Ecodesign management modelling for petrochemicals manufacturing

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Abstract. Creation of the necessary conditions for the sustainable development, design and manufacturing of competitive products, improvement of the environmental and industrial safety are the major tasks for the petrochemical manufacturers. Handling these tasks is impossible without applying the modern management systems that allow for establishment and implementation of the enterprise’s performance self-assessment approach in terms of quality assurance and control, compliance with the environmental legislation, and international standards of social responsibility and manufacturing greening. For making optimal decisions at the management level in regard to the petrochemical manufacturing greening, it is essential that a relevant efficiency parameters monitoring system is applied. In this context, the authors offer a mathematical model that demonstrates a method of improvement of the petrochemical manufacturers’ earning power through mastering the green technologies. The mathematical model parameters include the profit, resource productivity of produced petrochemicals, environmental R&D costs, as well as specific quantities of atmospheric emissions. The model proposed by the authors can be used to analyze and predict effectiveness of the petrochemical manufacturing greening.

1. Introduction

Availability of the global competition and world-wide products in line with the ongoing shortening of the product life cycle entails continuous implementation of the effective technological, economic and organizational innovative solutions, as well as the innovations related to the ecodesign of the products.

Expansion of the production capacities is followed by the growing absolute quantities of industrial emissions. As such, the petrochemical sector heads the disapproval ratings in terms of the pollution indicators. The chemical industry accounts for 23 % and 5 % of the contaminated wastewater discharges and atmospheric emissions, respectively.

The Russian developing industries still lack the properly formed ecodesign-oriented outlook. Meanwhile, the responsible behavior of the industries in terms of the ecodesign solutions may significantly contribute to their stronger competitiveness, alongside with adding partners and outlets to the sales markets, and eventually to better production cost effectiveness.

As such, it is relevant and promising in this context to optimize the ecodesign of the modern petrochemical manufacturing facilities, alongside with improving the business efficiency by achieving the environmental sustainability of the production, increasing the investments in the innovative development of the industry sectors, and achieving the competitive preeminence of the companies.
2. Methodology and research findings

For improvement of the enterprises’ performance in terms of the ecodesign and resource saving activities, the present day researches already offer the relevant tools for assessment of organizational structures and production patterns, using the ecodesign efficiency assessment criterion. For the most part, the ecodesign efficiency assessment of an enterprise involves an investigation of the following aspects of the enterprise’s growth:

- advancement in terms of natural resources [1-4]. This is related to reduction of the energy and resource intensity of the manufacturing processes, minimization of wastes, and reduction of the negative environmental and public health impact. The indicators of the enterprise’s advancement in terms of natural resources should reflect the state of the environment, amounts of the environmental protection expenditures, as well as the energy and resource intensity of the production.

- material and technical development [5-8]. This is related to effective functioning of organizational structures and manufacturing processes, alongside with facilitating the production growth through utilization of new resource saving technological approaches. The main material and technical development criteria are the production capacity, labor productivity, cost of production etc.

It should be furthermore noted that the advancement of the production should be aimed at creating safe and comfortable working conditions, along with ensuring decent reward for labor. The social policy is important from the point of view of sustainable development of the enterprises, while allowing them to run business effectively during longer time [9, 10]. Therefore, within the framework of the production ecodesign efficiency assessment, the human resources development indicators can also be assessed, with such indicators reflecting the working conditions, for example, occupational injuries, occupational diseases, social support, average monthly wages etc.

In the long run, the elaborated information system should not only involve assessment of the production ecodesign status, but also allow improvement of the resource saving efficiency and quality of the entity management.

For making optimal decisions at the management level in regard to the petrochemical manufacturing greening, it is essential that an efficiency parameters prediction system is applied. This system can be implemented based on the economic and mathematical modeling methodology.

As part of the task-handling activities related to the methodological support for the petrochemical manufacturing ecodesign efficiency analysis and prediction system, the authors have developed a model that demonstrates a method of improvement of the petrochemical manufacturers’ earning power through mastering the green technologies. For that purpose, the correlation-regression analysis method has been used.

Any economic indicator is most often influenced by not just one, but a great number of factors. The main purpose of the multiple regression method is to build a model incorporating a great many of factors, as well as determine both single and aggregate influence of the factors on the modeled indicator in order to optimize it by composing a multiple linear regression equation.

To build an econometric model in the form of a multiple linear regression equation, as well as carry out a full quality analysis of the constructed model along with assessment of the statistical significance of the resulting model parameters, the authors use the resultant factor (Y) being demonstrated by an indicator that reflects the petrochemical enterprises’ market competitiveness, which in this case is the petrochemical sales profit. The sales profit has been determined by the authors by way of eliminating the direct costs (i.e. the costs directly related to the manufacture of petrochemicals) from the sales proceeds, as well as the selling expenses and administrative costs (i.e. the costs related to promotion and sale of petrochemicals).

The following parameters are taken as the factors having an impact on the resultant indicator (Y):

- resource productivity of the produced petrochemicals (the product output (in terms of product cost) to the cost of consumed resources);
- share of the environmental R&D costs in the total cost of petrochemicals production and sales;
specific quantities of atmospheric emissions at the petrochemical plants (emissions per unit of product output in terms of product cost).

These factors have been chosen for the following reasons: first, all of the factors above listed are directly related to the petrochemical manufacturing greening and resource saving activities at the industrial enterprises; secondly, these indicators are of the utmost significance, according to the Student's criterion.

Furthermore, the high quality of the constructed model is confirmed by the results of:

1) a correlation analysis showing that the factors are not linearly dependent; respectively, all variables can be included in the regression analysis;
2) a regression analysis, including:

- calculation of the determination coefficient, the value of which (R2 = 0.914, norm: 0.8 – 1) indicates that the constructed model very well describes the initial data;
- calculation of the F-criterion, the value of which (significance F = 0.018, norm: < 0.05) indicates the high significance of the resulting equation;
- calculation of the significance of the regression equation coefficients (t-statistics), the values of which confirm the impact the factors make on the attribute being tested, as well as the reasonability of inclusion thereof in the final regression equation.

So, the formula below represents the final regression equation (model) that demonstrates improvement of the petrochemical manufacturers’ earning power through mastering the green technologies:

\[ Y = 0.197 + 3.142X1 + 1.857X2 - 0.041X3 \]  

where Y is the petrochemicals sales profit;

- X1 is the resource productivity of produced petrochemicals (the product output (in terms of product cost) to the cost of consumed resources);
- X2 is the share of the environmental R&D costs in the total cost of petrochemicals production and sales;
- X3 is the amount of specific quantities of atmospheric emissions at the petrochemical plants (emissions per unit of product output in terms of product cost).

In analyzing this equation, we can say that the greatest impact on the petrochemicals sales profit is made by the resource productivity factor, i.e. the product output (in terms of product cost) to the cost of consumed resources (coefficient 3.142). It is a direct relationship where any decrease in the resource productivity of produced petrochemicals over a time period leads to decrease in the sales profit, and vice versa.

The second variable in order of significance is X2 standing for the share of the environmental R&D costs in the total cost of petrochemicals production and sales (coefficient 1.857). It is also a direct relationship where any increase in the environmental R&D costs leads to higher enterprise profitability. It should be noted that this relationship has a certain time lag "costs – effect".

A less significant factor is the specific quantities of atmospheric emissions per unit of product output in terms of product cost (coefficient 0.041). In this case, we can see an inverse relationship where the lower the quantity of atmospheric emissions the greater the petrochemical enterprise profitability. Maybe, it is the case of heat energy recycling, i.e. when the heat is returned back to the production cycle, with increasing the profit owing to the reduced operational expenditures.

As such, by manipulating the variables or factors in the model, it is possible to manage the petrochemical manufacturing efficiency, as well as increase the effect of resource conservation
measures. The principles of petrochemical manufacturing efficiency improvement within an environmental system must necessarily meet the following criteria:

- manufacturing of the petrochemicals with the lowest environmental impact;
- application of the "green" chemistry approaches; prevention of environmental pollution;
- reduction of raw material losses; making it possible to use renewable raw materials (including energy sources);
- maximization of the efficiency and effectiveness of the resource-saving measures being applied for the manufacturing;
- minimization of any hazards and risks; compliance with the economic criteria etc.

3. Conclusion

In the context of the growing anthropogenic industrial load on the ecosystem, a new development paradigm is needed that would be based on accommodation of the production activities to the capabilities and needs of the biosphere. The point at issue is the industrial-scale production greening by application of resource-saving technologies, reduction of biosphere pollution, development of alternative energy sources, disposal and recycling of industrial wastes etc.

In an attempt to provide methodological support for optimization of the ecodesign of the petrochemical manufacturing, the authors in this study offer the mathematical model that demonstrates the method of improvement of the petrochemical manufacturers’ earning power through mastering the green technologies. The resultant factor is derived from the petrochemicals sales profit, while the variable factors are derived from the resource productivity of the produced products, specific environmental R&D costs, and specific quantities of atmospheric emissions.

As such, by manipulating the variables or factors in the model, it is possible to manage the petrochemical manufacturing efficiency, as well as increase the effect of resource conservation measures. The model proposed by the authors can also be used to analyze and predict effectiveness of the petrochemical manufacturing greening.

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