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Application of Methods of the Solution of Multi-Criteria Tasks for Choosing an Effective Cargo Delivery Scheme

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ABSTRACT

The article considers the problem of choosing an efficient delivery scheme. Currently, when choosing ameans of transport, a route, or a delivery scheme, one-criterion evaluation is often usedin practice to identify the most important criteriataking into account restrictive conditions – these areusually the delivery cost or delivery time. The method of indicator ranking,currently used to select a means of transport or a route, is based on the expert assessment in the arrangement of grades. The expert's error increases the probability of making a wrong decision. It is proposed to apply the methods of the solution of multi-criteria tasks to select an efficient delivery scheme and compare the results obtained. For determining an effective cargo delivery schemein multimodal transport, it is recommended to apply a zoning method according tothe principle of preserving the hierarchical correlation of possible states of the environment, which had not previously been used for this practical problem. It can significantly reduce an impact of the expert's opinion on the decision made. The determination of aneffective cargo delivery scheme providesdifferent results when using different methods of the solution of multi-criteria tasks. The maximum efficiency of the decision made has been determined by usinga zoning method according tothe principle of preserving the hierarchical correlation of possible states of the environment.

Keywords: Efficiency, delivery scheme, multi-criteria assessment, multimodal transport, cargo delivery.

1. INTRODUCTION

The selection of an optimal transport-technological cargo delivery scheme is one of the main tasks to be solved by a transportation organizer. However, it considers the aspects related to the selection of aroute, a means of transport, delivery schemes, etc., including the possibility of mixed traffic.

Currently, when choosing ameans of transport, a route, or a delivery scheme, one-criterion evaluation is often usedin practice. The most important criteria are identified – these are usually the delivery cost or delivery time. At the same time, restrictive conditions on the use of any means of transport, type of rolling stock, track section, etc., are taken into account.

However, there are much more criteria to be taken into account. They can be as follows: the profitability of a transaction under the freight forwarding contract, the risk of cargo damage or cargo safety, reliability of compliance with delivery times, the financial stability of the carrier and other parties involved in the transportation, reliability ofthe carrier's compliance with contract terms, a package of carrier's services, the availability of additional services for the cargo assembly and delivery, etc. (Vyushkova, et. al. 2016). Note that there will probably be no delivery scheme, which is considered the best by all criteria. The choice will not be simple and clear,as in the one-criterion task, and the solution will be to find the optimal correlation of criteria (Batishchev 1994). The more of them will be taken into account when choosing delivery schemes, the more adequate the choice will be.

An integral indicator can be used to select an effective scheme of delivery (Klyushnikova & Shitova 2016). It can be calculated, for example, by a ranking method. The use of the experts' evaluations makes the calculation subjective, which increases the probability of making a wrong decision. This can be avoided by taking equal weight coefficients, but this will lead to the loss of accuracy of the solution made.

To identify the most adequate method to determine an effective delivery scheme, the alternatives will be assessed byvarious methods of the solution of multi-criteria tasks.

2. METHODS OF THE SOLUTION OF MULTI-CRITERIA TASKS TO CHOOSEAN EFFECTIVE CARGO DELIVERY SCHEME

Such well-known methods as Laplace, Wald, Savage, Hurwitz, Fishburne's and other methods can be used for the multi-criteria assessment of alternative schemes of cargo delivery (Auerbach & Gelrud 2001; Amelin 2005; Gegechkori 2004; Larichev 2000; Nogin 2002; Orlov 2006; Tarasov 2012; Tynkevich 2000). They are based on ordering the indicators in order of importance by the expert assessment and this is the disadvantageof such approaches. However, today there are methods that allow to avoid such shortcoming– this is thezoning method, in particular,thezoning method based on the principle of conservation of the hierarchical correlation of possible states of the environment (Podinovskii & Nogin 1982; Terentiev 2016; Terentiev & Prudovskiy 2015). It is based on the division of a set of possible states of nature in subsets according tothe principle of conservation of a given hierarchical correlation of possible states of nature. It is recommended to apply this method in multimodal transport to determine an effective cargo delivery scheme. This method has not previously been used for this practical problem. It can significantly reduce an impact ofthe expert's opinion on the decision made.

Let us consider the way the choice of an effective cargo delivery scheme is made by the presented methods and determine, which one allows to choose a delivery scheme with the greatest efficiency. The choice will be made on the example of 4 alternative (conditional) delivery schemes based on 3 criteria (see Table 8.1). The cargo to be carried is expensive and not perishable. A forwarder arranged the criteria in Table 8.1 in a descending order of importance. The target functions of criteria and a method for determining their values will be specified.

Table 8.1
Criteria for choosing a cargo delivery scheme

Options of cargo delivery schemes	*Criteria*		
	k_1	k_2	k_3
	Damage probability, % (of the cost)	Forwarder's profit, conventional monetary unit	Delivery time, hour
	Reference value of the criterion		
	Min	Max	Min
	The method of determining the value of the criterion		
	Stochastic	Deterministic	Deterministic
Scheme 1	15	60	27
Scheme 2	10	20	20
Scheme 3	12	40	28
Scheme 4	7	30	25

This task falls into a category of multi-criteria tasks, as a delivery scheme with an optimal correlationof the presented criteria needs to be chosen (Vyushkova, et. al. 2016). Table 8.1 shows that none of the options is the best in all criteria. To use the methods of solution of a multi-criteria task, it is necessary to bring the basic data matrix A_{ij} to the normalized values.

$$A_{ij} = \begin{pmatrix} 15 & 60 & 27 \\ 10 & 20 & 20 \\ 12 & 40 & 28 \\ 7 & 30 & 25 \end{pmatrix},$$

where i − delivery scheme number ($i = 1\ldots n$, $n = 4$), j – criterion number ($j = 1\ldots m$, $m = 3$),

Since in this case the target functions of the criteria are opposite by absolute indictors, an intermediate action should be made – it is necessary to bring them to the relative values (B_{ij} matrix). B_{ij} is calculated by Formula (1), if the j - parameter is minimized, and by Formula (2), ifit is maximized:

$$B_{ij} = \frac{\min_j (a_{ij})}{a_{ij}} \quad (1)$$

$$B_{ij} = \frac{a_{ij}}{\max_j (a_{ij})} \quad (2)$$

$$B_{ij} = \begin{pmatrix} 0.47 & 1.00 & 0.74 \\ 0.70 & 0.33 & 1.00 \\ 0.58 & 0.67 & 0.71 \\ 1.00 & 0.50 & 0.80 \end{pmatrix}$$

After determining the relative values, they should be normalized. The normalized values are represented in the matrix Z_{ij}.

$$Z_{ij} = \begin{Vmatrix} 0.17 & 0.40 & 0.23 \\ 0.25 & 0.13 & 0.31 \\ 0.21 & 0.27 & 0.22 \\ 0.36 & 0.20 & 0.25 \end{Vmatrix}$$

The Laplace's criterion involves the equiprobable distribution of the importance of all delivery criteria:

$$P = P\{k_1\} = P\{k_2\} = P\{k_3\} = \frac{1}{m} \quad (3)$$

where k_j – the j-th criterion.

The value of the efficiency of a delivery scheme S_i:

$$S_i = P \cdot \sum_{j=1}^{m} z_{ij} \quad (4)$$

$$S_1 = 0.33(0.17 + 0.40 + 0.23) = 0.264$$

$$S_2 = 0.33(0.25 + 0.13 + 0.31) = 0.228$$

$$S_3 = 0.33(0.21 + 0.27 + 0.22) = 0.231$$

$$S_4 = 0.33(0.36 + 0.20 + 0.25) = \underline{0.267}$$

The best option is the one with the highest value of the criterion. In this case, this is the fourth delivery scheme.

Wald's maximin criterion. As we strive to achieve a maximum value of the effectiveness of the choice of a delivery scheme, conditions of this task will include a "maximin" criterion, which is calculated by the following formula:

$$\max_{xi}\{\min_{kj} Z(x_i k_j)\} \quad (5)$$

Calculation results are presented in Table 8.2.

Table 8.2
Wald's maximin criterion

Delivery schemes, x_i	k_1	k_2	k_3	*Minimum number of lines*
x_1	0.17	0.40	0.23	0.17
x_2	0.25	0.13	0.31	0.13
x_3	0.21	0.27	0.22	0.21(maximin)
x_4	0.36	0.20	0.25	0.20

The third delivery scheme should be chosen on the basis of the maximin criterion.

Savage's criterion. In this case,the evaluation of alternatives is carried out not upon the original matrix, but upon the matrix of "regrets" ("risks"). The value of "regret" can be interpreted as a foregone gain (or loss of profits) compared to the maximum possible one under a given state of nature. An optimal Savage's criterion is calculated as follows:

$$\min_j \max_i (\max_i z_{ij} - z_{ij}) \quad (6)$$

The matrix of "regrets" is shown in Table 8.3.

Table 8.3
Savage's matrix of "regrets" ("risks")

Delivery scheme, x_i	k_1	k_2	k_3	*Maximum "regret", U_j*
x_1	0.23	0	0.17	0.23
x_2	0.06	0.18	0	0.18
x_3	0.06	0	0.05	<u>0.06</u>
x_4	0	0.16	0.11	0.16

Thus, the third delivery scheme is considered optimal on the basis of the Savage's criterion.

Hurwitz's criterion. To determine the optimal delivery scheme by using the Hurwitz's criterion, it is necessary to find the minimum and maximum values of lines of the efficiency matrix. The Hurwitz's criterion value $H_i(\lambda)$ for all options is calculated using the following formula:

$$H_i(\lambda) = \lambda \cdot x_{i\,\max} + (1 - \lambda) \cdot x_{i\,\min} \quad (7)$$

For the calculation,the most common situation will be considered – when a person making the decision has neither pessimistic nor optimistic views. Thereforea coefficient λ is equal to 0.5. The Hurwitz's criterion value is presented in Table 8.4.

Table 8.4
Maximum and minimum values of lines. Hurwitz's criterion

Delivery schemes, x_i	*Minimum number of lines, $x_{i\,min}$*	*Maximum number of lines, $x_{i\,max}$*	*The Hurwitz's criterion value, $H_i(0.5)$*
x_1	0.17	0.40	<u>0.29</u>
x_2	0.13	0.31	0.22
x_3	0.21	0.27	0.24
x_4	0.20	0.36	0.28

A delivery scheme with the maximum value $H_i(\lambda)$, the first delivery scheme, is chosen as an optimal one.

Fishburne'sspecific weight. The criterion weight is calculated as follows:

$$W_i = \frac{2(m+1-l)}{m(m+1)}, \quad (8)$$

where – rank; m – total number of criteria, $m = 3$.

The best alternative assessment criterion is calculated using the formula:

$$\max \sum_{j=1}^{m} z_{ij} \cdot W_{lj} \quad (9)$$

Calculation results are presented in Table 8.5.

Table 8.5
Specific weight of criteria and an effective solution upon the Fishburne's method

Delivery scheme x_i	*Rank 1* $W_1 = 0.500$	*Rank 2* $W_2 = 0.333$	*Rank 3* $W_3 = 0.167$	*The value of efficiency of the decision made*
x_1	0.085	0.133	0.038	0.256
x_2	0.125	0.043	0.052	0.220
x_3	0.105	0.090	0.037	0.232
x_4	0.180	0.067	0.042	<u>0.289</u>

According to the Fishburne's method, the fourth scheme is considered optimal.

A zoning method on the principle of preserving the hierarchical correlation of possible states of the environment to determine an effective delivery scheme

By using a zoning method on the principle of preserving the hierarchical correlation of possible states of the environment (Terentiev 2016; Terentiev & Prudovskiy 2015), we can evaluate the efficiency of delivery schemes D_i as follows:

$$D_i = \sum_{j=1}^{m} c_{ij} \cdot z_{ij} \tag{10}$$

where c_{ij} – a coefficient of importance of the indicator.

$$\begin{aligned} D_1 &= 0.5 \cdot 0.17 + 0.5 \cdot 0.4 + 0 \cdot 0.23 \\ &= 0.285 \text{ (when } \max Z_{ij} = Z_{i2}) \\ D_2 &= 0.33 \cdot 0.25 + 0.33 \cdot 0.13 + 0.33 \cdot 0.31 \\ &= 0.228 \text{ (when } \max Z_{ij} = Z_{i3}) \\ D_3 &= 0.5 \cdot 0.21 + 0.5 \cdot 0.27 + 0 \cdot 0.22 \\ &= 0.240 \text{ (when } \max Z_{ij} = Z_{i2}) \\ D_4 &= 1 \cdot 0.36 + 0 \cdot 0.2 + 0 \cdot 0.25 \\ &= \underline{0.360} \text{ (when } \max Z_{ij} = Z_{i1}) \end{aligned}$$

According to this approach, the first option of the delivery scheme should be considered as the most effective one. In our case, three criteria have been used, but the more criteria will be taken into account, in a more accurate way the area of effective solutions will be determined.

3. RESULTS

The results of determining an effective cargo delivery scheme by using the methods of Laplace, Hurwitz, Fishburne and the zoning method basedon the principle of preserving the hierarchical correlation of possible states of the environment can be represented in Figure 8.1 and Table 8.6.

The efficiency values obtained by using the considered methods of the solution of multi-criteria tasks are different. As can be seen from Table 8.6, the maximum value of efficiency of the decision made was determined by the zoning method according tothe principle of preserving the hierarchical correlation of possible states of the environment (0.36). When comparing the values of efficiency of decisions of different methods,it can be concluded that the modified zoning method allows to find the most efficient solution of a multi-criteria task on choosing a cargo delivery scheme.

Table 8.6.
Evaluation of efficiency of the selected delivery scheme by different methods of the solution of multi-criteria tasks

Options of cargo delivery schemes	*Laplace's method*	*Wald's method*	*Savage's method*	*Hurwitz's method*	*Fishburne's method*	*A zoning method on the principle of preserving the hierarchical correlation of possible states of the environment*
Scheme 1				0.285		
Scheme 2						
Scheme 3		0.210	0.06			
Scheme 4	0.267				0.289	0.360

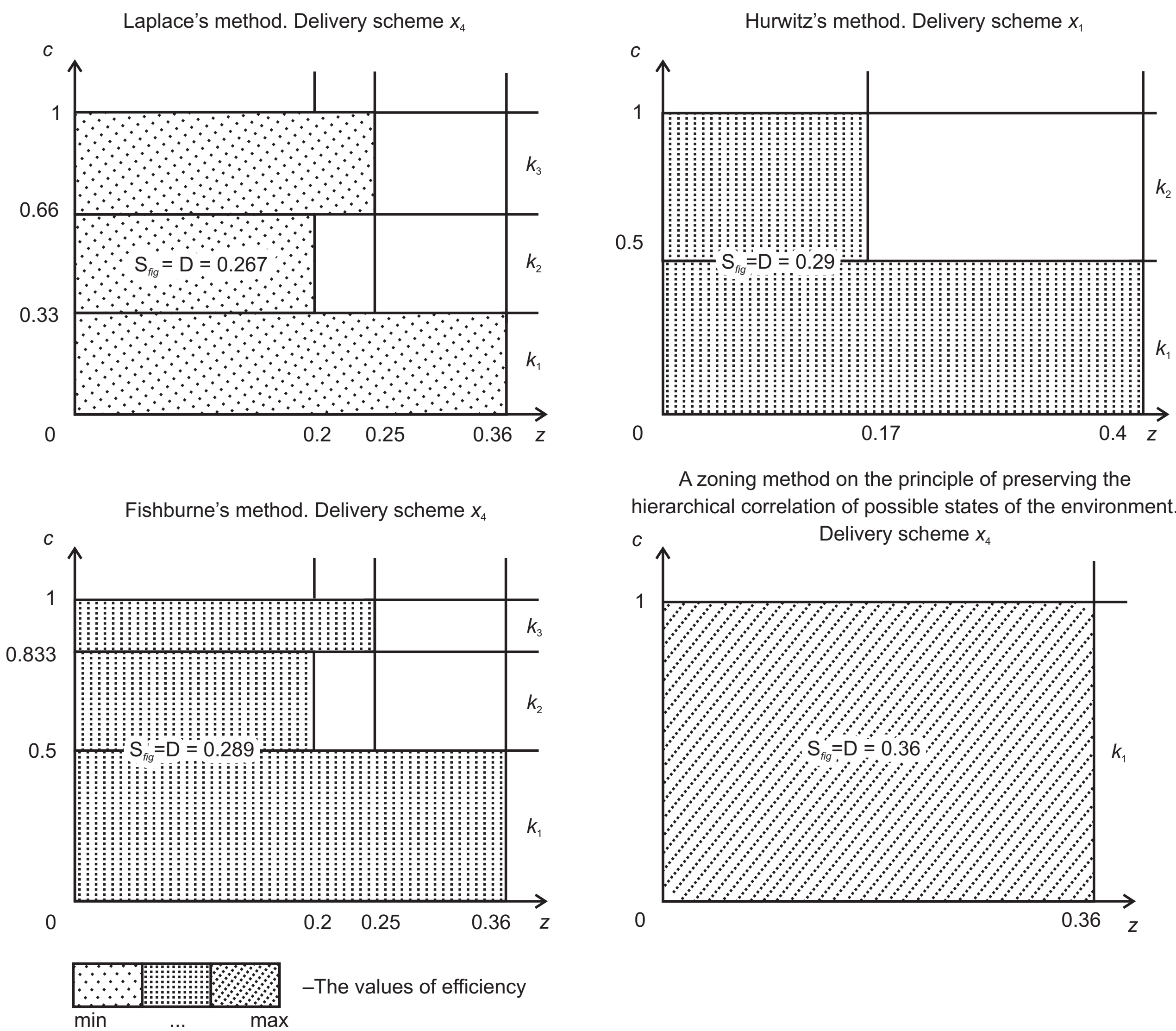

Figure 8.1: The values of efficiency of selected cargo delivery schemes by using the methods of the solution of multi-criteria tasks

4. CONCLUSION

The zoning method based on the principle of preserving the hierarchical correlation of possible states of the environment is recommended to be used in multimodal transport for determining an effective scheme of cargo delivery. This method had not previously been used for this practical problem, but it can significantly reduce an impact of the expert's opinion on the decision made and allowsfor the most efficient solution of a multi-criteria task of choosing a cargo delivery scheme.

During further research, it is planned:

1. To study in detail and structure the criteria for choosing delivery schemes in multimodal transport;
2. To make calculations on the choice of an efficient delivery scheme by using two basic data matrices similar to A_{ij}, one of which consists of the criteria in absolute terms and another one comprises the criteria expressed through the value of effect. In addition, a profit in purely economic terms will be clearly presented.

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