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Efficient and Versatile Methodology for Solving Solid Transportation Problem Using Excel Solver: A Comparative Study with LINGO Code

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Abstract

This research paper presents a novel and efficient methodology for solving the solid transportation problem (STP) using Excel Solver, a widely available and affordable software tool. The proposed approach offers versatility and rapid adjustment of constraints, making it suitable for solving multi-dimensional transportation problems. To validate the efficacy of the methodology, a numerical example is presented, illustrating the step-by-step process for finding the optimal solution. The numerical results, accompanied by figures and explanations, demonstrate the effectiveness of the proposed approach when compared to the results obtained using LINGO code.

By utilizing Excel Solver, this paper provides a user-friendly and accessible tool for researchers and practitioners seeking to solve the solid transportation problem. The methodology explains in detail how to utilize Excel Solver and formulate the problem constraints. One of the advantages of Excel Solver is its ease of use and flexibility in modifying constraints or the objective function to accommodate changing problem parameters.

The research results indicate successful solutions to the solid transportation problem using Excel Solver, with an optimal solution. The comparison with the results obtained from LINGO software confirms the effectiveness and accuracy of Excel Solver. Additionally, Excel Solver offers advantages such as providing the optimal solution directly without requiring initial solutions, as well as the availability of additional tools like macros or VBA to facilitate the solution process.

Keywords: Solid Transportation Problem, Optimization, Excel Solver, Lingo

1 Introduction

The transportation problem is a well-established optimization problem that has been extensively studied in the context of linear programming [1]. Originally, the problem involved moving various products from a set of sources to a set of destinations [2] with the objective of minimizing or maximizing the objective function to attain an optimal solution. As the transportation problem became more complex, additional dimensions were introduced, such as the diversity of products [3], the multiplicity of transportation stages, and the variety of transportation modes, which added more constraints to the problem-solving process [4]. With the proliferation of transport fleets, a new transportation problem technique emerged, known as the solid transportation problem [5], which aims to minimize transportation costs by redistributing the fleet to distribute products from sources to destinations to meet supply and demand.

Various methods have been developed to obtain an initial solution that is close to the optimal solution for the solid transportation problem [6]. One common approach is to convert the problem into a linear programming problem and use specialized software such as Lingo, Tora, MATLAB, or Python to solve it [7]. However, these software options may come at a high cost.

This paper presents a novel methodology for solving the solid transportation problem using Excel Solver, which is a widely available and affordable software tool [8]. Our proposed approach is designed to address the limitations of existing methods and can be extended to solve multi-dimensional transportation problems. By demonstrating the effectiveness of Excel Solver in solving the solid transportation problem, this paper aims to provide a useful and accessible tool for researchers and practitioners alike. We will explain how to solve the solid transportation problem using Excel Solver and formulate the problem constraints. The advantage of using Excel Solver includes its ease of use and flexibility to modify constraints or the objective function in response to changing problem parameters.

2 The Mathematical Formulation of STP

The mathematical form of STP can be formulated as follow[9]:

$$\text{Min } Z = \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} c_{ijk}\, x_{ijk} \qquad (1)$$

$$\sum_{j \in J} \sum_{k \in K} x_{ijk} = a_i \qquad \text{for } \forall \ \ i=1:I \qquad (2)$$

$$\sum_{i \in I} \sum_{k \in K} x_{ijk} = b_j \qquad \text{for } \forall \ \ j=1:J \qquad (3)$$

$$\sum_{i \in I} \sum_{j \in J} x_{ijk} = e_k \qquad \text{for } \forall \ \ k=1:K; \qquad (4)$$

$$x_{ijk} \geq 0 \qquad \text{for } \forall \ \ i, j \text{ and } k \qquad (5)$$

Where:

I, J and K are the set of sources, destinations and types of modes respectively.

c_{ijk} = unit transportation cost for ship one unit of product from source i to destination j by type k of vehicles.

x_{ijk}= total amount of products shipping from source i to destination j by type k of vehicles.

Load Solver to Excel

1- Go to File and select Options (If you use Excel 2007 click to windows image and select Options).
2- From Options click Add-in and from the box choose Solve Add-in and Ok in the button.
3- Now Go to Date and you will find solver in the right.

Figure (1) shows the previous stages. And if you use macOS the solver can be summoned in similar steps, with slight differences .But unfortunately, if you are using mobile devices, it is - up to now - that Solver cannot be dealt with, whatever the device's system.

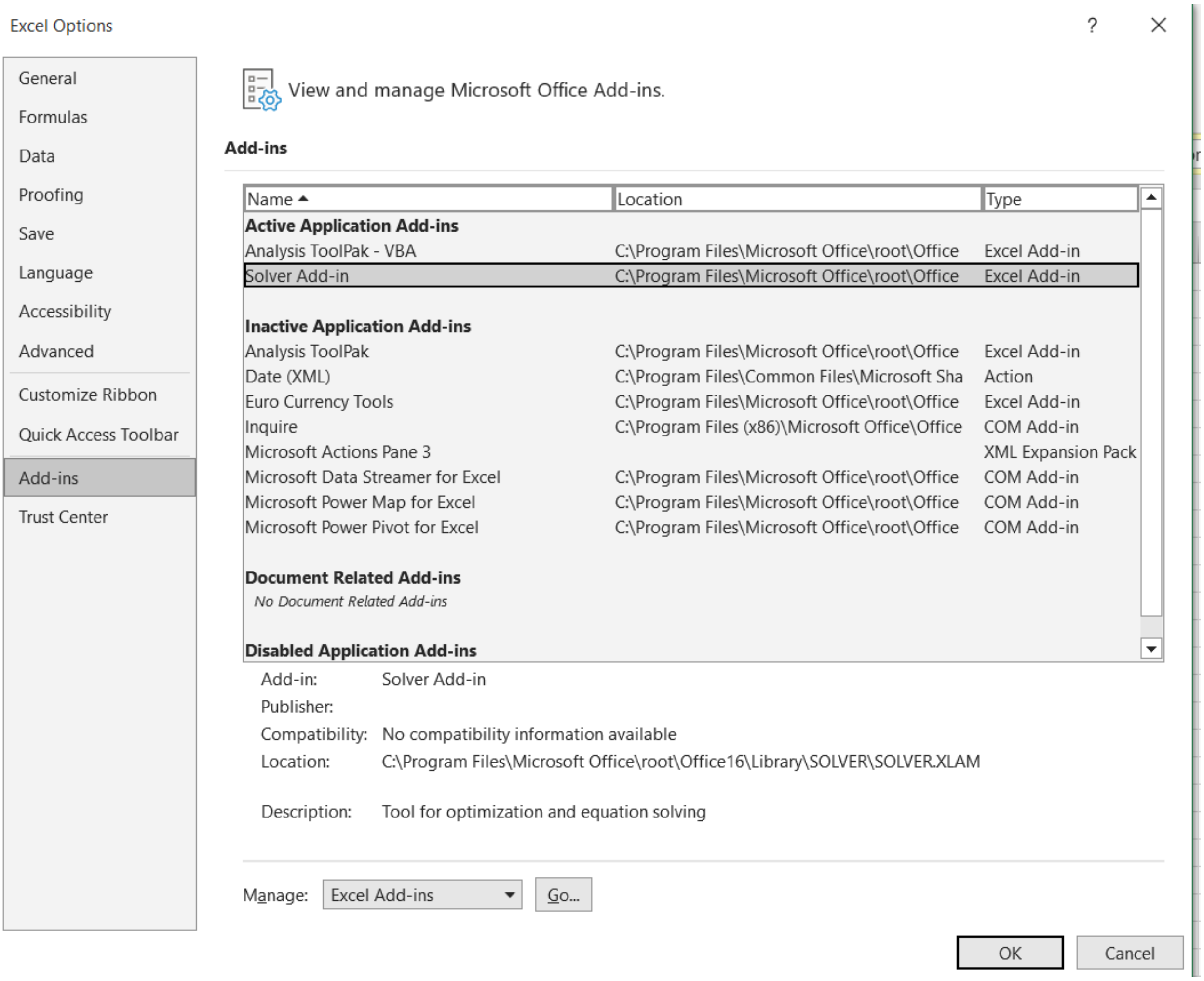

Fig. 1 Stages to load Solver to Excel

Numerical Example (Step by Step)

To clarify the steps for solving the solid transportation problem using the Excel solver, we review this numerical example, through which we will detail the solution using the program. Table 1 shows the solid transportation problem to be solved.

Table 1. The solid transportation problem

										capacity
	k1			k1			k1			30
		k2			k2			k2		30
			k3			k3			k3	40
	j1			j2			j3			Avail.
i1	1	4	5	7	8	3	4	7	6	20
i2	3	5	6	6	7	1	9	4	8	40
i3	6	8	5	4	5	9	6	2	3	40
Req.	32			24			44			

The steps to solve STP using Excel Solve are:

1- The transportation matrix is configured as in the example. It shows the cost of transporting a unit of products from each source to each destination. Cells B10:J12 (from row 10, column B to row 12, column J) contain the transportation unit cost, as shown in fig. 2.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2													
3													
4													
5											capacity		
6		k1			k1			k1			30		
7			k2			k2			k2		30		
8				k3			k3			k3	40		
9		j1			j2			j3			Avail.		
10	i1	1	4	5	7	8	3	4	7	6	20		
11	i2	3	5	6	6	7	1	9	4	8	40		
12	i3	6	8	5	4	5	9	6	2	3	40		
13	Req.	32			24			44					
14													
15													

Fig. 2 The transportation unit cost

2- Another table is made for the quantities of movables from each source to each destination, where the number of cells is equal to the number of cells of the transportation unit costs. Cells B24:J26 (look at figure 3) show the number of products shipped form source i to destination j, which are empty, as the solver will fill them according to the optimal solution to the transportation transfer problem.

3- To achieve the constraint equations, we write the supply and demand quantities and truck capacity. Cells N24:N26 are the production quantities. Cells B30, E30, H30 are the order quantities. Cells L19:N19 show the truck capacities.

4- Now we create cells similar to the numbers of previous cells for both supply, demand and capacity according to the constraints so that the solver can find the solution without violating the constraints. Cells L24:L26 are the sum of the quantities of transports from the first source to all destinations by all types of conveyance, where cell L24 is programmed as follows: =SUM(B24:J24). The programming for cell L25 is =SUM(B25:J25). The programming for cell L26 is =SUM(B26:J26).

5- In the same way as before, we program the demand cells. Where cell B28 is the total amount transferred to the first destination from all sources using all transport types. The programming for cell B28 is =SUM(B24:D26). The programming for cell E28 is =SUM(E24:G26). The programming for cell H28 is =SUM(H24:J26).

6- Now we are going to program the truck capacity cells for each truck which are cells L21:N21. Cell L21 is the total movables in the first truck (green color). It can be written in the form =SUM(B24:B26,E24:E26,H24:H26). The total movables in the second truck (blue color) are represented by cell M21, which is =SUM(C24:C26,F24:F26,I24:I26). While cell N21 is the total movables using the third truck (yellow color) and is equal to =SUM(D24:D26,G24:G26,J24:J26)

7- The cell that represents the objective function, cell N33, is programmed. It is the total product shipped to the network multiplied by the unit cost of transporting the product from each source to each destination using a specific mode of transportation. So cell N33 can be programmed to equal =SUMPRODUCT(B10:J12,B24:J26). By reaching this step, the transportation network in fig. 3 is ready to be solved using solver.

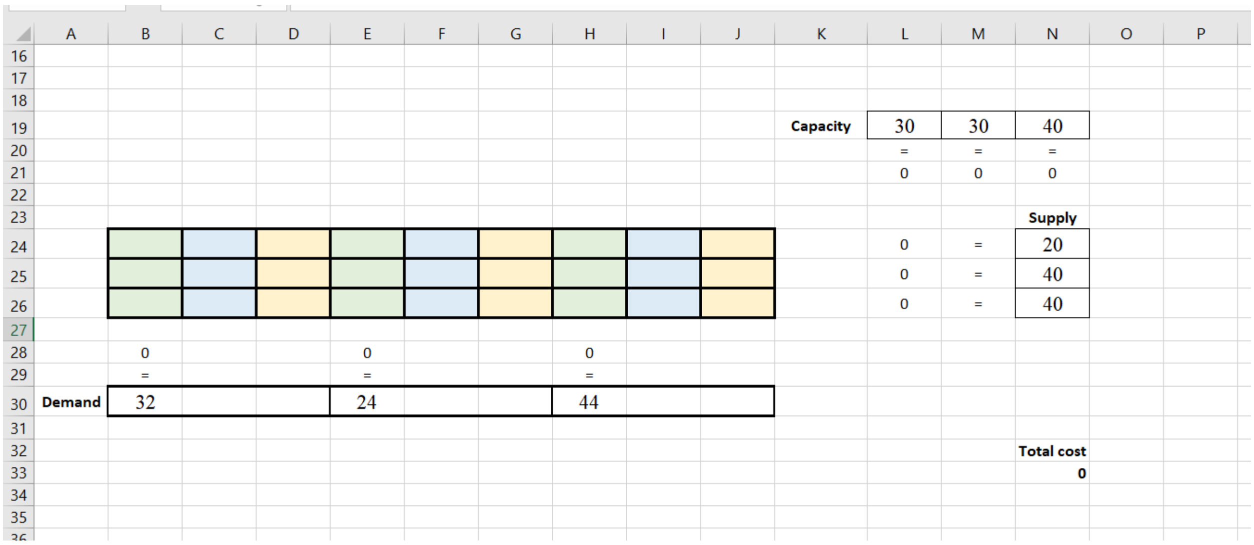

Fig. 3 The transportation network

8- Go To Data and choose solver. A window shown in fig. 4 is the solver window. (A) the objective function cell that we choose it by write it or click in the button and choose it from Excel. (B) shows shows the type of optimization. Here we do a minimization for the total cost so we select “Min”. (C) shows the X_{ijk} cells we can do it like (A). (D) shows the constrains. We add it manually by click Add and select the cell reference, operator and constraint. Finally (E) shows the programming and here is LP programming. After solve we can ask for some reports of sensitivity, duality and shadow prices as shown in fig. 5. Each report will be a new sheet.

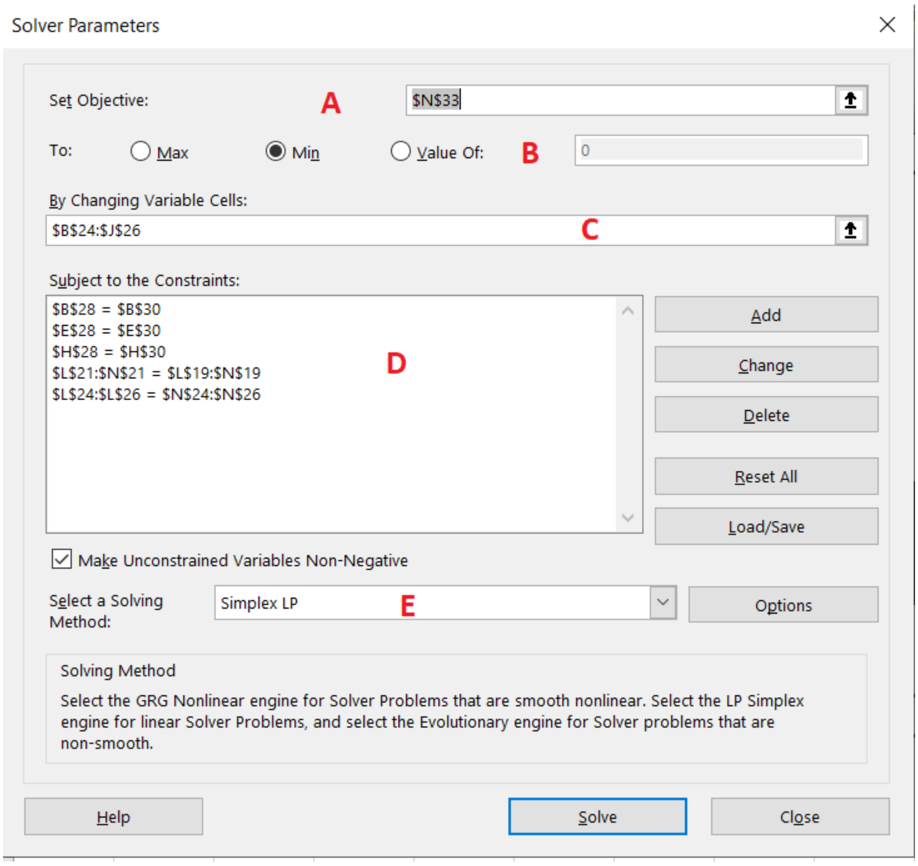

Fig. 4 The solver window

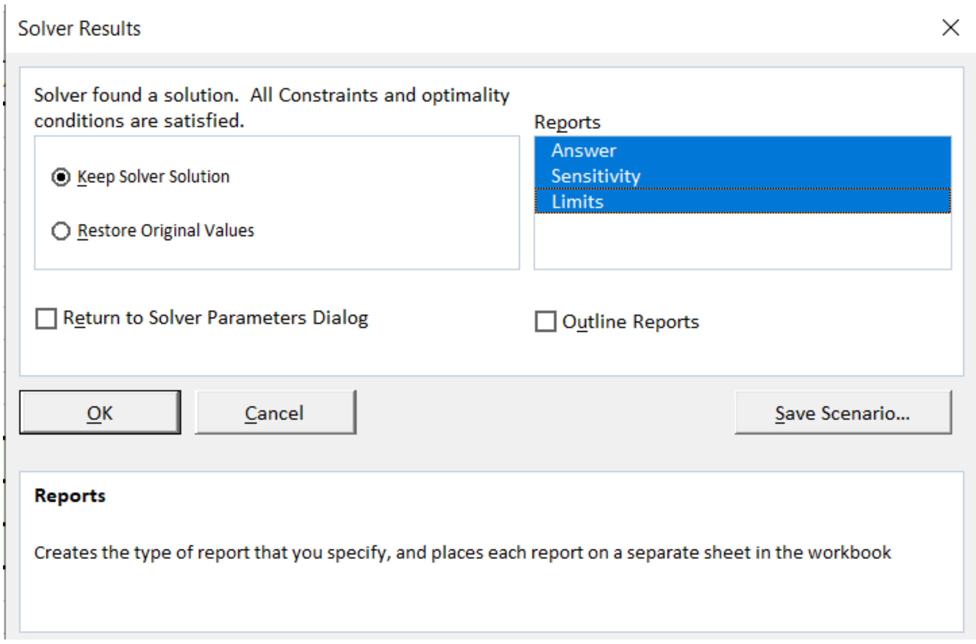

Fig. 5 Sensitivity, duality and shadow prices

9- Now, as shown in fig. 6, after finishing the solver the program generate the cells for objective function, total amount of products and sum of supply, demand and capacities automatically.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
17															
18															
19											Capacity	30	30	40	
20												=	=	=	
21												30	30	40	
22															
23														Supply	
24		20	0	0	0	0	0	0	0	0		20	=	20	
25		10	2	0	0	0	24	0	4	0		40	=	40	
26		0	0	0	0	0	0	0	24	16		40	=	40	
27															
28		32			24			44							
29		=			=			=							
30	Demand	32			24			44							
31															
32														Total cost	
33														196	
34															
35															

Fig. 6 The program generate the cells for objective function

Solving Using Lingo

The term "LINGO" stands for Linear Interactive and General Optimizer, which is a software tool designed to solve interactive linear and universal optimization problems [10]. The main objective of LINGO is to provide users with a platform to quickly input their model formulation, solve it, assess the accuracy or adequacy of the solution, make necessary adjustments to the formulation, and repeat the process as needed.

In this context, Fig. 7 illustrates the formulation of the equations used in a previous numerical example that were written as input to the LINGO code. Meanwhile, Fig. 8 provides a description of the output generated by the LINGO code. Additionally, Table 2 presents the fundamental variables used in the model.

```
LINGO Model - LINGO1
Model:
!objective function;
Min = 1*X111 + 4*X112 + 5*X113 + 7*X121 + 8*X122 + 3*X123 + 4*X131 + 7*X132 + 6*X133
 + 3*X211 + 5*X212 + 6*X213 + 6*X221 + 7*X222 + 1*X223 + 9*X231 + 4*X232 + 8*X233
+ 6*X311 + 8*X312 + 5*X313 + 4*X321 + 5*X322 + 9*X323 + 6*X331 + 2*X332 + 3*X333;
!supply;
X111 + X112 + X113 + X121 + X122 + X123 + X131 + X132 + X133 = 20;
X211 + X212 + X213 + X221 + X222 + X223 + X231 + X232 + X233 = 40;
X311 + X312 + X313 + X321 + X322 + X323 + X331 + X332 + X333 = 40;
!demand;
X111 + X112 + X113 + X211 + X212 + X213 + X311 + X312 + X313 = 32;
X121 + X122 + X123 + X221 + X222 + X223 + X321 + X322 + X323 = 24;
X131 + X132 + X133 + X231 + X232 + X233 + X331 + X332 + X333 = 44;
!capacity;
X111 + X121 + X131 + X211 + X221 + X231 + X311 + X321 + X331 = 30;
X112 + X122 + X132 + X212 + X222 + X232 + X312 + X322 + X332 = 30;
X113 + X123 + X133 + X213 + X223 + X233 + X313 + X323 + X333 = 40;
```

Fig. 7 The formulation of the equations

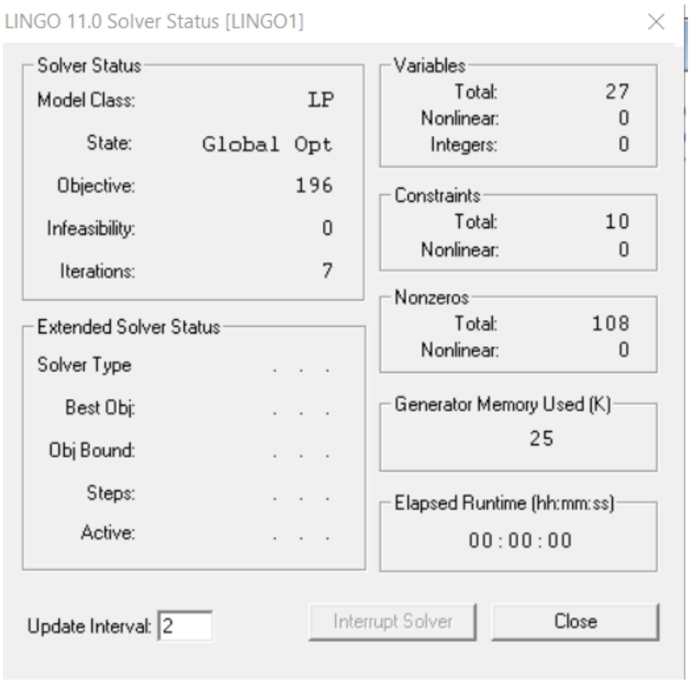

Fig. 8 a Description of the output generated by the LINGO code

Table 2 The fundamental variables used in the model

Variable	Value
X111	20
X211	10
X212	2
X223	24
X232	4
X332	24
X333	16

Results and Discussion

The solid transportation problem has been successfully solved using Excel Solver, with an optimal solution value of 196. The effectiveness of this approach was confirmed by comparing it with the output generated by specialized software known as "Lingo," which produced identical results.

One of the main advantages of using Excel Solver is that it provides the optimal solution directly, without requiring initial solutions. Additionally, Excel offers additional tools such as macros or VBA that can be used to facilitate the solution process. This approach can be extended to multi-dimensional transportation problems, which can benefit from Excel's versatility and scalability.

Moreover, it is crucial to utilize Excel's reporting features to generate reports tailored to specific needs. This step was highlighted in the solution process, emphasizing the importance of these reporting features in obtaining a more comprehensive understanding of the optimization problem.

Overall, the successful solution of the solid transportation problem using Excel Solver demonstrates the efficiency, versatility, and accessibility of this approach. It offers an affordable and user-friendly alternative to specialized software and can be extended to solve more complex transportation problems.

Conclusions

In conclusion, this paper has presented a practical and effective approach for solving solid transportation problems using Excel Solver. Through the step-by-step solution of a numerical example, we demonstrated the advantages of this approach, including its ease of use, affordability, and ability to produce optimal solutions directly. Moreover, we highlighted the potential of using additional tools, such as macros or VBA, to facilitate the optimization process and generate customized reports.

While existing research has explored the use of Excel Solver for linear programming and transportation problems, this paper contributes to the literature by presenting a methodology for formulating constraints in solid transportation problems. The comparison of our approach with the output generated by Lingo confirmed the effectiveness and accuracy of Excel Solver for solving solid transportation problems.

Overall, the results of this paper suggest that Excel Solver can be a practical and viable solution for solving various optimization problems, including solid transportation problems. Future research could focus on exploring the application of this approach to multi-dimensional transportation problems and incorporating more complex constraints.

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