Application of the Vogel Approximation Method to Reduce Transport-logistics Processes

INTRODUCTION

Logistics has undergone a major change in recent decades. Unlike in previous years, today it deals with the flow of material, information and financial resources in all areas of a company. This implies that logistics does not only deal with material flow in individual businesses, but also assesses individual influences from time, place and space point of view to satisfy customers and achieve optimal costs associated with these activities. It is a comprehensive science which improves corporate processes and enables the company to respond more quickly to market and customer demands. Nowadays, the emphasis is placed on the quality and high level of services provided; thus, the use of logistics is a necessity.

In any increasing competitive environment and even in companies, we must adopt an optimized transport logistic management system with the objective to increase the overall gain by minimizing the transportation costs. Along with economic improvement comes the shortening of travel routes, which is also associated with a reduction in the time required to carry out activities. Currently, there are many ways to optimize processes in a company. The most commonly used are those using operational research methods or graphical representations.

METHOD

The Vogel approximation method deals with finding an optimal solution taking into account the limited capacity. Each cell typically contains a certain rate. A difference is made between the two lowest rates in the row, and it is then written at the edge of the row; the same is done in the columns. Then the highest value from the rate differences is found. According to the value, the row or column in which the lowest rate is found is determined. This procedure is repeated until the transport task reaches the optimum result.

In this paper, the modified version of the Vogel approximation method is fundamental. The purpose of the modified version is to find the shortest distance, which enables completing the transport task without taking into account the restrictive capacities and rates.

The first step in this research is to adjust the distance matrix that was assembled during the previous method. The change takes place on the main diagonal, where zero values are located. These zero values will be changed to X. The input matrix only uses the distances of individual points. Thus, in doing the transport task, the difference between the two smallest distances in the row is first sought. The same procedure is repeated for other rows and columns. The highest value is selected from the differences, and it determines the selected column or row, from which the smallest value determining the distance is selected. This value is highlighted in yellow in the table. Now, there is another change compared to the standard Vogel approximation method. Instead of occupying only one cell, it is necessary to cross out the entire row and column in which the calculation procedure is located. This step is crucial in effectively calculating a route that will serve all scheduled stop points. The unloading place, where the transport task is located, is marked in yellow in the table.

Also, it is necessary to eliminate the possibility of more routes. It is required to remove such a point, which would early complete the transport task. If two identical values are found, it is purely a matter of choice which option will be chosen for the next calculation step. Subsequently, the procedure is repeated-from the recalculation of differences to crossing out unnecessary cells.

INPUT

The Vogel approximation method is applied in a small company, where the optimization of the logistic transport processes has not yet been dealt with. Essential data is collected, which is necessary for the compilation of a detailed list of current stopping points which the company serves by its internal transport. The task is to optimize the original routes. The original path is 64.9 kilometers.

The seven stopping points are-V1, V2, V3, V4, V5, V6, V7.

APPLICATION OF MODIFIED VAM

The task begins with calculating the smallest matrix of distances. This matrix has the dimensions of 7x7 cells.

Firstly, find the differences in the smallest distance values in each row and in each column. The values of individual differences are then written outside the table. In the first row V1 we calculate the difference of values for cells [V1; V3] = 11.5 km and [V1; V2] = 10.7 km. The difference of these values is 0.8 kilometres, written in the right-hand outer part of the table .

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	
V_1	X	~~10.7~~	11.5	22.1	24.4	29.2	25.9	0.8
V_2	10.7	X	~~1.0~~	12.0	14.3	19.0	15.7	9.7
V_3	~~11.5~~	1.0	X	~~11.0~~	~~13.3~~	~~18.0~~	~~14.8~~	10.0
V_4	22.2	~~11.7~~	10.7	X	4.0	7.9	4.7	0.7
V_5	24.9	~~14.4~~	13.4	3.9	X	7.3	4.7	0.8
V_6	24.7	~~14.2~~	13.3	3.8	1.9	X	4.6	1.9
V_7	26.3	~~15.8~~	14.8	4.8	4.8	4.2	X	0.6
	0.8	9.7	9.7	0.1	2.1	3.1	0.1	

Secondly, select the highest value of all the differences. In the table, this value is highlighted in yellow. The highest distance difference is 10.0 kilometres, located in row V3. As a result, it is determined that the selection of the smallest distance in row V3 follows. This value is based in cell [V3; V2] = 1.0 km and is highlighted in yellow inside the table.

This is followed by crossing out values that would untimely complete the transport task or would pose a multi-ring problem. It begins by crossing out all the values in the row and the column in which the calculation is located. A provisional route is V3 → V2 for the time being. It is necessary to avoid cycling of this route. Therefore, the value located in cell [V2; V3] is crossed out as well [5, 6, 19].

	V_1	V_2	V_3	V_4	V_5	V_6	V_7		
V_1	X	~~10.7~~	~~11.5~~	22.1	24.4	29.2	25.9	0.8	10.6
V_2	10.7	X	~~1.0~~	~~12.0~~	~~14.3~~	~~19.0~~	~~15.7~~	9.7	1.3
V_3	~~11.5~~	1.0	X	~~11.0~~	~~13.3~~	~~18.0~~	~~14.8~~	10.0	X
V_4	~~22.2~~	~~11.7~~	10.7	X	4.0	7.9	4.7	0.7	0.7
V_5	~~24.9~~	~~14.4~~	13.4	3.9	X	7.3	4.7	0.8	0.8
V_6	~~24.7~~	~~14.2~~	13.3	3.8	1.9	X	4.6	1.9	1.9
V_7	~~26.3~~	~~15.8~~	14.8	4.8	4.8	4.2	X	0.6	0.6
	0.8	9.7	9.7	0.1	2.1	3.1	0.1		
	11.5	X	0.8	0.1	2.1	3.1	0.1		

The procedure is repeated in the second step. First, differences of the smallest values for the rows and columns are calculated. There is nothing to subtract for row V3 row and columnV2 anymore, so the position outside the table is replaced by X. After calculating the differences, the highest value is selected, i.e. 11.5 below column V1. This determines the column from which the lowest possible value is selected. This value is 10.7 kilometres located in the cell with coordinates [V2; V1].

Then the entire column and row of the above-mentioned cell are crossed out. Due to the possibility of early completion of the transport task, it is necessary to check such cell values that would untimely return the calculation to the previous places of unloading without servicing all the specified delivery unloading places. The provisional route is as follows: **V3 → V2 → V1.** It is necessary to avoid early closure of the route from V1 to V3. Therefore, it is necessary to have the value in cell [V1; V3] also crossed out [5, 6, 20].

	V_1	**V_2**	**V_3**	**V_4**	**V_5**	**V_6**	**V_7**			
V_1	X	~~10.7~~	~~11.5~~	~~22.1~~	24.4	29.2	25.9	0.8	10.6	2.3
V_2	10.7	X	~~1.0~~	~~12.0~~	~~14.3~~	~~19.0~~	~~15.7~~	9.7	1.3	X
V_3	~~11.5~~	1.0	X	~~11.0~~	~~13.3~~	~~18.0~~	~~14.8~~	10.0	X	X
V_4	~~22.2~~	~~11.7~~	10.7	X	~~4.0~~	~~7.9~~	~~4.7~~	0.7	0.7	0.7
V_5	~~24.9~~	~~14.4~~	~~13.4~~	3.9	X	7.3	4.7	0.8	0.8	0.8
V_6	~~24.7~~	~~14.2~~	~~13.3~~	3.8	1.9	X	4.6	1.9	1.9	1.9
V_7	~~26.3~~	~~15.8~~	~~14.8~~	4.8	4.8	4.2	X	0.6	0.6	0.6
	0.8	9.7	9.7	0.1	2.1	3.1	0.1			
	11.5	X	0.8	0.1	2.1	3.1	0.1			
	X	X	2.6	0.1	2.1	3.1	0.1			

After the second modification, it is necessary to evaluate the differences in the rows and columns. The completely crossed out rows V2 and V3 are omitted. In addition, the differences of the smallest values in columns V1 and V2 are not counted. The highest value of all calculated differences is 2.6, which is located in column V3. On account of this, the lowest distance in column V3 is sought. The result is 10.7 km. This cell is yellow in the table again.

The provisional route calculated by the modified version of the Vogel approximation method is as follows: **V4 → V3 → V2 → V1**. Now again, it is also necessary to remove cells that would early terminate the transport task. Therefore, the cell with coordinates [V1; V4] with the value of 22.1 kilometres is crossed out.

	V_1	V_2	V_3	V_4	V_5	V_6	V_7				
V_1	X	~~10.7~~	~~11.5~~	~~22.1~~	24.4	~~29.2~~	25.9	0.8	10.6	2.3	2.3
V_2	10.7	X	~~1.0~~	~~12.0~~	~~14.3~~	~~19.0~~	~~15.7~~	9.7	1.3	X	X
V_3	~~11.5~~	1.0	X	~~11.0~~	~~13.3~~	~~18.0~~	~~14.8~~	10.0	X	X	X
V_4	~~22.2~~	~~11.7~~	10.7	X	~~4.0~~	~~7.9~~	~~4.7~~	0.7	0.7	0.7	X
V_5	~~24.9~~	~~14.4~~	~~13.4~~	3.9	X	~~7.3~~	4.7	0.8	0.8	0.8	0.8
V_6	~~24.7~~	~~14.2~~	~~13.3~~	3.8	1.9	X	~~4.6~~	1.9	1.9	1.9	1.9
V_7	~~26.3~~	~~15.8~~	~~14.8~~	~~4.8~~	~~4.8~~	4.2	X	0.6	0.6	0.6	0.6
	0.8	9.7	9.7	0.1	2.1	3.1	0.1				
	11.5	X	0.8	0.1	2.1	3.1	0.1				
	X	X	2.6	0.1	2.1	3.1	0.1				
	X	X	X	0.1	2.9	3.1	0.1				

The step which follows after further modification of the table is the calculation of the individual differences for the rows and columns of the table. The completely crossed out columns V1, V2, V3, as well as the rows V2, V3 and V4 are omitted. Then, the highest value is taken from all the differences in the outer part of the table. This value is 3.1 km and is located below column V6. The resulting value is 4.2 km, which is the lowest value of the determined column V6. This value is highlighted in yellow in the cell with coordinates [V7; V6].

After finding the minimum value, it is necessary to cross out all the values in both the column and the row. Furthermore, the cell with the value of 4.6 km and with coordinates [V6; V7] is crossed out. This point has to be eliminated as the early closure of the distribution stations circuit could occur. The provisional route calculated using the Vogel approximation method is**: V4 → V3 → V2 → V1** and **V7 → V6**.

	V_1	V_2	V_3	V_4	V_5	V_6	V_7					
V_1	X	~~10.7~~	~~11.5~~	~~22.1~~	~~24.4~~	~~29.2~~	25.9	0.8	10.6	2.3	2.3	2.3
V_2	10.7	X	~~1.0~~	~~12.0~~	~~14.3~~	~~19.0~~	~~15.7~~	9.7	1.3	X	X	X
V_3	~~11.5~~	1.0	X	~~11.0~~	~~13.3~~	~~18.0~~	~~14.8~~	10.0	X	X	X	X
V_4	~~22.2~~	~~11.7~~	10.7	X	~~4.0~~	~~7.9~~	~~4.7~~	0.7	0.7	0.7	X	X
V_5	~~24.9~~	~~14.4~~	~~13.4~~	3.9	X	~~7.3~~	~~4.7~~	0.8	0.8	0.8	0.8	0.8
V_6	~~24.7~~	~~14.2~~	~~13.3~~	~~3.8~~	1.9	X	~~4.6~~	1.9	1.9	1.9	1.9	1.9
V_7	~~26.3~~	~~15.8~~	~~14.8~~	~~4.8~~	~~4.8~~	4.2	X	0.6	0.6	0.6	0.6	X
	0.8	9.7	9.7	0.1	2.1	3.1	0.1					
	11.5	X	0.8	0.1	2.1	3.1	0.1					
	X	X	2.6	0.1	2.1	3.1	0.1					
	X	X	X	0.1	2.9	3.1	0.1					
	X	X	X	0.1	22.5	X	21.2					

The calculation is almost at the end of the transport task calculated by means of the modified Vogel approximation method. The differences for rows V2, V3, V4 and V5 are no longer counted since the rows are completely crossed out. This is also true for columns V1, V2, V3 and V6.

The highest value is sought of all the calculated differences from the outside of the table. Such a cell is in yellow and refers to column V5, from which the lowest value that is not crossed out is then selected. This is a cell with coordinates [V6; V5] with the value of 1.9 km. The provisional sections of the route are as follows: **V4 → V3 → V2 → V1** and **V7 → V6 → V5**. In order to avoid the early termination of the transport task, we also cross out cell [V5; V7].

	V_1	V_2	V_3	V_4	V_5	V_6	V_7					
V_1	X	~~10.7~~	~~11.5~~	~~22.1~~	~~24.4~~	~~29.2~~	25.9	0.8	10.6	2.3	2.3	2.3
V_2	10.7	X	~~1.0~~	~~12.0~~	~~14.3~~	~~19.0~~	~~15.7~~	9.7	1.3	X	X	X
V_3	~~11.5~~	1.0	X	~~11.0~~	~~13.3~~	~~18.0~~	~~14.8~~	10.0	X	X	X	X
V_4	~~22.2~~	~~11.7~~	10.7	X	~~4.0~~	~~7.9~~	~~4.7~~	0.7	0.7	0.7	X	X
V_5	~~24.9~~	~~14.4~~	~~13.4~~	3.9	X	~~7.3~~	~~4.7~~	0.8	0.8	0.8	0.8	0.8
V_6	~~24.7~~	~~14.2~~	~~13.3~~	~~3.8~~	1.9	X	~~4.6~~	1.9	1.9	1.9	1.9	1.9
V_7	~~26.3~~	~~15.8~~	~~14.8~~	~~4.8~~	~~4.8~~	4.2	X	0.6	0.6	0.6	0.6	X
	0.8	9.7	9.7	0.1	2.1	3.1	0.1					
	11.5	X	0.8	0.1	2.1	3.1	0.1					
	X	X	2.6	0.1	2.1	3.1	0.1					
	X	X	X	0.1	2.9	3.1	0.1					
	X	X	X	0.1	22.5	X	21.2					

In the previous step, the last unnecessary cells were eliminated. The last two values that were not marked or crossed out remain. In this step, these last cells are highlighted in yellow. These distance values logically complete the whole circular issue of this transport task.

RESULTS

The final route of the optimized route using the modified version of the Vogel approximation method is:

V1 → V7 → V6 → V5 → V4 → V3 → V2 → V1

The resulting length of the route is 25.9 + 4.2 + 1.9 + 3.9 + 10.7 + 1.0 + 10.37 **= 58.3 km**.

The original length of route was 64.9 km. The newly created route optimized by the Vogel approximation method is 58.3km. This will shorten the route by 6.6 km. The original and optimized route composition is shown in the below Table.

Current:	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_1	**64.9 km**
Optimized:	V_1	V_7	V_6	V_5	V_4	V_3	V_2	V_1	**58.3 km**

As the number of travelled kilometres is reduced, transport-logistic costs will also be reduced.

ROUTE	**COST PER 1 TRAVEL (Rs)**	**ANNUAL COSTS (Rs)**	**DIFFERENEC OF ANNUAL COSTS VS CURRENT ROUTE(Rs1)**
Current	585.36	29,269.8	
Opti. – VAM	525.82	26,291.31	-2,978.49

CONCLUSION

The paper verified that using operational research can improve logistic transport processes. According to the economic evaluation, annual costs may be reduced, and the total number of travelled kilometres has been decreased.