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Original Research

Application of Linear Programming Model for Industrial Supply Chain Network Design: A Case Study

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Abstract

A Linear Programming Model (LPM) capturing many practical aspects of network design problems and the optimization techniques, like transportation model, to be used were introduced in this study. The objective is to design the supply chain (SC) network so as to minimize annual system-wide costs and improve service level requirements, thereafter increase market share. This is because at current practices most companies do not have a means to sense real situations at their SC. The design approaches employed here followed three major methods namely data collection and aggregation; modeling and data validation; and use of solution techniques to produce a good optimized result. Finally, a general LPM that simultaneously locates multi plant and warehouses is applied to the case company that results in optimization of current network, design of new SC network, and large cost savings.

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INTRODUCTION

In recent years, numerous approaches have been proposed to improve manufacturing plant operations performance. Among many others, supply chain management has received considerable attentions. Despite its benefits, structuring supply chain (SC) network is a complex decision making process. At strategic level companies have to decide where to locate new facilities, how to allocate resources to the various facilities, and how to manage the transportation of products through the chain in order to satisfy customer demands.

As Christopher (1992), Suhong (2006), and Nicholas (2005) have reported effective supply chain management (SCM) has becomes a potentially valuable way of securing competitive advantage and improving organizational performance since competition is no longer between organizations, but among supply chains. The phrase “Supply Chain Management” came in to use in the early 1990s. The Global Supply Chain Forum defined SCM as the integration of key business processes from the end user through original suppliers that provide products, services, and information that add value for customer Peter and Groznik (2006).

The benefits of an effective SC can be: cycle time reduction, inventory cost reduction, optimized transportation, increased order fill rate, early prediction of disturbance to downstream, increase customer service, and increase returns on assets Change (2009) and Gunasekaran (2004). To achieve these benefits, the decisions that are to be taken should be strategic, tactical, and operational.

The principles of SCM that can ensure the above benefits are (1) customer segmentation, (2) customizing SC networks, (3) demands planning, (4) sourcing suppliers strategically, (5) integration of technology, and (6) performance measure Daniel (2005) and David (1997). The supply network must be optimized and react to supply uncertainties and demand variability to serve customers demand Steven (2006).

In general, different authors agree that SCM involves in integrating three key flows across the boundaries of the supply chain: product/material, information, and financial flow Change (2009); Chopra (2006) and Handfield (2006). Figure 1 below shows a simplified supply chain management system.

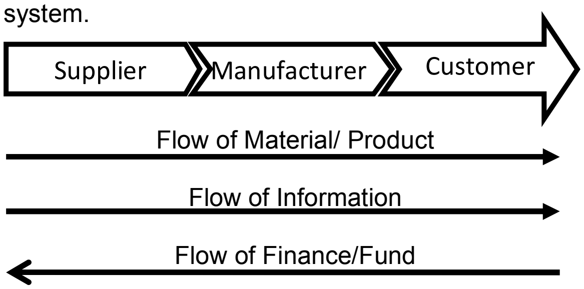


Figure 1: Simplified supply chain diagram.

Successful integration of the three flows has produced improved efficiency and effectiveness. Hence, the initial step in implementing and practicing SCM system is supply chain network design. Therefore, the study is mainly focusing on SC network design.

Numerous modeling approaches in SCM have been proposed so far, these includes linear programming, mixed integer programming, stochastic programming, heuristic methods, and simulation based methods of Gunasekaran (2004); Daniel (2005); Bernard (1996); Stamey (2007); Vidal (2001); Beamon (1998); and Thomas (2005). Among all, in this study especial focus is given to SC network design with Linear programming models or techniques. This is because it considers the structure of the network and also incorporates other optimization models to reach at final decisions.

MATERIALS AND METHODS

Network configuration may involve issues relating to plant, warehouse, transportation, and retailer location. These are strategic decisions since they have a long-lasting effect on the firm. To come up with a better network design, appropriate number of warehouses, location of each warehouse, and the size and capacity of each warehouse has to be identified and determined.

The objective is to design the SC network so as to minimize annual system-wide costs and improve service level requirements, thereafter increase market share. Increasing the number of warehouses typically yields: improvement in service level, increase in inventory costs, increase in overhead and set-up costs, reduction in outbound transportation costs, and increase in inbound transportation costs. In this setting, the tradeoffs are clear. In essence, the firm must balance the costs of opening new warehouses with the advantages of being close to the customer. Thus, warehouse location decisions are crucial determinants for the efficiency of the product distribution. The design approaches therefore, require the following three major activities to produce a good optimized result Chopra (2006).

1. Data collection and aggregation regarding transportation rates, mileage estimation, warehouse costs, & service level requirements;
2. Modeling and data validation; and
3. Use of solution techniques.

A general Linear Programming Model (LPM) of the distribution network design is as presented in equation 1. In the equation we get three different models namely: pure linear programming, integer programming and transportation model. The total cost function is the minimum value of sum of fixed plants and warehouses costs (integer programming and linear programming), and transportation cost in supply of raw material and distribution of finished goods (transportation model). This model can simultaneously locate multi plant and warehouses for a company. The constraints to this objective function are given in equation 2 to equation 9.

Objective Function

Total cost = Min

$$\left\{ \sum_{i=1}^{n} F_i Y_i + \sum_{e=1}^{t} F_e Y_e + \sum_{h=1}^{l} \sum_{i=1}^{n} C_{hi} X_{hi} + \sum_{i=1}^{n} \sum_{e=1}^{t} C_{ie} X_{ie} + \sum_{e=1}^{t} \sum_{j=1}^{m} C_{ej} X_{ej} \right\} \quad ..(1)$$

Subject to Constraints

Total amount shipped from supplier cannot exceed supplier's capacity;

$$\sum_{i=1}^{n} X_{hi} \leq S_h \text{ for } h = 1, 2, 3 \ldots L \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Amount shipped out of factory cannot exceed the quantity of raw material received;

$$\sum_{h=1}^{l} X_{hi} - \sum_{e=1}^{t} X_{ie} \geq 0 \text{ for } i = 1, 2, 3.. n \ \ldots\ (3)$$

Units produced in factory cannot exceed factory capacity;

$$\sum_{e=1}^{t} X_{ie} \leq K_i Y_i \text{ for } i = 1, 2, 3 \ldots n \ \ldots\ldots\ldots\ (4)$$

Amount shipped out of warehouse cannot exceed quantity received from factories;

$$\sum_{e=1}^{t} X_{ie} - \sum_{j=1}^{m} X_{ej} \geq 0 \text{ for } e = 1, 2, 3..t \ldots\ldots \quad (5)$$

Amount shipped through warehouses cannot exceed its capacity;

$$\sum_{j=1}^{m} X_{ej} \leq W_e Y_e \text{ for } e = 1, 2, 3 \ldots t \ldots\ldots\ldots \quad (6)$$

Amount shipped to customer must equal the customer demand; and

$$\sum_{e=1}^{t} X_{ej} = D_j \text{ for } j = 1, 2, 3 \ldots m \ldots\ldots\ldots\ldots\ldots \quad (7)$$

Each factory or a warehouse is either open or closed.

$Y_i, Y_e, \in \{0, 1\}$.. (8)

$X_{ie}, X_{ej} \geq 0$ ………………………….………………......(9)

Where,

m = number of markets or demand points
n = number of potential factory locations
l = number of suppliers
t = number of potential warehouse locations
D_j = annual Demand from customer j
K_i = potential Capacity of factory at site i
S_h = supply capacity at supplier h
W_e = potential warehouse capacity at site e
F_i = fixed Cost of locating a Plant at site i
F_e = fixed cost of locating a warehouse at site e
C_{hi} = cost of shipping one unit from supply source h to factory i
C_{ie} = cost of shipping one unit from factory i to warehouse e
C_{ej} = cost of shipping one unit from warehouse e to customer j
Y_i = 1 if plant is located at site i, 0 otherwise
Y_e = 1 if warehouse is located at site e, 0 otherwise
x_{ej} = quantity transported from warehouse e to market j
X_{ie} = quantity transported from plant i to warehouse e
X_{hi} = quantity shipped from supplier h to factory at site i.

Once the model has been developed based on network configurations, the next step is to optimize the configuration of the logistics network. In practice, mathematical optimization techniques, which include exact algorithms that are guaranteed to find optimal solutions is used. A case study of East Africa Bottling Share Company has been undertaken to validate the model development of the supply chain network design; to find possible ways of reconfiguring the distribution centers; and find areas of optimization. In the study extensive data collection and analysis has been carried out. Also promising results have been achieved.

Data Collection and Analysis

A case study of East Africa Bottling Share Company has been undertaken to validate the model development of the supply chain network design; to find possible ways of reconfiguring the distribution centers; and find areas of optimization. In the study, extensive data collection and analysis has been carried out. Also promising results have been achieved.

In the current business operations of the company, some segments of the markets for the company's product experience shortage (Figure 2). The shortage may either be owing to shortage of supply from the company or lack of supply to specific market segment while excess supply is experienced in others. This means the company is losing its sale because the customer may cancel the order or shift to some other brand. But the company does not have well established means to sense market where shortage is experienced and also mechanisms how to supply the market accordingly. Hence, new supply chain network design will be developed and evaluated with the Linear Programming Model (LPM) for the company.

Existing Supply Chain Network Diagram of the Company

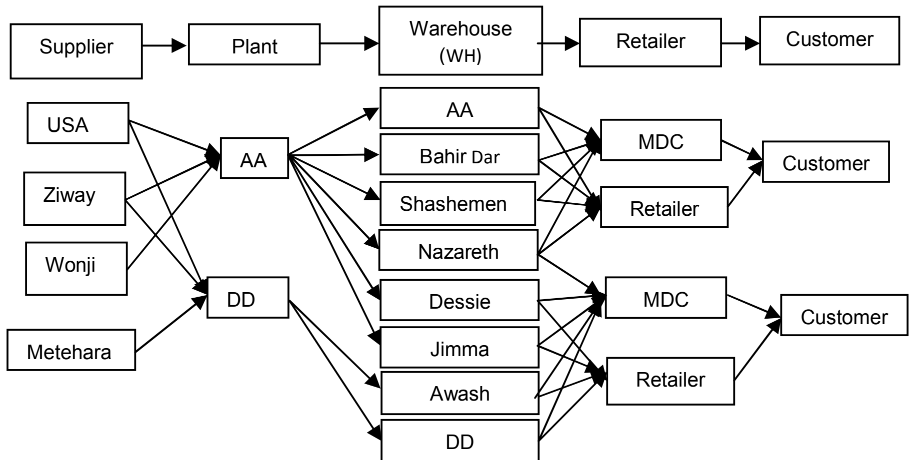
To clearly portray how the Linear Programming Model of SC network design works, it is important to thoroughly scrutinize the existing SC structure of the company. The company has few geographic regions which it directly supplies, seven regional towns and Addis Ababa, whereas the rest regions are supplied by agents whose numbers are variable. A simplified schematic diagram of the SC for the company's existing operation is given in Figure 2.

Raw material Type and Price Analysis

The raw materials that are utilized for the production of the company's product mix include concentrate, sugar, bottle, crown, Carbone dioxide (CO_2) and caustic soda. Table 1 depicts the sources of raw materials.

Production Capacity of the Company

The two plants of the company are operating at about 90 percent of actual production capacity. This is far greater than the actual demands shown in Table 3 by 388,000 cases. Therefore, for all practical purposes production capacity of 90 percent will be used. Table 2 shows the capacities of the two plants.



USA= United States of America, AA= Addis Ababa, DD=Dire Dawa, MDC= Manual Distribution Centers

Figure 2: Existing supply chain network of the case company.

Table1: Raw material type, sources and their respective prices.

No	Raw Material	Source
1	Concentrate	USA
2	Sugar	Wonji/Metehara
3	Bottle	AA
4	Crown	AA
5	CO_2	In house production
6	Caustic Soda	Ziway

Table 2: Actual production capacity of the company per year.

Capacity in Cases per year				
Plants	**Line 1**	**Line 2**	**Line 3**	**Total**
Addis Ababa	660,000	816,000	1,440,000	2,916,000
DD Plant	468,000	-	-	468,000
Grand Total				3,384,000

Warehouses and their Supply Regions

There are five warehouses that receive deliveries directly from the manufacturing plant at Addis Ababa. Warehouses and their supply regions are,

- Addis Ababa market is supplied by 265 Manual Distribution Centers (MDCs).
- Awash is mainly supplied by the plant at Dire Dawa
- Nazareth warehouse covers Nazareth, Mojjo, Ziway, Arsi, and Wolenchiti areas.
- Shashemene warehouse covers demand regions of Awassa, Bale, and Arsi-Negelle.
- Dessie warehouse supplies areas within radius of 20Km excluding Kombolcha.
- Bahir Dar warehouse covers regions to Chagni and Addis-Zemen.
- Jimma warehouse supplies Jimma-Agaro and Jimma-Sekoro.

The remaining geographic regions are supplied by agents who have franchise from the Company. Other basic data are presented in the next section.

Basic Data Presentation and Related costs

Described below are some of the issues related to data collection and the calculation of costs required for the optimization models.

(i) Annual Demand at Warehouses

In Addis Ababa, each retailer is supplied by manual distribution centers (MDCs) nearby. It can be assumed that demand is concentrated at the point of MDC location. The MDCs can further be aggregated based on the total distance to serve a specific market segment. This is determined by the customer service level set by the company, which is 12 hours a day.

In regions where there are warehouses, demand is taken to be fixed at the warehouse location. In fact there are places which can have supply from multiple warehouses. As there is no warehouse in Addis Ababa, the company directly ships and sells its products to agents at MDCs. In such cases, multiple of MDCs are grouped based on their geographic proximity to represent demand at a specific location. All MDCs at Addis Ababa are summed together to represent a single warehouse. As a result there are demand locations at seven towns. The amount of cases shipped to these destinations annually (average) is given in Table 3.

Table 3: Annual demands at depots (warehouses).

Warehouse	AA	Bahir Dar	Dessie	Jimma	Nazareth	Shashemene	Awash	DD
Demand	1284800	183040	183040	183040	274560	274560	91520	183040

Source: Company's report

(ii) Transportation Rates

The cost of transporting products from a specific source to a specific destination is a function of the distance between these two points. The cost per case of soft drink per km can be calculated in two ways. Firstly, assuming that third party vehicles can be rented and secondly, using own transport system. Considering the relevant carrier and operational costs, the average transportation cost per case per Kilometer is found to be 0.06 Birr in a round trip. The summary for all cases are presented in the following three consecutive tables (4, 5 & 6).

Table 4: Warehouses and their distances from the plants in Kilometers.

From / To	Warehouse Locations							
	AA	**Bahir Dar**	**Dessie**	**Jimma**	**Nazareth**	**Shashemene**	**Awash**	**DD**
AA plant	0	560	400	335	100	250	240	515
DD plant	515	1075	915	830	415	695	275	0

Note: The warehouses at AA & DD are integrated with the plant

Table 5: Type of trucks and their capacity

No.	Type	Number of trucks			Capacity in cases	
		AA	DD	Total	AA	DD
1.	4 Pallet truck	15	3	18	4500	900
2.	6 Pallet truck	2	9	11	900	4050
3.	8 Pallet truck	2	2	4	1200	1200
4.	10 Pallet truck	1	0	1	750	0
5.	Hauler Trailer(22 pallet)	15	9	24	33000	19800
	Total				40350	25950

Note: A 4 pallet truck has a capacity of transporting 300 cases. A single pallet means 300/4 which is equal to 75 cases. Therefore, capacities of other trucks can be calculated by multiplying their pallet capacity by 75.

The company uses vender managed inventory and agents must fulfill minimum criteria to qualify for it. Agents owned trucks and their capacity are given in Table 6.

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Table 6: Types of third party trucks and their capacity.

No.	Type	Location									
		AA	**WH**	**Nazareth**	**Shash**	**Mekelle**	**Jimma**	**DD**	**De**	**BD**	**Total**
1	4 Pallet	16	-	-	-	-	-	1	1	1	18
2	6 Pallet	-	-	-	-	2	-	-	-	-	11
3	8 Pallet	13	-	5	4	7	2	2	-	-	4
4	Hauler Trailer	-	16	-	-	-	-	9		-	24

AA= Addis Ababa, WH= Warehouse, Shash= Shashamane, DD= Dire Dawa, De= Dessie, , BD= Bihir Dar

(iii) Potential Warehouse Locations:

This factor is considered to use the excess production of 388,000 cases. Hence, potential warehouse locations are identified based on the factors like potential markets, weather condition, and population. Based on these considerations and company's expert discussion; Mekelle and Gonder towns were identified as warehouse locations in addition to the already located ones. The major reasons to be established in these two towns are:

- Demand is high in the two towns;
- MDCs can easily be established;
- Agents can be cultivated in nearby towns; and
- Competitor is present in Gonder town (PEPSI COLA)

(iv) Warehouse Capacities:

The capacity of warehouses can be calculated by taking in to consideration the total physical size of the demand units. Also, factors on accounts of storing, retrieving, and other recording place allowances are considered. Generally speaking the capacity of warehouse is referred to as the average amount of demand the warehouse serves. In this particular case, the warehouse capacity in each location is found to be the peak weekly demands as shown in table 3 on annual base.

(v) Warehouse Costs:

From related warehouse costs, only warehouse fixed cost is needed to be found for the very reason that (1) it is this cost that widely differs from place to place, and (2) it is incurred regardless of the amount of material stored. Fixed warehouse costs at both Addis Ababa and Dire Dawa are integrated with the main plants. The fixed cost of warehouse for different locations is given in Table 7.

(vi) Service Level Requirements:

Though not exclusively mentioned, the company aspires to meet demand within 12 hrs. Assume that order processing and loading/unloading as well as waiting time will take a total of 6 hrs. The remaining 6 hrs can be taken to be service level the company wants to maintain, that is about 180 km assuming a loaded truck travels at 30km/hr.

Table 7: Annual warehouse fixed costs.

Warehouse	Bahir Dar	Dessie	Jimma	Nazareth	Shashemene	Awash
Fixed cost	120000	100000	120000	170000	120000	100000

Source: Company's report

RESULT AND DISCUSSION

Model formulation and data validation are typically done by reconstructing the existing network configuration using the collected data, and comparing the output of the model to existing data. Here, to validate the model, existing distribution costs to warehouses are calculated using analytical method and is compared against the optimization model done using solver. The cost of transport/km/case is 0.06 Br, and the distances between the plants and warehouses are given in table 4. Accordingly, the transportation costs/case is as depicted in table 8.

Table 8: Average transportation cost in Birr/case between plants and WH locations.

To \ From	AA	BD	Dessie	Jimma	Nazareth	Shashemene	Awash	DD
AA plant	0	33.6	24	18.9	6	15	14.4	30.9
DD plant	30.9	64.5	54.9	49.8	24.9	41.7	16.5	0

Source: Company's report

Note: The warehouses at AA & DD are integrated with the plant.

Based on the available data the total transportation cost for existing network can be calculated first analytically and then compared with the optimization solution techniques. Finally, optimization with the renewed setting will be made.

(a) Analytical Approach

Table 9 shows the results of the transportation costs. Analytically, the total annual transportation cost from plants to warehouses using equation 2.1 results 21,278,400 Birr. The actual transportation cost obtained from plants is almost equal with this value.

Table 9: Annual Costs based on transportation cost in Birr between plants and warehouses.

From To	Warehouses							
	AA	**BD**	**Dessie**	**Jimma**	**Nazareth**	**Shashemene**	**Awash**	**DD**
AA Plant	0	33.6	24	18.9	6	15	14.4	30.9
DD Plant	30.9	64.5	54.9	49.8	24.9	41.7	16.5	0
Demand	1284800	183040	183040	183040	274560	274560	91520	183040
Cost	0	6150144	4392960	3459456	1647360	4118400	1510080	0

(b) Using Solution Techniques to Optimize Distribution Costs

A general form of the linear programming model for the distribution network is given in section 2 of equation 1 and the related constraints are given in equations 2 to 9. In equation 1 Constraints 2 & 3 will have no room to entertain for this particular case company. This is because there is only one source of each categories of raw material consumed. Hence, the optimization formula can therefore, be modified to suit the company, i.e.

Total cost = Min $\left\{\sum_{i=1}^{n} F_i Y_i + \sum_{e=1}^{t} F_e Y_e + \sum_{i=1}^{n}\sum_{e=1}^{t} C_{ie} X_{ie} + \sum_{e=1}^{t}\sum_{J=1}^{m} C_{ej} X_{ej}\right\}$ …..(10)

To see the benefit of supply chain network design for the company, two sets of optimization are considered:

1. **Optimization based on existing set of operation of the company**: in this case, the existing plant and warehouse location are fixed.
2. **Optimization with renewed setting:** in this option, all warehouse locations are set to change and optimization techniques are used to arrive at a minimum cost scenario.

Optimization Based on Existing Set of Operation

Based on the existing network structures the plant at Addis Ababa supplies all the WH locations except Dire Dawa, which is supplied by the Dire Dawa plant. In the optimization approach, a built-in MS-Excel tool called solver is utilized. In this scenario, the total annual cost is found to be Br. 21, 086,208. Thus, it resulted in 192,192 Birr annual saving from the actual cost investigated with the analytical method which is 21,278,400 Birr. All the demand is met and all warehouses supply demands within their proximity. The excess transportation capacities to transport 149, 840 cases from Addis Ababa and 248,960 cases from Dire Dawa are used to serve third party distributors or agents who directly take shipments from plants. The detailed analyze is shown in Table 10.

Table 10: Optimized Minimum Cost for the Existing Network.

	Average Transportation cost per case (crate) between Potential WH locations								
	Addis Ababa	**Bahir Dar**	**Dessie**	**Jimma**	**Nazret**	**Shashemene**	**Awash**	**DD**	**Capacity**
AA plant	0	33.6	24	18.9	6	15	14.4	30.9	2624400
DD plant	30.9	64.5	54.9	49.8	24.9	41.7	16.5	0	432000
Demand	1284800	183040	183040	183040	274560	274560	91520	183040	
Amount to be transported from plant WH									
	Addis Ababa	**Bahir Dar**	**Dessie**	**Jimma**	**Nazret**	**Shashemene**	**Awash**	**DD**	**Capacity**
AA plant	1284800	183040	183040	183040	274560	274560	91520	0	2624400
DD plant	0	0	0	0	0	0	0	183040	432000
Demand	1284800	183040	183040	183040	274560	274560	91520	183040	
Supply plant	**Excess Capacity**								
AA	149840								
DD	248960								
Unmet Demand	0	0	0	0	0	0	0	0	
									Total Cost (TC)=21086208

Optimization with Renewed Setting

The basic problem with agents is that, they are not likely to travel longer distances to collect shipments. For instance, it is difficult to find distributors and MDCs in towns located far from plants. The total cost they incur coupled with their capacity to satisfy market largely hampers their performance. Besides, the opportunity the company loses is taken up by competitors right away. Therefore, it is better for the company to outreach as much markets as possible. Accordingly, warehouses at Mekelle and Gondar towns are identified as potential sites in addition to the already existing ones. Other places in the country have relatively level topography and nearby to AA and DD plant, hence, agents can easily be found.

After potential places in the country have proposed, the optimal solution taking into consideration all potential market locations is formulated in the MS-Excel Solver. The problem formulation and results are as presented in Table 11.

Table 11: Minimum cost scenario for the renewed network

Distance Matrix between the Plants and potential warehouse locations

	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle	Capacity
AA plant	0	560	400	335	100	250	240	515	738	780	2624400
DD plant	515	1075	915	830	415	695	275	0	1253	1295	432000
Demand	1284800	183040	183040	183040	274500	274560	91520	183040	1760	183040	

Average Transportation cost per case (crate) between Potential WH locations

	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle	Capacity
AA plant	0	33.6	24	20.1	6	15	14.4	30.9	44.28	46.8	2624400
DD plant	30.9	64.5	54.9	49.8	24.9	41.7	16.5	0	75.18	77.7	432000
Demand	1284800	183040	183040	183040	274560	274560	91520	183040	1760	183040	

Amount to be transported from plant WH

	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle	Capacity
AA plant	1284800	183040	183040	183040	149840	274560	0	0	183040	183040	2624400
DD plant	0	0	0	0	0	0	91520	183040	0	0	432000
Demand	1284800	183040	183040	183040	274560	274560	91520	183040	183040	183040	
Supply plant	Excess Capacity										
AA	0										
DD	32720										
Unmet Demand	0	0	0	0	0	0	0	0			

Amount to be transported from plant WH

	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle	Fixed W H Cost
AA	3	33.6	24	20.1	6	15	14.4	30.9	44.28	46.8	0
Bahir Dar	33.6	1.2	29.4	53.7	39.6	48.6	48	64.5	10.68	52.2	200000
Dessie	24	29.4	0.9	44.1	30	45	38.4	54.9	40.08	22.8	150000
Jimma	20.1	53.7	44.1	0.6	26.1	53.1	34.5	51	64.38	66.9	100000
Nazret	6	39.6	30	26.1	1.8	11.4	8.4	24.9	50.28	52.8	170000
Shashemene	15	48.6	39	53.1	11.4	1.2	19.8	36.3	59.28	61.8	150000
Awash	14.4	48	38.4	34.5	8.4	19.8	0.3	16.5	58.68	61.2	75000
DD	30.9	64.5	54.9	51	24.9	36.3	16.5	1.5	75.18	77.7	0
Gonder	44.28	10.68	40.08	64.38	50.28	59.28	58.68	75.18	0.9	62.88	120000
Mekelle	46.8	52.2	22.8	66.9	52.8	61.8	61.2	77.7	62.88	1.2	120000
Demand	1284800	183040	183040	183040	274560	274560	91520	183040	1760	183040	

Amount to be transported from plant WH

	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle	Open= 1
AA	1284800	0	0	0	0	0	0	0	0	0	1
Bahir Dar	0	183040	0	0	0	0	0	0	0	0	1
Dessie	0	0	183040	0	0	0	0	0	0	0	1
Jimma	0	0	0	183040	0	0	0	0	0	0	1
Nazret	0	0	0	0	274560	0	0	0	0	0	1
Shashemene	0	0	0	0	0	274560	0	0	0	0	1
Awash	0	0	0	0	0	0	91520	0	0	0	1
DD	0	0	0	0	0	0	0	183040	0	0	1
Gonder	0	0	0	0	0	0	0	0	183040	0	1
Mekelle	0	0	0	0	0	0	0	0	0	183040	1
Demand	1284800	183040	183040	183040	274560	274560	91520	183040	183040	183040	1

WH	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle
Excess Capacity	0	0	0	0	0	0	0	0	0	0

WH	AA	Bahir Dar	Dessie	Jimma	Nazret	Shashemene	Awash	DD	Gonder	Mekelle
Unrnet Demand	0	0	0	0	0	0	0	0	0	0

TC=47470227

In the renewed network optimization, the Dire Dawa Plant which was used to supply only Dire Dawa and its area is now utilized to supply Dire Dawa, Awash and half of Nazareth. In doing so, the company can increase its responsiveness by fully utilizing its whole capacity to supply itself. In this scenario a total of 366,080 market demands in cases which is equivalent to 8,785,680 Birr are achieved, and at the same time all demands are met. The final supply chain network design is therefore, as given in figure 2 and 3 respectively.

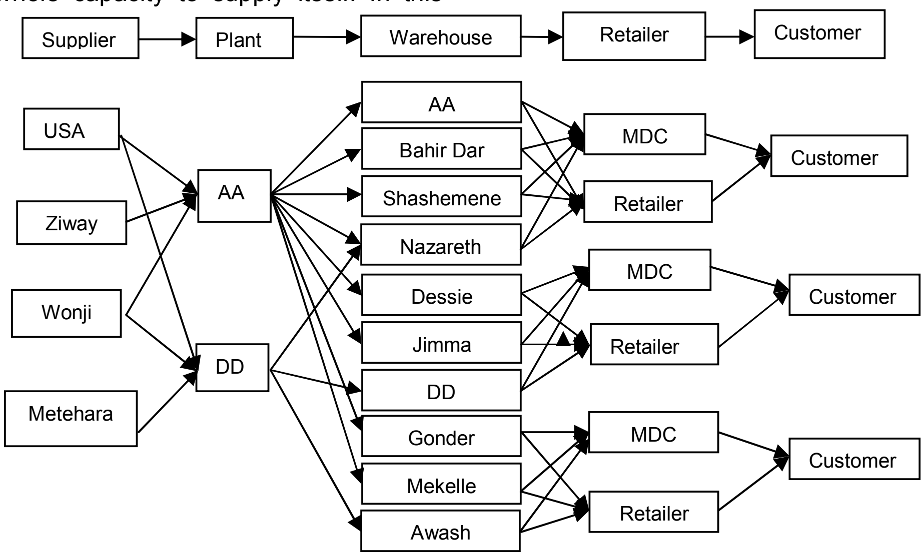

Figure 2: Renewed supply chain network design of the case company.

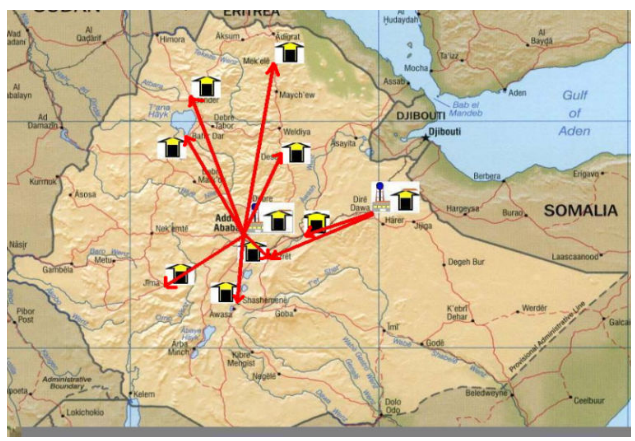

Figure 3: Renewed warehouse locations on the Map of Ethiopia.

CONCLUSIONS

The objectives of SC network design are to achieve enhanced responsiveness and minimized total distribution cost for manufacturing plant. These objectives are attained through proper modeling of the distribution network and applications of optimization techniques.

In this research, an attempt has been made to model the supply chain network design and justify with the case analysis. The following are the results of the case analysis for East Africa Bottling Share Company:

- Three new warehouses shall be established at Mekelle, Gonder, and Kazanchis.
- Plant at Addis Ababa supplies warehouses at Kazanchis, Bahir Dar, Dessie, Shashemene, Jimma, Gonder, Mekelle, Nazareth, and part of Awash.
- Plant at Dire Dawa ships to Dire Dawa, Awash and some part of Nazareth.

Furthermore, many interesting results are realized. First, by the application of network model optimization techniques, an annual cost saving of 192,192 Birr is achieved. Secondly, by renewing the existing network design of the company a market share of 366,080 cases per year which is equivalent to 8,785,680 Birr can be realized.

Finally, SC network design has a high economic benefit for manufacturing company. The mathematical model developed and optimization techniques employed here will be good grounds for any similar bottling companies with a need to design appropriate SC network thereby reduce their costs. Therefore, this model could be easily adapted to another manufacturing plant based on their existing operating situations. Furthermore, a future study on multi criteria decision making of warehouse locations for bottling companies is required.

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