MODELING OF THE SYSTEM OF NATURAL RESOURCES MANAGEMENT IN RAILWAY INDUSTRY

Tagiltseva, Yulia A., *Rostov State Transport University, Rostov-on-Don, Russia.*
Drozdov, Nikita A., *Rostov State Transport University, Rostov-on-Don, Russia.*

ABSTRACT

The article considers the strategy of creation of ecological and economic system of nature management at enterprises of the railway industry. The process of managing such a system is revealed with the help of game theory and the construction of a game-theoretic model of development. The model proposed by the authors can serve as a basis for constructing an innovative scenario in which the possibility of combining, in a strategic perspective and under given initial conditions, the economic benefits and goals of state environmental policy, corporate environmental programs, is mathematically proven.

Keywords: ecological safety, strategic planning, management, economy, nature management system, railway transport, game theory, development model.

Background. *Russia's obligations to observe the established rules of the World Trade Organization inevitably affected the national transport complex, which, in comparison with the developed countries, has low environmental indicators due to deterioration of technical means, and the slow introduction of «green» innovations. At the same time, increasing the environmental friendliness and competitiveness of transport is undeniably interrelated factors. Today and in the long term, the competitive advantages of the Russian transport system can be largely achieved through introduction of innovative technologies, use of renewable energy sources, and environmentally friendly modes of transport that have a minimal negative impact on the environment [1].*

Preservation of natural wealth, compliance with environmental standards, ensuring environmental safety and adoption of competent environmental management solutions are the main tasks, the solution of which is assigned to managers of transport enterprises in this area. But all this becomes a real thing only on the basis of a unified strategy, consistent implementation of planned economic results.

In the logic of existing ideas, the stable functioning and development of Russia's railway transport is primarily connected with JSC Russian Railways. Research confirms: it is the presence of a single economic entity with a vertically integrated structure that provides the country's economy with the lowest cost of transportation [3], which in itself requires a systematic approach and availability of a well-established system of strategic management.

At present, the system of balanced indicators of D. P. Norton and R. S. Kaplan is considered as one of the most well-known and developed systems of strategic management [2]. However, the inability to fully assess the effectiveness of management decisions makes it vulnerable. It would probably be possible to compensate for this shortcoming from the point of view of economic tasks on the basis of methods of morphological analysis, which were studied in particular by P. V. Kurenkov, V. A. Makeev, E. A. Mamaev, E. L. Kuzina [4, 5], but so far there are no methods of complex use of methods of morphological analysis and a system of balanced indicators.

In this regard, the formation of a socio-ecological and economic strategy for sustainable development of the nature management system in rail transport should include two components, namely, improving its efficiency, increasing profit and profitability, while ensuring environmentally sound sustainable development of the territories.

Objective. *The object of the authors is to consider the issue of modeling of nature management system on railways.*

Methods. *The authors use general scientific and engineering methods, game theory methods, comparative analysis, scientific description.*

Results. *To consider the strategy for development of the nature management system in railway transport, we will characterize it as a system for ensuring the country's environmental and economic safety with the help of the industry's enterprises, and at the same time, taking into account two subsystems invariably interconnected and interdependent – railway transport and the environment.*

The subsystem of railway transport includes the economy of freight and commercial work, passenger, suburban, transportation, track, car, water supply and water disposal, electrification and power supply, automation and telemechanics, etc. Each and all together they have a direct impact on the components of the subsystem of the environment: climate, air basin, soil, geological environment, water objects.

In the context of development of the railway transport infrastructure, it is possible to single out socio-economic objects financed with participation of the state budget; construction of access roads to new natural deposits on the basis of public-private partnership agreements; increase in the capacity of railway lines at the expense of JSC Russian Railways funds, as well as creation of tracks for non-private use by private investors. And the most important task today is to determine the amount of financing and economic incentives for infrastructure programs [3].

In the course of solving this task, the elements of management of nature management processes can be presented in the form of a chain: planning–investment–technology–infrastructure–nature protection measures–impact on nature–eco-economic efficiency. Based on such a scheme, the planning parameters, such as investments in new technologies, investments in environmentally friendly infrastructure, the pace of introduction of new environmentally friendly technologies, the beneficial effect from introduction of new technologies, the economic effect of environmental investment activity [4] take on a weighty load.

Considering the ecological and economic efficiency of rail transport, it must be remembered that the nature management system, as already stressed, assumes a rigid mutual dependence of two subsystems: railway transport and the environment [5], so we will use the theory of games, which in this case allows us to recognize the existence of unifying strategies of the world economy, economy and politics.

Table 1

The matrix of the game-theoretic model

	ST			
		CONS	CRIS	INNS
RAIL	CONS	4,5/4,5+	4,5–/4,5	4,5–/4,5
	CRIS	4,5–/4,5–	4,5–/4,5–	4,5–/4,5–
	INNS	4,5–/4,5+	4,5–/4,5–	4,5+/4,5+

The game theory emphasizes the strategic interaction between two or more players, each of them has a set of available strategies and the winnings of any one depends on the chosen strategies of all players. Unlike the game against the «dead nature», where the player maximizes his winnings in this fixed environment, in game theory, each player seeks to maximize his winnings, provided that all other participants also tend to maximize their respective payouts. Therefore, with n-players, we get n simultaneously maximally resolved problems.

The most famous and most commonly used concept of the solution in game theory, which we are also using, is the Nash equilibrium. The bottom line is in a situation where no player has the incentive to deviate unilaterally from the chosen strategy. That is, he cannot improve his winnings by deviating from it. In addition, the situation does not change if two players win simultaneously, while the third receives a lower return. Each player seeks to balance, rather than maximizing his own winnings without taking into account winning of others. Often there can be more than one equilibrium. In such cases, players tend to have different preferences and try to concentrate on one option [6].

Let's determine the conditions of the game within the framework of the socio-ecological and economic strategy of the nature protection activity of the railway enterprise. The quality of the environment is of enormous interest to society, and it is ensured by the interaction of economic entities (rail transport) and environmental (natural environment). The third most important component of the system is the state, which determines the nature of nature management, influencing enterprises through tax policy. The players in this three-element model are railway transport and the state, the game criterion is the impact on the environment.

Railway transport, using natural resources, produces services that are sold on the market. Hence, from the point of view of game theory, its interest in the system of nature management is entitled to be designated as a gain in environmental management costs in provision of services, and utility for railways can be perceived as an economic result of implementation of any of the game's nature use strategies. With an increase in the economic result, the price for railway transport services is reduced or remains unchanged, with a decrease – is increasing. This means that mathematically the result itself will look like a ratio of one to the level of the costs of nature management. In addition to the purely economic indicator, there is a certain coefficient m, which is associated with savings in payments for the use of natural resources by the state. When improving the quality of the natural environment, the state reduces the amount of payments, which leads to additional benefits of transport.

The state, being the second player, denotes via its interest an increase in collection of payments for inefficient use of natural resources and improvement of the quality of the natural environment. It can indirectly affect the environmental policy of companies, determining the amount of payments for nature management. The usefulness in the game-theoretic model for the state is expressed as the sum of payments for the use of natural resources and the synergistic coefficient k that increases utility for the state in the event of a decrease in the number of payments by enterprises (the quality of the natural environment increases) and decreasing it in the event of deterioration in the quality of nature use (pollution of the natural environment).

Thus, the game-theoretic model in the game «Interests in the system of nature management in rail transport» assumes that:

- *Number of players – two: railway transport (RAIL) and state (ST).*
- *Number of strategies – three for each player: conservative scenario (CONS), innovative scenario (INNS), crisis scenario (CRIS).*
- *Units of utility of each player – a conditional «utile». At the same time utiles for two players will differ, that is, it makes no sense to compare the utility by the numerical value. For example, if in the implementation of any strategy S for any pair of players, the utility of both will be equal to the same number, this does not mean that they have the same utility.*

The main task of planning of the improvement of environmental and economic efficiency in railway transport is the selection of optimal actions in terms of resource costs and the final result. Since rail transport operates in its own interests and the state operates in its own interests, it is logical to assume that, using the provisions of game theory, it is possible to build a model of players' interaction, on the basis of which it will be possible to draw conclusions about the most or less effective options for a particular player, predict their actions, which will help mathematically determine the winning strategy for nature management. So, let's consider in more detail the process of interaction between players.

First of all, it is necessary to take into account that the players act independently of each other. The state independently determines the priorities of the nature use policy, the railway transport chooses for itself an economic policy at the interface with the environment. Therefore, it can be argued that:

- *Srail = (CONS, INNS, CRIS);*
- *Sst = (CONS, INNS, CRIS);*
- *Urail = {1; 9};*
- *Ust = {1; 9}.*

As it was already said, for railway transport the gain is the sum of economy of expenses on nature management and a gain from economy on payments for nature management. Mathematically, this reduces to the formula:

$$Urail = (4,5 - C) + m, \qquad (1)$$

where C is cost of improving environmental and economic efficiency; m is coefficient of saving on payments for nature management.

The number 4.5 is taken as the median between 0 and 9, that is, a point where the starting utility for rail transport is determined by the middle of the scale. In other words, initially the utility is unchanged and equals the middle between the minimum and the *maximum. The methodology for calculating the coefficient m also requires comments. The scale of its measurement depends on what kind of policy the state chooses, that is, the coefficient will decrease in the crisis scenario (the state is engaged in «shutting holes» in the budget, which is why it does not motivate nature users to invest in innovative development) and increase under the innovative scenario (the state carries out a corresponding fiscal policy, increasing the amount of payments for inefficient use of natural resources and thereby encouraging enterprises to invest in «green development»). From here:*

- *in the crisis scenario: $C \to min$, $m \to min$;*
- *in the conservative scenario: $C = Const$, $m \to min$;*
- *in the innovative scenario: $C \to max$, $m \to max$.*

In the conservative scenario, the unchanged nature management policy $m \to min$, since, as practice shows, in the long term, even if there is no change in externalities, the component of the potential winnings of rail transport from a reduction in payments for the use of natural resources will decrease, because the effectiveness of the technologies used in the process will inevitably fall, technologies will not keep pace with the requirements for environmental management. Nevertheless, it should be noted that if the conservative scenario is preserved, the indicator m, although it tends to fall to the minimum values, it will still happen much more slowly than in the crisis scenario. Analyzing the indicators, we come to the conclusion that Urail = m – C, that is, the utility deviates in the positive direction when the amount of the saved payments for the use of natural resources exceeds the financial expenses for the modernization of production, in the negative – in the reverse situation.

Now about winning of the state in the game. Recall that for the state, this is the sum of the financial indicator of improving the quality of the natural environment and the amount of payments for nature management. Mathematically, it looks like this:

$$Ust = (4{,}5 + Q) + k, \qquad (2)$$

where Q is an aggregated indicator of the quality of the natural environment; k is coefficient of payment for restoration of the destroyed natural environment. Conditionally, we can say that $k = 1 / m$.

The aggregated indicator Q has an intangible basis for the state and is not quantifiable. The effect of this indicator is expressed by such components as harm reduction to the environment, improving the quality of the environment, increasing voter loyalty to the state due to the improvement of the state of natural resources, etc. Other indicators are formed in a similar way to the situation with the player «Railway Transport».

So the following dependencies and patterns look:

- *in the crisis scenario: $Q \to min$, $k \to max$;*
- *in the conservative scenario: $Q = Const$, $k \to max$;*
- *in the innovative scenario: $Q \to max$, $k \to min$.*

Let's now combine data for each scenario for each player:

- *in the crisis scenario: $C \to min$, $m \to min$; $Q \to min$, $k \to max$;*
- *in the conservative scenario: $C = Const$, $m \to min$; $Q = Const$, $k \to max$;*
- *in the innovative scenario: $C \to max$, $m \to max$; $Q \to max$, $k \to min$.*

Based on the experience of analyzing the application of environmental solutions in railway transport by E. L. Kuzina, let's say that in the long term, the positive effect of implementing environmental technologies is higher than investments in environmental protection [4], that is, $m > C$, and therefore it is possible to determine how the players' performance indicators in different scenarios will change. To do this, we will compose a matrix of the game-theoretic model for each player in the game process (Table 1). The sign «+» means an increase in the utility of the player in the profile of strategies, the sign «–» – decrease.

In the process, three Nash equilibriums were formed, not all of which are Pareto-efficient. It is obvious that only the strategy of INNS-INNS can be considered a Pareto-effective option.

Conclusion. *Thus, it is mathematically proven that in the strategic perspective and under given initial conditions (innovative orientation of state policy), the compatibility of innovation and environmental compatibility in the programs of railway transport development is inevitably beneficial. This determines the need for strategic planning, taking into account the growth of the ecological and economic efficiency of the enterprises of the industry in the system of nature management and the introduction of environmentally friendly technologies.*

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Information about the authors:
Tagiltseva, Yulia A. – Ph.D. student of Rostov State Transport University, Rostov-on-Don, Russia, 79185065822@ya.ru.
Drozdov, Nikita A. – Ph.D. student of Rostov State Transport University, Rostov-on-Don, Russia, dharmaface@yandex.ru.

Article received 18.07.2016, accepted 20.12.2016.