RESEARCH ARTICLE   OPEN ACCESS

"Minimization of Inventory & Transportation Cost Of an Industry"-A Supply Chain Optimization

Nonihal Singh Dhakry*, Prof. Ajay Bangar**

*Student of Student of M.E.(PIS), Mechanical Engineering Maharana Pratap College of Technology, Gwalior, Madhya Pradesh, India
**(Prof. Mechanical Engineering Department) Maharana Pratap College of Technology, Gwalior, Madhya Pradesh, India

ABSTRACT
In this paper a study on three in-stock strategies – flow-through, regional and single DC central stock and developed a simple transportation-inventory model in order to compare their total costs is done. We have also described a distribution model proposed by in which the model is formulated as a non-linear integer optimization problem. Due to the non-linearity of the inventory cost in the objective function, two heuristics and an exact algorithm is proposed in order to solve the problem.
The results obtained from the transportation-inventory models show that the single DC and regional central stock strategies are more cost-efficient respectively compared to the flow-through approach. It is recommended to take the single DC and the regional central stock strategies for slow moving and demanding products respectively: Minimizing inventory & transportation cost of an industry: a supply chain optimization

Keyword:- Supply chain, Preliminary Distribution model , Cross-Dock and Direct Shipment Models Lagrangian Method

I. INTRODUCTION

1.1 Supply chain management

SCM is the management of a network of interconnected businesses involved in the provision of product and service packages required by the end customers in a supply chain. Supply chain management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption.

According to (Berman et al [2006] there are two important issues in the supply chain area that contribute to the total cost of the supply chain network namely transportation and inventory costs. That being said retail companies can achieve significant savings by considering these two costs at the same time rather than trying to minimize each separately.

As mentioned above in this paper the two distribution strategies mainly direct delivery and shipment through crossdock are considered where a group of products are shipped from a set of suppliers to a set of plants. The cost function consists of the total transportation, pipeline inventory, and plant inventory costs.

The presence of the plant inventory cost has made the model to be formulated as a non-linear integer programming problem. According to (Berman et al [2006]) the objective function is highly nonlinear and neither convex nor concave; therefore,

a greedy heuristic is suggested to find an initial solution and an upper bound.

And then a branch-and-bound algorithm is developed based on the Lagrangian relaxation of the non-linear program. Before getting into the formulation portion of the model, I am going to provide a brief background of the two distribution strategies discussed in the report and then briefly state the assumptions made by (Berman et al [2006]) in order to have a solvable problem.

For many retail companies products are shipped by suppliers through one of the following shipment strategies. The first one is direct shipment where products get shipped directly from the supplier to the DC/plant without stop. The second method of shipment is milk-run (peddling) where trucks pick up products from different suppliers on their ways and finally drop them at one or several DCs. The last but not least is cross-dock where products get shipped to DCs through cross-dock by suppliers. Below is a graphical representation of the three distribution strategies.

II. METHODOLOGY

2.1 Preliminary Distribution Model

Before getting into the modeling portion of my work, I would like to briefly explain inventory requirements for each of the product groups and how they vary according to different distribution channels (Shapiro [2005]).[4] As shown in Figure 2, products can flow in three different paths. In the first path,

product is shipped through a cross dock to a store, meaning that no inventory is held in that place. Inventory is only held at a store. Costs associated with this path are transportation as well as fixed and variable processing costs at cross dock site.Cost of transportation is also related to the shipment volume (either truckload (TL) or less-than-truckload (LTL).

In the second path, product is directly shipped by the supplier to stores. The only costs associated with this path are the costs of transportation and inventory at stores. In the third path inventory is only held both at DCs and stores. Again transportation, inventory holding and fixed as well as variable processing costs are considered for this path.
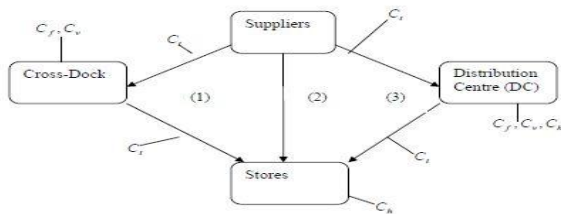

Figure 2 – Distribution strategies (Shapiro [2005])

In the modeling of the network, I have considered a supply chain in which suppliers ship product either directly to stores, or cross dock site or DCs as explained earlier. Location and capacity allocation decisions have to be made for distribution centre (DC). Multiple DCs may be used to satisfy demand at a market.

The goal is to identify distribution locations as well as quantities shipped between various points that minimize the total fixed and variable costs. Define the following decision variable preliminary version of the problem.

The objective function minimizes the total fixed and variable costs of the supply chain network. The constraint in equation 1 specifies that the total amount shipped from a supplier cannot exceed the supplier's capacity. The constraint equation 2 enforces that amount stocked in the DC cannot exceed its capacity. The constraint in equation 3 states that the amount shipped out of a cross-dock site is exactly equal the amount received from the supplier. The constraint in equation 4 specifies that the amount shipped out of a DC site cannot exceed the amount received from the supplier. The constraint in equation 5 specifies that the amount shipped to a customer must cover the demand.

2.2 Cross-Dock and Direct Shipment Models

Before getting into the details of the final model that I developed and used for 1 supplier, 1 cross-dock and 2 distributions centers case as well as assumptions that I made in order to maintain the linearity of the objective function I would like to briefly describe an optimization model suggested by

Objective Function

Min

$$\sum_{i=1}^{n} y_i*(F_i+V_i) + \sum_{e=1}^{t} y_e*(F_e+V_e) + \sum_{h=1}^{l}\sum_{i=1}^{n} c_{hi}*x_{hi} + \sum_{h=1}^{l}\sum_{e=1}^{t} c_{he}*x_{he} +$$

$$\sum_{h=1}^{l}\sum_{j=1}^{m} c_{hj}*x_{hj} + \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}*x_{ij} + \sum_{e=1}^{t}\sum_{j=1}^{m} c_{ej}*x_{ej}$$

Subject to

1. $$\sum_{i=1}^{n}\sum_{e=1}^{t}\sum_{j=1}^{m}(x_{hi}+x_{he}+x_{hj}) \leq S_h \quad for\ h=1,...,l$$

Total amount shipped from a supplier cannot exceed the supplier's capacity

2. $$\sum_{j=1}^{m} x_{ij} \leq K_i*y_i \quad for\ i=1,...,n$$

Amount stocked in the DC cannot exceed its capacity

3. $$\sum_{h=1}^{l} x_{he} - \sum_{j=1}^{m} x_{ej} \equiv 0 \quad for\ e=1,...,t$$

The amount shipped out of a cross-dock site is exactly equal the amount received from the supplier

4. $$\sum_{h=1}^{l} x_{hi} - \sum_{j=1}^{m} x_{ij} \geq 0 \quad for\ i=1,...,n$$

The amount shipped out of a DC site cannot exceed the amount received from the supplier

5. $$\sum_{h=1}^{l}\sum_{i=1}^{n}\sum_{e=1}^{t} x_{ij} + x_{ij} = D_j \quad for\ j=1,...,m$$

The amount shipped to a customer must cover the demand

.

(Berman et al [2006]) that is the solution to a distribution strategy selection problem where cost functions of both direct delivery and shipment through a cross-dock are modeled and compared.

There are two important issues in the supply chain area that contribute to the total cost of the supply chain network namely transportation and inventory costs. That being said retail companies can achieve

significant savings by considering these two costs at the same time rather than trying to minimize each separately. As mentioned above in this paper the two distribution strategies mainly direct delivery and shipment through cross dock are considered where a group of products are shipped from a set of suppliers to a set of plants.

The cost function consists of the total transportation, pipeline inventory, and plant inventory costs. The presence of the plant inventory cost has made the model to be formulated as a non-linear integer programming problem. The objective function is highly nonlinear and neither convex nor concave; therefore, a greedy heuristic is suggested to find an initial solution and an upper bound. And then a branch-and-bound algorithm is developed based on the Lagrangian relaxation of the non-linear program. Before getting into the formulation portion of the model, I am going to provide a brief background of the two distribution strategies discussed in the paper and then briefly state the assumptions made in order to have a solvable problem.

2.3 -Design Of Model
2.3.1 Distribution Strategies
For many retail companies products are shipped by suppliers through one of the following shipment strategies. The first one is direct shipment where products get shipped directly from the supplier to the DC/plant without stop. The second method of shipment is milk-run (peddling) where trucks pick up products from different suppliers on their ways and finally drop them at one or several DCs. The last but not least is cross-dock where products get shipped to DCs through cross-dock by suppliers.

2.3.2 Model Assumptions
As mentioned earlier to have a solvable problem, a couple of assumptions have been made in this paper

.1. It is assumed that the product quantities are infinitely splittable, in other words a product can be shipped in any quantity within a vehicle shipment.
2. Delivery frequency can be any positive number and is not limited to a set of potential members.
3. Products are always available for shipping at suppliers, no matter which distribution strategy is chosen
.4. Inbound-outbound coordination at the cross-dock is ignored.
5. All units of the same flow (a flow is a combination of supplier, plant and, product) are assigned to the same transportation option, i.e., direct or through the same cross-dock.
6. Each truck is fully loaded. Only the volume of products is concerned when calculating truck capacity usage. The transportation costs are only determined by the source and destination, regardless of the weight.

	PROCESS	Mr SANDEEP	Mr ASHUTOSH	Mr DEEPESH	Mr RAHUL	Mr AIAY
MILK RUN	DELIVERY TIME	M	M	S	M	M
	DELIVERY FREQUENCY	S	M	M	M	M
	INVENTORY COST(PLANT)	S	M	M	M	M
	INVENTORY COST(PIPE LINE)	M	S	M	M	M
DIRECT	DELIVERY TIME	S	M	S	S	S
	DELIVERY FREQUENCY	S	S	M	S	S
	INVENTORY COST(PLANT)	M	H	H	H	M
	INVENTORY COST(PIPE LINE)	M	S	S	M	S
CROSS DOCK	DELIVERY TIME	M	H	H	H	H
	DELIVERY FREQUENCY	H	M	H	H	H
	INVENTORY COST(PLANT)	S	S	M	S	S
	INVENTORY COST(PIPE LINE)	H	M	H	H	H

Table - 1Delivery Time, Deliver Frequency ,Inventory Cost Of Varies Distribution Strategy

DATA COLLECTED THROUGH QUSTIONAIRE THROUGH VARIOS DOMAIN EXPERTS

DISTRIBUTION	PROCESS	Mr SANDEEP	Mr ASHUTOSH	Mr DEPESH	Mr RAHUL	Mr AJAY
MILK RUN	INVENTORY	96500	98630	97560	96800	97200
	TRANSPORTATION	150760	135900	125800	150500	140200
DIRECT	INVENTORY	963005	986000	110006	120500	160050
	TRANSPORTATION	105006	110560	125308	106008	986200
CROSS DOCK	INVENTORY	105100	125000	130500	963200	952000
	TRANSPORTATION	125000	135000	126500	114000	115800

Table – 2 1 ,Inventory Cost & transportation cost Of Varies Distribution Strategy

III. DATA ANALYSIS

3.1 CALCULATION OF INVENTORY AND TRANSPORTATION COST USING LAGRANGIAN METHOD

Table 1b
Parameters for network in figure 1.

F	Fixed order cost	10
$g_j, \forall j \in J$	Fixed shipping cost from supplier to DC	1
$a_j, \forall j \in J$	Unit shipping cost from supplier to DC	1
β	Transport weight	1
z_α	Service level parameter	1.96
θ	Inventory weight	1
L	Lead time	1
h	Unit holding cost	2
χ	Days per year	1

3.2 For Milk Run

Lagrangian Method to *n*-dimensional case we find and optimum of a differentiable function

$$Z = f(x), \quad x = (x_1, x_2 ...... x_n) \in R^n$$

Whose variable are subject ot the M $(\leq n)$ constraints

$$gi(x) = 0, i = 1, 2 .... m \text{ and } x \geq 0$$

Where the $gi(x)$ are also differentiable. We form the Lagrangian Function

$$L(x, \lambda) = f(x) - \sum_{i=1}^{m} \lambda i \ gi(x)$$

Involving the Lagrangian multiplier

$$\bar{\lambda} = (\lambda_1 \lambda_2 .... \lambda_m)$$

These necessary condition for max (or min.) of $f(x)$ are the system of (m + n) equation

$$\frac{dl}{dxi} = \frac{df}{dxi} - \sum_{i=1}^{m} \lambda i \frac{dgi}{dxj} = 0 \ j = 1, 2 ...... n$$

Parameters for Lagrangian relaxation runs.

Parameter	Value
Maximum number of iterations	400
Minimum alpha multiplier	0.00000001
Maximum number of iterations before halving alpha	12
Crowder's damping factor	0.3
Initial Lagrange multiplier value	$10\bar{u} + 10f_j$

$$y = (y_i, y_e, v_i, v_e, x_{ih}, x_{eh}, x_m, x_n)$$
$$g_1(y) = x_{hi} + x_{ij} + h_{ij} - 50 = 0$$
$$g_2(y) = x_{ij} - 3.4 = 0$$
$$g_3(y) = x_{hi} - x_{iy} - 10$$
$$g_4(y) = x_{hi} - x_{ij} - 18 = 0$$
$$g_5(y) = x_{ij} + x_{iy} - 12.5 = 0$$

We constaints the Lagrangian function for multiplying $f(y)$

$$\vdots f(y) - \lambda_1 g_1(y) - \lambda_2 g_2(y) - \lambda_3 g_3(y) - \lambda_4 g_4(y) - \lambda_5 g_5(y)$$

This gives the following necessary condition :

$$\frac{\partial l}{\partial y} = 2x_1 - \lambda_1 - \lambda_2 = 0$$

$$\frac{\partial l}{\partial y} = 3x_1 + \lambda_1 - \lambda_3 = 0$$

$$\frac{\partial l}{\partial y} = x_{ij}\lambda_1 - \lambda_3 - \lambda_5 = 0$$

$$\frac{\partial l}{\partial y} = x_{ij} - y_{ij} - \lambda_5 = 0$$

$$\frac{\partial l}{\partial y} = x_i - \lambda_5 + \lambda_3 - \lambda_4 = 0$$

DISTRIBUTION STRATEGY	INVENTORY COST	TRANSPORTATION COST
MILK RUN	98760.60	178950.56
DIRECT	109865.32	196563.82
CROSS-DOCK	98560.71	146892.62

$$y_i = \frac{2\lambda_1 + \lambda_2}{4}$$

DISTRIBUTION STRATEGY	INVENTORY COST	TRANSPORTATION COST
MILK RUN	94343.512	114075.135
DIRECT	98798.677	152533.377
CROSS-DOCK	93798.673	142533.324

$$y_e = \frac{2\lambda_5}{4}$$

$$x_m = \frac{\lambda_1 + 2\lambda_3}{2}$$

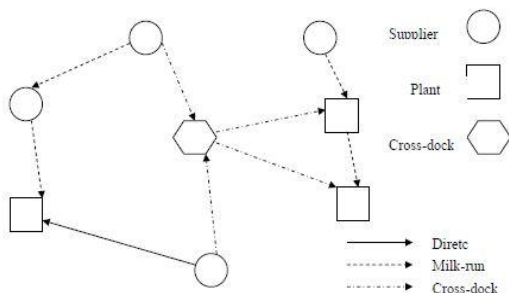$$x_{ij} = \frac{\lambda_1 + \lambda_2 + 3\lambda_4}{5}$$

$$\lambda^* = (\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5) = \left(\frac{40}{9}, \frac{51}{9}, \frac{314}{3}, \frac{127}{2}, \frac{413}{17}\right)$$

By substituting the values of $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5$ then get transportation cost and inventory cost.

Transportation Cost = 114075.1358
Inventory Cost = 94343.512

IV. RESULT
4.1 -Developed a distribution strategy model
Developed a table of three distribution of strategy with the help of questionnaire through domain experts of various organization

Developed two objective function for transportation and inventory and transportation model and reduce the cost of transportation and inventory by lagrangian methods for different strategies.

4.2-Comparison Between Data Given By Experts And Data Calculated From Lagrangian Method

4.2.1 Comparison By Experts

Table – 3 Comparison By Experts
4.2.2 - Comparison By Lagrangian Method
Table – 3 Comparison by Bylagangian Method

V. CONCLUSION

➢ Achievement of significant cost savings and improvements in profitability requires a typical retail company to make long-term decisions regarding the structure of its supply chain network and bringing its facilities, suppliers and customers closer together under the strategic supply chain planning .
➢ As part of my study I have developed a transportation-inventory model for a single source to multiple distribution strategy. I have also studied the distribution model proposed by (Berman) that can be used for transportation system.
➢ We will develop a questionnaire we get further information for objective function and to minimize the transportation cost and inventory cost and reduce the cost of transportation and inventory by lagrangian methods for different strategies.
➢ Developed a table of three distribution of strategy with the help of questionnaire through domain experts of various organization

VI. Acknowledgement

References
[1] A. Tversky and D. Kahneman, "Advances in Prospect Theory: Cumulative Representation of Uncertainty," *Journal of Risk and Uncertainty*, vol.5, pp.297-323, , October, 2005
[2] Berman O., Whang Q. [2006], "Inbound Logistic Planning: Minimizing Transportation and Inventory Cost" transportation Science, 2006
[3] 1989Berman O., Whang Q. [2006], "Inbound Logistic Planning: Minimizing

Transportation and Inventory Cost" transportation Science, 2006

[4] Chopra S., Meindl P. [2003], Supply Chain Management: Strategy, Planning, and Operations, 2nd ed. Prentice Hall

[5] D. Schmeidler, "Subjective probability and expected utility without additivity", *Econometrica,* vol.57, pp.571-587,

[6] Edited by John Quiggin, *Generalized Expected Utility Theory.* Massachusetts: Kluwer, 1993, ch. 2.

[7] Fisher M. L. [1997], "What is the Right Supply Chain for Your Product?" Harvard Business Review, 1997

[8] Shafer G., *A mathematical theory of evidence.* Princeton University Press, Princeton, NJ, 1976.

[9] A. Tversky and D. Kahneman, "Advances in Prospect Theory: Cumulative Representation of Uncertainty," *Journal of Risk and Uncertainty*, vol.5, pp.297-323, 1992.

[10] Shapiro, J. F., Wagner S., Jacobs K. [2004], "A Practical Guide to Supply Chain Network Design" SLIM Technologies, September, 2004

[11] H. Tamura, "Behavioral models for complex decision analysis," *European Journal of Operational Research,* vol. **166**, pp.655-665, 2005.

[12] H. Tamura and Y. Miura, "Value judgment of the sense of security for nursing care robots based on the prospect theory under uncertainty," *Int. J. of Knowledge and System Sciences,* vol. **3**, pp.28-33, 2006.

[13] H. Tamura, "Behavioral models of decision making under risk and/or uncertainty with application to public sectors," *Annual Reviews in Control,* vol. **32**, pp.99-106, 2008.

[14] H. Tamura, Y. Miura and M. Inuiguchi, "Value judgment for the sense of security based on utility theoretic approaches," *International Journal of Knowledge and Systems Sciences,* vol.2, No.2, pp.33-38, 2005.

[15] R. R. Yager, "Decision Making under Dempster-Shafer Uncertainties," *Int. J. General Systems* vol.20, pp.233-245, 1992.

[16] R. R. Yager, "Uncertain modeling and decision support," *Reliability Engineering and System Safety*, vol. **85**, pp.341-354, 2004.