UDC 338

Barskiy I.
Post-graduate student,
Donetsk State University of Management, Ukraine;
e-mail: i.barskiy@marport.net; ORCID ID: 0000-0002-4156-3825
Makarenko M.
Doctor of Economics, Professor,
Azov maritime institute National university «Odessa maritime academy», Mariupol, Ukraine;
e-mail: marimakva@gmail.com; ORCID ID: 0000-0003-2006-3474
Gusakov S.
Post-graduate student,
Donetsk State University of Management, Ukraine;
e-mail: gusakov@mpw.uspa.gov.ua; ORCID ID: 0000-0001-7871-3930
Kalinina A.
Ph. D. in Economics, Associate Professor,
Azov maritime institute National university «Odessa maritime academy», Mariupol, Ukraine;
e-mail: tendernessrose@rambler.ru; ORCID ID: 0000-0003-2150-5326
Ustinov R.
Ph. D. in Economics, Associate Professor,
Mariupol Institute of the Interregional APM, Ukraine;
e-mail: Ustynov@gmail.com; ORCID ID: 0000-0003-4288-1072

ENVIRONMENTAL MANAGEMENT AS A TOOL FOR PROVIDING RESILIENCE OF THE SEA PORT

Abstract. It is proved the importance of environmental management to ensure sustainable development of the port. Based on the study of academic literature, the factors of external and internal environment that determine the need for the development of environmental management are identified. A generalized model of the environmental management system is proposed and the need to introduce a rational management system at all levels of port management is emphasized. It is emphasized that the problem of developing a system of ecological and economic model of management and decision making requires the use of theory and methods of modern information technology, as well as methods of adaptive and intelligent management of port processes in real time based on a set of technological and economic and environmental criteria. It is offered the general principle of formation of the combined criteria of management on all levels of hierarchy according to decomposition of management system structure of a production function and at the account of both economic and ecological parameters. A system-wide generalized technological, economic and environmental criterion for management and decision-making has been developed, which includes both qualitative and quantitative characteristics of services and environmental parameters of pollutants. For all technological and transport processes the local control criteria corresponding to the general system criterion on observations of technological and ecological parameters are received. Variants of criteria of operative management of operational function of port are developed. It is emphasized that the specific choice of quality criteria is determined by many factors, such as the specifics of the problem, the nature and complexity of the object, the simplicity and feasibility of the proposed algorithms. Relevant principles are given for the selection of the appropriate criterion. The concept of ecological management of port's operational function is formulated.

Keywords: environmental management, environmental criteria, seaport, management system, management principles.

JEL Classification M11

Formulas: 29; fig.: 2; tabl.: 0; bibl.: 24.

Барський І. М.
аспірант,
Донецький державний університет управління, Україна;
e-mail: i.barskiy@marport.net; ORCID ID: 0000-0002-4156-3825
Макаренко М. В.
доктор економічних наук, професор,
Азовський морський інститут Національного університету «Одеська морська академія», Маріуполь, Україна;
e-mail: marimakva@gmail.com; ORCID ID: 0000-0003-2006-3474
Гусаков С. В.
аспірант,
Донецький державний університет управління, Україна;
e-mail: gusakov@mpw.uspa.gov.ua; ORCID ID: 0000-0001-7871-3930
Калініна А. Г.
кандидат економічних наук, доцент,
Азовський морський інститут національного університету «Одеська морська академія», Маріуполь, Україна;
e-mail: tendernessrose@rambler.ru; ORCID ID: 0000-0003-2150-5326
Устинов Р. Г.
кандидат економічних наук, доцент,
Маріупольський інститут Міжрегіональної академії управління персоналом, Україна;
e-mail: Ustynov@gmail.com; ORCID ID: 0000-0003-4288-1072

ЕКОЛОГІЧНИЙ МЕНЕДЖМЕНТ ЯК ІНСТРУМЕНТ ЗАБЕЗПЕЧЕННЯ СТІЙКОСТІ МОРСЬКОГО ПОРТУ

Анотація. Доведено значення екологічного менеджменту для забезпечення сталого розвитку порту. На основі опрацювання академічної літератури виділено чинники зовнішнього і внутрішнього середовища, що зумовлюють потребу розвитку екологічного менеджменту. Запропоновано узагальнену модель системи екологічного менеджменту і підкреслено необхідність введення раціональної системи менеджменту на всіх рівнях управління порту. Підкреслено, що проблема розроблення системи еколого-економічної моделі управління й ухвалення рішень вимагає використання теорії і методів сучасних інформаційних технологій, а також методів адаптивного та інтелектуального управління технологічними процесами порту в реальному масштабі часу на базі комплексу технолого-економічних та екологічних критеріїв. Запропоновано загальний принцип формування комбінованих критеріїв управління за всіма рівнями ієрархії відповідно до декомпозиції структури системи управління виробничою функцією і при обліку як економічних, так і екологічних параметрів. Розроблений загальносистемний узагальнений технолого-економічний та екологічний критерій управління й ухвалення рішень, що включає як якісні, і кількісні характеристики послуг, так і екологічні параметри забруднювачів. Для всіх технологічних і транспортних процесів одержані локальні критерії управління, відповідні загальносистемному критерію за спостереженнями технологічних та екологічних параметрів. Розроблено варіанти критеріїв оперативного управління операційною функцією порту. Підкреслено, що конкретний вибір критерію якості визначається багатьма чинниками як щодо специфіки завдання, що вирішується, характером і складністю об'єкта, простотою і реалізованістю запропонованих алгоритмів. Для вибору відповідного критерію наведено відповідні принципи. Сформульовано концепцію екологічного управління операційною функцією порту.

***Ключові слова*:** екологічний менеджмент, екологічні критерії, морський порт, система управління, принципи управління.

Формул: 29; рис.: 2; табл.: 0; бібл.: 24.

ISSN 2306-4994 (print); ISSN 2310-8770 (online)

Introduction. The intensive development of maritime transport throughout the world, characterized by the rapid development of integration and globalization processes, has a significant impact on economic growth of both individual regions and states. Such circumstances can explain the role and importance of seaports as city-forming enterprises. Their activities are in the focus not only of the consumers of their services. Therefore, the formation of a new society focused on knowledge, information technologies and cannot occur without due attention to the environmental component of enterprises' activities. However, at present, the resulting economic and commercial indicators of ports' activities do not include aggregate environmental costs, including the assessment of environmental damage and the costs of restoring air, water, land and biological resources to an acceptable level according to the standards.

Criteria have not been formed to assess enterprises that meet the requirements of the «green» economy. The actual payments for pollution are still extremely low, which does not allow not only to ensure the reproduction of ecological resources at a cost, but also not to cover the current environmental costs. To overcome these trends and achieve the goals of sustainable and balanced socio-ecological and economic development of ports, it is necessary to formulate principles and criteria for sustainable development of ports.

Today, seaports need to look for untapped technological, technical, organizational and managerial opportunities that can be used to ensure the sustainable development of the port. Ecological management prevents pollution of the environment, port waters, water resources, air. In order to preserve natural resources, their development, rational consumption, appropriate technologies are needed to manage environmental processes that occur in seaports. Thus, the ecological activity of the port falls within the scope of specialists' research in order to develop and implement modern tools in the mechanism of environmental management

Analysis of research and problem statement. The analyses of relevant materials [1—4] on the research topic proves the relevance of the studied issues of environmental management of seaport, because the existing system of nature management does not ensure the coordination of economic and environmental interests of modern ports. Their irrational use and environmental pollution continue in almost all world ports [5—8], so the goals of society must be realized through the achievement of the relevant goals of industry's enterprises. This approach will achieve the global environmental goals of society.

Insufficient development of environmental management in ports can be explained by the influence of external and internal factors [9—12]. First of all, such factors include market transformations, changes in logistics chains, the spread of globalization, fierce competition in the industry, government policy, human resources development, lack of financial resources and so on [13—17].

The action of such or similar factors leads to decrease of attention according to the problems of environmentally safe work, protection of the environment from the consequences of activities, pollution in all areas, deterioration of public health [18—20].

Therefore, special sanctions are applied to the port, which may limit its financial activities and require additional funds to eliminate the negative consequences of its activities [21—24]. Therefore, the responsibility raises and understanding of the need to plan and implement environmental measures to achieve the stability of the seaport also increases.

Unsolved aspects of the problem. Despite the constant increase in the relevance of environmental issues in the activities of ports, it requires further research system and criteria for managing the environmental parameters of port.

The purpose of the article is to form a combined criteria of port management system, taking into account both economic and environmental parameters of its development.

Research results. On the basis of elaboration of academic literature [8—10; 19; 23; 24] it is possible to allocate the factors causing necessity of development of ecological management (*Fig. 1*).

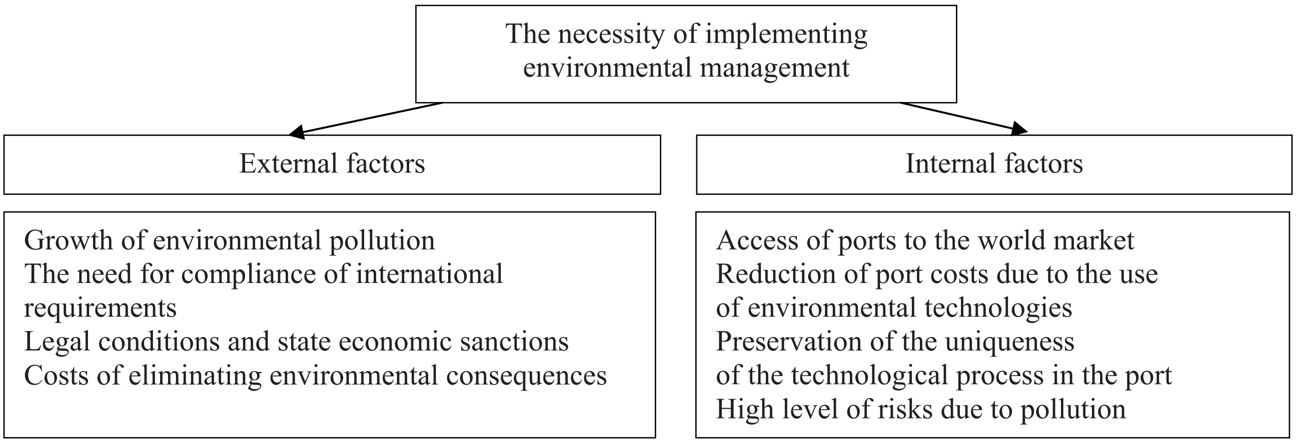

Fig. 1. **Factors that determine the need for environmental management**

Seaports in the event of emergency consequences of their activities incur material losses to eliminate the environmental consequences, but their own funds are sometimes insufficient for this. According to world experience, companies should invest money not in eliminating the consequences, but in preventing environmental pollution, which can ensure the effective organization of environmental management.

Intensification of foreign economic activity of ports, access to world markets, strict rules of international trade and competition in world markets, ports use international standards. Today, the environmental activities of ports are regulated by legislation, standards that define the system of environmental management, which serves as a common way of action for ports, necessary to achieve its environmental goals and the gradual solution of problems. The systematic concept «environmental management» defines the generalized model of environmental management, which is shown in *Fig. 2*.

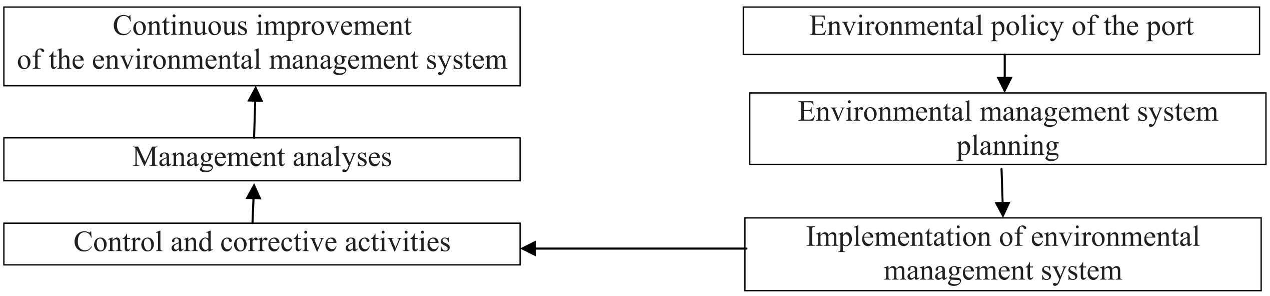

Fig. 2. **Model of ecological management system**

The standard provides a set of rules and requirements for ports, without offering specific methods for organizing assessments and assessments of environmental management in the port. Therefore, it is necessary to form their own organizational foundations for the functioning and evaluation of environmental management. This will help to improve to improve the environmental management of ports, promote the quality of their services in the conditions of fierce global competition and expand their capabilities in world markets. In addition, it should be emphasized that environmental management creates more favorable conditions and additional opportunities for investment, and also improves the image of ports in the market.

Scientists of different countries have put the proposal according to introduce a rational management system at all levels of port management.

The problem of developing a system of ecological and economic model of management and decision-making requires the use of theories and methods of modern information technologies, as well as methods of adaptive and intelligent management of port processes in real time based on a set of technological and economic and environmental criteria.

ISSN 2306-4994 (print); ISSN 2310-8770 (online)

The modern theory of choice and decision-making is based on two approaches: quantitative and qualitative. The quantitative approach assumes to each possible decision a quantitative estimation (number) of value of some vector, in the general case of function (indicator of quality of the decision). However, this approach does not cover many natural situations of choice and decision-making. Another approach to evaluating decisions based on the language of blurred criteria and models, as the most appropriate for many real complex processes and objects, has much wider possibilities.

With the creation of a modern management system of seaports, the problems of ensuring their sustainable development, namely the study of the rational relationship between production function, consumption and the amount of environmental pollution are becoming increasingly important.

Within the framework of such approach, it is possible to use the theory of production function, complex modeling, methods of the theory of optimal control. A special place should be occupied by such issues as control of environmental pollution in the implementation of its production functions, namely the maintenance of the vessel in the port, loading and unloading operations.

Assume that the utility function has the form *U*(*P*, *C*), where *P* and *C* its arguments which represent the amount of resource consumption and the amount of pollution. They can be vector quantities. It is necessary that the following conditions are met:

$$\frac{\partial U}{\partial P} > 0, \frac{\partial U}{\partial C} < 0, \frac{\partial^2 U}{\partial P^2} < 0, \frac{\partial^2 U}{\partial C^2} < 0, \lim \frac{\partial \mathrm{U}}{\partial \mathrm{P}}_{P\to 0} = \infty\}. \quad (1)$$

Next, we also take some assumptions about the nature of the investigated function, assuming that the nature of the function *U*(*P*, *C*). This applies to such a property as «substitution». It is known from microeconomics that in the case of reducing the consumption of *P* by Δ*P*, in order for the value of the utility function not to change, it is necessary to reduce the amount of pollution *C* by Δ*C*. This effect is determined by the marginal rate of substitution, as in the case of production functions:

$$NS = \frac{dC}{dP} = -\frac{\partial U}{\partial P}\Big/\frac{\partial U}{\partial C}. \quad (2)$$

The assumption that will be applied to the utility function *U*(*P*, *C*) will be as follows: at a low level of consumption to compensate for the reduction of *P* by the appropriate unit, it is required to reduce the amount of pollution by a sufficiently large value. On the contrary, with an unlimited increase in *P*, the value of Δ*C* required to compensate for the corresponding unit of consumption tends to 0. This can be interpreted as the lines of function are NS, which defined by equations in the form $NS\ (P, C) = NS_0$, where $NS_0 > 0$, have the nature of hyperbole. The curve $C = f_c(P, NS_0)$, defined by the written equation must have the following properties: $\lim_{p\to 0} f_c(P, NS_0) = \infty$, $\lim_{p\to\infty} f_c(P, NS_0) = 0$, i $f_c(P, NS_0)$ gradually decreases with increasing P.

Since $NS = \frac{\partial C}{\partial P}$ i $\frac{dC}{dP} = -\frac{\partial NS}{\partial P}\Big/\frac{\partial NS}{\partial C}$, then the condition of gradual decrease of the function $f_c(P, NS_0)$ can be set as $-\frac{\frac{\partial NS}{\partial P}}{\frac{\partial NS}{\partial C}} < 0$, or calculating the partial derivatives of the function $NS = NS(P, C)$, we obtain the equation

$$\left(\frac{\partial^2 U}{\partial P^2} - \frac{\frac{\partial U}{\partial P}}{\frac{\partial U}{\partial C}} \cdot \frac{\partial^2 U}{\partial P \partial C}\right)\left(\frac{\partial^2 U}{\partial C^2} - \frac{\frac{\partial U}{\partial P}}{\frac{\partial U}{\partial C}} \cdot \frac{\partial^2 U}{\partial P \partial C}\right) < 0. \quad (3)$$

This condition is valid in particular, if $\partial^2 U / \partial P \partial C \leq 0$. An example of a utility function that satisfies the above constraints is the function $U\ (P, C) = aP^{\alpha} - bC^{\beta}$, where $a, b > 0$; $0 < \alpha < 1$, $\beta > 1$. As a criterion to be maximized, the functional is accepted:

$$J(P, C) = \int_0^T U(P, C)e^{-\gamma t}\, dt, \quad (4)$$

where $P \equiv P(t)$, $C \equiv C(t)$ $I\gamma$ — discount rate.

Consider the problem of control in the port over the pollution using the cleaning processes. The neoclassical one-product two-factor function $V = F(K, L)$ will be used as a production (operational) function, where K is the value of fixed capital and L is the value of human resources. We can assume that fixed capital has depreciation, which is characterized by a constant rate $\mu > 0$, and for simplicity, we assume that L = const, that does not change over time ($L = 0$).

Pollution and the polluter are not used in production as useful product, but they are its by-product. We can assume that the magnitude of the pollutant is directly proportional to the magnitude of the manufacturing product and is a fraction of it ε, $0 < \varepsilon < 1$. Thus, pollution is measured in the same units as the main product. We will also assume that the natural decline of waste at any given time is a fraction of their total amount.

Society, in turn, can allocate a part of the social product on fighting with the pollution. It is assumed that the efficiency (productivity) of costs to reduce pollution is constant. The consumption of one unit of service (product) reduces pollution by δ units ($\delta > 1$).

The task of pollution management is to determine the particles $\alpha(t)$ and $\beta(t)$ of the release, which is intended for consumption and pollution control, respectively.

Thus, we have the following ecological and economic model of the system:

$$\begin{cases} P = \propto F(K, L) \\ \dot{K} = F(K,L) - \propto F(K,L) - \beta F(K,L) - \mu K, \\ \dot{C} = \varepsilon F(K,L) - \delta\beta F(K,L) - \theta C \end{cases} \quad (5)$$

where $0 \le \alpha(t) \le 1$, $0 \le \beta(t) \le 1$, $\alpha(t) + \beta(t) \le 1$.

The problem of optimal control (4, 5) is the problem of estimating the vector $u(t) = (\alpha(t), \beta(t))$, which can be solved, for example, using the maximum principle.

Denote by ψ_1 the double variable corresponding to the equation (5), i.e. $\psi_1(t)$ is an objectively determined estimate of capital $K(t)$ at the moment t, and by ψ_2 is an objectively determined estimate of pollution $C(t)$.

We introduce the Hamiltonian H for the problem (4, 5) in the form of H (α, β) = $= U(P, C)e^{-\gamma t} + [(1 - \propto - \beta)F(K,L) - \mu K] + \psi_2[(\varepsilon - \delta\beta)F(K,L) - \theta C]$.

The connected (double) system of equations will look like:

$$\begin{cases} \dot{\psi}_1 = -\left\{\frac{\partial U}{\partial P} \propto \frac{\partial F}{\partial K} e^{-\gamma t} + \psi_1\left[(1-\alpha-\beta)\frac{\partial F}{\partial K} - \mu\right] + \psi_2(\varepsilon - \delta\beta)\frac{\partial F}{\partial K}\right\} \\ \dot{\psi}_2 = -\frac{\partial U}{\partial C} e^{-\gamma t} + \psi_2\theta \end{cases}. \quad (6)$$

Renomalizing the double estimates as $q_1 = \psi_1 e^{\gamma t}$ i $q_2 = \psi_2 e^{\gamma t}$, we have a related system in the form:

$$\begin{cases} \dot{q}_1 = -\left\{\frac{\partial U}{\partial P} \propto \frac{\partial F}{\partial K} + q_1\left[(\gamma + \mu - (1-\alpha-\beta)\frac{\partial F}{\partial K} - \mu\right] + q_2(\varepsilon - \delta\beta)\frac{\partial F}{\partial K}\right\} \\ \dot{q}_2 = -\frac{\partial U}{\partial C} + q_2(\theta + \gamma), \end{cases} \quad (7)$$

and the Hamiltonian H is equal to:

$$\mathrm{H} = e^{-\gamma t}\{U(\propto F(K,L), c) + q_1[(1 - \propto - \beta)F(K,L) - \mu K] + q_2[(\varepsilon - \delta\beta)F(K,L) - \theta C]\}. \quad (8)$$

According to the maximum principle, if the equation $u(t) = (\alpha(t), \beta(t))$ is optimal, then there are continuous functions $q_1(t)$ and $q_2(t)$ satisfying the above conditions (7). The functions $\alpha(t)$ and $\beta(t)$ maximize the value of the hamiltonian H at time t.

Maximizing the function H can be reduced to maximizing the expression:

$\varphi(\alpha, \beta) = \varphi_0(\alpha) + \zeta\beta$, where $\alpha, \beta \ge 0$, $\alpha + \beta \le 1$ and $\varphi_0(\alpha) = U(\alpha F(K,L), \mathrm{C}) - q_1(\alpha F(K, L)$, (9)

where $\zeta = -(q_1 + q_2\delta)F(K, L)$

in the case $\zeta > 0$ it is obvious that the maximum of the function (q) is reached at $\alpha + \beta = 1$. If $\zeta < 0$, then the maximum $\varphi(\alpha, \beta)$ is reached at $\beta = 0$.

When $\zeta = 0$, then β is arbitrary and α is either equal 1, or is a solution of the equation $\frac{\partial \varphi_0}{\partial \alpha} = 0$. The detailed analyses of the behavior of optimal trajectories in the presented model is

ISSN 2306-4994 (print); ISSN 2310-8770 (online)

quite complex because it contains two control parameters. However, bearing in mind the significant role played in describing the optimal trajectories of the equilibrium point, we will try to answer the question. Are there balanced growth trajectories (equilibrium points) in the presented model that satisfy the necessary conditions of the maximum principle, and how many? Prove that there are exactly two equilibrium points. In one such provision, no means are spent on pollution control. This state of the model was called «the balance of the dark age». It is characterized by a high level of production (a large amount of fixed capital), a high level of consumption and an extremely high level of pollution, which is regulated only by natural cleaning processes. The state of equilibrium, in which the costs of both consumption and the fight against pollution are carried out, is called the equilibrium of the «golden age». It differs from the equilibrium of the dark age by lower levels of capital, consumption and pollution. The equilibrium state is described by the quotation $\dot{K} = 0$, $\dot{C} = 0$, i.e.

$$(1 - \alpha - \beta)F(K, L) = \mu K; \tag{10}$$

$$(\varepsilon - \delta\beta)F(K, L) = \theta C. \tag{11}$$

Since the value of *K* in the equilibrium state is constant and, of course, positive, it follows from the last equation that the sum (α + β) of the corresponding optimal controls is constant and strictly less than 1. Therefore, α < 1, β < 1, and the case occurs ζ ≤ 0 and then the corresponding values). From the last equation we obtain that at the equilibrium point the control β (and hence α) is constant. Since α < 1, $\frac{\partial \varphi_0}{\partial \alpha} = 0$, i.e.

$$\frac{\partial U(\alpha F(K,L), C)}{\partial P} = q_1. \tag{12}$$

It follows that the function $q_1(t)$ is a constant. The formula $(\varepsilon - \delta\beta)F(K, L) = \theta C$ shows that in this case $q_2(t)$ must also be constant. From the above formula we obtain the expression q_2 through the function *U*:

$$q_2 = \frac{1}{\theta + \gamma} \cdot \frac{\partial U}{\partial C}. \tag{13}$$

Thus, the equation takes (12) the following form:

$$q_1\left(\gamma + \mu - \frac{\partial F}{\partial K} + \beta\frac{\partial F}{\partial K}\right) - q_2(\varepsilon - \delta\beta)\frac{\partial F}{\partial K} = 0. \tag{14}$$

The water resource of the coastal region is an important component of life, and therefore the problem of its rational use from the standpoint of economic and environmental monitoring is relevant not only for ports but also for the entire coastal region.

The following is the approach to economic-mathematical modeling and optimization of the water use process in the region when the cost of water consumption is taken into account, i.e. when the unit price of water is set or being set. Let in consumers use the total water resource of the region. Water consumers in the region are ports, industrial enterprises, agricultural enterprises and others. Two cases can be investigated.

1. Suppose first that each consumer Пi spends some water, but does not change its quality. Let *R* is the resource of all water; xi water consumption by thei-м consumer; $p_i(x_i)$ is profit received from water consumption in the amount of X_i *i*-м consumer; $\overline{x_i}$ limit value of water consumption by the *i*-м enterprise. Here $p_i(x_i)$ is a utility function and only 1 resource is considered. Then the task of maximizing the profits of all consumers from the use of water is as follows:

$$\sum_{i=1}^{n} p_i(x_i) \to \max; \tag{15}$$

$$\sum_{i=1}^{n} x_i \le R\,; \tag{16}$$

$$0 \le x_i \le \overline{x_i}.$$

In the conditions of market economy, we will assume that there is no exchange of information on water consumption between consumers, because they are not interested in disclosing their useful functions $p_i(x_i)$. The coordinating state (regional) body sets some price for water. Each consumer orders the required amount of water at a given price. Depending on the ratio between the total demand for water and its available resource, the coordinating body adjusts the price and informs consumers of its new value. To solve the above problem (15—16), we write the Lagrange function:

$$L(x, u) = \sum_{i=1}^{n} p_{i(x_i)} + u\left(R - \sum_{i=1}^{n} x_i\right) = \sum_{i=1}^{n} p_{i(x_i)} - u\sum_{i=1}^{n} x_i + uR, \tag{17}$$

where u is the unit price of water volume (Lagrange multiplier). So, we have the following task now:

$$L(x,u) \to \max, 0 \le x \le \bar{x}. \tag{18}$$

Which for concave utility functions $p_{i(x_0)}$, — that usually occurs, can be solved as a family of subtasks:

$$p_i(x_i) - u^* x_i \to \max \quad 0 \le x_i \le \overline{x_i}, i = \overline{1,n}, \tag{19}$$

where u^* is the proposed optimal solution of the double prescribed problem. Therefore, if the price u^* is known, then there is a decentralization of problems (15; 16; 19). However, u^* is usually unknown. Therefore, the following procedure can be suggested. Let we know $u^к$, $k = 0, 1, 2, ...$ the water price at time t_k. Then each water consumer determines his x_i^k, by solving the task

$$p_i(x_i) - u^k x_i \to \max \quad 0 \le x_i \le \overline{x_i},\ i = \overline{1,n}. \tag{20}$$

The new water price u^{k+1} is determined by changing u^k in proportion to the difference between the total water demand $\sum_{i=1}^{n} x_i^k$ and its supply R taking into account the mandatory positivity:

$$u^{k+1}: u^{k+1} = \max\{0, u^k + \gamma_k(\textstyle\sum_{i=1}^{n} x_i^k - R)\}, \tag{21}$$

where γ_k is some step factor. It should be noted that the expression $\sum_{i=1}^{n} x_i^k - R$ in the above equation is a generalized gradient of the objective function

$$\varphi(u) = \max_{0 \le x_i \le \bar{x}_i} L(x,u),\ i = \overline{1,n}. \tag{22}$$

Under the assumptions which was made, this function will be one that does not differentiate for those $u = u^k$, when at least one of the problems (20) has more than one optimal solution. This procedure (21) is a method of generalized gradient descent to solve the problem of minimizing the function $\varphi(u)$ at $u \ge 0$. Therefore, the step factor γ_k can be based on the usual conditions for this method: $\gamma_k \ge 0$, $\gamma_k \to 0$ for $k \to \infty$, $\sum \gamma_k = \infty, \sum \gamma_{k^2} < \infty$. Note again that u^* can be interpreted as the optimal payment for water, and x_i^k – as the demand for water of the i-th consumer at the price u^k. Therefore, the ratio is the difference analogue of the Walras equation, which describes the dynamics of prices in a competitive market and the procedure for forming the optimal (i.e. equilibrium) price.

Thus, the stated algorithm simulates the procedure of market pricing for the «common resource» — water. If in each model (15; 16) x_i is a vector$x_i \in R_+^m$, then the problem (20) will have the following form:

$$p_i(x_i) - u^k \textstyle\sum_{j=1}^{m} x_{ij} \to max,\ \ x_i \in X_i \complement R_+^m,\ \ \ i = \overline{1,n}. \tag{23}$$

2. In practice, in the process of water use, part of the water is polluted and its quality and composition deteriorate due to the discharge of industrial waste into the aquatic environment. Therefore, economic and mathematical modeling should take into account these environmental factors and build ecological and economic models of the water use process. In this model, first of all, the purpose function (15) and constraints (16) will be supplemented by the following constraints:

$$\textstyle\sum_{i=1}^{n} C_i^s(x_i) \le \overline{C^s}, s = \overline{1,S}. \tag{24}$$

Where $C_i^s(x_i)$ is the dependence between the volume of water consumption and the increase in the concentration of the s-th pollutant in the water C^s the presence of the s-th pollutant in the water, S is the number of pollutants which are taken into account. In this case together with the price of water should be introduced tax v_s, by which is levied the unit of the s-th pollutant, discharged into the water.

Thus, to solve the problem (20; 24) requires some adaptive algorithm for pricing for water and taxation for the discharge of pollutants, which has the following form:

- Choose arbitrary u^0 і $v_s^0, s = \overline{1,S}$. Then: the optimal structure of water uses x_i is determined independently by each consumer on the condition of maximum profit:

$$p_i(x_i) - u^k x_i - \textstyle\sum_{s=1}^{S} v_s^k C_i^s(x_i) \to \max \quad 0 \le x_i \le \overline{x_i}, i = \overline{1,n}; \tag{25}$$

- The new price u^{k+1} of water is determined according to (21).

ISSN 2306-4994 (print); ISSN 2310-8770 (online)

- New rates v_s^{k+1} of taxes for water pollution are calculated by the formula:

$$v_s^{k+1} = \max\{0,\ v_s^k + \gamma_k^s(\sum_{i=1}^{n} C_i^s(x_i) - \overline{C_s})\}, s = \overline{1,S}. \quad (26)$$

This algorithm additionally requires the convexity of the function $C_i^s(x)$ and the existence of an internal point of plural given by the constraints (24). In conclusion, it should be noted that random fluctuations and uncertainties in the magnitude of water demand require a stochastic model of water use by many consumers, i.e.:

$$E\{\sum_{i=1}^{n} p_i(x_i, \omega)\} \to \max \quad (27)$$

$$\sum_{i=1}^{n} x_i \leq R \quad (28)$$

$$0 \leq x_i \leq \overline{x_i}, i = \overline{1,n},$$

where $p_i(x_i, \omega)$ is the profit received from water consumption by the води i-th consumer in the amount of x_i, depending on the random parameters ω with a given distribution law; E is a sign of mathematical expectation. To solve the problem (27; 28) we can use a stochastic analogue of the above algorithm. Note also that it would be possible to present a model of water use in the case of possible transfer of excess water resources for a given consumer to another partner at a certain price. Note that as a function $p_i(x_i)$ can take the function of the vector argument $X_i = (x_{i1}, \ldots, x_{im})$, where $\{x_{ij}\}$ is the j-th resource used by the i-th enterprise and, in particular, we can take the concave generalized function of Cobb-Douglas in such type:

$$p_i(X_i) = \gamma_i \prod_{j=1}^{m} x_{ij}^{a_{ij}} = \gamma_i x_{i1}^{\alpha_{i1}} \cdot x_{i2}^{\alpha_{i2}} \cdot \ldots \cdot x_{im}^{\alpha_{im}}, \quad (29)$$

where $\gamma_i > 0$, $\alpha_{ij} \geq 0$ are given numbers such that $\sum_{j=1}^{m} \propto_{ij} = \forall\ i = \overline{1,n}$.

Conclusion. Thus, it was proposed the general principle of forming combined management criteria at all levels of the hierarchy in accordance with the decomposition of the structure of the management system of the production function and taking into account both economic and environmental parameters.

It was developed the system-wide generalized technological, economic and ecological criterion of management and decision-making which includes both qualitative, and quantitative characteristics of services, and ecological parameters of pollutants.

For all technological and transport processes the local control criteria corresponding to the general system criterion on supervision of technological and ecological parameters are received. Variants of criteria of operative management of operational function of port are developed.

The specific choice of quality criteria is determined by many factors, such as the specifics of the problem to be solved, the nature and complexity of the object, the simplicity and feasibility of the proposed algorithms.

To select the appropriate criterion, it can be based on the following principles:

- the principle of compromises, i.e. a compromise between adequacy and mathematical simplicity, practical utility, convenience and ease of implementation in practice;
- the principle of information insufficiency and uncertainty, ie the lack of accurate information leads to the possibility and necessity of choosing a criterion that obeys the mathematical and software simplicity of implementation;
- the principle of relativity of the criterion, i.e. the absence of general practical recommendations and considerations of the preferred choice of the criterion from a possible class of criteria;
- the principle of development, necessity and importance of taking into account modern approaches to the description of vague and mixed information uncertainties;
- the principle of absence and relativity of the optimal criterion of efficiency and quality.

With the approach to the formation of the criterion, the concept of management is as follows:

- it is formed the criterion of management on the measured values of technological, economic and ecological parameters;
- it is optimized the operational activity of the port according to the formed management criterion;

- the environmental and economic parameters are controlled, and in case of exceeding the permissible norms, measures are taken to reduce the concentration of harmful substances by reducing productivity, optimizing the modes of operation of local processes, etc.

- the integrated accounting of pollutant emissions is conducted from the beginning of the year and, if necessary, an adjustment is made to their permissible current concentration;

- it is controlled the current values of the concentration of harmful substances released into the atmosphere, water without allowing to exceed their limit values.

Література

1. Braathen N. A. Environmental Impacts of International Shipping: the Role of Ports. OECD Publishing. Paris, France : Nils Axel Braathen, 2011.
2. Psaraftis H. N., Kontovas C. A. Balancing the economic and environmental performance of maritime transportation. *Transportation Research D*. 2010. Vol. 15. № 8. P. 458—462.
3. Woo J. K., Moon D. S. H. The effects of slow steaming on the environmental performance in liner shipping. *Maritime Policy and Management*. 2014. Vol. 41. № 5. P. 1—16.
4. Klopott M. Restructuring of environmental management in Baltic ports: case of Poland. *Maritime Policy and Management*. 2013. Vol. 40. № 5. P. 439—450.
5. Chiu R. H., Lai I. C. Green port measures: empirical case in Taiwan. *Proceedings of the Eastern Asia Society for Transportation Studies*. 2011. Vol. 8. P. 1—15. URL : https://www.hindawi.com/journals/mpe/2014/802976.
6. Homsombat W., Yip T. L., Yang H., Fu X. Regional cooperation and management of port pollution. *Maritime Policy and Management*. 2013. Vol. 40. № 5. P. 451—466.
7. Chang Y. T. Environmental efficiency of ports: a data envelopment analysis approach. *Maritime Policy and Management*. 2013. Vol. 40. № 5. P. 467—478.
8. Winnes H., Styhre L., Fridell E. Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management*. 2015. Vol. 17. P. 73—82.
9. Zis T., North R. J., Angeloudis P., Ochieng W. Y., Bell M. G. H. Environmental Balance of Shipping Emissions Reduction Strategies. *Transportation Research Record: Journal of the Transportation Research Board*. 2015. Vol. 2479. P. 25—33.
10. Gonzalez A. M., Bergqvist R., Monios J. A global review of the hinterland dimension of green port strategies. *Transportation Research Part D: Transport and Environment*. 2018. Vol. 59. P. 23—34.
11. Smirnov G., Artemyeva A. The Cosmoplanetary Economy of Lost Humanity: the Postnonclassical Version of Noospheric Ontology (Philosophical Reflection). *Philosophy and Cosmology*. 2021. Vol. 26. P. 156—168.
12. Nitsenko V., Mardani A., Kuksa I., Sudarkina L. Additional opportunities of systematization the marketing research for resource conservation practice. *Management Theory and Studies for Rural Business and Infrastructure Development.* 2018. Vol. 40 (3). P. 361—368.
13. Nguyen N. T. Marine Culture of Northeast Vietnam: Approaching from the Theory of Culture Ecology. *Future Human Image*. 2020. Vol. 13. P. 66—75.
14. Yatsenko O., Nitsenko V., Mardani A., Tananaiko T. The impact of global risks on the world trade and economic environment. *Financial and credit activity: problems of theory and practice*. 2018. Vol. 4 (27). P. 435—444.
15. Soroka L. Modern Challenges to Establishing Global Law on Sustainable Development of Space Activities. *Advanced Space Law*. 2020. Vol. 6. P. 64—71.
16. Nitsenko V., Chukurna O., Mardani A., Streimikis J., Gerasymchuk N., Golubkova I., Levinska T. Pricing in the Concept of Cognitive Marketing in the Context of Globalization: Theoretical, Methodological and Applied Aspects. *Montenegrin Journal of Economics*. 2019. Vol. 15 (4). P. 131—147.
17. Gochua A., Zedelashvili T. Cyber Threats and Asymmetric Military challenges In the Context of Nuclear Security: Ukrainian and International Cases Analysis. *Ukrainian Policymaker*. 2020. Vol. 7. P. 20—27.
18. Koliadenko S., Golubkova I., Babachenko M., Levinska T., Burmaka L. Development and use of it solutions in logistics. *Financial and credit activity: problems of theory and practice*. 2020. Vol. 3 (34). P. 230—236.
19. Latysheva O., Rovenska V., Smyrnova I., Nitsenko V., Balezentis T., Streimikiene D. Management of the sustainable development of machine-building enterprises: a sustainable development space approach. *Journal of Enterprise Information Management*. 2020. Vol. 34 (1). P. 328—342.
20. Osaulenko O., Yatsenko O., Reznikova N., Rusak D., Nitsenko V. The Productive Capacity of Countries Through the Prism of Sustainable Development Goals: Challenges to International Economic Security and to Competitiveness. *Financial and credit activity problems of theory and practice*. 2020. Vol. 2 (33). P. 492—499.
21. Yashchyshyna I., Svider O., Kushnir O., Konovalova M. Corporate social responsibility of the enterprise: shortcomings and social effects for Ukrainian society. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*. 2020. Vol. 1. P. 152—157.
22. Mikhno I., Koval V., Shvets G., Garmatiuk O., Tamošiūnienė R. Discussion: Green Economy in Sustainable Development and Improvement of Resource Efficiency. *Central European Business Review*. 2021. Vol. 10 (XX). P. 1—15.
23. Kotenko S., Nitsenko V., Hanzhurenko I., Havrysh V. The Mathematical Modeling Stages of Combining the Carriage of Goods for Indefinite, Fuzzy and Stochastic Parameters. *International Journal of Integrated Engineering*. 2020. Vol. 12 (7). P. 173—180.
24. Pylypenko H., Fedorova N., Huzenko I., Naumenko N. Paradoxes of economic development: science and innovation in the modern world. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*. 2020. Vol. 2. P. 153—159.

Статтю рекомендовано до друку 15.05.2021

ISSN 2306-4994 (print); ISSN 2310-8770 (online)

References

1. Braathen, N. A. (2011). Environmental Impacts of International Shipping: the Role of Ports. OECD Publishing. Paris, France: Nils Axel Braathen.
2. Psaraftis, H. N., & Kontovas, C. A. (2010). Balancing the economic and environmental performance of maritime transportation. *Transportation Research D*, *Vol. 15* (8), 458—462. https://doi.org/10.1016/j.trd.2010.05.001.
3. Woo, J. K., & Moon, D. S. H. (2014). The effects of slow steaming on the environmental performance in liner shipping. *Maritime Policy and Management*, *Vol. 41* (5), 1—16. https://doi.org/10.1080/03088839.2014.931607.
4. Klopott, M. (2013). Restructuring of environmental management in Baltic ports: case of Poland. *Maritime Policy and Management*, *Vol. 40* (5), 439—450. https://doi.org/10.1080/03088839.2013.798440.
5. Chiu, R. H., & Lai, I. C. (2011). Green port measures: empirical case in Taiwan. *Proceedings of the Eastern Asia Society for Transportation Studies*, *Vol. 8*, 1—15.
6. Homsombat, W., Yip, T. L., Yang, H., & Fu, X. (2013). Regional cooperation and management of port pollution. *Maritime Policy and Management*, *Vol. 40* (5), 451—466. https://doi.org/10.1080/03088839.2013.797118.
7. Chang, Y. T. (2013). Environmental efficiency of ports: a data envelopment analysis approach. *Maritime Policy and Management*, *Vol. 40* (5), 467—478. https://doi.org/10.1080/03088839.2013.797119.
8. Winnes, H., Styhre, L., & Fridell, E. (2015). Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management*, *Vol. 17*, 73—82. https://doi.org/10.1016/j.rtbm.2015.10.008.
9. Zis, T., North, R. J., Angeloudis, P., Ochieng, W. Y., & Bell, M. G. H. (2015). Environmental Balance of Shipping Emissions Reduction Strategies. *Transportation Research Record: Journal of the Transportation Research Board*, *Vol. 2479*, 25—33. https://doi.org/10.3141/2479-04.
10. Gonzalez A., M., Bergqvist, R., & Monios, J. (2018). A global review of the hinterland dimension of green port strategies. *Transportation Research Part D: Transport and Environment*, *Vol. 59*, 23—34. https://doi.org/10.1016/j.trd.2017.12.013.
11. Smirnov, G., & Artemyeva, A. (2021). The Cosmoplanetary Economy of Lost Humanity: the Postnonclassical Version of Noospheric Ontology (Philosophical Reflection). *Philosophy and Cosmology*, *Vol. 26*, 156—168. https://doi.org/10.29202/phil-cosm/26/13.
12. Nitsenko, V., Mardani, A., Kuksa, I., & Sudarkina, L. (2018). Additional opportunities of systematization the marketing research for resource conservation practice. *Management Theory and Studies for Rural Business and Infrastructure Development*, *Vol. 40* (3), 361—368. https://doi.org/10.15544/mts.2018.34.
13. Nguyen, N. T. (2020). Marine Culture of Northeast Vietnam: Approaching from the Theory of Culture Ecology. *Future Human Image*, *Vol. 13*, 66—75. https://doi.org/10.29202/fhi/13/7.
14. Yatsenko, O., Nitsenko, V., Mardani, A., & Tananaiko, T. (2018). The impact of global risks on the world trade and economic environment. *Financial and credit activity: problems of theory and practice*, *Vol. 4* (27), 435—444. https://doi.org/10.18371/fcaptp.v4i27.154279.
15. Soroka, L. (2020). Modern Challenges to Establishing Global Law on Sustainable Development of Space Activities. *Advanced Space Law*, *Vol. 6*, 64—71. https://doi.org/10.29202/asl/6/7.
16. Nitsenko, V., Chukurna, O., Mardani, A., Streimikis, J., Gerasymchuk, N., Golubkova, I., & Levinska, T. (2019). Pricing in the Concept of Cognitive Marketing in the Context of Globalization: Theoretical, Methodological and Applied Aspects. *Montenegrin Journal of Economics*, *Vol. 15* (4), 131—147. https://doi.org/10.14254/1800-5845/2019.15-4.10.
17. Gochua, A., & Zedelashvili, T. (2020). Cyber Threats and Asymmetric Military challenges In the Context of Nuclear Security: Ukrainian and International Cases Analysis. *Ukrainian Policymaker*, *7*, 20—27. https://doi.org/10.29202/up/7/3.
18. Koliadenko, S., Golubkova, I., Babachenko, M., Levinska, T., & Burmaka, L. (2020). Development and use of it solutions in logistics. *Financial and credit activity: problems of theory and practice*, *Vol. 3* (34), 230—236. https://doi.org/10.18371/fcaptp.v3i34.215518.
19. Latysheva, O., Rovenska, V., Smyrnova, I., Nitsenko, V., Balezentis, T., & Streimikiene, D. (2020). Management of the sustainable development of machine-building enterprises: a sustainable development space approach. *Journal of Enterprise Information Management*, *Vol. 34* (1), 328—342. https://doi.org/10.1108/JEIM-12-2019-0419.
20. Osaulenko, O., Yatsenko, O., Reznikova, N., Rusak, D., & Nitsenko, V. (2020). The Productive Capacity of Countries Through the Prism of Sustainable Development Goals: Challenges to International Economic Security and to Competitiveness. *Financial and credit activity: problems of theory and practice*, *Vol. 2* (33), 492—499. https://doi.org/10.18371/fcaptp.v2i33.207214.
21. Yashchyshyna, I., Svider, O., Kushnir, O., & Konovalova, M. (2020). Corporate social responsibility of the enterprise: shortcomings and social effects for Ukrainian society. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, *Vol. 1*, 152—157. https://doi.org/10.33271/nvngu/2020-1/152.
22. Mikhno, I., Koval, V., Shvets, G., Garmatiuk, O., & Tamošiūnienė, R. (2021). Discussion: Green Economy in Sustainable Development and Improvement of Resource Efficiency. *Central European Business Review*, *Vol. 10* (XX), 1—15. https://doi.org/10.18267/j.cebr.252.
23. Kotenko, S., Nitsenko, V., Hanzhurenko, I., & Havrysh, V. (2020). The Mathematical Modeling Stages of Combining the Carriage of Goods for Indefinite, Fuzzy and Stochastic Parameters. International *Journal of Integrated Engineering*, *Vol. 12* (7), 173—180. https://doi.org/10.30880/ijie.2020.12.07.019.
24. Pylypenko, H., Fedorova, N., Huzenko, I., & Naumenko, N. (2020). Paradoxes of economic development: science and innovation in the modern world. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, *Vol. 2*, 153—159. https://doi.org/10.33271/nvngu/2020-2/153.

The article is recommended for printing 15.05.2021