Optimization of Distribution Model & Milk Cost at Heritage Dairy

By

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Summary

The optimization model presented is used for finding the most optimal cost of transportation for distributing the milk from the distribution center to all the customer locations of Heritage Dairy Company. Transportation includes a significant proportion of the expenditure for the dairy industry. To get the minimal cost of transportation we must make sure we have the correct data such as the capacity of the truck which transports the milk from the distribution center to all the six customer locations, the distance between each source and destination points of the transportation, extra charges that need to be paid to travel from source to destination.

We were able to secure some amount of data from one of the supervisors and managers of Heritage dairy Company. The data provided by them has helped us run the optimization model to analyze the most optimal cost for transporting the milk from source to destination. The data included the variables such as Shipping costs per truck, the weekly demand at each customer location, capacities of distribution centers, quantity of milk that needed to be transported, and finally the number of trucks that travel to each customer location.

We have also executed some research to make sure we are using the right optimization model to analyze the data and derive the optimal transportation cost for all the locations overall. Once we were able to decide on the right optimization model, we made use of the Microsoft Excel along with an extra add-in called the Solver add-in to develop an optimization model for the most optimal cost of transportation. We were also able to develop a sensitivity report using one-way analysis in the Solver Model to be able to understand the sensitivity analysis better and to derive a conclusion based on the report. Based on our analysis, we came up with some insights and recommendations which would help Heritage optimize their costs.

Introduction

Company

The Heritage Diary company is a well reputed packaged milk company in the South Indian Region as well as the North Indian Region in different cities around India because of their quality milk and their affordable prices. Most of the milk sold by Heritage Diary is bought from the local farmers at three locations called Sanghvi, Rai and Gokul. In this process, the distribution and packaging centers play a crucial role in collecting the milk from farmers on time, packaging the milk and then distributing the milk to all the customer locations using milk trucks. The demand varies from location to location because of competition from other local brands, but Heritage Diary has proven to be a trustworthy company among a few customer locations which makes it the one of the popular brands for buying milk.

Problem

In order to ensure a sustainable supply chain system and smooth business flow, Heritage needs to continuously meet the demand across various locations with sufficient amounts of storage in distribution centers and timely distribution. It becomes more complex when there are many delivery locations and distribution centers to meet the demand. However, an optimized design of the supply chain with a good record of data could make the process efficient and easier. This project helps in optimizing such a supply chain system by reducing the overstock and meeting the demand of delivery locations and therefore reducing the costs from the data observed.

Proposed Solution

Heritage dairy typically distributes the milk in large trucks with only 3000-liter capacity. Transportation costs generally include labor costs, vehicle service costs, fuel costs and toll charges. Utilizing the historical transportation cost data and the demand data received from the company officials, we used the data for demand in liters across multiple locations and the average cost per truck for distribution from distribution center to delivery locations to analyze and build an optimal solution for the costs incurred on transportation of milk from distribution centers, so we can reduce the possible loss from overstocking. To make this happen, we make use of the linear optimization models and its tools such as the solver add-in and generate some sensitivity reports to get an understanding of how to minimize the transportation cost.

Main Chapter

Data Collection

To solve the problem of least transportation cost requires shipping costs from each distribution center to the customer location, the storage capacities of the distribution centers and the weekly demands of the six customer locations. Upon approaching the manager for the data, he provided us with the data of shipping costs of a single truck to transport 3000 liters of milk from each distribution center to each customer location, the weekly demand of milk for 3 years i.e. for 156 weeks of all the customer locations and the storage capacities of the distribution centers directly in excel files. The first 10 weeks demands for each of the customer locations are shown in the Table 1.

Table 1: Weekly demands of the milk for customer locations

Weeks	Bangalore	Chennai	Mysore	Hyderabad	Haryana	Tirupathi
1	552080	847223	820125	649266	447492	356065
2	581612	724358	778444	675432	434849	362160
3	497834	807848	760041	626512	508464	350548
4	532542	882657	785555	681258	421911	365249
5	573318	794817	767269	676520	455494	382459
6	605068	915346	772851	645207	401225	351515
7	521871	851275	724795	666058	459766	355311

8	560642	830059	727400	623084	432904	348554
9	578412	963669	701797	708222	452937	344065
10	512921	841963	772420	649990	410769	360152

Data Analysis

Analyzing the data for the model took multiple steps. Firstly, the weekly demands of all the customer locations are needed to establish the requirement constraints from available data. To achieve this, the best fit distribution for the weekly demand data was fitted using the Risk add-in in excel. Open the fit icon in the Risk add-in in excel and then specify a range that contains the data to be fitted as shown in Figure 1. The best fit for the weekly demand data of Chennai is the normal distribution and the result is copied to the cell L2 (Figure 3) using the ‘Write to Excel’ icon in the right bottom of Figure 2. Similarly, the best fit values are obtained for all the weekly demands of other customer locations from the Best fit model in excel and presented in Table 2.

Table 2: Weekly demands obtained from the best fit distribution using Risk in excel.

Bangalore	Chennai	Mysore	Hyderabad	Haryana	Tirupathi
554121	852364	755042	649258	447289	355063

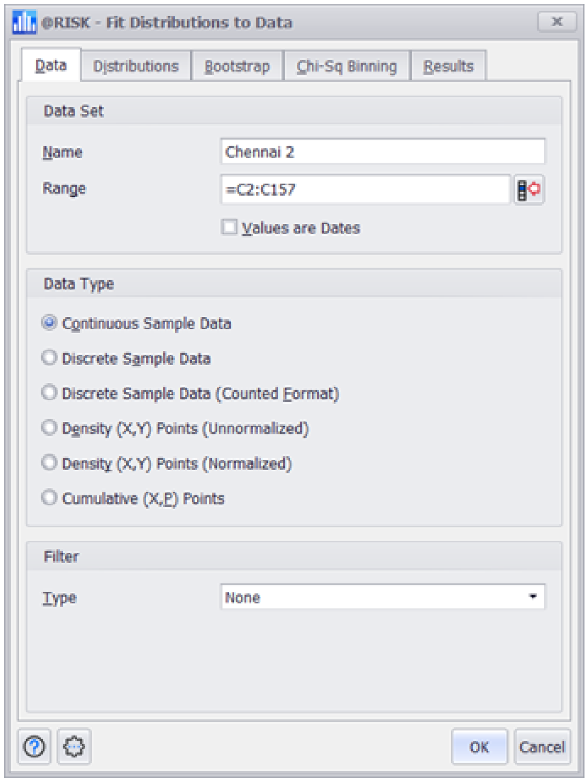


Figure 1: Specify the range of data(Chennai column)

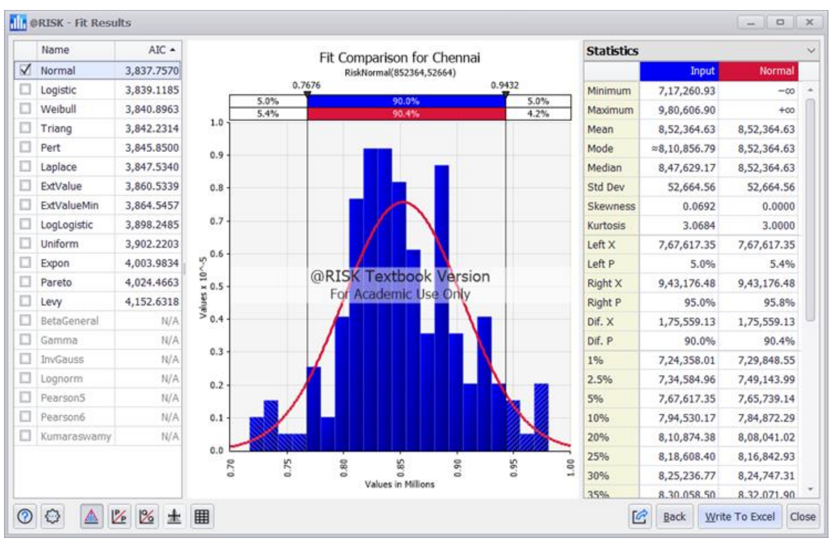


Figure 2: Best fit output for weekly demand of Chennai (Normal Distribution)

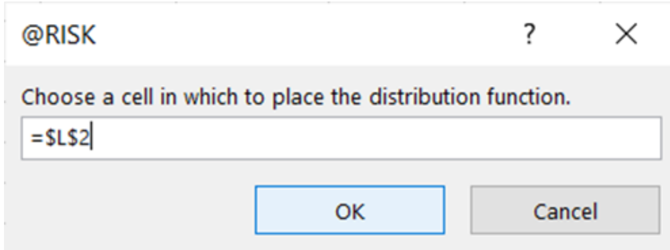


Figure 3: Best fit distribution function value in the cell

Optimization Model

Once we were done with data retrieval, we were ready to create the model. Our model's decision variables, inputs, objective function and constraints are shown in Table 3, Table 4, Table 5, and Table 6 respectively.

Table 3: To commence with the model, we have following ***Decision Variables***

Decision Variable	Definition
S_1	Quantity of milk delivering from Sangvi to Bangalore
S_2	Quantity of milk delivering from Sangvi to Mysore
S_3	Quantity of milk delivering from Sangvi to Chennai
S_4	Quantity of milk delivering from Sangvi to Hyderabad
S_5	Quantity of milk delivering from Sangvi to Haryana
S_6	Quantity of milk delivering from Sangvi to Tirupati
R_1	Quantity of milk delivering from Rai to Bangalore

R_2	Quantity of milk delivering from Rai to Mysore
R_3	Quantity of milk delivering from Rai to Chennai
R_4	Quantity of milk delivering from Rai to to Hyderabad
R_5	Quantity of milk delivering from Rai to Haryana
R_6	Quantity of milk delivering from Rai to Tirupati
G_1	Quantity of milk delivering from Gokul to Bangalore
G_2	Quantity of milk delivering from Gokul to Mysore
G_3	Quantity of milk delivering from Gokul to Chennai
G_4	Quantity of milk delivering from Gokul to Hyderabad
G_5	Quantity of milk delivering from Gokul to Haryana
G_6	Quantity of milk delivering from Gokul to Tirupati

Table 4: For the ***Inputs*** we have the following

Inputs	**Definition**	**Given Values**
S_{1cost}	Cost of transportation from Sangvi to Bangalore	290
S_{2cost}	Cost of transportation from Sangvi to Mysore	397

S_{3cost}	Cost of transportation from Sangvi to Chennai	127
S_{4cost}	Cost of transportation from Sangvi to Hyderabad	201
S_{5cost}	Cost of transportation from Sangvi to Haryana	337
S_{6cost}	Cost of transportation from Sangvi to Tirupati	133
R_{1cost}	Cost of transportation from Rai to Bangalore	301
R_{2cost}	Cost of transportation from Rai to Mysore	106
R_{3cost}	Cost of transportation from Rai to Chennai	256
R_{4cost}	Cost of transportation from Rai to Hyderabad	318
R_{5cost}	Cost of transportation from Rai to Haryana	132
R_{6cost}	Cost of transportation from Rai to Tirupati	394
G_{1cost}	Cost of transportation from Gokul to Bangalore	225
G_{2cost}	Cost of transportation from Gokul to Mysore	204
G_{3cost}	Cost of transportation from Gokul to Chennai	212

G_{4cost}	Cost of transportation from Gokul to Hyderabad	137
G_{5cost}	Cost of transportation from Gokul to Haryana	239
G_{6cost}	Cost of transportation from Gokul to Tirupati	254
SQ_1	Number of trucks for transportation from Sangvi to Bangalore	$S_1/3000$
SQ_2	Number of trucks for transportation from Sangvi to Mysore	$S_2/3000$
SQ_3	Number of trucks for transportation from Sangvi to Chennai	$S_3/3000$
SQ_4	Number of trucks for transportation from Sangvi to Hyderabad	$S_4/3000$
SQ_5	Number of trucks for transportation from Sangvi to Haryana	$S_5/3000$
SQ_6	Number of trucks for transportation from Sangvi to Tirupati	$S_6/3000$
RQ_1	Number of trucks for transportation from Rai to Bangalore	$R_1/3000$
RQ_2	Number of trucks for transportation from Rai to Mysore	$R_2/3000$
RQ_3	Number of trucks for transportation from Rai to Chennai	$R_3/3000$
RQ_4	Number of trucks for transportation from Rai to Hyderabad	$R_4/3000$

RQ_5	Number of trucks for transportation from Rai to Haryana	$R_5/3000$
RQ_6	Number of trucks for transportation from Rai to Tirupati	$R_6/3000$
GQ_1	Number of trucks for transportation from Gokul to Bangalore	$G_1/3000$
GQ_2	Number of trucks for transportation from Gokul to Mysore	$G_2/3000$
GQ_3	Number of trucks for transportation from Gokul to Chennai	$G_3/3000$
GQ_4	Number of trucks for transportation from Gokul to Hyderabad	$G_4/3000$
GQ_5	Number of trucks for transportation from Gokul to Haryana	$G_5/3000$
GQ_6	Number of trucks for transportation from Gokul to Tirupati	$G_6/3000$

Our objective in this case is to minimize the shipping/transportation cost of milk.

Table 5: Here is the ***Objective Function***

Objective Function	**Definition**
Minimize the cost: $[(S_{1cost}*SQ_1) + (S_{2cost}*SQ_2) + (S_{3cost}*SQ_3) + (S_{4cost}*SQ_4) + (S_{5cost}*SQ_5) + (S_{6cost}*SQ_6) + (R_{1cost}*RQ_1) + (R_{2cost}*RQ_2) + (R_{3cost}*RQ_3) + (R_{4cost}*RQ_4) + (R_{5cost}*RQ_5) + (R_{6cost}*RQ_6) + (G_{1cost}*GQ_1) + (G_{2cost}*GQ_2) + (G_{3cost}*GQ_3) + (G_{4cost}*GQ_4) + (G_{5cost}*GQ_5) + (G_{6cost}*GQ_6)]$	To minimize the cost of milk distribution we have to add all the products of cost of transportation from each distribution center to the customer location and the number of trucks required for transferring the milk from distribution center to customer location.

Table 6: For this model, we have the following ***Constraints***

Constraints	Equation
Weekly demand of milk in Bangalore, in liters	$S_1 + R_1 + G_1 <= 554121$
Weekly demand of milk in Mysore, in liters	$S_2 + R_2 + G_2 <= 852364$
Weekly demand of milk in Chennai, in liters	$S_3 + R_3 + G_3 <= 755042$
Weekly demand of milk in Hyderabad, in liters	$S_4 + R_4 + G_4 <= 649258$
Weekly demand of milk in Haryana, in liters	$S_5 + R_5 + G_5 <= 447289$
Weekly demand of milk in Tirupathi, in liters	$S_6 + R_6 + G_6 <= 355063$
Total storage capacity of distribution center at Sangvi, in liters	$S_1 + S_2 + S_3 + S_4 + S_5 + S_6 <= 1400000$
Total storage capacity of distribution center at Rai, in liters	$R_1 + R_2 + R_3 + R_4 + R_5 + R_6 <= 1600000$
Total storage capacity of distribution center at Gokul, in liters	$G_1 + G_2 + G_3 + G_4 + G_5 + G_6 <= 700000$

Non-negativity	$S_1, S_2, S_3, S_4, S_5, S_6, R_1, R_2, R_3, R_4, R_5, R_6, G_1, G_2, G_3, G_4, G_5, G_6 >= 0$

Solution Results and Analysis

The Solver solution is obtained by using the Linear Optimization model that appears in Figure 4. The dairy incurs a total transportation cost of $180303.36 by using the shipments listed in Figure. Except for the eighteen routes shown, no other routes are used. Most of the shipments occur on the low-cost routes, but this is not always the case. For example, the route from Rai to Bangalore is relatively expensive, but it is used. On the other hand, the route from Gokul to Chennai is relatively cheap, but it is not used. A good shipping plan tries to use cheap routes, but it is constrained by capacities and demands.

We also observed that the available capacity is not all used. The reason is that total capacity is 3700000 liters, whereas total demand is only 36,13,137. Even though the demand constraints are of the "≥" type, there is clearly no reason to send the regions more than they request because it only increases shipping costs. Therefore, the optimal plan sends them the minimal amounts they request and no more. In fact, the demand constraints could have been modeled as "=" constraints, and Solver would have reached exactly the same solution.

Unit Shipping Cost, in $

Distribution centers	Customer Locations							Truck Capacity	3000
	Bangalore	Mysore	Chennai	Hyderabad	Haryana	Tirupathi			
Sangvi	290	397	127	201	337	133			
Rai	301	106	256	318	132	394			
Gokul	225	204	212	137	239	254			

Decision Variables

	Customer Locations									
Distribution centers	Bangalore	Mysore	Chennai	Hyderabad	Haryana	Tirupathi		Total Distributed		Capacity
Sangvi	0	0	755042	289895	0	355063		1400000	<=	1400000
Rai	213484	852364	0	0	447289	0		1513137	<=	1600000
Gokul	340637	0	0	359363	0	0		700000	<=	700000
Total	554121	852364	755042	649258	447289	355063				
	>=	>=	>=	>=	>=	>=				
Weekly Demand	55412114	852364	755042	649258	447289	355063				

No. of trucks

	Customer Locations						
Distribution centers	Bangalore	Mysore	Chennai	Hyderabad	Haryana	Tirupathi	Total
Sangvi	0	0	251.6807	96.6316667	0	118.3543	466.6667
Rai	71.1613333	284.121333	0	0	149.0963	0	504.379
Gokul	113.545667	0	0	119.787667	0	0	233.3333

Objective function

Minimize total shipping cost	180303.36

Figure 4: Data Sheet

Microsoft Excel 16.0 Sensitivity Report
Worksheet: [Project- Distribution model at Heritage.xlsx]Sheet1
Report Created: 11-03-2022 16:45:59

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
D13	Sangvi Bangalore	0	0.00033333	0.09666667	1E+30	0.00033333
E13	Sangvi Mysore	0	0.101	0.13233333	1E+30	0.101
F13	Sangvi Chennai	755042	0	0.04233333	0.039	0.04633333
G13	Sangvi Hyderabad	289895	0	0.067	0.000333333	0.039
H13	Sangvi Haryana	0	0.07233333	0.11233333	1E+30	0.07233333
I13	Sangvi Tirupathi	355063	0	0.04433333	0.061666667	0.04833333
D14	Rai Bangalore	213484	0	0.10033333	0.035	0.004
E14	Rai Mysore	852364	0	0.03533333	0.058	0.03533333
F14	Rai Chennai	0	0.039	0.08533333	1E+30	0.039
G14	Rai Hyderabad	0	0.035	0.106	1E+30	0.035
H14	Rai Haryana	447289	0	0.044	0.061	0.044
I14	Rai Tirupathi	0	0.083	0.13133333	1E+30	0.083
D15	Gokul Bangalore	340637	0	0.075	0.000333333	0.035
E15	Gokul Mysore	0	0.058	0.068	1E+30	0.058
F15	Gokul Chennai	0	0.04966667	0.07066667	1E+30	0.04966667
G15	Gokul Hyderabad	359363	0	0.04566667	0.035	0.00033333
H15	Gokul Haryana	0	0.061	0.07966667	1E+30	0.061
I15	Gokul Tirupathi	0	0.06166667	0.08466667	1E+30	0.06166667

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
D17	Total Bangalore	554121	0.10033333	554121	86863	213484
E17	Total Mysore	852364	0.03533333	852364	86863	852364
F17	Total Chennai	755042	0.04633333	755042	86863	213484
G17	Total Hyderabad	649258	0.071	649258	86863	213484
H17	Total Haryana	447289	0.044	447289	86863	447289
I17	Total Tirupathi	355063	0.04833333	355063	86863	213484
K13	Sangvi Total Distribute	1E+06	-0.004	1400000	213484	86863
K14	Rai Total Distributed	2E+06	0	1600000	1E+30	86863
K15	Gokul Total Distributec	700000	-0.02533333	700000	213484	86863

Figure 5: Sensitivity Report

Sensitivity Analysis

There are many sensitivities analyses we could perform on this basic transportation model. For example, we could vary any one of the unit shipping costs, capacities, or demands. The effect of any such change in a single input is captured nicely in Solver's sensitivity report, shown in Figure. The top part indicates the effects of changes in the unit shipping costs. The results here are typical. For all routes with positive flows, the corresponding reduced cost is zero, whereas for all routes not currently being used, the reduced cost indicates how much less the unit shipping cost would have to be before the company would start shipping along that route. For example, if the objective coefficient (shipping cost per liter of milk) from Sangvi to Mysore decreased by more than 0.101, this route would become attractive. In other words, if the shipping cost per truck from Sangvi to Mysore decreased by more than $303 (=0.101*3000=$303), this route would become attractive.

The bottom part of Figure is useful because of its shadow prices. For example, centers Sangvi and Gokul are currently shipping all of their capacity, so the company would benefit from having more capacity at these centers. In particular, the report indicates that each extra unit of capacity at Sangvi and Gokul is actually reducing the shipping cost by 0.4 cents and 2.533 cents respectively. Meaning, increase in storage capacity at Sangvi and Gokul reduces the shipping cost by further optimizing the supply chain system. However, because the allowable increase for each of these is 213484, you know that after an increase in capacity of 213484 at either center, further increases will probably be worth less than the current shadow prices.

One-Way Analysis for Gokul

In this one-way analysis we are considering Total capacity of Gokul as an input. The total capacity of Gokul in the optimization model is 700000 but here we will observe the difference in objective and decision variables by changing the total capacity of Gokul. The minimum value kept is 500000, the maximum value is 2000000 and the increment will take place by 50000. With these values when we ran our one-way analysis we got "Not Feasible" as a result from 500000 to 600000. From 650000, if we observe our shipping cost i.e., objective function we will notice the shipping cost is the highest on 650000 by 181570 and then it kept on decreasing till 1200000 to 168783. From 1250000 the objective cost is insensitive with increasing capacity of Gokul to 2000000 by $168711. Another observation is decision variables S1, S2, S5, R3, R4, R6, G2, G3, G5 and G6 are zero(0) in all the scenarios, which means in those decision variables distribution centers are not supplying to those customer locations. Also, decision variables S3, S6, R2 and R5 are insensitive to the increasing total capacity of the Gokul distribution center. Where decision variables S4 and G1's demand gradually increases and then become insensitive as total capacity increases of Gokul and the demand decreases of decision variables R1 and G4 as the Gokul's total capacity increases.

Oneway analysis for Solver model in Optimization Model worksheet

capacity of Sangvi (cell M21) values along side, output cell(s) along top

	D39	D21	E21	F21	G21	H21	I21	D22	E22	F22	G22	H22	I22	D23	E23	F23	G23	H23	I23	Data for chart D39
500000	Not feasible																			Not feasible
550000	Not feasible																			Not feasible
600000	Not feasible																			Not feasible
650000	Not feasible																			Not feasible
700000	Not feasible																			Not feasible
750000	Not feasible																			Not feasible
800000	Not feasible																			Not feasible
850000	Not feasible																			Not feasible
900000	Not feasible																			Not feasible
950000	Not feasible																			Not feasible
1000000	Not feasible																			Not feasible
1050000	Not feasible																			Not feasible
1100000	Not feasible																			Not feasible
1150000	Not feasible																			Not feasible
1200000	Not feasible																			Not feasible
1250000	Not feasible																			Not feasible
1300000	Not feasible																			Not feasible
1350000	180503	0	0	755042	239895	0	355063	263484	852364	0	0	447289	0	290637	0	0	409363	0	0	180503
1400000	180303	0	0	755042	289895	0	355063	213484	852364	0	0	447289	0	340637	0	0	359363	0	0	180303
1450000	180103	0	0	755042	339895	0	355063	163484	852364	0	0	447289	0	390637	0	0	309363	0	0	180103
1500000	179903	0	0	755042	389895	0	355063	113484	852364	0	0	447289	0	440637	0	0	259363	0	0	179903
1550000	179703	0	0	755042	439895	0	355063	63484	852364	0	0	447289	0	490637	0	0	209363	0	0	179703
1600000	179503	0	0	755042	489895	0	355063	13484	852364	0	0	447289	0	540637	0	0	159363	0	0	179503
1650000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
1700000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
1750000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
1800000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
1850000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
1900000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
1950000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449
2000000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0	179449

When you select an output from the dropdown list in cell V4, the chart will adapt to that output.

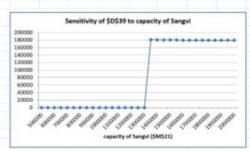
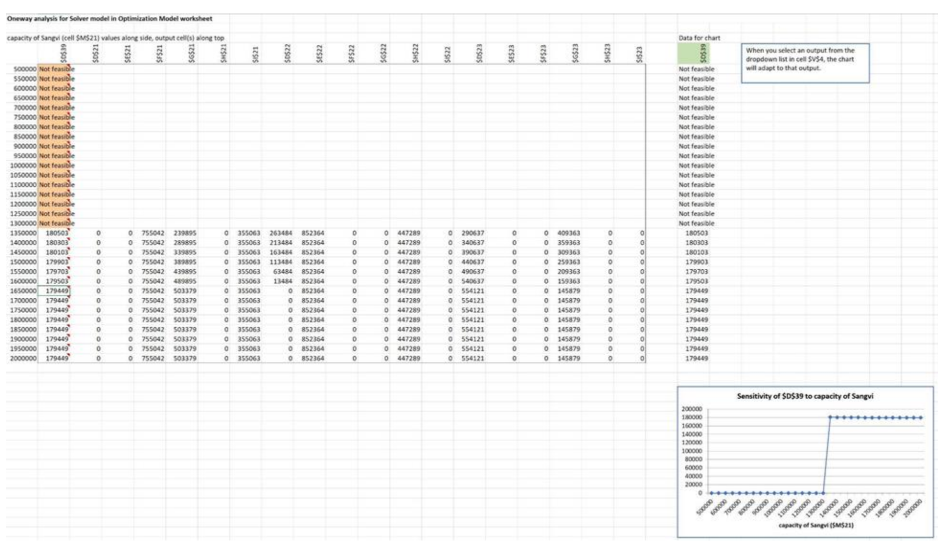


Figure 6: One-Way Analysis for Gokul

One-Way Analysis for Sangvi

In this one-way analysis we are considering Total capacity of Sangvi as an input. The total capacity of Sangvi in the optimization model is 1400000 but here we will observe the difference in objective and decision variables by changing the total capacity of Sangvi. The minimum value kept is 500000, the maximum value is 2000000 and the increment will take place by 50000. With these values when we ran our one-way analysis we got "Not Feasible" as a result from 500000 to 1300000. From 1350000, if we observe our shipping cost i.e., objective function we will notice the shipping cost is the highest on 13500000 by 180503 and then it kept on decreasing till 1600000 to 179503. From 1650000 the objective cost is insensitive with increasing capacity of Sangvi to 2000000 by $179449. Another observation is decision variables S1, S2, S5, R3, R4, R6, G2, G3, G5 and G6 are zero (0) in all the scenarios, which means in those decision variables distribution centers are not supplying to those customer locations. Also, decision variables S3, S6, R2 and R5 are insensitive to the increasing total capacity of the Sangvi distribution center. Where decision variables S4 and G1's demand gradually increases and then one insensitive as total capacity increases of Sangvi and the demand decreases of decision variable R1 and G4 as the Sangvi's total capacity increases.



Oneway analysis for Solver model in Optimization Model worksheet

capacity of Sangvi (cell M21) values along side, output cell(s) along top

	D39	D21	E21	F21	G21	H21	I21	D22	E22	F22	G22	H22	I22	D23	E23	F23	G23	H23	I23
500000	Not feasible																		
550000	Not feasible																		
600000	Not feasible																		
650000	Not feasible																		
700000	Not feasible																		
750000	Not feasible																		
800000	Not feasible																		
850000	Not feasible																		
900000	Not feasible																		
950000	Not feasible																		
1000000	Not feasible																		
1050000	Not feasible																		
1100000	Not feasible																		
1150000	Not feasible																		
1200000	Not feasible																		
1250000	Not feasible																		
1300000	Not feasible																		
1350000	180503	0	0	755042	239895	0	355063	263484	852364	0	0	447289	0	290637	0	0	409363	0	0
1400000	180303	0	0	755042	289895	0	355063	213484	852364	0	0	447289	0	340637	0	0	359363	0	0
1450000	180103	0	0	755042	339895	0	355063	163484	852364	0	0	447289	0	390637	0	0	309363	0	0
1500000	179903	0	0	755042	389895	0	355063	113484	852364	0	0	447289	0	440637	0	0	259363	0	0
1550000	179703	0	0	755042	439895	0	355063	63484	852364	0	0	447289	0	490637	0	0	209363	0	0
1600000	179503	0	0	755042	489895	0	355063	13484	852364	0	0	447289	0	540637	0	0	159363	0	0
1650000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
1700000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
1750000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
1800000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
1850000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
1900000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
1950000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0
2000000	179449	0	0	755042	503379	0	355063	0	852364	0	0	447289	0	554121	0	0	145879	0	0

Data for chart

D39
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
Not feasible
180503
180303
180103
179903
179703
179503
179449
179449
179449
179449
179449
179449
179449
179449

Figure 7: One-Way Analysis for Sangvi

Two-Way Sensitivity Analysis

1.By changing the demands of Mysore and Tirupathi assuming all other demand constraints are fixed, the maximum demand that can be achieved with a trade-off between Mysore and Tirupathi to have optimized supply chain distribution is 950000 liters.

2.Except Sangvi - Hyderabad, the quantity of milk supplied through all other routes from Sangvi are insensitive to the simultaneous changing demands of Mysore and Tirupati.

3. Except Rai - Bengaluru, the quantity of milk supplied through all other routes from Rai are insensitive to the simultaneous changing demands of Mysore and Tirupathi.

4. Except Gokul - Bengaluru, Gokul - Hyderabad the quantity of milk supplied through all other routes from Gokul are insensitive to the simultaneous changing demands of Mysore and Tirupati.

5. By changing the demands of Mysore and Tirupati assuming all other demand constraints are fixed, the supply from Rai to Bengaluru won't have any impact until the combined demand goes beyond 700000 liters.

6. By increasing the demands of Mysore and Tirupati assuming all other demand constraints are fixed, the supply from Sangvi to Hyderabad increases until the combined demand stays within 950000 liters for a feasible solution.

7. By increasing the demands of Mysore and Tirupati assuming all other demand constraints are fixed, the supply from Gokul to Hyderabad decreases until the combined demand stays within 950000 liters for a feasible solution.

demand for Mysore (cell D27) values along side, demand for Tirupathi (cell I27) values along top, output cell in corn

D39	50000	100000	150000	200000	250000	300000	350000	400000	450000	500000	550000	600000
2E+05	131811	134028	136245	138461	140678	142895	145111	147328	149545	151779	154195	156611.8413
3E+05	141445	143661	145878	148095	150311	152528	154745	156979	159395	161812	164229	166645.1747
4E+05	151078	153295	155511	157728	159945	162179	164595	167012	169429	171845	174262	Not feasible
5E+05	160711	162928	165145	167379	169795	172212	174629	177045	179462	Not feas	Not feas	Not feasible
6E+05	170345	172579	174995	177412	179829	182245	184662	Not feas	Not feas	Not feas	Not feas	Not feasible
7E+05	180195	182612	185029	187445	189862	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
8E+05	190229	192645	195062	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
9E+05	200262	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
1E+06	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible

Figure 8: Sensitivity of Shipping cost (objective function) due to variations in the demands of Mysore and Tirupati

G21	50000	100000	150000	200000	250000	300000	350000	400000	450000	500000	550000	600000
2E+05	149258	149258	149258	149258	149258	149258	149258	149258	149258	144958	94958	44958
3E+05	249258	249258	249258	249258	249258	249258	249258	244958	194958	144958	94958	44958
4E+05	349258	349258	349258	349258	349258	344958	294958	244958	194958	144958	94958	Not feasible
5E+05	449258	449258	449258	444958	394958	344958	294958	244958	194958	Not feas	Not feas	Not feasible
6E+05	549258	544958	494958	444958	394958	344958	294958	Not feas	Not feas	Not feas	Not feas	Not feasible
7E+05	594958	544958	494958	444958	394958	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
8E+05	594958	544958	494958	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
9E+05	594958	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
1E+06	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible

Figure 9: Sensitivity of quantity of milk shipped from Sangvi to Hyderabad with variations in the weekly demands of Mysore and Tirupati

D22	50000	100000	150000	200000	250000	300000	350000	400000	450000	500000
2E+05	0	0	0	0	0	0	0	0	0	4300
3E+05	0	0	0	0	0	0	0	4300	54300	104300
4E+05	0	0	0	0	0	4300	54300	104300	154300	204300
5E+05	0	0	0	4300	54300	104300	154300	204300	254300	Not feas
6E+05	0	4300	54300	104300	154300	204300	254300	Not feas	Not feas	Not feas
7E+05	54300	104300	154300	204300	254300	Not feas	Not feas	Not feas	Not feas	Not feas
8E+05	154300	204300	254300	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas
9E+05	254300	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas
1E+06	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas

Figure 10: Sensitivity of quantity of milk shipped from Rai to Bangalore with variations in the weekly demands of Mysore and Tirupati

D23	50000	100000	150000	200000	250000	300000	350000	400000	450000	500000	550000	600000
2E+05	200000	200000	200000	200000	200000	200000	200000	200000	200000	195700	145700	95700
3E+05	300000	300000	300000	300000	300000	300000	300000	295700	245700	195700	145700	95700
4E+05	400000	400000	400000	400000	400000	395700	345700	295700	245700	195700	145700	Not feasible
5E+05	500000	500000	500000	495700	445700	395700	345700	295700	245700	Not feas	Not feas	Not feasible
6E+05	600000	595700	545700	495700	445700	395700	345700	Not feas	Not feas	Not feas	Not feas	Not feasible
7E+05	645700	595700	545700	495700	445700	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
8E+05	645700	595700	545700	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
9E+05	645700	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
1E+06	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible

Figure 11: Sensitivity of quantity of milk shipped from Gokul to Bangalore with variations in the weekly demands of Mysore and Tirupati

G23	50000	100000	150000	200000	250000	300000	350000	400000	450000	500000	550000	600000
2E+05	500000	500000	500000	500000	500000	500000	500000	500000	500000	504300	554300	604300
3E+05	400000	400000	400000	400000	400000	400000	400000	404300	454300	504300	554300	604300
4E+05	300000	300000	300000	300000	300000	304300	354300	404300	454300	504300	554300	Not feasible
5E+05	200000	200000	200000	204300	254300	304300	354300	404300	454300	Not feas	Not feas	Not feasible
6E+05	100000	104300	154300	204300	254300	304300	354300	Not feas	Not feas	Not feas	Not feas	Not feasible
7E+05	54300	104300	154300	204300	254300	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
8E+05	54300	104300	154300	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
9E+05	54300	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible
1E+06	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feas	Not feasible

Figure 12: Sensitivity of quantity of milk shipped from Gokul to Hyderabad with variations in the weekly demands of Mysore and Tirupati

Conclusion

In this project, using Excel Solver, Excel Solver Table add-in, and Risk. We, as a team, demonstrated the optimal solution for the Heritage Dairy Company problem of reducing the transportation cost. Through the optimization model that we built, we were able to achieve our goal of finding the least cost way of distributing the milk to customer locations.

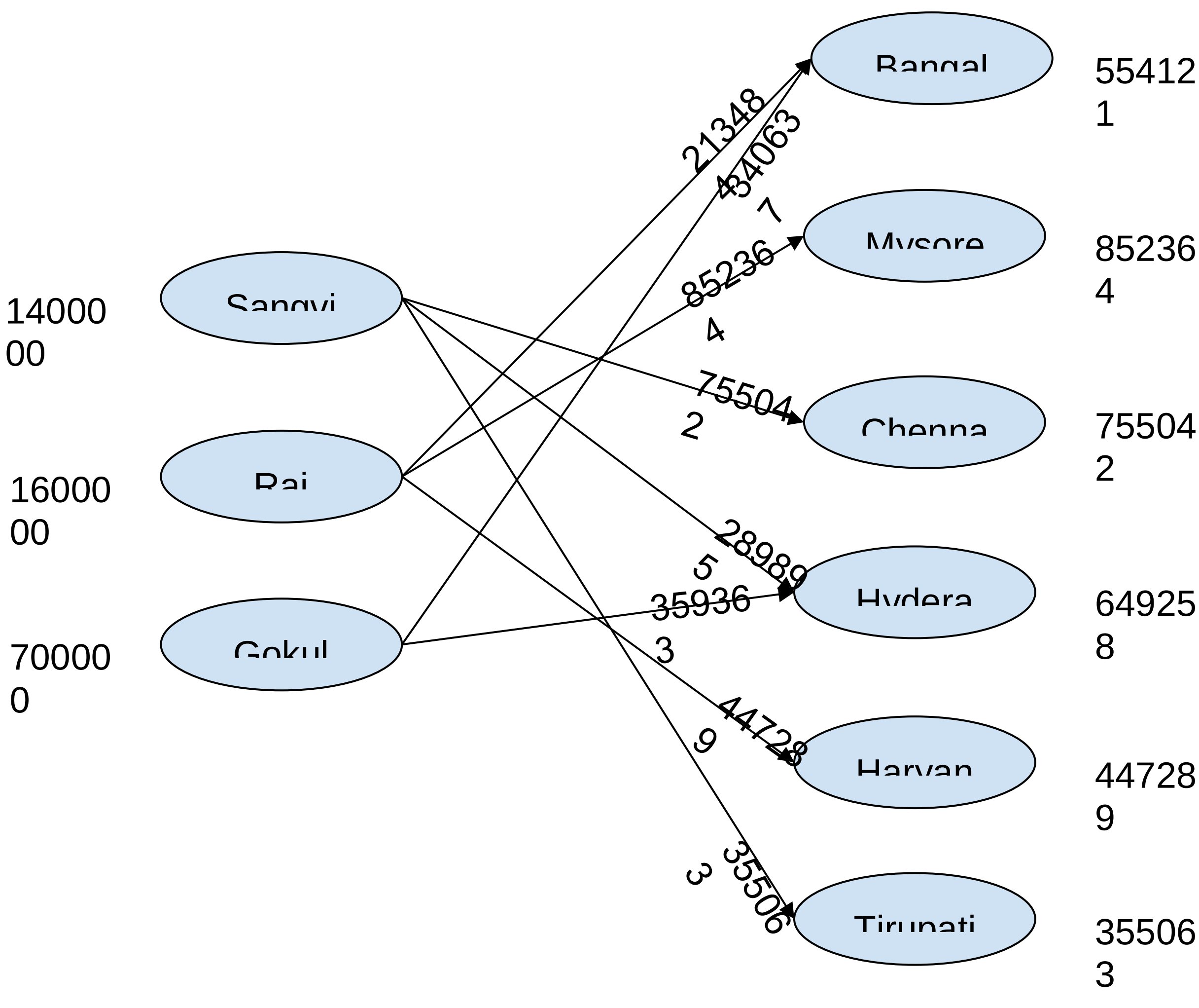


Figure 13:

This linear programming optimization model results show that the cost of distributing the required quantities of milk from three distribution centers to six customer locations in the eight routes is $180303.36. We would suggest the Heritage Dairy to consider the eight shipping routes Sangvi to Chennai, Hyderabad, Tirupati; from Rai to Bangalore, Mysore, Haryana and from Gokul to Bangalore, Hyderabad to achieve the least shipping cost of $180303.36.

From the sensitivity we were able to see how the optimal shipping cost function responds to changes to different parameters like capacity constraints of the distribution centers, weekly demand of the customers and shipping costs per liter of milk. The reduced cost column in the sensitivity report showed us the shipping costs to be reduced per liter of milk in order to choose that particular route. Generally, the reduced costs are zero for the chosen routes and non-zeros for the routes that are not chosen. Interestingly, the reduced cost is zero for the route Sangvi to Hyderabad that is not chosen. Meaning, if further cost reductions up to zero per liter of milk, it is still not an optimal route.

Furthermore, we also learned additional results by running One-way and Two- way sensitivity analysis using Excel Solver Table tool. Our prime objective of this study was to see how the Objective function and all the decision variables are changing if we increase the capacities of Sangvi and Gokul separately using one-way analysis and the weekly demands of the Mysore (highest demand) and Tirupati (least demand) simultaneously using the two-way analysis. We observed that the shipping cost increases as the demand increases. However, at some points, the problem becomes infeasible. As soon as the total demand is greater than the total capacity, it is impossible to meet the demand which results in infeasible solutions.

There are some drawbacks for using this model in a real environment. Several statistical analyses may be performed on the historical weekly demand data. The customer demands are typically estimated from some type of forecasting model, which we would not be able to do in this project. Instead, we used the best fit method for the demand distribution to obtain the weekly demands of the customer locations.