OPTIMIZATION OF REFRACTORY MATERIAL DISTRIBUTION IN A METALLURGICAL COMPANY

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Abstract

Basic types of decision-making tasks include problems with alternative options for decision making. The task of managers is to choose a way that will lead to an optimal solution based on assessing certain criteria. An example of these tasks is the given problem that falls into the category of optimizing transportation routes, i.e. transportation tasks, in general.

This article aims to determine the optimal distribution of refractory material in a metallurgical company with minimal transport costs.

Keywords: Optimization, transportation task, management decisions

1. INTRODUCTION

In the industrial managerial practice, we often meet with decision problems whose optimal or close-to-optimum solution can be found by applying some unconventional methods. These are not only problems of strategic nature but also problems of operational, tactical management.[1] One of such problems in the sphere of metallurgical production is the problem of optimal distribution of refractory material according to the requirements of single plants, using in-house transport with minimal transportation costs. [2]

2. PROBLEM DEFINITION

In the metallurgical company, there are 4 stores of refractory materials and 5 plants which take these materials. The task is to propose a method of their distribution so that the total transport performance in tonne-kilometres (tkm) is minimal while the transport is as economical as possible.

The specific situation is shown in **Table 1**; the numbers indicate different distances between storage areas and withdrawing plants in kilometres. Storage capacity cannot be exceeded and customer requirements must be met.

Table 1 Representation of input values of the decision problem

Plant (j) / Store (i)	1	2	3	4	5	Storage capacity (Q_i)
A	1.5	**1**	2	2.5	**0.5**	500
B	2	1.5	**1**	3	1.5	450
C	2.5	3	4	**0.5**	3.5	350
D	**1**	2	1.5	2.5	3	400
Plant requirements (P_j)	600	400	150	250	300	1700

Such defined problem of managerial decision-making represents a typical task of linear programming within the category of the so-called transportation tasks.[3] This problem of managerial decision-making belongs among the so-called balanced transportation tasks when the plant requirements P_i are equal to the storage capacity Q_i.[4]

Storage capacity - Q_i
Plant requirements - P_j
The distance between the *i-th* store and the *j-th* plant - c_{ij}
The amount of refractory material transported from the *i-th* store to the *j-th* plant

Requirement for the minimum total transport performance in tonne-kilometres is expressed by the following objective function:

$$Z = \sum_{i=1}^{4} \sum_{j=1}^{5} c_{ij}.x_{ij} = min. \quad (1)$$

under the below-written binding conditions of not exceeding the storage capacity and meeting the plant requirements:

$$\sum_{j=1}^{5} x_{ij} = Q_i \quad (2)$$

$$\sum_{i=1}^{4} x_{ij} = P_j \quad (3)$$

3. THEORETICAL SOLUTION PROCEDURE

To solve this problem, we use the delta method which has the following solution stages:

- Finding the minimum distances in columns - *min* c_{ij}.
- Compiling the differential matrix Δc_{ij} by subtracting
  c_{ij} - *min* c_{ij} by columns
- To the fields with zero values in the *Δ* matrix, we assign the entire amount of material required by the respective plant and find an excess or unused capacity by rows di

$$d_i = Q_i - \sum_j x_{ij} \quad (4)$$

- By successive shifts from rows with $d_i < 0$ to rows with $d_i > 0$, we then find the optimal solution. During shifts, we care for complying with the test function (minimum deterioration of the function against the first division). Shifts happen in columns whereas we verify all possible shifts also by chains over the rows $d_i = 0$.

4. SOLUTION

Minimum values are indicated in bold in **Table 1**.

Then we compile the differential matrix Δ presented in **Table 2**.

Table 2 Differential matrix - Δ matrix

0.5	0	1	2	0
1	0.5	0	2.5	1
1.5	2	3	0	3
0	1	0.5	2	2.5

To the fields with zero values in the *Δ* matrix, we assign the entire amount of material required by the respective plant and calculate d_i.

Table 3 Δ matrix modified by d_i

	1	2	3	4	5	d_i
A		400			300	-200 = 500 - (400 + 300)
B			150			+300 = 450 - 150
C				250		+100 = 350 - 250
D	600					-200 = 400 - 600

Movements must be from stores A, D to stores B, C which would not be fully used by the first assignment. The best shift will be from field A_2 to field B_2 because this will mean the smallest deterioration in the objective function (in the differential matrix, in rows B, C and columns eligible for shifts - 1., 2., 5., this implies the smallest value of $\Delta c_{ij} = \Delta c_{B2} = 0.5$).

Table 4 Situation after the first shift

	200 ↓			300	0
	200	150			+100
			250		+100
600					-200

Capacity of store A is now balanced

Within further shifts, 200 units must be transferred from store D to stores B, C to achieve balanced capacities in all the stores (di = 0).

Direct shift D1 → B1 and the following indirect shifts come into question:

D1 → A1	A2 → B2	0.5 + 0.5 = 1
D1 → A1	A5 → B5	0.5 +1 = 1.5

A direct shift of each unit amount deteriorates the objective function by 1 and is therefore equivalent to the first indirect shift (the same deterioration by 1). This will provide two optimal solutions:

Table 5 Situation after the direct shift

	200			300	0
100	200	150			0
			250		+100
500					-100

Table 6 Situation after the indirect shift

100	100			300	0
	300	150			0
			250		+100
500					-100

It remains to move the last 100 units from store D to store C:

The direct shift:
D1 → C1 - deterioration by 1.5

Indirect shifts:

D1 → A1	A2 → C2	0.5 + 2 = 2.5
D1 → A1	A5 → C5	0.5 + 3 = 3.5

D1 → B1 B2 → C2 1 + 1.5 = 2.5
D1 → B1 B3 → C3 1 + 3 = 4

The best shift is the direct shift D1 → C1.

5. OPTIMAL SOLUTION

Then we get the following optimal solution:

Table 7 Optimal solution 1

	200			300
100	200	150		
100			250	
400				

Table 8 Optimal solution 2

100	100			300
	300	150		
100			250	
400				

In both cases, the total transport volume is 1 775 tkm.

6. CONCLUSION

It can be stated that the application of the delta method can be successfully used to solve less extensive transportation tasks when we very quickly get a suboptimal (optimal) solution to the given task.[5] When knowing the transportation cost per kilometre, we also obtain the total transport costs for both solutions, which will be the same. If we only solve the problem not dealing with it any longer, it is not necessary to invest money into specialized software; in such a case, we make do with this method of solution.[6]

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