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Demand Variability And Supply Disruptions In Decentralized Retail Centres In A Supply Chain Network

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Abstract

The efficient management of the manufacturer–retail centre linkage in a supply chain network, is a multi-attribute decision making problem. It determines the market share and shapes the penetration of products into the market and retail centres. This demands that the customer strategic importance, cost, risk, e.t.c need to be harmonised. In this work a multi attribute decision model was used to determine the impacts of the retail centre risk in the form of demand variability or supply disruptions among other factors for a selected supply chain network that has eight retail centres.

The results of the demand variability of the eight retail centres are 1(0.44), 2(0.10), 3(0.88), 4(0.75), 5(0.56), 6(0.73), 7(0.25), 8(0.32), while the supply disruption are 1(0.35), 2(1.13), 3(1.13), 4(0.93), 5(0.93), 6(0.95), 7(0.35), 8(1.10) respectively.

A sensitivity analysis of the decision criterion also showed the consequences of changes in the priority of the criteria and sub-criteria over the final decision. This helps the decision maker respond quickly and appropriately to changes in the fund management philosophy and competitive advantage position

Keywords: Decentralized retail centres, Demand variability and Supply disruptions

1. Introduction

1.1 Preview: According to Zigiarias (2000), managers recognize the need to deliver products quickly to the market in other to be in a more competitive position, and as such there is need to effectively manage the distribution and logistics aspect of the value chain to ensure products are produced at the right quality and quantity while satisfying time and price optimization.

The vast literature available underpins the criticality of the situation, unfortunately existing models do not appear to pay enough attention to situations in which several conflicting and competing factors affecting supply chain decision making (Korpela et al., 2001) and so decision making is taken as a single criterion process in which only demand is considered during optimization.

One of the most important linkages in the supply chain is the manufacturer –retail centre linkage. This linkage determines the market share and shapes the penetration of products into the market allocation of products to retail centres and it is typically a multi attribute decision making problem in which criteria like risk, customer strategic importance, cost e.t.c. need to be harmonised.

1.2 Categories of Supply Chain

The supply chain is classed using different criteria. Kaminsky and Ahn (2001) classified traditional supply chain into pull and push supply chain. They described a push-based supply chain as one in which production and distribution decisions are based on long-term forecast, leading to slow reaction to changing market place. Being demand driven, they are coordinated with true customer demand rather than forecasted demand. A pull system leads to a decrease in lead time, decrease in system inventory, decrease in system variability, and an increase in customer service, however they make it difficult to take advantage of economies of scale in manufacturing and transportation since system are not planned far ahead of time. The supply chain system in pull (demand driven) environments work with traditional push elements. The Adaptive Supply Chain Network (ASCN) allows all stakeholders in the supply chain both within and outside make collaborative efforts to share knowledge, make collaborative decisions and; sense and respond immediately to changing conditions. The ASCN allows companies to resolve order to a chaotic supply chain for higher profits.

Dismukes et al. (2003) also classified supply chain into three main types; lean supply chain (LSC), agile supply chain (ASC), and hybrid supply chain (HSC). An LSC employs continuous improvement processes to focus on the elimination of waste or non-value stops across the chain. It is supported by the reduction of set-up times to allow for the economic production of small quantities, thereby achieving cost reduction, flexibility, and aiming for external responsiveness by responding to customer requirements. The LSC can provide higher profits and can be accurately forecasted.

An ASC basically focuses on responding to unpredictable market changes and capitalizing on them. It tries to achieve a speedier delivery and lead time flexibility. It deploys new technologies and methods, utilizes information systems/technologies and data interchange facilities, puts more emphasis on organization issues and people (knowledge and empowered employees), integrates the whole businesses process, enhances innovations all over the company, and forms virtual companies and production based on customer designed orders

An HSC generally involves ‘‘assemble to order’’ products whose demand can be quite accurately forecasted. The chain helps to achieve mass customization by postponing product differentiation until final assembly. Both lean and agile techniques may be utilized for component production. The company– market interface has to be agile to understand and satisfy customer requirements by being responsive, adaptable and innovative. Different product types at different stages of life cycle might need different supply chain strategies. A supply chain should be both lean and agile to respond effectively and speedily to changes in the market places.

2.0 The ranking and measurement frame work

The following summarizes a typical distribution problem

i) There is at least one production facility and retail centre

ii) Production capacity is limited

iii) Retail centre is not owned by the firm

iv) Discrete number of retail centre with varying demands, cost risk including supply disruptions and customer strategic importance.

To address the above, where the manufacture-retailer linkage is not owned by the manufacturing firm, this work uses the technique for order preference by similarity to an ideal solution (TOPSIS). This method is a popular approach to the Multiple Attribute Decision Making (MADM) techniques which are used in diverse fields such as engineering, economics, management science, transportation planning and etc, deal with candidate priority alternatives with respect to various attributes.

TOPSIS was first developed by Hwang and Yoon (Hwang and Yoon, 1981) for solving a MADM problem. TOPSIS simultaneously considers the distances to the ideal solution and negative ideal solution regarding each alternative and selects the most relative closeness to the ideal solution as the best alternative. That is, the best alternative is the nearest one to the ideal solution and the farthest one from the negative ideal solution.

A relative advantage of TOPSIS is the ability to identify the best alternative quickly (Hwang and Yoon, 1981; Lotfi et al., 2011). The approach proposed in this work involves the initial ranking the retail centres, measurement criteria sensitivity analysis for the risk, demand variability and supply disruption. The TOPSIS is ideal for this problem because according to Liu and Wang (2011), it has been found to be more suitable for the risk avoider decision maker i.e. decision maker who wants to make profit while avoiding as much risk as possible. It is used in this work also to help idealize the maximum positive criteria like demand and customer strategic importance while minimizing negative criterion such as risk and cost. The structure of the retail ranking problem is given in Table 1.

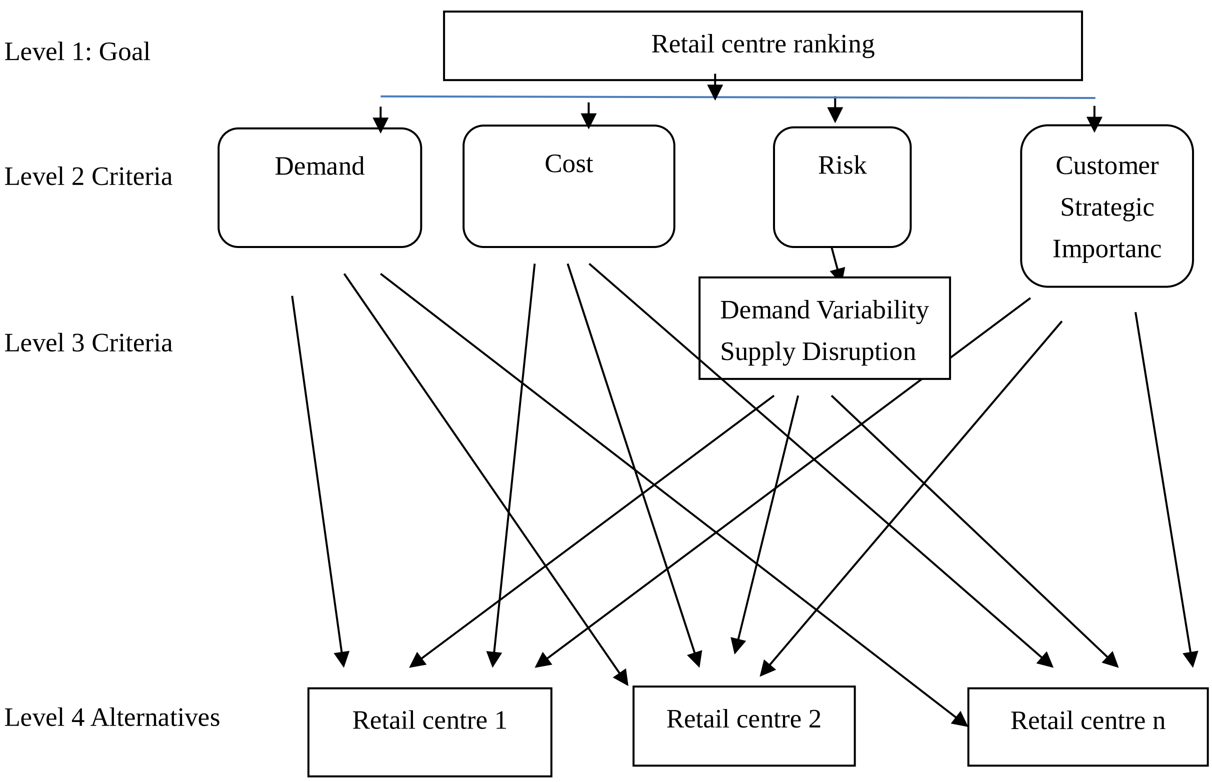

Figure 1: Structure of the Retail Ranking Problem

2.1 Retail Centre Ranking

The ranking of the retail centre which is a multi-criteria is done via an integration of the TOPSIS and the Eigen weighting. The steps are as follows:

2.1.1 Problem Definition

The problem is that of ranking a set of retail centre using a set of criteria

2.1.2 Generating Alternatives and Identifying Criteria

Alternatives are generated by the decision maker(s), and this is the set to be prioritized based on the different criteria. The Criteria to be used in evaluation is then analyzed with the decision maker(s), after which the list of criteria is drawn.

2.2 Measurement Criteria

The following are the measurement criteria used in this study

2.2.1 Demand Criteria

This is the quantity of products requested for by the final consumer at a particular retail centre and the demand helps in the determination of how profitable the retail centre is. Traditionally it is used in the allocation of product but due to the fact that production facility has limited capacity each retail centre may not be satisfied.

2.2.2 Risk Criteria

This is an attribute or criteria that can affect the quantity of goods sent to a particular retail centre. Risk can be in the form of demand variability or supply disruptions. It is probabilistic in nature and be may difficult to quantify; this necessitates the use of MADM in evaluating it in relation to each retail centre. There are different kinds of risk in the supply chain and are classified as demand and supply risk (Ravasizadah et al., 2011). Risks in supply chains represent one of the major business issues today. Since every organization strives for success and uninterrupted operations, efficient supply chain risk management is very crucial (Jereb et al., 2012).

2.2.3 Demand Variability

In the case of demand variability, the risk expresses the tendency of the centre in not meeting its obligatory customer demands.

2.2.4 Supply Disruptions

The supply disruption occurs as a result of the manufacturer not being able to get product across to the centre at a particular scheduled time. It may come as a result of problematic transportation. etc. The net effect is loss to the company.

2.2.5 Customer Strategic Importance

This refers to how a retail centre is to the organization. There is a tendency that a retail centre with high strategic importance will have a higher fill rate i.e. will have more allocation and more priority than that with a lower customer strategic importance.

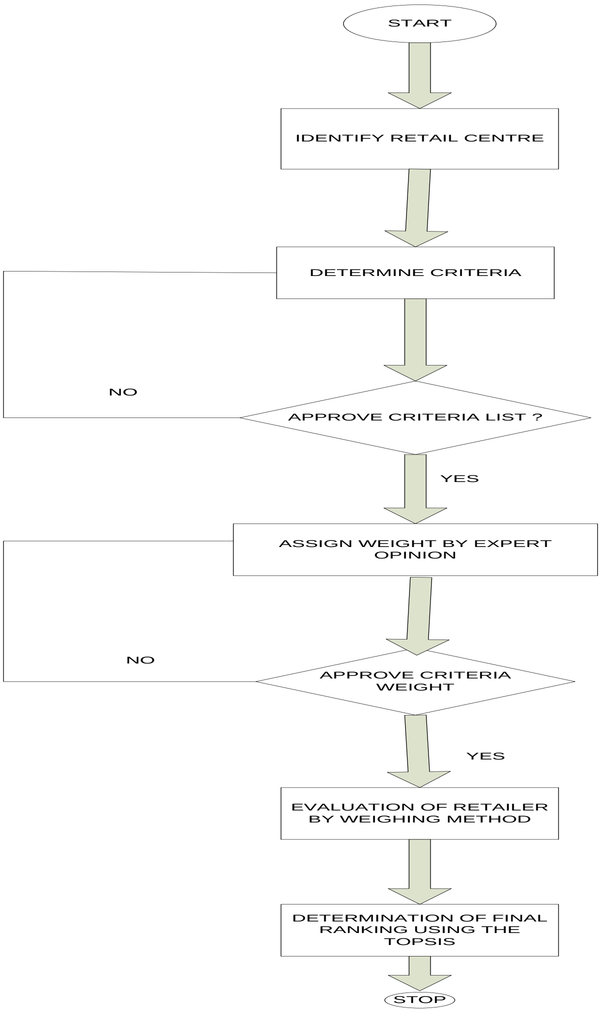

Figure 2: Schematic Diagram Showing the Stages Involved In the Retail Centre Problem

2.2.6 Cost

This is a very crucial factor in the overall ranking, because for any business concern, the cost of transporting products from one location to another is usually significant.

3.0 Application

3.1 Notations

The following notations are used in this work;

C_{ij} represents the unit cost of transporting the product from plant i, to warehouse j

C_{jk} represents the unit cost of transporting product from warehouse j, to retail centre k

D_j represents the demand at the warehouse j.

D_k represents the demand at retail centre k

s_j represents the weight of the retail centre

U_i represents the quantity of product available for distribution at plant i.

U_j represents the warehouse capacity.

U_r represents the retail centre demand

x_{ij} represents the quantity of product sent from plant i , to warehouse j,

y_{jk} represents quantity of products sent from warehouse j, to retail centre k.

C represents the total distribution cost of the firm from the plant to the retail centre

i represent manufacturing plant

j represents warehouse

k represents retail centre

p represents the total number of plants available

q represents the total number of warehouses available

r represents the total number of retail centres available

3.2 Criteria Weighting

This is done using the Eigen vector, and it uses a pair wise comparison using a given comparison scale. Decision maker(s) weigh criterion with respect to each other and the final weight is then determined by using the mathematical function below equation 1 (Toloie and Farokhi, 2011):

$$W_j = \lim_{K\to\infty} \frac{e.D_K}{e^t.D_k.e} \quad \text{...1}$$

W_j is the j^{th} Weight vector

D is the initial pair wise comparison matrix

e is the unit column vector that all elements are equal to 1

e^t is the transposing matrix of e

K is an integer

3.3 Determination of Final Ranking using the TOPSIS

The TOPSIS is then used in the prioritization of the set of retail centre and the following steps are involved:

i) The alternative performance matrix is constructed, it is as shown below

Table 1: A Table Showing Performance of Criteria against Alternative.

	Criterion 1	Criterion 2	…	Criterion n
Alternative 1	x_{11}	x_{12}	….	x_{1n}
Alternative 2	x_{21}	x_{22}	….	x_{2n}
.	. .		…. .	
.	.	.	.	.
.	.	.	.	.
.	. .		.	.
Alternative m	x_{m1}	x_{m2}	….	x_{mn}
	w_1	w_2	…	w_n

(Source: Toloie and Farokhi, 2011).

ii) Calculation of normalized decision matrix. The normalized value n_{ij} is calculated as:

$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m}(x_{ij})^2}}$ j = 1,……, M, i = 1,……N 2

iii).Calculation of the weight normalized decision matrix; the weighted normalized value v_{ij} is calculated as:

$v_{ij} = n_{ij}w_{ij}$ j = 1,…..m , i = 1,…..,n 3

iv). Determination of the positive ideal (A^+) and negative ideal solution(A^-)

$A^+ = \{V_1^+, \ldots, V_N^+\} = \{\max v_{ij} \,|i\varepsilon j\}, \{\min v_{ij} \,|i\varepsilon j\}$ 4

$A^- = \{V_1^-, \ldots, V_N^-\} = \{\min v_{ij} \,|i \in j\}, \{\max v_{ij} \,|i \in j\}$ 5

v). Calculation of the separation of each alternative from the positive ideal (d^+) and negative ideal (d^-) solution measures, using the n dimensional Euclidean distance.

$d_j^+ = \sqrt{\sum_{i=1}^{n}(v_{ij} - v_i^+)^2}$,j =1… m 6

$d_j^- = \sqrt{\sum_{i=1}^{n}(v_{ij} - v_i^-)^2}$, j = 1,…..m 7

vi). Calculation of the relative closeness (s_j) to the ideal solution

$s_j = \frac{d_j^-}{d_j^+ + d_j^-}$, j =1,…….,m 8

vii). Ranking the preference order: the closer the s_j is to 1, implies the higher priority of the jth alternative.

3.4 The General Model

The generalized model for the supply chain optimization can be summarized as

Minimize $C = \sum_{i=1}^{p}\sum_{j=1}^{q} C_{ij}X_{ij} + \sum_{j=1}^{q}\sum_{k=1}^{r} C_{jk}y_{jk}$ (9)

Subject to $\sum_{i=1}^{p} X_{ij} = U_i$ (10)

$\sum_{j=1}^{q} X_{ij} \leq U_J$ (11)

$\sum_{i=1}^{p} X_{ij} = \sum_{k=1}^{r} y_{jk}$ (12)

$\sum_{k=1}^{r} y_{jk} \leq U_r$ (12)

$y_{jk} \leq \frac{U_i}{4}$ (13)

$D_k \geq s_j U_r$ (14)

$y_{jk}, X_{ij} \geq 0$ (15)

$y_{jk}, X_{ij} = \text{integer}$ (16)

4.0 Results and Discussion

The model is applied to the retail centre allocation problem of a manufacturing firm and the result obtained is presented in this section.

4.1 Retail Centre Ranking

The multi attribute decision making method in section three is applied to a real life problem to demonstrate its utility. The objective is determining the weight/rank/importance of each retail centre to the firms' organizational success and this weight will help determine the fill rate (minimum % of inventory that must be supplied each time distribution is done).

4.2 Calculation of the Weights of Criteria

After forming the decision hierarchy for the problem, the weights of the criteria (based on the objective), the weight of the sub-criteria (based on their related criterion) and also alternatives (based on the criteria or sub-criterion) to be used in the evaluation process are calculated using the eigen vector method. The result obtained from the computations using the MATLAB software based on the pair wise comparison in table 1 are presented in table 2.

Table 1: Pair wise comparison of criteria

Criteria	Demand	Risk	Customer importance	Cost
Demand	1	1/5	2	1/4
Risk	5	1	6	1
Customer importance	½	1/6	1	1/7
Cost	4	1	7	1

Table 2: Weight of the various criteria

Criteria	Weight
Demand	0.0374
Risk	0.4619
Customer importance	0.0095
Cost	0.4912

Similar procedure is carried out for the risk sub-criteria (supply disruption and demand variability) using pair wise comparison in table 3 to give the final weights in table 4

Table 3: Pair wise comparison of sub-criteria

Criteria	Demand variability	Supply disruption
Demand variability	1	1/7
Supply disruption	7	1

Table 4: Weight of sub criteria

Criteria	Weight
Demand variability	0.020
Supply disruption	0.980

4.3 Determination of Weights Using Judgmental Weighting

Using this method, weights are given to criterion based on expert opinion as presented in table 5.

4.3.1 Final Criteria Weighting

This is done by finding the mean of the weighting based on the eigen vector and the judgmental method and the result is presented for final weighting for criteria and sub-criteria in table 5.

Table 5: Criteria weights using experts' judgment

Criteria	Weights
Demand	0.4
Risk	0.1
Customer importance	0.2
Cost	0.3

Table 6: Final weights for all criteria

Criteria		Weight	Final weighting
Demand		0.2187	0.2187
Risk	Demand variability	0.02	0.0056
	Supply disruption	0.98	0.2752
Customer importance		0.1047	0.1047
Cost		0.3956	0.3956

3.3.2 Evaluation of the Alternatives and Determination of the Final Rank/Weight

For this stage, the TOPSIS is used in the evaluation of the obtained criteria weights.

4.3.3 Construction of Normalized Decision Matrix

This is done to remove units from each of the criterion in table 7 and the table 8 below shows the value obtained. The weighted normalized decision matrix is then evaluated using weights in table 6 above and normalized weights of table 8 and the result is presented in table 9 below.

Table 7: Performance of alternative against criteria

Retail centre	Demand	Variability	Supply disruption	Customer	Cost
1	40228	0.44	0.35	1.00	1577170
2	12141	0.10	1.125	0.74	1274805
3	17502	0.88	1.125	0.38	246505
4	6780	0.75	0.925	0.38	161540
5	10269	0.56	0.925	0.40	422545
6	22067	0.73	0.950	0.54	1515150
7	19026	0.25	0.350	0.72	997360
8	13946	0.32	1.10	0.60	1183375

Table 8: Normalized matrix

Retail centre	Demand	Variability	Supply disruption	Customer importance	Cost
1	0.7043	0.2755	0.1362	0.5621	0.5237
2	0.2122	0.0626	0.4379	0.4159	0.4233
3	0.3059	0.5510	0.4379	0.2136	0.0818
4	0.1185	0.4969	0.3600	0.2136	0.0536
5	0.1795	0.3506	0.3600	0.2248	0.1403
6	0.3857	0.4571	0.3697	0.3035	0.5031
7	0.3326	0.1565	0.1362	0.4047	0.3311
8	0.2438	0.2003	0.4281	0.3372	0.3929

Table 9: The Weighted normalized matrlx

Alternative	demand	Variability	Supply disruption	Customer importance	Cost
1	0.1540	0.0015	0.0375	0.0588	0.2071
2	0.0464	0.0003	0.1205	0.0435	0.1674
3	0.0669	0.0031	0.1205	0.0223	0.0323
4	0.0259	0.0026	0.0990	0.0223	0.0212
5	0.0392	0.0019	0.0990	0.0235	0.0555
6	0.0843	0.0025	0.1017	0.0317	0.1990
7	0.0727	0.0008	0.0374	0.0423	0.1309
8	0.0533	0.0011`	0.1178	0.0350	0.1554

4.4 Determination of the Ideal Solution

The positive and negative ideal solutions are as determined and shown in the tables. The positive solutions reflect the best ideal retail centre and it seeks a maximum of the benefit criteria like customer importance and volume of demand while minimizing the cost criteria like cost, and risk (supply disruption and demand variability), while the negative ideal solution presented in the table 10 represents the worst solution, it seeks minimal benefit criteria and maximum cost criteria.

Table 10: The positive and negative ideal solution

Ideal solution	demand	Variability	Supply disruption	Customer importance	Cost
Positive	0.1540	0.0003	0.0374	0.0588	0.0212
Negative	0.0259	0.0031	0.1205	0.0223	0.2071

4.5 Final Ranking

The final ranking is shown in table 11 and it reflects the separation of each retail centre to the positive and negative ideal solution. From the table it’s seen that retail centre 4 has a final weight of 0. 56 and ranking of first (highest) thus any distribution planning operation by the firm must give it a fill rate of at least 56 % of its total demand. The same rule applies to all other retail centers.

Table 11: The final weight and ranking

Retail centre	d+	d-	S	Ranking
1	0.1859	0.1567	0.45	4
2	0.2002	0.0495	0.19	7
3	0.1260	0.1795	0.41	5
4	0.1467	0.1871	0.56	1
5	0.1392	0.1537	0.52	2
6	0.2029	0.0620	0.23	6
7	0.1375	0.1237	0.47	3
8	0.1875	0.0303	0.13	8

4.6 Sensitivity Analysis

Sensitivity Analysis of the decision criterion is also carried out to show the consequences of changes in the priority of the criteria and sub criteria over the final decision. This helps the decision maker react quickly to changes in the fund management philosophy and competitive advantage position, thus making it more agile.

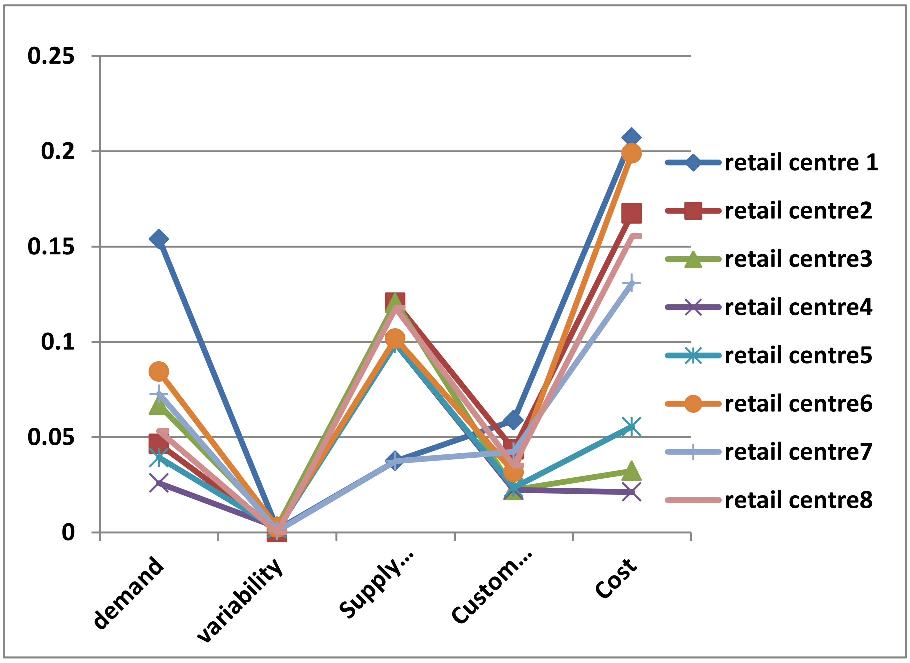

Figure 1: A graph of criterion against alternatives

Sensitivity analysis of the eight decision alternatives with respect to five criteria shows that the performance of retail centre 1, 7 and 3 varied a bit more than the rest. In all the 8 retail centres cost was the most important criterion followed by the supply disruption except for retail center 2 in which the reverse was the case. For retail centre 1, demand was more important than supply disruption, just as the case in retail centre 7, the demand was the third most important criterion followed by customer strategic importance and finally variability. Also from the graph 1 any change in the future values of the criteria can be factored in and subsequent adjustment put in place.

5. Conclusion

Supply chain management aims to achieve a very high consumer service satisfaction while reducing cost. The decision of what to supply a set of retail centre in a decentralized system is critical especially when manufacturer's capacity is limited and in short supply and there is the risk element. Decision making then tends to be difficult requiring effective consideration of criteria like risk (supply disruption and demand variability), customer strategic importance, demand, and cost. This study used the TOPSIS methodology to prioritise 8 retail centres in view of multi attribute factors. The eigen weighting method and the judgmental weighting were used for criteria weighting. Results obtained from the study showed that the model is applicable and can be used for problems of this nature.

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