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AUTOMATIC SOLUTION OF TRANSPORT PROBLEMS USING A NEW ADD-IN TO EXCEL

Simona Filipova-Petrakieva, Ivan Stankov

Abstract: *Transport problem is a basic problem arising in transportation the products from several distributors to several clients. The solution of this problem consists of determining optimal transportation according to needed allocations the products. In fact, this problem describes with linear programming model which in general solves with simplex method. The algorithm of this method is a build-in tool for Excel – SOLVER. Unfortunately when it has the large amount of input data the filling of the Excel's tables is a very difficult process. Thus, in this paper is suggested an add-in which visualize and make easier inputting the initial data. It is based on the Visual Studio tools for development the add-ins for MS Office. The main advantage of this solution consists of a user-friendly interface of the mathematical model of the problem which significantly makes easily and good visualization the input data and final solution in tables. As an illustrative example, the proposed add-in is applied for solving the real problem connected with transportation the products of pharmacy company.*

Key-words: *transport problems (closed and open – with insufficiency or overstock); Simplex method; Add-in to Excel for good data visualization, created by Visual Studio Tools for MS Office*

1. INTRODUCTION

Transport problem (TP) is a type of linear programming problem where some products transfer from several sources to several destinations, which will be called distributors and clients, respectively. Although the formation it can be used to represent more general assignment and scheduling problems as well as transportation and distribution problems.

Transport problem (TP) is a specific type linear programming problem. It is preliminarily known the amount of the products keeping in store by each distributor and the respective quantities necessary for each client. It exist transport paths between distributors and clients. The objective function is to minimize the total transport costs for transferring the products from each distributor to each client. The definition of basic transport problem and its varieties are given in [1, 2, 3]. So here it will be remembered in briefly [4].

The mathematical model of closed TP is:

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$$
\begin{aligned}
& f(x) = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}.x_{ij} \to \min \\
& \sum_{j=1}^{m} x_{ij} = a_i, \ i = 1,2,\dots,n \\
& \sum_{i=1}^{n} x_{ij} = b_j, \ \ j = 1,2,\dots,m \\
& \sum_{i=1}^{n} a_i = \sum_{j=1}^{m} b_j \\
& 0 \le x_{ij} \le d_{ij}, \ i = 1,2,\dots,n, \ \ j = 1,2,\dots,m
\end{aligned} \tag{1}
$$

where:

- Each distributor $A_i, \ i = \overline{1, n}$ keeps in store one type of product in respective quantities ($a_i, \ i = \overline{1, n}$) and each client $B_j, \ \ j = \overline{1, m}$ has a need of this product in respective quantity ($b_j, \ \ j = \overline{1, m}$).
- c_{ij} is the cost for transportation the unit of the product from *i*-th distributor to *j*-th client.
- x_{ij} and d_{ij} are the amount of transported production and the capacity of the channel from *i*-th distributor to *j*-th client, respectively.

Opened TP model with insufficiency arises when the supplement is smaller than the consumption

$$
\sum_{i=1}^{n} a_i \le \sum_{j=1}^{m} b_j \tag{2a}
$$

but opened TP model with overstock arises when the supplement is bigger than the consumption:

$$
\sum_{i=1}^{n} a_i \ge \sum_{j=1}^{m} b_j \tag{3a}
$$

Opened TP models become to closed type when in (2a) and (3a) introduce a fictive distributor A^F_{n+1} and a fictive client B^F_{m+1}, respectively. Then the associate production in A^F_{n+1} and B^F_{m+1} are $a^F_{n+1} = \sum_{j=1}^{m}\left(x_{ij} - b_j\right)$ and $b^F_{m+1} = \sum_{i=1}^{n}\left(a_i - x_{ij}\right)$.

In the opened TP with insufficiency also changes the objective function as follows:

$$
f(x) = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}.x_{ij} + \sum_{j=1}^{m} r_j.\left(x_{ij} - b_j\right) \to \min \ , \tag{2b}
$$

where it introduces respective fines r_j, which are due to the client from the fictive distributor A^F_{n+1}, which cannot satisfies the needs of clients.

Note: If some of transport paths don't exist, i.e. the channel (distributor A_i, client B_j) has no capacity then it doesn't participate as a variable x_{ij} in objective function and in constrains).

The three mentioned above TP (1, 2 and 3) can be solved by simplex method - universal tool for solving linear problems. These solutions are made on illustrative examples considered in [4].

It also exist the solution of TP based on other software platform as Matlab [5].

Other approach for solving the TP is using the graph's theory [6]. It transforms the specific linear programming model of the TP to the undirected graph which analyses and it finds the final optimal solution.

When it is nessecary to solve TP in big data models it applies specific algorithms to obtain the final solution [7]. Authors of this book explain how organizations can use big data analytics to make accurate final decisions. They discuss modeling tools and methods for predictive analytics, opinion mining to predict rises and falls in the stock price index, the use of a modified stacking ensemble machine learning algorithm using genetic algorithms, prescriptive simulation, and more.

In this paper is suggested an add-in for Excel which improve the visualization of the input data and the solution process of real TP with big dimensions.

The paper is organized as follows. In the next paragraph is described the real TP for transportation the products of pharmacy company which have distributors, keeping the production in storages, and clients, getting the products in shops. All storages and shops are located in the territory of Republic Bulgaria. In the next to the last section of the paper is proposed the add-in for Excel ensuring easier setting the input data and better visualization of the solution process. The paper finishes with conclusion remarks about advantages of the new add-in.

2. PROBLEM STATEMENT

Let consider a real pharmacy company which produces and packs up in boxes its production.

Note: For simplicity, it will assume that all boxes have the same volume.

Company supplies the storages of 5 distributors, located in the following towns: Sofia, Plovdiv, Blagoevgrad, Kazanlak and Karlovo and 10 clients, which shops, located in Sofia 1, Sofia 2, Plovdiv, Ruse, Varna, Burgas, Pleven, Vidin, Sandanski and Haskovo.

Note: For simplicity each storage and each shop will be modeled as an exactly point.

The distances between distributors and clients are given in kilometers in Table 1, which is divided in two separately tables with respect to its replacement in the paper.

Table 1

Distributors / Clients	Sofia 1	Sofia 2	Plovdiv	Ruse	Varna
Sofia	9	18	145	309	438
Plovdiv	151	157	10	315	368
Blagoevgrad	96	97	205	412	558
Kazanlak	196	275	104	203	302
Karlovo	140	157	61	258	355

Distributors / Clients	Burgas	Pleven	Vidin	Sandanski	Haskovo
Sofia	388	163	195	164	226
Plovdiv	258	195	365	228	78
Blagoevgrad	448	265	285	66	285
Kazanlak	190	148	350	355	98
Karlovo	250	136	288	312	138

In Table 2 are given the present quantities of production haven in each distributor, but in Table 3 are shown the respective requests from clients (as number of boxes). The aim of the problem is to find a plan of transportations which satisfies the needs of clients and at the same time minimize the full transport outcomes.

Table 2

Distributors	Present production – $a_i,\ i=\overline{1,5}$, number of boxes
Sofia	700
Plovdiv	600
Blagoevgrad	370
Kazanlak	450
Karlovo	620

Note: Let assume that each truck spend the same amount of fuel. Then because of the fact that uses identical trucks and the price of 1 liter fuel is constant, the coefficients c_{ij} in the objective function will associate to the distances between the considered towns.

Table 3

Clients	Sofia 1	Sofia 2	Plovdiv	Ruse	Varna
Necessary production $b_j,\ j=\overline{1,5}$ **boxes**	100	200	150	300	550

Clients	Burgas	Pleven	Vidin	Sandanski	Haskovo
Necessary production $b_j,\ j=\overline{6,10}$, **boxes**	190	170	260	340	480

The respective mathematical model of the considered TP is:

$$
\begin{aligned}
& f(x) = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}.x_{ij} \to \min \\
& \sum_{j=1}^{m} x_{ij} = a_i,\ i = \overline{1,5} \\
& \sum_{i=1}^{n} x_{ij} = b_j,\ \ j = \overline{1,10} \\
& \sum_{i=1}^{n} a_i = \sum_{j=1}^{m} b_j \\
& 0 \le x_{ij} \le d_{ij},\ i = \overline{1,5},\ \ j = \overline{1,10}
\end{aligned}
\quad . \qquad (4)
$$

It is obvious that (4) is closed type TP without blocked transportations because it satisfies the balance between availabilities in the storages and satisfied the needs of the shops and there is none blocked transportations.

$$\sum_{i=1}^{5} a_i = 2740 = \sum_{j=1}^{10} b_j \ . \qquad (4a)$$

Note: For simplicity, it assumes that transportations of the products makes from trucks with identical carrying capacities $d_{ij} = 500$ boxes.

3. MODELING AND SOLVING THE CONSIDERED REAL TRANSPORT PROBLEM

Solution of the balanced TP without blocked transportations (4) with build-in Excel tool “Solver” is made in [8]. The advantage of this solution consists of the automation of the solution and decreasing the calculation time. But the main disadvantage of these shows when there is a big amount of input data which have to be visualizing during their setting. For this reason in this section proposes a new add-in for Excel which makes easy and intuitive the solution of the TP with big dimensions. It is developed by Visual Studio.

Features and functions of Visual Studio Tools for development the add-ins in MS Office

Visual Studio Tools for Office is a set of tools for development the add-ins for MS Office by modules written on CLI compatible languages. New application unifies the functionality and user interface of MS Office applications in .NET application.

In all versions of MS Office till 2003 the add-ins applications allowed only creation the Component Object Models using Visual Basic or Visual C++. Last version of Visual Studio 2015 is compatible with previous versions of MS Office – 2007, 2010 and 2013. It proposes to the developer possibilities for creation the 2 different types of projects document-level customizations and application-level add-ins. First ones are based on one work book or document, but second ones are affect to the user interface of the applications for MS Word, Excel, PowerPoint, Outlook or InfoPath.

Functionality of the new add-in for solving transport problems

The proposed add-in ensures dynamic solution of TP visualizing the separately steps of the solution and presenting the data which give easier interpretation to the user. To describe it functionality first it has to set the input data which makes as follows:

1. After starting the add-in from Toolbar chooses the option (Fig. 1).

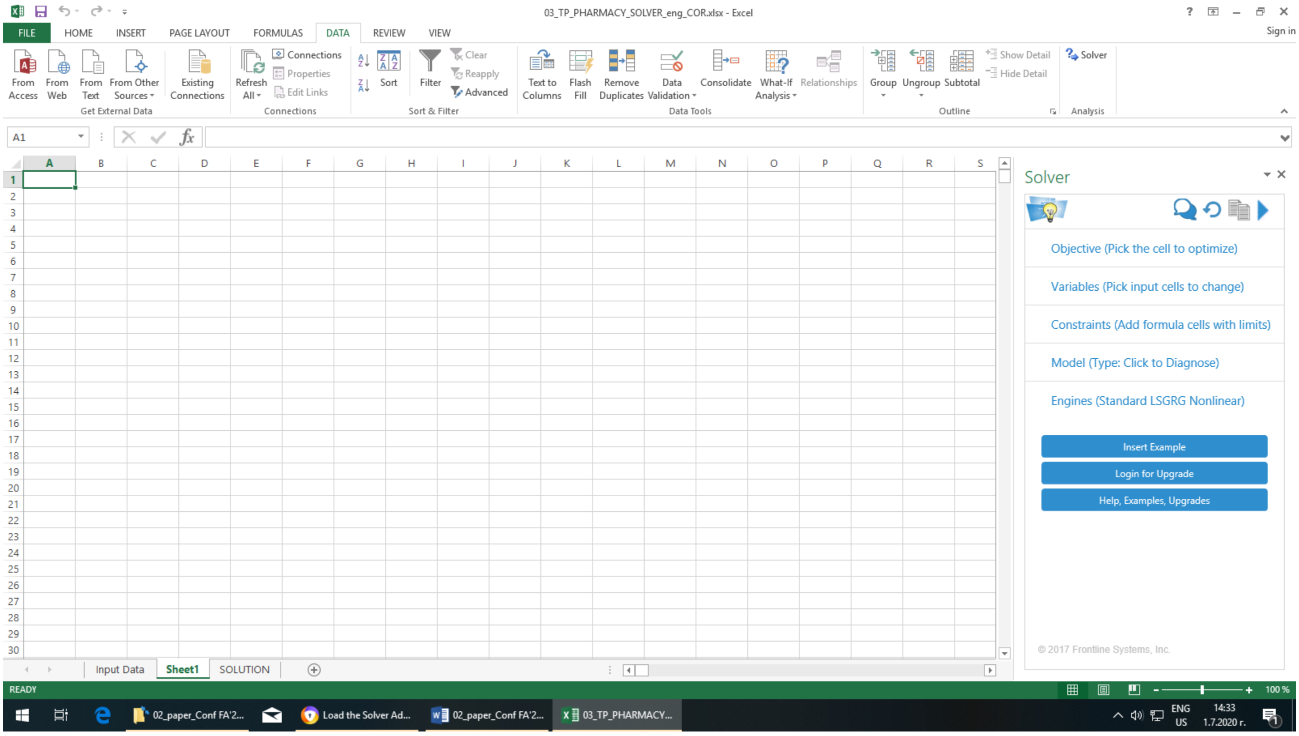

Fig. 1. *Choice of the type of solving problem*

2. It types the names of the towns where are located the shops of the clients (Fig. 2).

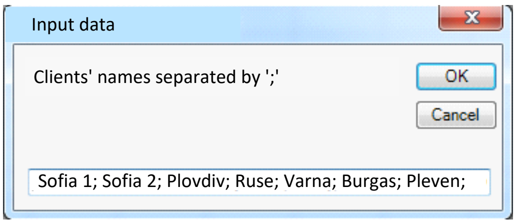

Fig. 2. *Input data for clients*

3. It types the names of the towns where are located the storages of the distributors (Fig. 3).

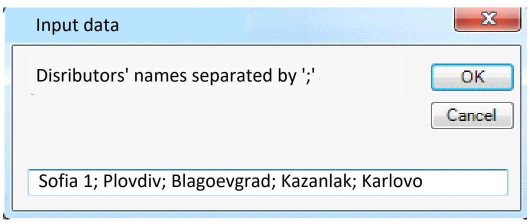

Fig. 3. *Input data for distributors*

4. It types the distances between the towns with the shops of clients and the towns with the storages of distributors (Fig. 4).

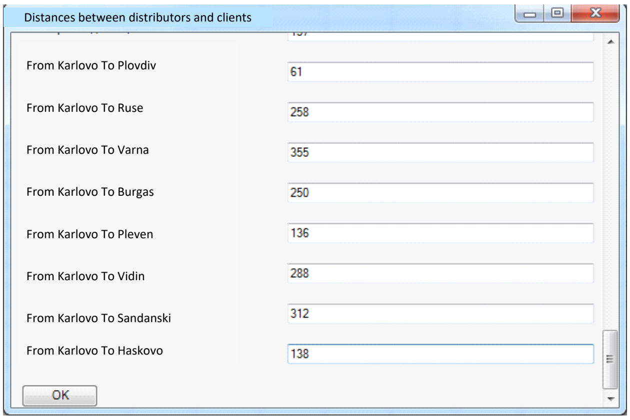

Fig. 4. *Distances between each pair (distributor, client), km*

5. It types the present production in storages of the distributors (Fig. 5).

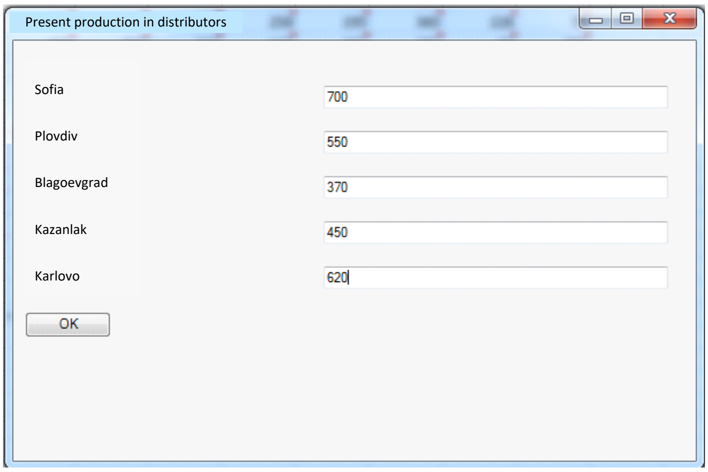

Fig. 5. *Present production in distributors*

6. It types the requests from the clients (Fig. 6).

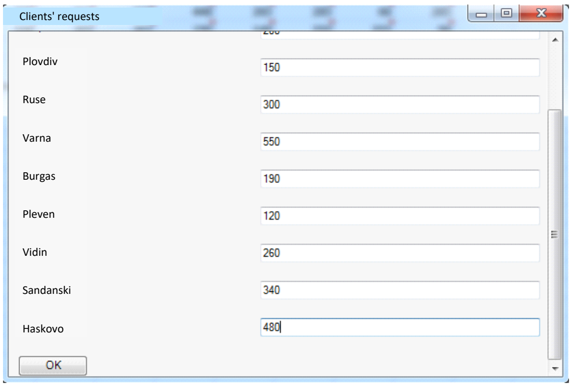

Fig. 6. *Requests from clients*

7. It types the load capacities d_{ij} of the trucks which are equal each others for simplicity of the calculation without drop the generality of the solution (Fig. 7).

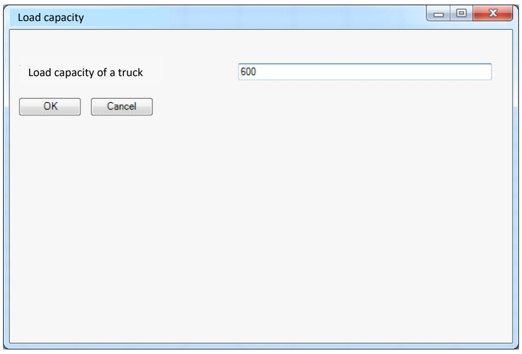

Fig. 7. *Load capacities of the trucks*

After setting the input data the solution process starts automatically and it visualizes in Excel two tables (Fig. 8). In the first table are put the distances between distributor's storages and client's shops. But in the second one it finds the solution of the problem with simplex method which is build-in in optimization module "Solver" in Excel.

C_{ij}	Sofia 1	Sofia 2	Plovdiv	Ruse	Varna	Burgas	Pleven	Vidin	Sandanski	Haskovo
Sofia	9	18	145	309	438	388	163	195	164	226
Plovdiv	151	157	10	315	368	258	195	365	228	78
Blagoevgrad	96	97	205	412	558	448	265	285	66	285
Kazanlak	196	275	104	203	302	190	148	350	355	98
Karlovo	140	157	61	258	355	250	136	288	312	138

$d_{ij = const.}$
600

			b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}				
			Client - B_1	Client - B2	Client - B3	Client - B4	Client - B5	Client - B6	Client - B7	Client - B8	Client - B9	Client - B_{10}				
		x_{ij}	Sofia 1	Sofia 2	Plovdiv	Ruse	Varna	Burgas	Pleven	Vidin	Sandanski	Haskovo		Production taken from distributors		Suppliments in distributors
a_1	Distributor - A1	Sofia	100	170	0	50	0	0	120	260	0	0		700	=	700
a_2	Distributor - A2	Plovdiv	0	0	70	0	0	0	0	0	0	480		550	=	550
a_3	Distributor - A3	Blagoevgrad	0	30	0	0	0	0	0	0	340	0		370	=	370
a_4	Distributor - A4	Kazanlak	0	0	0	250	10	190	0	0	0	0		450	=	450
a_5	Distributor - A5	Karlovo	0	0	80	0	540	0	0	0	0	0		620	=	620
																2690
		Supplied products from the distributors	100	200	150	300	550	190	120	260	340	480				
			=	=	=	=	=	=	=	=	=	=				
		Needs of the clients	100	200	150	300	550	190	120	260	340	480	2690			Objective function
																439610

Fig. 8. *Initial data and optimal solution of the considered transport problem*

The final optimal solution of the considered transport problem has the same advantages as the respective one calculated by "Solver", because essentially it uses this optimization procedure but only difference is in simplification the process of filling the input data. Here again the value of the objective function is $f(x) = 439610$, which is proportional of the outcomes for transportation of all production from distributors to clients. In fact, it estimates the sum of distances, which are traveled from the trucks carrying the products from distributors to clients, i.e. from storages to shops. At the same time all of the requests from clients are satisfied and all production is transported from storages to shops.

As an additional advantage of the solution, obtained by new add-in, consist of the possibility for the user to get the information about that the respective quantity of production x_{ij} from which distributor is taken and to which client is transported. And it appears only by click on the respective cell from second table with left-button of the mouse. This option significantly helps users when they solve TP with big dimensions - a lot of distributors and clients.

4. CONCLUSION

The proposed new add-in for Excel ensures dynamic visualization during the process of setting the input data and gives more detail information in solution of the considered transport problem with respect to the associated solution gotten by build-in Excel tool for optimization “Solver”. There are no restrictions on the maximum number of distributors and clients in solving the task. These are required only by the available computing resources in the respective version of Excel that you are working with.

The new add-in is created by Visual Studio Tools for MS Office. On one side, it has all advantages of the solution obtained by “Solver” as intuitive interface; good presentation of the input data in tables’ forms and significantly reducing the calculation time with respect to manual solution of the TP. On the other side, it gives an opportunity to expand the functionality of Excel by using CLI compatible languages and unifies the user interface of MS Office applications in .NET application.

The proposed new add-in is very useful tool for teaching the students and persons, which practically every day have to solve transport problems with large dimensions in real time, because it gives an opportunity for clearly inputting the input data; quickly finding the final optimal solution and easy interpretation the output data so to take the appropriate actions with respect to the current situation, because “Time is money.”.

REFERENCES

[1] Taha, H. Operations research: an introduction, 10-th edition, Pearson, Print ISBN: 9780134444017, 0134444019, eText ISBN: 9780134480190, 0134480198, 2017.

[2] Transportation Problem. (n.d.) McGraw-Hill Dictionary of Scientific & Technical Terms, 6E. (2003). Retrieved April 6 2020 from

https://encyclopedia2.thefreedictionary.com/Transportation+Problem

[3] Transportation Problem. (n.d.) The Great Soviet Encyclopedia, 3rd Edition. (1970-1979). Retrieved April 6 2020 from

https://encyclopedia2.thefreedictionary.com/Transportation+Problem

[4] Petrakieva, S., G. Georgieva-Taskova. Automatic solution of transport problems with Excel, 13-th International Conference “Challenges in Higher Education Research in 21-st century”, Sozopol, Bulgaria, ISBN: 978-954-580-356-7, pp. 91-95, June 2015.

[5] Georgiev I., St. Karakoleva. Solving transport problems with Matlab, Proceeding of Scientific Student Session, Rousse, ISSN: 1311-3321, pp. 30-35, 1999.

[6] Kolman, B., R. Beck. Special Types of Linear Programming Problems, in Elementary Linear Programming with Applications (Second Edition), 1995.

https://www.sciencedirect.com/topics/computer-science/transportation-problem

[7] Tavana, M., K. Puranam, Handbook of Research on Organizational Transformations through Big Data Analytics, ISBN-13: 9781466672727, ISBN-10: 1466672722, EISBN-13: 9781466672734, DOI: 10.4018/978-1-4666-7272-7, November 2014.

https://www.igi-global.com/dictionary/solving-solid-transportation-problems-with-multi-choice-cost-and-stochastic-supply-and-demand/43346

[8] Petrakieva S. Automatic solution of transport problems with Excel, 14-th International Conference "Challenges in Higher Education Research in 21-st century", Sozopol, Bulgaria, pp. 46-49, 31 May – 3 June 2016.

Authors: *Assoc. prof. Dr. Simona Filipova-Petrakieva*, Technical University of Sofia, Faculty of Automatics, dept. „Theoretical electrical engineering",
e-mail: petrakievas-te@tu-sofia.bg;

Assist. prof. Dr. Ivan Stankov, Technical University of Sofia, Faculty of Computer Systems and Technologies, dept. „Computer systems",
e-mail: istankov@tu-sofia.bg