Solving A Transportation Problem Actual Problem Using Excel Solver

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Abstract— The research work introduces a step by step tutorial to solve transportation problems by using an M.S. Excel solver add-on. This research is carried out based on the actual data of a transportation company. The studied transportation network includes ten sources and nineteen destinations. It was required to minimize the total ton-kilometers. The real data, the solution algorithm, the Excel solver tutorial, as well as the optimal solution, are included.

Index Terms— Transportation Problem, Excel Solver, Transportation Problem Case Study, Minimizing Transportation Costs

I. INTRODUCTION

With a company that owns more several sources to distribute its products to several destinations, the transportation problem plays a significant role in such companies. Transportation problem aims at finding the optimal distribution of goods from several sources to several destinations. The objective of the optimal distribution is to minimize both transportation cost, distance, and time.

The transportation problem was founded by Gaspard Monge (1871) [1]. Then Tolstoi, A.N. started to study the transportation problem in the 1920s. F.L. Hitchcock (1941) [2] worked on the

distribution of products from several sources to numerous localities. Koopman [3] worked on the optimum utilization of transportation systems and used a model of transportation, in activity analysis of production and allocation. It is known as Hitchcook Koopman transportation problem.

Enormous advanced researches were prepared in transportation problem models. Kaur, L. et al [4] introduced a new approach to solving the multi-objective transportation problem. It is a simple approach to obtain the best compromise solution of linear multi-objective transportation problems directly. Afwat, M. et al [5] present a new method to solve multi-objective transportation problems called product approach. They use fuzzy programming to convert the objectives which have different units to membership value then aggregate them by product. This approach is an easy and fast method to find solutions close to the optimum solution. Al-Rajhi et al [6] prepared a decomposition algorithm for solving a class of bi-criteria multistage transportation problems. They presented the mathematical formulation of different bi-criteria multistage transportation problem and an

algorithm for solving a class of them. The studied class can be solved using the decomposition technique of linear programming. That was done by utilizing the special nature of the transportation problem. The method of finding the no-dominated extreme points in the criteria space. Ellaimony et al [7] solved a class of bi-criteria multistage transportation problems using dynamic programming techniques. Their algorithm is based on a dynamic programming technique with its capabilities to generate inherent parametric study during the solution. The technique is used to solve the bicriteria transportation problems. A method to find the non-dominated extreme points in the objective space is already developed. The dynamic programming technique is used to find the shortest route for transportation networks and methods for solving bicriteria linear programming. More other researches related to transportation problem are prepared for fuzzy transportation problem, interactive multi-objective transportation problem, and transshipment. Abdelati, M.H. [8] developed an interactive fuzzy multi-objective transportation problem approach. He applied his strategy to minimize both transportation time and fuel consumption through the non-productive kilometers between garages and the starting stations of Cairo Public Transportation Authority buses. He could reduce the studied objectives by 23% to 25% of the actual distribution.

II. TRANSPORTATION PROBLEM MATHEMATICAL FORMULATION

The mathematical model of the classical transportation problem is presented in most operations research and management science references such as Hillier, F. [9], Taha, H.A. [10], Lee, S.M. [11], Winston, W.L. [12], and more other references. The following equation represents the classical balanced transportation problem model. Balanced transportation problem exists when the total availabilities of sources equal the total requirements of destinations.

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}, \qquad j = 1,2,\dots n; i = 1,2,\dots m$$

Subject To:

$$\sum_{j=1}^{n} x_{ij} = a_i, \qquad i = 1,2,\dots,m$$

$$\sum_{i=1}^{m} x_{ij} = b_j, \qquad j = 1,2,\dots,n$$

$$x_{ij} \geq 0\ for\ all\ i\ and\ j.$$

Where:

Z: is the total transportation cost, time or ton-kilometers.

C_{ij}: are the unit costs of transportation. It could be money, time or distance.

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X_{ij}: are the amounts in tons that should be transported from source (i) to destination (j).
a_i: are the sources availabilities in tons.
b_j: are the destinations requirements in tons.
m: the total number of sources.
n: the total number of destinations.

For balanced transportation problem, the total amounts of sources availabilities equals the total amounts of destinations requirements. $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$.

III. EXCEL SOLVER FOR TRANSPORTATION PROBLEM

To solve transportation problems usually requires three steps. These steps are as follows. First, finding the initial basic feasible solution. Then the test of optimality. Next, moving towards optimality. These steps can be applied to solve small examples of transportation problems. With examples of a large number of sources and destinations, the three steps need considerable effort and time to solve such problems. When considering real-world applications of transportation problems for real transportation companies, it will be complicated, close to impossible, to solve more significant problems. Excel solver can solve such big transportation problems easily and very fast with less effort.

Excel solver is an add-on that exists in M.S. Excel. The solver is prepared in different versions with different limitations by Frontline Systems Inc. By Using Excel solver, we can easily find an optimal (maximum or minimum) solution for the objective function of an optimization model subject to its constraints on the values of other formula cells on a worksheet.

Many researchers start to use excel solver to find the optimal solutions for their optimization problems. Vincent, E.O. [13] outlined the steps which are required for installing Excel Solver in Microsoft Word 2010 for use in solving linear programming problems. He applied excel solver to solve a transportation problem example. Vats, B.N. et al. [14] discussed and compared different models for solving transportation problems for finding an optimal method. All models have been compared with the Excel Solver technique for finding the best possible method. Ipsilandis, P.G. [15] examined an efficient approach in solving combinatorial programming problems with the use of spreadsheets. A practical application, which demonstrates the procedure, concerns the development of a spreadsheet-based DSS for the Multi-Item Procurement Problem with Fixed Vendor Cost. The DSS has been build using exclusively standard spreadsheet features and can solve real problems of substantial size. The benefits and limitations of this approach are also discussed. Çerkini, B. et al. [16] applied an excel solver to find minimal transportation cost. The problem is prepared as a linear programming model to minimize the total production and transportation cost. They added more constraints to the transportation problem based on their study work.

IV. CASE STUDY COLLECTED DATA

The data of a company located in Upper Egypt is studied in this research. They want to distribute their products which exist in 10 different cities to 19 other cities. The collected data includes all distances from all sources to all destinations in kilometers, the sources availabilities in tons, and the destinations requirements in tons. All data are prepared using M.S. Excel, as in the screenshot in Figure (1). In this Figure, cells C278 to U287 represent the distances between sources and destinations in kilometers. Cells V278 to V287 represents the availabilities of all ten sources in tons. Cells C288 to U288 represents the requirements of all destinations in tons.

Destinations / Sources	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	Availabilities
S1	26	13	70	87	86	117	135	232	261	280	33	345	348	319	344	373	150	125	246	1463
S2	53	40	97	114	113	144	162	259	288	307	360	372	375	346	371	40	177	152	273	840
S3	109	96	53	70	69	100	118	214	243	262	315	327	330	301	321	355	133	108	228	2139
S4	98	85	34	15	14	45	63	159	188	257	260	272	275	246	271	300	88	53	173	929
S5	202	189	137	114	89	78	40	56	85	104	157	169	172	143	168	197	25	50	70	3436
S6	223	210	158	135	110	99	61	35	64	83	136	148	151	122	147	176	46	71	49	1699
S7	248	235	183	160	135	124	86	10	39	58	111	123	126	97	122	151	71	96	24	1390
S8	334	321	269	246	221	210	172	76	47	28	25	37	40	11	36	65	157	182	62	1589
S9	358	345	293	270	245	234	196	100	71	52	49	61	64	32	12	41	181	206	86	2691
S10	318	305	253	230	205	194	156	60	31	12	65	77	80	51	71	105	141	166	46	2936
Requirements	1392	911	822	635	888	572	1128	917	1284	1346	1057	540	386	1214	1063	326	2049	1859	723	19112

Figure (1): Screenshot of the data collected table for the studied transportation problem.

V. SOLUTION ALGORITHM

Solving a transportation problem using an Excel solver can be done quickly using the following solution algorithm.

1. Prepare two tables in Microsoft Excel, as in Figure (2) below. The upper one is the "Data Table," which contains the unit costs from all sources to all destinations. The lower one is

the "Results Table." It is empty to be filled by an excel solver. The results table will contain the optimal solution for the transportation problem. In the screenshot below, the unit costs at the data table exists at cells from (C278) to (U287), while the results table exists at cells from (C293) to (U302).

Data Table:

Sources \ Destinations	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19
S1	26	13	70	87	86	117	135	232	261	280	33	345	348	319	344	373	150	125	246
S2	53	40	97	114	113	144	162	259	288	307	360	372	375	346	371	40	177	152	273
S3	109	96	53	70	69	100	118	214	243	262	315	327	330	301	321	355	133	108	228
S4	98	85	34	15	14	45	63	159	188	257	260	272	275	246	271	300	88	53	173
S5	202	189	137	114	89	78	40	56	85	104	157	169	172	143	168	197	25	50	70
S6	223	210	158	135	110	99	61	35	64	83	136	148	151	122	147	176	46	71	49
S7	248	235	183	160	135	124	86	10	39	58	111	123	126	97	122	151	71	96	24
S8	334	321	269	246	221	210	172	76	47	28	25	37	40	11	36	65	157	182	62
S9	358	345	293	270	245	234	196	100	71	52	49	61	64	32	12	41	181	206	86
S10	318	305	253	230	205	194	156	60	31	12	65	77	80	51	71	105	141	166	46

Results Table:

Sources \ Destinations	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	Total Out		Availabilities
S1																				0	=	1463
S2																				0	=	840
S3																				0	=	2139
S4																				0	=	929
S5																				0	=	3436
S6																				0	=	1699
S7																				0	=	1390
S8																				0	=	1589
S9																				0	=	2691
S10																				0	=	2936
Total In	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=			Total Ton-Kilometers
Requirements	1392	911	822	635	888	572	1128	917	1284	1346	1057	540	386	1214	1063	326	2049	1859	723			0

Figure (2): Screenshot of the prepared tables for Excel solver.

2. Prepare two one-row tables, as shown in Table (1). The upper of them should be filled by the Excel solver by calculating the summation of distributed products at each destination. The lower of them should contain all destinations requirements. This way, the Excel solver will compare the summation at the upper to the fixed values at the lower one-row Table. In the screenshot below, the upper one-row Table exists at cells (C304) to cell (U304), while the lower one-row Table exists at cells (C306) to (U306).

3. The same upper procedures are carried out for sources. So, on the right side of the results table in step (5.1), prepare two one-column Tables. The left of them should be filled by the Excel solver by calculating the summation of distributed products at each source. The right table should be fixed, which includes all sources' availabilities. This way, the Excel solver will compare the summation at the left one-column table to the set values at the right one. In the screenshot below, the left one-column table exists at cell (W293) to cell (W302),

while the right one-column table exists from cell (Y293) to cell (Y302)

Table (1): All formulas that needed for the one-row, one-column tables and the objective function cell.

	Cell	Formula
One-row table for destinations	C304	0
	D304	0
	. . .	. . .
	U304	0
One-column table for sources	W293	0
	W294	0
	. . .	. . .
	W302	0
Objective function cell	Y309	0

4. Prepare just one cell to calculate the total transportation cost, or total ton-kilometers according to your problem objective function. This cell could exist anywhere in your spreadsheet. But we preferred to put it in the intersection of the fixed row in step (2) and the fixed column at step (3). i.e., cell (Y306).

5. In each cell of the non-fixed one-row Table that was created in step (2), i.e., table with cells (C307 to U307) in the screenshot below, ask M.S. Excel to calculate the summation of all amounts that were distributed by Excel solver for each destination. We do this by adding formulas at each cell of this non-fixed one-row Table. All formulas of these cells are illustrated in Table (1).

6. In each cell of the non-fixed one-column Table that was created in step (3), i.e., table with cells (W293 to W302) in the screenshot below, ask M.S. Excel to calculate the summation of all amounts that were distributed by Excel solver for each source. We do this by adding formulas at each cell of this non-fixed one-column Table. Again, all formulas of these cells are illustrated in Table (1).

7. In the objective function cell, i.e., cell (Y306), calculate the total cost or total ton-kilometers by multiplying all unit costs in the data table by all amounts that were distributed by excel solver in the results table. The formula of this cell is illustrated in Table (1).

8. Make sure that the Excel solver is activated in your M.S. Excel. The "Solver" icon exists under the "Data" menu in M.S. Excel. If the solver icon is not there on your Excel, you can activate it under: File => Option => Add-Ins => Solver Add-in => OK, as shown in screenshot in Figure (3)
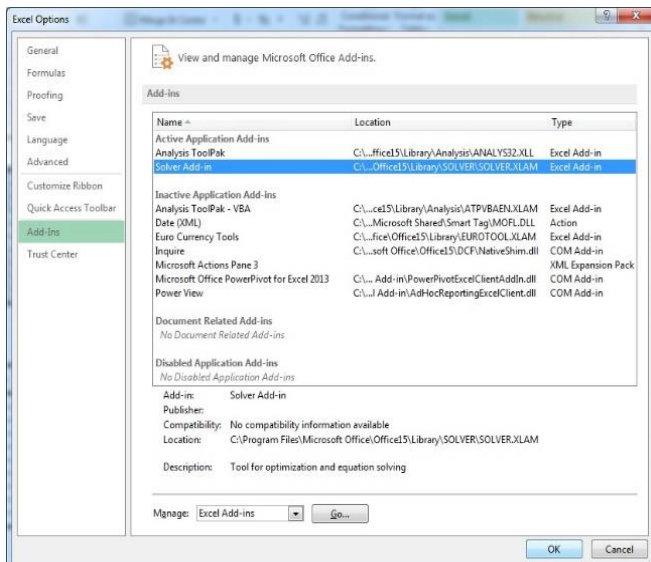

Figure (3): Screenshot for activating M.S. Excel solver

9. Now start the Excel solver. Under the "Data" menu, at the most right, the "Solver" icon should exist. By clicking the solver icon, the solver parameters pop up window appears. There are some parameters here that need to be adjusted as in the following steps more details in Figure (4).
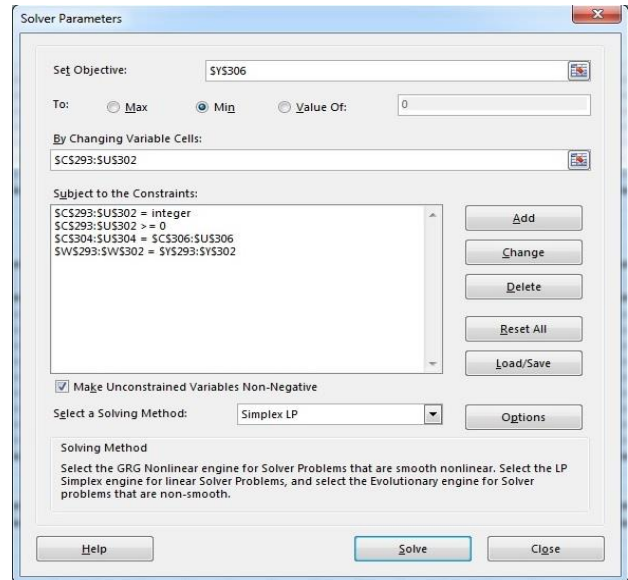

Figure (4): M.S. Excel Solver Pop Up Windows

10. On the set objective field, we write the cell location, which we calculate the total transportation cost. It is cell (Y306) in our case study in this paper.

11. To minimize or maximize according to your problem objective function. In our case study, we choose Min.

12. By changing variable costs: These should be the cell where the values of X_{ij} should exist. These are cells from (C293) to (U302) in this case study.

13. Subject to constraints. Here we should have four sets of constraints according to our case study. Note that the cell numbers may differ according to your data in the excel sheet.

(a) A set of constraints to tell excel solver that we need the decision variables to be integers. In our case study, this set is: C293:U302 = Integer.

(b) A set of constraints to tell excel solver that we need the decision variables to be greater than or equal zero. In our case study, this set is: C293:U302 ≥ 0.

(c) A set of constraints to tell excel solver that the total amounts that are shipped from any source must equal the availability of this source. In our case study, this set is: W293:W302 = Y293:Y302.

(d) A set of constraints to tell excel solver that the total amounts that are shipped to any destination must equal the requirements of this destination. In our case study, this set is: C304:U304 = C306:U306.

14. Choose Simplex LP.

15. Click Solve button.

16. The problem solution, as well as the total transportation cost, will appear in their appropriate prepared cells.

VI. CASE STUDY RESULTS

Table (2) below summarizes the solution of the case study. It was found that the total ton-kilometers equals 684,334 for the studied month. The total ton-kilometers of the actual distribution in the same month was 932,572. The optimal distribution could reduce the total ton-kilometers by a percentage of 26.62% of the actual ton-kilometers.

Table (2): Optimal Distribution of Products.

$X_{i,j}$	Amount	$X_{i,j}$	Amount	$X_{i,j}$	Amount	$X_{i,j}$	Amount
$X_{1,1}$	552	$X_{1,2}$	911	$X_{2,1}$	689	$X_{2,16}$	151
$X_{3,1}$	151	$X_{3,3}$	822	X_{34}	635	$X_{3,5}$	531
$X_{4,5}$	357	$X_{4,6}$	572	$X_{5,17}$	2049	$X_{5,18}$	1387
$X_{6,7}$	1128	$X_{6,8}$	99	$X_{6,18}$	472	$X_{7,8}$	818
$X_{7,1}$	572	$X_{8,11}$	663	$X_{8,12}$	540	$X_{8,13}$	386
X_{9}	239	$X_{9,14}$	1214	$X_{9,15}$	1063	$X_{9,16}$	175
$X_{9,1}$	1284	$X_{10,10}$	1346	$X_{10,11}$	155	$X_{10,19}$	151
$X_{10,9}$							

VII. CONCLUSION

M.S. Excel solver add-on is one of the best tools to solve transportation problem case studies. A step by step tutorial for solving a transportation problem by using excel solver is included. The optimal solution that was generated could reduce the total ton-kilometers for a particular month by a percentage of 26.62% of the actual ton-kilometers.

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