

Efficient Transportation Cost Minimization Strategies in Supply Chain Management: A Comprehensive Analysis and Optimization Framework by using Solver Methodology & Python Programming

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Abstract:- Transportation cost optimization plays a vital role in the operations of sand manufacturing companies that depend on third-party logistics for the efficient movement of their products. This research focuses on reducing the total transportation costs for a sand manufacturing company by selecting the best logistics supplier using the PuLP library, a popular open-source Linear Programming tool in Python. The objective is to minimize the total transportation cost while meeting the demand requirements of customers by determining the optimal allocation of sand shipment from the company's multiple warehouses to various customers while considering factors such as distance, freight rates, and capacity constraints. To address this transportation problem, the PuLP library is employed. PuLP provides a powerful interface for formulating and solving solver capabilities to facilitate finding the optimal solution that minimizes the total transportation cost. By leveraging the Pulp library, sand manufacturing companies can optimize their transportation operations and reduce the total transportation cost associated. The project aims to provide valuable insights into supplier selection for improved cost efficiency, enhanced customer service, and increased operational effectiveness.

Keywords:- Transportation Cost Reduction, Logistics Management, Python Programming, Prescriptive Analytics, Microsoft Solver, Linear Programming.

I. INTRODUCTION

The objective of this research study based on operational research and Python programming is to optimize the transportation cost in the supply chain and logistics management system. The Python programming section of this study and development approach is based on the Python

Programming Mindmap available as open-source with 360DigiTMG (ak.1) [Fig. 1].

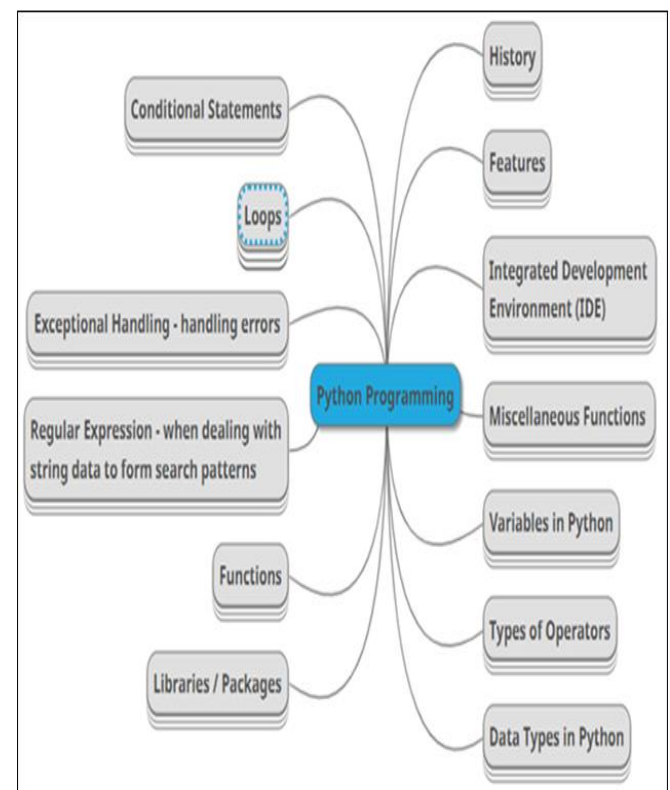


Fig 1 The Python Programming Mindmap
(Source: Mind Map - 360DigiTMG)

The Python programming mindmap visually outlines key concepts and components of Python programming, serving as a helpful reference for understanding and implementing Python code efficiently

The transportation of products plays a crucial role in the efficient operation of manufacturing companies. In the case of sand manufacturing companies, minimizing transportation costs is essential for maintaining profitability and competitive advantage. This research study focuses on optimizing the quantity of sand transported from different warehouses to different demand ends by using different logistics to minimize transportation costs. To achieve this objective, a Solver-based approach is employed, leveraging mathematical modelling and optimization techniques.

The sand manufacturing company, under consideration for this study, faces the challenge of efficiently distributing sand from multiple warehouses to various locations where demand exists. Each warehouse has a limited capacity, and there are costs associated with transporting sand from each warehouse to different demand points. The goal is to determine the optimal quantity of sand to be transported from each warehouse to meet demand while minimizing transportation costs. In this project, the assumption made for the research study is that the company can supply the sand in whatever quantity is required by the demand end. Therefore, the constraint considered is that the supply of sand is equal to the demand for sand. Moreover, each logistics charge a different freight rate for transporting the sand from warehouses to the demand end.

II. METHODS AND TECHNIQUES

➤ *Data Collection:*

The dataset comprises a total of 63,687 rows and 23 columns, representing data collected over one year from April 2022 to March 2023. From these columns, we specifically selected Party Name (Demand End), Warehouses (Supplier End), Quantity of Sand for each transaction, Distance from Warehouses to Parties, and the Cost per Metric Ton.

Secondary data collection involves the utilization of existing data that has been previously collected by other researchers, organizations, or sources. This approach proves valuable when primary data collection is not feasible or when researchers seek to complement their findings with additional information. Conducting a literature review is a common method of gathering secondary data, involving the examination of academic papers, books, and other publications to synthesize relevant information and identify research gaps. Official statistics, such as census data, economic indicators, and health statistics, are compiled and made available by governments and organizations, serving as a valuable resource for researchers to analyze trends and patterns. Online databases offer a vast array of secondary data, including research articles, reports, and datasets, providing researchers with a wealth of information to draw upon. Historical data, sourced from records, archives, and documents, allows researchers to explore past events, social changes, and cultural shifts.

➤ *Solver Methodology:*

The Solver method is a powerful optimization tool commonly used in operations research. It utilizes mathematical models and algorithms to find optimal solutions to complex problems. In this research study, the Solver method will be employed to solve the transportation problem by formulating it as a Linear Programming (LP) or Mixed-Integer Linear Programming (MILP) model.

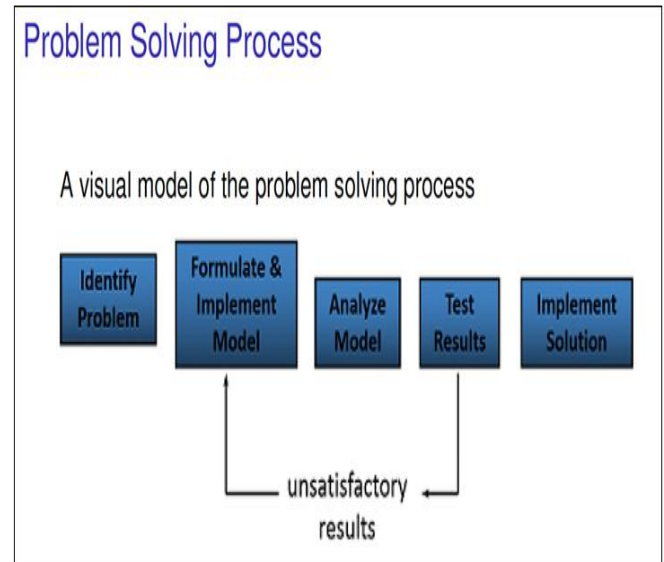


Fig 2 Illustrates the Problem-Solving Process flow that was Employed in our Research Study

The process flow involves identifying the problem, formulating and implementing a model, analyzing its effectiveness, testing results, and finally implementing the solution to address the identified issue [Fig.2].

• *Formulating the Model:*

The first step in the Solver methodology is formulating the model. This involves developing a mathematical representation of the transportation problem. The transportation problem involves determining the optimal allocation of goods from multiple warehouses (sources) to multiple destinations (demand points) while minimizing transportation costs. The model will consider factors such as the capacity of each warehouse, the demand at each location, and the transportation costs associated with each route. In this case, the objective is to minimize the total transportation costs for a sand manufacturing company.

• *Decision Variables:*

Identify the variables to be determined (decision variables) and represent them in terms of algebraic symbols [7]. Let's define the decision variables for the transportation model. Suppose we have 'm' warehouses and 'n' demand points. We can create a matrix of decision variables, denoted as X (i, j), where I represent the warehouse and j represents the demand point. The decision variable X (i, j) represents the quantity of sand transported from warehouse i to destination j.

• *Objective Function:*

The objective of the problem is expressed as a mathematical expression in decision variables.[1] The objective of the model is to minimize the total transportation costs. We can define the objective function as the sum of transportation costs for all pairs of warehouses and demand points.

$$\text{Minimize } Z = C(i, j) * X(i, j)$$

- ✓ Here, C (i, j) represents the transportation cost per unit of sand from warehouse i to destination j.
- ✓ X (i, j) represents the quantity of sand transported from warehouse i to destination j.

• *Constraints:*

The model will include constraints that ensure the total quantity of sand supplied from each warehouse does not exceed its respective capacity and that the total demand at each destination is met. Additionally, constraints may include non-negativity constraints on the decision variables.

- ✓ Total units supplied from each warehouse is equal to the total units available at each warehouse

- ✓ Total units required at each destination are equal to the total units available at each destination.
- ✓ Number of units supplied from the warehouse to the destination is greater than or equal to zero.

• *Solver Implementation:*

Once the mathematical model is formulated, it can be implemented using the Solver tool in spreadsheet software like Microsoft Excel. The Solver algorithm will search for the optimal solution by adjusting the decision variables within the defined constraints, ultimately minimizing transportation costs. Follow these steps to implement the Solver methodology.

- ✓ From the given data identified unique warehouses (sources) and destinations (demand point), and determined the supply and demand values for each warehouse and destination respectively, as well as the average distance and freight rate for each combination.[1]
- ✓ We have constructed a table in a spreadsheet to mention the determined supply and demand values for each warehouse and destination (demand point), average distance, and freight rate for each combination [Fig. 3, 4, 5, 6][4].

Max Supply	
Warehouse	Supply
Warehouse 1	
Warehouse 2	
Warehouse 3	
Warehouse 4	
Total Supply	

Fig 3 Shows the Value of the Maximum Supply of Sand Production in each Warehouse

Demand Per Customer	
Customer Name	Demand
Customer 1	
Customer 2	
Customer 3	
Customer 4	
Customer 5	
Total Demand	

Fig 4 Shows the Value of the Maximum Quantity of Sand Required for each Customer

Avg Distance From Warehouse To Destination					
Warehouse	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
Warehouse 1					
Warehouse 2					
Warehouse 3					
Warehouse 4					

Fig 5 Shows the Average Distance (Round Trip Distance) from Respective Warehouses to Customer Places

Freight Rate From Warehouse To Destination					
Warehouse	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
Warehouse 1					
Warehouse 2					
Warehouse 3					
Warehouse 4					

Fig 6 Shows the Average Freight Rate from Respective Warehouses to Destination

- We Constructed a Table in a Spreadsheet to Calculate the Transportation Cost [Fig.7].

Transportation Cost From Warehouse To Destination					
Warehouse	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
Warehouse 1					
Warehouse 2					
Warehouse 3					
Warehouse 4					

Fig 7 Shows the Transportation Cost Associated with each Warehouse and Destination Calculated using the below-Mentioned Formula.

Transportation Cost = Average Distance *Freight Rate

the Destination and Constraints. Entered the Supply and Demand Values from [Fig.3,4] Respectively [5].

- We then Constructed a Table in a Spreadsheet to Specify the Decision Variable cells that Represent the Quantity of Sand to Transport from the Respective Warehouse to

✓ Constraints:

- Total Out = Supply
- Total In = Demand
- $X_{ij} \geq 0$

Decision Variable								
Quantity Of Sand To Transport From Warehouse To Destination								
Warehouse	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5	Total Out		Supply
Warehouse 1	X_{ij}	X_{ij}	X_{ij}	X_{ij}	X_{ij}		=	
Warehouse 2	X_{ij}	X_{ij}	X_{ij}	X_{ij}	X_{ij}		=	
Warehouse 3	X_{ij}	X_{ij}	X_{ij}	X_{ij}	X_{ij}		=	
Warehouse 4	X_{ij}	X_{ij}	X_{ij}	X_{ij}	X_{ij}		=	
Total In								
	=	=	=	=	=			
Demand								

Fig 8 Shows the Quantity of Sand to Transport from Respective Warehouse to Destination and Constraints

The presented table visually maps sand transportation allocation, detailing quantities moved from warehouses to customers. It facilitates optimization by ensuring supply-demand equilibrium in transportation strategies [Fig.8].

- We also Constructed a Table in a Spreadsheet to Specify the Objective Function. In this Case, the Objective is to Minimize the Cost [1].

Objective Function
Total Minimum Transportation Cost
₹ 0.00

Fig 9 Shows the Objective Function which has to be Minimized Calculated using the below-Mentioned Formula

The objective function "Total Minimum Cost" is a mathematical expression that aims to minimize the overall cost associated with transporting sand from warehouses to customer destinations [Fig.9].

$$\text{Total Minimum Transportation Cost} = \text{SUMPRODUCT}(\text{Transportation Cost} * \text{Quantity of Sand To Transport From Warehouse To Destination} (X_{ij}))$$

- In this research study we have used Microsoft Office version 2016. Any Microsoft Office version suits the Solver. We clicked the "Data" tab in Microsoft and then selected "Solver" in the Analysis group. If we can't find Solver, we need to ensure that it is enabled in the Add-ins settings. If the Solver add-in is not already installed, we can install it by following the steps: "File" > "Options" > "Add-Ins" and enable the Solver Add-In [Fig.10].

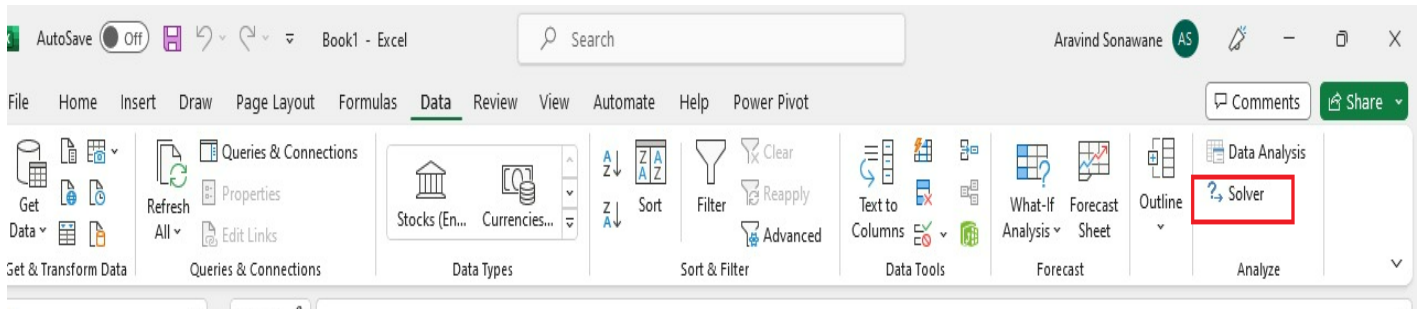


Fig 10 In Microsoft Excel Data Tab we could able to See the Solver Button

*If no tab present we need to follow the below steps: [Fig. 11, 12, 13]



Fig 11 Enhancing their Experience and Optimizing their Workflow

The process involves accessing Excel's settings by clicking on the "Home" tab and then selecting the "Options" button. This step allows users to customize Excel's behaviour and appearance, enhancing their experience and optimizing their workflow [Fig.11].

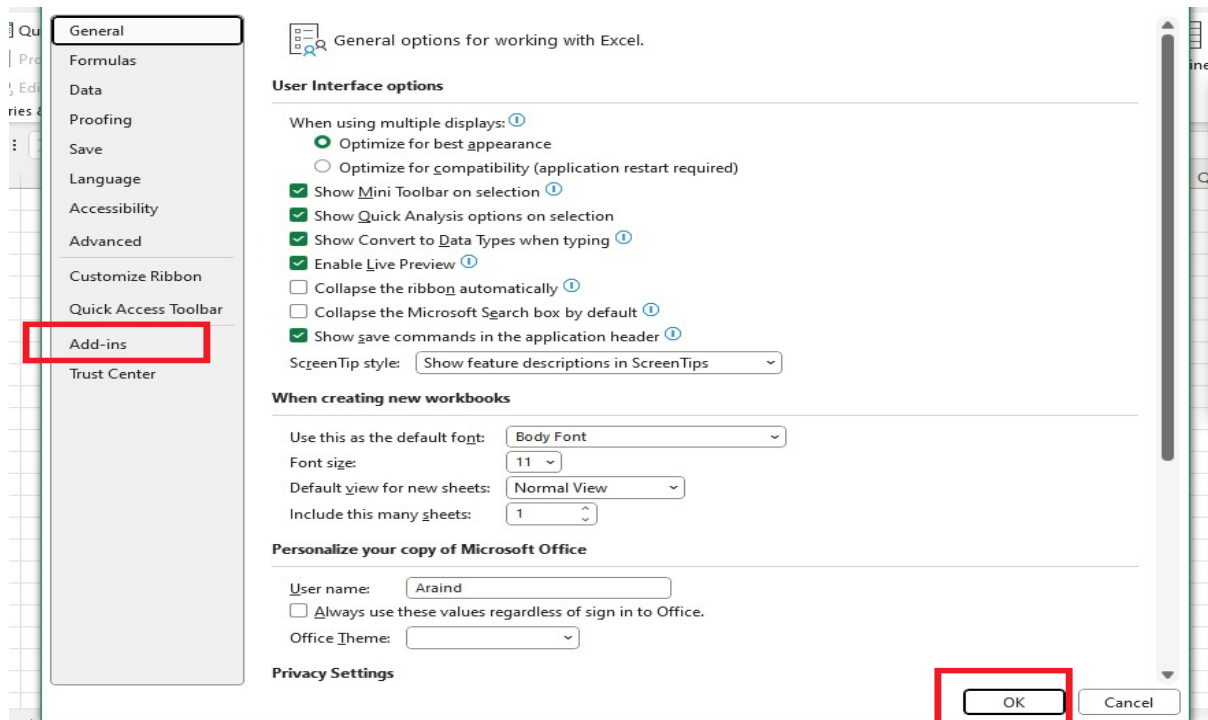


Fig 12 Here we can Select the Relative Add-Ins Options and can click OK button.

This step involves accessing the "Add-ins" option and confirming by clicking the "OK" button, facilitating the integration of additional functionalities within Excel [Fig.12].

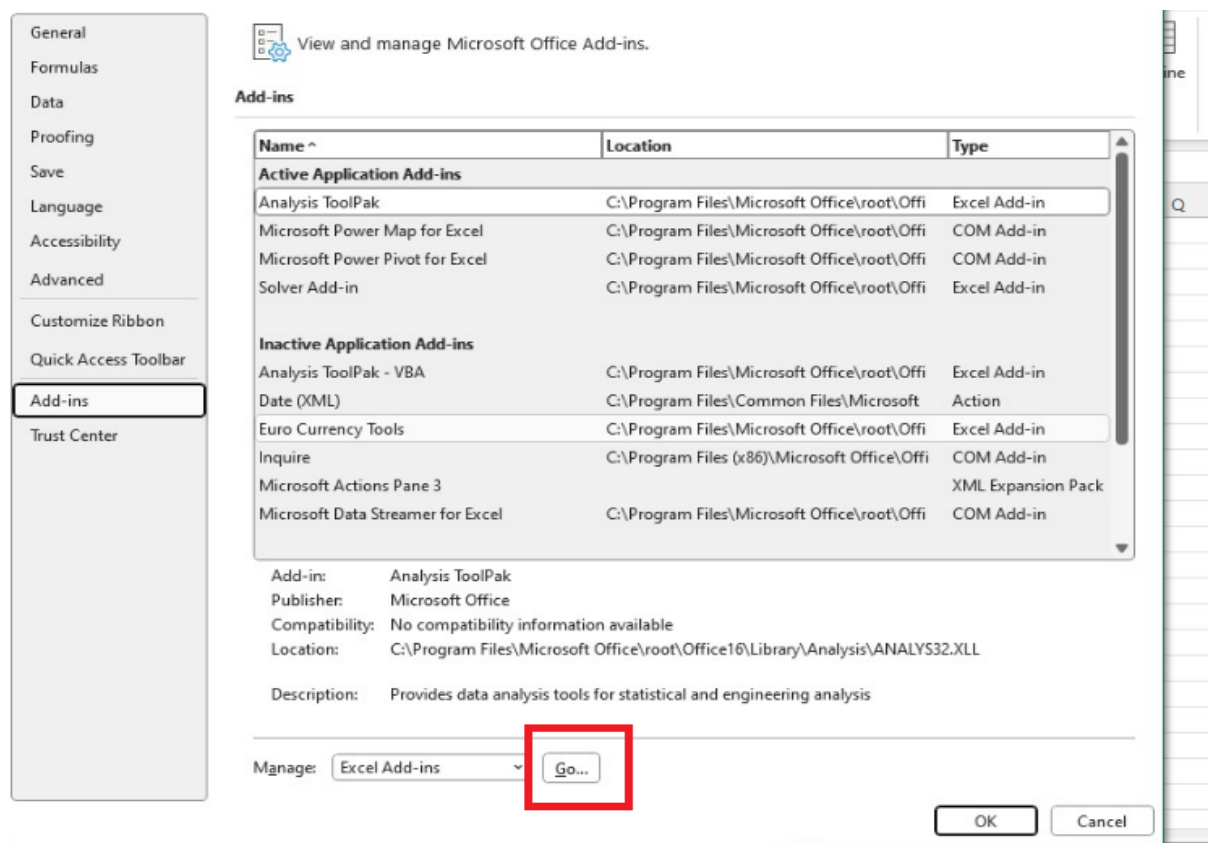


Fig 13 We have Clicked the “Go” Button after we had Clicked the add-ins Button.

After clicking the "Add-ins" button, proceeding by clicking the "Go" button initiates the process to manage and activate Excel's available add-ins for enhanced functionality [Fig.13].

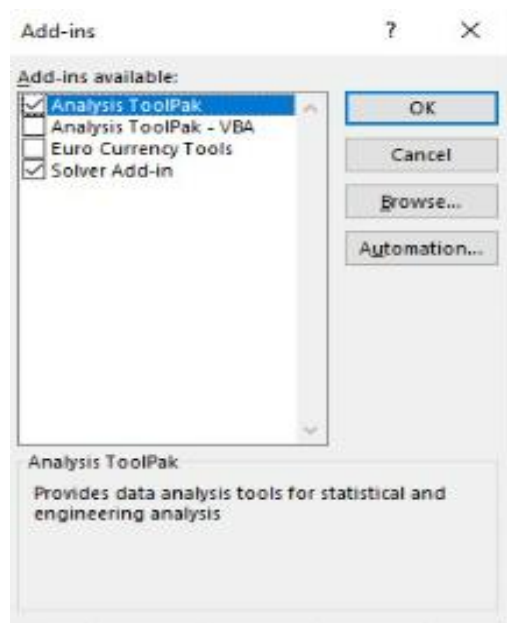


Fig 14 Here we Need to be Select the “Analyse ToolPak” and “Solver Add-in” box and click the OK button.

- In the Solver Parameters dialog box, we have selected the objective function as ‘min’, constraints were added using the ‘Add’ button, solving method was selected as ‘Simplex LP’, and then the ‘Solve’ button. Once the solver found solution results were displayed for decision variable cells [Fig.15] and objective function cell.

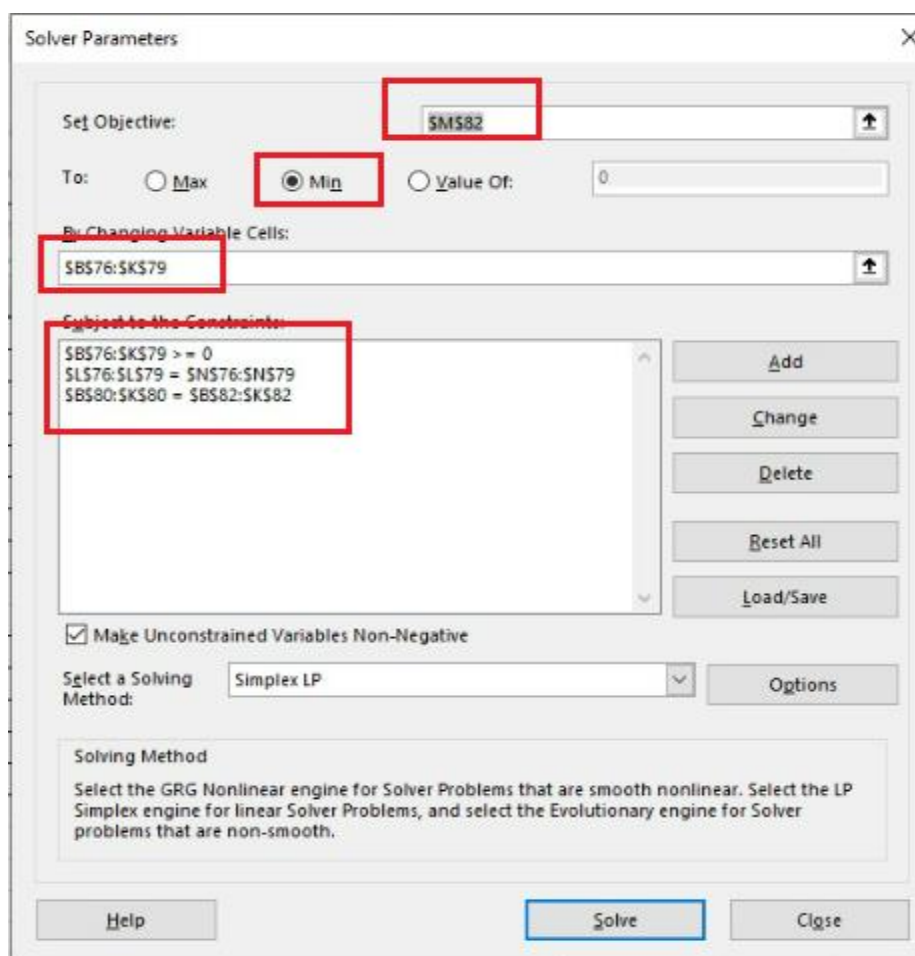


Fig 15 Shows that needs to select Objectives (Min), Decision variables and the constraints we used.

➤ *The Second Method we use is Python -Pulp Library*

The Pulp library, also known as PuLP (Python Linear Programming), is a popular Open-Source Linear Programming (LP) modelling package for the Python Programming language. It provides a high-level interface for creating Linear and Mixed-Integer programming models and solving them using various optimization solvers.

PuLP allows users to define decision variables, objective functions, and constraints concisely and intuitively. It supports a wide range of mathematical operations, such as addition, subtraction, multiplication, and division, allowing users to express complex optimization problems.

Additionally, PuLP offers a variety of solver interfaces, enabling users to choose from a range of external optimization solvers to solve their models. These solvers include both open-source solvers like CBC (Coin-or Branch and Cut), GLPK (GNU Linear Programming Kit), and SCIP (Solving Constraint Integer Programs), as well as commercial solvers like Gurobi, and Xpress.

By leveraging the capabilities of the PuLP library, users can efficiently formulate and solve Linear programming problems in Python, making it a valuable tool for optimization tasks in various domains such as supply chain management, logistics, scheduling, and resource allocation.

III. RESULTS AND DISCUSSIONS

With the help of the PuLP library and Microsoft Solver method, we have successfully minimized the sand transportation costs for given data. The results indicate the effectiveness of this approach in achieving significant cost reductions. The optimized allocation of different transportation routes, well-organized logistics process, and improved resource utilization and overall profitability by saving shipment (transportation) costs.

➤ *We Got Optimized Transportation Costs In Different Scenarios as:*

- *Actual Freight Rate -5.57% reduction in transportation cost.*
- *Common Freight rate for each warehouse -14.53 % reduction in transportation cost.*
- *Combination of different Freight rates - 9.38 % reduction in transportation cost.*
- *Freight rate in Rupees based on customer - 10.42 % reduction in transportation cost.*

The Solver methodology, with its user-friendly spreadsheet interface, provided a quick and effective way to evaluate different scenarios and make informed decisions. On the other hand, the PuLP library offered a more flexible and powerful approach, allowing for complex modelling and the incorporation of additional constraints and objectives.

Overall, the research study demonstrated the practicality and effectiveness of the Solver methodology and the PuLP library in optimizing transportation costs. By minimizing costs, the sand manufacturing company was able to enhance its overall supply chain performance, provide better customer service, and gain a competitive advantage in the market.

IV. CONCLUSION

This paper has given an overview of different methodologies used in minimizing the transportation cost. We have developed a model for supply chain planning by using the PuLP library and Microsoft Solver methodology. This study demonstrates the effectiveness of the Pulp Library and Microsoft Solver method in minimizing sand transportation costs. By optimizing the allocation of sand shipments across various transportation routes, we achieved significant cost reductions. The streamlined logistics process resulting from this optimization strategy improves resource utilization and enhances overall profitability.

Depending on one's requirement in the future we can use any scenario from the above 4 scenarios, which will help to get optimum solution. We can explore research for the future by some additional factors like fluctuations in fuel prices, seasonal variations, and time constraints, to create a more comprehensive and dynamic sand transportation cost minimization model. The application of this method to other industries and Supply Chain Management of logistics scenarios could provide valuable insights into cost optimization in diverse contexts.

V. ACKNOWLEDGMENTS

We acknowledge that with the consent from 360DigiTMG, we have used the Python Programming Mindmap (ak.1) which is available as open-source in the official website of 360DigiTMG.

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- *The authors declare that they have no relevant financial or non-financial interests to disclose.*

➤ *Author Contributions:*

Author Bharani Kumar Depuru has conceptualized the research and development of the model and provided with the necessary technical resources, also guided and directed the study. Aivarajan S.N led the research and contributed to the analysis and model development. Material preparation, data collection and analysis were performed by Shreya.S and Ankita Yadav under the guidance of Aivarajan S.N and Bharani Kumar Depuru. The first draft of the manuscript was written by Shreya.S and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

➤ *Data Availability Statement:*

The datasets used, generated and/or analysed during this study are not publicly available due to internal Data Privacy Policy but are available from the corresponding author on reasonable request.

➤ *Compliance with Ethical Standards*

• *Disclosure of Potential Conflicts of Interest:*

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

• *Research involving Human Participants and/or Animals:*

It is declared by all the authors that there was no involvement of any human and/or animal trial or test in this research.

• *Informed consent:*

As there were no human subject involved in this research hence a informed consent is not applicable to the best of the authors' understanding.

• *Conflict of Interest Statement:*

The authors declare that there are no conflicts of interest that could influence the results or interpretation of this manuscript. This research was conducted in an impartial and unbiased manner, and there are no financial, personal, or professional relationships that might be perceived as having influenced the content or conclusions presented in this work.

REFERENCES

- [1]. Khan, Muztoba. (2014). Transportation Cost Optimization Using Linear Programming. International Conference on Mechanical, Industrial and Energy Engineering 2014 26-27 December 2014, Khulna, BANGLADESH. ICMIEE-PI-140224.
- [2]. Vamsikrishna, A. & Raj, Vigneshwar & Sharma S G, Divya. (2021). Cost Optimization for Transportation Using Linear Programming. https://doi.org/10.1007/978-981-16-0976-3_2.
- [3]. Uzorh, Engr & Nnanna, Innocent. (2014). Supply Chain Management Optimization Problem. <https://doi.org/10.13140/RG.2.2.19682.58566>.
- [4]. Oba, Kenneth & Abere, Abiye. (2023). Optimization of Shipping Cost of Sand for Selected Construction Projects of Julius Berger. 12. 16-20. <https://doi.org/10.5923/j.ijcem.20231201.02>.
- [5]. Çerkini, Bashkim & Bajrami, Roberta & Kosova, Robert & Shehu, Valentina. (2015). Transportation Cost Optimization. Academic Journal of Interdisciplinary Studies. <https://doi.org/10.5901/ajis.2015.v4n2s1p42>.