impact of the components for economic development in the regions on the aggregate and partial indicators of their ecological development:

$$Y_{ak} = f(X_{ek}, X_{es}, X_{e\check{z}}, X_{et}), \quad (7)$$

$$Y_{vp-s} = f(X_{ek}, X_{es}, X_{e\check{z}}, X_{et}), \quad (8)$$

$$Y_{ta} = f(X_{ek}, X_{es}, X_{e\check{z}}, X_{et}), \quad (9)$$

$$Y_{in} = f(X_{ek}, X_{es}, X_{e\check{z}}, X_{et}), \quad (10)$$

$$Y_{mp} = f(X_{ek}, X_{es}, X_{e\check{z}}, X_{et}) \quad (11)$$

It is interesting to compare the impact of the complex indicator of the economic development on the complex indicator of the ecological development obtained by the double correlation analysis with the general impact of all the components of economic development on the complex indicator of the development obtained through the polynomial correlation analysis. The complex indicator of the economic development is obtained by adding the weighed values of

Tab. 3: Results of the double correlation analysis of the impact of economic development on the ecological development in a country's regions (values of the correlation coefficient r)

Indicators			Ecological development														
			2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
			Complex indicator of ecological development (Y_{ak})	Complex indicator of ecological development (Y_{ak})	Complex indicator of ecological development (Y_{ak})	Collected and consumed water (thou. m^3) per operating economic entity (Y_{vp-s})	Collected and consumed water (thou. m^3) per operating economic entity (Y_{vp-s})	Collected and consumed water (thou. m^3) per operating economic entity (Y_{vp-s})	Pollutants emitted from stationary sources of pollution (in tons) per operating economic entity (Y_{ta})	Pollutants emitted from stationary sources of pollution (in tons) per operating economic entity (Y_{ta})	Pollutants emitted from stationary sources of pollution (in tons) per operating economic entity (Y_{ta})	Released waste water (thou. m^3) per operating economic entity (Y_{in})	Released waste water (thou. m^3) per operating economic entity (Y_{in})	Released waste water (thou. m^3) per operating economic entity (Y_{in})	Forested areas compared to the area of the region (as a percentage) (Y_{mp})	Forested areas compared to the area of the region (as a percentage) (Y_{mp})	Forested areas compared to the area of the region (as a percentage) (Y_{mp})
Economic development	Complex indicator of economic development		-0.77	-0.70	-0.74	0.21	0.41	0.44	-0.53	-0.67	-0.82	-0.50	-0.34	-0.50	-0.57	-0.47	-0.36
	Components	Industry (X_{ep})	-0.56	-0.54	-0.47	-0.49	-0.43	-0.42	-0.56	-0.59	-0.69	-0.58	-0.63	-0.45	-0.56	-0.68	-0.53
		Construction (X_{es})	-0.63	-0.64	-0.71	-0.61	-0.60	-0.65	-0.58	-0.56	-0.51	-0.61	-0.54	-0.50	0.56	0.61	0.79
		Agriculture ($X_{ež}$)	0.50	0.51	0.48	0.77	0.76	0.62	-0.41	-0.58	-0.54	0.67	0.70	0.56	-0.55	-0.52	-0.48
		Transport (X_{et})	-0.25	-0.25	-0.35	-0.39	-0.24	-0.44	0.40	-0.37	0.34	-0.38	-0.19	-0.27	-0.22	-0.21	-0.18

Source: own

Tab. 4: Results of the polynomial correlation analysis of the impact of economic development on the ecological development in a country's regions (values of the correlation ratio R^2)

Indicators	Ecological development														
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
	Complex indicator of ecological development (Y_{ak})	Complex indicator of ecological development (Y_{ak})	Complex indicator of ecological development (Y_{ak})	Collected and consumed water (thou. m^3) per operating economic entity (Y_{vp-s})	Collected and consumed water (thou. m^3) per operating economic entity (Y_{vp-s})	Collected and consumed water (thou. m^3) per operating economic entity (Y_{vp-s})	Pollutants emitted from stationary sources of pollution (in tons) per operating economic entity (Y_{ta})	Pollutants emitted from stationary sources of pollution (in tons) per operating economic entity (Y_{ta})	Pollutants emitted from stationary sources of pollution (in tons) per operating economic entity (Y_{ta})	Released waste water (thou. m^3) per operating economic entity (Y_{in})	Released waste water (thou. m^3) per operating economic entity (Y_{in})	Released waste water (thou. m^3) per operating economic entity (Y_{in})	Forested areas compared to the area of the region (as a percentage) (Y_{mp})	Forested areas compared to the area of the region (as a percentage) (Y_{mp})	Forested areas compared to the area of the region (as a percentage) (Y_{mp})
Complex indicator of economic development (X_{ek}, X_{es}, $X_{ež}$, X_{et})	0.57	0.52	0.30	0.24	0.31	0.43	0.54	0.59	0.50	0.41	0.32	0.48	0.36	0.21	0.14

Source: own

its components. The independent variables of the polynomial correlation are the same as the components of economic development, but in this case their interrelationship and not their importance is assessed.

We can see from Tab. 4 that the components of economic development (industry, construction, agriculture and transport) account for 57 percent of the total impact of the development on the ecology in a region (R^2 = 0.57). During a period of three years, this impact changed for the worse and nearly doubled. This is a very worrying fact.

On the other hand, this indicator was nearly the same (R^2 = 0.58) for Southeast European countries (Golusin et al., 2011). Thus, we can state that Lithuania is in the same situation as other countries.

The components of the economic development in the regions account for approximately half, about 50 percent, of the total impact of development on the region, except for the fourth indicator – forested areas. Here, the economic development accounts for only 14 percent of the total impact. This means that forested areas are mostly influenced not by economic development but by other factors involved in the region's development, possibly social ones.

Conclusions

In order to purposefully manage the sustainable development of regions and thus reduce the amount of social tensions in the country, we need to be able to adequately assess the state of the main components of sustainable development (economic, social and ecological development) at a certain period in time, as well as to determine their interrelationships.

Various methods have been suggested for the formation of the indexes of economic and social development in regions on the basis of the indicators that directly reflect the current situation. However, such methods differ both in the number of the suggested indicators and in their content. There are very few suggestions for integrating these indicators into one aggregate value. When talking about quantitative assessments of ecological development, it is notable that a common feature is that they all – some to a larger degree, some to a lesser degree – reflect the non-renewable resources like water, air and land. Such an approach is methodically correct, as it does not contradict the very essence of sustainable development – to meet the current needs of a society without compromising the ability of future generations to meet their own needs. Thus, the principle structure of the ecological development index should cover at least several main indicators reflecting the above resources. In turn, these indicators could be detailed further.

In reality, the economic development of a region is a complex process that is expressed by many aspects, which in turn are described by a certain number of indicators. An analysis of their content allowed us to distinguish four components of economic development in a region: industry, construction, agriculture and transport, i.e. the spheres that create material products or provide services for such products. Every component is reflected by 4-5 indicators.

Recently, multicriteria assessments have been more widely applied to quantitative assessments of the state of complex phenomena, as they allow for aggregating a larger number of indicators expressed in different dimensions and varying in different directions into one value. Two categories of these assessments may be distinguished: compensated and non-compensated value methods. The first methods are based on the assumption that the maximizing indicators can counterweigh the minimizing ones; whereas the second methods negate the possibility of compensation between indicators.

The compensated value methods are not suitable for the quantitative assessment of ecological development, as they include not only non-renewable but also renewable resources in the model. Such an approach distorts the overall picture and does not meet the essence of sustainable development, as the losses of non-renewable resources are 'covered' by the results of daily human activities. Therefore, it is purposeful to use non-compensated value multicriteria methods for the assessment of ecological development and to form the system of indicators exclusively from minimizing indicators. Based on similar reasoning, the system of indicators for the economic development should include exclusively maximizing indicators.

The multicriteria assessment of the economic and ecological development in the regions of Lithuania allowed for the application of a correlation-regression analysis of the impact of economic development on the ecological development. It was determined that the economic development in the regions of Lithuania, as a complex assessment indicator, has a negative impact on the ecological development. This was confirmed by the value of the correlation coefficient, which amounted to 0.77. Economic development increased the amount of emitted pollutants (r = 0.82) and released waste water (r = 0.5).

Out of the four components of economic development, construction has the biggest negative effect on the ecology (r = 0.71). It is followed by industry (r = 0.47), which also causes the highest emissions of pollutants (r = 0.69). These are followed by agriculture (r = 0.54) and transport (r = 0.51). Generally we can state that, with several exceptions, the values of the double correlation coefficients testify to a rather large negative impact of the economic development on the indicators for ecological development in the regions.

The components of economic development in the regions of Lithuania (industry, construction, agriculture and transport) account for 57 percent of the total impact of development on the ecology. Their impact on the individual indicators of ecological development, except for the forested areas indicator, accounts for approximately 50 percent of the total impact. However, economic development accounts for only 14 percent of the total impact on forested areas. Thus, the main impact on this indicator comes from factors that were not assessed, i.e. non-economic development factors.

References

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

Belton, V., & Stewart, T. J. (2002). *Multiple criteria decision analysis: an integrated approach*. Dordrecht.

Boggia, A., & Cortina, C. (2010). Measuring sustainable development using a multi-criteria model: A case study. *Journal of Environmental Management*, *91*(11), 2301-2306. https://dx.doi.org/10.1016/j.jenvman.2010.06.009.

Bolcárová, P., & Kološta, S. (2015). Assessment of sustainable development in the EU 27 using aggregated SD index. *Ecological Indicators, 48*, 699-705. https://dx.doi.org/10.1016/j.ecolind.2014.09.001.

Chansarn, S. (2013). Assessing the Sustainable Development of Thailand. *Procedia Environmental Sciences*, *17*, 611-619. https://dx.doi.org/10.1016/j.proenv.2013.02.077.

Čiegis, R., Ramanauskienė, J., & Šimanskienė, L. (2010). *Lietuvos regionų darnaus vystymosi vertinimas* [Evaluation of sustainable development of Lithuanian regions]. Klaipėda: Klaipėdos universiteto leidykla.

Counties of Lithuania 2010. Retrieved from http://osp.stat.gov.lt/services-portlet/pub-edition-file?id=14761.

Counties of Lithuania 2011. Retrieved from http://osp.stat.gov.lt/services-portlet/pub-edition-file?id=2068.

Counties of Lithuania 2012. Retrieved from http://osp.stat.gov.lt/services-portlet/pub-edition-file?id=2068.

Ginevičius, R. (2009). Socioekonominių sistemų būklės kiekybinio įvertinimo problematika [Some problems of quantitative evaluation of the state of social-economic systems]. *Verslas: teorija ir praktika*, *10*(2), 69-83. https://dx.doi.org/10.3846/1648-0627.2009.10.69-83.

Ginevičius, R., & Podvezko, V. (2007). Complex assessment of sustainable development of state regions with emphasis on ecological and dwelling conditions. *Ekologija*, 53 (Supplement), 41-48.

Ginevičius, R., & Podvezko, A. (2012). Features of applying decision-making methods to evaluation of financial stability of commercial banks. *Business: Theory and Practice, 13*(4), 314-323.

Ginevičius, R., Gedvilaitė, D., & Bruzgė, Š. (2015). Assessment of a country's regional economic development on the basis of Estimation of a Single Process (ESP) method. *Entrepreneurial business and economics review (EBER)*, *3*(2), 141-153. https://dx.doi.org/10.15678/EBER.2015.030210.

Ginevičius, R., Podvezko, V., & Podvezko, A. (2011). A new approach for evaluating of socio-economical processes by multi-criteria decision methods. In *The 7th International Scientific Conference. Business and management – 2012. May 10-11, 2012, Vilnius, Lithuania*.

Golusin, M., Munitlak, I. O., & Teodorovic, N. (2011). The review of the achieved degree of sustainable development in South Eastern Europe – The use of linear regression method. *Renewable and Sustainable Energy Reviews*, *15*(1), 766-772. https://dx.doi.org/10.1016/j.rser.2010.07.064.

Hamilton, K. (2001). *Indicators of sustainable development: genuine savings. Note for technical discussion on sustainable development indicators*. Paris.

Hwang, C. L., & Yoon, K. (1981). *Multiple attribute decision making – methods and applications. A state of the art survey*. Berlin, Heidelberg, New York: Springer Verlag.

Jia, Z., Haifeng, X., Jincheng, S., & Xuelin, Z. (2007). Assessment of Sustainable Development System in Suihua City, China. *Chinese Geographical Science*, *17*(4), 304-310. https://dx.doi.org/10.1007/s11769-007-0304-6.

Kondyli, J. (2010). Measurement and evaluation of sustainable development. A composite indicator for the islands of the North Aegean region, Greece. *Environmental Impact Assessment Review*, *30*(6), 347-356. https://dx.doi.org/10.1016/j.eiar.2009.08.006.

Lange, G. M. (2003). *Policy Applications of Environmental Accounting*. Environmental Economics Series Papers.

Mardani, A., Jusoh, A., Zavadskas, E. K., Khalifah, Z., & Nor, K. M. (2015). Application of multiple-criteria decision - making techniques and approaches to evaluating of service quality: a systematic review of the literature. *Journal of Business Economics and Management*, *16*(5), 1034-1068. https://dx.doi.org/10.3846/16111699.2015.1095233.

Mardani, A., Jusoh, A., Zavadskas, E. K., Zakuan, N., Valipour, A., & Kazemilari, M. (2016). Proposing a new hierarchical framework for the evaluation of quality management practices: a new combined fuzzy hybrid MCDM approach. *Journal of Business Economics and Management*, *17*(1), 1-16. https://dx.doi.org/10.3846/16111699.2015.1061589.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., & Olsson, L. (2007). Categorising tools for sustainability assessment. *Ecological Economics*, *60*(3), 498-508. https://dx.doi.org/10.1016/j.ecolecon.2006.07.023.

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

Rochen, M., & Dincer, I. (2001). Exergy as the confluence of energy, environment and sustainable development. *Exergy International Journal*, *1*(1), 3-13. https://dx.doi.org/10.1016/S1164-0235(01)00004-8.

Wallis, A. N., Graymore, M. J. M., & Richards, A. J. (2011). Significance of environment in the assessment of sustainable development: The case for south west Victoria. *Ecological Economics*, *70*(4), 595-605. https://dx.doi.org/10.1016/j.ecolecon.2010.11.010.

Zinatizadeh, S., Azmi, A., Monavari, S. M., & Sobhanardakani, S. (2017). Evaluation and prediction of sustainability of urban areas: A case study for Kermanshah city, Iran. *Cities*, *66*, 1-9. https://dx.doi.org/10.1016/j.cities.2017.03.002.

Zolfani, S. H., Maknoon, R., & Zavadskas, E. K. (2015). Multiple nash equilibriums and evaluation of strategies. New application of MCDM methods. *Journal of Business Economics and Management*, *16*(2), 290-306. https://dx.doi.org/10.3846/16111699.2014.967715.

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Abstract

IMPACT OF ECONOMIC DEVELOPMENT ON THE ECOLOGY IN THE REGIONS OF LITHUANIA

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All three components of sustainable development (SD) – economic, social and ecological – are closely interrelated and have both direct and reverse impacts. To better understand the SD phenomenon and to manage it purposefully, we need to perform two essential tasks: first, a quantitative analysis of the status of the components; and second, a quantitative assessment of their impact on one another. Both economic development and ecological development are complex processes that manifest themselves in many aspects; thus, the quantitative assessment of the condition of these processes is based on multi-criteria methods. The article analyses the impact of economic development of the regions of the state on the ecological development as an essential component thereof. The latter statement represents the purpose of the study. The set of economic development indices is formed based on the possibility to obtain the required statistical information. Only those indices that reflect irreversible resources: water, air and land resources – are included in the system of economic development indices. Following the assessment of the condition of economic development and of the ecological development, the interrelation between the economic development and the ecological development shall be analysed based on correlation and regression analysis.

It has been determined that economic development in the regions of Lithuania has a negative impact on the ecological development in those regions (r = 0.82). The components of economic development reflect only 57% of its impact on the ecology; whereas construction (r = 0.71) and industry (r = 0.47) have the biggest negative impact.

Key Words: *Sustainable development of regions, impact of economic development on the ecology, multicriteria assessment methods, correlation analysis.*

JEL Classification: *Q01, R11, O01.*

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