Improvement of the Vehicles Fleet Structure of a Specialized Motor Transport Enterprise

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Abstract

The article considers the developed system of solid domestic waste collection and removal. The scientists’ contribution and various methods to improve this system are analysed. A mathematical model estimating the efficiency of a specialized motor transport enterprise functioning, engaged in collecting and removing solid domestic waste is drawn. The optimum rolling stock structure for the specialized motor transport enterprise is determined. Also, the results and the conclusions of the executed research are presented.

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1. Analysis of the status question

The settlement activity is permanently connected with the formation of the solid domestic waste (SDW). The infrastructure is created and is functioning as a result of SDW utilization. It includes the specialized enterprises for SDW collecting and removing, posts of their concentration and places of processing or burial. The aim for the system functioning of solid domestic waste collecting and removing is the observance of sanitary and hygienic requirements, requirements for environmental protection, settlement esthetics with the use of rational routes and safety traffic.

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The most important task at achieving this aim is the organization of timely collection and removal of solid domestic waste with the smallest labor and material inputs.

The volume and intensity of solid waste formation are influenced by a number of factors:
- demographic (number and density of population);
- climatic (climatic zone, season);
- local features (density and nature of building, architectural features), etc.

The listed factors cause the essential variability both the volumes of SDW formation and the requirements to the frequency of their collecting and removing. It causes the adaptation problem for the rolling stock structure of the specialized motor transport enterprise (SMTE), the modes of its work, and also the container park to the external changing conditions [7, 8, 12, 23-28, 52, 55].

One of the most important stages in the optimization of the specialized motor transport enterprise work is the improvement of the transport process. The direct solution of the problem of the transport process improvement for the specialized motor transport enterprise is difficult because the motor transport enterprises is a difficult object for the optimization, in this regard choosing the influence direction it is necessary to analyse various approaches to the optimization problems solution of SMTE functioning.

According to R. Dreyper and N. Li researches there are two groups of the optimization problem solution: the optimization with extremum storing and the optimization on sensitivity.

Academician Ivakhnenko A.G. suggests to classify the methods of extremum searching on two stages:
- when finding object "near extremum";
- when finding object on "extremum inclination".

At the first stage the method with extremum filling is used and at the second stage the optimization method on sensitivity is applied.

If the specialized motor transport enterprise is considered as an object of optimization, it will be "on extremum inclination".

Modern operating experience testifies that effectiveness indicators of SMTE work significantly differ from optimum values, in other words their indicators are on "inclination of the extreme height", in this regard it will be more expedient to use the optimization method on sensitivity.

The following methods are widespread and effectively used.
- Gauss-Zeidel's method (serial change of variables). This method resolves into consecutive change of $\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n$ variables values and the establishment of partial extrema.
- Gradient method. The essence of this method consists in the definition of the representing point movement in such direction at which the difference with the instant direction of gradient vector would be minimum.

- Method of the quickest descent. The use of the quickest descent method is connected with the definition of the gradient vector direction in the point characterizing an initial status of the system. Further the movement in the gradient vector directions is carried out until the moment when $\frac{dF}{dl}$ partial derivative taken along the vector direction doesn't become equal to zero. In a point when $\frac{dF}{dl}$ partial derivative is equal to zero value, the gradient vector direction is established again, and the movement along it is made up to the conversion into zero by partial derivative taken according to the new direction of gradient, etc.

By now the research methods basing on the thesis of the sensitivity theory being developed by professor Shchipakov A.P. and further advanced by academician Petrov B.N. are developed and effectively applied in various scientific and practical fields.

In his scientific papers Abdashitov R.T. proposes the simple and effective technique for the analysis and the calculation of technical and economic indicators of the studied object on the basis of the economic characteristics optimization of the production systems using the methods of the sensitivity theory.

The analysis results of modern approaches to the optimum structure formation of vehicles fleet allow to draw the following conclusions [1-6, 9-11, 13-22, 29-51, 53, 54, 56-59].

1. At the moment the problem of increasing SMTE functioning efficiency connected with the competitiveness growth due to the expenses optimization is actual. Thus it is important to consider not only operation costs of rolling stock but also the environment factors characterized by the requirement change both in transportations volumes and their structures.
2. Functioning of the specialized motor transport enterprises at the present stage is characterized by the dynamic change of the environment factors caused by the fluctuations of market situation and compelling SMTE to adapt for these changes. The changeable factors of the environment are: the volumes of transport work caused by the needs of transportations customers, the block of the economic factors causing the ratio of the income and expenses, the standard acts regulating the activity of the public motor transport enterprises and SMTE. As a result during operating it is important to know not only all these factors but also to consider their change and features of influence for the effective management of the production and the improvement of the production economic activity of SMTE.

3. The existing methods of efficiency increase of SMTE operation are directed on the formation of the rational structure of fleet for the public motor transport enterprises which are carrying out traditional freight or passenger traffic. SMTE work which in particular consists in collecting and removing of solid domestic waste, is characterized by a number of features which don't find reflection in modern scientific approaches, for example, containers variety for SDW collecting and ways of their loading in the bodies of specialized vehicles.

2. The mathematical model of SMTE functioning efficiency

We will present systems of solid domestic waste collecting and removing as the scheme for the mathematical model formation of SMTE functioning efficiency (figure 1).

![Diagram of SMTE functioning efficiency](image_url)

**Fig. 1.** System scheme of solid domestic waste collecting and removing. $Q$ – SDW volume in $u$-point of concentration; $k$ – containers quantity of $j$-type in $u$-point of concentration; $t_{uj}$ – duration of containers unloading in $u$-point of concentration; $P_{u}$ – SDW concentration point; $M_{k}$ – route of SDW collecting and removing; $L_{k}$ – length of $k$-route; $N_{kk}$ – number of containers on the route; $t_{ki}$ – duration of containers unloading on the route; $Q_{k}$ – volume of removed SDW on $k$-route; $N_{i}$ - number of $i$-type vehicles.

When forming mathematical model the difficult system – the specialized motor transport enterprise – is presented in the form of the scheme (figure 2).
Fig. 2. Connection of efficiency indicator of the specialized motor transport enterprise functioning with the structure of rolling stock and container fleet. $Q$ – volume of SDW formation, t; $N_i$ – number of vehicles of $i$-type, unit; $K_j$ – containers number of $j$-type, unit; $M_{ij}$ – route parameter of solid domestic waste collecting and removing when using $i$-type vehicles and $j$-type containers; $F$ – transportation cost 1 t·km of SDW; $A$ – operational expenses.

Criterion function $F$, forming vector of useful effect, may be presented as:

$$F = \{F_1, F_2, ..., F_n\},$$  

(1)

where $F$ – transportation cost of 1 m$^3$ of solid domestic waste;

$n$ – types number of vehicles.

Variable parameters of criterion function make up the models of vehicles

$$N_i = \{N_{i1}, N_{i2}, ..., N_{in}\},$$  

(2)

and types of used containers

$$K_j = \{K_{j1}, K_{j2}, ..., K_{jm}\},$$  

(3)

where $N_i$ – number of specialized vehicles of $i$-model;

$K_j$ – containers number of $j$-type.

Environment parameter is volume of solid domestic waste ($Q$). This volume may be presented as a sum of volumes being collected on $i$-routes ($Q_i$).

$$Q = \sum_{k=1}^{m} Q_k,$$  

(4)

where $Q_k$ – transportations volume on $k$-route;

$m$ – routes number.

Transportations volume for $k$-route may be presented as:
\[ Q_k = \frac{T_h q_i N_i}{\frac{t_{li}}{V_t} + t_{durj}}, \]  

where \( T_h \) – order time, h; 
\( q_i \) – capacity of \( i \)-type vehicle, \( m^3 \); 
\( l_{li} \) – trip length with freight of \( i \)-type vehicle, km; 
\( \beta \) – coefficient of run usage; 
\( V_t \) – technical speed of vehicle, \( \text{km/h} \); 
\( T_{durj} \) – duration of loading and unloading operations at using \( j \)-container fleet, h.

\[ t_{durj} = t_{lj} K_j, \]  

where \( t_{lj} \) – duration of unloading of one \( j \)-container, h; 
\( K_j \) – number of \( j \)-containers, item.

The annual volume of transportations on \( Q_{ak} \) route may be presented as:

\[ Q_{ak} = \frac{T_h q_i N_i D_{wyj}}{\frac{t_{li}}{V_t} + t_{lj} K_j}, \]  

where \( D_{wyj} \) – days number in a year of rolling stock work on the route at using \( j \)-container fleet.

Days number in a year of rolling stock work on the route at using \( j \)-container fleet:

\[ D_{wyj} = \frac{365}{P_j}, \]  

where \( P_j \) – periodicity of solid domestic waste removing at using \( j \)-container fleet, days.

The total annual volume of transportations may be denoted as:

\[ Q = \sum_{i=1}^{n} \sum_{j=1}^{u} \frac{T_h q_i N_i D_{wyj}}{\frac{t_{li}}{V_t} + t_{lj} K_j}, \]  

where \( n \) – number of rolling stock types; 
\( u \) – number of containers type.

The operational costs of rolling stock maintenance in technically working order are accepted as a vector of the fixed internal parameters:

\[ A = \{a_1, a_2, \ldots, a_n\}. \]  

where \( a_i \) – costs of rolling stock maintenance of \( i \)-group vehicles in technically working order.

On the basis of the considered dependences the general view of the criterion function for the optimization of transport operation cost on criterion of minimum expenses is established:
\[
F = \frac{\sum_{i=1}^{n} N_i \cdot a_i + \sum_{j=1}^{u} K_j \cdot b_j}{\sum_{i=1}^{n} \sum_{j=1}^{u} \frac{h_i}{t_{ij}} N_{ij} + t_{cj} K_j} \rightarrow \min,
\]

where \( b_j \) – cost of maintaining the containers of the \( j \)-group.

While model forming the vehicle time spent in an order and the technical speed of the vehicle are accepted to invariable values.

The criterion function considered above allows to develop the structure of solid domestic waste collecting and removing which will allow to carry out the production with the minimum operational expenses.

The optimum structure formation for rolling stock of the specialized motor transport enterprise is carried out with the use of the sensitivity theory thesis on the basis of the coefficients ponderability determination of the regression equation.

3. Results

The experimental research is fulfilled on the basis of the specialized motor transport enterprise “Management Company specialized car fleet” Ltd. in Orenburg.

Analyzing the fleet structure the following research stages were carried out for its optimization:
- formation of basic data matrix, including the information on the structure of vehicles and containers fleet, and the related operational expenses;
- rationing of basic data matrix consisting in reduction of all expenses values to the value of the basic period;
- determination of coefficients values of the regression equation;
- determination of the optimum fleet structure according to the developed model.

The general view of the regression equation is presented as dependence:

\[
F = 78,0795 - 0,58238 \cdot N_1 - 0,26243 \cdot N_2 - 0,24151 \cdot N_3 - 2,70992 \cdot N_4 + 0,00066 \cdot K_1 + 0,01361 \cdot K_2,
\]

where \( N_i \ldots N_i \) – vehicles number in \( i \)-group.

\( K_j \ldots K_j \) – containers number in \( j \)-group.

The structure of vehicles fleet and containers before and after the optimization is presented in figure 3.

4. Online license transfer

According to the results of the fulfilled research it is possible to draw the following conclusions.

The developed mathematical model for the functioning of the motor transport enterprise establishes the interrelation of unit cost of transport operation from the rolling stock structure of the motor transport enterprise, external agitations and the internal fixed parameters that allows to solve effectively a problem of the infrastructure optimization at SDW collecting and removing by the method of the sensitivity theory.

1. As the optimization parameter the cost choice for 1 m\(^3\) of solid domestic waste was proved, the rolling stock and container fleet structure was used as the varied parameters of the optimization model, the change of transport work is used as an external factor. The specified parameters are recommended to be used for the optimization of rolling stock structure of the motor transport enterprise of various type and appointment.
2. The assessment of the optimization results adequacy in the conditions of the operating motor transport enterprise showed that the error of the regression model for the efficiency of enterprise functioning makes 8%.

3. The presented system application for the fleet structure optimization of specialized vehicles and containers in practice of MTE activity allowed to reduce cost of transport operation to 9%.

![Fig. 3. The structure of vehicles and containers fleet before and after the optimization. (a) the dynamics of vehicles fleet structure; (b) the dynamics of containers fleet structure.](image)

References


