Global J. Environ. Sci. Manage. 7(4): 503-522, Autumn 2021

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

ORIGINAL RESEARCH PAPER

Modelling the impact of environmental responsibility on the development of enterprises

M. Pinskaya[1,*] O. Meleshchenko[2], O. Kovalchuk[3], O. Karpenko[4], E. Kompanets[4]

[1]*Financial Research Institute of the Ministry of Finance of the Russian Federation, Moscow, Russian Federation*
[2]*Taras Shevchenko National University of Kyiv, Kyiv, Ukraine*
[3]*Kyiv National University of Culture and Arts, Kyiv, Ukraine*
[4]*Dragomanov National Pedagogical University, Kyiv, Ukraine*

ARTICLE INFO

Article History:
Received 19 January 2021
Revised 04 April 2021
Accepted 05 May 2021

Keywords:
Environmental initiative
Environmental responsibility
Integrated indicator
Social activity
Strategy

ABSTRACT

BACKGROUND AND OBJECTIVES: The requirements of stakeholders for the qualitative transformation of the approaches of industrial enterprises – environmental users to introduction of economic activities cause an increase in the role of environmental responsibility as their strategic priority for development. The purpose of the study is to improve the practical tools for calculating and developing strategies for the development of environmental responsibility of industrial enterprises.
METHODS: In the study, tools for assessing the level of environmental initiative of an industrial enterprise as an integrated indicator of environmental initiative are suggested. It is expressed as the arithmetic mean of ten factors of environmentally proactive behavior of industrial enterprises. To achieve the objectives of the study, methods of criterion-qualitative assessment are suggested, such as expert assessment and survey. The assessment system includes ten factors rated on a 10-point scale and weighted by significance. The integrated indicator of the environmental initiative acquires values within, is a stimulant of environmental responsibility.
FINDINGS: One justified a scientific and methodological approach to assessing the level of environmental responsibility or the industrial enterprise, including calculation of the corresponding taxonomic indicator with consideration of the quantitative factors of its environmental responsibility and the qualitative and quantitative factors of environmental initiative. This enables the possibility to assess the relevant state of environmental responsibility and determine the volumes for further correction of the ecological strategy for the development of the industrial enterprise.
CONCLUSION: As a conclusion, practical recommendations are made for the implementation of organizational and economic support of environmental responsibility in the development strategy of an industrial enterprise taking into account the impact of its environmental initiative and environmental duty. The level of environmental responsibility of industrial enterprises taken into account when developing recommendations on adjustment of their environmental strategy of development is determined, which as a whole allowed to form organizational and economic support for environmental responsibility of the enterprises under study. Thus, an enterprise, which only ensures compliance with environmental emission standards (compensation strategy or sufficiency strategy) cannot be characterized by a high level of environmental responsibility. To ensure a high level of environmental responsibility, an industrial enterprise must rely on a proactive strategy or a strategy for sustainable use of nature.

DOI: 10.22034/gjesm.2021.04.02

NUMBER OF REFERENCES **28**

NUMBER OF FIGURES **3**

NUMBER OF TABLES **9**

*Corresponding Author:
Email: *mily.pinskaya@mail.ru*
Phone: +79163528460
Fax: +79163528460

Note: Discussion period for this manuscript open until January 1, 2022 on GJESM website at the "Show Article.

INTRODUCTION

In the context of increasing environmental problems in the 21st century, enterprises, which use natural resources, face the task to strike a balance between economic development and minimizing the negative environmental impacts of economic activity. The requirements of stakeholders, concerning the qualitative transformation of approaches, taken by industrial enterprises, which use natural resources, to their economic activity, give rise to the role of environmental responsibility, as their strategic development priority (Zare *et al.,* 2016). The issue regarding the observance of environmental responsibility principles becomes increasingly relevant at the level of interaction between the community and enterprises in the areas, where the latter are located (Hadj, 2020). Since industrial enterprises particularly place the greatest stress on the environment, it is important to provide an organizational-economic mechanism for ensuring their environmental responsibility in due course (Panyam *et al.,* 2018). The need for ecologically friendly and equitable economic development remains the most difficult issue in the context of growing environmental-economic problem (Hovardas, 2016). The pursuit of the sustainable development of the ecological-economic system, providing a wide range of technological capabilities and high productiveness of business activities requires today's organizations to be more involved in managing these processes (Chen and Hamilton, 2020). The projection of the concept of sustainable development on the enterprise level causes the escalation of ecological and socio-economic conflict, which, on the one hand, is aimed at profit maximization, and on the other hand, is stemming from the requirements of the social sector and ecological control authorities to increase the social and ecological standards of economic activity (Fujii and Managi, 2016). However, the ecological efficiency is determined not only by the industrial base. It can be achieved by changing goals and targets, which are being pursued by industries, operational management and the methods of its implementation (Hong *et al.,* 2016). It is, therefore, necessary to refuse outright the purely consumerist approach and to follow a policy that takes account of ecological and social factors (Singh *et al.,* 2016). Consequently, the top management of industrial companies should be aware of the fact that positive or negative assessment of the ecological activity of a company on the part of stakeholders and, first of all, the local community significantly affects the future success of products on the market, and business competitiveness as well (Malá *et al.,* 2017).

Thus, in the context of increasing environmental problems in the 21st century, the enterprises, which use natural resources around the world, face an important task to strike a balance between the development of their economic activities and minimizing environmental problems, which arise due to these activities (Yue *et al.,* 2020). The concept of socio-environmental responsibility of business was originally interpreted as the enhanced principle "polluter pays", well-known in the economics of nature use, which evolved into the requirement of environmental entrepreneurship initiative (Jovovic *et al.,* 2017). At the same time, experts introduced a broad interpretation of the principle of sustainability within the "Sustainable Development Triangle" (Ji and Long, 2016). According to this approach, modern-day business activities are challenged to combine three interrelated goals in practice, namely, economic efficiency, environmental responsibility and social activity (Sáez-Martínez *et al.,* 2016). All highly-developed countries nowadays recognize the need for theoretical underpinning and taking practical steps to shape enterprise environmental policy, which would envisage the care for nature conservation, environmental quality, the wise use of existing and potential natural resources, maintaining the ecological balance of nature and ensuring the living conditions of human (Elsawah *et al.,* 2017). In accordance with these statements, the logical response of companies to the demands of public opinion would be the observance of environmental responsibility principles at all stages of industrial activity (Zhu and Zhao, 2018). At the same time, a range of issues still remains insufficiently developed in scientific literature. Among them, in particular, are the issues related to the meaning of the concept of industrial enterprise's environmental responsibility, assessing its level, determining the nature of the impact, exerted by environmental initiative and commitment, on the level of environmental responsibility. Consequently, one should continue to study the issue related to the organizational-economic mechanism for ensuring environmental responsibility of industrial enterprises according to

the requirements of stakeholders, as well as the issue of choosing an appropriate development strategy, considering ecological factors. The relevance of the research problem, its practical importance and the deficient theoretical elaboration of the mentioned aspects led to the choice of the topic, objective and tasks of the research paper. The purpose of this study is to improve the practical tools for calculating and developing strategies for the development of environmental responsibility of industrial enterprises. This study were set to achieve the theoretical foundations and the current condition of the system of ecological responsibility of the industrial enterprises; to develop the scientific and methodological approach to assessing the level of ecological responsibility of the industrial enterprises with the consideration of the level of their ecological initiative and ecological responsibility; to calculate the integrated indicator of environmental responsibility for Volkswagen AG; to justify the scientific basis for choosing an environmental strategy for the development of the industrial enterprises in terms of considering the impact of the existing level of environmental responsibility of the enterprise in these strategies. This study was conducted for for Volkswagen AG (Germany, Poland) in the period of 2012-2018.

MATERIALS AND METHODS

The local community can act both as an object of environmental responsibility, and as a fully-fledged entity in the process of its formation at an industrial enterprise (Domenech and Bahn-Walkowiak, 2019). The assessment system should provide a general idea about the level of industrial enterprise's environmental responsibility, confirmed by outcomes, social (non-financial) reports, statistical data, as well as to form the information base for further analysis, detecting potential risks and the decision-making process (Borland *et al.,* 2016). To assess the environmental initiative of an enterprise, one considers it appropriate to use the questionnaire method, as the concept of enterprise's environmental initiative is distinctly subjective. A questionnaire refers to the qualitative methods of information assessment and has a range of advantages, such as the ability to cover large target groups, a high level of result formalization, the minimal impact of the researcher on the interviewee, responsiveness, and disadvantages, associated with the need for data verification, consistency check, etc. That is why a questionnaire should be necessarily combined with the evaluation of statistical error or the consistency of experts' opinions (Jiang *et al.,* 2019). It is time to review the key advantages and disadvantages of expert methods. A direct estimation method can be applied, when the subjects of examination, which determine the final results, are directly comparable since these subjects are of similar nature and therefore have a common benchmark standard (Wang *et al.,* 2016a). The method of direct estimation makes it possible to take into account the degree of predominance of a particular indicator in relation to others (Graafland, 2018). But when estimating the composite index of effectiveness, the wrong estimate of the indicator with lower value, if its position relative to other indicators has been determined correctly, can lead to the serious distortion of the final result (Wang *et al.,* 2016b).

The ranking method and its types can be applied in the following cases:

- to arrange any kinds of objects or phenomena in time or space (Wilmer *et al.,* 2018);
- to arrange objects according to any indicator, which does not need to be accurately measured (Cao *et al.,* 2017);
- if a particular indicator should be measured, but can not be measured at the moment for practical or theoretical reasons (Anthony *et al.,* 2016).

Environmental initiative of industrial enterprises is a category that is difficult to quantify. Given this statement, it is advisable to use high-quality, heuristic research methods to assess it. Thus, the integrated indicator of environmental initiative is determined on the basis of the method of expert survey conducted among employees of the enterprise under study and environmentalists. During this study, a survey to determine the scores of the level of environmental initiative of enterprises in each assessment category was conducted among 50 employees of the industrial enterprise under study, including middle managers and technical staff. Experts were asked to assign ranks (from 10 - the most significant, to 1 - the least significant) to each of the assessment categories. This choice of the target audience of the survey was due to the need to ensure the impartiality of expert opinions. Thus, none of the experts was interested in certain results of the survey, their opinion was completely

independent. When assessing the objects of a survey, experts often disagree on the problem to be solved. In this regard, there is a need to quantify the level of agreement of experts. Obtaining a quantitative measure of agreement allows a more reasonable interpretation of the reasons for differences of opinion. To this end, the level of agreement between the opinions of experts was determined through the use of the concordance coefficient. The concordance coefficient determines the degree of agreement of expert assessments, varies in the range of $0 < K < 1$, with 0 meaning complete disagreement, and 1 meaning complete agreement. The results of the survey are considered statistically significant at $K > 0.55$. The calculated concordance coefficient for the enterprise under study is higher than its control value of $K = 0.77$, thus, it can indicate a high level of agreement of experts. Therefore, the results of the conducted study are credible and suitable for further use. Given that the environmental responsibility of industrial enterprises is considered as a system of their environmental duty and environmental initiative, the indicators of the level of environmental responsibility are suggested to be divided into two blocks — the block of environmental duty and the block of environmental initiative. At the same time, by the nature of the impact on the level of environmental responsibility, all indicators are divided into stimulants, the increase of which contributes to the increase of the level of environmental responsibility, and disincentives, the increase of which causes a decrease of the level of environmental responsibility.

During the second stage, the standardization of indicators is carried out using Eqs. 1, 2 and 3.

$$r_{ik} = \frac{y_k - \bar{y}_k}{V_k} \quad (1)$$

Where,

$$\bar{y}_k = \frac{1}{z}\sum_{i=1}^{z} y_k \quad (2)$$

$$V_k = \left[\frac{1}{z}\sum_{i=1}^{z}(y_k - \bar{y}_k)^2\right]^{\frac{1}{2}} \quad (3)$$

Where, k=1,2...,n; y_{ik} - the value of the index k for the unit i; $\bar{y}_k$ - arithmetic mean value of the index k; V_k - standard deviation of the index k; r_{ik} - the standardized value of the index k for the unit i.

The highest values of incentives and the lowest values of disincentives form the coordinates of desired development benchmark using Eqs. 4, 5 and 6.

$r_{0_t} = \max r_{ik}$, if index к is an incentive; (4)

$r_{0_t} = \min r_{ik}$, if index к is a disincentive. (5)

The development benchmark will therefore have coordinates:

$$D_0 = (r_{01}, r_{02}, ..., r_{0n}) \quad (6)$$

To obtain the taxonomic index of development the following equations are used. According to interpretation, the closer its value is to 1, the higher level of development it shows as Eqs.7, 8, 9 and 10.

$$p_i = 1 - \frac{b_{i0}}{b_0} \quad (7)$$

Where,

$$b_{i0} = \left[\sum_{V=1}^{n}(r_{iv} - r_{0t})^2\right]^{\frac{1}{2}},\ n = 1,2,..,t \quad (8)$$

$$b_0 = \bar{b}_0 + 2V_0 \quad (9)$$

$$\bar{b}_0 = \frac{1}{t}\sum_{i=1}^{t} b_{i0} \quad (10)$$

Where, b_0 - the distance between separate points-units and the point D_0, which presents the development benchmark, V_0 - standard deviation of the index b_{i0}.

For Volkswagen Aktiengesellschaft, the overall taxonomic environmental responsibility index will change by 1.79%, along with the change of index from the environmental commitment block by 1% and the constant value of the index from the environmental initiative block. If the environmental initiative index changes by 1% while the environmental commitment index remains sustainable, the overall taxonomic environmental responsibility index will change by 1.27%. In the light of the above, for the researched Volkswagen Aktiengesellschaft, both environmental commitment and environmental initiative blocks have relatively equal impact on the resultant environmental responsibility index, with a slight prevalence of environmental commitment block. The composite taxonomic environmental responsibility

index, constructed from the environmental commitment and environmental initiative blocks, synthetically characterizes the changes in property values of the researched groups. One of the important advantages of this indicator is the characterization of direction and the scope of changes in the processes described by a set of initial data. The taxonomic method enables one to determine the level of environmental responsibility of industrial enterprises by assessing the distance from the coordinates of the benchmark-point to the standardized values of indicators. The factitious benchmark has been defined by taking into account the differentiation of incentive and disincentive features of impact on the object under study. Through series of manipulations, the calculated distance has been transformed into the index with range (0; 1). Thus, the level of ecological responsibility of the enterprises is proposed to be assessed using the taxonomy method, which is used to reduce the factor space, manifesting itself in the aggregation of the information space, in the result of which one observes the formation of a general index. The methodology for the assessment of industrial enterprise's environmental responsibility, presented in this research, makes it possible to specify the areas of ecological strategy, which need improvement, as well as to define the level of its sustainability. It also provides a basis for the comparison of the actual level of environmental responsibility among different companies, which can be performed in further researches.

RESULTS AND DISCUSSION

It is believed that in order to build an effective system of nature management, it is necessary to form new strategic areas of intersubjective relationships in the natural resource block of the economy, which will allow to create a certain margin of safety of the economy from negative external or internal influences. It is believed that this important strategic area is a multilevel approach to management decision-making, which takes into account the external and internal environment of the main industrial enterprises polluting the region, the creation of intersectoral partnership in the field of environmental protection. In modern economic conditions, the basis is created for the implementation of environmental management actions through the business environment, which must take into account the emerging contradictions of stakeholders. It is there that the most complete interaction of regional and local (enterprise level) levels of transition to sustainable development takes place. It is the environmental responsibility of industrial enterprises that is the key to taking into account the environmental interests of their stakeholders. The transition of economic systems at the macro, meso and micro levels to the path of sustainable development is due to the importance of preserving the environment not only for the existing generation, but also for future generations. Analysis of environmental costs as a component of assessing the level of environmental initiative of industrial enterprises allows to assess the functioning of the environmental management system, to monitor environmental protection costs, to analyze the relationship of environmental characteristics with financial and economic indicators of company activities. At each stage of the process of implementation of the environmental initiative of an industrial enterprise, the costs for the generation of adequate reporting information, effective management decisions and further optimization of environmental costs should be monitored. It should be stressed that the process of optimizing environmental costs should, in addition to the objectives of the enterprise, take into account the requirements of the local community and other stakeholders. Optimization should not cause deterioration of the environment due to reduced costs for the restoration of the damaged state of the environment. Environmental responsibility of industrial enterprises is one of the fundamental factors for shifts towards sustainable development at both micro and macro levels. Environmental responsibility of an industrial enterprise is defined as a set of mechanisms, tools, measures for the implementation of its environmental initiative and environmental duty. Environmental duty is defined as a set of environmental obligations to the local community and administrative bodies. The environmental initiative of an enterprise is considered as a set of measures of the environmental program of the enterprise, which go beyond normatively established requirements and meet requirements of the local community concerning environmental protection. This creates an appropriate categorical framework in the field of research of environmental responsibility of industrial enterprises for theoretical cognition of its forms

and relationships with the internal and external environments of industrial enterprises. In accordance with the objective of the environmental initiative, there arises a problem related to the assessment of its level, since it is a category that cannot be fully quantified. Assessing the environmental initiative of industrial enterprises should, first of all, heighten the interest of the main stakeholders, represented by local authorities and the community, since the level of the environmental initiative expresses enterprise's interest in participating in social dialogue regarding the ecologization of industrial activity and regional development strategy. The assessment of the environmental initiative level should be carried out using both qualitative methods, such as expert surveys and questionnaires, and quantitative methods. It should be noted that particular attention should be put to the analysis of environmental costs and investment in nature protection measures, since these categories specifically reveal the efficiency of the environmental management system of industrial enterprises. Thus, one offers to carry out the assessment of the level of the ecological initiative of the industrial enterprises upon the following scheme in Fig. 1.

During the first stage, one forms a statistical database based on the listed sources of information. During the second and third stages, one carries out the processing of data, which have been obtained using the questionnaire and expert survey, and further calculates the integral environmental initiative index based on data processing. The fourth stage covers the analysis of environmental costs and capital investment in nature protection activities. At

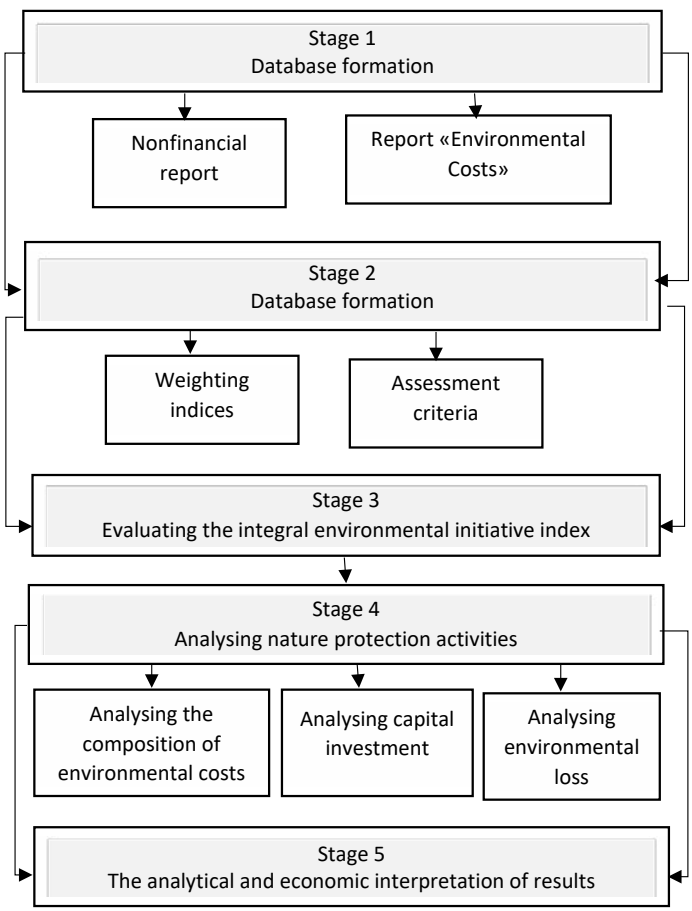


Fig. 1: Stages of assessing the environmental initiative of industrial enterprises

the last stage, one suggests the economic-analytical interpretation of attained results, more specifically, the analysis of growth rate and dynamic pattern of indices, obtained during the researched period. It is time to consider the process of calculating the integral environmental initiative index. The fundamental phase of this process is to form a system of evaluation categories, which would reveal the most substantial and significant aspects of the environmental initiative activities of industrial enterprises and meet the main international ecological standards. As to the system of evaluation categories for assessing the environmental initiative of industrial enterprises, special attention should be paid to the existence and scope of the compensatory policy. Since ecologically responsible development strategy always includes environmental restoration from damages caused by industrial activity, one considers it appropriate to add a corresponding category to the range of enterprise initiatives. It is called-activity, concerning the compensations for environmental damage to the community. Thus, one proposed a system of evaluation categories for determining the level of the ecological initiative of the industrial enterprises (Table 1).

It includes 10 entries and can be implemented within the process of expert survey and the analysis of enterprise non-financial reports. The given system enables one to take into account both the external indicators of environmental activities and the subjective evaluations of experts. This makes it possible to conduct the most optimized assessment of the enterprise environmental initiative level and specify the priority areas for activities, which are of particular interest to the main stakeholders of industrial enterprises led by the local community. Consequently, the implementation of enterprise's own environmental initiative requires a specific set of methods depending on the peculiarities of industrial activity. The role of the environmental initiative of industrial enterprises in the implementation of their environmental responsibility is to restore the damaged environment and provide compensations for environmental damage to the community. It is implemented through a series of measures taken beyond the regulatory requirements. The issue of environmental responsibility assessment is one of the most essential problems of managing the socially

Table 1: The system for assessing the environmental initiative of industrial enterprises

Evaluation category	Key assessment criteria
Activity, concerning the compensations for environmental damage to the community	Compensatory ecological payments to employees, availability of sanitary protection zone of the enterprise, environmental restoration
Undertaking the environmental activities and measures	Own initiatives to improve environmental education of the community, environmental enhancement due to the public activities, held during the entire analyzed period
Atmospheric air protection	Availability of air quality monitoring system, amount of capital investment in this field, the quality of air cleaning equipment
Optimization of waste management areas	Waste disposal policy, the level of waste utilization, amount of capital investment in this field
Protection of water bodies, which are used by the enterprise	Activities aimed at restoration of the damaged coastline, availability of wastewater quality monitoring system, amount of capital investment in this field
Willingness to cooperate with the community	Conducting public hearings and consultations, ensuring feedback, availability of community engagement programs
Condition of the surrounding area	Pollution condition of the surrounding area, restoration and landscaping activities, sanitary protection zones
Non-financial reporting, full disclosure of the environmental information	The frequency of non-financial reports publication, their compliance with international standards, the quality and transparency of the reported information
Effectiveness of environmental management system	Availability of ISO Series Certificates, amount of capital investment in this field
Conducting an internal environmental audit	The frequency of internal ecological audits, corrective actions and removal of disadvantages, which were revealed during the audit

responsible practices of industrial enterprises. This question remains relevant both for all stakeholders and for industrial enterprises themselves. The gradually increasing amount of industrial companies, which claim themselves to be highly supportive of environmental responsibility principles, cause the need for verifying if the information about the level of their environmental responsibility is factually accurate. Consequently, it is a crucial task nowadays to develop a methodology for the assessment of environmental responsibility, which would be accessible and easily understandable for all interested parties. The enhanced and comprehensive assessment of the environmental responsibility of the industry, corporation, or a particular enterprise cannot be carried out independently by the concerned parties alone, for the reason of resource sufficiency, mainly information and time. Thus, one of the major tasks of this research was to develop the methodology for assessing the environmental responsibility of industrial enterprises, which would be relatively easy to use and contain accessible information database. Considering the details given above, one suggests the following scheme to be used for assessing the environmental responsibility of an industrial enterprise. During the first stage, one carries out the qualitative and quantitative analysis of indicators, calculates the numerical score of the enterprise environmental initiative level and the coefficients-indices of environmental commitment and environmental initiative for the researched enterprises, defines their incentive or disincentive impact on the resultant index. The standardization of the calculated coefficients, caused by the different dimensions of initial data, is performed at the second stage. One determines the benchmark indices, calculates the partial taxonomic indices for the environmental responsibility and environmental initiative levels. During the third stage, one conducts the comprehensive evaluation of the obtained indices, determines the impact of each partial index on the overall level of environmental responsibility of the researched industrial enterprises, identifies the resources for further development and improvement. The generalized algorithmic scheme, which displays the procedure for the assessment of environmental responsibility (ER), is shown in Fig. 2. The suggested method for the assessment of environmental responsibility is based on the determination of so-called taxonomic distance, that is, the distance between points in multivariable space, the dimension of which is determined by the number of features describing the object under study. The undoubtful advantage of a taxonomic method is the procedure of the so-called standardization of indicators, as a result of which the object properties, represented by different qualitative and quantitative indicators, are transformed into a single standardized measurement system. The algorithm for determining the taxonomic index of development includes several stages. At the first stage, one forms an observation matrix, which contains the most complete property characteristic of the researched set. The metrics, included in the matrix, are diverse since these metrics describe different object properties and are measured in different units.

After the standardization procedure, all selected indices should be divided into incentives and disincentives based on their impact on the level of environmental responsibility. Indices, high values of which are desirable in terms of the chosen aspect of the research, are considered to be incentives. In this research, one have examined 10 indices from two blocks, environmental commitment and environmental initiative, among which all indicators of the environmental commitment block are characterized by an incentive effect, proceeding from their mathematical expressions. Among the indices of the environmental initiative block, some are characterized by disincentive features. This includes, in particular, the share of stranded environmental costs (environmental fines, penalties, other sanctions) and the share of running NE (nature environment) protection costs, as its growth indicates the obsolescence of cleaning equipment and low efficiency. Other indices of the environmental initiative block are characterized by an incentive impact on the resultant index, proceeding from their mathematical expressions. Following the strategy of cleaner production, which is expressed in waste management, reducing emissions into the atmosphere and water is considered the main area of implementation of the environmental duty of industrial enterprises. It should be stressed that in recent years a high interest in the implementation of measures to improve energy efficiency, due to high prices for fuel and energy resources has become a characteristic feature for industrial enterprises.

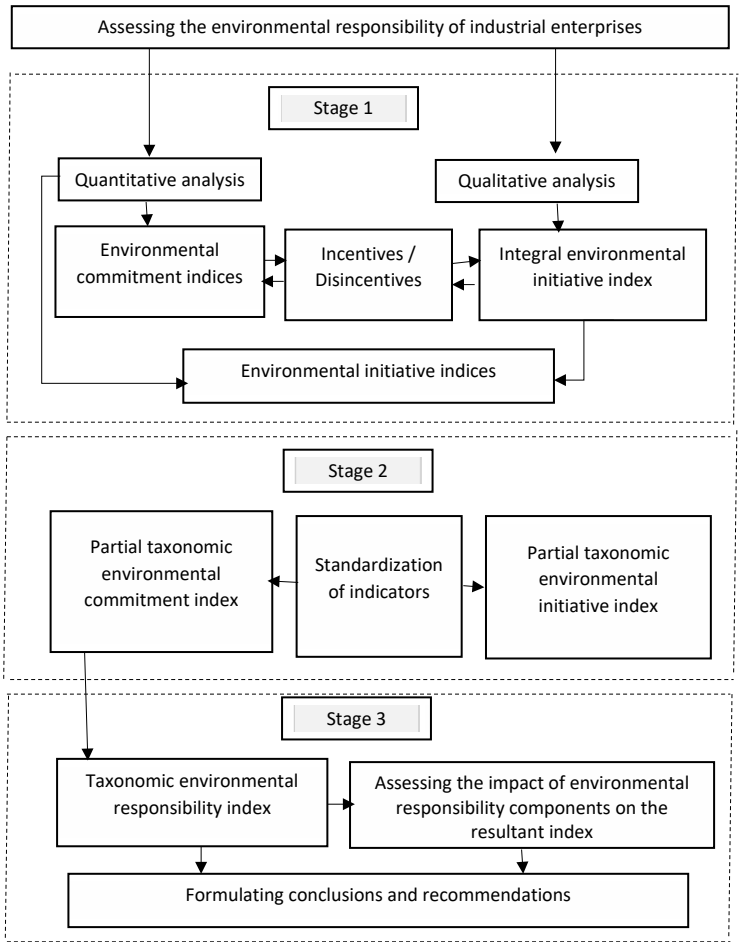


Fig. 2: Stages of assessing the environmental responsibility of industrial enterprises

This conditioned the inclusion of the coefficients of waste intensity for emissions into the environment by categories of "atmospheric air", "water", and "wastes", the coefficient of waste utilization, energy intensity of production (Table 2) in the system of indicators of the bloc of environmental duty.

Nevertheless, the indicators of efficiency of a system of environmental management should be included in the indicators of the block of environmental initiative as presence of environmental management at an enterprise allows to speak about the sufficient level of environmental responsibility. Thus, these indicators include indicators of the structure of environmental costs, namely capital investments, current environmental protection costs, the coefficient of environmental damage as an indicator of compliance with environmental legislation, which is also a result of the implementation of an environmental management system (Table 3).

Summing up the above, it should be note that all the criteria for the level of environmental responsibility of industrial enterprises are suggested to be divided into two groups — those, which are related to environmental obligations, in other words to environmental responsibility, and those, which are related to the own environmental initiative of a company and defined as voluntary. The environmental duties of an industrial enterprise include responsibility for environmental damages caused by production activities, compliance with environmental regulations and limits on emissions to NE. The group of criteria for own environmental initiative should include

two subgroups of indicators — activities concerning protection and restoration of the damaged nature environment, the existence of environment quality monitoring system, environmental management system, and the effectiveness of communication with stakeholders. The results of the calculation of the integrated indicator of the environmental initiative for 2012-2018 are given in Table 4.

However, in addition to the directly integrated indicator of environmental initiative, considerable

Table 2: Indicators for assessing the level of environmental responsibility of industrial enterprises — block of environmental commitment

Indicator name (y_{ik}), nature of impact on the level of environmental responsibility (stimulator/disincentive)	Calculation procedure	Notations
Coefficient of waste intensity by category of "air emissions", stimulator, (y_1)	$y_1 = 1 - \frac{W_A}{P}$, $y_1 \to 1$	W_A — total air emissions, thousands of tons; P — volume of manufactured products, thousands of tons
Coefficient of waste intensity by category of "discharges into water bodies", stimulator, (y_3)	$y_2 = 1 - \frac{W_o}{P}$, $y_2 \to 1$	W_0 – total discharges into water bodies, thousands of tons
Coefficient of waste intensity by category of "waste", stimulator, (y_3)	$y_3 = 1 - \frac{W}{P}$, $y_3 \to 1$	W — total wastes, thousands of tons
Coefficient of waste utilization, stimulator, (y_4)	$y_4 = \frac{W_w}{W}$, $y_4 \to 1$	W_w — volume of waste used, thousands of tons
Coefficient of energy intensity of production, stimulator, (y_5)	$y_5 = 1 - \frac{E}{C}$, $y_5 \to 1$	E — energy costs for the manufacture of products, thousands of euros; C— net cost of manufactured products, thousands of euros

Table 3: Indicators for assessing the level of environmental responsibility of industrial enterprises — block of environmental initiative

Indicator name (y_{ik}), nature of impact on the level of environmental responsibility (stimulator/ destimulator)	Calculation procedure	Notations
Share of capital investments in environmental measures in the total costs of NE protection, stimulator, (y_6) Share of current costs for NE protection in the total costs of NE protection, destimulator, (y_7) Share of unrecovered environmental costs paid from profits, destimulator, (y_8)	These indicators will enable management to assess the operation of the environmental management system, the level of implementation of objectives of enterprise "greening", to monitor the costs of NE protection, and to analyze the relationship of environmental characteristics with financial and economic indicators of an enterprise.	
Coefficient of environmental loss capacity of production, stimulator, (y_9)	$y_9 = 1 - \frac{T+S}{C}$, $y_9 \to 1$	T— amount of accrued environmental tax, thousands of euros; S — sanctions for violation of environmental legislation, thousands of euros.
Integrated indicator of environmental initiative, stimulator, (y_{10})	It reflects the activities of an enterprise for the implementation of self-initiated measures to protect the environment. It includes expert assessments of measures to compensate the community for losses from NE pollution, optimization of waste management, the state of the surrounding area in the sanitary zone of an enterprise, etc.	

attention should also be paid to the environmental costs of industrial enterprises (Table 5), priority areas of environmental financing.

At the fourth stage, one constructs the benchmark vector of development with coordinates r_{0_t}. It also involves determination of the taxonomic environmental responsibility index for Volkswagen Aktiengesellschaft for the period 2012-2018. First of all, one should form an observation matrix (Table 6).

To convert the observation matrix into a dimensionless form, it is necessary to standardize its elements using the equations (1-3) to obtain a new matrix (Table 7). In accordance with the results of grouping indices into incentives and disincentives with the help of the equations (4-6), one forms a reference vector with the corresponding coordinates: D_0 =(1.179; 1.392; 1.501; 1.556; 1.274; 1.689; -0.897; -1.328; 1.603; 1.018).

Based on the calculated values, one determined the distance between the elements of a standardized matrix and the elements of the reference vector using Formula 8. Further calculations of intermediary indices and the taxonomic index, which reflects the dynamics of environmental responsibility in 2012-2018, were conducted using the Excel software package and are shown in Table 8.

As a result of the made analysis of the assessment of the levels of significance of the suggested categories, the following conclusions can be drawn. Experts have identified the following most important assessment categories, which have the greatest impact on the level of environmental initiative of an enterprise: activities to compensate the community for environmental damage, protection of air and

Table 4: Data for the analysis of the block of ecological initiative of the enterprise under study for 2012–2018

Environmental costs, thousands of euros	2012	2013	2014	2015	2016	2017	2018
Environmental payments	69,300.0	82,100.0	96,100.0	148,300.0	145,850,0	193,715.7	216,961.6
including fines, sanctions	19,000.0	22,620.0	32,650.0	45,300.0	73,000.0	0.0	0.0
Capital investment in environmental measures	235,469.0	307,600.0	289,102.0	693,883.0	1,034,304.0	430,945.6	486,968.5
Current costs of NE protection	26,984.5	21,612.1	16,707.1	12,114.0	18,384.1	15,331.8	16,865.0
Total costs of NE protection	331,753.5	411,312.1	401,909.1	854,297.0	1,198,538.1	639,993.1	720,795.1
Costs by category, thousands of euros	2011	2012	2013	2014	2015	2016	2017
Atmospheric air protection	142,000.0	237,200.0	325,600.0	718,400.0	730,250.0	209,957.6	228,853.8
Return water treatment	55,000.0	36,500.0	29,800.0	24,100.0	30,080.0	8,793.0	9,408.5
Waste management	78,000.0	106,600.0	133,800.0	161,000.0	169,000.0	22,636.1	269,935.0
Environmental management	7,600.0	10,800.0	7,200.0	5,900.0	5,500.0	372.5	383.7

Table 5: Coefficients characterizing the level of environmental initiative of the enterprise under study for 2012–2018

Indicators	2012	2013	2014	2015	2016	2017	2018
Share of capital investments in environmental measures in the total costs of NE protection	0.710	0.748	0.719	0.812	0.863	0.673	0.676
Share of current costs of NE protection in the total costs of NE protection	0.081	0.053	0.042	0.014	0.015	0.024	0.023
Share of unrecovered environmental costs	0.274	0.276	0.340	0.305	0.501	0.000	0.000
Coefficient of environmental loss capacity of production	0.996	0.997	0.997	0.996	0.997	0.996	0.996
Integrated indicator of environmental initiative	0.361	0.305	0.401	0.508	0.489	0.546	0.549

Table 6: Observation matrix for the assessment of environmental responsibility

	Indicators	2012	2013	2014	2015	2016	2017	2018
Environmental commitment block	Atmospheric emission capacity index (y_1)	0.949	0.955	0.956	0.963	0.963	0.968	0.967
	Waste water discharge capacity index (y_2)	0.590	0.537	0.598	0.586	0.426	0.505	0.509
	Waste capacity index (y_3)	0.071	0.053	0.046	0.050	0.014	0.143	0.174
	Waste utilization index (y_4)	0.586	0.528	0.552	0.552	0.615	0.749	0.728
	Product's energy-output ratio index (y_5)	0.885	0.876	0.880	0.887	0.897	0.883	0.900
Environmental initiative block	Share of capital investment in nature protection measures (y_6)	0.730	0.748	0.719	0.812	0.863	0.673	0.676
	Share of running NE protection costs (y_7)	0.061	0.053	0.042	0.014	0.015	0.024	0.023
	Share of stranded environmental costs (y_8)	0.374	0.276	0.340	0.305	0.501	0.201	0.302
	Product's ecological loss capacity index (y_9)	0.994	0.997	0.997	0.996	0.997	0.996	0.996
	Integral environmental initiative index (y_{10})	0.461	0.305	0.401	0.508	0.489	0.546	0.549

Table 7: Standardized matrix for the assessment of environmental responsibility

	Indicators	2012	2013	2014	2015	2016	2017	2018
Environmental commitment block	(y_1) incentive	-1.574	-0.775	-0.597	0.373	0.475	1.079	1.018
	(y_2) incentive	-0.474	0.027	1.140	1.292	-1.657	-0.206	-0.122
	(y_3) incentive	0.163	-0.490	-0.619	-0.538	-1.175	1.057	1.601
	(y_4) incentive	-1.140	-0.726	-0.488	-0.485	0.133	1.458	1.247
	(y_5) incentive	0.730	-1.336	-0.901	-0.140	0.948	-0.575	1.274
Environmental initiative block	(y_6) incentive	-0.468	0.068	-0.334	0.974	1.689	-0.981	-0.949
	(y_7) disincentive	1.958	0.677	0.227	-0.897	-0.849	-0.496	-0.519
	(y_8) disincentive	0.165	0.183	0.535	0.347	1.416	-1.328	-1.328
	(y_9) incentive	-0.076	1.603	0.347	-1.734	0.243	-0.478	0.096
	(y_{10}) incentive	-0.941	-1.525	-0.524	0.591	0.393	0.987	1.018

water bodies used by enterprises, the effectiveness of environmental management and environmental audit. It is a matter of deep concern that the survey showed the lowest level of satisfaction with these indicators. Therefore, the data obtained during the study can be used to assess the level of environmental initiative of industrial enterprises in terms of the implemented measures and their level of significance directly for a particular enterprise and local community. The integrated indicator of the environmental initiative is within (0; 1) and is interpreted as follows: the higher the indicator, the higher the level of environmental

initiative of the industrial enterprise under study. Thus, using the suggested methodology, one obtained the partial taxonomic indices of environmental commitment and environmental initiative for the researched enterprises, as well as the overall taxonomic environmental responsibility index. Since the taxonomic indicators of the level of ecological responsibility of the studied industrial enterprises have multi-directional dynamics, one considers it appropriate to use the method of economic and mathematical modeling for the explanation of the influence of the blocks of environmental responsibility and environmental initiative on the resulting indicator (Gast *et al.,* 2017). One of the possible ways to evaluate the quality of property package for result analysis is to apply generalized Harrington desirability function (Bombiak and Marciniuk-Kluska, 2018; Cai *et al.,* 2018). The interpretation of obtained results using this approach is one of the easiest ways to transform the natural values of individual responses into the dimensionless scale of desirability and priority (Xu *et al.,* 2020). To construct a generalized function means to generate the obtained values of property indices (which have different units of measurement, including qualitative, esthetic, psychological and personal features) into a dimensionless desirability scale. The function of the desirability scale is to set up a correspondence between the obtained values of property indices and expert's evaluations of desirability for a particular index. A standard scale contains five valuation levels in the total range from 0 to 1, which reflect different desirability rates. The value 0.37 is a critical point, where unsatisfactory indices turn into satisfactory ones. The distinct advantage of this scale in the interpretation of the numerical values of environmental responsibility is its versatility, the ability to evaluate calculated data in a quality manner for separate companies and the entire industry. The desirability scale has a range from 0 to 1. Under this approach to valuation, it is convenient to use the additional scores 0.2 and 0.8 to make the desirability function more "sensitive" to the changes of informative index x within the "satisfactory" area and less sensitive out of it. Then, one should analyze the values and dynamics of calculated environmental responsibility indices. Table 4 shows that the environmental responsibility of Volkswagen Aktiengesellschaft in the period 2012-2018 was at the sufficient level. Since the taxonomic indicators of the level of ecological responsibility of the studied industrial enterprises have multi-directional dynamics, one considers it appropriate to use the method of economic and mathematical modeling for the explanation of the influence of the blocks of environmental responsibility and environmental initiative on the resulting indicator. As noted in (Sharma and Gupta, 2020), multiplicative models, and Cobb–Douglas production function, in particular, reflect the development of socio-economic systems in the most objective way, avoiding the influence of subjective factor. It helps to detect isolated factors influencing the resultant index, which is the objective of this study. For the given two-factor regression, the partial elasticity coefficient indicates, how much the taxonomic environmental initiative index will change in percentage terms, if one of the factors changes by one percent while the other factor keeps the constant values. It helps to identify leaders and outsiders in the field of corporate environmental responsibility and provides a basis for the construction of development benchmark vectors, taking into account ecological factors. To implement environmental responsibility policy at an industrial enterprise one should coordinate objectives, tasks, areas of activity for the whole range of its subsystems. The deliberate integration of environmental responsibility principles into the enterprise development strategy requires designing a coherent, systematic plan for achieving this aim. The procedure of implementing environmental responsibility at an industrial enterprise should therefore take place according to a certain scheme. To implement environmental responsibility at an industrial enterprise, the following steps must be taken: using the developed mechanism for its implementation, it is necessary to analyze the internal and external factors, which affect company's capability to undertake particular environmental activities. The next step is to examine the ability of an industrial enterprise to impose the key principles of environmental responsibility on economic activity. Provided that an enterprise is capable of environmental responsibility implementation, the next step would cover the search for methods and tools, the formation of an appropriate organizational-economic mechanism for ensuring environmental responsibility of industrial enterprises. The whole range of selected tools should be based on the well-defined information base of research. Thus, one

can proceed to the next step of the scheme, that is, the creation of the information base. The final step provides control over the effectiveness of previous steps.

The key outcomes, which can be achieved by implementing the system of environmental responsibility, include the following:

- improvement of the natural environment;
- reduced number of fines and penalties for the violations of established limits on discharges into NE;
- improved communication with representatives of the external environment of an enterprise;
- positive environmentally-conscious reputation of a company;
- optimization of investment policy in the field of NE protection;
- higher environmental compatibility of enterprise's production system.

Particular attention should be put to the implementation of the developed environmental responsibility system into the general development strategy. Talking about a large industrial company, when designing its strategy, one often defines the key directions for the development, upon which separate mini-strategies are similarly being designed and further integrated into the general one, therefore implementing the integrated approach to solving this task. One of the key factors, which influence the choice of a development strategy for any industrial company, is competitive growth. For industrial enterprises, the ecological compatibility of production systems and demonstration of environmental responsibility serve as one of such factors. However, the major problem for the existing types of development strategies is still the lack of a long-term vision of the environmental component. It is obvious that designing an organization's development strategy from the perspective of environmental responsibility concept is that integrant, which is essential for the fulfilment of core business tasks.

As it is commonly known, the concept of an environmentally responsible industrial enterprise involves the existence of a separate environmental strategy, which is part of its overall development strategy. A decision to develop such a strategy is usually enhanced by the following facts:

- consumer requirements for the open information about the ecological safety of production are increasingly spreading out across the world;
- banks and insurance organizations take into account company's business reputation, which includes its ecological status when making decisions on granting of credits or choosing an insurance policy;
- ecological control, provided by the government, is getting increasingly tightened;
- strengthening the international standards of environmental management, etc.

Thus, the organizational-economic system for ensuring the environmental responsibility of an industrial enterprise should become an integral part of its development strategy. When designing the development strategy of an industrial enterprise, which is aimed at adherence to the concept of environmental responsibility, it is essential to take into account not only external factors, which reflect the state control, consumer opinion, ecological status of competitors, but also observe the internal principles of ecological safety. Only in this case, an organization will be able to achieve balanced environmental management and economic growth at the same time (Fig. 3).

Thus, designing an organization's strategy following the environmental responsibility principles is that integral part of its general economic policy, without which it is impossible to meet the targets of economic development for a separate enterprise and a country as a whole. When choosing a strategy for the development of industrial enterprises, one should take into account regional ecological development strategies. In fact, the harmonious combination of ecologization tasks at the local and regional levels makes it possible to achieve sustainable socio-economic development. Thus, the adjustment of an enterprise's development strategy should be made in two directions – in accordance with the level of industrial enterprise's environmental responsibility and taking into account the ecological living conditions of inhabitants in a particular region. Inhabitants, who live in districts with different living conditions, will have consequently different requirements for the development of their settlement areas and, accordingly, for the main industrial enterprises-pollutants of the environment. Thus, the inhabitants of areas with worsened and strained living conditions will demand ecologization strategy and environmental improvement, while

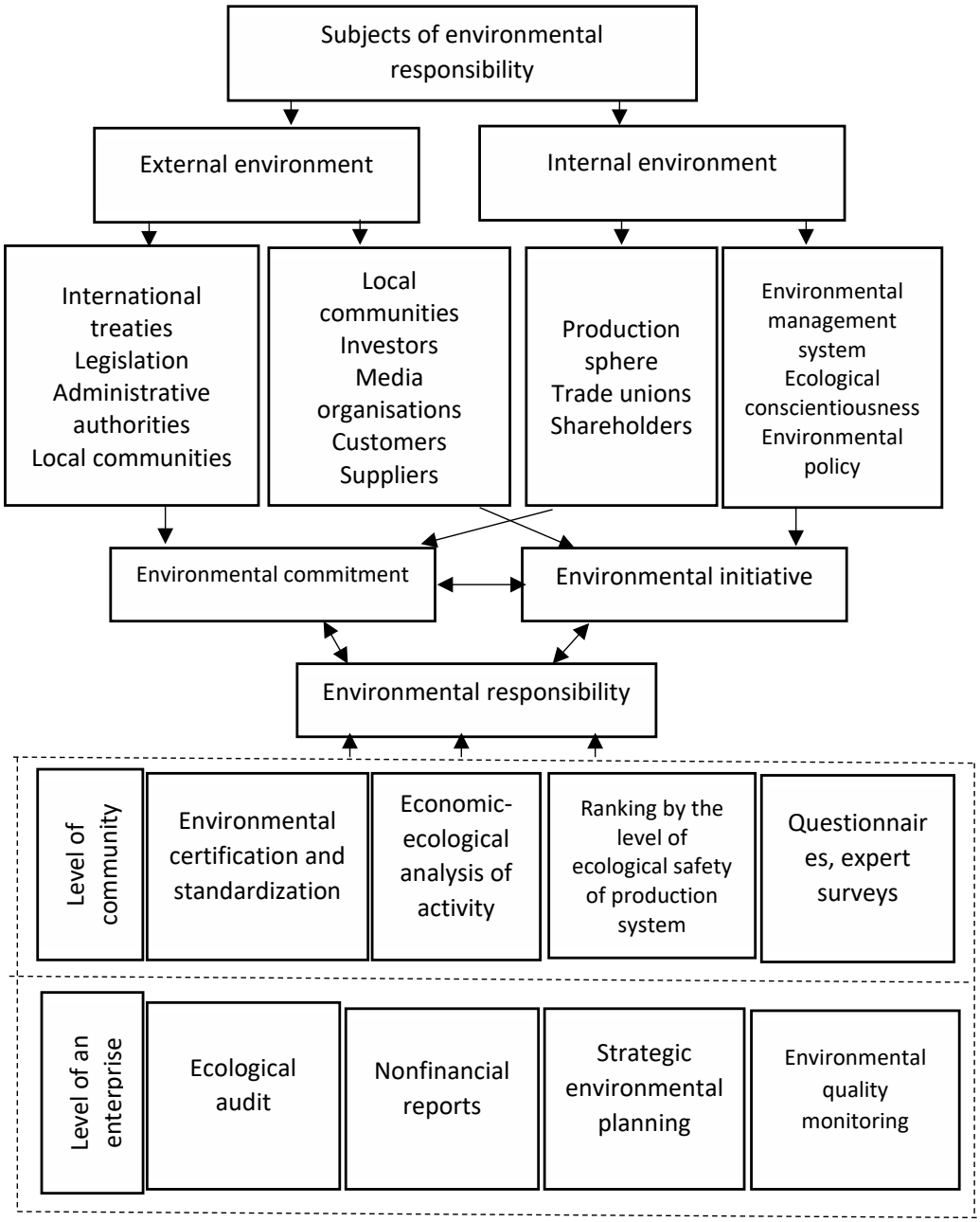


Fig. 3: Organizational-economic support of environmental responsibility of industrial enterprises

the local communities in areas with satisfactory living conditions will pay greater attention to environmental initiatives, the implementation of new environmentally friendly ways to manufacture products at industrial enterprises. In the light of the above, it becomes evident that the type of the development strategy of an enterprise is related to its environmental responsibility level and the ecological living conditions of inhabitants since the community acts as a full participant in the process of designing

Table 8: Taxonomic indices of environmental responsibility, environmental commitment and environmental initiative for the period 2012-2018

Indicators	2012	2013	2014	2015	2016	2017	2018
Overall taxonomic environmental responsibility index	0.683	0.673	0.678	0.684	0.691	0.701	0.712
Partial taxonomic environmental commitment index	0.618	0.591	0.598	0.585	0.538	0.614	0.679
Partial taxonomic environmental initiative index	0.668	0.690	0.684	0.745	0.653	0.632	0.683

Table 9: Ecological strategy for the development of industrial enterprises*

level of environmental responsibility	Areas of enterprise activity	Type of an ecological strategy	Type of territory depending on ecological living conditions
Unsatisfactory (0-0.37]	Purification of emissions, discharges, development of a strategy concerning waste management at the end of the manufacturing-technological cycle. Undertaking pollution abatement measures. Compliance with the requirements for disclosure of external environmental reporting.	Protective strategy Regulatory environmental management	3.4
Satisfactory (0.37-0.63]	Reduction of emissions to the regulatory level. Internal ecological audit (of different types and purposes). Long-term environmental measures, including technological changes. Responsibility of department managers to uphold ecological parameters of the production system.	Compensation strategy (sufficiency strategy) Effective environmental management	2.3
Sufficient (above 0.63)	Preventive reduction of environmental emissions. Adherence to the eco-standards of the products in the international markets. Including the concept of sustainable development in the company's reporting. External and internal ecological audit of the enterprise.	Proactive strategy (balanced nature management strategy) Management of the environmentally responsible organization	1; 2; 3

*All regions of the country were divided into 4 groups according to the level of favourable living conditions: 1- satisfactory conditions; 2- worsened conditions; 3 – strained conditions; 4- ecological disaster zone.

and implementing the environmentally-friendly strategy for the development of industrial enterprises. Thus, the choice of a development strategy for an industrial enterprise should be adjusted, having into consideration its environmental responsibility level and the ecological conditions of the region. An enterprise, which only adheres to the regulatory requirements for ecological quality (sufficiency strategy), can not have a high level of environmental responsibility. Moreover, against the background of increasing ecological decay, the reduction of emissions to the efficacy level (compromise strategy) is only a mean step of environmental responsibility. To this end, the environmental situation in the regions of Poland and Germany, where the enterprises of Volkswagen Aktiengesellschaft are located, was analyzed in terms of territorial concentration of production, economic development of land, population density, environmental pollution, the level of adverse natural and anthropogenic processes. All regions of the countries under study were divided into 4 types according to the level of favorable living conditions: 1 - satisfactory conditions; 2 - deteriorating conditions; 3 - stressful conditions; 4 - environmental disaster zone. A highly responsible industrial company in respect of the environment should be guided by the balanced

nature management strategy, which responds to the trends in the field of strategic management and sustainable development (Table 9).

In this way, the choice of ecological strategies for the development of industrial companies can have various scenarios. However, companies, possessing outmoded equipment and poor state of technology in use, are not able to perform the prompt implementation of the proactive strategy. For that reason, one highly recommends the researched industrial companies, ranking as temporarily satisfactory, to align with the compensation strategy. In addition, one considers it appropriate to formulate for each of the researched companies a set of recommendations for increasing their environmental responsibility level. The key advantages of each type of suggested development strategies in relation to the external and internal environment of the company are as; 1) sufficiency strategy – the reduction of costs, increase in transparency (public control); 2) compromise strategy – the social comprehensiveness, establishing a social dialogue with stakeholders; 3) balanced nature management strategy - uniqueness (the specific nature of organization), the efficient cooperation between the business community, government and public organizations. In general, to optimize the environmental losses of the enterprise, the following measures are recommended: accelerated depreciation of fixed assets, which have environmental significance (treatment facilities, environmental quality monitoring systems), as well as obsolete production equipment; material and intangible incentives for staff in the area of development of engineering solutions and innovation proposals for the greening of production activities and environmental management system, energy efficiency and optimization of waste management; compliance with ISO and EMAS standards in the area of environmental protection, control over the effectiveness of the system of environmental responsibility in enterprises using a number of scientifically sound indicators suggested in the study. It should be emphasized that in addition to optimizing the environmental strategy of an enterprise, these measures will create a positive image of a company, increase the competitiveness of products through "green" advantages, which is especially important in European markets.

CONCLUSION

Based on the conducted study, the following conclusions can be made.

1) The scientific-methodical approach to assessing the level of environmental responsibility of an industrial enterprise is substantiated, which provides for the calculation of the relevant taxonomic indicator taking into account the quantitative factors of its environmental commitment (taxonomic indicator of environmental commitment) and qualitative and quantitative factors of environmental initiative (taxonomic indicator of environmental initiative), as well as their stimulating or destimulating effect on the level of environmental responsibility of an industrial enterprise. 2) The thus obtained numerical values of the taxonomic indicator of the level of environmental responsibility of an industrial enterprise allow to assess its current state and determine the scope and nature of the impact of mandatory and initiative components on the overall level of environmental responsibility for further correction. 3) Based on a critical analysis of the content of development strategies of industrial enterprises in the environmental sphere, there was identified the need to take into account in these strategies the current level of their environmental responsibility differentiated by the desirability scale, and environmental living conditions in the cities where these enterprises are located. This makes it possible to take into account both economic and environmental-social factors when selecting an environmental strategy for the development of industrial enterprises. 4) The level of environmental responsibility of industrial enterprises taken into account when developing recommendations on adjustment of their environmental strategy of development is determined, which as a whole allowed to form organizational and economic support for environmental responsibility of the enterprises under study.

AUTHOR CONTRIBUTIONS

M. Pinskaya performed an experimental design and analyzed the data. O. Meleshchenko defined the concept and methodology of the research. O. Kovalchuk ranked the data into tables and figures. O. Karpenko performed the literature survey. E. Kompanets customized the manuscript to meet the requirements of the journal.

ACKNOWLEDGMENT

This study was carried out within the framework of the research project [0113UK007514] "Formation of a mechanism for effective regulation and management of activity of enterprises", The European Academy of Sciences LTD, London, UK.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

ABBREVIATIONS

b_0	Distance between separate point-units and the point D_0, which presents the development benchmark
C	Net cost of manufactured products, thousands of euros
D_0	Development benchmark
E	Energy costs for the manufacture of products, thousands of euros
EMAS	Eco-Management and Audit Scheme
Eqs.	Formula
ER	Corporate Environmental Responsibility
etc	And so on (et cetera)
f	Environmental responsibility dependence function
Fig.	Figure
Fp	Fisher's test
HR	Human resources
ISO	International Organization for Standardization
K	Concordance coefficient
k	Number of indicators
max	Maximum value
min	Minimum value
n	Interval value
NE	Nature environment
P	Volume of manufactured products, thousands of tons
R^2	Determination coefficient
r_{ik}	Standardized value of the index *k* for the unit *i*
S	Sanctions for violation of environmental legislation, thousands of euros
	The amount of accrued environmental tax, thousands of euros
t	Time lag
V_0	Standard deviation of the index b_{i0}
V_k	The standard deviation of the index k
W_A	Total emissions into the atmosphere, thousands of tons
W_0	Total discharges into water bodies, thousands of tons
W	Total wastes, thousands of tons
W_w	Volume of waste used, thousands of tons
y_1	Atmospheric emission capacity index
y_2	Wastewater discharge capacity index
y_3	Waste capacity index
y_4	Waste utilization index
y_5	Product's energy-output ratio index
y_6	Share of capital investment in nature protection measures
y_7	Share of running NE protection costs
	Share of stranded environmental costs
y_9	Product's ecological loss capacity index
y_{10}	Integral environmental initiative index
y_{ik}	Value of the index *k* for the unit *i*
$\overline{y}_k$	The arithmetic mean value of the index k
z	Integer

REFERENCES

Anthony, B.J.; Majid, M.A., (2016). Development of a green ICT model for sustainable enterprise strategy. J. Soft Comput. Decis. Support Syst., 3(3): 1-12 **(12 pages).**

Bombiak, E.; Marciniuk-Kluska, A., (2018). Green human resource management as a tool for the sustainable development of enterprises: Polish young company experience. Sustainability, 10(6): 1739-1749 **(11 pages).**

Borland, H.; Ambrosini, V.; Lindgreen, A.; Vanhamme, J., (2016). Building theory at the intersection of ecological sustainability and strategic management. J. Bus. Ethics, 135(2): 293-307 **(15 pages).**

Cai, W.; Liu, C.; Zhang, C.; Ma, M.; Rao, W.; Li, W.; Gao, M., (2018). Developing the ecological compensation criterion of industrial solid waste based on emergy for sustainable development. Energy. 157: 940-948 **(9 pages).**

Cao, S.; Shang, D.; Yue, H.; Ma, H., (2017). A win-win strategy for ecological restoration and biodiversity conservation in Southern China. Environ. Res. Lett., 12(4): 404-411 **(8 pages).**

Domenech, T.; Bahn-Walkowiak, B., (2019). Transition towards a resource efficient circular economy in Europe: policy lessons from the EU and the member states. Ecol. Econ., 155: 7-19 **(13 pages).**

Sharma, G.; Gupta, S., (2020). Modelling the impact of corporate sustainability on economic performance with reference to Indian financial industry. World Rev. Entrepreneurship, Manage. Sustainable Develop., 16(3): 317-328 **(12 pages).**

Xu, F.; Yang, M.; Li, Q.; Yang, X., (2020). Long-term economic consequences of corporate environmental responsibility: Evidence from heavily polluting listed companies in China. Bus. Strategy Environ., 29(6): 2251-2264 **(14 pages).**

Elsawah, S.; Pierce, S.A.; Hamilton, S.H.; Van Delden, H.; Haase, D.; Elmahdi, A.; Jakeman, A.J., (2017). An overview of the system dynamics process for integrated modelling of socio-ecological systems: Lessons on good modelling practice from five case studies. Environ. Model. Software. 93: 127-145 **(19 pages).**

Fujii, H.; Managi, S., (2016). Research and development strategy for environmental technology in Japan: A comparative study of the private and public sectors. Technol. Forecast. Soc. Change, 112: 293-302 **(10 pages).**

Gast, J.; Gundolf, K.; Cesinger, B., (2017). Doing business in a green way: A systematic review of the ecological sustainability entrepreneurship literature and future research directions. J. Cleaner Prod., 147: 44-56 **(13 pages).**

Graafland, J.J., (2018). Ecological impacts of the ISO14001 certification of small and medium sized enterprises in Europe and the mediating role of networks. J. Cleaner Prod., 174: 273-282 **(10 pages).**

Hadj, T.B., (2020). Effects of corporate social responsibility towards stakeholders and environmental management on responsible innovation and competitiveness. J. Cleaner Prod., 250: 119-130 **(12 pages).**

Hovardas, W.; Jiang, R.; Yang, C.; Zhang, F.; Su, M.; Liao, Q., (2016). Establishing an ecological vulnerability assessment indicator system for spatial recognition and management of ecologically vulnerable areas in highly urbanized regions: A case study of Shenzhen, China. Ecol. Indic., 69: 540-547 **(8 pages).**

Hovardas, T., (2016). Two paradoxes with one stone: A critical reading of ecological modernization. Ecol. Econ., 130: 1-7 **(7 pages).**

Ji, X.; Long, X., (2016). A review of the ecological and socioeconomic effects of biofuel and energy policy recommendations. Renewable Sustainable Energy Rev., 61: 41-52 **(12 pages).**

Jiang, Z.; Ding, Z.; Zhang, H.; Cai, W.; Liu, Y., (2019). Data-driven ecological performance evaluation for remanufacturing process. Energy Convers. Manage., 198: 111-124 **(15 pages).**

Jovovic, R.; Draskovic, M.; Delibasic, M.; Jovovic, M., (2017). The concept of sustainable regional development–institutional aspects, policies and prospects. J. Int. Stud., 10(1): 255-266 **(12 pages).**

Malá, D.; Sedliacikova, M.; Dušak, M.; Kaščáková, A.; Musová, Z.; Klementová, J., (2017). Green logistics in the context of sustainable development in small and medium enterprises. Drvna industrija: Znanstveni časopis za pitanja drvne tehnologije, 68(1): 69-79 **(11 pages).**

Panyam, V.; Dave, T.; Layton, A., (2018). Understanding ecological efficiency and robustness for network design using thermodynamic power cycles. In ASME 2018 international design engineering technical conferences and computers and information in engineering conference. American Society of Mechanical Engineers Digital Collection. 110-118 **(9 pages).**

Sáez-Martínez, F.J.; Díaz-García, C.; Gonzalez-Moreno, A., (2016). Firm technological trajectory as a driver of eco-innovation in young small and medium-sized enterprises. J. Cleaner Prod., 138: 28-37 **(10 pages).**

Singh, S.; Olugu, E.U.; Musa, S.N., (2016). Development of sustainable manufacturing performance evaluation expert system for small and medium enterprises. Procedia CIRP, 40: 608-613 **(6 pages).**

Chen, Z.; Hamilton, T., (2020). What is driving corporate social and environmental responsibility in China? An evaluation of legacy effects, organizational characteristics, and transnational pressures. Geoforum, 110: 116-124 **(9 pages).**

Wang, Q.; Qiu, S.; Yuan, X.; Zuo, J.; Cao, D.; Hong, J.; Zheng, Y., (2016). Stability of ecological industry chain: an entropy model approach. Environ. Sci. Pollut. Res., 23(14): 14316-14326 **(11 pages).**

Wang, Q.; Yuan, X.; Zuo, J.; Zhang, J.; Hong, J.; Lin, C., (2016). Optimization of Ecological Industrial Chain design based on reliability theory–a case study. J. Cleaner Prod., 124: 175-182 **(8 pages).**

Wilmer, H.; Augustine, D.J.; Derner, J.D.; Fernández-Giménez, M.E., Briske, D.D.; Roche, L.M.; Miller, K.E, (2018). Diverse management strategies produce similar ecological outcomes on ranches in Western Great Plains: social-ecological assessment. Rangeland Ecol. Manage., 71(5): 626-636 **(11 pages).**

Zare, R.; Nouri, J.; Abdoli, M.A.; Atabi, F., (2016). Application integrated fuzzy TOPSIS based on LCA results and the nearest weighted approximation of FNs for industrial waste management-aluminum industry: Arak-Iran. Indian J. Sci. Technol., 9(2): 2-11 **(10 pages).**

Yue, B.; Sheng, G.; She, S.; Xu, J., (2020). Impact of consumer environmental responsibility on green consumption behavior in china: The role of environmental concern and price sensitivity. Sustainability, 12(5): 174-189 **(16 pages).**

AUTHOR (S) BIOSKETCHES

Pinskaya, M., Doctor of Economics, Associate Professor, Financial Research Institute of the Ministry of Finance of the Russian Federation, Moscow, Russian Federation. Email: *mily.pinskaya@mail.ru*

Meleshchenko, O., Doctor of Philology, Professor, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine. Email: *olexm@ukr.net*

Kovalchuk, O., Candidate of social communication, Assistant, Kyiv National University of Culture and Arts, Kyiv, Ukraine. Email: *kovalchuk77@ukr.net*

Karpenko, O., Doctor of Pedagogical Sciences, Professor, Dragomanov National Pedagogical University, Kyiv, Ukraine. Email: *karpenko@ua.fm*

Kompanets, E., Candidate of Agricultural Sciences, Associate Professor, Dragomanov National Pedagogical University, Kyiv, Ukraine. Email: *kompanets_e@i.ua*

COPYRIGHTS

©2021 The author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers.

HOW TO CITE THIS ARTICLE

Pinskaya, M.; Meleshchenko, O.; Kovalchuk, O.; Karpenko, O.; Kompanets, E., (2021). Modelling the impact of environmental responsibility on the development of enterprises. Global J. Environ. Sci. Manage., 7(4): 503-522.

DOI: 10.22034/gjesm.2021.04.02

url: https://www.gjesm.net/article_243912.html