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# Approaching Modes of Transport Problems Facilitated by the use of Winqsb software

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*Abstract* — **Transport, as essential activity in merchandises distribution, knows a large scale of approaches in the sense of this process optimization attempts. Minimizing transport distances, costs and study of the effect which have a certain transport unit cost over the transport optimal program and the total cost are the fundamental problems confronted to logisticians in realizing an optimal distribution of products to final beneficiaries. Taking in consideration all mentioned above, the made research use be use sub modules of Network Modeling from WinQSB software.**

***Keywords- WinQSB, optimization, objective function, optimal solution, fictive source***

## I. INTRODUCTION

In general, modeling the merchandises transport and distribution problems suppose displacement on a certain path of some quantities (flow unit), from certain sources or suppliers in others called destinations or consumers [1].

The transport problem is subdivided in a series of particular cases. Without pretending an exhaustive treatment of the subject, in this paper we will try to present the main problem types associated to merchandises physical distribution.

The start is made from a simple example of a company which delivers a homogeneous product, available in its own enterprises in $a_i$ $(i = \overline{1,m})$ quantities in the regional warehouses $D_i$, in the demanded quantities $b_i$.

Due to the majority of practical contexts, in which the equilibrium condition is not fulfilled, the start was from an example of non-equilibrated problem. It is possible that some hypothesis or constants of the transport problem modify form a period to another, leading to minor or greater ampleness changes in the optimal solution.

For a better understanding of these types of problems is necessary a larger analysis based on an application, the Network Modelling Module contained by WinQSB software.

## II. PROBLEM DATA

A company manufactures the same type of product in four different enterprises and distributes it in four regional warehouses. The production capacity and warehouse storage are given in Table 1. The fabrication costs for this product are identical in all four enterprises, the only relevant costs being the transport ones between enterprise and the warehouses, presented also in Table 1, expressed in monetary units.

TABLE I.

| Destinations / Source | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Available [units/month] |
|---|---|---|---|---|---|
| $S_1$ | 3 | 4 | 6 | 2 | 20.000 |
| $S_2$ | 5 | 6 | 3 | 7 | 15.000 |
| $S_3$ | 2 | 7 | 5 | 6 | 55.000 |
| $S_4$ | 8 | 5 | 2 | 8 | 60.000 |
| Demand [units/month] | 50000 | 10000 | 20000 | 30000 | 150.000<br>110.000 |

It wishes to determine the delivery mode from the enterprises to the warehouses in order to achieve the minimization of the transport total cost, respecting the constraints lied to the enterprises production capacities and the warehouse necessary.

As can be observed, between the total demand and total available (total offer) is a difference of 40000 pieces, which impose to equilibrate the problem by introducing a fictive consumer which overtake the necessary difference. Introducing the transport problem data into WinQSB software can be made in two ways: under matrix form or by graphical representation [2]. Implicitly, the Network Modelling Module presumes the first way.

| From \ To | Destination 1 | Destination 2 | Destination 3 | Destination 4 | Supply |
|---|---|---|---|---|---|
| Source 1 | 3 | 4 | 6 | 2 | 20000 |
| Source 2 | 5 | 6 | 3 | 7 | 15000 |
| Source 3 | 2 | 7 | 5 | 6 | 55000 |
| Source 4 | 8 | 5 | 2 | 8 | 60000 |
| Demand | 50000 | 10000 | 20000 | 30000 | |

Figure 1. Main window of Network Modelling Module

## III. SOLVING DIFFERENT VARIANTS

After data input, problem solve is made by choosing one of the available options of the Solve and Analyze menu, respectively [3]:

- Solve the Problem – open a new window with final results under matrix form;
- Solve and Display Steps-Network – visualization of problem solving steps in graphical form;
- Solve and Display Steps-Tableau – visualization of problem solving steps in matrix form;
- Select Initial Solution Method – offers the possibility to chose a method in order to find the final solution from the above available ones (Fig.2):

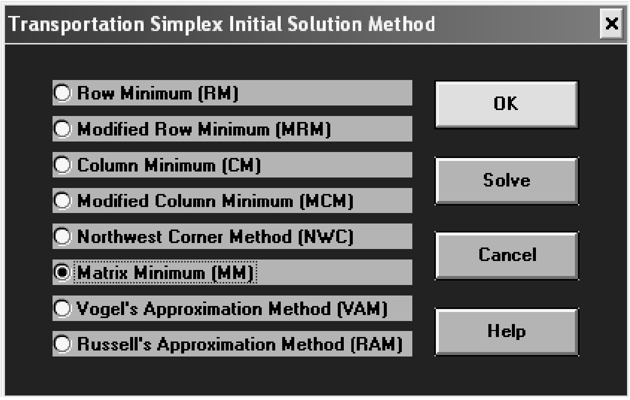


Figure 2. Initial Solution Method selection window

Choosing the method Matrix Minimum [MM], the obtained results were:

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 4 | 20000 | 2 | 40000 | 0 |
| 2 | Source 2 | Destination 4 | 5000 | 7 | 35000 | 0 |
| 3 | Source 2 | Unused_Supply | 10000 | 0 | 0 | 0 |
| 4 | Source 3 | Destination 1 | 50000 | 2 | 100000 | 0 |
| 5 | Source 3 | Destination 4 | 5000 | 6 | 30000 | 0 |
| 6 | Source 4 | Destination 2 | 10000 | 5 | 50000 | 0 |
| 7 | Source 4 | Destination 3 | 20000 | 2 | 40000 | 0 |
| 8 | Source 4 | Unused_Supply | 30000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 295000 | |

Figure 3. Optimal Solution obtained by Matrix Minimum method

The transport total cost is minimum 295000m.u. if:

- Enterprise 1 supplies Warehouse 4 with 20000 pieces
- Enterprise 2 supplies Warehouse 4 with 5000 pieces
- Enterprise 3 supplies Warehouse 1 with 50000 pieces
- Enterprise 3 supplies Warehouse 4 with 5000 pieces
- Enterprise 4 supplies Warehouse 2 with 10000 pieces
- Enterprise 4 supplies Warehouse 3 with 20000 pieces
- The fictive consumer covers the rest of demand, respectively 40000 pieces, thus: 10000 pieces receives from Enterprise 2 and 3000 pieces from Enterprise 4.

The associated graph of the studied problem is presented in Fig. 4.

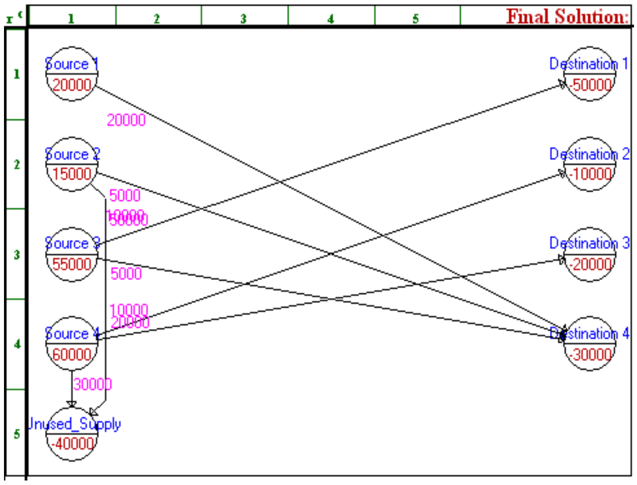


Figure 4. Optimal Solution obtained by Matrix Minimum method

## 1. *Repartition of Diminished Production*

For the next month is previewed a production diminish due to a number of striking actions. Thus, is previewed that the total production will decrease by 30%, being distributed in this way: 5000 pieces from Enterprise 1 and 2, 15000 pieces from Enterprise 3 and the rest of 20000 pieces from Enterprise 4.

a.) The first way to approach this problem is to minimize the transport costs. It can be observed a difference between the total demand and offer (110000>105000), which also impose a re-equilibration of the problem by introducing a fictive source ($S_5$).

TABLE II.

| Destinations / Source | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Available [units/month] |
|---|---|---|---|---|---|
| $S_1$ | 3 | 4 | 6 | 2 | 15.000 |
| $S_2$ | 5 | 6 | 3 | 7 | 10.000 |
| $S_3$ | 2 | 7 | 5 | 6 | 40.000 |
| $S_4$ | 8 | 5 | 2 | 8 | 40.000 |
| $S_5$ | 0 | 0 | 0 | 0 | 5.000 |
| Demand [units/month] | 50000 | 10000 | 20000 | 30000 | 110.000<br>110.000 |

The demands of Warehouse 1, 2 and 3 is fully covered; meantime the Warehouse 4 demand is covered only by 83.33%.

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 4 | 15000 | 2 | 30000 | 0 |
| 2 | Source 2 | Destination 1 | 10000 | 5 | 50000 | 0 |
| 3 | Source 3 | Destination 1 | 40000 | 2 | 80000 | 0 |
| 4 | Source 4 | Destination 2 | 10000 | 5 | 50000 | 0 |
| 5 | Source 4 | Destination 3 | 20000 | 2 | 40000 | 0 |
| 6 | Source 4 | Destination 4 | 10000 | 8 | 80000 | 0 |
| 7 | Unfilled_Demand | Destination 4 | 5000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 330000 | |

Figure 5. Solution obtained by minimizing the transport costs

b.) A second option is to distribute the decreased production proportionally with the normal demands [4]. The diminished production represents 70% of the normal production. So, the repartition will look like this:

| From \ To | Destination 1 | Destination 2 | Destination 3 | Destination 4 | Supply |
|---|---|---|---|---|---|
| Source 1 | 3 | 4 | 6 | 2 | 15000 |
| Source 2 | 5 | 6 | 3 | 7 | 10000 |
| Source 3 | 2 | 7 | 5 | 6 | 40000 |
| Source 4 | 8 | 5 | 2 | 8 | 40000 |
| Demand | 35000 | 7000 | 14000 | 21000 | |

Figure 6. Problem data for proportional repartition

The obtained results in this case are:

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 4 | 15000 | 2 | 30000 | 0 |
| 2 | Source 2 | Destination 4 | 1000 | 7 | 7000 | 0 |
| 3 | Source 2 | Unused_Supply | 9000 | 0 | 0 | 0 |
| 4 | Source 3 | Destination 1 | 35000 | 2 | 70000 | 0 |
| 5 | Source 3 | Destination 4 | 5000 | 6 | 30000 | 0 |
| 6 | Source 4 | Destination 2 | 7000 | 5 | 35000 | 0 |
| 7 | Source 4 | Destination 3 | 14000 | 2 | 28000 | 0 |
| 8 | Source 4 | Unused_Supply | 19000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 200000 | |

Figure 7. Solution for diminished production proportional repartition

In this case it can be observed a diminution of the transport total cost in comparison with the anterior case from 295000m.u. to 200000m.u. The associated graph is:

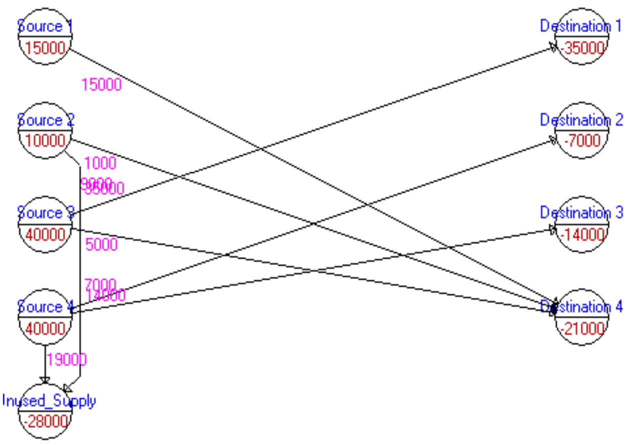


Figure 8. Associated Graph for proportional repartition of the Diminished Production

## *2. Blocking a Transport Path*

It has been taken into consideration another variant of the initial transport problem.

Up to now was admitted that every path between source and destination can be used at a certain transport price. Starting from the hypothesis that not all the transport paths are available, i.e. path (S3, D1) is temporarily blocked due to some modernization works. So, Enterprise 3 can not deliver directly the goods the Warehouse 1, leading to appear modifications of the actual optimal transport schedule. In order to block this path, we will introduce a very high transport cost [4].

| From \ To | Destination 1 | Destination 2 | Destination 3 | Destination 4 | Supply |
|---|---|---|---|---|---|
| Source 1 | 3 | 4 | 6 | 2 | 15000 |
| Source 2 | 5 | 6 | 3 | 7 | 10000 |
| Source 3 | M | 7 | 5 | 6 | 40000 |
| Source 4 | 8 | 5 | 2 | 8 | 40000 |
| Demand | 35000 | 7000 | 14000 | 21000 | |

Figure 9. Introducing a new transport cost for (S3, D1) path

Result in this way a major change in the transport schedule. The current solution is no longer the optimal one. The blocked path (S3, D1) is no longer used in the new transport schedule, presented below:

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 1 | 15000 | 3 | 45000 | 0 |
| 2 | Source 2 | Destination 1 | 10000 | 5 | 50000 | 0 |
| 3 | Source 3 | Destination 4 | 21000 | 6 | 126000 | 0 |
| 4 | Source 3 | Unused_Supply | 19000 | 0 | 0 | 0 |
| 5 | Source 4 | Destination 1 | 10000 | 8 | 80000 | 0 |
| 6 | Source 4 | Destination 2 | 7000 | 5 | 35000 | 0 |
| 7 | Source 4 | Destination 3 | 14000 | 2 | 28000 | 0 |
| 8 | Source 4 | Unused_Supply | 9000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 364000 | |

Figure 10. Current solution for (S3, D1) blocked path

## *3. Effect of Transport Unitary Cost Variation over the Optimal Transport Plan*

The last case to be taken in consideration in this paper proposes to study the effect produced by the variation of a certain unitary transport cost over the optimal transport schedule and the afferent transport total cost. Starting from the same initial problem, we assume that to realize the transport from Enterprise 3 to Warehouse 1 there are several paths which can be used in a month or other, function of the road repairing and modernization program. The possible path changes have a direct effect over the mentioned cost took in consideration ($c_{31}$). Starting from the (S3, D1) path cost, meaning $c_{31}$ =2, we consider the optimal solution previously considered (Fig.3) and we remake the calculations.

The Network Modelling Module offers the possibility to perform „What-If" or parametrical type analysis by appealing the respective options from the Solve and Analyze menu. Choosing the Perform What-If Analysis option has as effect opening a new window in which are specified the elements to be modified.

If the transport unitary cost between Enterprise 3 to Warehouse 1 rises with one monetary unit, we obtain the same optimal transport schedule, but the total cost is 345000m.u. (Fig.11).

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 4 | 20000 | 2 | 40000 | 0 |
| 2 | Source 2 | Destination 4 | 5000 | 7 | 35000 | 0 |
| 3 | Source 2 | Unused_Supply | 10000 | 0 | 0 | 0 |
| 4 | Source 3 | Destination 1 | 50000 | 3 | 150000 | 0 |
| 5 | Source 3 | Destination 4 | 5000 | 6 | 30000 | 0 |
| 6 | Source 4 | Destination 2 | 10000 | 5 | 50000 | 0 |
| 7 | Source 4 | Destination 3 | 20000 | 2 | 40000 | 0 |
| 8 | Source 4 | Unused_Supply | 30000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 345000 | |

Figure 11. Optimal solution for (S3, D1) one unitary cost variation

If the transport unitary cost between Enterprise 3 to Warehouse 1 rise with two monetary units, the total cost will increase with 100000m.u, becoming 395000m.u, the paths and quantities still remaining the same (Fig.12).

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 4 | 20000 | 2 | 40000 | 0 |
| 2 | Source 2 | Destination 4 | 5000 | 7 | 35000 | 0 |
| 3 | Source 2 | Unused_Supply | 10000 | 0 | 0 | 0 |
| 4 | Source 3 | Destination 1 | 50000 | 3 | 150000 | 0 |
| 5 | Source 3 | Destination 4 | 5000 | 6 | 30000 | 0 |
| 6 | Source 4 | Destination 2 | 10000 | 5 | 50000 | 0 |
| 7 | Source 4 | Destination 3 | 20000 | 2 | 40000 | 0 |
| 8 | Source 4 | Unused_Supply | 30000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 345000 | |

Figure 12. Optimal solution for (S3, D1) two unitary cost variation

If the transport unitary cost between Enterprise 3 to Warehouse 1 rise with three monetary units, besides the increase of the objective function value to 400000m.u. it will appear also a change in the optimal transport schedule as follows:

- Enterprise 1 continue to supply Warehouse 4 only with 20000 pieces
- Enterprise 2 supplies now Warehouse 1 with 15000 pieces
- Enterprise 3 still supplies Warehouse 1 with 35000 pieces and Warehouse 4 with 10000 pieces
- Enterprise 4 supplies Warehouse 2 with 10000 pieces and Warehouse 3 with 20000 pieces
- The fictive Warehouse covers the rest of demand (40000 pieces), being supplied with 10000 pieces from Enterprise 3 and 30000 pieces from Enterprise 4.

| 09-05-2010 | From | To | Shipment | Unit Cost | Total Cost | Reduced Cost |
|---|---|---|---|---|---|---|
| 1 | Source 1 | Destination 4 | 20000 | 2 | 40000 | 0 |
| 2 | Source 2 | Destination 1 | 15000 | 5 | 75000 | 0 |
| 3 | Source 3 | Destination 1 | 35000 | 5 | 175000 | 0 |
| 4 | Source 3 | Destination 4 | 10000 | 6 | 60000 | 0 |
| 5 | Source 3 | Unused_Supply | 10000 | 0 | 0 | 0 |
| 6 | Source 4 | Destination 2 | 10000 | 5 | 50000 | 0 |
| 7 | Source 4 | Destination 3 | 20000 | 2 | 40000 | 0 |
| 8 | Source 4 | Unused_Supply | 30000 | 0 | 0 | 0 |
| | Total | Objective | Function | Value = | 440000 | |

Figure 13. Optimal solution for (S3, D1) three unitary cost variation

It can concluded that as long as the unitary cost is less than 4, $c_{31} \leq 4$, the optimal transport schedule is the one presented in Fig.3, but when the cost overpass this value, the obtained solution is no longer the optimal one.

The total cost becomes $f = 195000 + 50000 \cdot c_{31}$ (tab.3).

It can be also observed that as long as transport unitary cost continues to increase, the (S3, D1) path is more and more rarely used, becoming in the final abandoned.

TABLE III.

| **Transport unit cost value between (S3, D1)** | **Objective Function** | **Observations** |
|---|---|---|
| $c_{31}$= 2 | f= 195000 + 50000x2 = **295000** | Optimal Transport Plan – fig.3 |
| $c_{31}$= 3 | f= 195000 + 50000x3 = **345000** | Optimal Transport Plan – fig.11 |
| $c_{31}$= 4 | f= 195000 + 50000x4 = **395000** | Optimal Transport Plan – fig.12 |
| $c_{31}$= 5 | f= 265000 + 35000x5 = **440000** | Transport Plan is no longer the optimal one, the quantity transported on (S3, D1) path decreased with 15000 pieces |
| $c_{31}$= 6 | f= 265000 + 35000x6 = **475000** | |
| $c_{31}$=7 | f= 265000 + 35000x7 = **510000** | |
| $c_{31}$= 8 | f= 405000 + 15000x8 = **585000** | Transport Plan is no longer the optimal one, the quantity transported on (S3, D1) path decreased with 35000 pieces |
| $c_{31}$=9 | f= 52.000 + 0x9 = **525000** | Abandoned (S3, D1) path |

## IV. Conclusions

The transport optimal plan for the proposed problem is:

- Enterprise 1 supplies Warehouse 4 with 20000 pieces
- Enterprise 2 supplies Warehouse 4 with 5000 pieces and the Fictive Warehouse with 10000 pieces
- Enterprise 3 supplies Warehouse 1 with 50000 pieces and Warehouse 4 with 5000 pieces
- Enterprise 4 supplies Warehouse 2 with 10000 pieces, Warehouse 3 with 20000 pieces and the Fictive Warehouse with 30000 pieces

Thus, the Objective Function is f = 20000 x 2 + 5000 x 7 + 10000 x 0 + 50000 x 2 + 5000 x 6 + 10000 x 5 + 20000 x 2 + 30000 x 0 = 295.000m.u.

Were studied and analyzed the next cases:

1) Production decrease by 30%, which supposed:

a) Minimization of transport costs – difference between the total demand and total offer (diminished with 30%) imposed a re-equilibration of the problem by introduction of a fictive source. The value of the Objective Function in this case was 330000m.u.

b) Repartition of the decreased production proportionally with the normal demands – in this case the transport total cost decreased to 200000m.u.

2) Blocking the S3-D1 Transport Path lead to major modification of the Transport Plan, conducing to the Objective Function value augmentation up to 364000m.u

3) Variation of Transport Unitary Cost on S3-D1path

a) increase by 1m.u. of transport unitary cost between Enterprise 3 to Warehouse 1 lead to a Objective Function value f = 195000 + 50000 x 3 = 345000m.u. and the optimal transport plan remained the same;

b) doubling the transport unitary cost between Enterprise 3 to Warehouse 1 lead to the same optimal transport plan, the Objective Function value increase with 50000m.u., becoming : f= 195000 + 50000 x 4 = 395000m.u;

c) increment with three monetary units of the transport unitary cost between Enterprise 3 to Warehouse 1 determined a modification of the optimal transport plan and the increase of the objective function value to 400000m.u.

In conclusion, as long as the unitary cost is less than 4, $c_{31} \leq 4$, the optimal transport plan is the one presented in Fig.3, but when the cost overpasses this value, the obtained solution is no longer the optimal one. The total cost becomes $f = 195000 + 50000 \cdot c_{31}$.

According to Table 3, it observe that the transport plan supports certain modifications and the unitary cost $c_{31}$ increment brings along augmentation of the total transport cost, up to the moment when $c_{31}$ reaches value of 9, when this path is aborted.

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