Supply Chain Management in a Dairy Industry – A Case Study

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ABSTRACT - **Supply chain management is the plan and control of material and information flow among suppliers, facilities, warehouses and customers with the objectives of minimization of cost, maximization of customer services and flexibility. The supply chain of a business process comprises mainly five activities viz., Purchase of materials from suppliers, transportation of materials from suppliers to facilities, production of goods at facilities, transportation of goods from facilitates to ware houses and transportation of goods from ware houses to customers.**

In this paper, a supply chain model is developed for a dairy industry, located in Andhra Pradesh, India. The supply chain includes four echelons namely raw milk suppliers, plant, warehouse and customers. In this model, emphasis is mainly on production and distribution activities, with a view to find out purchase plan of raw milk, production plan of product mix and transportation plan of the products.

Index Terms- **Supply chain management, Transportation, Production plan, Customer zones**.

I. INTRODUCTION

Supply chain management (SCM) is a rapidly evolving area of interest to academicians and business management practitioners alike. Coordinating the external and internal activities of a firm is the basic philosophy of supply chain management. It is about managing the entire process in a collective and unified fashion.

Most of the manufacturing firms are organized as networks of manufacturing and distribution facilities that procure raw materials transform them into intermediate and finished products and distribute the finished products to customers. The simplest network consists of facilities which perform procurement, manufacturing and distribution. These networks are called value added chains or supply chains.

A supply chain consists of all stages involved directly or indirectly in fulfilling a customer request. The supply chain not only includes the manufactures and suppliers but also retailers and customers themselves with in each organization.

A supply chain is an integrated system wherein a number of various business entities (i.e. suppliers, manufacturers, industrial customers, distributors, retailers) work together to address issues of both materials flow and information flow. A reference model - the Supply Chain Operations Reference model (SCOR), has been developed by the Supply-Chain Council (SCC) [1]. This process reference model contains standard description of management process and a framework of relationships among the standard processes. Ganeshan et.al. [5] explored the basics of supply chain management from a conceptual perspective by tracing the roots of the definition and the origins of the concept from a broad stream of literature. Pyke and Cohen [6] analyzed the management of materials in an integrated supply chain and develop a markov chain model for a three level production distribution system. Cohen and Huchzermeier [3] presented a survey of the literature pertaining to analytic approaches for global supply chain strategy analysis and planning. The integrated supply chain network model is developed to capture the complexities of a multi-product, multi-echelon, multi-country, multiperiod planning problem for the optimal choice of facility locations, capacity and technology used. Sabri and Beamon [4] developed an integrated supply chain model for use in simultaneous strategic and operation supply chain planning. .Lee and Kim [7] proposed a hybrid approach to solve production and distribution problems in supply chains. Thomas and Griffin [8] define the categories of operational co ordination, buyer and vendor, production and distribution, inventory and distribution. Arntzen et.al [9] provide the most comprehensive

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deterministic model for supply chain management with an objective function containing the cost and time elements. Even though supply chain management is relatively new, the idea of co-ordinate planning is not new. The study of multi-echelon inventory/distribution systems began as early as 1960 by Clark and Scarf [2]. Since then many researchers have investigated multi echelon inventory and distribution systems. Less research has been aimed at co-ordination of procurements, production and distribution systems. In this paper an attempt has been made to develop a coordinated supply chain-planning model with procurement, production and distribution systems.

II. MODEL FORMULATION

The proposal of the model is to find an optimal strategic plan for an integrated supply chain model.

Notations

MC_{tvp}	Cost of material p purchased by vendor v at time t
PC_{tfg}	Production cost of goods g produced by facility f at time t
$VFTC_{tvp}$	Transportation cost of material p Transported from vendor v to facility f at time t
$FWTC_{tfwg}$	Transportation cost of goods g transported from facility f to ware house w at time t
$WZTC_{twcg}$	Transportation cost of goods g transported from ware house w to customer location c at time t
$FMIC_{tfp}$	Inventory cost of mterial p of facility f at time t
$FGIC_{tfg}$	Inventory cost of goods g of facility f at time t
WIC_{twg}	Inventory cost of goods g of warehouse w at time t
BOM_{gp}	Amount of material p needed for producing goods g
AV_{tvp}	The amount of material p purchased by vendor v at time t
R_{tvfp}	The amount of material p which vendor v Transported of facility f at time t.
AF_{tfp}	The inventory of material p in the facility f at time t
R_{tfg}	Amount of good g which facility f produced at time t
AF_{tfg}	The inventory of goods g at facility f at time t.
R_{tfwg}	The amount of goods g which facility f transported to ware house w at time t.
AW_{twg}	The inventory of good g in the ware house w at time t.
R_{twcg}	The amount of good g which ware house w transported to customer c at time t.
AC_{tcg}	The demand of goods g by customer c at time t.

Assumptions

1. Capacities of vendors are fixed.
2. Demand is deterministic.
3. Variable cost per unit production is constant

Mathematical model

This model consists of four echelons namely Suppliers, Plants, Distribution Centers (DCs), and Customer zones (CZs).

A multi-objective function is formulated to minimize cost subject to supplies, plant and distribution capacities, production and distribution through put limits and customs demand requirements. Total cost includes fixed costs of production and distribution, variable costs of production, distribution and transportation.

Various costs involved in the supply chain are

1. Material Cost = $\sum_{vp} MC_{tvp} * AV_{tvp}$
2. Production cost = $\sum_{fg} PC_{tfg} * R_{tfg}$
3. Transportation cost =

$$\sum_{vfp} VFTC_{tvfp} * R_{tvfp} + \sum_{fwg} FWTC_{tfwg} * R_{tfwg} + \sum_{wcg} WCTC_{twcg} * R_{twcg}$$

4. Inventory cost =

$$\sum_{ft} FMIC_{tfp} * AF_{tfp} + \sum_{fg} FGIC_{tfg} * AF_{tfg} + \sum_{wg} WIC_{twg} * AW_{twg}$$

The objective function of the model is to minimize the total cost associated with the supply chain which includes material, production, transportation and inventory costs.

Minimize Z=

$$\sum_{vsp} MC_{tvp} * AV_{tvp} + \sum_{fg} PC_{tfg} * R_{tfg} + \sum_{vfp} VFTC_{tvfp} * R_{tvfp}$$

$$+ \sum_{fwg} FWTC_{tfwg} * R_{tfwg} + \sum_{wcg} WCTC_{twcg} * R_{twcg} + \sum_{ft} FMIC_{tfp} * AF_{tfp}$$

$$+ \sum_{fg} FGIC_{tfg} * AF_{tfg} + \sum_{wg} WIC_{twg} * AW_{twg}$$

The above stated problem is solved subjected to the following constraint set.

1. Upper – Lower bound restrictions

$0 \leq R_{tvfp} \leq R_{tvfp}\_UPbound$
$0 \leq R_{tfwg} \leq R_{tfwg}\_UPbound$
$0 \leq R_{twcg} \leq R_{twcg}\_UPbound$
$R_{tfg}\_LPbound \leq R_{tfg} \leq R_{tfg}\_UPbound$
$et_{vf}=1;\ et_{tw}=1;\ et_{vc}=1;$

2. Flow Conservative restrictions

$$\sum_{t} R_{tvfp} = LV_{tvp} \forall t, v, p$$

$$AF_{tfp} + \sum_{v} R_{(t-et_{vf})vfp} - \sum_{g} BOM_{gp} * R_{tfg}$$

$$= AF_{(t+1)fp} \forall t, f, p$$

$$AW_{twg} + \sum_{f} R_{(t-et_{fw})fwg} - \sum_{c} R_{twcg} = AW_{(t+1)wg}$$

$$\forall t, w, g$$

$$\sum_{w} R_{(t-et_{wc})wcg} = AC_{tcg} \quad \forall t, c, g$$

III. CASE STUDY

The above developed model is applied to Visakha Dairy situated in Andhra Pradesh, India. The above dairy has six vendors located at Vsiahapatnam, Vizianagaram, Tuni, Ramabadrapuram, Narsipatnam and Srikakulam. It has two facilities located at Visakhapatnam and kakinada to meet the customer demands. Five warehouses are situated at Visakapatnam, Vizianagaram, Srikakulam Kakinada and Rajahmundry. Its customer locations are situated at Visakhapatnam, Vizianagaram, Srikakulam, Kakinada and Rajamundry.

The input data required for the design of supply chain for the above stated industry is given below.

Input Data

Material Cost

v \ p	1	2	3	4	5	6
1	1140	1160	991	1135	872	1056

Vendor to facility transportation cost

v \ f	1	2	3	4	5	6
1	3.26	26.33	36.24	28.56	84.8	33.35
2	32.98	6.02	66.24	55.56	103.8	3.26

Facility to ware house transportation cost

For facility1

g \ w	1	2	3	4	5	6
1	3.26	3.26	3.26	3.26	3.26	3.26
2	11.9	11.9	11.9	11.9	11.9	11.9
3	13.6	13.6	13.6	13.6	13.6	13.6
4	8.9	8.9	8.9	8.9	8.9	8.9
5	7.56	7.56	7.56	7.56	7.56	7.56

For facility 2

g \ w	1	2	3	4	5	6
1	10.9	10.9	10.9	10.9	10.9	10.9
2	4.52	4.52	4.52	4.52	4.52	4.52
3	3.26	3.26	3.26	3.26	3.26	3.26
4	19.8	19.8	19.8	19.8	19.8	19.8
5	18.4	18.4	18.4	18.4	18.4	18.4

Ware House to customer transportation cost

c \ w	1	2	3	4	5
1	0	11.9	13.16	8.9	7.56
2	13.26	0	1.26	3	4.1
3	9.96	1.3	0	4.26	5.56
4	6.74	3	4.26	0	1.24
5	4.3	4.34	5.36	1.24	0

In the above table the transportation cost for good 1 is shown and the same table repeats for the remaining goods.
Inventory carrying cost at the facility for the raw material and goods are considered as Zeros.

Inventory const at warehouse

g \ w	1	2	3	4	5	6
1	0.07	0.05	0.07	0.05	0.07	0.05
2	0.07	0.05	0.07	0.05	0.07	0.05
3	0.07	0.05	0.07	0.05	0.07	0.05
4	0.07	0.05	0.07	0.05	0.07	0.05
5	0.07	0.05	0.07	0.05	0.07	0.05

Capacities of Vendors (in thousands)

v / p	1	2	3	4	5	6
1	178	43	325	45	22	20

Capacities of facilities for producing different goods

g / f	1	2	3	4	5	6
1	25000	11000	7500	4000	4000	32000
2	4000	15000	0	150	4000	30000

Capacities of ware house to hold different products

g / w	1	2	3	4	5	6
1	25000	100000	7000	3000	4000	25000
2	1500	5000	0	0	1000	20000
3	1500	4000	0	500	2000	8000
4	1000	3000	0	0	1000	6000
5	0	500	500	500	300	5000

Demands for different goods at different customer locations

g / c	1	2	3	4	5	6
1	23760	10903	7000	3199	3624	23726
2	1072	4624	0	0	304	16684
3	1254	3564	0	106	2076	7352
4	962	3234	0	0	806	6210
5	0	195	0	158	193	4659

The Problem is solved using LINGO student version package.

IV. RESULTS AND DISCUSSIONS

The optimal solution for the model is

Table I: Quantities of material to be procured version different vendors.

v / p	1	2	3	4	5	6
1	106565	43000	32500	0	22000	29000

Table II: Quantities of goods transported from vendors to facilities

v / f	1	2	3	4	5	6
1	106565	9850	32500	0	22000	0
2	0	33150	0	0	0	29000

Table III: Amounts of goods produced at both the facilities

g / f	1	2	3	4	5	6
1	23048	105920	7000	3313	2003	28631
2	4000	1500	0	150	4000	3000

Table IV: Amounts of goods transported from facilities to warehouse

From Facility F1

g / w	1	2	3	4	5	6
1	23048	105920	7000	3199	3003	23726
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	114	0	4905

From Facility F2

g / w	1	2	3	4	5	6
1	712	3383	0	0	621	0
2	1072	4819	0	44	497	16684
3	2216	6798	0	106	2882	13316
4	0	0	0	0	0	0
5	0	0	0	0	0	0

Table V: Amounts of goods to be transported from ware houses to customer Zones.

From ware house 1

g / c	1	2	3	4	5	6
1	23760	109303	7000	3199	3624	23726
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

From Ware House 2

g / c	1	2	3	4	5	6
1	0	0	0	0	0	0
2	1072	4624	0	0	304	16684
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	195	0	44	193	0

From ware house 3

g / c	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	1254	3564	0	106	2076	7352
4	962	3234	0	0	806	5964
5	0	0	0	0	0	0

From ware house 5

g / c	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	246
5	0	0	0	114	0	4659

Table I represents the procurement plan which indicates quantities of raw materials to be procured from different vendors. As both the material cost and transportation costs to both the facilities is high from vendor 4 (i.e., Ramabadrapuram) and the demand for the raw material can be fulfilled by the remaining vendors, raw material should not be procured from the vendor 4. Table III represents the production plan for the optimal product mix. It gives us the quantities of material to be produced by both the facilities considering the demands of the customers and their transportation cost.

Table II, IV and V represent the transportation plans for the plant. Table II shows the quantities of material to be transported from different vendors to both the facilities. Table IV shows the quantities of different goods to the shipped to the warehouses from both the facilities. Table V shows the quantities of different goods to be transported from different warehouse to all the customer locations. The Transportation cost to ware house 4 is very high from both the facilities and it is also very far away from all the customer zones, so the warehouse 4 is discarded from the plan. From the above obtained plans the total cost of the supply chain is calculated as Rs.27, 41,039/- per one time period (i.e.12 hours). The obtained value is Rs.2,02,539/- less than the existing cost.

V. CONCLUSIONS

In this paper supply chain network is designed for a dairy industry. This network includes material purchase plan, production plan, inventory plan and transportation plan. From the results it is observed that the total cost of the supply chain is 9.8 percent lesser than the existing cost. This model can be extended to varying demand and costs. This can also be applied to fast moving consumer goods.

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