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Management of the sustainable development of machine-building enterprises: a sustainable development space approach

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Abstract

Purpose – The paper embarks on the development of theory and methodology for managing the sustainable development of machine-building enterprises through the use of quantitative modeling tools. The article proposes an algorithm for estimating the position of an enterprise in its competitive space for sustainable development.

Design/methodology/approach – The three dimensions of sustainability (social, economic, environmental) are represented by the equations based on the multiple criteria of sustainability. The three-dimensional space is constructed and the effects of managerial decisions can be quantified in terms of the latter space.

Findings – The proposed model is applied in the case of Ukrainian machinery construction company. The effects of introduction of the environmentally friendly business strategy are assessed in the three-dimensional sustainability space. The changes in the level of sustainability can be estimated based on the projected changes in the criteria of sustainability.

Originality/value – The proposed methodology combines expert knowledge, empirical data and quantitative methods in order to quantify the level of sustainability of enterprises. The model can be extended to include additional dimensions and applied to different empirical cases.

Keywords Sustainable development, Three-dimensional space, Environmental component, Economic steadiness, Social responsibility, Ecological activity

Paper type Research paper

1. Introduction

The need to implement a sustainable development strategy at different hierarchical levels of management and regulation entails the need to assess economic, environmental and social sustainability parameters: "economic–provides for the formation of an economic system harmonized with the environmental factor in the development; social–affirms the human right to a high standard of living in the conditions of ecological safety; ecological–determines the conditions and limits of restoration of the ecological systems" (Danylyshyn *et al.*, 1999; Novikova *et al.*, 2012), including water conservation, renewable energy waste and recycling management (Burlutskii and Burlutskii, 2016).

Although the ideas of sustainable development and approaches to their practical application at different levels of management and regulation are widely represented in modern scientific research, the problems of complex assessment of the level of sustainable development of industrial (machine-building) enterprises remain unresolved, as the level monitoring algorithm ensuring sustainable development of the Ukrainian enterprise (taking into account the conditions of the competitive environment) based on the assessment, modeling and forecasting of results and integrand parameters for the three pillars of sustainable development: economic, social and environmental has not been developed.

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All the researches were united in one block, which includes: economical sustainability, social sustainability and environmental sustainability. Many scientists set aside the economical sustainability as one of main parts of sustainable development. The absence of the financial resources has an impact on social and ecological components. So we can safely assume that industrial enterprise must organize such conditions, which decrease and mitigate a pressure for workers and enforce the environment protection by means of the dimensional approach. If it is connected with economic development, we see obvious things such analyzing, modeling, use of different principles, methods, tools, resources, procedures and so on. For example, Burlutskii and Burlutskii emphasized that economic development influences the social part of such development (Burlutskii and Burlutskii, 2016). Ge *et al.* studied the effect from the implementation of green innovation strategy on sustainable development of the 241 enterprises. There was used an approach called "environmental uncertainty" and the opportunities to decrease a pressure for economic stability of the enterprises (Ge *et al.*, 2018). Birkel *et al.* offered that sustainable development of the enterprise depends on several factors of the risks: economic, social, legal/political, ecological and technical and IT risks in the framework of the concept of "Industry 4.0" (Birkel *et al.*, 2019). Vitiea and Lim affirm that the enterprises should collaborate with local community in the framework of the development of environmental protection and corporate social responsibility (Malesios *et al.*, 2018). Malesios *et al.* formed a model and analyzed the impact of the SME's management on its economic growth by means of sustainability (Laumann and Torben, 2018). Laumann and Torben created a new way to influence optimization cost and transformation of the work of the enterprise from the linear model to the circular economy (Prieto-Sandoval *et al.*, 2018). Prieto-Sandoval *et al.* resolved the problem of economic sustainability using the circular economy in SME (Zenya and Nystad, 2018). Zenya and Nystad created a new tool for assessing corporate sustainability – the Enterprise Sustainability Evaluation Tool (E-SET). They notice that it can be used for "self-assessment and comparison purposes, will provide a comprehensible sustainability score and its graphical representation" (Stojanovic, 2019). Stojanovic in his research comes up with a hybrid approach, which is based on ecological management and might solve "the gap between ecological and economic theoretical models and ecological and economic behavior" (Dalevska *et al.*, 2019).

Dalevska *et al.* used the group of indicators for estimating economic development of the enterprise (Olejarz *et al.*, 2018). Olejarz *et al.* highlight that the factors of the labor performance can solve the problem of economic growth of machine-building enterprises (Chukurna *et al.*, 2019). Chukurna *et al.* calculated the economic effect of the exchange rates on prices of machine-building enterprises (Ahmad *et al.*, 2020). Noor Hazlina Ahmad *et al.* added also individual, organizational and institutional factors, which impact the work of SME (Sala *et al.*, 2012). For more qualitative analysis of the abovementioned factors, Sala, Farioli, Zamagni (Stiglitz *et al.*, 2009), Stiglitz *et al.* (Matushevska and Katkova, 2017) propose to use different methods (SEEA, LCC, CBA, EIA, LCA, LCSA, SEA) for assessment of all the parts of sustainable development of the enterprise. Matushevska and Katkova (Yemelyanov *et al.*, 2018) supported these ideas, which were researched in different scientific approaches for economic sustainability of the industrial enterprises and developed the system of principles, methods, procedures and tools. Yemelyanov *et al.* (Dergachova *et al.*, 2019) distinguished the economic development of the machine-building enterprises where it was separated into several types: resource-cost economic development, resource-saving economic development and combined economic development. Dergachova *et al.* used the combined approach based on econometric modeling and assessing the state of four subsystems with different space and time localization and further defining the level of mutual balance for the research of economic sustainability (Tang *et al.*, 2020).

Dodds and Venables noticed that sustainable development of the engineering cannot progress in isolation with no social and environment components on a long-term basis

(Kabaya *et al.*, 2019). And in our opinion it is necessary to add an economical aspect because the profitability determines the stability of the other parts of sustainability. Kabaya *et al.* researched the opportunities for building ecosystem services "using a participatory scenario approach and spatial ecological-economic modelling techniques" (Sandova, 2015).

Machine-building industry activity (machine-building enterprises in particular) is connected with harmful influence on the environment by various factors, namely: emissions into atmosphere, water and land pollution, noise pollution and so on. Under conditions of European integration of Ukraine and arrangement of strict ecological requirements for machine-building companies, the problem of ecological indicators improvement is of great importance. Imperfect functioning of machine-building enterprises in ecological problem solving causes the topicality of this research, namely formation of the model of ecologically oriented development ("sustainable development") of machine-building enterprises on purpose to increase their competitiveness.

The purpose of our research is to propose quantitative approaches to model the level of sustainable development in enterprises. The paper discusses the relevant theoretical contexts in and develops the model for sustainability assessment in Section 2. The model is applied to the case of Ukrainian companies in Section 3. Finally, Section 4 concludes.

2. Methods

The objective of the research is to deepen scientific and methodological foundations for assessing the possibility of managing the components of sustainable development of industrial enterprises. To achieve this goal, it is necessary to develop a methodology for assessing the competitive level of ensuring the sustainability of enterprise development on the basis of modeling and forecasting the parameters of components of such development, which is aimed at identifying enterprise problems (not only by individual characteristics, but also by the enterprise as a whole) and which would allow assessing the dynamics parameters, compare the enterprise with competitors, make adjustments and outline possible management prospects to increase overall sustainability and enterprise competitiveness.

The results of this task are presented in the article – assessment based on modeling should be aimed at identifying the problems of the enterprise (not only by individual characteristics, but also by the enterprise as a whole), would allow to evaluate the dynamics of parameters, make comparisons with competitors, make adjustments and outline possible management prospects to increase overall sustainability and enterprise competitiveness. Based on our recent studies of assessing the ability to manage components of sustainable development of enterprises (Tang *et al.*, 2020; Ge *et al.*, 2018; Birkel *et al.*, 2019; Vitiea and Lim, 2019; Malesios *et al.*, 2018; Laumann and Torben, 2018; Prieto-Sandoval *et al.*, 2018; Zenya and Nystad, 2018; Stojanovic, 2019; Dalevska *et al.*, 2019; Olejarz *et al.*, 2018; Chukurna *et al.*, 2019; Ahmad *et al.*, 2020; Sala *et al.*, 2012; Stiglitz *et al.*, 2009; Matushevska and Katkova, 2017; Yemelyanov *et al.*, 2018; Dergachova *et al.*, 2019; Kahn, 1995; Basiago, 1999; Kuznetsova *et al.*, 2020; Dodds and Venables, 2005; Kabaya *et al.*, 2019; Sandova, 2015), it becomes possible to develop an algorithm for assessing, forecasting and modeling the results of exposure to one component of sustainable development to improve the overall sustainability of the enterprise. In this regard, the research has been carried out using a number of modern methodological concepts and theories:

(1) sustainable development of enterprises (Dodds, and Venables (Kabaya *et al.*, 2019));

(2) circular economy (Vitiea, and Lim (Laumann and Torben, 2018), Malesios *et al.* (Laumann and Torben, 2018), Laumann, and Torben (Prieto-Sandoval *et al.*, 2018), Prieto-Sandoval *et al.* (Zenya and Nystad, 2018), Zenya, and Nystad. (Stojanovic, 2019), Noor Hazlina Ahmad *et al.* (Sala *et al.*, 2012), Sala, Farioli, and Zamagni (Stiglitz *et al.*, 2009), Tang, Ng and Skitmore (Kahn, 1995), Kabaya *et al.* (Sandova, 2015));

(3) economic systems modeling (Stojanovic (Dalevska *et al.*, 2019), Dalevska (Olejarz *et al.*, 2018), Stiglitz, Sen, and Fitoussi (Matushevska and Katkova, 2017));

(4) competitive space for enterprises (Matushevska, and Katkova, (Yemelyanov *et al.*, 2018), Yemelyanov, Kurylo, and Petrushka T.O. (Dergachova *et al.*, 2019), Dergachova *et al.* (Tang *et al.*, 2020), Kuznetsova, Kuznetsov, and Podoliak (Dodds and Venables, 2005), Sandova *et al.* (Minyuk *et al.*, 2002), Kalinina Ye (Kuznetsova, 2006) and Kuznetsova (Ilyenko, 2013));

(5) the model of competitive-price space (Ilyenko (Latysheva, 2014a), Latysheva (Latysheva, 2017; Latysheva, 2014b; Novokramatorsky Mashinostroitelny Zavod)).

The paper proposes a modeling approach to assess the level of sustainable development in an enterprise based on expert assessments in the competitive space model. The company can be compared to the competing entities by means of the quantitative indicators. The case of Ukrainian agricultural machinery companies is considered.

Analysis of theoretical and methodological approaches to the formation of a system for managing sustainable development (Stojanovic, 2019) suggests that the parameters of resource conservation and environmental safety are highlighted in the list of environmental factors that guarantee sustainable development. In accordance with the goals and objectives set in this study, this article proposes an improved approach to creating a model for assessing and monitoring competitiveness parameters (including environmental) in the context of ensuring the sustainable development of the enterprise and constant focus on the environmental component of activity in machine-building enterprises.

The research has been conducted by applying "three-dimension space" (Figure 1) and "competitive space," which are based on the models used to evaluate other indicators: costs (Kuznetsova, 2006; Ilyenko, 2013), international business entity (Latysheva, 2014a), competitiveness and sustainability (Latysheva, 2017; Latysheva, 2014b; Novokramatorsky Mashinostroitelny Zavod).

From mathematical point of view, "three-dimension space" (Figure 1) is presented in the form of pyramid (Chukurna *et al.*, 2019; Ahmad *et al.*, 2020; Gracheva *et al.*, 2005; Rozen, 2002; Sovetov and Yakovlev, 2001; Kalinina, 2007). "Three dimension space" has been formed in addition by plane (Figure 1): parallel to the plane YZ (plane ABD), parallel to the plane YX (plane BCD), parallel to the plane ZX (plane ABC), plane placed angularly (plane ACD). Their extremities coordinates are (Figure 1): A (Z_{max}, X_{min}, Y_{max}), B (Z_{min}, X_{min}, Y_{max}), C (Z_{min}, X_{max}, Y_{max}), D (Z_{min}, X_{min}, Y_{min}). "Three dimension space" (Figure 1) parameters may be changed in three directions (rise, fall and be invariable). The coordinates of extreme points of "three dimension space" must have next values: A (Z_{max},X_{min},Y_{max}), B (Z_{min},X_{min},Y_{max}), C (Z_{min},X_{max},Y_{max}), D (Z_{min},X_{min},Y_{min}). On the basis of this mathematical approach (Figure 1), it is suggested to make the model of competitive environment (space of competitive level of sustainable development) for enterprise (machine-building enterprise) (Figure 2). Machine-building enterprise has to consider global processes in the economic space (space of competitive level of sustainable development). The parameters of "space" for balancing of indexes of sustainable development as a mechanism (instrument) for a management by the constituents of sustainable development on machine-building enterprise on base model "three dimension space" (Figure 2) are defined within the enterprise: Y_{axis} – economic steadiness of economic activity of enterprise (E_K) of machine-building products – degree of conformity of economic activity of the company to the requirements of target customers in comparison to the competitors; Z_{axis} – social responsibility of enterprise (C) of the enterprise; X_{axis} – ecological activity (E) of the enterprise – stage (ability and readiness) and effectiveness of ecological programs development and realization at the enterprise according to the present requirements of ecological safety.

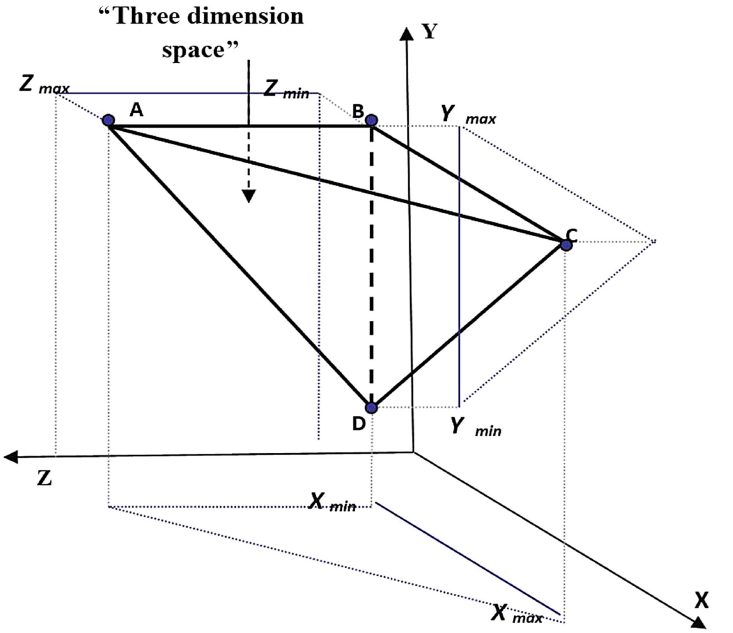

Figure 1.
The model of "three dimension space" (Sovetov and Yakovlev, 2001; Kalinina, 2007).

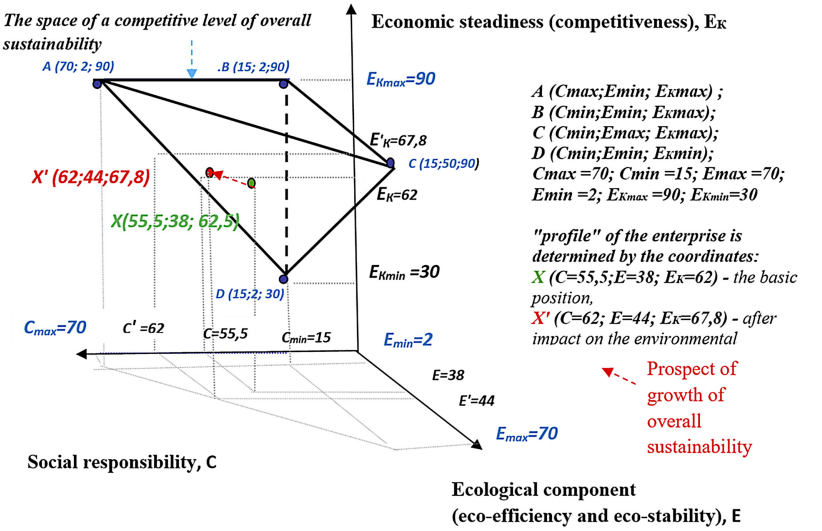

Figure 2.
Change of position of machine-building enterprise within the scope of the "level of sustainability of development" in the direction of the prospect of growth of overall sustainability due to the impact on the environmental component (Kuznetsova, 2006) and (Ilyenko, 2013)

In the model of ensuring the level of sustainable development, the maximum and minimum values of the parameters of the space of the "level of sustainable development" were established on the basis of the results obtained by the experts of the Committee on Industrial Policy of the Cabinet of Ministers of Ukraine. These limit values were calculated and based on a set of ratings (on a 100-point scale) obtained from leading specialists of economic and environmental services of enterprises. The "best" indicator was set on the basis of the

possible maximum that can be achieved in the current state of the national economy, and the "worse" was based on comparable indicators of the enterprises of the industry, and the parameters for the model were grouped and evaluated by main components:

(1) economic sustainability and competitiveness of the enterprise's economic activity;

(2) social responsibility (degree and efficiency of implementation of ideas of socially responsible business in economic activity);

(3) environmental efficiency of the enterprise (the ratio between the result and the resources used, the level of implementation and effectiveness of eco-friendly programs, projects, etc.).

In the model, the coordinates of the boundary points mean the boundaries of the space; for the description, the same is described mathematically and the skin and plains of the space can be described mathematically, passing through three points.

When estimating parameters it is necessary to carry out full-fledged analysis of all the components on the basis of expertise. Positioning process of enterprise in competitive space (space of competitive level of sustainable development, "profile" of enterprise "*Z*"): if Cmin $\leq C \leq$ Cmax, *E*min $\leq E \leq$ *E*max, $E_K$min $\leq E_K \leq E_K$max, (f(0,0,0)>0, f(*C*,*E*, E_K)>0), the plant into "space for sustainable development" ("competitive space", "competitive level of overall sustainability") (Figure 2).

Minimum level of economic constancy or economic activity of enterprise (*E*κmin) is shown by itself with a definite level of the financial state, economic indicators of economic activity, below which any further (break-even) activity (a production of goods at the market at the established level of competition) is impossible (makes no economic sense). The maximal level of economic constancy and competitiveness (*E*κmax) characterizes the maximally accessible at this market level economic indicators, profitability, quality and other, which cannot be excelled in local conditions or be improved with possibilities of modern development. A maximal level (Cmax) means that a higher limit exceeding the existing one is impossible to reach at this stage of development. Minimum level of eco-friendliness parameters (*E*min) means that below them according to a current legislation, an enterprise is forbidden to operate. The worse is the determined result of introduction of the nature protection programs, the lower is the estimation of level of eco-friendliness. A maximal level of eco-friendliness parameters of economic activity (*E*max) means that a higher level of ecological results with that economic activity is not possible to achieve at this stage of development of industry, which is predefined by the existent level of development of technique and technology.

Application of model of three-dimensional space gives possibility of a vivid image of profile of a concrete enterprise (there appears a possibility to compare points in space, to compare the level of its stability to the level of competitors or with its own results in dynamics).

It is necessary to form development strategy of the enterprise (according to estimation results). If this requirement is not fulfilled, the enterprise is outside the "space for sustainable development" ("competitive space", "competitive level of overall sustainability"). So, it is necessary to carry out the analysis of external and internal environment, elicit "gaps" in the activity and define lines of further development. If the enterprise moves to the "perspective of competitiveness rise" area, space parameters move to optimal level of enterprise economic competitiveness (economic steadiness) and its social responsibility for all low scale of negative influence on the environment (Latysheva, 2017; Novokramatorsky Mashinostroitelny Zavod).

Under such conditions, complex increase of enterprise competitiveness on the basis of ecological marketing and innovative development has to be done. Special attention should be

paid to its place determination in general competitive environment. The use of economic–mathematical instruments for competitive profile presentation of the enterprise as three-dimensional space would be chosen as the best area of competitive environment modeling for enterprise (Latysheva, 2014b).

One of the important stages of simulation was the choice of the form of communication, which characterizes the dependence of the integral indicator (a component of sustainable development) on the factors affecting it. Available alternatives were additive and multiplicative models. Special literature does not give unambiguous recommendations on this issue. In our opinion, the empirical way of choosing a connection is the only possible one. The chosen model should correspond to the essence of the investigated processes (economic, environmental or social), to be quite simple in terms of its mathematical processing and economically interpreted.

The following criteria were used when choosing a communication form: multiple determination coefficients, Fisher's criterion, residual variance, mean error of approximation. The result was the election of an additive form of a model with regulated and unregulated factors:

$$I = a_0 + \sum_{j=1}^{k} (a_j z_j) + \sum_{i=k+1}^{n} (a_i x_i) + u, \tag{1}$$

I – integral assessment of components of sustainable development of a separate enterprise; zj – weakly regulated factors; x_i – regulated factors; u – factors are due to industry features; a_0 – free member; a_j – coefficients of regression under weakly regulated factors; a_i – coefficients of regression under controlled factors.

Using algorithm of management of parameters of competitive space (Latysheva, 2017; Novokramatorsky Mashinostroitelny Zavod) for balancing of indexes of sustainable development, parameters for space of competitive level of sustainable development by machine-building enterprise and optimal function defining the competitive space (Figure 2) for sustainable development were defined, considering the best and the worse estimation of corresponding parameters of the competitors at the machine-building market.

3. Results

The checkup proves that the machine-building enterprise is in "space of competitive level of sustainable development" (Figure 2), because the following conditions (according to the parameters of innovative and ecological activity and to the services competitiveness) are complied. Component optimization – "ecological activity" was conducted due to the implementation of the program of ecologically oriented plant control and measures for lowering of the harmful environmental effects. After implementation of additional measures for environmental safety, vector motion to the perspective of competitiveness rise of machine-building enterprise became the result of technique approbation. Maximum and minimum parameters for competitive space were defined by the experts in order to estimate the enterprise (considering the best and the worse estimation of corresponding parameters of the competitors at the machine-building market). The model space to ensure sustainability of the maximum and minimum values of "space of competitive level of sustainable development" was established on the basis of the results obtained estimates of experts – specialists of Committee on Industrial Policy of the government of Ukraine (Latysheva, 2014b).

Optimal function $f(C; E; E_K)$ (formula 2) defines the competitive space (space "competitive level of sustainability"), level of sustainability of the enterprise: $C_{\max}$ was defined at 70-point level, $C_{\min}$ is 15, $E_{\max}$ is 70, $E_{\min}$ is 2, $E_{K\max}$ is 90 and $E_{K\min}$ is 30. Point "Z" ($f(C; E; EK)$) defines the position of machine-building enterprise before and after optimization ecological measures

accordingly (see Figure 2). Equation for a plane passing through three points (formula 2):

$$f(C, E, E_K) = (C - C_{\max}) \times (E_{\max} - E_{\min}) \times (E_{K\min} - E_{K\max})(E_K - E_{K\max}) \times (E_{\max} - E_{\min}) \times (C_{\max} - C_{\min})(E - E_{\min}) \times (C_{\max} - C_{\min}) \times (E_{K\min} - E_{K\max}) \quad (2)$$

The economic component of sustainable development (E_k) is proposed to determine the level of financial and economic state of an industrial enterprise, its competitiveness (detailed with economic, innovative, technical, export parameters of economic activity, etc.). Social component (C) is characterized by the level of compliance of the enterprise with the current requirements of corporate social responsibility. The ecological component (E) is determined by the degree of compliance of economic activities with environmental norms, safety standards and requirements of normative documents, as well as the level of implementation and effectiveness of environmental programs and eco-projects (Latysheva, 2014b).

To determine the parameters (coordinates) of the "profile" of enterprise "Z", the main indicators of ensuring the sustainable development of the enterprise were analyzed. In order to determine the parameters of the economic component, the indicators of financial results (production volume, gross sales income, cost, expenses for the period, net financial result, main indicators of profitability of the enterprise, etc.) were systematized and transferred to the point estimation, indicators of financial stability, business activity, liquidity and other indicators of innovative activity and efficiency of investment activity.

The general characteristics of the social component were translated into point scores and the integral indicator of the aggregated indicators was noted on the basis of the analysis of the following data: general indicators (social responsibility index, long-term development index, ratio of social investments and profit, etc.); employment rates (the proportion of workers released during the period under study on the initiative of the employer in the total number of employees, the coefficient of personnel turnover, etc.); wages (the ratio of average salary to employees of the corporation with average industry, the share of labor costs in the cost of production, etc.); occupational safety (coefficient of occupational injury, expenses for improvement of working conditions per one employee of a corporation, etc.); training and healthcare workers (the cost of a corporation for healthcare workers per employee, the share of employees who undergo an annual medical examination at the corporation's total number of employees); and others.

The general characteristics of the ecological component were obtained on the basis of the points transferred to the point of view of the following indicators: total annual payments of the enterprise for environmental pollution within the limit, for normative use of natural resources, the number of cases of violations in the field of environmental protection, fines; the level of environmental requirements, the environmental safety of the personnel and the population in the zone of influence of the enterprise, the aggregate pollution (integral index) are determined on the basis of an assessment of the overall level of influence on NPPs (volume of emissions into the atmosphere, wastewater discharges, waste generation).

The processing of statistical data on the rating assessment of components of sustainable development of enterprises and the formation of regression models (2) allowed obtaining a set of equations:

$$f(E_K) = 22.899 + (uek) - 0.858E_{K1} + 0.568E_{K2} - 0.285E_{K3} + 0.309E_{K4} - 0.628E_{K5} - 0.724E_{K6} - 0.742E_{K7} + 0.182E_{K8} - 2.665E_{K9} + 6.345E_{K10} - 1.380E_{K11} - 1.771E_{K12} + 1.277E_{K13} + 0.441E_{K14} - 4.584E_{K15} + 1.531E_{K16}, \quad (3)$$

$$f(E) = -8.488 + (ue) - 0.158E1 + 0.935E2 + 0.211E3 + 0.479E4 + 0.052E5 + 0.029E6 + 0.229E7 + 0.302E8 + 2.029E9 - 1.714E10 - 0.255E11 + 1.103E12 - 0.204E13 - 0.371E14 - 0.235E15 - 1.408E16, \quad (4)$$

$$f(C) = 2.951 + (uc) + 0.281C1 - 0.041C2 + 0.079C3 - 0.927C4 + 0.374C5 - 1.796C6 + 0.0002C7 - 0.061C8 + 0.235C9 + 0.170C10 - 0.466C11 + 1.058C12, \quad (5)$$

where $f(E_k)$, $f(E)$, $f(C)$ are the functions of the rating assessment of the components (components) of sustainable development (economic, environmental and social, respectively), E_{ki}, E_i, C_i –coefficients, uek, ue, uc – slopes related to branch (cluster) features and position of the enterprise in the cluster.

The empirical application of the model proceeds by considering the case of Ukrainian enterprises. For enterprise "*Z*" the following coefficients are obtained through the exert assessment:

$$f(C) = 2.951 + (-4.489) + 0.281 \times 90 - 0.041 \times 96 + 0.079 \times 78 - 0.927 \times 20 + 0.374 \times 78 - 1.796 \times 10 + 0.0002 \times 33 - 0.061 \times 32 + 0.235 \times 47 + 0.170 \times 85 - 0.466 \times 58 + 1.058 \times 38 = 55.5, \quad (6)$$

$$f(E) = -8.488 + (1.045) - 0.158 \times 5 + 0.935 \times 30 + 0.211 \times 17 + 0.479 \times 32 + 0.052 \times 100 + 0.029 \times 26 + 0.229 \times 96 + 0.302 \times 44 + 2.029 \times 16 - 1.714 \times 2 - 0.255 \times 47 + 1.103 \times 38 - 0.204 \times 45 - 0.371 \times 45 - 0.235 \times 86 - 1.408 \times 39 = 38.0, \quad (7)$$

$$f(E_K) = 22.899 + (-0.944) - 0.858 \times 88 + 0.568 \times 78 - 0.285 \times 94 + 0.309 \times 93 - 0.628 \times 87 - 0.724 \times 92 - 0.724 \times 92 - 0.742 \times 98 + 0.182 \times 92 - 2.665 \times 29 + 6.345 \times 29 - 1.380 \times 60 - 1.771 \times 38 + 1.277 \times 23 + 0.441 \times 18 - 4.584 \times 23 + 1.531 \times 27 = 62.5, \quad (8)$$

$$f(C;E;E_K) = (f(C) - C_{max}) \times (E_{max} - E_{min}) \times (EK_{min} - EK_{max}) - (f(EK) - EK_{max}) \times (E_{max} - E_{min}) \times (C_{max} - C_{min}) - (f(E) - E_{min}) \times (C_{max} - C_{min}) \times (EK_{min} - EK_{max}) = (55.5 - 70) \times (70 - 2) \times (30 - 90) - (62 - 90) \times (70 - 2) \times (70 - 15) - (38 - 2) \times (70 - 15) \times (30 - 90) = f(55.5;38;62.5) = 157280 \geq 0, \quad (9)$$

This indicates the rise of its general competitiveness and level of "sustainable development" ("competitive level of sustainability") (see Figure 2). After implementation of the program of ecologically oriented development control "Z," the rise of the following levels is noted (see Figures 2–4). While constantly improving their traditional products, "Z" at the same time provides the market with the wide range of novel solutions. So, the positioning process of machine-building enterprise, which is represented Figure 3, is the object of analysis in the competitive conditions; the appropriate model of a sustainable development enterprise strategy within the limits of his competition profile is Figures 3 and 4.

If the enterprise has the possibility to move own position on the field of competitiveness increase (Figures 3 and 4), it means that the parameters of existent field, which provides sustainable development, gravitate for providing optimal competitiveness of economic and innovative activity of enterprise at a low level of negative effect on the environment, his fact needs more detailed analysis; that`s why the analysis has been done in the frozen limits of appropriate productive and competitive space in order to get more objective results about assessment of the position of machine-building enterprise (as the object of analysis) on the competitive conditions.

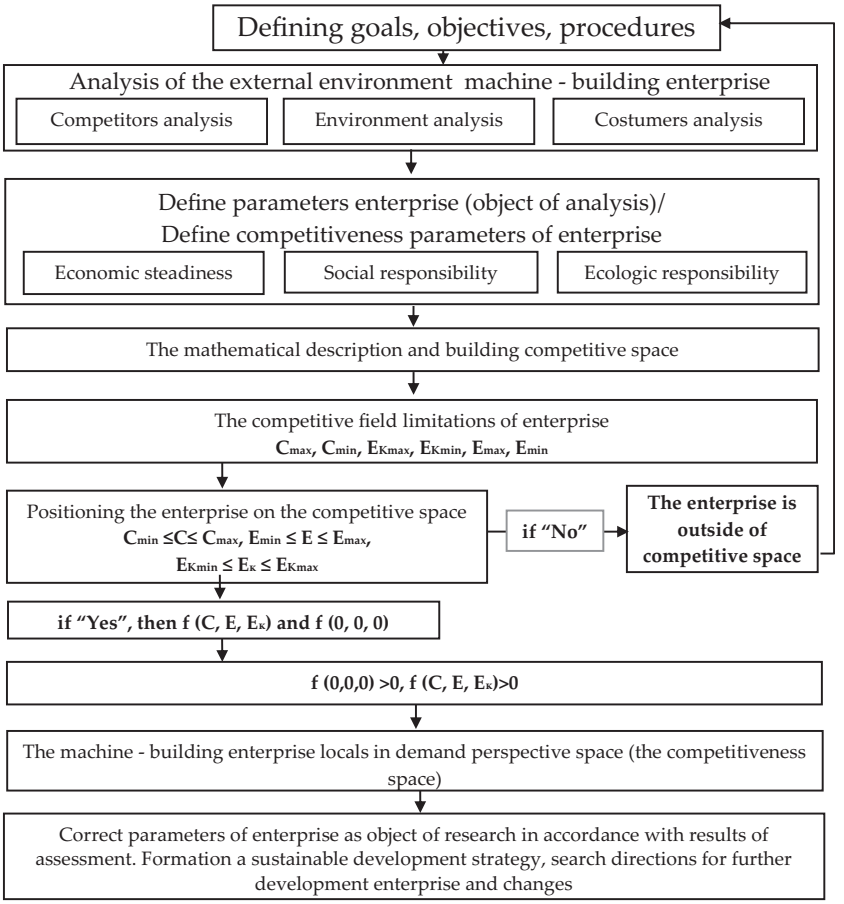

Figure 3.
The positioning model of machine-building enterprise in the competitive space

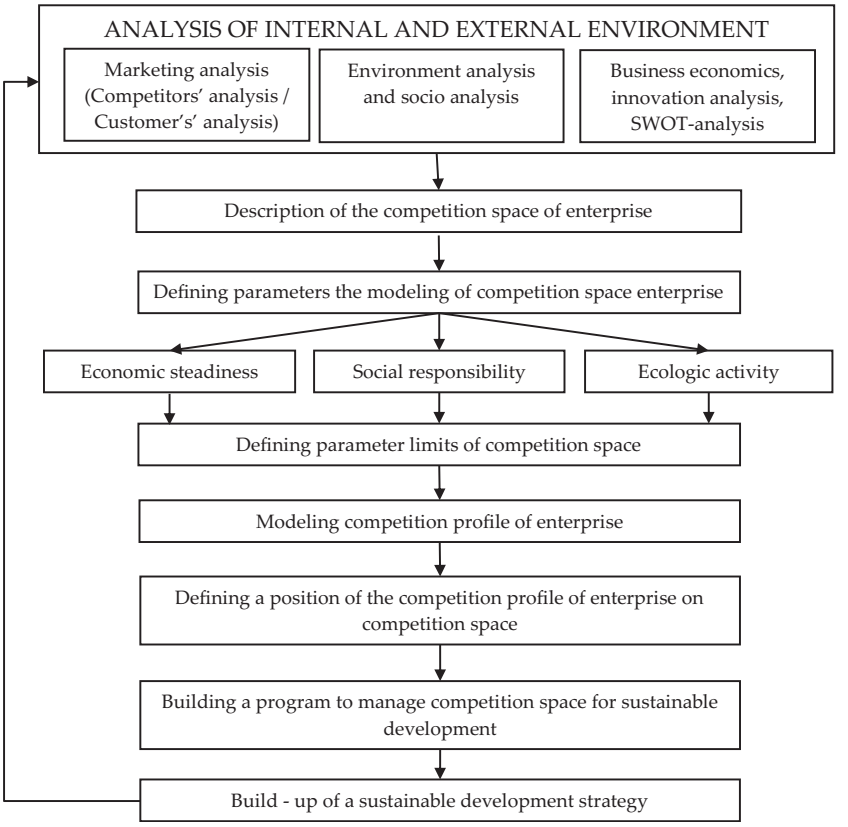

Figure 4.
The modeling of strategy of a sustainable development enterprise (in limits of competition space)

If a company does not get in limited competition space (outside of competitive space) (see Figures 2–4), then it characterizes inconstancy of its development, this enterprise is not able to provide the successful functioning at the market and development at the level with maximum operating parameters in a competitive environment. The model allows to show after what constituents an enterprise must search backlogs and possibilities to increase the level of constancy of development to provide survival and reception of competitive advantages.

4. Conclusions

We present the methodological approach that describes the management principles for components of sustainable development on machine-building enterprise. So, there is an opportunity to control the general competitiveness of the enterprise due to the control measures of one component ("ecological factors"). The introduced approach for "competitive space" formation (parameters of services competitiveness of machine-building enterprise, its innovative and ecological activity were chosen as the main control parameters) gives the opportunity to improve effectiveness of the enterprise in the competitive environment.

After formation of competitive space, there is a possibility to estimate the enterprise position toward the limits of its competitive space; gaps are defined according to the specified

characteristic; from defining a movement control (along the vector of one key space component – "ecological activity" for balancing of indexes of sustainable development) to a rise on the general competitiveness of the enterprise. Whereas there is still no generally accepted position in the scientific literature currently for evaluating the performance of environmental component management to ensure the sustainable development of an industrial enterprise, as well as the algorithm for measuring changes in overall sustainability and competitiveness after impact on an environmental component, the article proposes a new approach to assessing the overall level (competitively sufficient level) of sustainable enterprise development based on the results of graphoanalytical modeling of competitive space for sustainable development of enterprises, which provides an opportunity to evaluate the position of the company and identify existing problems in ensuring sustainable development compared to competitors.

The results of the model of sustainable development parameters proposed in the article allow the enterprise to develop, adjust and substantiate the strategy of optimal integration of the environmental component management system into the strategy of the development of industrial enterprises based on the obtained assessments of existing shortcomings and obstacles to ensure the sustainability and competitiveness of industrial enterprise within its specific development. The limitations of this research may be related to the difficulty of collecting, summarizing and analyzing reliable information when assessing the parameters of components of sustainable development and the boundaries of a competitive space for sustainable development of enterprises in a particular industry or sector of the economy. The results of modeling of enterprises include the complex evaluation of level of sustainable development of machine-building enterprises. To improve the sustainable development management of a machine-building enterprise, it is proposed to develop an algorithm of realization the monitoring processes for providing the sustainable development of machine-building enterprise (a strategy of a sustainable development).

The research proposes an algorithm for forming a system of sustainable development through the model of the enterprise profile, which is based on the definition of integral parameters in three components of sustainable development: economic, social and ecological. After constructing the space of the competitive level of sustainability of the industrial enterprise, it is possible to assess the position of the enterprise relative to the limits of its competitive space, to identify the bottlenecks of the enterprise by the characteristics described and to outline the possible prospects for controlling the movement along the vector of one component of the space (within the framework of the purpose of this study environment) to change the position in terms of the prospect of increasing overall sustainability and competitiveness of the enterprise. To determine the parameters (coordinates) of the "profile" of enterprise "*Z*," the main indicators of ensuring the sustainable development of the enterprise were analyzed (production volume, gross sales income, cost, expenses for the period, net financial result, main indicators of profitability of the enterprise, etc.; business activity, liquidity and other indicators of innovative activity and efficiency of investment activity; social responsibility index, long-term development index, ratio of social investments and profit, etc.; the level of environmental requirements, the environmental safety of the personnel and the population in the zone of influence of the enterprise, volume of emissions into the atmosphere, wastewater discharges, waste generation, etc.). The introduced approach for "space of competitive level of sustainable development" formation gives the opportunity to improve effectiveness of the enterprise in the competitive environment. The advantage of the model in balancing indexes of sustainable development is in its versatility and flexibility. It enables to use it for enterprises under any conditions of their development and state of environment. Perspectives for further research are the development of an optimal strategic model for ecologically oriented enterprises.

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