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РУХОМИЙ СКЛАД ЗАЛІЗНИЦЬ І ТЯГА ПОЇЗДІ

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FORMALIZATION OF ROLLING STOCK DISTRIBUTION PROCESSES BY USING DYNAMIC MODEL

Purpose. The scientific article formalized process improving the efficiency of rolling stock distribution in railways for loading goods by introducing concentration of loading at the terminal by using a dynamic model. **Methodology.** According to the experience, the distribution of rolling stock by the infrastructure operator is a complex process. The questions on transport expeditionary service, working technologies of separate subjects of railway industry and the question of forming organization principles of running carriages with different patterns of ownership are considered. The system of rolling stock distribution based on logistical control principles on railways should meet the next methodological criteria: reduction of empty run and waiting time under one freight operation, forming the correct informative area for all participants of the transportation, arranging conditions for rapid and maximally profitable decision-making as for the further movement of the rolling stock. **Findings.** Created a list of the necessary conditions under which there must be a dynamic development of the transport sector and meet the current market requirements. The algorithm and process logistic control allocation of railway rolling stock are considered. Proved that relationship between the participants of the transportation process of initial conditions for reform be composed based on non-discriminatory access to cargoes resources. **Originality.** The work of dispatcher staff in transportation process management as an employee of the transportation department in terms of demand for rolling stock at all stages of transportation management analyzed. For the first time proposed a dynamic model, that reproduces the information field for all participants in traffic. It established that the railways have to create a system of distribution of rolling stock, which must meet the following criteria: reduction in empty mileage and waiting time under one cargo operation; create conditions for rapid and most profitable decision for further movement of rolling stock. **Practical value.** Application of the developed method of rolling stock distribution for the formation of unit trains will significantly reduce the logistics costs in the supply chain and increase its competitiveness in foreign markets. The development of such a system is intended to create a truly independent regulator of the logistic – transportation process in the conditions of creation of the unified information space.

Keywords: logistics technology; rolling stock; railway transport; management of railway; dynamic model of resource distribution

Introduction

Increasing the efficiency of cargo transporting by rail and water transportation is one of the key tasks that be addressed to reduce logistics costs. Rational use of infrastructure resources [12] in general and the rolling stock resources in particular is the absent chain in the branch reforming now. So nowadays according to the LLC Ukrzaliznytsia data the total waiting time of technological operations is nearly 30% more than the execution

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time of these operations, while this index is 60% less than in the European countries. This statistics visually displays the level of operating consumptions, which connected with the infrastructure maintenance in waiting time.

Taking into account a swift tendency to integrate railway industry into market conditions, which related to considerable reduction of the majority of the qualitative work indexes and deficit of budgetary investments, the guidance of the industry had to solve questions for overcoming this problem as soon as possible. The most important task is to create favorable conditions for involving investors and to set up preconditions for logistic infrastructure development.

Purpose

The scientific article formalized process improving the efficiency of rolling stock distribution in railways for loading goods by introducing concentration of loading at the terminal by using a dynamic model.

Methodology

The main regulations of a new law «On the railway transport of Ukraine» [1] worked out exactly for the solution of the question. So, it is planned to substitute the term «railway» into the new one « infrastructure operator», to form a new organ the National Commission on Transport Adjusting (NCTA) for correcting the rate compound and involving private ferrymen for transportation. Now days there are a lot of non-solving problems which concern investment constituent, calculation of the railway rate (NCTA) without customer and others like that, but the obvious thing is to solve problem concerning the creation of equivalent terms for ferrymen in the real conditions of the operative transportation planning.

Findings

The distribution of rolling stock by the infrastructure operator is a complex process. A list of scientific sources that contain solutions to the problem of rolling stock management analyzed. Having regarded to the setting task in the context of reformatting in modern terms, the questions on transport expeditionary service [4], working technologies of separate subjects of railway industry and the question of forming organization principles of running carriages with different patterns of ownership [1], [10] are considered. The economic constituent at forming the transport-logistic system of carriages control taking into account the internal generalize economic efficiency and corresponding quality of services are important [6]. This approach takes into account the economic component and can used by developed EU railways. The geographical position of Ukrainian railways as a whole obligates to examine any innovations in management with a review on further integration of the accrued system into international transport network [5, 7] using the up-to-date information and intellectual technologies.

Taking into account the orientation of today's reformation and raising of our task as one of the basic principles is introduction the EU railway experience to the existent realities [13]. For this reason, reform the rolling stock distribution process along with European railways.

Thus, make the system of rolling stock distribution based on logical control principles on railways. The system should meet the next criteria:

– reduction of empty run and waiting time under one freight operation;

– forming the correct informative area for all participants of the transportation;

– arranging conditions for rapid and maximally profitable decision-making as for the further movement of the movable unit.

Developing of such system is to make really self-contained regulator of transporting process without changes in staff constituent and significant [8].

Relations between the participants of the transportation process under reformation conditions must base on the principles of non-discriminatory access to the infrastructure resources [9].

According to the prospective state of the relationship between participants of the transportation [11] on the domestic railways, each of them is able to influence on the transportation quality in whole. The participants of the transportation process as for the degree of

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responsibility and influence on the transportation insurance in right quality distributed in relationship shown in Figure 1. This approach can use as a basis to ground the distribution of financial results in terms of improving quality, due to rolling stock supply.

Shown in Figure 1 system on the today's stage of the industry reformation divides the functions of infrastructure management and rolling stock management, the eventual result must be the acceptance of existent EU directives within the framework of the real conditions of LLC «Ukrzaliznytsia» (UZ). New methods in client relations, fundamentally new strategic approach in transportation planning [7], cooperation of the comprehensive efforts of the industry with economic strategy of the country development on the whole, and others like that belong to the basic requirements and standards of the railway system which must be formed as a result of the reformation process.

As the infrastructure owner (UZ) is responsible for the compliance of the main indicators quantity of the transportation quality, it is the owner has the priority right to financial result. However, it means that the most cost of transportation activity be take into account in the results of the participant work. Thus, when applying specific transport technology and providing rolling stock for each participant of the transportation process, the share of financial results (revenue rate) for freight transportation be calculate individually depending on the performed transportation work and activities.

The practical objective of this system is to create conditions for putting the carriage under loading which is under unloading at the particular ground.

Look at the work of dispatcher staff in transportation process management as an employee of the transportation department in terms of demand for rolling stock at all stages of transportation management.

Taking into account, the existing operational management model the hierarchical scheme of rolling stock management levels on the railway and the allocation of responsibilities for commitments show in Figure 2. In this context, the ground of active work that subordinates to the employee who associated with transportation within his competence is considered as hierarchical level of transportation.

The process of the system running begins with the instructions on the freight operation completion provided by the consignee, after unloading car or group of cars. For the time that remains to prepare the car commercially (removal mounting elements, removal of freight residues, etc.), to supply shunting locomotive, the employee of the transportation department must make the right decision on further «destiny» of the car. A similar problem concerns the distribution of empty rolling stock on the sorting and polling stations but in reverse hierarchical direction.

The authors suggested presenting and formalizing information as to distribution of the rolling stock on the operating domain using the method of dynamics of averages. The choice of the method is due to the possibility of its application to practical purpose in the form of the system of automated workplace. Taking into account the set tasks, the rational method of solving the problem will be the application of the classical Runge-Kutt method. Among many methods for solving tasks with method of dynamics of averages the most common in practical application will be Runge-Kutt method of the fourth order, which has necessary parameters. It is this method that allows to obtain necessary results required by the accuracy of the calculations and it differs from others by relative simplicity.

Model activities of the dispatcher staff as a queuing model system, which aims to create a right market competitive condition of using rolling stock. Thus, an approach to modeling operational activities of the dispatcher staff according to the distribution of cars based on the principles of the queuing theory. The main objective of the model is to get an important information to assess transition probability of the cars state from empty to load considering initial system parameters.

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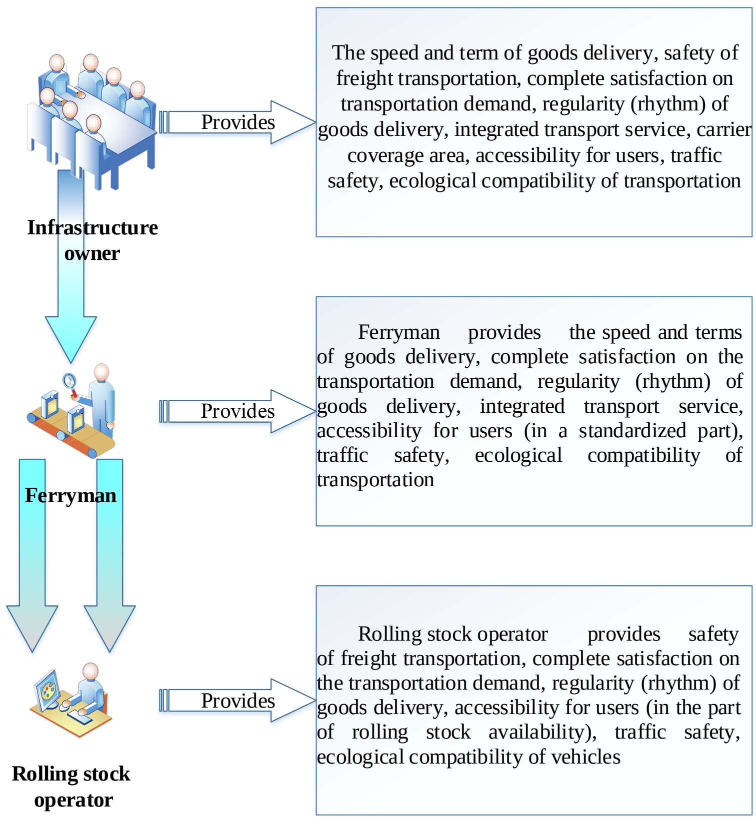

Fig. 1. Rolling stock management operator in the existent railway system on the way of reformation.

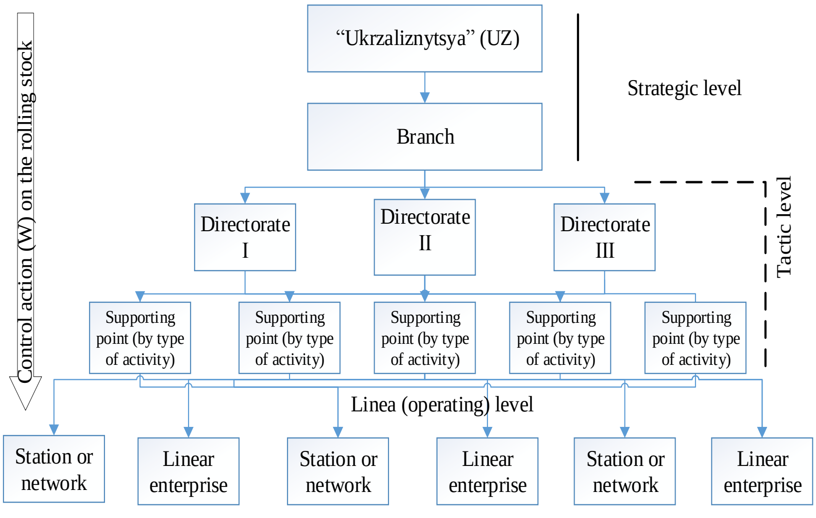

Fig. 2. Hierarchical scheme of rolling stock management levels on the railway.

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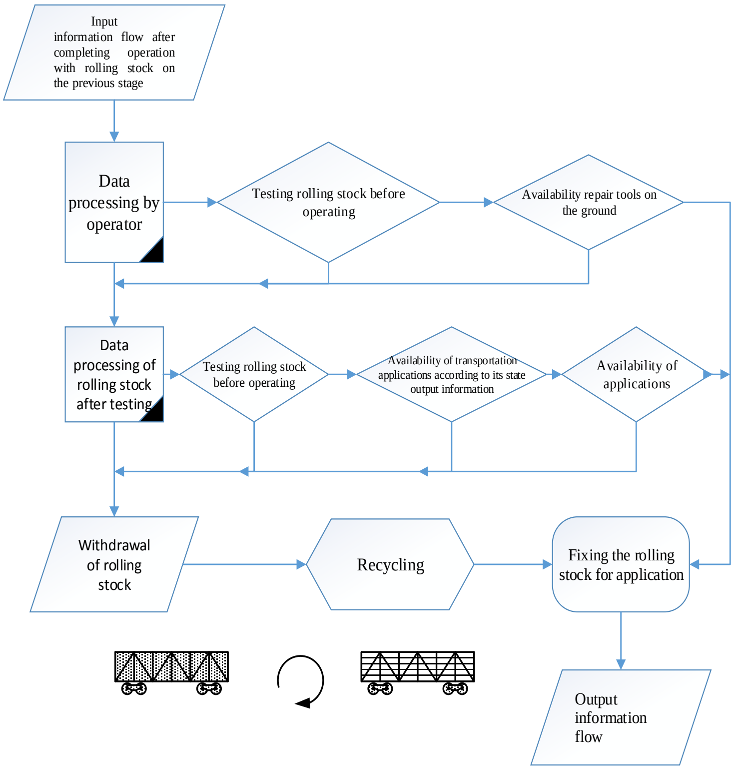

Fig. 3. Structural – logical model of the infrastructure operator work of rolling stock distribution

$$
\begin{cases}
\dfrac{dU_1^L(t)}{dt} = -U_1^L(t)W_1 + \sum\limits_{i=1}^{n} U_1^E(t)W_{i,1}, \\
\dfrac{dU_2^L(t)}{dt} = -U_2^L(t)W_2 + \sum\limits_{i=1}^{n} U_2^E(t)W_{i,2}, \\
\ldots, \\
\dfrac{dU_n^L(t)}{dt} = -U_n^L(t)W_n + \sum\limits_{i=1}^{n} U_i^E(t)W_{i,n}, \\
\dfrac{dU_1^E(t)}{dt} = \sum\limits_{i=1}^{n} U_i^L(t)W_i - U_1^E(t)\sum\limits_{j=1}^{n} W_{1,j}, \\
\dfrac{dU_2^E(t)}{dt} = \sum\limits_{i=1}^{n} U_i^L(t)W_i - U_2^E(t)\sum\limits_{j=1}^{n} W_{2,j}, \\
\ldots \\
\dfrac{dU_n^E(t)}{dt} = \sum\limits_{i=1}^{n} U_i^L(t)W_i - U_n^E(t)\sum\limits_{j=1}^{n} W_{n,j}.
\end{cases}
\qquad (1)
$$

In the model (1):

$U_i^L(t)$ – part of loaded cars involved in the i-th loading area, which is equal n; $U_i^E(t)$ – part of empty cars that can be used in the i-th loading area is accepted that $\sum\limits_{n} U_i^E(t) = 1$; $W_{i,j}$ – probability that the empty car of the i-th loading area will be used for loading in the loading area j in the time interval (t; t + Δt); W_i – probability of discharging the loaded car in the loading area i, is accepted that $\sum\limits_{n} W_i = 1$.

For calculating the model work the conditional data are taken, W_i parameters are hypothetical, calculations in real time scale are connected with heavy implementation expenses and can be used without big error.

The system (1) is linear, in matrix form can be written U(t)=WU(t) and was shown in normal Cauchy form. The problem of the stability simulation in providing loading resource of railway ground is come to a range forecasting of eigenvalues in W matrix. An important task of the system is that the railway ground saved not only resistance of some of its state as a whole and will

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have stable operation at the variation of parameters, which consists of the following:

– type of freight and its transportation requirements;

– car specifications, such as type, carrying capacity, design features, etc. ;

– technological requirements for loading;

– economic component as the primary goal of customer and owner of rolling stock.

For calculating the model work the conditional data are taken, W parameters are hypothetical, calculations in real time scale are connected with

$$
= \begin{cases}
-W_1 & 0 & \cdots & 0 & {}_{1,1} & {}_{2,1} & \cdots & {}_{n,1} \\
0 & -W_2 & \cdots & 0 & {}_{1,2} & {}_{2,2} & \cdots & {}_{n,2} \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
0 & 0 & \cdots & -W_n & {}_{1,n} & {}_{2,n} & \cdots & {}_{n,n} \\
{}_1 & {}_2 & \cdots & {}_n & -W_{1,1}-..-W_{1,n} & 0 & \cdots & 0 \\
{}_1 & {}_2 & \cdots & {}_n & 0 & -W_{2,1}-..-W_{2,n} & \cdots & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
{}_1 & {}_2 & \cdots & {}_n & 0 & 0 & \cdots & -W_{n,1}-..-W_{n,n}
\end{cases} \quad (3)
$$

When solving this problem, modeling of stable and control system of the particular ground acquires eigenvalues λ_i from possible probabilities of the W_i and $W_{i,j}$ matrix (3). Characteristic feature of this dependence is function λ_i from W_i and $W_{i,j}$ that can be evaluated through its own vectors Ri and Si of the W matrix.

Vector of loading resources N (t) can be shown as

$$u_k(t) = \sum_{i=1}^{n} c_i e^{\lambda_i t} r_{k,i}, \; k \in [1; m], \qquad (4)$$

where $r_{k,i}$ – components with number k of eigenvector Ri, m – matrix dimension (2), heavy implementation expenses and can be used without big error.

$$U_i^L(t) = f\left[\left(\beta_1, \beta_2, \ldots \beta_z\right), (t)\right], \qquad (2)$$

where $\tilde{\beta}_{1,z}$ – vector constraint requirements for a car.

One of the most important examples of the restriction on space 1520 mm is the index of throughput and estimated capacity.

The states matrix is:

$c_i = S_i^T U_0$ – is determined by the initial values vector of loading resource (loaded, empty) U0 and eigenvectors Si of the transpose matrix state (3).

Examine the conventional railway ground E, which consists of three directions and has a working gondola park numbered 1000 units. Assume that all gondola cars are interchangeable. If using cars on each direction is equal for rolling stock operator ($U_1^П(t) = U_2^П(t) = U_3^П(t) = 1/3$), then the system come to a relatively steady state in 10 hours from the beginning the cars distribution actions with a coincidence of all three schedules in one (Figure 4).

Table 1

Tabulating general given data for subsequent calculations in evident comparison.

Directorate on the conventional ground	Distribution of rolling stock in the first variant	Distribution of rolling stock in the second variant
$U_1^П$	1/3	1/2
$U_2^П$	1/3	3/10
$U_3^П$	1/3	1/5

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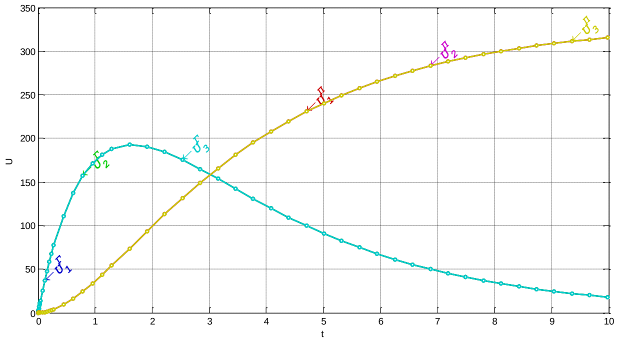

Fig. 4. The simulation results for conventional ground П and three equal- weighted directions ($U_1^П(t) = U_2^П(t) = U_3^П(t) = 1/3$)

If using cars on each direction is not equal for rolling stock operator, the first conventional direction has the highest priority, the third one has – the least priority (i.e is approved $U_1^П(t) = 0.5, U_2^П(t) = 0.3, U_3^П(t) = 0.2$), even through the day from the starting the cars distribution actions (Figure 5) the system will not come to a steady state (the state of the gondola distribution comes to a relatively steady state only in 30 hours.).

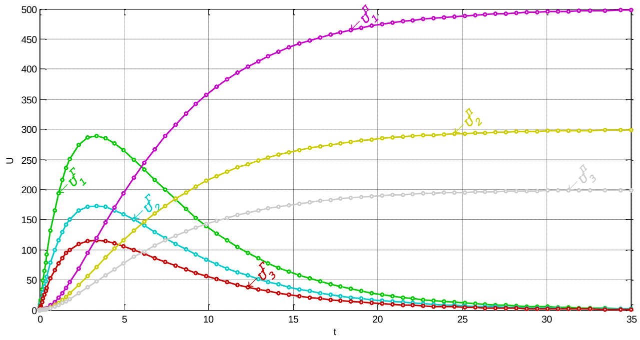

Fig. 5. The simulation results for the conventional ground П and three directions with different weight characteristics ($U_1^П(t) = 0.5, U_2^П(t) = 0.3, U_3^П(t) = 0.2$)

It points out to the necessity to consider the uniformity while reallocating rolling stock along the ground in terms of non-discriminatory access to their infrastructure.

Originality and Practical value

Thus, the model allows conclude about the ability to manage some parameters over time that is it will characterize the process stability to ensure railway ground by the loading resource. Further development of the model may be carried out by taking into account the interchangeability of rolling stock and its state.

The task set solve owing to the modern methods of statistics and mathematical simulation. The analysis of methods and facilities, which use by the author of the thesis work for solving the set task, afford ground for the conclusion as for the authenticity of results, received in the researches. It can be confirmed by the representativeness of the statistical material selection, considerable amount of grounds researches and carrying out the verification model test for adequacy and accuracy according to the known criteria.

This result used as a basis to ground the distribution of financial effect in terms of improving quality. Model of decision support system for optimal distribution of rolling stock in the transportation process shown in Figure 6.

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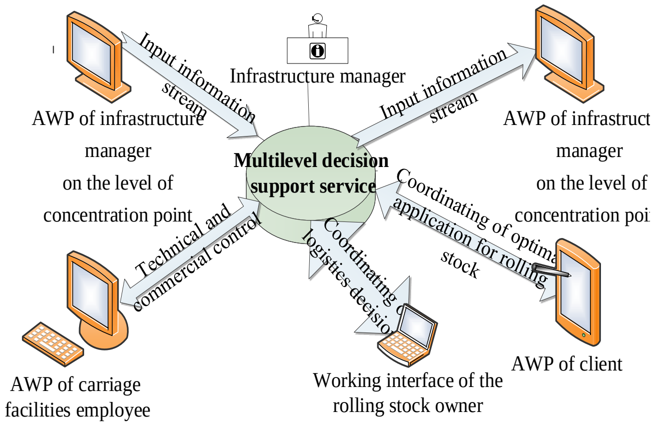

Fig. 6. Model of decision support system for optimal distribution of rolling stock.

Conclusions

The offered logistic model, in terms that formed towards restructuring the rail transport, allows developing optimal technology work of the concentration point with rational use of rolling stock and the work of locomotive with all transport network requirements. Using the offered models allows infrastructure operator to reduce operating costs while managing (W) rolling stock, to reduce local car circulation and as a result, the period of delivery. The offered approach is its use in the intellectual control system of optimal distribution of rolling stock. The model allows us to predict rolling stock location by the type and stat in each period of time that will significantly increase the rate of useful work on the railway ground.

Conclusions, methods and practical recommendations are collect personally by the author at the direct analysis of the work of the Railway Transport Directorate. The authors developed the main functions of the automated workplace, improved the model for the distribution of rolling stock using the method of dynamics of averages, taking into account the condition of the car, identified the basic conditions for forming new approach to the management of rolling stock among which the creation of a competitive market of grain cargoes transportation.

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ФОРМАЛІЗАЦІЯ ПРОЦЕСУ РОЗПОДІЛУ РУХОМОГО СКЛАДУ З ВИКОРИСТАННЯМ ДИНАМІЧНОЇ МОДЕЛІ

Мета. Стаття спрямована на формалізацію процесу підвищення ефективності розподілу рухомого складу на залізницях під завантаження шляхом концентрації навантажувальних робіт на терміналах за допомогою динамічної моделі. **Методика.** Як показує досвід, для оператора інфраструктури розподіл рухомого складу є складним процесом. У роботі проаналізовано транспортно-експедиційне обслуговування, технологію роботи окремих суб'єктів залізничної галузі й формування організаційних принципів керування вагонами підприємств різних форм власності. Установлено, що система розподілу рухомого складу, заснована на принципах логістичного контролю на шляху прямування, повинна відповідати наступним методологічним

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критеріям: скорочення часу пропуску й очікування вантажних операцій, формування достовірного інформаційного середовища для всіх учасників транспортування, створення умов для прийняття швидкого й максимально вигідного рішення щодо подальшого руху рухомого складу. **Результати.** Створено перелік необхідних умов для динамічного розвитку транспортного сектора відповідно до поточних вимог ринку. Розглянуто алгоритм логістичного управління процесом розподілу залізничного рухомого складу. Доведено, що відносини між учасниками транспортного процесу на початкових етапах реформ формуються на основі недискримінаційного доступу до ресурсів вантажів. **Наукова новизна.** Проаналізована робота диспетчерського персоналу з точки зору попиту на рухомий склад на всіх етапах управління транспортним процесом. Уперше запропонована динамічна модель, яка відтворює інформаційне поле для всіх учасників переміщення рухомого складу. За її допомогою встановлено, що залізниці повинні створювати систему розподілу рухомого складу, яка має відповідати наступним критеріям: зменшення пробігу й тривалості очікування вантажних операцій, створення умов прийняття швидкого й вигідного рішення щодо подальшого просування рухомого складу. **Практична значимість.** Застосування розробленого методу розподілу рухомого складу для формування одиничних поїздів дозволить значно зменшити логістичні витрати в ланцюгу постачання й підвищити його конкурентоспроможність на зовнішньому ринку. Розвиток такої системи покликаний створити справді незалежний регулятор транспортно-логістичного процесу в умовах формування єдиного інформаційного середовища.

Ключові слова: логістична технологія; рухомий склад; залізничний транспорт; управління залізницею; динамічна модель розподілу ресурсів

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ФОРМАЛИЗАЦИЯ ПРОЦЕССА РАСПРЕДЕЛЕНИЯ ПОДВИЖНОГО СОСТАВА С ИСПОЛЬЗОВАНИЕМ ДИНАМИЧЕСКИХ МОДЕЛЕЙ

Цель. Статья предполагает формализацию процесса повышения эффективности распределения подвижного состава на железных дорогах под погрузку путем концентрации погрузочных работ на терминалах с помощью динамической модели. **Методика.** Как показывает опыт, для оператора инфраструктуры распределение подвижного состава является сложным процессом. В работе проанализировано транспортно-экспедиционное обслуживание, технология работы отдельных субъектов железнодорожной отрасли и формирование организационных принципов управления вагонами предприятий различных форм собственности. Установлено, что система распределения подвижного состава, основанная на принципах логистического контроля в пути следования, должна отвечать следующим методологическим критериям: сокращение времени пропуска и ожидания грузовых операций, формирование достоверной информационной среды для всех участников транспортировки, создание условий для принятия быстрого и максимально выгодного решения по дальнейшему продвижению подвижного состава. **Результаты.** Создан перечень необходимых условий для динамического развития транспортного сектора в соответствии с современными требованиями рынка. Рассмотрен алгоритм логистического управления процессом распределения железнодорожного подвижного состава. Доказано, что отношения между участниками транспортного процесса в начальных условиях реформ строятся на основе недискриминационного доступа к ресурсам грузов. **Научная новизна.** Проанализирована работа диспетчерского персонала с точки зрения спроса на подвижной состав на всех этапах управления

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транспортным процессом. Впервые предложена динамическая модель, которая воспроизводит информационное пространство для всех участников перемещения подвижного состава. С ее помощью установлено, что железные дороги должны создавать систему распределения подвижного состава, соответствующую следующим критериям: уменьшение пробега и времени ожидания грузовых операций, создание условий для принятия быстрого и выгодного решения по дальнейшему продвижению подвижного состава. **Практическая значимость.** Применение разработанного метода распределения подвижного состава для формирования одиночных поездов позволит значительно уменьшить логистические затраты в цепочке поставок и повысить его конкурентоспособность на внешнем рынке. Развитие такой системы призвано создать действительно независимый регулятор транспортно-логистического процесса в условиях формирования единой информационной среды.

Ключевые слова: логистическая технология; подвижной состав; железнодорожный транспорт; управление железной дорогой; динамическая модель распределения ресурсов

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