

ORIGINAL RESEARCH PAPER

## Improvement of implementation processes of corporate environmental responsibility in conditions of urbanization

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### ABSTRACT

**BACKGROUND AND OBJECTIVES:** During the disclosure of the conceptual foundations of the environmental responsibility implementation in the functioning of corporations, the need to implement such approaches to conducting business activities that will provide rational usage of nature and balanced development of the national economy in accordance with the concept of sustainable development, where economic interests will be combined with ecological and social one, was identified.

**METHODS:** On the basis of mathematical modeling methods and the developed algorithm, proposals regarding the implementation of economic forms of corporate environmental responsibility are substantiated. In particular, the author proposed a methodology for determining the integral indicator, which in turn makes it possible to calculate the level of corporative environmental responsibility.

**FINDINGS:** In general, only 30-40% of corporations in Ukraine are environmentally responsible. In 2022, the share of implemented quality management and environmental protection certification systems among environmentally responsible corporations was 67%. The following indicators have the most significant positive influence on the change in the implementation level of corporate environmental responsibility: the number of certified quality management and environmental protection systems by Ukrainian corporations and the amount of current corporations' expenditures on environmental protection.

**CONCLUSION:** It has been suggested to stimulate the formation of corporate environmental responsibility system at the national level by developing and using effective financial and economic tools. This will make it possible to level the capabilities of corporations, introduce proven international standards and principles of environmental responsibility, and bring the national economy to the path of sustainable development.

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## INTRODUCTION

The problems of balanced and sustainable economy development, which have become especially urgent in recent years, point out the need to solve issues related to increasing the production efficiency of the economy corporate sector with the simultaneous improvement of the employees' social situation and the population of the region, where the main activities of corporations are carried out. The emphasis of many countries of the world on the innovative development of the economy, without which successful integration into the world economic system is impossible, reveals new issues connected with the corporations social and environmental responsibility to their employees and the state (Graafland and Noorderhaven 2018). Besides this, the development of each country's economy and its effective integration into the system of international relations require the announcement of strict requirements for the environmental safety of production and the development of effective economic implementation forms of the corporate environmental responsibility. According to the experience of the last decades (Chandna, 2017), the best results in ensuring sustainable economic growth were achieved by those countries that have managed to combine economic efficiency with social responsibility through the establishment of economic mechanisms with the simultaneous optimization of the social institutions activities, that act as a means of harmonizing the interests and purposes of subjects who interact in the process of economic activity. Therefore, not only the achievement of the main goals of human development is based on economic growth, but also economic growth, in turn, depends on social, demographic, cultural, political, environmental factors, etc. (Shubham et al., 2018). Nowadays, it is becoming obvious for corporate business that ensuring strong positions in the national and global economy is achieved through responsible entrepreneurship. Necessary aspects for ensuring responsible business include increasing openness and building balanced relationships with all those groups which are directly affected by the business, and, in turn, affect or depend on its success (Helfaya and Moussa 2017). This is actually one of the fundamental approaches to understanding the responsibility of business to society, that is, corporate social responsibility. This approach is

currently used by the majority of corporations (Chuang and Huang 2018) that are mainly industry leaders which have chosen a strategy of increasing openness and transparency, disclosing the results of their activities in non-financial reports, which are becoming an important element of the responsible business culture. This responsibility means the need to report to society for the economic, environmental, and social impact that occurs as a result of business activity (Tan et al., 2017). Thus, corporate social responsibility and environmental responsibility are important during the implementation of the sustainable development concept at the national level. Increasing level of environmental responsibility improves the corporations' efficiency both in the short- or in the long-term perspective (Zou et al., 2019). Therefore, Corporate Social Responsibility (CSR) and Corporate Environmental Responsibility (CER) are vital competitive factors. Since the level of corporate environmental responsibility, in the nearest future, will determine the company's position on the international market, as well as among consumers of its products (Han et al., 2019). In other words, environmental responsibility is the "entrance ticket" to the international business community. A decisive role in the implementation of CER is played by economic methods and tools, first of all, the creation of environmental funds and a system of material motivation for environmental protection activities (Li et al., 2017). The implementation of those tools will contribute to the improvement of the corporations' activities results, increase the efficiency of the management system, and will also form a positive corporations' image, expand the number of potential consumers at the expense of "environmentally conscious" buyers, as well as increase the corporations' competitiveness. In the process of forming the corporate environmental responsibility, a decisive role plays economic forms and tools, the implementation of which contributes to improving the corporations' activities results, increasing the efficiency of the management system, and forming a positive corporation image (Zou et al., 2019). There are two regulators groups of environmental behavior of economic entities. The first group is aimed at forcing environmental polluters to limit their ecologically destructive impact (Hartmann et al., 2017). In turn, the second group of regulators is aimed at encouraging nature users to improve the environment (Zare et

*al., 2016*). Society's awareness of responsibility for the state of the environment and natural resources for future generations necessitates the justification and implementation of ecological approaches to the operation of industrial corporations. These ecological approaches will ensure rational usage of nature and balanced ecological and economic development of the national economy. The global community is becoming more and more environmentally friendly, and consumer-oriented businesses take into account and support such changes by implementing the social responsibility concept. In the scientific literature, the general theoretical aspects of the corporate environmental responsibility are disclosed, however, not enough attention is paid to the analysis of the economic forms of the corporations' environmental responsibility and the justification of effective mechanisms for its implementation as integral prerequisites for the sustainable development of the national economy. This led to the search for ways to solve this problem and the choice of the research topic. The purpose of the study is to develop practical recommendations for the introduction of economic forms of implementation of corporate environmental responsibility. To achieve this purpose, the following tasks were set and solved: to develop a model of implementation of the principles of corporate social responsibility in the activities of Ukrainian corporations; using mathematical modeling methods, formulate proposals for the introduction of economic forms of implementation of environmental responsibility; justify ways to optimize the impact of corporations on the environmental situation in Ukraine. The study was conducted in Ukraine during the period of 2012-2022.

## **MATERIALS AND METHODS**

The theoretical and methodological basis of the research became the fundamental provisions of economic theory, the economics of enterprise management, the economics of nature usage, the theory of social and corporative environmental responsibility and sustainable development, as well as scientific works and methodological developments of leading scientists in the field of economic forms implementation of corporative environmental responsibility. Before moving on to modeling the implementation of CER in accordance with the economic functioning forms, it is necessary to define

a number of key concepts of this process. The main principles of modeling are: identifying the purpose of the model; identification of a limited number of factors that have a decisive influence on the system; establishing the type of the relationship between the selected factors; establishing the principle of connections multiplicity between factors and highlighting the main connections that determine the nature of the development and changes of this system. The essence of mathematical modeling lays in replacing the original object with its mathematical model and in further studying of the model with the help of computational logic algorithms. The criterion of the CER level, as a dependent variable, can be the ecological and economic state of the economic entity, in turn, the independent variables will be represented by macroeconomic indicators that affect the formation of the ecological and economic state of corporations through internal and external influence. The authors propose to divide the algorithm for mathematical modeling of CER implementation into ten stages ([Fig. 1](#)).

Stage 1. Identification of economic forms of implementing corporate environmental responsibility (conducting a comparative analysis of economic forms of the implementation environmental aspect of corporation's social reports, as well as researching the level of implementation of the product (service) quality system; development analysis of the social and ecological corporation infrastructure; assessment of the corporations' impact on the environment, etc.). Stage 2. Analysis of problematic cases and threats to the CER formation (objectively existing threatening factors in certain spheres of corporate enterprises activity, in particular, challenges of the competitive environment, economic, political, social and environmental risks). External (exogenous) threats that depend on the state and characteristics of the environment in which the corporation exists. The effect of external threats is not controlled by the corporation; therefore, they must be considered when making management decisions, and targeted efforts must be made to reduce their impact. Internal (endogenous) threats are mostly formed within the business entity, i.e. corporations can directly influence them. In order to be environmentally responsible, corporations must constantly face internal and external threats affecting its activities in the field of ecology. Each corporation must have

*Implementation of corporate environmental responsibility*

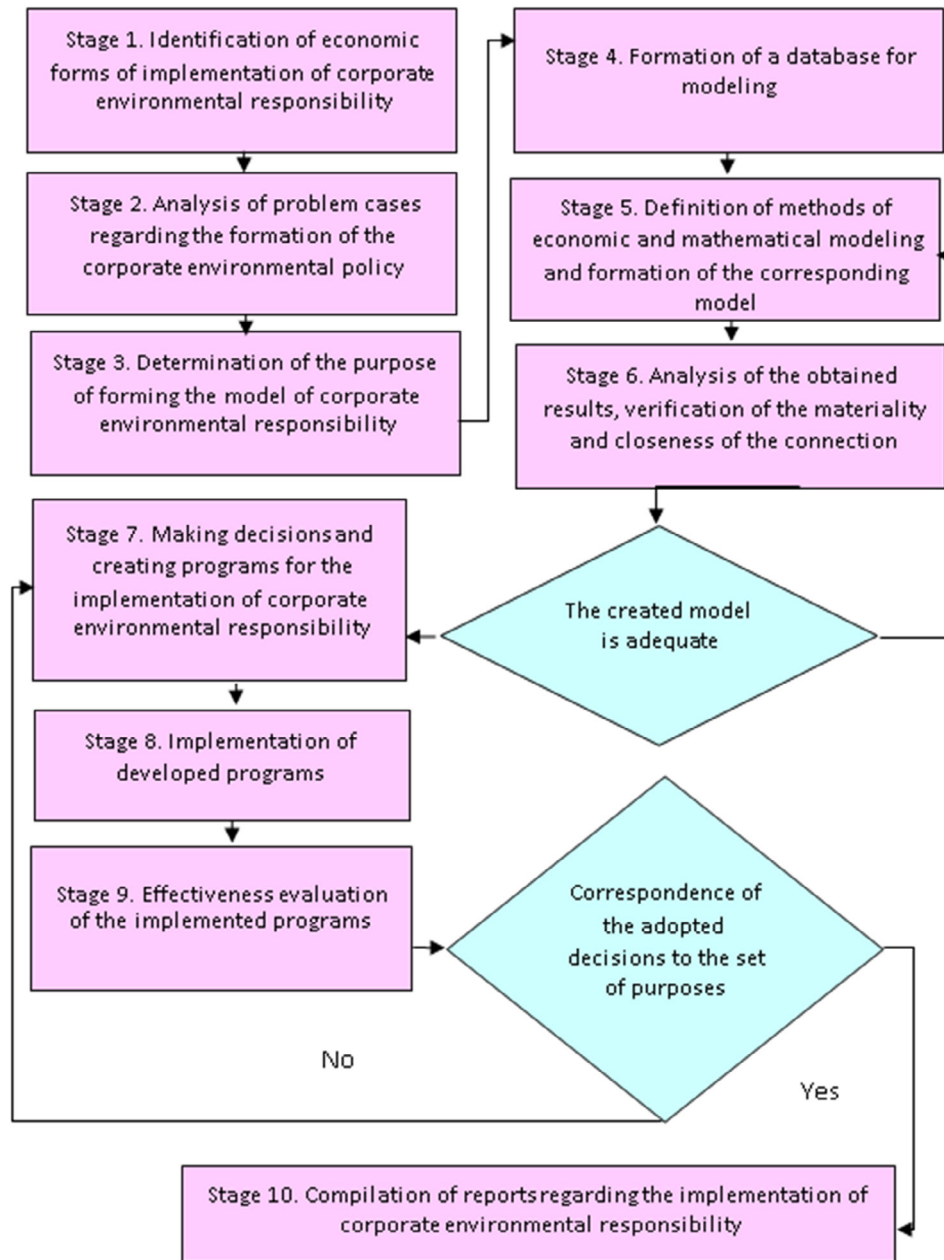


Fig. 1: Algorithm for step-by-step implementation of mathematical modeling regarding the implementation of corporate environmental responsibility

its own mechanism for environmental protection, which considers the size of the corporation, the field of its activity, and the level of corporate culture. However, most measures (elements of CER) to minimize the negative impact of their activities on the surrounding natural environment (SNE) are the

same for all organizations. Stage 3. Defining the purpose of the CER evaluation model (establishing mutually beneficial and long-term relations between all interested participants: consumers, management, state authorities, investors, shareholders, suppliers, partners, experts, public organizations, and other

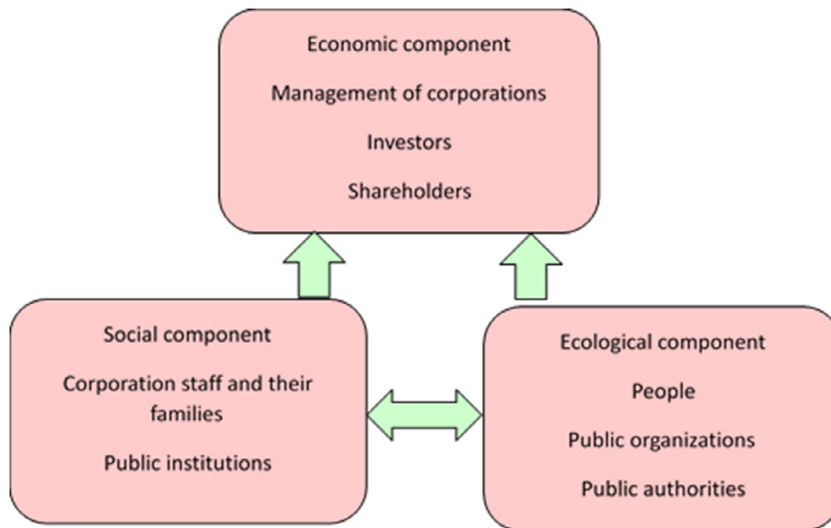


Fig. 2: Main categories of stakeholders involved into the process of CER implementation

participants) (Fig. 2).

Stage 4. Formation of indicators database for modeling (for developing and implementing the environmental responsibility of the corporation, it is necessary to form indicators system that will characterize various aspects of corporations' activities). Eventually, the system of these indicators determines the level of CER implementation (Wang et al., 2018). Stage 5. Determination of economic-mathematical modeling methods based on the specifics of the task, as well as the content of the modeling object (a number of mathematical modeling methods are represented by the method of expert evaluations, the method of principal components, the method of correlation-regression analysis, the method of taxonomic indicators, the method of potential, the method hierarchy analysis, center of gravity method, etc.). Formation of the CER implementation model is the final point of this stage. Stage 6. Analysis of the obtained results, as well as verification of the materiality, closeness of the connection, model adequacy. The purpose of the analysis of the obtained results is to assess the impact of factor characteristics on the resulting characteristic. This, in turn, will make it possible to monitor significant changes in the corporations' activities, and take them into account in the process of development, implementation, adaptation and

adjustment of environmental responsibility and CSR in general. The study of factor characteristics should be carried out systematically and comprehensively, as well as determine which of the factors have the most significant influence, and the change of which can cause potential threats or, on the contrary, create additional opportunities for corporations. Stage 7. Making decisions and development of programs for the CER implementation (for example, the final form of environmental responsibility functioning is a system of programs, the coordination of which gives a set of tasks and an "ecological order", taking into account the characteristics of each region, therefore targeted programming can become the main tool for the implementation of environmentally oriented corporate policy). Stage 8. Implementation of developed programs (program implementation process consists of consecutive stages, which are developed by specialists from CSR and finally approved by the management). Stage 9. Evaluating the effectiveness of the programs implemented. It is carried out, as a rule, using a system of statistical and socio-ecological indicators, including integral indicators, that summarize objective and subjective components of the ecological situation. Stage 10. Compilation of reports on CER implementation. Formed reporting is a tool for informing employees, shareholders, partners and society in general

about how exactly and how quickly the corporation implements the goals of environmental stability and social well-being laid down in its mission or strategic plans (the report can be presented in the form of an appropriate thematic section of the annual corporate report or in the form of a separate document describing the corporation's activities in the environmental sphere, i.e. a report on sustainable development). The disclosed problems of environmental responsibility in the report allows to justify the management's actions in order to improve or maintain a certain level of activities effectiveness. The corporation's management, in compliance with a model, analyzes the management system with a certain periodicity in order to ensure its relevance, adequacy and effectiveness. The task of the analysis is to evaluate the implementation of environmental policy tasks, including the following indicators: ensuring the environmental safety of production, reducing the impact on the environment. Therefore, the basis of the model regarding the implementation of corporations' environmental responsibility are the subjects of the corporate sector, whose interests are mutually determined and interconnected: economic, environmental and social interests of consumers, business, the state and members of society.

## RESULTS AND DISCUSSION

All developed countries of the world recognize the need for theoretical justification and financing of environmental policy, which, in turn, ensures the preservation of the natural environment, the rational usage of real and potential natural resources, the preservation of ecological balance and the provision of living conditions for society. Nowadays, many countries of the world have created national programs for environmental protection and rational usage of natural resources. They have a fundamentally new character compared to the previous nature protection policy, which had strict limits of action and was based on the concept of eliminating the consequences related with environmental damage. The basis of industrial policy in the sphere of environmental protection and its financing measures is the principle of a normative and qualitative state of the environment, which is ensured either by a system of norms and standards for the maximum allowable levels of anthropogenic load, the consist of pollution, emissions, or by a system of corporation's taxation

that allows non-compliance with the established requirements of nature usage. Both principles can be effectively combined. States use a variety of means in order to stimulate the private sector, encourage it to comply with new legislative norms. In total, there are more than 200 such mechanisms in the countries of the European Union, in particular: direct grants for the construction and operation of environmental protection equipment, as well as urban and rural water treatment facilities, which relieve industrial corporations from excessive costs; preferential provision of loans to the private sector; tax benefits system (Aguado and Holl 2018). The market mechanism of environmental protection activities, which includes the usage of environmental subsidies, loans, fees, fines, taxes, credits and quotas related to the emission of harmful substances, is becoming increasingly developed and widespread (Lee et al., 2018). They, in turn, make it possible to allocate financial resources and accumulate them in state accounts or in special funds. This is the practice in the USA, where private industrial capital receives a variety of assistance in the field of environmental (Yang and Liu 2018). State subsidies are of particular importance in this assistance. In addition to direct subsidies in the USA industry, indirect subsidies are also widely used: subsidies provided by municipalities are used for the construction of sewage treatment plants and processing of industrial waste, etc. Receiving subsidies is an encouraging mechanism for the further investment, which, in turn, leads to an increase of American corporations' current costs for environmental protection. Environmental subsidies take the form of innovation subsidies that cover part of the costs for the development of new technologies, and loans for environmental protection equipment, as well as for the restoration of environmental quality or subsidies to cover loans. Such a policy is typical for Austria, where, among other things, there is an investment premium for capital investments into nature protection (El Ghouli et al., 2018). In the Netherlands, at the expense of state funding, effective measures are being taken to reduce pollution and develop clean technologies. An additional discount (10-15%), compared to the usual tax discount on investment costs, is applied to specific investments in the field of reducing environmental pollution. Moreover, in many countries, such as: Denmark, Norway, Sweden, the Netherlands, Canada, the state

subsidizes the development of technologies, equipment, alternative energy supply sources, energy-saving measures (Jiang *et al.*, 2018). Tax reductions for more environmentally friendly cars are applied in Austria, Germany, Norway, Sweden and the Netherlands, this is an example of tax benefits. In the USA, as one of the forms of state subsidies, it is practiced to withdraw interest received on obligations from the total amount of taxes, the funds from which were directed to reducing pollution of land and water resources, atmospheric air, etc. (Orsdemir *et al.*, 2019). In Spain, along with tax benefits, special subsidies (up to 30% of investment costs) are provided for research activities in the areas of monitoring, emission reduction, and prevention of environmental pollution (Kim *et al.*, 2017). All subsidies, aimed at programs to prevent environmental pollution, are provided to corporations from the state budget or from special funds of the nature protection ministries. Thus, for example, in Austria, there is an environmental fund, in Sweden — a fund for prevention of contamination as a result of fuel burning, in Turkey — a fund for prevention of environmental pollution, etc. (Chen *et al.*, 2018). Additional motivation for corporations' environmental responsibility are the reduction of tax rates, as well as the provision of preferential state subsidies to corporations that make changes in their production process to reduce harmful emissions; encouraging the processes for improvement of automobiles with the purpose of environmental protection. Thanks to subsidies, financial institutions can perform functions similar to licensing. In most countries that use such subsidies, there are laws according to which non-fulfillment of the established requirements leads to the termination of financial assistance. Direct state funding of scientific developments and research is quite important for the improvement of environmental awareness of society. In the USA, almost three quarters of the Environmental Agency's scientific budget directs on contracts and subsidies for individual developments, which are carried out mainly in industry. In contrast to subsidies for treatment facilities and equipment, the right to receive them is given to demonstration projects (Choudri *et al.*, 2017). Lending is an important economic lever for regulating nature protection activities. In particular, some economists point out that the Federal Reserve System of the United States,

which concentrates all banking capital, should set higher interest rates on loans directed to "polluting" projects and provide certain benefits to industry and factories that develop environmentally friendly technology or install purification equipment (Wong *et al.*, 2018). Accelerated depreciation of purification equipment is considered an important lever for stimulating environmental protection activities in the USA. The tax reform law established three times shorter amortization term for purification equipment compared to industrial one. In addition to the 10% tax discount for investments into purification equipment in the USA, there are also other tax benefits (Zhang 2017). Along with incentives, there are coercive levers that are applied to violators of environmental norms and standards. First of all, this is a prohibition on the production of any chemical substances with increased toxicity, and also requirements on stopping emissions of pollutants in cities and areas where a critical sanitary and hygienic situation has emerged (Testa *et al.*, 2017). In some countries, a progressive tax has been established for industrial corporations that emit pollutants beyond the limits of permissible norms. A number of legislative norms define possible sanctions in case of non-compliance with established environmental norms, and in some cases even criminal liability or prohibition of the corporation's production activities may occur (Ruepert *et al.*, 2017). Integral components of CSR are the following: environmental protection, rational usage of natural resources, creation of appropriate conditions for corporation's environmental responsibility and human life. A corporation's environmental responsibility is an indicator of its corporate social responsibility. Environmentally responsible corporations comply with the norms of current environmental legislation, which, in turn, contributes to reducing costs from environmental pollution. The main axiom of nature management is the principle "ecologically- means economically", which is implemented by minimizing environmental damage, minimizing waste (Samimi and Nouri, 2023) and preventing environmental pollution (Table 1).

Environmental responsibility is gaining more and more importance in the activities of global corporations, it is reflected in reporting and is an integral component of corporate strategy. A positive trend is observed in Ukraine, because over the past

### Implementation of corporate environmental responsibility

Table 1: Corporations' benefits and losses depending on the level of environmental responsibility

Benefits of environmentally responsible corporations	Losses in business because of non-compliance with environmental requirements
Reduction of material losses due to reuse of recyclable materials and rational consumption of raw materials.	Excessive growth of material costs compared to competitors who use low- or no-waste technology
Reduction of production energy consumption, savings on lighting and heating.	Lagging behind in the field of promising scientific and research developments that contribute to the corporation's, compared to the similar development of competitors
Absence of unplanned expenses for payment of insurance	Worse opportunities to attract investors.
Recruitment of highly educated and qualified staff.	The growth of insurance costs.
Capital investment into promisingly profitable areas.	The increase in fines for violation of requirements, standards, etc.
Obtaining income from the sale of environmentally friendly products and/or the provision of environmental services.	Increased attention from the local authorities, as well as strict external control over the implementation of environmental standards.
Attracting "green consumers", increasing sales.	Worse conditions for employment of qualified personnel.
Strengthening the manufacturer's reputation, expanding the possibility of advertising goods and services on the market due to the usage of "green" marketing.	Loss of consumers who prefer to purchase ecologically safe goods and services.
Better cooperation with the local community.	Worsening of reputation. Unfavorable development perspective.

Table 2: Expert evaluation of the influence of socially responsible corporate activity on the implementation of the sustainable development principles in Ukraine

Potential consequences of socially responsible corporate activity	Probability, %
Caring for the environment, rational consumption and usage of natural resources	65.8
Social, economic and ecological balance and development	57.0
Improving population health, increasing life duration and labor activity	44.3
Activation of socially responsible activities of the state, society, business, and individuals in order to create conditions for sustainable development	43.7
The formation of a high values' system, as well as the cultural and spiritual development of human society	43.7
Use of resource-saving technologies in the production process	40.5
Modernization of social relations, consolidation of society and authorities' efforts in order to ensure sustainable development	39.2
Formation and implementation of a consumption model in compliance with the principles of sustainable development	26.6
High ranking of Ukraine in terms of sustainable development at the international level	12.0

two decades, the number of corporations participating in the policy of social responsibility has significantly increased. This is due to the following factors: a broad understanding of the connection between economic activity and issues of social development; recognition of the importance of risk management and an increasing awareness of the economic benefits that organizations can gain from integrating

social development policies into their strategies; the demands of stakeholders for corporations to provide the most transparent reporting system. Moreover, Ukraine belongs to those states that have taken a strategic course on introducing the sustainable development principles into the economic system (Table 2).

The method for determining the CER level of



Table 3: The initial data for calculating the level of environmental responsibility implementation of Ukrainian corporations

Initial data	Years									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
The number of environmentally responsible corporations (which form a report on sustainable development), units, $a_1$	184	195	190	226	245	259	324	334	350	261
Total number of corporations, units, $a_2$	782	789	802	806	812	802	852	836	717	637
The number of corporations involved into environmental protection activities, units, $a_3$	508	513	521	524	528	521	554	543	466	414
Capital investments from the corporations' own funds for environmental protection, million USD, $a_4$	241.76	524.6	515.6	538.36	466.04	1327.04	1165.2	1045.4	1177.8	684.8
The total amount of current expenditures on the protection and rational usage of natural resources, considering all financing sources, million USD, $a_5$	441.24	585.03	768.46	727.27	960.65	1127.94	1316.47	1357.91	1320.57	1615.55
The number of corporations' certified systems the field of environmental quality management and nature protection, units, $a_6$	45	60	70	73	105	146	171	300	328	339
The number of new low-waste, resource-saving, ecologically oriented technological processes implemented by corporations, units, $a_7$	341	551	597	670	396	434	471	419	364	375
The total amount of capital investments aimed at the protection of the natural environment, considering all sources of funding, million USD, $a_8$	161.42	250.07	315.14	246.07	218.14	587.1	600.93	545.88	737.99	709.56
Amount of current corporations' expenses for environmental protection, million USD, $a_9$	442.44	576.66	752.45	707.92	936.3	1097.88	1283.24	1319.55	1288.92	1576.21

Ukraine was formed. The initial data for evaluating the level of corporations' environmentally responsible activities are given in Table 3.

According to this methodology, the system of indicators for the analysis of environmentally responsible activities includes the following assessment criteria: the fullness of corporation's involvement into environmentally responsible activities; distribution range of economic forms

of environmental responsibility implementation; the degree of financial support for corporations' environmental responsibility (Table 4).

The conclusions of the conducted selective statistical study of Ukrainian corporations made it possible to interpret the trends of various indicators for all corporations of the country. In the author's opinion, the system of these indicators for assessing the corporations' level of environmental responsibility

Table 4: System of indicators for the analysis of corporations' environmental responsibility in Ukraine

Evaluation criteria	Indicator	Years									
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
The fullness of corporation's involvement into environmentally responsible activities	The specific weight of ecologically responsible (ER) corporations in their total number ( $a_1 / a_2 \times 100\%$ )	23.53	24.71	23.69	28.04	30.17	32.29	38.03	39.95	48.81	40.97
	The specific weight of the corporations' current expenditures for environmental protection in the total amount of current expenditures, considering various sources ( $a_9 / a_5 \times 100\%$ )	97.27	98.57	97.92	97.34	97.47	97.33	97.48	97.18	97.60	97.56
Distribution range of economic forms of environmental responsibility implementation	The average number of implemented quality management and environmental protection certification systems per unit of an ER corporation ( $a_6 / a_1 \times 100\%$ )	12.1	14.1	14.6	15.2	18.3	23.1	24.6	32.9	41.9	50.3
	The average number of resource-saving technologies per one ER corporation ( $a_7 / a_1$ )	1.85	2.83	3.14	2.96	1.62	1.68	1.45	1.25	1.04	1.44
The degree of financial support for corporations' environmental responsibility	The average amount of current expenditures on environmental protection per one corporation ( $a_9 / a_3$ )	0.870	1.124	1.443	1.351	1.774	2.106	2.317	2.428	2.766	3.807
	The level of financing of environmental activities by corporations ( $a_8 / a_4$ )	0.67	0.48	0.61	0.46	0.47	0.44	0.52	0.52	0.63	0.72

will contribute to the formation of a qualitative system of CSR in Ukraine. A comprehensive analysis of the calculated indicators revealed that Ukrainian corporations have an insignificant implementation level of the environmental component in their activities: only 30-40% of corporations from the total number are environmentally responsible; the share of implemented quality management and environmental protection certification systems among environmentally responsible corporations was 61% in 2019; the level of funding of environmental protection measures by Ukrainian corporations does not meet the real needs of investment in this area. It is hard to make an integral assessment of the implementation level of corporations' environmental responsibility using calculated indicators, because they have different dimensions, and their aggregation

is inefficient. For the purpose of defining the general implementation level of corporations' environmental responsibility, it was proposed to use the integral indicator, which in turn allows to determine the rank of corporations' environmental activities. The generalized utility function, or the Harrington scale, was used as an integral efficiency indicator (Mulia et al., 2017; Ayala-Ponce et al., 2018; Graafland 2019). The basis of the aforementioned indicator is the idea of transforming the natural values of each indicator of corporate environmental responsibility (Table 5) into a dimensionless form  $f_{h_i}$  (Table 6) with further determination of partial functions according to the Harrington scale  $k_{h_i}$  (Table 7) and the integral indicator of the realization level of corporate environmental responsibility K (Table 8).

Therefore, according to Harrington's scale of

Table 5: Natural values of CER implementation indicators

Year	$h_1$	$h_2$	$h_3$	$h_4$	$h_5$	$h_6$
2012	29	97.53	11.3	1.74	9.08	0.72
2013	30	96.62	13.0	2.49	10.90	0.74
2014	29	96.45	13.9	2.72	13.12	0.61
2015	33	95.85	14.2	2.63	12.01	0.76
2016	35	96.30	17.8	1.57	14.68	0.78
2017	37	96.34	22.7	1.62	17.94	0.67
2018	38	96.61	25.9	1.71	21.93	0.59
2019	40	96.35	41.9	1.50	23.28	0.60
2020	45	96.73	48.6	1.28	24.84	0.49
2021	41	96.85	61.1	1.75	38.38	0.35

Table 6: Definition of the dimensionless form of CER implementation indicators

Year	Dimensionless form of indicators					
	$f_{h_1}$	$f_{h_2}$	$f_{h_3}$	$f_{h_4}$	$f_{h_5}$	$f_{h_6}$
2012	0.644	1.000	0.185	0.638	0.236	0.930
2013	0.667	0.991	0.212	0.915	0.284	0.958
2014	0.644	0.989	0.228	1.000	0.342	0.783
2015	0.733	0.983	0.233	0.969	0.313	0.985
2016	0.778	0.987	0.291	0.577	0.382	1.000
2017	0.822	0.988	0.372	0.596	0.467	0.858
2018	0.844	0.991	0.425	0.629	0.571	0.761
2019	0.889	0.988	0.686	0.552	0.606	0.766
2020	1.000	0.992	0.797	0.470	0.647	0.635
2021	0.911	0.993	1.000	0.645	1.000	0.451

desirability, the implementation level of corporations' environmental responsibility in Ukraine is generally assessed as satisfactory. This is due to the influence of the following factors: low motivation for the implementation of resource-saving and low-waste technologies and processes by corporations; lack of qualified management in the field of corporations' environmentally responsible activities; insufficient efforts to form own standards for environmental protection, aimed at improving environmental friendliness and product quality, and as a result - obtaining competitive advantages; incompleteness of tools for legal regulation of corporations' greening

activities; insufficient financing in the sphere of reducing the impact of corporations activities on the environment. Based on the calculated integral indicator of the corporate environmental responsibility level, the authors will consider the approach of assessing the impact of various factors of corporation activities on the general CER level using mathematical modeling methods. With the help of a multifactor linear regression model, it is possible to reveal the type of dependency between the implementation level of corporations' environmental responsibility and the proposed factors. In order to determine the influence of various factors on the

Table 7: Calculation of partial functions for different years

Year	Partial function $k_{h_i} = \exp(-\exp(-f_{h_i}))$					
	$k_{h_1}$	$k_{h_2}$	$k_{h_3}$	$k_{h_4}$	$k_{h_5}$	$k_{h_6}$
2012	0.59	0.69	0.44	0.59	0.45	0.67
2013	0.60	0.69	0.45	0.67	0.47	0.68
2014	0.59	0.69	0.45	0.69	0.49	0.63
2015	0.62	0.69	0.45	0.68	0.48	0.69
2016	0.63	0.69	0.47	0.57	0.51	0.69
2017	0.64	0.69	0.50	0.58	0.53	0.65
2018	0.65	0.69	0.52	0.59	0.57	0.63
2019	0.66	0.69	0.60	0.56	0.58	0.63
2020	0.69	0.69	0.64	0.54	0.59	0.59
2021	0.67	0.69	0.69	0.59	0.69	0.53

Table 8: Calculation of the integral indicator of the CER implementation level

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
<i>K</i>	0.574	0.584	0.584	0.593	0.588	0.596	0.608	0.617	0.620	0.643
Evaluation according to the result on Harrington's scale of desirability	S	S	S	S	S	S	S	S	S	D

Remark: S – satisfactorily; D – good

CER level, multiple correlation coefficients were calculated using the “data analysis – correlation” package of the Excel spreadsheet. The authors select the parameters of the multi-factor linear model of the dependence of the integral indicator of CER level (*K*) on the number of environmentally responsible corporations ( $a_1$ ), the size of capital investments for environmental protection at the expense of own funds ( $a_4$ ), the number of certified corporate quality management and environmental protection systems ( $a_6$ ), the number of new low-waste, resource-saving, ecologically-oriented technological processes implemented by corporations ( $a_7$ ), the volume of current expenses of corporations for environmental protection ( $a_9$ ) (Eq. 1):

$$k = c_0 + c_1a_1 + c_4a_4 + c_6a_6 + c_7a_7 + c_9a_9 \quad (1)$$

where  $c_0, c_1, c_4, c_6, c_7, c_9$  – coefficients of the factor linear model dependence of the integral indicator level in relation to the CER implementation.

Equation parameters (Eq. 1): correlation coefficients are determined using the “regression” tool of the “Data Analysis” package of the Excel spreadsheet (Microsoft Office). The authors build a multifactorial regression of the dependence of the integral level of corporate environmental responsibility on the most significant factors of the ecological and economic state of corporations in Ukraine. After calculations of the equation parameters, the multivariable linear model of the dependence of the CER implementation level will have the following form (Eq. 2):

$$k = 0.531 + 0.057a_1 + 0.002a_4 + 0.137a_6 + 0.053a_7 + 0.003a_9 \quad (2)$$

The research has shown that the value of the determination coefficient ( $R^2=0.9839$ ) – close to unity. Therefore, the model can be considered as adequate. The determination coefficient estimates the variation share of the result due to the factors presented in the equation in the overall variation of the characteristics values. This share is 98.39%, it indicates a high degree of dependence of the result variation on the variation of factors, that is, a close connection between the factors and the result. A high value of  $R^2$  confirms that the application of this model is adapted for any corporations. It has been proven that the following factors have the greatest positive influence on the change in the CER level: factor  $a_6$ , which reflects the amount of certified quality management and environmental protection systems in the field of enterprises activities (correlation coefficient  $r=0.9395$ ) and factor  $a_9$ , which reflects the amount of corporations' current expenses aimed at environmental protection ( $r=0.9358$ ). Analysis of the multi-factor regression equation makes it possible to estimate the influence degree of key factors on the resulting indicator:

- an increase in the amount of environmentally responsible corporations ( $a_1$ ) by 1 point, in case when all other factors remain unchanged, will lead to an increase in the integral indicator of the implementation level of corporations' environmental responsibility by 0.0574 units;
- an increase in the size of capital investments for environmental protection at the expense of corporations' own funds ( $a_4$ ) by 1 point, in case when all other factors remain unchanged, will lead to an increase in the integral indicator of the implementation level of corporations' environmental responsibility by 0.002 units;
- an increase in the number of implemented certified systems of quality management and environmental protection by corporations ( $a_6$ ) by 1 point, in case when all other factors remain unchanged, will lead to an increase in the integral indicator of the implementation level of corporations' environmental responsibility by 0.1371 units;
- an increase in the number of new low-waste, resource-saving, ecologically oriented technological processes implemented by corporations ( $a_7$ ) by 1 point, in case when all other factors remain unchanged, will lead to an increase in the integral

indicator of the CER implementation level by 0.0533 units;

- an increase in the size of corporations' current expenses for environmental protection ( $a_9$ ) by 1 point, in case when all other factors remain unchanged, will lead to an increase in the integral indicator of the CER implementation level by 0.0031 units.

If the values of all factors are equal to zero, then the level of corporate environmental responsibility is equal to 0.5311 units. The following indicators have the greatest positive influence on the change in the implementation level of CER: the number of implemented certified systems of quality management and environmental protection by Ukrainian corporations, as well as the number of corporations' current expenses for environmental protection. As a detailed analysis of Ukrainian corporations shows, the practical implementation of the proposed theoretical and mathematical models is complicated by: the low motivation to implement resource-saving and low-waste technologies and technological processes; lack of qualified management of corporations' environmentally responsible activities; insufficient attention to the formation of own standards in the field of environmental protection; incompleteness of tools for legal regulation of corporations' greening activities; insufficient financing in the sphere of reducing the impact of corporations activities on the environment. Therefore, it is proposed to stimulate the formation of the CER system at the national level, first of all, by developing and applying effective financial and economic tools of motivation. A perspective for further studies can be the correction of the obtained results based on the ESG Transparency Index methodology ([ESG transparency index 2020 Ukraine, 2021](#)). The ESG Transparency Index of Ukrainian companies calculated by the Corporate Governance Professional Association (CGPA) and the Center for the Development of Corporate Social Responsibility supported by the Center for International Private Enterprise (CIPE). The index evaluates the transparency of Ukrainian companies using the ESG criteria (social, environmental and governance ones). Based on these criteria there was evaluated information posted on the websites of Ukrainian companies, top 50 taxpayers, for 2020, and the companies that voluntarily joined the study.

## CONCLUSION

Based on the study of world experience, it was found, that the main economic means to stimulate the environmental responsibility of corporations are the following: application of a diverse system of tax payments and tax benefits, provision of subsidies and loans, as well as direct government funding of scientific developments and research, which in turn will significantly promote the implementation of environmental technologies by private business. The following taxes are the most common in European countries: tax on products containing environmentally harmful substances; tax on waste and its disposal; tax/charge for water pollution. Particular attention should be paid to the experience of the Scandinavian countries, whose tax systems define clear directions of environmental taxation and specify tax payments by objects, which in turn allows implementing the principle of targeting the received income. At the stage of analyzing the obtained results, checking the materiality, closeness of the connection and adequacy of the model, it was proved that the built regression model is completely valid, the application of this model is adapted for any corporation. It is mathematically proven that the following two factors have the greatest positive influence on the change in the CER level: the amount of certified quality management and environmental protection systems in the field of enterprises activities (correlation coefficient  $r = 0.9395$ ) and the amount of corporations' current expenses aimed at environmental protection ( $r = 0.9358$ ). According to Harrington's scale of desirability, the implementation level of corporate environmental responsibility in Ukraine is generally assessed as satisfactory. The prospect of further research is the development of strategies regarding the improvement of corporations' environmental responsibility for the purpose of country's sustainable development and increased rational nature usage. To solve the problems mentioned in the paper systematically and qualitatively, a theoretical model has been developed that combines the basic principles of corporate social responsibility (sustainable development, accountability, transparency), the mechanisms of their implementation and the corresponding methodology for assessing the level of their implementation in the economic activity of corporations. An integrated approach to the implementation of the above basic

principles by Ukrainian corporations will make it possible to significantly increase their environmental responsibility, in particular ecological, economic and social efficiency, to ensure the sustainable development of the national economy as a whole.

## AUTHOR CONTRIBUTIONS

O. Katerna performed an experimental design and analyzed the data. O. Prykhodko defined the concept and methodology of the research. M. Yudin ranked the data into tables and figures. K. Molchanova performed the literature survey.

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## CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. 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 observed by the authors.

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**ABBREVIATIONS**

$a_j$	Value of the $j$ -th indicator, characterizing the $i$ -th year
$a_1$	The number of environmentally responsible corporations (which form a report on sustainable development), units
$a_2$	Total number of corporations, units
$a_3$	The number of corporations involved into environmental protection activities, units
$a_4$	Capital investments from the corporations' own funds for environmental protection, million USD
$a_5$	The total amount of current expenditures on the protection and rational usage of natural resources, taking into account all financing sources, million USD
$a_6$	The number of corporations' certified systems the field of environmental quality management and nature protection, units
$a_7$	The number of new low-waste, resource-saving, ecologically oriented technological processes implemented by corporations, units
$a_8$	The total amount of capital investments aimed at the protection of the natural environment, taking into account all sources of funding, million USD
$a_9$	Amount of current corporations' expenses for environmental protection, million USD
$c_0, c_1, c_4, c_6, c_7, c_8$	Coefficients of the factor linear model dependence of the integral indicator level in relation to the CER implementation.
CER	Corporate Environmental Responsibility
D	Good
ER	Ecologically responsible
Eq.	Equation
et al.	et alii

etc.	et cetëra
Fig.	Figure
$f_{h_i}$	The indicator of corporations' environmental responsibility in dimensionless form.
$f_{h_j}$	The standardized value of the $j$ -th indicator, characterizing the $i$ -th year
$h$	The number of indicators used to assess the level of corporations' environmental responsibility
i.e.	id est
$k_{h_i}$	The partial function that was defined using the Harrington scale
$R^2$	The determination coefficient
$r$	The correlation coefficient
S	Satisfactorily
SNE	surrounding natural environment
USA	The United States of America

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