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DETERMINATION OF AN OPTIMAL DISTRIBUTION STRATEGY FOR A SUPPLY CHAIN ORGANIZATION: A CASE OF DELTA BEVERAGES, BULAWAYO, ZIMBABWE

[1]Absalom Jaison, Chinhoyi and [2]Tavengwa Masamha

[1]University of Technology, Department of Mathematics
[2]Chinhoyi University of Technology, Department of ICT and Electronics

ABSTRACT

Supply Chain Management (SCM) is a strategic management operation involving movement of goods from suppliers through to customers. Proper management of SCM reduces costs. Delta Beverages uses SCM in the production and distribution of their commodities. A best operation strategy reduces costs. In this paper, customers whose minimum demand of soft drinks per month is100 crates were considered. Their distances and distribution costs from the current single warehouse were calculated and compared with those obtained through the clustering algorithm. A financial implication of having the optimal number of warehouses was analyzed. The Nearest Center Reclassification Algorithm and Weiszfeld Algorithms were used to calculate customer distribution cost using, 2, 3 and 4 clusters (warehouses). A simulation was done in Arena considering randomly selected customers from each cluster. Results were compared with Excel results. A best operation strategy was recommended to Delta Beverages. A project valuation of either to expand or remain with single warehouse was done using Real Option valuation technique.

Keywords: Clustering Problem, Facility Location, Supply Chain Management, Clustering Algorithm, Nearest Center Reclassification.

INTRODUCTION

A supply chain is a set of organizations that are involved in the different processes and activities that produce value in form of products and services in the hands of the ultimate customer that is according to [14]. Supply chain management (SCM) is one of the areas in logistics which has attracted much attention [14]. SCM is defined by [17] as a process of planning, implementing and controlling the operations of the supply chain in an efficient way. SCM has to be sustainable i.e. the processes and systems must be non-polluting, conserve energy, economically efficient, safe and use healthy workers, communities and consumers as well as socially and creatively rewarding for all working people and their community. [3], [18] indicated that SCM flows are divided into financial, information and product flows. To be sustainable a production process should provide social, environmental and economic benefits not only to the living generation but to the future generations as well. Financial flow consists of credit terms, payment schedules, consignment and title ownership arrangements. Information flow involves transmitting orders and updating the status of delivery. Product flow includes movement of goods from a supplier to a customer as well as any customer returns or service needs. Supply chain management is divided into planning and execution of the planned strategies. The planning and execution has to human, worthy; dignified and intrinsically satisfying for them to be sustainable. Planning uses advanced algorithms to determine the best way to fill an order whilst execution involves tracking the physical status of goods, management of materials and financial information involving all parties. According to [2], [3], the development of SCM resulted into development of facility location models. These facilities will be used to process, store or distribute the commodities to customers or other distribution points. Several questions that resulted from developments of these models are: (i) What properties does a facility location model have to fulfill to be acceptable within the supply chain context. (ii) Are there existence facility location models which already fit into the supply chain context? (iii) Does SCM need facility location models at all?

In this paper the product flow and planning application are used. Different decisions should be made and coordinated for the smooth running of operations at strategic and operational levels according to the length of the time and importance of the decisions in a sustainable way. Strategic decision is related to physical distribution structure of the supply chain including locating facilities and allocating these facilities to customers [11]. On operational level, decisions on transportation, scheduling and inventory levels have to be made considering customer demands, transportation costs, inventory costs and other costs as indicated by [1]. Sustainably these decisions cater for economic efficiency and satisfying to the consumer. Delta Beverages, at strategic level, as they produce their commodity, soft drinks, needs to know how much to produce in a given time that should meet demand from customers for a specific period. Their operational level, should as well decide for the best transportation schedule to supply the commodity to customers at minimum possible cost. They need to know where to supply how much of the commodity to minimize costs and satisfy demand. These process considerations are economically efficient for the company, safe and healthful for both workers and the consumers.

Presently all customers are purchasing soft drinks from one warehouse by either going to the warehouse or placing an order and have it delivered to their shops. It is an advantage to customers to come and purchase from the warehouse since they get the commodity there and then but pays for that by waiting in a queue for a long time. Those customers who opt to place orders and have their orders delivered, take a risk of having the order stay for more than one day before it is delivered. It is evident that the status quo is not sustainable in the sense that the customers are inconvenienced and the seller is disadvantaged by having lower profitability. The paper looks at minimizing distribution costs and time associated with Delta Beverages operations and customer deliveries. The paper identifies if the current single warehouse being used to supply customers is optimal. Options to add more warehouses to ease distribution are investigated and conclusions made regarding what the optimal distribution strategy Delta Beverages should implement to satisfy their customers at a minimum possible cost. The set of open-facilities should minimize the cost function i.e. cost incurred by serving each client and that incurred by opening each facility. The motivation here is to make the storage and distribution of the products more sustainable mainly in terms of customer satisfaction cost effectiveness.

This is a multiple facility location problem (MFLP) that tries to locate facilities so as to serve optimally a given set of customers whose locations and requirements are known. Simple MFLP will have n demand points (customers) and m facilities will be given so that their locations are determined and customers assigned to facilities so as to minimise the sum of weighted distances from facilities to assigned points [10], [12]. MFLP is considered as a clustering problem.

AIM AND OBJECTIVES

The paper aims at coming up with an optimal distribution strategy for Delta Beverages that will be used to satisfy demand at the same time minimizing operational costs for the organization. The objectives are: (i) Identify optimal location(s) for additional warehouse(s) to be used for distributing the commodity. (ii) Develop a distribution schedule for the commodity that minimizes costs. (iii) Evaluate and come up with an optimal number of additional warehouses and recommend an operation strategy that maximises net-profit during a planning horizon of one month. (iv) Develop a simulation model for distribution of the commodity that can be used by management to forecast demand. (v) Evaluate the financial impact of either expanding or not expanding the current operations using real option valuation techniques.

The paper addresses the questions: (i) where should additional warehouse(s) be opened? (ii) how many warehouses should be opened? (iii) what distribution scheduling technique should be used? (iv) what is the cost of expansion? The answers to these questions were reached at in line with sustainability.

DATA AND METHODS USED

715 customer details were available from the Operations Department of Delta Beverages. A 20% sample was randomly selected that had 143 customers. Data from these customers with a minimum monthly demand of 100 crates of soft drinks who were located within a distance of 20km from the current warehouse were considered. Demand data for customers' purchases for a period of nine months from July 2011 to March 2012 was averaged to give an average monthly demand for each of the selected customers. This averaged demand and unit transportation cost which was estimated at US$1.50 was used as "weight" for each customer in the determination of the optimal location using Weiszfeld Algorithm (WA) [5]. Microsoft Excel and Matlab were used. Customer locations were determined using their physical addresses. Each customer was identified with a unique Cartesian coordinate representation (x_i, y_i). Initial cost of the current location was determined and comparisons were made with the developed options in Excel.

[9], [16] indicated that WA requires minimisation of the total distribution cost given by:

$$TC = \sum_{i=1}^{n} c_i f_i \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2} \qquad (1)$$

The coordinate $(\bar{x}, \bar{y})$ is an optimal position, (x_i, y_i) are customer location, c_i is unit transportation cost and f_i is traffic flow of the item demanded by customer *i*. Replacing $c_i f_i$ with w_i, the optimal point, $(\bar{x}, \bar{y})$ in a given cluster that minimizes distribution cost is given by:

$$\bar{x} = \frac{\sum_{i=1}^{n} \frac{w_i x_i}{\sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}}}{\sum_{i=1}^{n} \frac{w_i}{\sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}}} \qquad (2)$$

$$\bar{y} = \frac{\sum_{i=1}^{n} \frac{w_i y_i}{\sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}}}{\sum_{i=1}^{n} \frac{w_i}{\sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}}} \qquad (3)$$

The three iterative steps were followed to determine the optimal cluster locations that will give minimum cost. The Nearest Centre Reclassification Algorithm (NCRA) uses the algorithm as defined by [5], [11], and [12] below.

1. Set	$r=0$	The number of reassignments
2. Compute	*For* $i=1, 2, \ldots m$	The center x_i^k of Ω_i^k
3. Compute	*For* $j=1, 2, \ldots n$	Distance $d_{ij} = \|a_j - x_i^k\|$, $i=1,2, \ldots m$
	For $j=1, 2, \ldots n$	If $a_j \in \Omega_{pk}$ and $d_{jl} = \min d_{ji} < d_{jp}$ $(i=1, 2, ..m)$ *then*
		$\Omega_l^k = \Omega_l^k \cup \{a_j\}$, $\Omega_l^k = \Omega_l^k \setminus \{a_j\}$(**reassign** a_j)
		$r = r+1$. **Endif**
4. If	$r=0$	**Stop**
5. endif	$\Omega^{k+1} = \Omega^k$	

k=k+1 **Go to 1**

Step 0: Set iteration counter, k = 1. Calculate a center point.

$$\bar{x}^k = \frac{\sum w_i x_i}{\sum w_i}, \quad (4)$$

$$\bar{y}^k = \frac{\sum w_i y_i}{\sum w_i} \quad (5)$$

Step 1: Set

$$\bar{x}^{k+1} = \frac{\sum_{i=1}^{n} \frac{w_i x_i}{\sqrt{(x_i-\bar{x}^k)^2+(y_i-\bar{y}^k)^2}}}{\sum_{i=1}^{n} \frac{w_i}{\sqrt{(x_i-\bar{x}^k)^2+(y_i-\bar{y}^k)^2}}} \quad (6)$$

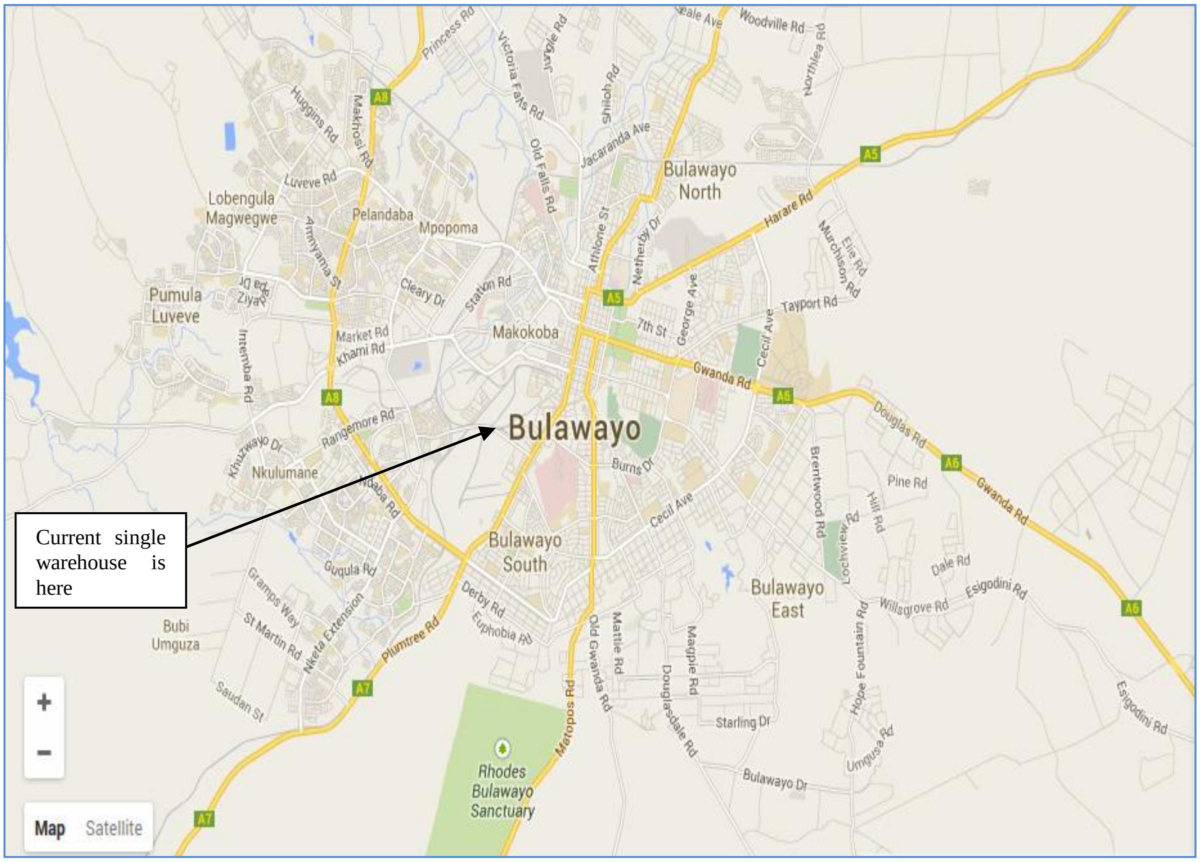
$$\bar{y}^{k+1} = \frac{\sum_{i=1}^{n} \frac{w_i y_i}{\sqrt{(x_i-\bar{x}^k)^2+(y_i-\bar{y}^k)^2}}}{\sum_{i=1}^{n} \frac{w_i}{\sqrt{(x_i-\bar{x}^k)^2+(y_i-\bar{y}^k)^2}}} \quad (7)$$

Step 2: If $\bar{x}^{k+1} = \bar{x}^k$ *and* $\bar{y}^{k+1} = \bar{y}^k$ ***stop,*** *otherwise set* $k = k + 1$ *and* ***go to Step 1***.

The algorithm was used for 2, 3 and 4 clusters. Optimal locations were got. After identifying the optimal number of clusters a Real option Valuation for an option to expand was done to see the financial implications in taking the optimal decision of having additional warehouses.

STUDY AREA

The map below indicates the area that the research was carried out. Customer demand and their locations were identified and shown in Cartesian representation (x_i, y_i). Customers at different positions were then plotted in a Cartesian plane as shown in Fig 2. The NCRA was applied and optimal solutions (positions) were got.



RESULTS AND DISCUSSIONS

A single cluster (warehouse) has a distribution cost of $341, 940.04. Summary tables for optimal locations in each run for 2, 3 and 4 cluster problems are given below for four and five runs that were performed for each cluster separately.

Cluster	1^{st} run	2^{nd} run	3^{rd} run	4^{th} run
1	(5.8, 7.7)	(5.8, 7.7)	(5.9, 7.6)*	(5.9, 7.6)
2	(13.1, 7.8)	(12.8, 7.8)	(12.6, 7.7)*	(12.7, 7.7)
Cost	$225,116.70	$222,397.75	$222, 016.61*	$222,094.28

Table 4.1: Two Cluster center points

Cluster	1^{st} run	2^{nd} run	3^{rd} run	4^{th} run
1	(5.1, 8.0)	$(5.3, 8.1)^*$	(5.1, 8.1)	(5.3, 8.2)
2	(10.6, 7.1)	$(10.7, 7.0)^*$	(10.7, 7.0)	(10.7, 6.8)
3	(14.1, 8.2)	$(13.4, 8.0)^*$	(13.2, 8.0)	(13.0, 8.0)
Cost	$217,378.75	$175, 498.09*	$210,160.54	$213,290.31

Table 4.2: Three Cluster center points

Cluster	1^{st} run	2^{nd} run	3^{rd} run	4^{th} run	5^{th} run
1	(4.4, 7.3)	(4.7, 7.3)	(4.8, 7.1)	$(4.9, 6.7)^*$	(4.8, 7.0)
2	(8.7, 8.4)	(8.5, 8.4)	(8.4, 8.4)	$(8.1, 8.9)^*$	(8.3, 8.5)
3	(12.0, 7.5)	(12.1, 7.6)	(12.2, 7.6)	$(12.3, 7.6)^*$	(12.2, 7.6)
4	(14.7, 7.9)	(15.4, 7.7)	(15.6, 7.6)	$(15.9, 7.6)^*$	(15.6, 7.6)
Cost	$196,944.29	$193,310.61	$192,301.75	$188, 812.40*	$191,587.66

Table 4.3: Four Cluster center points

Fig. 1 represents costs for the three options and shows that the three cluster option has a minimum cost in the second run.

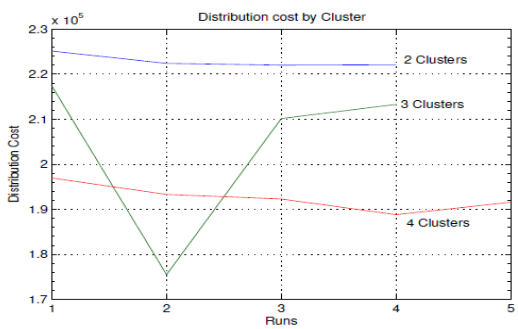


Fig. 1: Distribution costs of three options with different number of clusters

Fig. 2 presents the optimal clusters, representing warehouses, located at points (5.3, 8.1), (10.7, 7.0) and (13.4, 8.0). The three cluster setup gave a minimum distribution cost of **$175,498.09**, compared to **$341,940.04** of the current single warehouse setup. The two cluster setup had a minimum cost of **$222,016.61** whilst the four cluster setup had **$188,812.40.** The results show savings of 166, 442.31, 119,923.43 and 153, 127.64 respectively. These cost savings are very much sustainable for the company since there is great economic efficiency, no health hazards introduced, no flouting of government regulations, no threat to the environment, no social interference with the public and no threat to health and safety of the employees. Such savings would ensure continuation of production thus assuring future generations of the same benefits.

Fig. 2: Customer locations with three distribution points

An Arena model was developed with the idea of using it for a given period to forecast demand and gave the results below. Comparison of results got was made with those recorded from the actual sales. Table 4.4 shows the results of selected customers with absolute differences between the demand values for each customer shown.

Cluster	Customer	Arena Result	Excel Result	Absolute % difference
	Cust37	647	591	9.4%
	Cust45	262	230	13.9%
	Cust46	258	263	1.9%
	Cust47	291	246	18%
1	Cust68	357	337	5.9%
	Cust78	523	536	2.4%
	Cust94	120	108	11.1%
	Cust102	541	543	0.3%
Cluster 1 Total		**[2999]**	**[2854]**	
	Cust16	261	323	19.1%
	Cust19	171	149	14.8%
	Cust26	335	364	8.0%
	Cust27	128	142	9.9%
	Cust31	476	460	3.5%
	Cust32	475	483	1.7%
2	Cust35	399	413	3.4%
	Cust40	304	304	0%
	Cust48	275	264	4.2%
	Cust82	512	556	7.9%
	Cust145	395	402	1.7%
Cluster 2 Total		**[3731]**	**[3860]**	
	Cust36	583	586	0.5%
	Cust49	397	455	12.7%
	Cust57	479	468	2.4%
	Cust62	352	340	3.5%
	Cust69	117	126	7.1%
	Cust81	469	465	0.9%
3	Cust84	116	123	5.7%
	Cust89	241	227	6.2%
	Cust90	214	220	2.7%
	Cust91	429	378	13.5%
	Cust96	122	108	13%
	Cust98	316	260	21.5%
	Cust106	115	102	12.7%
	Cust122	120	114	5.3%
Cluster 3 Total		**[4070]**	**[3972]**	

Table 4.5 Comparison of Arena results and actual demand

Discounted cash flows for single and three cluster (warehouse) setup were computed using Microsoft Excel. The present values (PV) of the two options were then used in a Binomial tree model for computing the real option values of the two options. The two options were to (i) Remain operating with the single warehouse or (ii) Expand the current operation by having two more warehouses.

CONCLUSION

The optimal and sustainable number of warehouses should be three, located at **(5.3, 8.1), (10.7, 7.0)** and **(13.4, 8.0)**. The distribution cost using three warehouses located at the above locations was $175,498.09 which is very sustainable as compared with $341, 940.04 for a single cluster (warehouse). An arena model developed can be used to forecast demand (within 10%) and a distribution schedule can be developed for any given period. The option to expand to three warehouses has an option value of $48,094,907 and the organisation can exercise the option to expand the current operations to three warehouses. The option is sustainable since its friendly to the environment, economically beneficial as well as socially beneficial since more people will get employed once more warehouses are established.

The current operation with one warehouse has an option value of $821,679 compared to the PV of $6,764,868 (from DCF) whilst the option of expanding had a PV of $12,930,252 (from DCF) and option value $48,094,907 indicates that its best to exercise the option with the larger option value i.e. go for the option to expand since it gives a high OV. So an operation strategy for Delta Beverages is to expand to three warehouses so that they maximise revenue and minimise distribution costs.

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ABOUT THE AUTHORS:

Absalom Jaison is a Lecturer at Chinhoyi University of Technology, Mathematics Department, Chinhoyi, Zimbabwe

Tavengwa.Masamha is a Lecturer with Chinhoyi University of Technology, Computer Science Department, Chinhoyi, Zimbabwe