Design Of Distribution Network For Ajmer Vidhut Vitran Nigam Limited Using Concept Of Supply Chain Management

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Abstract- Supply chain management is basically used for effective and economical supply of any product. A supply chain (SC) distribution network design model is developed in this paper for Ajmer Vidhut Vitran Nigam Limited (AVVNL), Ajmer. The goal of the model is to select the optimum numbers, locations and distribution centers to deliver products to sources at the least cost while satisfying desired service level. A maximal covering approach is used in statement of the service level. The model distinguishes itself from other models in this field in the modeling approach used. Because of somewhat imprecise nature of distribution, a property of MS Excel is used named Solver. To explore the viability of the proposed model and the solution approach, computational experiments are performed on realistic scale case problems.
Keywords– Supply chain, Distribution network design, Solver.
Abbreviations-
AVVNL- Ajmer Vidhut Vitran Nigam Limited, COG- Center of Gravity,

I. INTRODUCTION

A distribution network is designed for the most effective distribution of and product, supply or services. The most important tactical issue that firms have to resolve including allocation of volumes to plants and allocation of distribution centers. This research investigates the auction properties that influence efficiency (ability to maximize price and profit) as the distribution link of the supply chain. Also focuses on different key areas that are the roadmap to an effective, flexible and proactively responsive distribution operation[1]. Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a firm because it directly impacts both the supply chain cost and the customer experience. Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness. While customer service consist of many components, we will focus on those measure that are influenced by the structure of the distribution network. These include- Response time, Product variety, Product Availability, Customer experience, Order visibility, Return ability.

II. LITERATURE REVIEW

A. Types of Distribution Network –

There are three types of distribution network named Single Echelon, Two Echelon and Multi Echelon. In Single Echelon, there is no intermediate layer of facilities such as a warehouse or a distribution center. Products are shipped directly to customer from manufacturer. In Two Echelon, products are shipped from a manufacturing facilities to the customer through a warehouse or a distribution center and in Multi Echelon, products are shipped from a manufacturing facility to regional distribution centers through one or more central distribution centers.

A two echelon distribution network typically consist of manufacturing facilities, distribution centers, customers and the flow of material between them. The earlier research in the area of distribution network design mainly addresses following issues-

i) To find desire number of distribution centers.

ii) To find the location of each distribution centers.

iii) Determining the associate minimum cost of each distribution center.

B. Relavant Research in the area of Distribution Network Design-

Distribution network configuration theory has been an area of active research for the past several years. Many papers were published on configuring the distribution network assuming that the manufacturing plant and customer locations are fixed[2]. While Hasan Pirakul[3] used an integrated production-distribution approach. This research proposes a methodology to select optimum set of both plants and distribution centers from a potential set. This research proposes a two stage solution for this problem. In the first stage, the number of facilities and their locations are selected. While in the second stage the assignment of customers to distribution centers is done. The research tries to evaluate the importance of coordinating production and distribution planning in designing a distribution network.

Geoffrion proposes a solution considering multi-commodity, multi-plant, multi-distribution centers and multi-customers using Benders Decomposition method. According to this research, as Benders decomposition decomposes the master problem into many independent sub-problems, it is possible to solve the problem with virtually any number of commodities[4].

C. Solution Techniques-

The earlier research in this area proposed use of different techniques, mainly:

i) Mathematical Optimization Techniques.

ii) Simulation Modeling Techniques.

But, in this paper we used a technique known as Spreadsheet Modeling and Excel Solver. A mathematical model implemented in a spreadsheet is called a spreadsheet model. Major spreadsheet packages come with a built-in optimization tool called Solver. If the model has two variables, the graphical method can be used to solve the model. Very few real world problems involve only two variables. For problems with more than two variables, we need to use complex techniques and tedious calculations to find the optimal solution. The spreadsheet and solver approach makes solving optimization problems a fairly simple task and it is more useful for those who do not have strong mathematics background. The use of spreadsheet modeling and Excel Solver in solving linear and nonlinear programming problems in an introductory Operations Research course. This is especially useful for interdisciplinary courses involving optimization problems. We work through examples from different areas such as manufacturing, transportation, financial planning, and scheduling to demonstrate the use of Solver.

D. Supply Chaon Management-

Supply Chain Management is management of material, money, men, and information within and across the supply chain to maximize customer satisfaction and to get an edge over competitors. It is also defined as, according to Scott and Brook, “The chain linking each element of the manufacturing and supply process from raw materials to the end user, encompassing several organizational boundaries” and Christopher says, “The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole”.

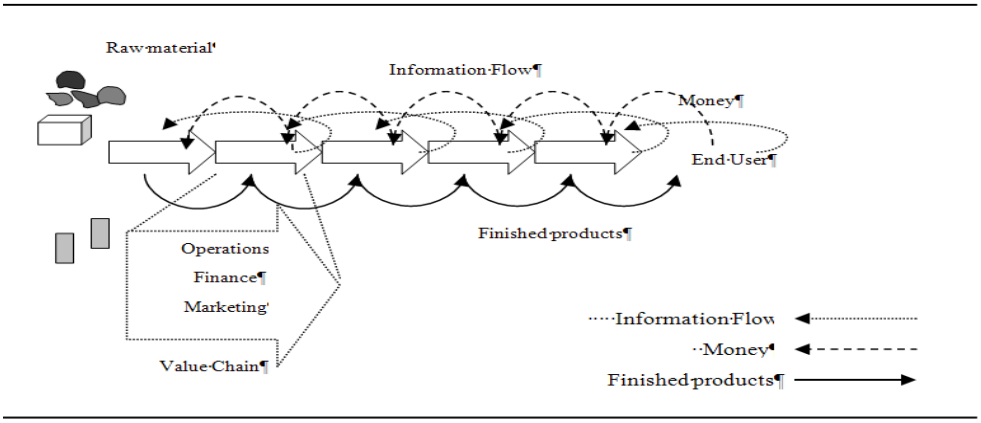


Figure 1. Supply Chain Management[Source: New and Payne, 1995]

III. DISTRIBUTION CENTRES

E. Defination-

Warehousing and distribution operations date back to the existence of production and transportation. Today, warehouses primarily serve as storage points along the supply chain between the origins of raw materials and the destinations for consumption of final products. Warehouses exist because of economies of scale in two areas—transportation and manufacturing. Lump sum shipping saves on labor and equipment usage.

Distribution centers are special forms of warehouses that focus on throughput where products from various manufacturers are combined into shipments of precise quantities for distribution according to customer needs. Before the mid-twentieth century, warehouses and distribution centers were largely isolated from other upstream or downstream activities in the supply chain. Today they are integral parts of the supply chain that link inputs to the final products to the consumers.

F. Location of Distribution Network in Supply Chain-

To this point, warehouses and distribution centers have been considered as individual entities. In fact, they form a network of nodes connected by lines (e.g. freight lanes and major ports and terminals) to suppliers, manufacturers, and markets. Supply chains are interwoven on this network. The agility of a supply chain depends on the intrinsic nature of this network. The supply chain follows the geographic distribution of resources and strategic partnerships. The network is critical for efficient distribution of materials and products and for the ability of promptly response to market changes.

Product variety and availability to customers will dictate the supply chain strategy and functions of the distribution network. Order visibility depends on how the retailers, distributors and suppliers are integrated through partnerships and information sharing. Level of centralization refers to the extent to which the individual distribution centers collaborate in complementing each other's market coverage. Transportation availability at warehouse locations significantly impacts transportation costs and a distributor's ability to respond to market[1].

G. Center-of-Gravity Model(COG)-

The center-of-gravity model helps determine the optimal location for an individual warehouse if proximity to customers is the only criterion. To select a site for an individual distribution center to serve local customers, the model suggests finding the location closest to the center of demand for all customers. Customers are assumed to be located on a grid system, each with a given fixed annual demand. The location of each customer is represented by an x and y coordinate. The COG model finds the approximate location for a single warehouse to best serve all customers. The center-of-gravity model is a weighted approach that locates the warehouse closest to customers with highest demand. This is an empirical method minimizing the distribution distances weighted by shipping volume[5]. The following formula is used to find the COG location (x, y) for the warehouse.

$$X = \frac{\sum_i^n x_i d_i}{\sum_i^n d_i} \quad (1)$$

$$Y = \frac{\sum_i^n y_i d_i}{\sum_i^n d_i} \quad (2)$$

Where x_i and y_i are the coordinates of the i_{th} customer, and d_i is annual demand of the i_{th} customer.
The COG method does not consider zoning requirements, land prices, warehouse taxes, labor availability and other factors. The method gives a location where the warehouse best responds to market demand.

IV. Model Description and Result Analysis

A. Model Description-

As stated above, the objective of the research is to develop a distribution network under supply chain of the Ajmer Vidyut Vitran Nigam Limited,Ajmer for Jhunjhunu District. The main objectives of the research could be stated in short as:

i) Analyze the existing distribution network.
ii) Propose a new distribution strategy
iii) Find the optimum number of distribution centers, their locations and
iv) Decide the associate minimum cost.

As stated earlier, each model represents a specific business case; hence an optimization model with the suitable constraints was developed. Total cost concept was used along with mathematical optimization technique. The important components of cost used in developing this model are:

i) Fixed initial set up cost.
ii) Transportation cost.
iii) Inventory cost

After analyzing the current distribution strategy, a new strategy was proposed to overcome its disadvantages. The highlights of the proposed distribution strategy are,

i) Each distribution center would store all products.
ii) Each distribution center would serve only the customers in its proximity (no specific distance constraint was modeled).
iii) Each customer would be served by only one distribution center.

The important steps in the development of the model can be described as,

i) Data collection.
ii) Mathematical formulation.
iii) Running the model.

B. Data Collection-

- Statement showing 25 KVA three phase transformers issued to sub division:

TABLE 1. DATA TABULATION OF 25KVA THREE PHASE TRANSFORMERS

S N	Store	Sub Division	25 KVA, Fiscal year 2011-12												
			Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	**Total**
1	JJN	Jhunjhunu	0	0	0	0	0	0	0	0	0	0	0	0	0
2	JJN	Jhunjhunu Rural	0	0	56	9	12	0	30	64	19	17	0	40	247
3	JJN	Bagar	0	0	6	0	13	2	8	0	0	0	0	0	29
4	JJN	Chirawa	0	0	0	3	0	3	4	4	0	0	0	0	14
5	JJN	Surajgarh	0	0	0	0	10	0	33	8	0	0	0	0	51
6	JJN	Sultana	0	70	0	0	10	0	0	5	0	0	0	0	85
7	JJN	Malsisar	3	0	0	6	11	0	7	0	0	0	0	7	34

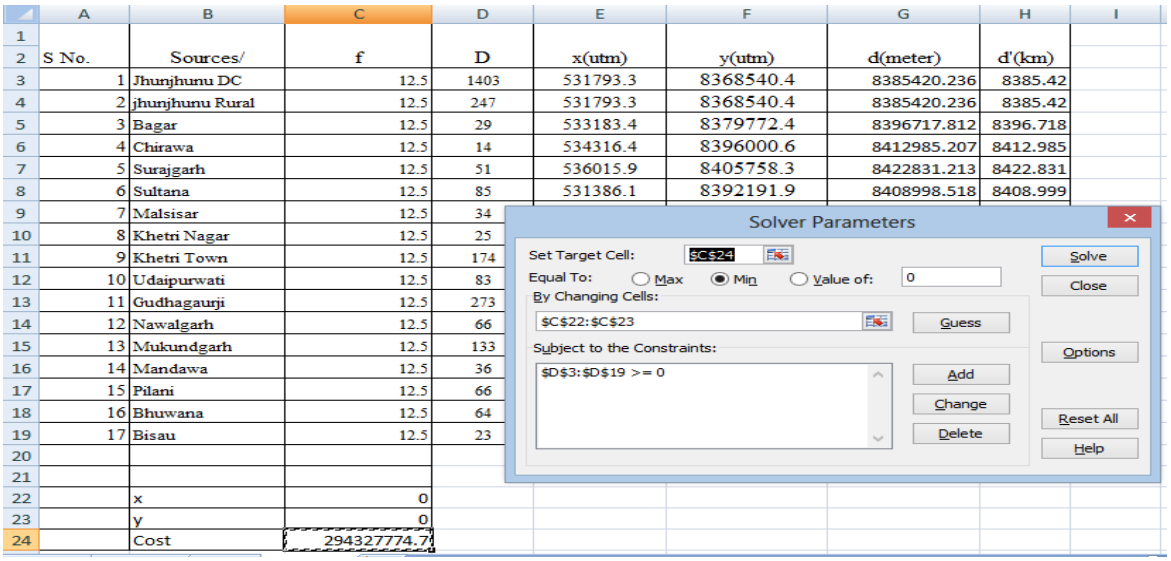
8	JJN	Khetri Nagar	0	0	0	0	6	6	6	7	0	0	0	0	25
9	JJN	Khetri Town	0	0	3	16	43	0	42	62	3	0	0	5	174
10	JJN	Udaipurwati	0	16	0	0	2	11	14	23	3	0	0	14	83
11	JJN	Gudhagaurji	0	63	43	31	15	39	40	20	2	0	0	20	273
12	JJN	Nawalgarh	0	0	0	0	0	25	5	21	5	0	0	10	66
13	JJN	Mukundgarh	0	0	0	10	96	0	0	0	0	0	0	27	133
14	JJN	Mandawa	0	0	13	0	0	8	13	0	0	0	0	2	36
15	JJN	Pilani	0	0	0	5	0	10	18	33	0	0	0	0	66
16	JJN	Bhuwana	0	1	0	0	15	10	20	0	4	10	0	4	64
17	JJN	Bisau	0	0	0	0	0	5	18	0	0	0	0	0	23
	Total		3	150	121	80	233	119	258	247	36	27	0	129	1403

- Statement showing position of sources in gps and (x,y) coordinates:

TABLE 2. DATA TABULATION OF POSITION OF SOURCES IN GPS AND (X,Y) COORDINATES

S No.	Sources/ Positions	GPS(N) [degree]	GPS(E) [degree]	x(utm)	y(utm)
1	Jhunjhunu DC	28.1300°	75.4000°	531793.3	8368540.4
2	Jhunjhunu Rural	28.1300°	75.4000°	531793.3	8368540.4
3	Bagar	28.1874°	75.5004°	533183.4	8379772.4
4	Chirawa	28.2401°	75.6456°	534316.4	8396000.6
5	Surajgarh	28.3093°	75.7327°	536015.9	8405758.3
6	Sultana	28.1316°	75.6120°	531386.1	8392191.9
7	Malsisar	28.3542°	75.2929°	538373.7	8356725.8
8	Khetri Nagar	28.0723°	75.8228°	529317.1	8415678.9
9	Khetri Town	27.9993°	75.7861°	527388.6	8411549.4
10	Udaipurwati	27.7288°	75.4715°	520407.7	8376340.5
11	Gudhagaurji	27.8672°	75.5331°	524182.3	8383265.3
12	Nawalgarh	27.8500°	75.2699°	524124.3	8353893.9
13	Mukundgarh	27.9451°	75.2248°	526903.4	8348903.3
14	Mandawa	28.0559°	75.1468°	530212.2	8340255.0
15	Pilani	28.3638°	75.6021°	537850.9	8391223.4
16	Bhuwana	28.2049°	75.8763°	532817.8	8421717.2
17	Bisau	28.2447°	75.0757°	535780.2	8332428.5

C. Data Entry and Model Formulation For Existing Distribution Network-



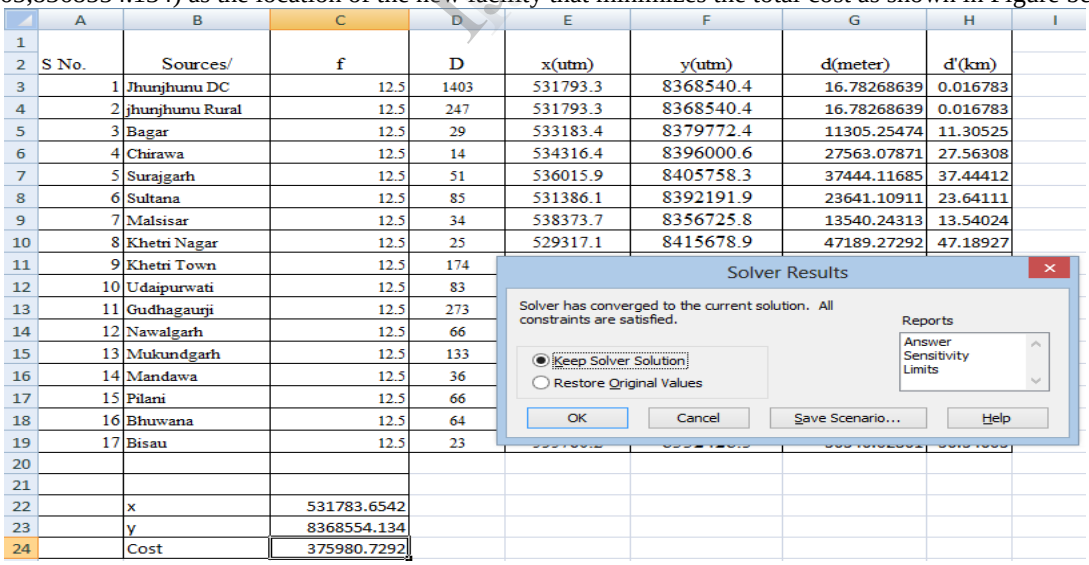
S No.	Sources/	f	D	x(utm)	y(utm)	d(meter)	d'(km)
1	Jhunjhunu DC	12.5	1403	531793.3	8368540.4	8385420.236	8385.42
2	jhunjhunu Rural	12.5	247	531793.3	8368540.4	8385420.236	8385.42
3	Bagar	12.5	29	533183.4	8379772.4	8396717.812	8396.718
4	Chirawa	12.5	14	534316.4	8396000.6	8412985.207	8412.985
5	Surajgarh	12.5	51	536015.9	8405758.3	8422831.213	8422.831
6	Sultana	12.5	85	531386.1	8392191.9	8408998.518	8408.999
7	Malsisar	12.5	34				
8	Khetri Nagar	12.5	25				
9	Khetri Town	12.5	174				
10	Udaipurwati	12.5	83				
11	Gudhagaurji	12.5	273				
12	Nawalgarh	12.5	66				
13	Mukundgarh	12.5	133				
14	Mandawa	12.5	36				
15	Pilani	12.5	66				
16	Bhuwana	12.5	64				
17	Bisau	12.5	23				
	x	0					
	y	0					
	Cost	294327774.7					

Figure 2: Model formulation containing solver parameters (source: JJN DC existing)

TABLE 3. FORMULAS USING IN ABOVE EXCEL SPREAD SHEET

Cell	Cell Formula	Equation	Copied to
G3	=SQRT((C22-E3)^2+(C23-F3)^2	1	G3:G19
B24	=SUMPRODUCT(G3:G19,D3:D19,C3:C19)	2	-

Click on the solver button and the optimal solution is returned in cells and thus identifies the coordinates (X, Y) = (531783.65,8368554.134) as the location of the new facility that minimizes the total cost as shown in Figure below:



S No.	Sources/	f	D	x(utm)	y(utm)	d(meter)	d'(km)
1	Jhunjhunu DC	12.5	1403	531793.3	8368540.4	16.78268639	0.016783
2	jhunjhunu Rural	12.5	247	531793.3	8368540.4	16.78268639	0.016783
3	Bagar	12.5	29	533183.4	8379772.4	11305.25474	11.30525
4	Chirawa	12.5	14	534316.4	8396000.6	27563.07871	27.56308
5	Surajgarh	12.5	51	536015.9	8405758.3	37444.11685	37.44412
6	Sultana	12.5	85	531386.1	8392191.9	23641.10911	23.64111
7	Malsisar	12.5	34	538373.7	8356725.8	13540.24313	13.54024
8	Khetri Nagar	12.5	25	529317.1	8415678.9	47189.27292	47.18927
9	Khetri Town	12.5	174				
10	Udaipurwati	12.5	83				
11	Gudhagaurji	12.5	273				
12	Nawalgarh	12.5	66				
13	Mukundgarh	12.5	133				
14	Mandawa	12.5	36				
15	Pilani	12.5	66				
16	Bhuwana	12.5	64				
17	Bisau	12.5	23				
	x	531783.6542					
	y	8368554.134					
	Cost	375980.7292					

Figure 3. Model formulation containing solver results (source: JJN DC existing)

From the map, these coordinates are close to the JJN DC. The precise coordinates provided by the gravity modelmay not correspond to a feasible solution. This is an existing distribution network of the AVVNL, Ajmer.

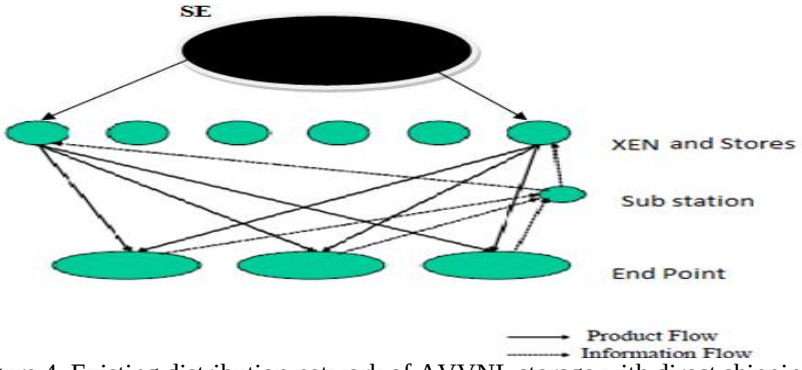


Figure 4. Existing distribution network of AVVNL storage with direct shipping

D. Modified Distribution Network

A survey is done to find the optimum number of distribution centers within the region. All sub division is situated on the four ways. First one(JJN DC modified) on the Jaipur- Loharu way, second one(Gudha) on the Jhunjhunu-Udaipurwati way, third one(Chirawa) on the Jhunjhunu-Pilani way and last one(Khetri Nagar) on Jhunjhunu-Narnaul way. These all are suitable locations to serve customer request. This means that there are four numbers of suitable locations in fulfilling customer demands.

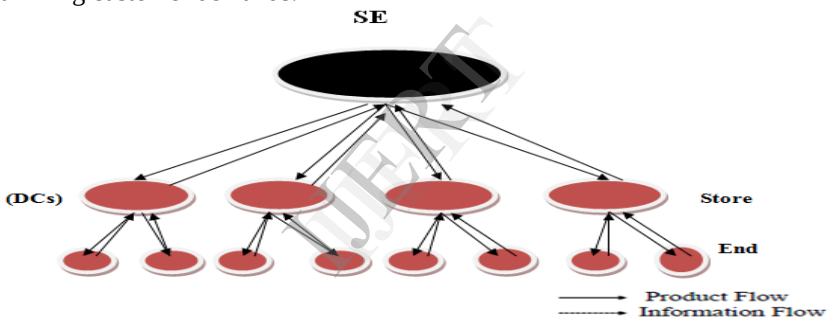


Figure 5. Modified distribution network of AVVNL Storage

Now, we got the different results for each distribution center according to previous process as applied for existing distribution center. And the results are as:

Total transportation cost of existing distribution network = **375980.72 Rs**

Total transportation cost of modified distribution network = 29079.57 + 89756.39 + 22304.14 + 15505.29

= **156645.4 Rs**

Difference of Total transportation cost in both cases = **375980.72- 156645.4**

= **219335.32 Rs**

E. Results

The efficiency of the distribution network = [(initial total cost- final total cost)/(initial total cost)]

= [(375980.72- 156645.4)/ 375980.72]* 100

= **58.33%**

V. Conclusion

This research studied the problem of designing a distribution network under a supply chain system that involves determining the best locations stores and the best strategy for distributing the product from the plants to the stores and from the stores to the customers. This research is developed a model by using a tool Solver in Excel for the problem. The results of model indicate that the procedure is both effective and efficient for a wide variety of problem sizes and structures.

The results of this model indicate that large cost savings can be achieved through systematic analysis of the logistics process of this company. The model with four distribution centers results in approximate **58.33%** of the cost savings. Optimally designed distribution network would primarily results in

i) Lower transportation costs
ii) Increased customer service level
iii) Decrease in order fulfillment lead time
iv) Greater demand visibility as each distribution center will be closer to customers

This approach suggested here can be easily used to design any model under supply chain and can be flexibly updated to reflect any changes in the process, strategy or demand pattern. The well defined structure of the data sets allows easy maintenance of the data. Using solver tool in Excel requires relatively less time to compute the feasible solution. This is an important feature from the user point of view, since the user can build different scenarios by making necessary changes in the model and achieve the results relatively quickly so that all customer demand is satisfied at minimum total costs of the distribution network resulted from the Store location, transportation, and inventory. This model is developed for Ajmer Vidyut Vitran Nigam Limited, Ajmer and minimized the expected total cost for designing an effective distribution network system in a supply chain.

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