$$\lim_{k\to\infty}\left|\left(l_{ij}\right)-\left(l_{ij}\right)_k\right|\to 0. \qquad (12)$$

Условие (12) можно проверить благодаря введённой норме матрицы (11).

Если последовательность матриц (9) является убывающей, то для всякого $\varepsilon > 0$ должен существовать такой номер $N = N(\varepsilon)$ и $m > 0$, что при $k > N$ имеет место [6, с. 238–246]:

$$\left\|\left(l_{ij}\right)_k-\left(l_{ij}\right)_{k+m}\right\|<\varepsilon. \qquad (13)$$

Тогда, задавшись значением ε, то есть допустимой точностью решения задачи, находим искомую матрицу межремонтных пробегов (l_{ij}).

Тем самым полностью снимается ограничение на решение задачи (3) с помощью метода динамического программирования с целью получения количественной оценки эталонного состояния отрасли.

Предлагаемая методика дает возможность практически освоить решение важной задачи транспортной науки – количественной идентификации эталонного состояния отрасли. Используемая в рамках методики многоуровневая модель управления отраслью позволяет анализировать ту или иную проблему на разных уровнях транспортной иерархии – от линейного до государственного и даже мирового.

Разработка модели и её применение в обозначенном контексте особенно актуальны с точки зрения географического фактора страны и наличия у нее явно недоиспользуемых транзитных ресурсов. Это естественным образом подводит к мысли о создании сети железных дорог планетарного уровня, обеспечивающей высокоскоростное, бесперегрузочное и всепогодное сухопутное перемещение пассажиров и грузов между пунктами, находящимися на разных континентах. Для этого достаточно вернуться к проектам полярной магистрали (строительство которой было заброшено в начале 50-х годов прошлого века) и тоннеля под Беринговым проливом.

В результате реализации подобных планов выявятся особенно рельефно конкурентные преимущества железных дорог над другими видами транспорта. В частности, с учетом степени их влияния на среду обитания человека.

Так, по данным зарубежных специалистов, вредных выбросов в расчёте на один пассажиро-километр у электрических поездов меньше в 300–400 раз по сравнению с авиационным и в 8–12 раз – в сравнении с автомобильным транспортом. Примерно такая же картина и относительно грузовых перевозок и, в том числе, морским транспортом.

А это при увеличении доли железных дорог на рынке перевозок не только улучшение экологической ситуации на планете, но скорее всего и возможность добиться снижения себестоимости транспортных услуг. Последнее, несомненно, положительно скажется и на социально-экономическом положении страны, о чём подробно говорится в [8].

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MODEL OF SOLUTION OF OPTIMIZATION PROBLEMS

Ustich, Petr A. *– D. Sc. (Tech), professor of Moscow State University of Railway Engineering (MIIT), Moscow, Russia.*

Ivanov, Alexander A. *– Ph.D. (Tech), associate professor of Moscow State University of Railway Engineering (MIIT), Moscow, Russia.*

Chernyshova, Lydia M. *– Ph.D. (Economics), associate professor of Moscow State University of Railway Engineering (MIIT), Moscow, Russia.*

ABSTRACT

The article refers to main outlines of mathematical model of rail transport. The authors substantiate the necessity to use dynamic programming method to optimize the parameters of the rail sector state. They argue the utility to use rail car department as a sort of department that is a «vehicle» of a key model idea. The authors suggest requirements concerning objective function, its formulae, and a tool to transform it into additive function via solving auxiliary optimization problem. They prove the necessity to realize a new paradigm of car designing model, which is mandatory for effective use of achieved optimum parameters of rail sector state. The management system for rail sector, as it is considered by the authors, is deemed to be multilevel and hierarchic, allowing there-by to analyze problems relevant to local conditions and objectives and according new possibilities to assess transit capacity of Russia and to create globally railway nets with scientifically bases management system. The implementation of such project might permit to achieve advantages for railway transportation, notably taking into account the maintenance of ecological balance and reduction of carriage costs, to gain part of market of truck, air and sea haulage.

ENGLISH SUMMARY

Background. *The ongoing reforming of railways, which are considered as complex technical, social and economic system, means first of all adopting of a chain of decisions aimed at changing of system parameters and links. It is impossible to predict the reaction of the system to external interference basing solely on previous expertise and intuition. On the contrary there is a need to foresee the expenses at different stages of reforms. Furthermore, as the reform of railways has a direct impact on the transport component of the costs of goods which are consumed by every member of society, then the knowledge of the final model of the state of railways will positively influence the public attitude towards the reform itself. So we are in need for a tool that permits to make decisions, based on system methodology.*

Objectives. *The system methodology can be formalized in the form of mathematical model of railway sector. The mathematical model of the railway sector could permit to solve one of the most important problems of transport science which consists of two tasks:*

– Optimization of railways' state regarding the established criterion of state parameters of railways (considering that the real state is far from the sample state and will approach it only within a certain period of time);

– Shaping-out of economically reasonable instruments of bringing railway sector nearer to sample state within the framework of reforming and updating of existing system.

Methods. *It is impossible to build one comprehensive model of all the processes in the railway sector. Only interlinked models of main departments and sectors of railways taken in their totality can take into account the diversity of processes. That is why the researcher should select a key element of such a totality as a basic model. The authors suggest that such a key element should be wagon section of railways, constituted by car facilities of operators of rolling stock and by car repair companies. The arguments are the following: the rail car is related to a final operation in technological cycle of railway carriage, turnover of the car is a key index for assessment of efficiency of railway as a whole, the arguments are also described in [5]. So the wagon section of railways can be considered as vehicle of mathematical model of railways. (The algorithm of wagon section interaction with other railways departments are described in [2]). The objective function should respond to two requirements: it should reflect the operation quality of the object which is one rank higher than the simulated object; to be conforming to information data base of the rail sector. The first requirement takes into account the fact that management system for railways has got multilevel and hierarchic character, providing planning and managing based on deductive logics. The objectives for top managers could be set accordingly to their position in multilevel hierarchic structure. According to the authors, the best index of efficiency of transport is the prime cost of a unit of operation in tons/kilometers. But the existing database of railways is not ready to use that index. That's why the authors suggest the objective function as a formulae (1) for prime cost of a unit of a wagon mileage.*

Results. *The objective function is determined through parameters presented in table 1. The parameters are the parameters of the wagon section as of a reduced model of a whole railway sector. It is necessary to note that (see formulae 1) the objective function is determined implicitly also by the state of other departments and sections by parameter d_k. The value of that parameter [2] should respond to optimal state parameters of k-department (besides wagon department). It is proved that function of many variables (1) presented as (2) has a global minimum. Having imposed appropriate restrictions and contingencies on the rail sector parameters (table 1) and having joined them to formulae (2) one achieves mathematical model of the rail sector. MIIT researchers have elaborated methods of optimization of parameters $\Psi^{(11)}$, $\Psi^{(14)}$ and $\Psi^{(19)}$, whose optimal values along with $\Psi^{(21)}$ should be used within algorithm of optimization of state parameters of the whole rail sector*

$$\Phi\left((l_{ij}),\psi^{(1)},\psi^{(2)},\ldots,\psi^{(22)}\right)\to\min \qquad (3)$$

as constant values. Thus will be achieved normalization of those 4 parameters [3]. Most reasonable method (reasons are described in [7]) of solution of the problem (3) is dynamic programming. But in order to proceed, it is necessary that formulae (1) should be additive. To transform it into additive form, it is sufficient to preliminary determine optimal matrix of mileage of a wagon between repairs (l_{ij}) with the help of solution of optimization problem put forward by MIIT

$$\begin{cases} f\left(l_{ij}\right)\to\min; & (4)\\ l_{ij}\le\psi^{(11)}; & (5)\\ \left|\dfrac{\psi^{(9)}}{\Pi\left(l_{ij}\right)}-\psi^{(10)}\right|\le\psi^{(20)}; & (6)\\ \left.\begin{array}{l} \psi_H^{(13)}\le\dfrac{l_{1j}}{l_{11}}\le\psi_B^{(13)},\ npu\ j=\overline{2,m_1};\\ \psi_{H_i}^{(13)}\le\dfrac{l_{ij}}{l_{i1}}\le\psi_{B_i}^{(13)},\ npu\ i=\overline{2,n},\ j=\overline{2,m_i}, \end{array}\right\}, & (7) \end{cases}$$

which can be used for solving problem (3) by the method of dynamic programming (Π (l_{ij}) – need for in-shed repairing of wagons of a certain type during the one-year period, methods are described in [4]). Problems (4) ÷ (7) can be also interpreted as an

economic model of wagon department of structured type.

Effective use of the results of solving of the problem (3), aimed at quantitate description of a sample state of railways, can be achieved in real conditions, if a wagon at the stage of its designing will be inscribed into operation environment (as it is practiced for respecting overall dimensions standards).

The authors argue that in the period before rail sector restructuring in Russia the challenges of a certain incompatibility between wagon designing and operation process were neutralized by the system of management of technical state of the wagons, on the basis of five principles (in-time finding of defaults, technical maintenance and repairing at the route, special preparation works before loading, technical revision and capital repairs, engineering of specifications and ordering of new wagons instead of old ones). The system permitted to achieve a certain balance between costs of technical maintenance and traffic safety level. The authors indicate some new risks linked to decentralization of wagon sector of railways and underline the need for scientifically substantiated recommendation and for implementation of measures in order to consolidate interests and activities of now different actors within the system of management of technical state of wagons. That's why they suggest to use at the stage of wagon designing within optimization problem (4) ÷ (7) a new object for study which is a system «wagon – operation environment» and give some concrete recommendations concerning enhancing of different functions of management system (table 2; for instance to ensure the detection of defaults with the help of built-in sensors and so on), algorithm of analysis of a sample car design as of an object of a control of technical state, technical maintenance, routine repairs (Pic.1), restrictions of objective function (e. g. safety factors, capacity of repairing works), optimal mileage between repairs (calculated on the basis of formulae).

There are two remarks on the joint solution of two optimization problems (3) and (4) ÷ (7) in order to numerically describe the sample state of railway sector.

1. To solve those problems it is necessary to use so called periphery problems, and each of those problems can be shown as a program realized with the help of computer.

2. As it was shown, in order to overcome the restrictions, preventing use of the methods of dynamic programming, it is sufficient to preliminary determine matrix of mileage between repairs. So it is necessary to possess values of some parameters of state of railways, which are mentioned in the problem (4) ÷ (7). But those parameters can be determined only after solving the problem (3). To overcome the collision and to determine matrix (l_{ij}) it is possible to use the method of iteration. The authors briefly describe algorithm of iterations.

Conclusions. *The suggested set of methods allows quantitatively identify sample state of rail sector of the economy. The multilevel model of rail sector management permits analyzing different problems at different levels of transport hierarchy from section level to national and even international levels.*

The implementation of the model can give possibility to enhance and realize transit capacity of Russia and also to create a global network of railways. Then the railways will be able to prove some advantages over other transportation modes. In the sphere of environment protection the harmful emissions of electric trains are 300–400 times less than the emissions of airplanes and 8–12 times less than the emissions of motor transport.

Key words: railways, complex system, state parameters, optimization, management system, mathematical model, transport sector reforming, objective function, method of dynamic programming, reference state of a system.

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Координаты авторов (contact information): Устич П. А., Иванов А. А. (Ustich P. A., Ivanov A. A.) – wwx720@mail.ru, Чернышова Л. М. (Chernyshova L. M.) – (495) 684–24–68.

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