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Logistical Route Optimization to Reduce Transportation Cost

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Abstract. Many manufacturing companies produce their products in few locations and transport them to the different shops or demand points.

In this paper work we will use the power of IP - Solver and Microsoft Solver Foundation in order to resolve logistical route optimization problem to reduce transportation cost of the fruit juice factory or to find the least expensive way to produce and transport products to the customers and meet customer demand. Fruit juice company produces juice in three different factories: F1, F2 and F3. Each week, the fruit juice factory must transport juice to the five different demand points: D1, D2, D3, D4 and D5. Speaking mathematical terms, our goal is to find minimal cost logistical route while passing all predetermined points on the way. This kind of problem is called:"A transportation problem" and can be set up as a integer linear programming model with the below specifications: Minimizing total production and shipping cost, Constraints - The amount shipped from each production point cannot exceed plant capacity. Every demand point must receive its required demand. Transportation trucks have the limit of loading quantity. Also, each shipping amount must be nonnegative

At the end we will compare IP - Solver and Microsoft Solver Foundation results and least expensive way with the utmost expensive way.

Keywords: Cost, Integer Programming, mathematical model, IP - Solver and Microsoft Solver Foundation.

1 Introduction

In this paper we choose a company that produces fruit juice in three different factories and shipping its products to the five different locations or demand points as shown in the figure below:
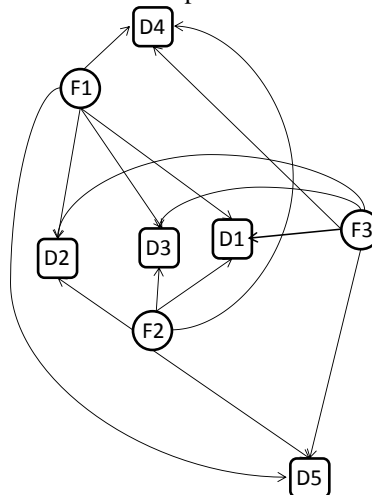

Figure 1. Distribution Network from Production Points to the Demands Points

2 Minimizing Cost for Fruit Juice Transportation

Minimizing cost as optimization transportation problem is a typical problem in Supply Chain Optimization field. This problem is especially important in distribution and retail environments with transportation management needs. For example, many companies plan and do organize deliveries of goods from distribution centers to stores. Many times these deliveries consist of multiple segments. A likely question is**:** "What would be the most optimal route for the truck if it needs to pass number of points on its way?

In this walkthrough we will utilize the power of Microsoft Solver and Microsoft Solver Foundation in order to resolve Logistical route optimization problem. Technically speaking our objective is to find a least cost logistical route while passing all predefined points on the way.

Mathematical expression for calculation transportation cost per juice litter is:

C=(ck*L) / m
                    [1]

ck - Operator cost per 1 km

L – Total length between production points and demand point

m – Is average capacity of truck loading with juice per juice litter

The total cost (C) is proportional to the length of the routes. Operator cost (ck) includes maintenance and direct costs of operation (driver wage, fuel consumption, tires, brake shoes, etc.) [4]. Vehicle depreciation costs are included as a part of operator cost too. Based on the mathematical expression [1] and data's we have the cost per litter shown in the table below:

Table 1. Cost per juice litter from production point to demand point

Production Point	Shop 1	Shop 2	Shop 3	Shop 4	Shop 5
Factory 1	$0.10	$0.07	$0.08	$0.04	$0.09
Factory 2	$0.06	$0.05	$0.04	$0.10	$0.10
Factory 3	$0.05	$0.06	$0.07	$0.11	$0.16

The mathematical model (integer linear programming formulation) for this task will look like following:

$$Min \sum_{i}^{m} \sum_{j}^{n} Cij * Sij$$

Constraints:

$$\sum_{j}^{n} Sij \leq Fi \qquad i = 1,...,m$$

$$\sum_{i}^{m} Sij = Dj \qquad j = 1,...,n$$

$$Sij \leq maxT \qquad \begin{matrix} i = 1,...,m \\ j = 1,...,n \end{matrix}$$

$$Sij \geq 0 \qquad \begin{matrix} i = 1,...,m \\ j = 1,...,n \end{matrix}$$

3 Minimizing Transportation Cost

Minimizing Transportation Cost can be set up as a linear Solver model with the following specifications:

Target cell - Minimize total production and shipping cost.

Changing cells - The amount produced at each production point that is shipped to each shop.

Constraints - The amount shipped from each production point can't exceed plant capacity. Each demand point must receive at least its required demand. Also, every changing cell cannot be negative.

Below table shows first page of the Microsoft Excel Solver

Table 2. First page of the Microsoft Excel Solver

	Shop 1	Shop 2	Shop 3	Shop 4	Shop 5	Capacity		
Factory 1	$ 0.10	$ 0.07	$ 0.08	$ 0.04	$ 0.09	10000		
Factory 2	$ 0.06	$ 0.05	$ 0.04	$ 0.10	$ 0.10	20000		
Factory 3	$ 0.05	$ 0.06	$ 0.07	$ 0.11	$ 0.16	40000		
Shipments								
	Shop 1	Shop 2	Shop 3	Shop 4	Shop 5	Sent		Capacity
Factory 1	0	0	0	9000	1000	10000 <=		10000
Factory 2	0	0	10000	0	10000	20000 <=		20000
Factory 3	3000	9000	2000	1000	0	15000 <=		40000
Received	3000	9000	12000	10000	11000			
	>=	>=	>=	>=	>=			
Demand	3000	9000	12000	10000	11000			
Max Truck Capacity	10000							
Total Cost	$ 2,790.00							

Cells B4:F6 contains cost from table 2. Cell B18 is Target Cell. Changing cells are B10:F12. Constraints (Sent) G10:G12 are less or equal to Capacity I10:I12. Constraints (Received) B13:F13 are bigger or equal to the demand B15:F15. Cells B15: F15 contains demands for each shop. I10:I12 is production capacity and BF16 is Maximum truck transportation capacity.

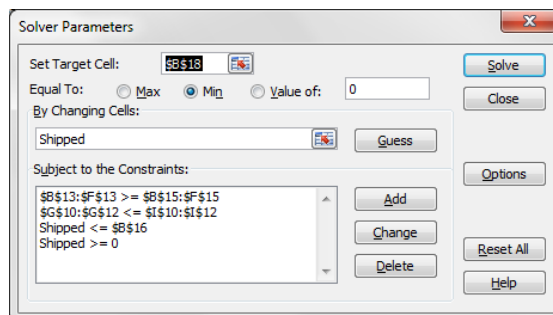All above constrains are entered into Microsoft Solver.

Figure 1. Solver Parameter

Minimized total cost of 2,790 is shown in cell B18 in table 2.

Table 3. Answer Report

Cell	Target Name	Value		
B18	Total Cost >=	$2,790.00		

Cell	Adjustable Name	Value	Lower Limit	Target Result	Upper Limit	Target Result
B10	Factory 1 Shop 1	0	0	2790	0	2790
C10	Factory 1 Shop 2	0	0	2790	0	2790
D10	Factory 1 Shop 3	0	0	2790	0	2790
E10	Factory 1 Shop 4	9000	9000	2790	9000	2790
F10	Factory 1 Shop 5	1000	1000	2790	1000	2790
B11	Factory 2 Shop 1	0	0	2790	0	2790
C11	Factory 2 Shop 2	0	0	2790	0	2790
D11	Factory 2 Shop 3	10000	10000	2790	10000	2790
E11	Factory 2 Shop 4	0	0	2790	0	2790
F11	Factory 2 Shop 5	10000	10000	2790	10000	2790
B12	Factory 3 Shop 1	3000	3000	2790	10000	3140
C12	Factory 3 Shop 2	9000	9000	2790	10000	2850
D12	Factory 3 Shop 3	2000	2000	2790	10000	3350
E12	Factory 3 Shop 4	1000	1000	2790	10000	3780
F12	Factory 3 Shop 5	0	0	2790	10000	4390

In below tables are shown Answer, Sensitivity and Limits report as output of the Microsoft IP Solver.

Table 4. Limits Report

Target Cell (Min)

Cell	Name	Original Value	Final Value
B18	Total Cost >=	$ 2,790.00	$ 2,790.00

Adjustable Cells

Cell	Name	Original Value	Final Value
B10	Factory 1 Shop 1	0	0
C10	Factory 1 Shop 2	0	0
D10	Factory 1 Shop 3	0	0
E10	Factory 1 Shop 4	9000	9000
F10	Factory 1 Shop 5	1000	1000
B11	Factory 2 Shop 1	0	0
C11	Factory 2 Shop 2	0	0
D11	Factory 2 Shop 3	10000	10000
E11	Factory 2 Shop 4	0	0
F11	Factory 2 Shop 5	10000	10000
B12	Factory 3 Shop 1	3000	3000
C12	Factory 3 Shop 2	9000	9000
D12	Factory 3 Shop 3	2000	2000
E12	Factory 3 Shop 4	1000	1000
F12	Factory 3 Shop 5	0	0

Table 5. Sensitivity Report

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B10	Factory 1 Shop 1	0	0.12	0.1	1E+30	0.12
C10	Factory 1 Shop 2	0	0.08	0.07	1E+30	0.08
D10	Factory 1 Shop 3	0	0.08	0.08	1E+30	0.08
E10	Factory 1 Shop 4	9000	0	0.04	0.03	0
F10	Factory 1 Shop 5	1000	0	0.09	0	0.03
B11	Factory 2 Shop 1	0	0.04	0.06	1E+30	0.04
C11	Factory 2 Shop 2	0	0.02	0.05	1E+30	0.02
D11	Factory 2 Shop 3	10000	0	0.04	0.02	0.03
E11	Factory 2 Shop 4	0	0.02	0.1	1E+30	0.02
F11	Factory 2 Shop 5	10000	-0.03	0.1	0.03	1E+30
B12	Factory 3 Shop 1	3000	0	0.05	0.04	0.05
C12	Factory 3 Shop 2	9000	0	0.06	0.02	0.06
D12	Factory 3 Shop 3	2000	0	0.07	0.03	0.02
E12	Factory 3 Shop 4	1000	0	0.11	0	0.03
F12	Factory 3 Shop 5	0	0	0.16	1E+30	0

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
G10	Factory 1 Sent	10000	-0.07	10000	1000	9000
G11	Factory 2 Sent	20000	-0.03	20000	0	8000
G12	Factory 3 Sent	15000	0	40000	1E+30	25000
B13	Received Shop 1	3000	0.05	3000	7000	3000
C13	Received Shop 2	9000	0.06	9000	1000	9000
D13	Received Shop 3	12000	0.07	12000	8000	2000
E13	Received Shop 4	10000	0.11	10000	9000	1000
F13	Received Shop 5	11000	0.16	11000	9000	1000

With Solver Foundation is easier to make and solve real optimization models. Solver Foundation uses an optimization modeling language (OML) for specifying optimization models; a .NET API and runtime (Solver Foundation Services) for model creation, reporting, analysis and strong built-in solvers [7]. Key features contain:

Modeling and solving action plans by using constraints, goals and data.
Programming in OML, in C# imperatively, in F# functionally, or in any .NET language.
Interfaces to known tools such as Excel and SharePoint to create and solve models [7].
Microsoft Solver Foundation is a .NET solution for mathematical optimization and modeling [7].
Below table shows all required data entered in datasheet.

Table 6. First page of the Foundation Solver

Source	Destination	SRC	DST	Cost	Shipments		Source	SCR	Sent	Capacity
Factory 1	Shop 1	0	0	0.1	0		Factory 1	0	10000	10000
Factory 1	Shop 2	0	1	0.07	0		Factory 2	1	20000	20000
Factory 1	Shop 3	0	2	0.08	0		Factory 3	2	15000	40000
Factory 1	Shop 4	0	3	0.04	10000					
Factory 1	Shop 5	0	4	0.09	0		Destination	DST	Received	Demand
Factory 2	Shop 1	1	0	0.06	0		Shop 1	0	3000	3000
Factory 2	Shop 2	1	1	0.05	0		Shop 2	1	9000	9000
Factory 2	Shop 3	1	2	0.04	9000		Shop 3	2	12000	12000
Factory 2	Shop 4	1	3	0.1	0		Shop 4	3	10000	10000
Factory 2	Shop 5	1	4	0.1	11000		Shop 5	4	11000	11000
Factory 3	Shop 1	2	0	0.05	3000					
Factory 3	Shop 2	2	1	0.06	9000					
Factory 3	Shop 3	2	2	0.07	3000					
Factory 3	Shop 4	2	3	0.11	0					
Factory 3	Shop 5	2	4	0.16	0					

Solver Foundation OML with eight (8) constrains is shown below:

```
Model[
 Parameters[
  Sets[Any],
  SRC,
  DST
 ],
 Parameters[
  Reals[-Infinity, Infinity],
  Cost[SRC, DST]
 ],
 Decisions[
  Reals[0, Infinity],
  Shipments[SRC, DST]
 ],
 Constraints[
  Constraint1 ->
Shipments[0,0]+Shipments[0,1]+Shipments[0,2]+Shipments[0,3]+Shipments[0,4]<=10000,
  Constraint2 ->
Shipments[1,0]+Shipments[1,1]+Shipments[1,2]+Shipments[1,3]+Shipments[1,4]<=20000,
  Constraint3 ->
Shipments[2,0]+Shipments[2,1]+Shipments[2,2]+Shipments[2,3]+Shipments[2,4]<=40000,
  Constraint4 -> Shipments[0,0]+Shipments[1,0]+Shipments[2,0]>=3000,
  Constraint5 -> Shipments[0,1]+Shipments[1,1]+Shipments[2,1]>=9000,
  Constraint6 -> Shipments[0,2]+Shipments[1,2]+Shipments[2,2]>=12000,
  Constraint7 -> Shipments[0,3]+Shipments[1,3]+Shipments[2,3]>=10000,
  Constraint8 -> Shipments[0,4]+Shipments[1,4]+Shipments[2,4]>=11000
 ],
 Goals[
 Minimize[
  TotalCost -> Annotation[Sum[{i, SRC}, {j, DST}, Cost[i, j]*Shipments[i,j]], "order", 0]
 ]
]]
```

Solver Foundation OML with two (2) constrains is shown below:

Model[

 Parameters[

  Sets[Any],

  SRC,

  DST

 ],

 Parameters[

  Reals[-Infinity, Infinity],

  Cost[SRC, DST],

  Capacity[SRC],

  Demand[DST]

 ],

 Decisions[

  Reals[0, Infinity],

  Shipments[SRC, DST]

 ],

 Constraints[

  SentCapacity -> Foreach[{x,SRC},Sum[{z, DST}, Shipments[x,z]]<=Capacity[x]],

  ReceivedDemand -> Foreach[{y,DST},Sum[{z, SRC}, Shipments[z,y]]>=Demand[y]]

 ],

 Goals[

  Minimize[

   TotalCost -> Annotation[Sum[{i, SRC}, {j, DST}, Cost[i, j]*Shipments[i,j]], "order", 0]

  ]

 ]

]

Same solver foundation results will be for both models.

Table 7. Solver Foundation Results

Solver Foundation Results	
Name	**Value**
Solution Type	Optimal
TotalCost	2760
Shipments[Factory 1, Shop 1]	0
Shipments[Factory 1, Shop 2]	0
Shipments[Factory 1, Shop 3]	0
Shipments[Factory 1, Shop 4]	10000
Shipments[Factory 1, Shop 5]	0
Shipments[Factory 2, Shop 1]	0
Shipments[Factory 2, Shop 2]	0
Shipments[Factory 2, Shop 3]	9000
Shipments[Factory 2, Shop 4]	0
Shipments[Factory 2, Shop 5]	11000
Shipments[Factory 3, Shop 1]	3000
Shipments[Factory 3, Shop 2]	9000
Shipments[Factory 3, Shop 3]	3000
Shipments[Factory 3, Shop 4]	0
Shipments[Factory 3, Shop 5]	0

4 Comparison Between Minimal and Maximal Total Cost

Below chart shows comparison between minimal and maximal cost for IP Solver respective Microsoft Foundation Solver. Maximal cost for IP Solver is around 60% higher than minimal cost. Maximal cost for Microsoft Foundation Solver is around 68% higher than minimal cost. Using optimal distribution network will impact cost and time saving.
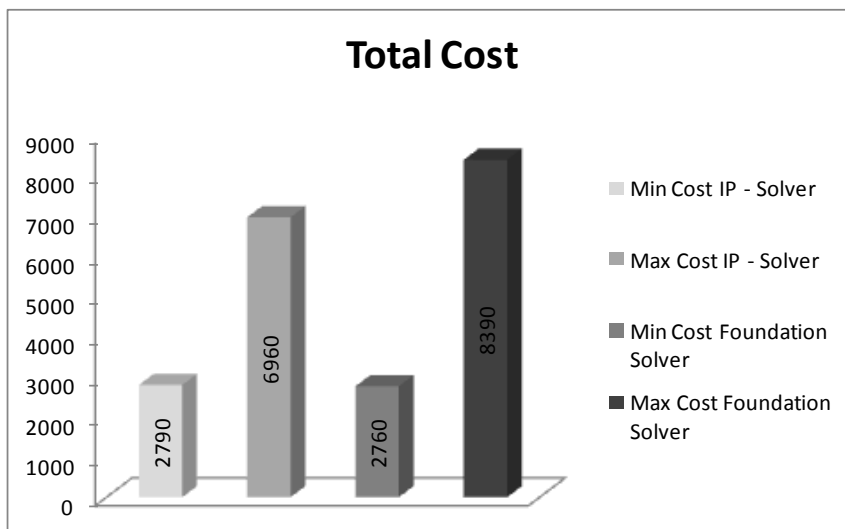

Figure 3. Comparison between min and max cost

Also difference between minimal cost for IP – Solver and Microsoft Foundation Solver is very small, around 1% while difference between maximal costs is around 17% as shown in the chart.

5 Conclusion

Logistical route network is flexible and adaptive based on the circumstances and demands. Optimization problems in many fields can be modeled and solved using IP Solver or Microsoft Foundation Solver. In this paper work we have used them to resolve logistical route optimization problem in order to reduce transportation cost. Matrices range in this paper work in 3 x 5 but the same procedure will be used for the cases with higher range of the matrices N x M.
Optimization problems in general are real world problems we meet in many areas such as mathematics, science, engineering, business and finances. In this matter, we find the optimal or most efficient way of using limited resources to reach objective of the situation. In this paperwork the main goal is maximizing the profit, minimizing the cost, minimizing the total distance travelled and using IP Solver or Microsoft Foundation Solver, this can be achieved very well.

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