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МОДЕЛЮВАННЯ ЗАДАЧ ТРАНСПОРТУ ТА ЕКОНОМІКИ

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STRATEGIC MANAGEMENT OF TRANSPORT CARGO COMPLEX

Purpose. Making the qualitative administrative decisions defining strategy and tactics of transport cargo complexes development, and also its subsystems, is possible only in the presence of flexible optimization model. This model has to consider multiparametricity and multicriteriality of the given task, uncertainty and vagueness of input information, and also to provide process automation of searching the best parameters of the given production facility. The purpose of the research is to develop procedures for the strategic management of complex with view of the most important factors and their stochastic nature, which will execute the improvement of technical equipment of TCC. **Methodology.** The problem of strategic management is based on solving the complex of issues of the optimal number of shunting locomotives, optimal processing capability of handling the front and rational capacity of warehouses. The problem is solved on the basis of the proposed optimality criterion – the specific set of profit per unit of capital assets of freight industry. The listed problems are solved using simulation modeling of the freight industry. **Findings.** The use of developed procedure allows one to improve the technical equipment of the freight stations and complexes. **Originality.** For the first time it was developed the procedure of strategic management of development. This procedure allows taking into account the probabilistic nature of demand for services of transport freight complexes and technological processes of client services on the complex stations. The proposed procedure can be applied during when planning the investments in the creation of transport freight complexes. **Practical value.** Use as a basic tool of simulation models of complex cargo operation allows estimating the effectiveness of the capital investments, the level of operating costs, as well as the quality of meeting the demands of potential customers in transportations at the stage of transport cargo complex.

Keywords: management; transport junction; shunting locomotive; processing ability; profit; functional dependence; optimization

Introduction

Making the qualitative administrative decisions defining strategy and tactics of transport cargo complexes (TCC) development, and also its subsystems is possible only in the presence of flexible optimization model. This model should take into account the multiparametricity and multicriteriality of the given task, uncertainty and vagueness of the input information, as well as provide the process automation of searching the best parameters of the given production facility [1, 2, 5].

In this regard during the design, planning and management of the TCC a set of interrelated optimization problems should be considered. Their solution is a multistage iterative process consisting of two mandatory interacting phases. They are planning and regulation. Planning is realizing at the level of strategic management and regulation – at the level of tactical (operational) one [6, 11]. Optimal development strategy of TCC is determined by the parameters reflecting the most important of their relationships, as well as the connections with other subsystems (number of loading and unloading machines, feed to the cargo fronts, the working hours of cargo front during the 24, etc.) [7, 8, 9].

At the present time the researchers developed a number of models designed for managing the different objects of railway transport, which are based on different methods [3, 4, 12, 13], but the issue of planning and management of TCC was not considered at all or was covered in fragments.

Purpose

The purpose of the article is to develop the procedure of strategic management of cargo complexes taking into account the most important factors and their stochastic nature that will improve the technical equipment of DCC.

Methodology

Strategic management of cargo complex provides the formation of the development plan of technological system, first of all, the development of fixed assets of the enterprises that are the part of TCC. Fixed assets, which are used directly during servicing the car traffic volume, include switch powers, means of freight mass processing – freight-handling mechanisms, as well as the corresponding storage equipment. Thus, the main problems of optimal management of the cargo complex at the strategic level include the following ones:

– substantiation of the optimal number of switch powers that will be used for servicing freight trains coming to the transportation junction;

– determination of the optimal processing capacity of handling fronts, namely, determining the necessary number of mechanisms of the certain type providing the appropriate significance of the processing capacity of the front;

– calculation of the storage capacity of transportation junction, sufficient for storage processing of the incoming cargo.

The optimal number of locomotives should ensure demand for TCC services (first technological phase), which is described by the incoming applications (car flow that are coming in groups – in freight trains).

Optimal processing capacity of the cargo front should ensure uninterrupted performing of the service operations of loading and unloading of cars in the transportation junctions (second technological phase). Processing capacity of the front is determined on the basis of the known number of locomotives that provide car supply to the front and their removal after the service operations.

Optimal capacity of the storage complex should ensure the need for storage of goods (third technological phase), that are coming to the TCC. It is determined on the basis of the known number of switch powers and processing capacity of cargo front.

At the first stage the minimal number of switch powers that will ensure the timely movement of cars, which have arrived to the transportation junction, to the handling fronts and their removal from the front after servicing is calculated. Thus, it is reasonable the assumption on the lack of idle waiting of cars at the handling front for service (this assumption provides sufficient processing capacity of the front, which is provided on the next stage of developing a strategic management plan of TCC):

$$T_{\text{оо}}^{\text{ваг}} \to 0\,, \tag{1}$$

where $T_{\text{оо}}^{\text{ваг}}$ – is total downtime of cars at the handling front waiting for the start of servicing, hrs.

According to the accepted efficiency criterion of the TCC operation at the stage of strategic management [5] the following expression can be used as the target function:

$$\Pi_{\text{ОФ}}(N_l) = \frac{\text{Д}_t - \text{В}_t(N_l)}{\text{ОФ}_t(N_l)} \to \max\,, \tag{2}$$

where N_l – is the number of switch powers servicing the car traffic volume.

At the initial stages of the simulation, when the technical equipment of cargo complex is uncertain, the mathematical model of justification of optimal number of switch powers includes the assumption of independence of TCC income on the locomotive number:

$$\text{Д}_t = \text{const}\,. \tag{3}$$

Among the costs of TCC enterprises it is reasonable to consider in the justification of optimal number of switch powers the operational component Е_t as well as in general form – the taxes Н_t. In this case the costs for debt capital payments and capital expenditures can be taken equal to zero:

$$\text{С}_t = 0\,,\ \text{К}_t = 0\,,\ \text{С}_t \neq \text{К}_t\,. \tag{4}$$

The case when К_t is greater than zero, is a kind of task that involves the acquisition of new mate-

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riel with full payment of their value (in this case $С_t = 0$) or partially (in this case, $С_t > 0$).

In general terms, the tax amount of TCC enterprises can be determined on the basis of profits as follows:

$$Н_t = (Д_t\ \delta_{VAT} - Е_t)\ \delta_p, \tag{5}$$

where δ_{VAT} – is the rate of value added tax; δ_p – is the rate of income tax.

Note that the costs $Е_t$ in the expression (5) is a function of the number of TCC switch powers.

Among the selected in [5] operating cost components the costs associated with the movement of car supply depend functionally on the number of locomotives N_l. Thus, the total operating costs related to the execution of storage operations and the maintenance costs for the operation of handling fronts are constant ones relating to the number of locomotives:

$$Е_t^l = Е_t^{скл} + Е_t^{нрф} = \text{const}. \tag{6}$$

It is assumed in the study that the total balance value of the storage space, handling fronts, approach lines, as well as administrative and household structures of TCC does not depend on the number of switch powers, involved in the servicing of the car traffic volume:

$$Б_t^l = Б_t^{скл} + Б_t^{нрф} + Б_t^{пл} + Б_t^{сп} = \text{const}. \tag{7}$$

Based on the average balance value $Б_{од}^{лок}$ for one locomotive the value $Б_t^{лок}$ is defined as follows:

$$Б_t^{лок} = Б_{од}^{лок}\ N_l. \tag{8}$$

Taking into account the above mentioned assumptions the objective function for the task of determining the optimal number of locomotives can be written as:

$$П_{ОФ}(N_l) = \frac{\left[Д_t\ (1-\delta_{VAT}\ \delta_p) - (1-\delta_p)\ Е_t^l\right]}{Б_t^l + Б_{од}^{лок}\ N_l} - \frac{(1-\delta_p)\ Е_t^{пл}(N_l)}{Б_t^l + Б_{од}^{лок}\ N_l} \to \max. \tag{9}$$

To solve the task of finding the extremum of function (9) regarding N_l it is necessary to determine the functional dependence $Е_t^{пл}(N_l)$. Using the calculation principle adopted in [5] the operational costs associated with the movement of car supply on the TCC territory during the period t can be represented as follows:

$$Е_t^{пл} = \sum_{i=1}^{N_l} \left[\begin{array}{l} c_{пост\,i}^{лок}\ \tilde{t}_{оч\,i}^{лок} + c_{зм\,i}^{лок}\ \tilde{t}_{рух\,i}^{лок} + \\ + \sum_{j=1}^{\tilde{N}_{wi}^l} \left(\begin{array}{l} c_{пост\,j}^{ван}\ \tilde{t}_{оч\,j}^{ван} + c_{зм\,ij}^{ван}\ \tilde{t}_{пер\,j}^{ван} + \\ c_{пост\,j}^{пор}\ \tilde{t}_{оч\,j}^{пор} + c_{зм\,kj}^{пор}\ \tilde{t}_{пер\,j}^{пор} \end{array} \right) \end{array} \right], \tag{10}$$

where $\tilde{N}_{wi}^l$ – is a number of cars, serviced by i locomotive during the period t; $c_{пост\,i}^{лок}$ – is the fixed costs concerning the operation of the i switch power, hrn/hr; $\tilde{t}_{оч\,i}^{лок}$ – is the total downtime of the i locomotive waiting for the arrival of freight train or the end car servicing at the front of freight operations, hr; $c_{зм\,i}^{лок}$ – is unit costs for operation of the i locomotive during its movement, hrn/hr; $\tilde{t}_{рух\,i}^{лок}$ – is total time of idling of the i locomotive when servicing the car traffic volume during the period t, hr; $c_{пост\,j}^{ван}$ – is unit costs for downtime of the j car in the loaded condition, hrn/hr; $\tilde{t}_{оч\,j}^{ван}$ – is time of idling of the j car in the loaded condition waiting for the delivery to the freight operation front, hr; $c_{зм\,ij}^{ван}$ – is unit costs for displacement of the j car by the i locomotive to the freight operation front, hrn/hr; $\tilde{t}_{пер\,j}^{ван}$ – is the time of displacement of the j car to the front of freight operation, hr; $c_{пост\,j}^{пор}$ – is unit costs for down time of the j car in the unloaded condition, hrn/hr; $\tilde{t}_{оч\,j}^{пор}$ – is down time of the j car in the unloaded condition when waiting for removal of the freight operation front, hr; $c_{зм\,kj}^{пор}$ – is unit costs for removal of the j car by the k locomotive from the freight operation front ($k = 1...N_l$), hrn/hr; $\tilde{t}_{пер\,j}^{пор}$ – is the time of displacement of the j car from the front of freight operation, hr.

Unit costs for displacement of the loaded cars to the handling front and for removal of empty cars from the front are determined on the basis of costs for idling of cars in loaded or unloaded state respectively, unit costs of the locomotive to displace, as well as the number of cars in the supply:

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$$c_{\text{зм}ij}^{\text{ван}} = c_{\text{пост}\,j}^{\text{ван}} + \frac{c_{\text{зм}i}^{\text{лок}}}{\tilde{n}_{\text{вп}j}}, \qquad (11)$$

$$c_{\text{зм}kj}^{\text{пор}} = c_{\text{пост}\,j}^{\text{пор}} + \frac{c_{\text{зм}k}^{\text{лок}}}{\tilde{n}_{\text{вп}j}}, \qquad (12)$$

where $\tilde{n}_{\text{вп}j}$ – is the number of cars in the supply, which include the *j* car.

Time technological indices that make up the expression (10) and the number of cars in the supply $\tilde{n}_{\text{вп}j}$ are random variables whose values depend on the number of switch powers used when servicing the car traffic volumes. Therefore, the values of operating costs $\text{Е}_t^{\text{пл}}$ are calculated using the simulation modeling of service process and estimation of the dependency $\text{Е}_t^{\text{пл}}(N_l)$ is possible on the basis of regression analysis of the results of simulation experiment conducted for the given parameters of TCC.

Solving the problem of maximizing the objective function (9) by choosing the optimal value of the parameter N_l is possible taking into account the following restrictions:

1) the value of the parameter N_l is an integer greater than 1:

$$N_l \geq 1,\ N_l \in \mathbb{Z}, \qquad (13)$$

where $\mathbb{Z}$ – is a set of integers;

2) the total number of cars that were delivered as a part of freight trains within the period of time *t*, is equal to the total number of cars that were delivered to the front of freight operation by all the switch powers of the station (i.e., it is expected no-failure operation of the serving system – all the demand for transport services is provided):

$$\sum_{i=1}^{N_T} \tilde{N}_{wi} = \sum_{j=1}^{N_l} \sum_{k=1}^{\tilde{N}_{\text{п}j}^{\text{ван}}} \tilde{n}_{\text{вп}jk}^{\text{ван}}, \qquad (14)$$

where N_T – is a number of freight trains, that were delivered to the TCC during the investigated period of time, trains/period; $\tilde{N}_{\text{п}j}^{\text{ван}}$ – is the number of car supplies that are serviced by the *j* locomotive when delivering cars to the handling front; $\tilde{n}_{\text{вп}jk}^{\text{ван}}$ – is the number of cars in the *k* supply that are serviced by the *j* locomotive when delivering the cars to the freight operation front;

3) the total number of cars that were delivered to the front of handling operations is equal to the total number of cars that were removed from the front by switch motors (i.e. all the cars that were delivered to the handling front should be serviced):

$$\sum_{j=1}^{N_l} \sum_{k=1}^{\tilde{N}_{\text{п}j}^{\text{ван}}} \tilde{n}_{\text{вп}jk}^{\text{ван}} = \sum_{j=1}^{N_l} \sum_{k=1}^{\tilde{N}_{\text{п}j}^{\text{пор}}} \tilde{n}_{\text{вп}jk}^{\text{пор}}, \qquad (15)$$

where $\tilde{N}_{\text{п}j}^{\text{пор}}$ – is the number of supplies of the serviced cars that the *j* locomotive removes from the handling front; $\tilde{n}_{\text{вп}jk}^{\text{пор}}$ – is the number of cars serviced in the *k* supply. They being removed from the handling front by the *j* locomotive.

Processing capacity of the handling front is determined on the basis of performance of handling mechanisms (HM) used at the front for servicing the cars. In general terms, the processing capacity of the front $W_{\text{вф}}$ is the following sum:

$$W_{\text{вф}} = \sum_{i=1}^{N_g} w_i, \qquad (16)$$

where N_g – is the number of the HM, included to the handling front; w_i – is the performance of the *i* HP, tn/hr.

In case when for calculating of the processing capacity the average value of the performance mechanism w_g is used the expression (16) can be written as follows:

$$W_{\text{вф}} = N_g\ w_g. \qquad (17)$$

When the w_g value is known, the estimation task of the optimal processing capacity of the handling front is transformed into the task of justification of the optimal number of mechanisms N_g. Similar to the expression (2) the objective function to solve this problem is the maximum value of the profit per unit for cost unit of the capital assets:

$$\Pi_{\text{ОФ}}(N_g) = \frac{\text{Д}_t - \text{В}_t(N_g)}{\text{ОФ}_t(N_g)} \rightarrow \max. \qquad (18)$$

When solving task (18) the assumption (3) and (4) are also appropriate. It is reasonable to represent the operating costs for cargo complex operation for this task as:

$$\text{Е}_t = \text{Е}_t^g + \text{Е}_t^{\text{нрф}}, \qquad (19)$$

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where $\mathrm{Е}_t^g$ – is the constant of operating costs relative to N_g, hrn:

$$\mathrm{Е}_t^g = \mathrm{Е}_t^{\text{скл}} + \mathrm{Е}_t^{\text{пл}} = \text{const}\,. \qquad (20)$$

Fixed assets of the TCC enterprises when solving the task (18) is also reasonable to divide into the constant component relative to N_g and the component that depends on the number of HM:

$$\text{ОФ} = \text{Б}_t^g + \text{Б}_t^{\text{нрф}}, \qquad (21)$$

where Б_t^g – the total balance value of the storage space, switch locomotives, access lines, as well as the administrative and household structures of the cargo complex, hrn:

$$\text{Б}_t^g = \text{Б}_t^{\text{скл}} + \text{Б}_t^{\text{лок}} + \text{Б}_t^{\text{пл}} + \text{Б}_t^{\text{сп}} = \text{const}\,. \qquad (22)$$

The balance value of the handling front equipment can be determined on the basis of average balance value for one mechanism $\text{Б}_{\text{од}}^{\text{мех}}$:

$$\text{Б}_t^{\text{нрф}} = \text{Б}_{\text{од}}^{\text{мех}}\ N_g\,. \qquad (23)$$

Thus, the objective function for the problem of determining the optimal number of HM, taking into account the adopted notations and assumptions, as well as the relationship (5) can be written as follows:

$$\Pi_{\text{ОФ}}(N_g) = \frac{\left[\text{Д}_t\ (1-\delta_{VAT}\ \delta_p) - (1-\delta_p)\ \mathrm{Е}_t^g\right]}{\text{Б}_t^g + \text{Б}_{\text{од}}^{\text{мех}}\ N_g} -$$

$$-\frac{(1-\delta_p)\ \mathrm{Е}_t^{\text{нрф}}(N_g)}{\text{Б}_t^g + \text{Б}_{\text{од}}^{\text{мех}}\ N_g} \to \max\,. \qquad (24)$$

Operating costs for the operation of handling fronts when serving customers over the period t can be determined for known values of the HM downtime waiting for the arrival of cars, downtime of cars during maintenance and downtime of cars waiting for the start of service at the front:

$$\mathrm{Е}_t^{\text{нрф}} = \sum_{i=1}^{N_g} \left[\begin{array}{l} c_{\text{пост}i}^{\text{мех}}\ \tilde{t}_{\text{оч}i}^{\text{мех}} + \\ \sum\limits_{j=1}^{\tilde{N}_{wi}^g} \left(\begin{array}{l} c_{\text{пост}j}^{\text{ван}}\ (\tilde{t}_{\text{оч}j}^{\text{ф}} + \tilde{t}_{\text{обсл}j}) \\ + c_{\text{зм}i}^{\text{мех}}\ \tilde{t}_{\text{обсл}j} \end{array} \right) \end{array}\right], \qquad (25)$$

where $\tilde{N}_{wi}^g$ – is the number of cars that were serviced by the i HM during the period t; $c_{\text{пост}i}^{\text{мех}}$ – is the unit cost of the lost hour for i mechanism, hrn/hr; $\tilde{t}_{\text{оч}i}^{\text{мех}}$ – is the total downtime of the i mechanism during the period t, hr.; $\tilde{t}_{\text{оч}j}^{\text{ф}}$ – is the downtime of the j car in loaded condition waiting for the start of service at the handling front, hr.; $c_{\text{зм}i}^{\text{мех}}$ – is the unit cost of servicing the car by the i mechanism, hrn/hr; $\tilde{t}_{\text{обсл}j}$ – is the service time of the j car at the handling front, hr.

Determination of functional dependence $\mathrm{Е}_t^{\text{нрф}}(N_g)$ as the dependence $\mathrm{Е}_t^{\text{пл}}(N_l)$ is based on the processing of the simulation experiment results.

Maximization of the objective function (9) by choosing the optimal value of N_g is performed on the basis of the following restrictions:

1) number of HM is an integer larger than 1:

$$N_g \ge 1,\ N_g \in \mathbb{Z}\,; \qquad (26)$$

2) the total number of cars that came to cargo complex is equal to the total number of cars that were serviced at the front (all the cars coming to the TCC are served on the handling front):

$$\sum_{i=1}^{N_T} \tilde{N}_{wi} = \sum_{j=1}^{N_g} \tilde{N}_{wj}^g\,. \qquad (27)$$

The optimal capacity of storage is determined on the basis of data on incoming cargo traffic. The source of input material flow is the car supplies that are serviced at the handling front, as well as the means of other transport modes that interact with the railway transport in the junction.

Let us consider in detail the capacity optimization of storage facilities used for storing and processing of goods that are delivered by railway transport.

The average intensity of cargo receipt $\lambda_{\text{вх}}$ from the handling front for the period t is determined as the ratio of received cargo to the period of time based on the known value of the cargo share, which is overloaded by direct option (from the railway cars to other transport modes):

$$\lambda_{\text{вх}} = \frac{1-\eta_{\text{пр}}}{t} \sum_{i=1}^{\tilde{N}_T} \sum_{j=1}^{\tilde{N}_{wi}} q_{ij}\ \gamma_{ij}\,, \qquad (28)$$

where $\eta_{\text{пр}}$ – is the cargo share that is overloaded using the direct option.

If the known intensity of shipment from the storage $\lambda_{\text{вих}}$ (to other transport modes for further deliv-

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ery), the cargo volume $Q^t_{\text{скл}}$ that is constantly kept in stock for the period t, can be determined as follows:

$$Q^t_{\text{скл}} = (\lambda_{\text{вх}} - \lambda_{\text{вих}})\, t\,. \tag{29}$$

The value $Q^t_{\text{скл}}$ reflects value of the required storage capacity for servicing the material flow with set characteristics $\lambda_{\text{вх}}$ and $\lambda_{\text{вих}}$.

On the basis of $Q^t_{\text{скл}}$ and the known value of the admissible loading $\sigma_{\text{скл}}$ for 1 m^2 of the storage the required area of storage can be calculated using the formula:

$$S_{\text{скл}} = \frac{Q^t_{\text{скл}}}{\sigma_{\text{скл}}}\,. \tag{30}$$

It should be noted that the value $Q^t_{\text{скл}}$ does not reflect the total amount of certain constantly stored consignments. It is the accumulated value that indicates the average amount of cargo in stock at the end of period t. In this case, the calculation of cargo amount stored in the stock for the period t using the formula (29) is based on the assumption of uniformity of receipt and export of goods, when for the real object these processes are discrete in time and uneven.

The intensity of shipment is resulting indicator that reflects the interaction process in the cargo junction of several transport modes. If we consider the TCC system as the set of elements that interact in the process of moving cargo weight, the transport removing cargoes from transport junction is considered as the element of TCC system when performing operations within the storage complex only. When delivering the goods after their removal from the cargo complex the vehicles that perform these operations are considered as the elements of outside environment.

For this assumption the output intensity of cargo traffic volume $\lambda_{\text{вих}}$ is a random variable that is defined as follows:

$$\lambda_{\text{вих}} = \frac{1}{t}\sum_{i=1}^{\tilde{N}_v} v_i\,, \tag{31}$$

where $\tilde{N}_v$ – is a random variable of the amount of transport modes that arrived to the cargo complex to remove the cargo during the period t; v_i – is the amount of cargo that is removed by the i transport mode, tn.

It should be noted that with the known value of the average interval of transport mode coming to the TCC for removal of cargo, the mathematical expectation of the value $\tilde{N}_v$ is defined using the formula:

$$\mu(\tilde{N}_v) = \frac{t}{\mu(\tilde{\zeta}_{\text{вих}})}\,, \tag{32}$$

where $\mu(\tilde{N}_v)$ – is mathematical expectation of the number of transport modes that were removing cargo from the TCC during the period t; $\tilde{\zeta}_{\text{вих}}$ – is random variable of the arrival interval to the TCC of transport modes removing cargo, hr.; $\mu(\tilde{\zeta}_{\text{вих}})$ – is mathematical expectation of the random variable $\tilde{\zeta}_{\text{вих}}$, hr.

It should be noted that in determining the numerical values of cargo removal intensity from the storage it is necessary to take into account possible downtime (related to lack of cargo) of the vehicles arrived to TCC for loading. Therefore, the most appropriate instrument for selection of the value $\lambda_{\text{вих}}$ is the simulation experiment.

The system of storage facilities of cargo complex is not cumulative, i.e. the total amount of cargo arrived to the storage for a certain period of time T, which is considered in the process model, should be equal to the total cargo volume that was removed from the storage:

$$\sum_{i=1}^{n}\lambda_{\text{вх}i}\, t_i = \sum_{i=1}^{n}\lambda_{\text{вих}i}\, t_i\,, \tag{33}$$

where n – is the number of consecutive time periods; t_i – is the duration of the i period of time, hr.; $\sum_{i=1}^{n} t_i = T$.

Taking into account (33) the value $Q^t_{\text{скл}}$ for the period $t = T$ will be equal to zero. That is there is no need for storage facilities, since in the operation of the system according to the conditions (33) a uniform accumulation of cargo in stock and its removal out of it will take place. For real objects, which are characterized by uneven supply and removal of cargo, the need for storage facilities arises in situations when the received cargo is not fully removed from the storage to the date of the next batch.

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In this case, the need for storage facilities $Q_{\text{скл}}^{\text{потр}}$ is determined by the maximum current cargo volume:

$$Q_{\text{скл}}^{\text{потр}} = \max_{i=1\ldots n} Q_{\text{скл}}^{i}, \qquad (34)$$

where $Q_{\text{скл}}^{i}$ – is the current cargo volume, that is in stock during the period t_i, tn.

Operating costs for the operation of storage facilities can be determined on the basis of the self cost of 1tn × h. for cargo storage:

$$\text{Е}_t^{\text{скл}} = c_{\text{скл}} \sum_{i=1}^{n} Q_{\text{скл}}^{i}\, t_i, \qquad (35)$$

where $c_{\text{скл}}$ – is unit cost of the storage of 1 tn. of cargo during 1 hr., hrn/tn hr.

As you can see, the component of operating cost $\text{Е}_t^{\text{скл}}$ does not depend on the capacity of storage space, so, taking into account the assumptions (3) and (4) one can state that the costs of TCC enterprises are constant relative to the capacity of storages. Then according to the adopted performance criterion the objective function to solve the task of optimal capacity justification of the storage facilities has the following form:

$$\Pi_{\text{ОФ}}(Q_{\text{скл}}) = \frac{\text{Д}_t - \text{В}_t}{\text{ОФ}_t(Q_{\text{скл}})} \to \max. \qquad (36)$$

The fixed assets of TCC enterprises can be represented as the sum of the constant component relative to the $Q_{\text{скл}}$ and the component that depends on the storage capacity:

$$\text{ОФ} = \text{Б}_t^{w} + \text{Б}_t^{\text{скл}}, \qquad (37)$$

where Б_t^{w} – is the total balance cost of the cargo front equipment, switch powers, access lines, as well as the administrative and household structures of the cargo complex, hrn:

$$\text{Б}_t^{w} = \text{Б}_t^{\text{нрф}} + \text{Б}_t^{\text{лок}} + \text{Б}_t^{\text{пл}} + \text{Б}_t^{\text{сп}} = \text{const}. \qquad (38)$$

The balance value of the storage facilities can be represented as the product of the storage area and the average balance value of equipment $\text{Б}_{\text{кв.м}}^{\text{скл}}$ for 1 m^2 of the surface:

$$\text{Б}_t^{\text{скл}} = \text{Б}_{\text{кв.м}}^{\text{скл}} \frac{Q_{\text{скл}}}{\sigma_{\text{скл}}}. \qquad (39)$$

Taking into account the adopted notations the objective function for the task of justification of the storage optimal capacity on the basis of (36) can be written as follows:

$$\Pi_{\text{ОФ}}(Q_{\text{скл}}) = \frac{\text{Д}_t - \text{В}_t}{\text{Б}_t^{w} + \text{Б}_{\text{кв.м}}^{\text{скл}} \dfrac{Q_{\text{скл}}}{\sigma_{\text{скл}}}} \to \max. \qquad (40)$$

The limits to solve the task (40) should provide that the value of the storage capacity should meet the requirements for storage spaces:

$$Q_{\text{скл}} \geq Q_{\text{скл}}^{\text{потр}}. \qquad (41)$$

Primary analysis of the function $\Pi_{\text{ОФ}}(Q_{\text{скл}})$ suggests that the function takes maximum value at the minimum possible value $Q_{\text{скл}}$. Taking into account (41) and (34) one can conclude that for the adopted performance criteria of TCC operation the optimal capacity of storage is equal to the maximum value of cargo volume that is in stock over some period of time. In the above mentioned formulation to solve this task is possible only on the basis of simulation modeling of the process of receiving and removal of cargo from the storage.

According to the proposed methodology of strategic management, the optimal number of locomotives is defined in two stages:

– determination of the optimal number of locomotives when servicing the cars providing the absence of downtime waiting for the start of unloading after arrival to the handling front. At this the condition (1) is fulfilled, and the total balance value of the handling front equipment is assumed to be equal to zero (since at this stage the number of HM is unknown);

– clarification of the number of switch motors taking into account the known value of the optimal number of HM at the cargo front. At this the number of locomotives is determined on the basis of the known balance value of the handling front equipment.

After clarification of the optimal number of switch motors it is carried out the re-modeling of the cargo complex operation for the known number of HM in order to determine the intensity of the input cargo traffic volumes to the storage complex. On the basis of the parameters of incoming and outgoing cargo, as well as the technical and economic performance of the storage operation its optimal capacity is determined.

Findings

As a result of the studies it is determined the dependencies of technical parameters of the transport cargo complex operation on the technical parameters – the number of switch motors, handling machines and storage area, as well as the formed limitations for these dependencies.

The obtained dependencies make it possible to determine the costs for organization and technical equipment of TCC at the stage of the system design, and optimize the technical equipment to improve the operation of the existing facilities.

Originality and practical value

For the first time it was developed strategic management of the development, which allow taking into account the probabilistic nature of demand for TCC services and technological processes of customer servicing at the TCC stations. The proposed procedure can be applied when planning investments in TCC.

Conclusions

The proposed procedure of strategic management of TCC development requires the consistent justification of the optimal number of switch motors, determination of the optimal processing capacity of handling fronts, as well as calculating the storage capacity of transport junction. Use the simulation models of cargo complex operation as the main tool allow taking into account the probabilistic nature of demand for TCC services and technological processes of customer service at the cargo complex stations.

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СТРАТЕГІЧНЕ УПРАВЛІННЯ ТРАНСПОРТНИМ ВАНТАЖНИМ КОМПЛЕКСОМ

Мета. Прийняття якісних управлінських рішень, що визначають стратегію й тактику розвитку транспортно-вантажних комплексів, а також його підсистем, можливо лише при наявності гнучкої оптимізаційної моделі. Дана модель повинна враховувати багатопараметричність та багатокритеріальність поставленої задачі, невизначеність та нечіткість вхідної інформації, а також забезпечувати автоматизацію процесу пошуку найкращих параметрів даного виробничого об’єкта. Метою дослідження є розробка процедури стратегічного управління вантажними комплексами з урахуванням найбільш вагомих факторів та їх стохастичної природи, яка дозволить виконати удосконалення технічного оснащення транспортних вантажних комплексів (ТВК). **Методика.** Рішення задачі стратегічного управління базується на розв’язанні комплексу питань із визначення оптимальної кількості маневрових локомотивів, оптимальної переробної спроможності навантажувально-розвантажувальних фронтів та раціональної місткості складських приміщень. Задачі вирішуються на базі запропонованого критерію оптимальності – питомого прибутку комплексу на одиницю вартості основних фондів вантажного комплексу. Перелічені задачі вирішуються за допомогою імітаційного моделювання роботи вантажного комплексу. **Результати.** Використання розробленої процедури дозволяє виконати удосконалення технічного оснащення вантажних станцій та комплексів. **Наукова новизна.** Вперше розроблено процедуру стратегічного управління розвитком, який дозволяє врахувати ймовірнісну природу попиту на послуги транспортних вантажних комплексів і технологічних процесів обслуговування клієнтури на станціях транспортних вантажних комплексів. Запропонована процедура може бути застосована при плануванні інвестицій у створення транспортних вантажних комплексів. **Практична значимість.** Використання в якості основного інструменту імітаційних моделей функціонування вантажного комплексу дозволяє виконати оцінку ефективності капітальних вкладень, рівня експлуатаційних витрат, а також якості задоволення потреб потенційних клієнтів у перевезеннях ще на стадії проектування транспортного вантажного комплексу.

Ключові слова: управління; транспортний вузол; маневровий локомотив; переробна спроможність; прибуток; функціональна залежність; оптимізація

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СТРАТЕГИЧЕСКОЕ УПРАВЛЕНИЕ ТРАНСПОРТНЫМ ГРУЗОВЫМ КОМПЛЕКСОМ

Цель. Принятие качественных управленческих решений, определяющих стратегию и тактику развития транспортных грузовых комплексов, а также его подсистем, возможно только при наличии гибкой оптимизационной модели. Данная модель должна учитывать многопараметричность и многокритериальность поставленной задачи, неопределенность и нечеткость входной информации, а также обеспечивать автоматизацию процесса поиска наилучших параметров данного производственного объекта. Целью исследования является разработка процедуры стратегического управления грузовыми комплексами с учетом наиболее значимых факторов и их стохастической природы, которая позволит выполнить усовершенствование технического оснащения транспортних грузовых комплексов (ТГК). **Методика.** Решение задачи стратегического управления базируется на решении комплекса вопросов по определению оптимального количества маневровых локомотивов, оптимальной перерабатывающей способности погрузочно-разгрузочных фронтов и рациональной вместимости складских помещений. Задачи решаются на базе предложенного критерия оптимальности – удельной прибыли комплекса на единицу стоимости основных фондов грузового комплекса. Перечисленные задачи решаются с помощью имитационного моделирования работы транспортных грузовых комплексов. **Результаты.** Использование разработанной процедуры позволяет выполнить усовершенствование технического оснащения грузовых станций и комплексов. **Научная новизна.** Впервые разработана процедура стратегического управления развитием, которая позволяет учесть вероятностную природу спроса на услуги транспортных грузовых комплексов и технологических процессов обслуживания клиентуры на станциях комплекса. Предложенная процедура может быть применена при планировании инвестиций в создание транспортных грузовых комплексов. **Практическая значимость.** Использование в качестве основного инструмента имитационных моделей функционирования грузового комплекса позволяет выполнить оценку эффективности капитальных вложений, уровня эксплуатационных расходов, а также качества удовлетворения потребностей потенциальных клиентов в перевозках еще на стадии проектирования транспортного грузового комплекса.

Ключевые слова: управление; транспортный узел; маневровый локомотив; перерабатывающая способность; прибыль; функциональная зависимость; оптимизация

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