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1. INTRODUCTION

1.1 Project Scope

Linear programming is a method used to find the optimal solution to a problem with multiple constraints. One common application of linear programming is in the field of transportation, where the goal is to minimize the cost of transporting goods from multiple sources to multiple destinations.

To solve a transportation problem using linear programming, we first need to set up the problem as a linear program. This involves defining the decision variables, the objective function, and the constraints. The decision variables in a transportation problem are the amounts of goods to be shipped from each source to each destination. The objective function is typically the total cost of transportation, and the constraints are the limits on the availability of goods at the sources and the demand at the destinations.

Once the linear program has been set up, we can use a mathematical algorithm to find the optimal solution. This solution will minimize the total cost of transportation while satisfying all of the constraints.

Linear programming can solve many types of transportation problems, from simple ones with only a few sources and destinations, to more complex problems with many different types of goods and varying transportation costs. By using linear programming to find the optimal solution, businesses can save money and reduce the environmental impact of their transportation operations.

1.2 Problem Domain

Defining the problem domain is an important step in setting up a linear program, as it helps to clearly identify the decision variables, objective function, and constraints that need to be considered in the optimization. For example, in a transportation problem with three sources and two destinations, the problem domain would include the availability of goods at each source, the demand for goods at each destination, and the cost of transporting goods from each source to each destination.

Knowing the problem domain can also help to determine the appropriate mathematical algorithms and methods to use in solving the linear program. Different problem domains may require different approaches to optimization, and understanding the specific characteristics of the problem can help to find the most efficient solution.

1.3 Problem Evaluation

1.3.1 Company Details

As our client, we contacted one of the country's leading textile companies, Moose Clothing, located in Ja-Ela. Moreover, we requested the transportation cost data (from the MOOSE finance manager) for each delivery from two garments to selected five warehouses and distance to the warehouse, and the time duration. After the garment gave us the requested data, we performed a data preprocessing task and made tables according to the vehicle type. We also considered the distance from each garment to the selected warehouse.

In Appendix A – The company details attached with the appendix and Warehouse locations

1.3.2 Problem Identification

Moreover, let us discuss what we identified from the client's end as their problem. They have two manufacturing warehouses and two specific types of lorries to transport the products to different destinations. One of these two can load up to 750 kilos, and the other has a loading capacity of 1920 kilos, and the client is very keen to find an optimal way to transport the goods with a minimum cost.

1.3.3 Advantages of an improved Transportation Flow

MOOSE company hasn't a proper way to transport their apparel, and they mentioned the high cost of transportation. And the author identified this issue as a major issue for their company. Finally, the author decided to optimize transportation costs, and it will be given many advantages for our selected company. As a result, without any delays, the company can carry its units to the locations, can reduce their additional cost, and supply its units at a fair cost.

1.3.4 Research Objectives

The final objective of this paper is to find the most convenient way to transport apparel from garments to distributors using their selected trucks and minimize the transportation cost of the trucks.

LITERATURE REVIEW

A literature review on linear programming transport cost minimization problem would typically involve a summary and evaluation of previous research on the topic.

One key area of research in this field is the development of efficient algorithms for solving linear programming transport cost minimization problems. In a paper published in the journal Transportation Science, Lee et al. (2015) proposes a column generation algorithm for solving large-scale linear programming transport cost minimization problems. The authors demonstrate the effectiveness of their algorithm through numerical experiments, showing that it outperforms existing methods in terms of both solution quality and computational time.

Another important aspect of research in this area is the application of linear programming techniques to real-world transport cost minimization problems. For example, in a paper published in the journal European Journal of Operational Research, Al-Hussain et al. (2013) use linear programming to solve a transport cost minimization problem for a logistics company in Saudi Arabia. The authors develop a mathematical model that considers various constraints, such as capacity limits and time windows, and use this model to determine the optimal routes and quantities for the company's deliveries.

In 2007 by Albright, S., Zielinski, D., and Bazzan, A. (2007) titled "A review of linear programming approaches for transport cost minimization in logistics systems." In this paper, the authors review the various linear programming techniques that have been developed for minimizing transport costs in logistics systems, including the classical transportation model, the transshipment model, and the capacitated location model.

Another important reference is a paper by C. Sriskandarajah and P. T. Harker (1991) titled "Minimizing transportation costs: A review of models and algorithms." In this paper, the authors review the various mathematical programming models and algorithms that have been developed for minimizing transportation costs, including the classical transportation model, the transshipment model, the assignment model, and the location-allocation model.

Additionally, a paper by K. G. Murty (1983) titled "Linear programming methods for transportation problems" provides a comprehensive overview of the classical transportation model and its variants, including the northwest corner, minimum-cost cell, and Vogel's approximation methods. The paper also discusses the application of duality theory to transportation problems and the use of sensitivity analysis to identify optimal solutions.

In conclusion, the linear programming transport cost minimization problem literature is rich and diverse, covering both algorithmic developments and real-world applications. Researchers have made significant progress in developing efficient algorithms and applying these methods to real-world problems.

2. PROBLEM MODELING

3.1 Data Gathering

After contacting our client, we requested the transportation cost data spent on each delivery from two garments to selected five warehouses, the distance to the warehouse, and the time duration. After the garment gave us the requested data, we performed a data preprocessing task and made tables according to the vehicle type. Also, we considered the distance from each garment to the selected warehouse.In Appendix B – The author requested data from the company attached to this appendix(dataset)

Problem Formulation

3.2.1 Network Flow for both Vehicles

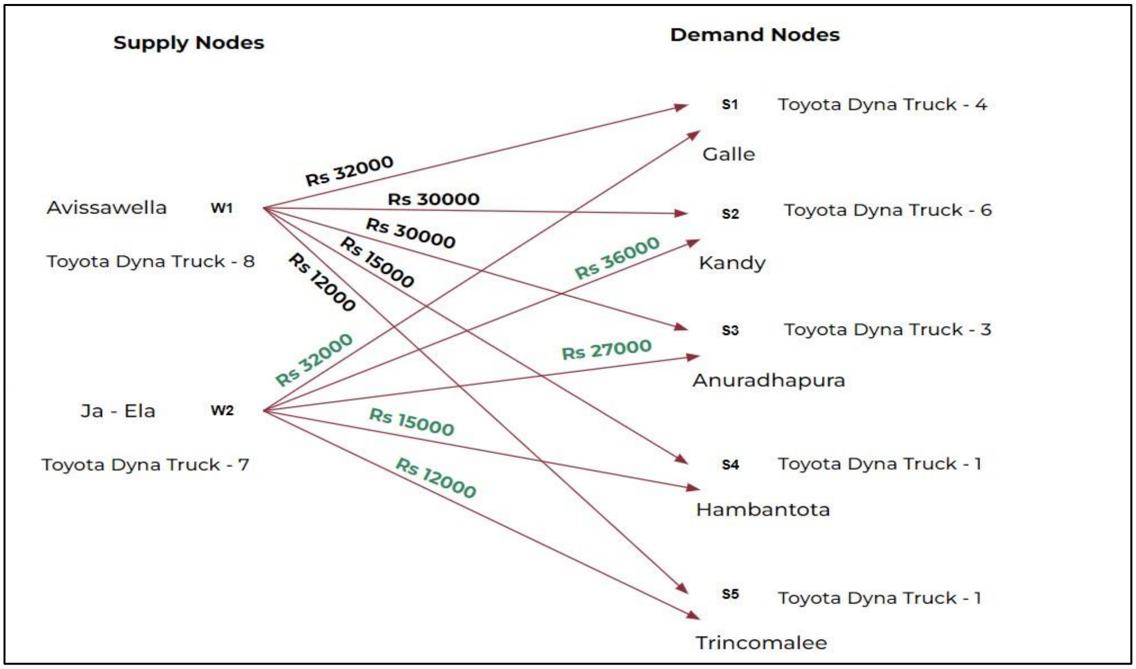


Figure 1. Network flow for Dyna Truck

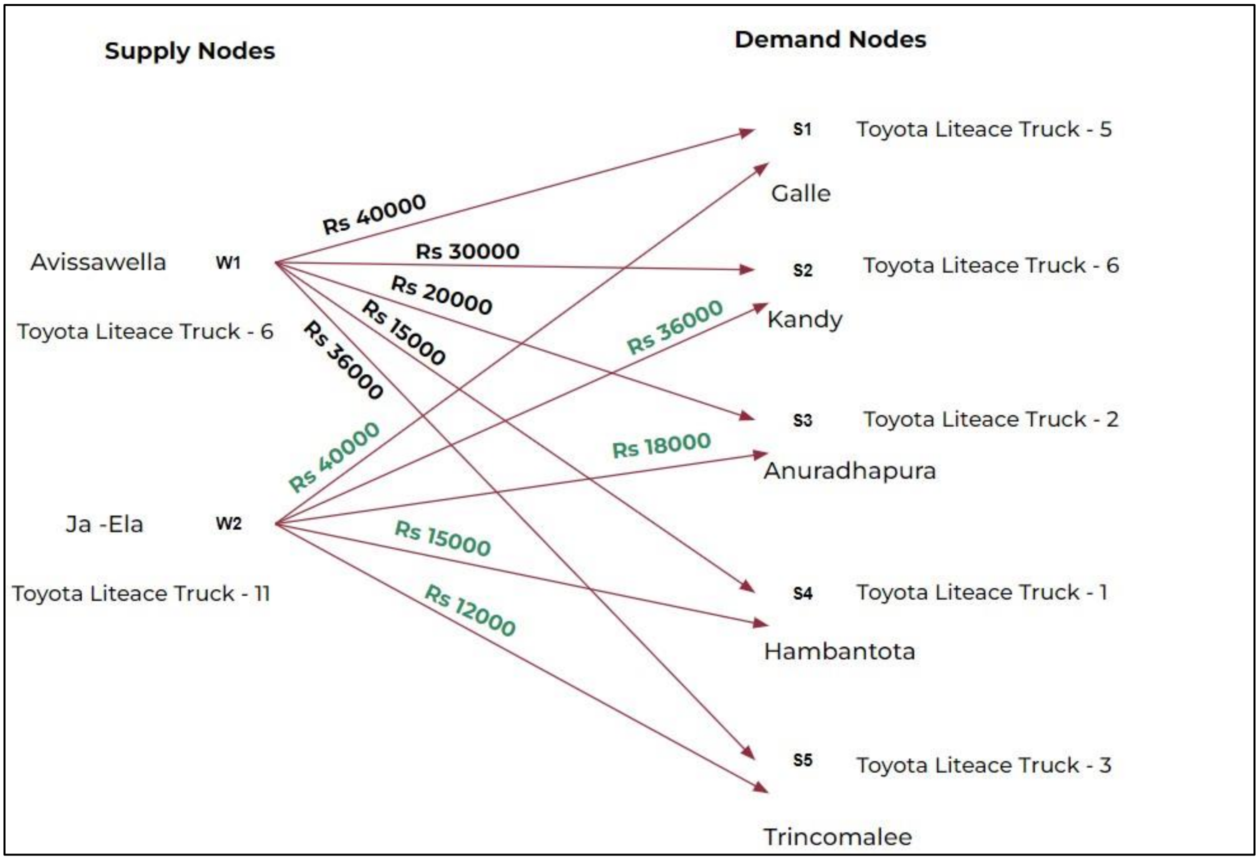


Figure 2. Network flow for Lite Ace truck

3.2.2 Decision variables, Objective Functions, Constraints

There are four basic components of the Linear Programming model. They're.

- Decision variables: A variable represents an unknown quantity (how many items to make, how much money to invest, etc.).
- Objective function (Z): In the decision variables, you can express the objective mathematically. Profit maximization or cost minimization are two examples of objectives.
- Constraints: What the problem requires or limits.
- Non-negativity constraints

The decision variables found by the company are mentioned below.

W1 – Warehouse 01, which located in Ja-Ela

W2 – Warehouse 02, which located in Avissawella

S1 – Supplier 01 in Galle

S2 – Supplier 02 in Kandy

S3 – Supplier 03 in Anuradhapura

S4 – Supplier 04 in Hambanthota

S5 – Supplier 05 in Trincomalee

A. TOYOTA Dyna Trucks

Decision Variable

X_{ij} = Number of loaded 1920KG Trucks (Dyna trucks) traveled from warehouse i to distribution location j

Objective Function

Minimize Z = 32000W1S1 + 30000W1S2 + 30000W1S3 + 15000W1S4 + 12000W1S5 + 32000W2S1 + 36000W2S2 + 27000W2S3 + 15000W2S4 + 12000W2S5

Constraints of Supply

W1S1 + W1S2 + W1S3 + W1S4 + W1S5 = 8

W2S1 + W2S2 + W2S3 + W2S4 + W2S5 = 7

Constraints of Demand

W1S1 + W2S1 >= 4

W1S2 + W2S2 >= 6

W1S3 + W2S3 >= 3

W1S4 + W2S4 >= 1

W1S5 + W2S5 >= 1

B. TOYOTA Lite Ace Truck

Decision Variable

X_{ij} = Number of 750KG Trucks (Lite Ace Trucks) traveled from warehouse i to distribution location j

Objective Function

Minimize Z = 40000W2S1 + 30000W1S2 + 20000W1S3 + 15000W1S4 + 36000W1S5 + 40000W2S1 + 36000W2S2 + 18000W2S3 + 15000W2S4 + 12000W2S5

Constraint of Supply

W1S1 + W1S2 + W1S3 + W1S4 + W1S5 = 6

W2S1 + W2S2 + W2S3 + W2S4 + W2S5 = 11

Constraints of Demand

W1S1 + W2S1 >= 5

W1S2 + W2S2 >= 6

W1S3 + W2S3 >= 2

W1S4 + W2S4 >= 1

W1S5 + W2S5 >= 3

3. PROBLEM-SOLVING

In this section fully demonstrate about Excel solver and how to use this for find the optimal solution for transport cost.

Step for formulating LP model,

- Identify the decision variables
- Identify the objective functions
- State the constraints
- Use Excel Solver for solution

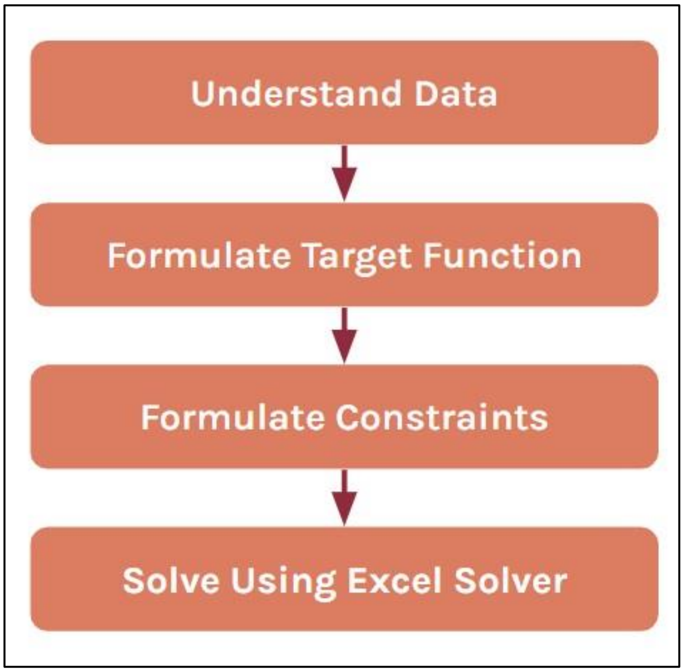


Figure 3. Steps of Solving

The first step is to add all the data to a table properly. When solving this type of problem using a solver, unstructured data is too much, and we must add all the data clearly on the table. It is easy to solve the problem and take a good idea.

The second step is to check whether total supply and total demand are equal or not. When taking the addition of all the supplies from two warehouses and taking all the demand from the wholesalers. After we can check whether this problem is feasible or not.

Total Supply = Total Demand (Feasible Problem)

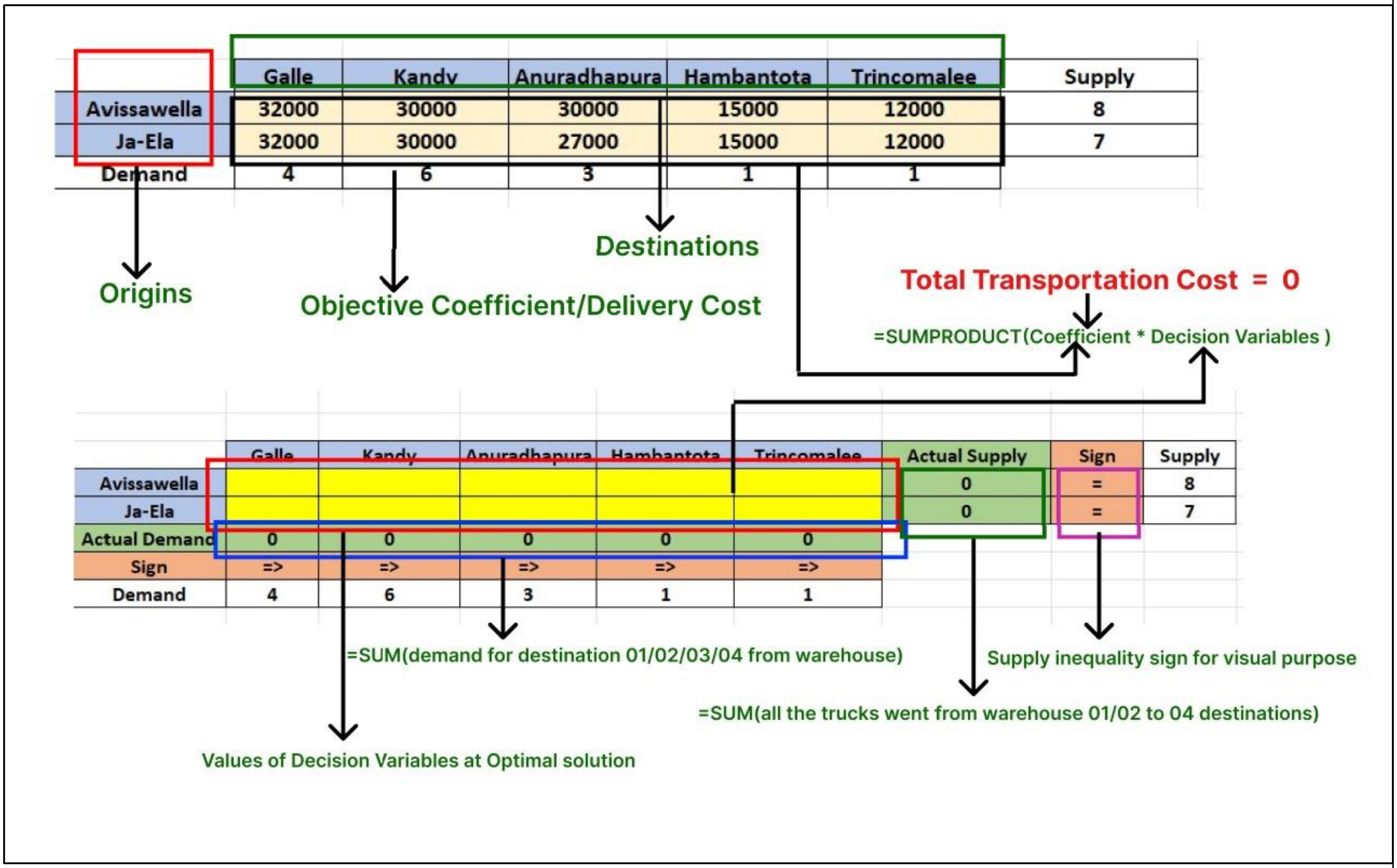
Total Supply != Total Demand (Unfeasible Problem)

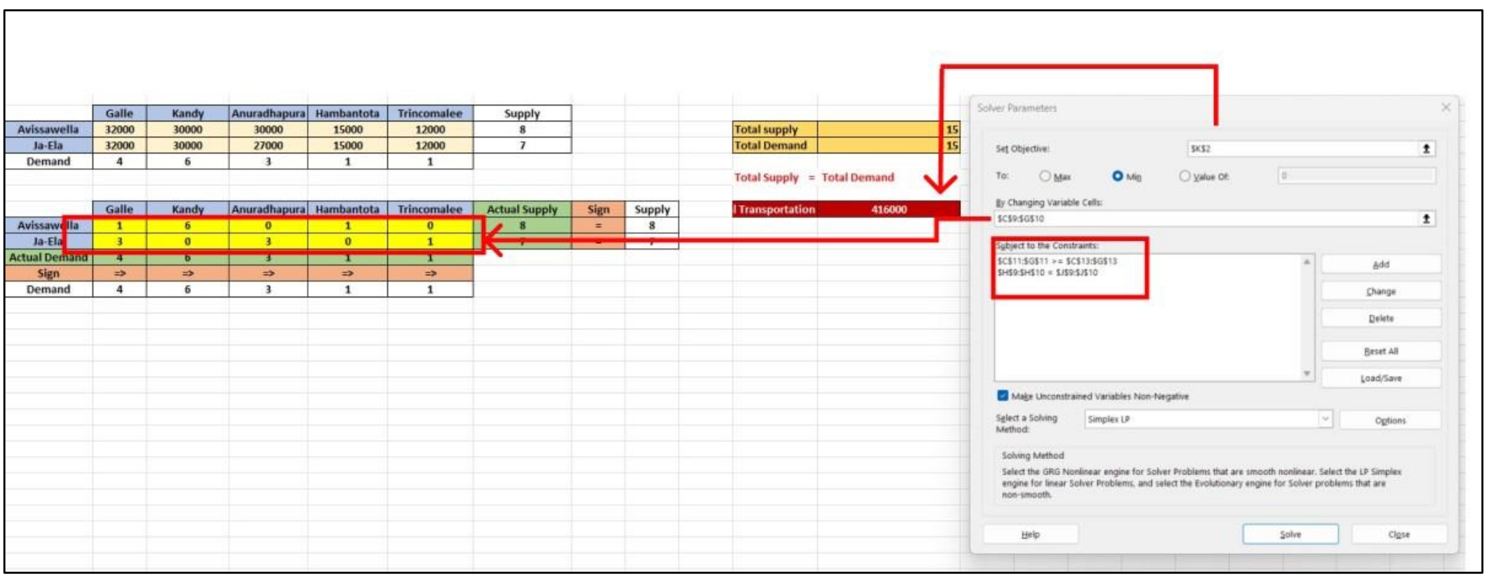
This is a feasible problem

The third step is setup equations on tables (for this attached image to explain more)

Then Use the SUMPRODUCT function to calculate the minimum cost.

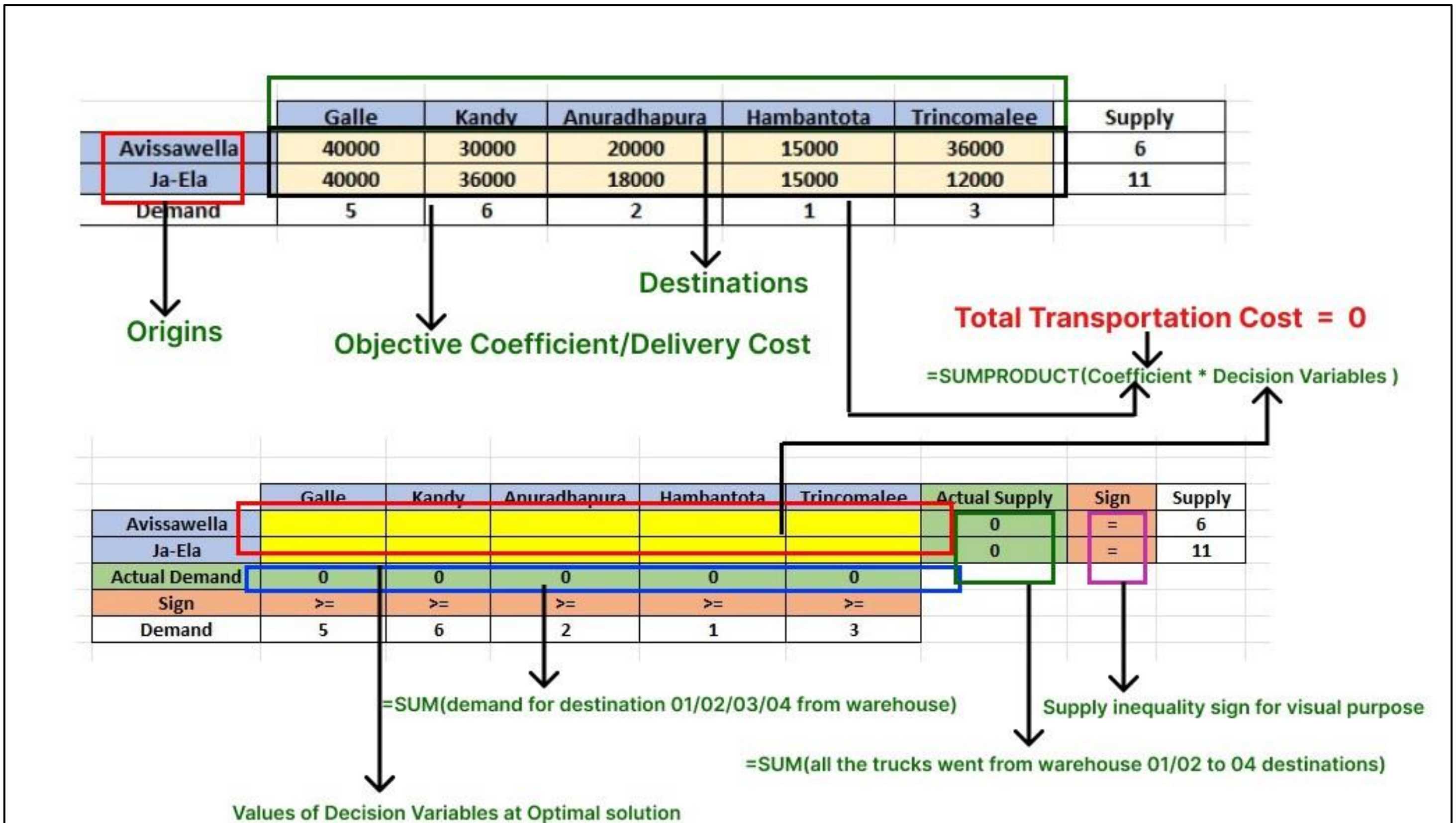
3.1 For Toyota Dyna Trucks

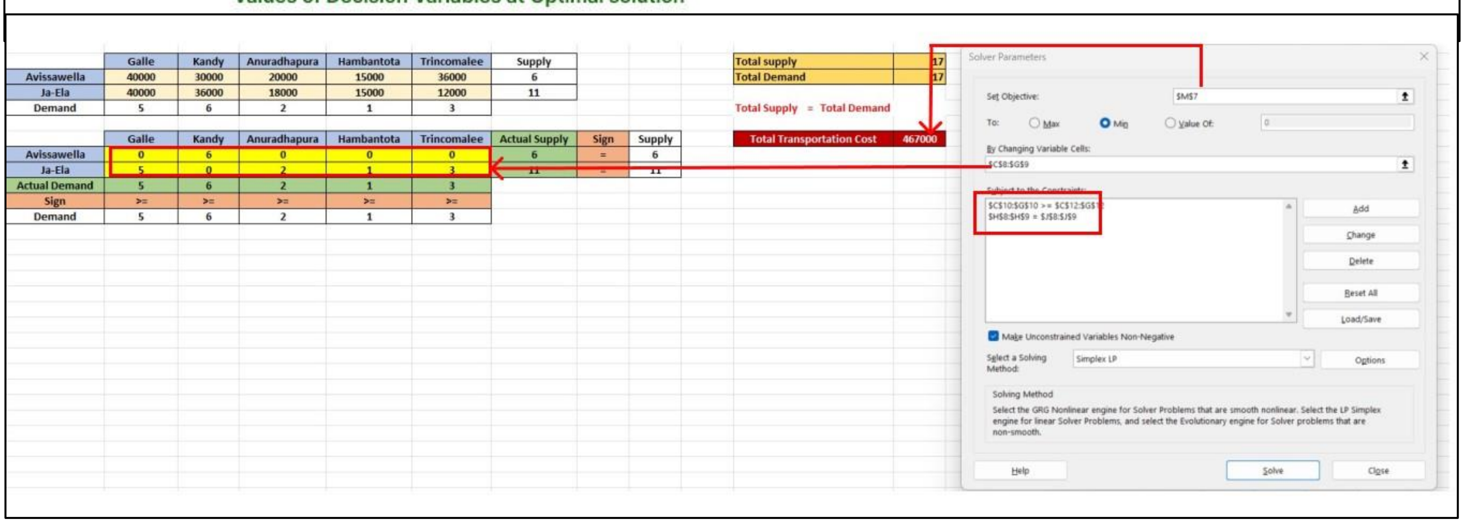




	Galle	Kandy	Anuradhapura	Hambantota	Trincomalee	Actual Supply	Sign	Supply
Avissawella	1	6	0	1	0	8	=	8
Ja-Ela	3	0	3	0	1	7	=	7
Actual Demand	4	6	3	1	1			
Sign	=>	=>	=>	=>	=>			
Demand	4	6	3	1	1			
Total Transportation Cost	416000							

3.2 For Toyota Lite Ace Truck





	Galle	Kandy	Anuradhapura	Hambantota	Trincomalee	Actual Supply	Sign	Supply
Avissawella	0	6	0	0	0	6	=	6
Ja-Ela	5	0	2	1	3	11	=	11
Actual Demand	5	6	2	1	3			
Sign	>=	>=	>=	>=	>=			
Demand	5	6	2	1	3			
Total Transportation Cost	467000							

Figure 5.Solution for Toyota Lite Ace Truck

4. Evaluation of the solution

Figures 4 and 5 display how many trucks and which type of truck to assign the delivery, and also some of the trucks were not delivering the items to some selected destinations. As a figure, the Toyota Lite Ace truck didn't deliver the items for the destination Kandy from Ja-Ela's warehouse. Moreover, the Toyota Lite Ace truck only delivered items for Kandy from the Avissawella. It didn't deliver any items for other areas.

And also, the Toyota Dyna truck didn't deliver the items for the destination Kandy and Hambanthota from Ja-Ela's warehouse; the Toyota Dyna truck only delivered items for Galle, Kandy, and Hambanthota from Avissawella. It didn't deliver any items for other areas.

TOYOTA Dyna Truck

Garment	Supply	Distribution Location
Ja-Ela	3	Galle
	3	Anuradhapura

Garment	Supply	Distribution Location
Avissawella	1	Galle
	6	Kandy
	1	Hambantota

TOYOTA LiteAce Truck

Garment	Supply	Distribution Location
Ja-Ela	5	Galle
	2	Anuradhapura
	1	Hambantota
	3	Trincomalee

Garment	Supply	Distribution Location
Avissawella	6	Kandy

4.1 Sensitivity Analysis Report

In appendix 6

5. REFLECTION

As technology advances, linear programming has become more effective. This has been widely applied to companies. The effectiveness and efficiency of the method can be proven through an example analysis. With linear programming, you can calculate transportation costs quickly and easily. Optimize the transportation plan to make the company more profitable and competitive. Moreover, our research decided to construct a transportation optimization model to solve the issue. A total of two warehouses and five destinations are included in this paper. This transportation model is optimized by using an EXCEL solver, and by using linear programming, the author can reduce the transportation cost of company MOOSE. As a result, the company transport cost was reduced to LKR 883,000, and the company profited LKR 35,000. Finally, we can conclude that this linear programming model helps reduce their transport cost by a considerable amount.

6. References

Choudhari, S., & Tindwani, A. (2017). Logistics optimisation in road construction project. *Construction Innovation*, *17*(2), 158–179. https://doi.org/10.1108/CI-03-2016-0014/FULL/XML

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Xia, Q., Ye, Z., Zhang, Z., & Lu, T. (2022). *Multi-objective optimization of aircraft landing within predetermined time window*. *4*, 198. https://doi.org/10.1007/s42452-022-05071-3

7. Appendix

In Appendix A – The company details attached with the appendix and Warehouse locations

MOOSE CLOTHING COMPANY

A Level 1 clothing company based in Sri Lanka Est. in 2018, Parented by Brandix.

Contact details

No. 71, Ganemulla Road, Weligampitiya Church Road, Ja-Ela

076 346 6673

hello@mooseclothingcompany.com

In Appendix C – Sensitivity Reports

Microsoft Excel 16.0 Sensitivity Report
Worksheet: [Excel Solver.xlsx]Toyota LiteAce
Report Created: 12/12/2022 3:41:30 AM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
C8	Avissawella Galle	0	0	40000	0	6000
D8	Avissawella Kandy	6	0	30000	6000	18000
E8	Avissawella Anuradhapura	0	2000	20000	1E+30	2000
F8	Avissawella Hambantota	0	0	15000	1E+30	0
G8	Avissawella Trincomalee	0	24000	36000	1E+30	24000
C9	Ja-Ela Galle	5	0	40000	6000	0
D9	Ja-Ela Kandy	0	6000	36000	1E+30	6000
E9	Ja-Ela Anuradhapura	2	0	18000	2000	6000
F9	Ja-Ela Hambantota	1	0	15000	0	3000
G9	Ja-Ela Trincomalee	3	0	12000	3000	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C10	Actual Demand Galle	5	28000	5	0	5
D10	Actual Demand Kandy	6	18000	6	0	5
E10	Actual Demand Anuradhapura	2	6000	2	0	2
F10	Actual Demand Hambantota	1	3000	1	0	1
G10	Actual Demand Trincomalee	3	0	3	0	1E+30
H8	Avissawella Actual Supply	6	12000	6	5	0
H9	Ja-Ela Actual Supply	11	12000	11	1E+30	0

Figure 6. Sensitivity Report for Dyna Truck

Microsoft Excel 16.0 Sensitivity Report
Worksheet: [Excel Solver.xlsx]Toyota LiteAce
Report Created: 12/12/2022 3:41:30 AM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
C8	Avissawella Galle	0	0	40000	0	6000
D8	Avissawella Kandy	6	0	30000	6000	18000
E8	Avissawella Anuradhapura	0	2000	20000	1E+30	2000
F8	Avissawella Hambantota	0	0	15000	1E+30	0
G8	Avissawella Trincomalee	0	24000	36000	1E+30	24000
C9	Ja-Ela Galle	5	0	40000	6000	0
D9	Ja-Ela Kandy	0	6000	36000	1E+30	6000
E9	Ja-Ela Anuradhapura	2	0	18000	2000	6000
F9	Ja-Ela Hambantota	1	0	15000	0	3000
G9	Ja-Ela Trincomalee	3	0	12000	3000	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C10	Actual Demand Galle	5	28000	5	0	5
D10	Actual Demand Kandy	6	18000	6	0	5
E10	Actual Demand Anuradhapura	2	6000	2	0	2
F10	Actual Demand Hambantota	1	3000	1	0	1
G10	Actual Demand Trincomalee	3	0	3	0	1E+30
H8	Avissawella Actual Supply	6	12000	6	5	0
H9	Ja-Ela Actual Supply	11	12000	11	1E+30	0

Figure 7. Sensitivity Report for lite Ace Truck