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METODOLOGY OF INCREASING THE EFFICIECY OF TRANSPORT SYSTEMS USING DECISION-MAKING METHODS

The developed methodology of formalization and the methods of solving the problem are given, which provide the construction of highly stable Pareto - optimal compromises from the condition that they are Nash equilibrium. The problem of decision making under uncertainty in road transport systems is investigated. The methodology of improving the efficiency and safety of transport systems in conditions of reduced performance based on models and decision-making methods is considered. The methodology of problem formalization is based on assumptions and axioms. The methodology is focused on use in systems where the motivation of decisions is determined by interests. Under these conditions, the constructed methods for calculating the equilibrium policy of control decisions in accordance with the formulation of the problem, which is formulated for unitary systems.

Keywords: transport, system, decision making, assumption, axiom.

Introduction. Road transport as big and permanently performing dynamic system is the connecting link of the expanded production process and it takes a special place in the economic development of the state. The production process of the road transport requires the solution of the set of complex interdependent tasks of the efficient transportation organization, supporting workability of the rolling stock, “extracting benefits” from transportation, providing safety of road traffic etc. In total these tasks presuppose the choice of the efficient modes of functioning transport system [1, 2, 3, 4]. The difficulties while solving these tasks are determined by stochastic character. The expenditures for manufacturing, technical maintenance and repairing exceed the price of the new transport means in several times. The cause of this phenomenon lies in the processes of components wear and degradation of units and systems, which leads to breaking workability, refusals and catastrophes. The processes of changing the technical condition have an occasional character, therefore finding efficient levers, providing efficiency and safety of transport means performance is an important and a topical task in saving labour and material resources. This leads to necessity of periodic executing special events in search of perfect systems to prevent malfunction and catastrophes. Their content implies monitoring the state, diagnosing the situation, workability, influencing the restoration of workability and providing safety, and choosing the modes of using transport means [5, 6].

Thus the problem of decision-making in choosing management actions aimed at prevention catastrophes and achieving “the highest system efficiency” occurs. The process of making decisions is the choice of the solution variant from several possible. It consists of the characteristic stages and it has iterative character. The problem of decision making in conditions of uncertainty and risks is not a new one. Its creation is connected with the names of Von Neumann, Morgenstern, Blackwell, Hirshick, Savage, Fishbern, Pfanzagl etc. While making decisions certain methods are used, which are classified by several signs. Depending on the situation of decisions making, they are divided into standard and non-standard [7].

Setting the tasks. The standard decisions are made in frequently repeated production situations. Knowledge and usage of standard rules speak about high qualification of engineering and management staff. This, first of all, reduces the time for making decisions, development and implementation of appropriate steps; for the second, it reduces the probability of making wrong decisions; for the third, the specialist frees up the time for making decisions in new and complex production and market situations, requiring collecting the information, its analysis, calculations, connected by the notion “researching the operations”. These are, so call, non-standard decisions. This problem is determined by the term “preventive safety” [8, 9, 10].

The peculiarity of the problem lies in the fact that safety requirements may not be considered as a goal. In fact, if demands of safety provision is considered as a goal, the way of achieving this goal is obvious and it implies disconnecting the system of transportation process. But the efficiency of using this system will be “zero”. Consequently, the problem of managing safety should be considered in terms of interests connected with using the system. Formally it requires the introduction of the class of systems where the motivation of behaviour is determined by the interests. Such systems are called “motivated interests” [7, 9].

The typical example of such systems is a transport means considered in the process of exploitation.

At the same time it has an additional feature which is a complex system as it consists of the set of subsystems and each of them has an individual resource of workability and reliability. If each such system is considered as isolated from the point of view including interests of the only subject, then it is supposed to be unitary. But altogether such systems are united into a single system used for implementation of interests for a certain subject, and these interests are dominating for subsystems. In these conditions the transport means is a corporative system. These conditions cause quite a serious problem of dynamic decisions making that requires adequate methodology of formalization and constructive methods. The needed methodology develops primarily for unitary systems [11, 12].

The method of solving the task. The unitary system is considered in the form of a holistic object used for implementation the interests of the only subject. It is supposed that dynamics of the unitary system is determined by the evolution of its inner states. The methodology of problem formalization is based on the following suggestions and axioms.

Assumption 1. The object is deteriorating. The dynamics of its states is described by Markov process implying continuous time and absorbing condition. The trajectories of the processes are cut at the moment of hitting. The moments of hitting are the moments of refusals or catastrophe of the system.

Assumption 2. It was set the number of alternative managing influences Y, aimed at managing evolution of the object via direct change of its states.

Assumption 3. There exist the relations of equivalency for multitude of S conditions. However only scale $X = \{x_1,\dots, x_n\}$ of titles for equivalency classes is ordered in accordance with the direction of evolution conditions.

The latter assumption helps to conclude that splitting a variety of conditions into classes of equivalency is not determined and it needs formation.

Definition 1. The titles of $x \in X$ classes of equivalency are called situations.

Definition 2. Indication of relation of the state $s \in S$ to the class of equivalency, which title is determined by the situation $x \in X$, is called diagnostics of the situation. The rule of diagnostics is determined by homomorphism $\langle S, < \rangle \to \langle X, R \rangle$, where $(<)$ – relation of order on S, R – relation of order on X.

Assumption 4. Diagnostics of the situations of the technical state is performed at discrete time moments with the time period $\tau \in T$.

Assumption 5. For each situation of the technical state $x \in X$ it was set a number of managing alternatives $Y_x \subset Y$ for applying in conditions from the proper equivalency class.

Axiom 1. Managing alternatives $y \in Y$ are chosen depending on the situations $x \in X$. Applying managing alternatives $y \in Y$ causes Markov process managed by discrete time.

Assumption 6. It was set a number of structural alternatives $G = T\times\Theta$, where T – a number of permissible values of the decision-making step, and Θ – a number of structural variants of the system. The alternatives $g \in G$ are aimed at managing the evolution of the object via changing parameters of the transition function of the process.

Assumption 7. The transition function of the managed process depends on the managing alternative $y \in Y$ as a condition, and on the structural alternative $g \in G$ as a parameter. It is indicated as $q^g(S|S\times Y)$.

Axiom 2. The structural alternatives are chosen from multitude G regardless of the states and the situations as the example.

Axiom 3. The interests of the subject are multi-aspect and they comprise three aspects: management, diagnostics and structural choice. These aspects are dependable to a certain extent, but they are not the opposite.

Assumption 8. On the number of managing alternatives Y it was set the a priori function of benefit $w^g(Y|S\times X)$, depending on the situations $x \in X$ and conditions $s \in S$ as the conditions and on the structural alternatives as the parameter. It sets the preferences on managing alternatives $y \in Y$ according to the condition:

$$w^g(y' \mid s, x) > w^g(y \mid s, x) \Longrightarrow y' \succ y, \text{ где } y', y \in Y_x, x \in X,\ s \in S_x.$$

The results of the diagnostics may be "beneficial" or "non-beneficial" in terms of the fulfillment of interests. However, it is impossible to assess "benefit" or "non-benefit" of the diagnostics of the situation. Nevertheless, as the function of the benefit $w^g(S\times X\times Y)$ is set, it is possible to implement an a priori assessment of "regrets" in terms of possible loss of utility while choosing the situation $x \in X$ in the determined condition $s \in S$ and in the determined alternative $y \in Y$. this assessment is described by the function indicated as

$$r^g(s,x,y) = |\, w^g(s,x,y) - \max_{y \in Y_x} \max_{x \in X_s} w^g(s,x,y)\,|, \ (s,x,y) \in S \times X \times Y.$$

The set of the enumerated objects forms information base I for decision-making.

According to Axiom 3, the formalization of the problem needs implementation of the three strategies: structural choice, managing and diagnosing the situations. They are determined by the following constructions.

The strategy of monitoring and structural choice: sequence

$$\{g = (g_n, \dots, g),\ g \in G;\ n = 1,2,\dots\}.$$

The key function of management: unambiguous indication

$$\pi: X \to Y,\ \pi(X) \in Y_x,\ x \in X.$$

The strategy of management: sequence

$$\{\pi_1^n = (\pi_n, \dots, \pi_1),\ n = 1, 2, \dots\}.$$

The key function of diagnostics: homomorphism

$$\delta: \langle S, R \rangle \to \langle X, R \rangle.$$

The strategy of diagnostics: sequence

$$\{\delta_1^n = (\delta_n, \dots, \delta_1),\ n = 1, 2, \dots\}.$$

Three strategies $\langle \{\pi_1^n\}, \{\delta_1^n\}, \{g_1^n\} \rangle$ – policy of managing decisions.

Quality criteria:

The quality of managing strategy π_1^n is described by the average utility of the type:

$$\varphi_n(\pi_1^n | g_1^n, \delta_1^n)(s) = \frac{1}{n} M_s^{(\pi_1^n | g_1^n, \delta_1^n)} \sum_{t=0}^{n-1} r^{g_{n-1}}\left(s_t, \delta_{n-t}(s_t), \pi_{n-t}\left(\delta_{n-t}(s_t)\right)\right),\ s \in S,$$

where $w^g(\square)$ – function of utility, set in Base 1, and expected value is taken at a probabilistic measure at the trajectories.

The quality of the monitoring strategy and the structural choice g is described by the expected average utility of the type:

$$\mu_n(\pi_1^n | g_1^n, \delta_1^n) = \int_S \varphi_n(\pi_1^n | g_1^n, \delta_1^n)(s) \beta_n(ds),$$

where $\beta_n(\square)$ – a probabilistic measure on the multitude S at the moments n = 1, 2, ...

$$\psi_n(\delta_1^n | g_1^n, \pi_1^n)(s) = \frac{1}{n} M_s^{(\delta_1^n | g_1^n, \pi_1^n)} \sum_{t=0}^{n-1} r^{g_{n-1}}\left(s_t, \delta_{n-t}(s_t), \pi_{n-t}\left(\delta_{n-t}(s_t)\right)\right),\ s \in S,$$

where $r^g(\square)$ – the function of regrets, set on Base I.

Setting the task:

Policy of decision-making $\langle \pi_1^n, \delta_1^n, g_1^n \rangle$, satisfying the conditions:

$$\begin{cases} \varphi_n(\pi_1^n | g_1^n, \delta_1^n)(s) \ge \varphi_n(\pi_1^n | g_1^n, \delta_1^n)(s), s \in S,\ \forall \pi_1^n,\ n = 1,2,\dots, \\ \mu_n(g_1^n | \pi_1^n, \delta_1^n) \ge \mu_n(g_1^n |, \pi_1^n \delta_1^n)\ \ \forall g_1^n,\ n = 1,2,\dots, \\ \varphi_n(\delta_1^n | \pi_1^n g_1^n,)(s) \le \varphi_n(\delta_1^n | \pi_1^n g_1^n,)(s), s \in S,\ \forall \delta_1^n,\ n = 1,2,\dots, \end{cases} \quad (1)$$

In addition, it is called balanced by Nash's definition.

The balance policy determines "the best" solution of the problem concerning preventive safety and efficiency implying the provision of the stable dynamic compromises according to the criteria of the strategic utility and the strategic risks on the unlimited area of using the system.

The task comprises development of balance policy in managing decisions. The formulated task determines only general task setting. For its practical solution it is explicitly needed the task of Base I for decision-making. Its task forms the second stage of solving the problem. It consists of the explicit formation of the transition function $q^g(S|S\times Y)$ and the utility function $w^g(S\times X\times Y)$.

The model of the transition function $q^g(S|S\times Y)$ is based on the assumption that a multitude of conditions S is a single section $S = [0,1] \subset R^1$ and the process of degradation is described by Markov process with monotonous cutting trajectories. Cutting of the trajectory occurs at the occasional moment of time and corresponds to hitting the absorptive condition.

These two assumptions enabled to get explicitly the transition function $q^{(\mu,\chi)}(t,\Gamma|s)$, $\Gamma = (a,b] \subset S$ of the degradation process that depends on two parameters: wear rate $\mu > 0$ and intensity of refusals $\chi > 0$ [13, 14].

Via using these parameters it was formed the function of utility, defined with the difference between "income" of using the object with the alternative of using $u \in U$, and "expenditures" for applying safety alternatives $v \in V$ and the structural alternative $\theta \in \Theta$ on condition of absence of failure (that is $s<1$). If, however, there is a failure(that is $s = 1$), then the content of expenditures includes the average value loss $\chi > 0$.

Conclusion. It was developed the methodology of formalization and it was considered the methods of problem solving that provide the formation of steady Pareto-optimal compromises on condition that they are Nash balance. The methodology is aimed at applying in the systems where the interests determine the motivation of decision-making. The obtained results are applied to the tasks of planning production process, managing transportation process, managing workability of the moving composition, safety of its exploiting.

Under the considered conditions it was developed the methods of calculating balance policy of managing decisions according to the task setting formulated for unitary systems. However, the real systems are complex and consist of the set of subsystems and each of them has its own individual interests. At the same time, for subsystems there are common domineering interests connecting the set of subsystems into the holistic system. Similar systems are called corporate. Under these conditions a much more complex problem of corporate decision making occurs. Its solution needs developing steady compromises at each moment of decision-making in the unlimited time period.

REFERENCES

1. Gerlici J. The stability analysis of two-wheeled vehicle model / J. Gerlici, V. Sakhno, A. Yefymenko, V. Verbitskii, , A. Kravchenko, K. Kravchenko // MATEC Web of Conferences 157,01007, 2018.

2. Rabinovich E. Evaluation of the powertrain condition based on the car acceleration and coasting data / E. Rabinovich, I.V. Gritsuk, V. Zuiev, E.Y. Evgeny, A. Golovan, V. Volkov, J. Gerlici, K. Kravchenko, O. Volska, N. Rudnichenko // SAE Technical Papers. Volume 2018, 2018.

3. Baran, P. Basic Dynamical Analysis and Comparison of Balancing Systems of Non-conventional Piston Machine FIK / P. Baran, M. Brezáni, P. Kukuča, P. Šťastniak // Procedia Engineering 192, 2017, pp. 34-39.

4. Hauser, V. Car body and bogie connection modification for track curves passability improvement / V. Hauser, O.S. Nozhenko, K.O. Kravchenko, M. Loulová, J. Gerlici, T. Lack // MATEC Web of Conferences 157, 03010, 2018.

5. Kravchenko O.P. Metodi intensivnogo zabezpechennja pracezdatnosti avtomobil'nih prichepiv / O.P. Kravchenko, A.V. Gogajzel', V.R. Malik // Navchal'nij posibnik. – Kiïv: UMK VO, 1990. – 116 s.

6. Gorbunov N.I. Ispol'zovanie metodov teorii prinjatija reshenij pri sozdanii transportnyh sredstv / N.I. Gorbunov, A.L. Kashura, S.V. Popov, E.A. Kravchenko, A.I. Fesenko // Politransportye sistemy: materialy V Vseros. nauch.-tehn. konf., Krasnojarsk, 21–23 nojabrja 2007 g.: v 2 – h ch. Ch. 1. – Krasnojarsk: Sib. feder. un-t; Politehn. in-t, 2007. – S. 14–20.

7. Baranov V.V. Processy prinjatija reshenij, motivirovannyh interesami / V.V. Baranov //. - M.: Fizmatlit, 2005. – 296 s.

8. Matrosov V.M. Model' i metody prinjatija upravljajushhih reshenij v probleme preventivnoj bezopasnosti / V.M. Matrosov, V.V. Baranov // Problemy upravlenija. 2006. №5. – S. 2–11.

9. Baranov V.V. Ispol'zovanie metodov teorii prinjatija reshenij v zadachah jekspluatacii transportnyh sistem / V.V. Baranov, A.P. Kravchenko, V.A. Drozdov, E.A. Kravchenko // Sbornik dokladov mezhdunarodnoj nauchno-tehnicheskoj konferencii "Transport, jekologija - ustojchivoe razvitie", 20 - 22 maja 2010. – Varna: TU, 2010. – S. 154-158.

10. Baranov V.V. Modeli poleznosti i riska v zadachah upravlenija degradirujushhimi sistemami / V.V. Baranov, V.M. Matrosov // Problemy upravlenija. 2007. №5. – S. 5–20.

11. Baranov V.V. O probleme i metodah korporativnogo vybora / V.V. Baranov // Izv. RAN. Teorija i sistemy upravlenija. 2006. №2. – S. 103 – 116.

12. Baranov V.V. Prinjatie reshenij v zadachah jekspluatacii transportnyh sistem / V.V. Baranov, A.P. Kravchenko, V.A. Drozdov, E.A. Kravchenko // «Naukovi notatki» Luc'kogo nacional'nogo universitetu. Mizhvuzivs'kij zbirnik. – Luc'k: LNTU, 2010. - S. 46-51.

13. Kravchenko A.P. Razvitie teorii obespechenija jekspluatacionnoj nadezhnosti avtopoezdov / A.P. Kravchenko // Vestnik Krasnojarskogo gosudarstvennogo tehnicheskogo universiteta. Vyp. 39. Transport. – Krasnojarsk: IPC KGTU, 2005. – S. 606–615.

14. Bazhinov A.V. Nadezhnost' avtomobil'nyh poezdov / A.V. Bazhinov, A.P. Kravchenko / Monografija. – Lugansk: Izd-vo «Noulidzh», 2009. – 412 s.

Кравченко О.П., Дижо Я., Горбунов М.І., Кравченко К.О. Методологія підвищення ефективності транспортних систем використанням методів прийняття рішень.

Досліджено проблему прийнятя рішень в умовах невизначенності в системах автомобільного транспорту. Розглянута методологія підвищення ефективності та безпеки транспортних систем в умовах зниження працездатності на основі моделей і методів прийняття рішень. Методологія формалізації проблеми основана на припущеннях і аксіомах.

Ключові слова: транспорт, система, прийняття рішень, припущення, аксіома.

Кравченко А.П., Дижо Я., Горбунов Н.І., Кравченко Е.А. Методология повышения эфективности транспортных систем использованием методов принятия решений.

Исследована проблема принятия решений в условиях неопределенности, возникающая в системах автомобильного транспорта. Рассматривается методология повышения эффективности и безопасности транспортных систем в условиях снижения работоспособности на основе моделей и методов принятия решений. Методология формализации проблемы основана на предположениях и аксиомах.

Ключевые слова: транспорт, система, работоспособность, принятие решений, предположение, аксиома.

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