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EVALUATING LOGISTICS DISTRIBUTION NETWORK DESIGNS OF FMCG SUPPLY CHAIN

Karuturi Aravind
Symbiosis Institute of Operations Management, Nashik,
Symbiosis International (Deemed University), Pune, India

ABSTRACT

FMCG products are sold in high volumes and are prices low. The low profit margins call for high operational efficiency in its supply chain. Having an optimal distribution network is must to be competitive in the industry. This paper evaluates different distribution configurations based on customer service factors and cost factors and suggests the suitable configuration for the FMCG supply chain with primary focus on consumer food products. TOPSIS analysis is carried out for the selection of optimal network configuration. Five configurations are taken as alternatives and 10 factors are taken as criteria. The weightage for the factors is calculated based on survey and interviews with professionals from FMCG and logistics companies. To avoid the biasness and uncertainty in data and judgement, a fuzzy TOPSIS method together with AHP analysis is carried out rather than traditional TOPSIS method. In this study, the factors are rated for food consumer products and the approach can be further extended to other FMCG categories.

Key words: Distribution network, FMCG, Consumer food products, Fuzzy TOPSIS method

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1. INTRODUCTION

Nearly everyone in the world uses FMCG products. Fast moving consumer goods (FMCG) are the high demand consumer products that sell quickly and at relatively low costs. Be it cereals, beverages or over-the- counter drugs like aspirin. They account for more than half of the consumer spending and are consumed at a rapid pace. The high inventory turnover calls for a robust distribution network. Companies invest huge amount of time and capital in designing optimal logistics networks.

Different distribution networks are available and it varies even within same industry (Chopra, 2003). Previous literature has suggested many configurations based on shipping ways, geographical location of suppliers and customers, mode of order placement etc. At a highest level, the performance of these configurations is determined on the basis of customer service factors and supply chain cost factors. One should always remember that, it is difficult to achieve highest level in all these factors. Companies try to provide acceptable service to the customer in a cost effective way. A definite framework is required in order to achieve that.

This study uses TOPSIS method in fuzzy environment for evaluation of various dimensions that have decisive effect on distribution networks in FMCG environment. The factors are evaluated with respect to consumer food products and rated accordingly. The configurations are ranked and optimal network configuration for consumer food product industry is identified.

Flow: The literature review is carried to understand the different network configurations and to identify various factors that influence the distribution network. Post this, a survey is conducted to set weights for the factors. Fuzzy TOPSIS method is carried out to propose the suitable configuration based on service factors and cost factors. Finally, the results are discussed and suitable conclusions are drawn.

2. LITERATURE REVIEW

Globalization has called for robust distribution networks. “Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness. As a result, companies in the same industry often select very different distribution networks” (Chopra, 2003, p.123) However, there are certain general points that are common to many companies. Detail research has been performed in the last decades, both at quantitative and qualitative level to provide various approaches for designing the optimal logistic network. Literature review showed a strong emphasis on operational research approaches. Wouda et al. (2002) wrote about the applications of MILP optimization in design of the optimal logistic network. Bottani and Montanari (2010) quantitatively assesses the effects of various logistic configurations on supply chain costs through simulation.

Chopra (2003) proposes six customer-related variables that influence the structure of network configurations. They are response time (It is the time taken from placing order and receiving delivery), product variety (maintaining multiple SKUs), product availability (probability of maintain the stock of the product), customer experience, order visibility (order tracking ability) and returnability (the ease of returning the products).

The other dimension for evaluating the distribution networks is the logistic costs. Research is available on strategic aspects of logistics costs and cost-effective logistics approaches. Zeng (2003) evaluated logistics costs from the sourcing point of view. Creazza et al. (2010) proposed a taxonomy to select suitable logistics network based on overall annual demand and total logistics cost. Chopra (2003) proposes four supply chain cost factors that are affected by design of the distribution network. They are inventory related costs (carrying cost and stockout cost), transportation costs, Facilities & Handling costs (Facilities, Handling and packaging) and information costs (information infrastructure, admin costs). Zeng and Rossetti (2003) also suggested logistics costs like transportation cost, handling cost and inventory carry cost impact the way a network configuration is designed.

Literature exists on identifying the suitable logistic configurations. Network design implies making strategic choices on location of the facilities, modes of transport, market allocation to these facilities etc. Tyan et al. (2003) deals with freight consolidation policies for global 3PL. Creazza et al. (2010) considered logistics network configurations based on shipment load namely FCL and LCL. Physical distribution channels with products being transferred from manufacturer to retail store are discussed in Rushton et al. (2014, pp. 53–55). Variables like transportation costs, COGS, number of facilities, shipments size and Direct Store Delivery share are considered for building cost-optimized network configuration. The robustness of the designed configuration is studied by altering variables both in isolation and in combination (Kellner et al., 2013)

Multiple variables are taken into consideration to design distribution network and operational research approaches are required to evaluate the configurations. Multiple Criteria Decision Analysis (MCDA) evaluates different criteria to select among the alternatives or factors. TOPSIS is one of the popular MCDA tool. Vimal et al. (2012) used this method for vendor selection in manufacturing industry. Balioti et al. (2018) used this technique to obtain optimum spillway for the construction of the dam. The issue with TOPSIS is the weight elicitation. TOPSIS is used along with AHP (Analytical Hierarchy Process), which is used for assigning weights. Human judgments are often uncertain and cannot count preferences with a definite number. "Considering the fuzziness in the decision data and group decision-making process, linguistic variables are used to assess the weights of all criteria and the ratings of each alternative with respect to each criterion" (Chen, 2000, p.2)

This literature review shows the different factors that affect the distribution network and the research happening on designing of logistics networks.

3. DISTRIBUTION NETWORK CONFIGURATIONS

Logistics network designs were analyzed from two main perspectives: Manufacturers' and Aggregators' point of view. Rushton et al. (2014, pp. 53–55) proposed distribution channels for consumer products from manufacturer to retail stores. We consider the following five network configurations (Figure 1):

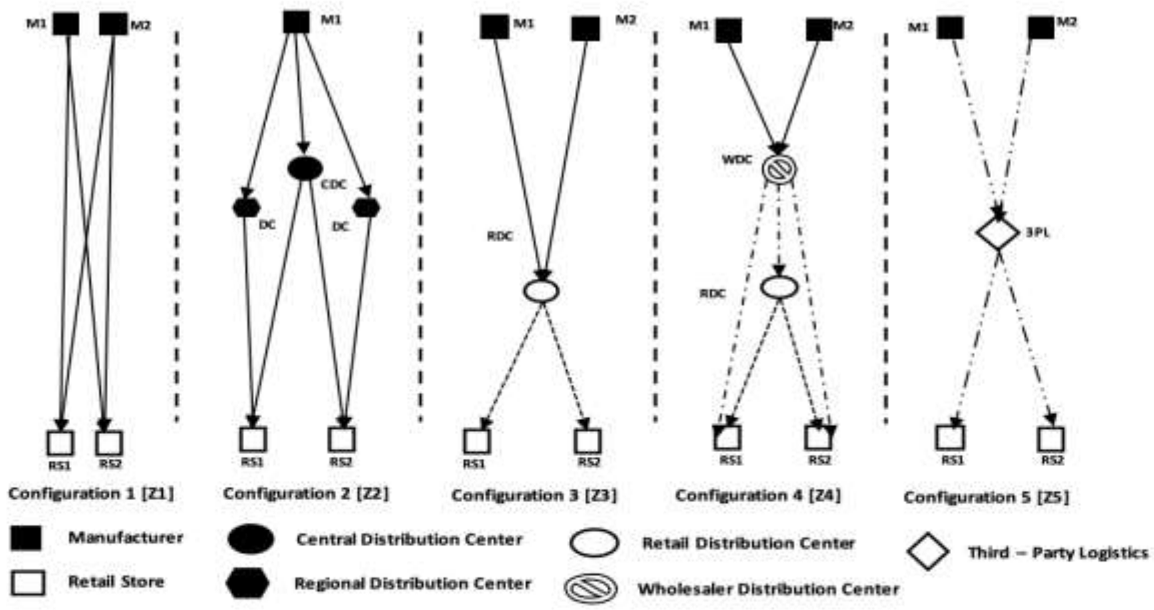

Figure 1. Network Configuration from manufacturer to retail store

Configuration1 [Z1]: *Manufacturer direct to retail store*: Manufacturer ships products directly to retail `store. The distribution is owned by manufacturer.

Configuration2 [Z2]**:** *Manufacturer via manufacturers' distribution operations to retail store:* Manufacturer holds the product in either CDC or in regional DC and are delivered to retail stores. The entire resources are owned by manufacturer.

Configuration3 [Z3]: *Manufacturer via retail distribution center to retail store:* Manufacturer deliver the product to retail distribution centers. Retailers then deliver them to their retail stores.

Configuration4 [Z4]: *Manufacturer to wholesaler to retail store:* Wholesalers act as intermediaries and deliver the products to Retailer distribution center or retail store with their own resources.

Configuration5 [Z5]: *Manufacturer via third party logistics to retail stores*: 3PLs provide distribution services to the manufacturer. They provide general distribution services as well as specialist services (product based).

Other alternate distribution configurations exist which are relatively rare or bypass the retail store completely. Our study is restricted to these five distribution channels.

4. FUZZY TOPSIS METHOD

Hwang and Yoon (1981) provides detail understanding TOPSIS. It is used to identify the optimal option from the set of alternatives available based on certain criteria. Often the ranking and weights are biased and cannot be expressed quantitively with a definite number. The better approach is to use the linguistic variables.

Chen (2000), modified TOPSIS to solve multi-facet decision making scenarios using linguistic variables to consider the randomness in data and in decision analysis.

Approach

Step 1 : Selection of the variables that are used to evaluate the alternatives.

Step 2: Construct the corresponding linguistic variables matrix for the weights of the variables and ratings of the alternatives. Table 1 (Chen, 2000, p. 5) and Table 2 (Chen, 2000, p. 5) shows the corresponding TFNs of the linguistic variables.

Table 1 Linguistic variables for the Criteria

Variable	Depiction	TFNs
	V L	(0,0,0.1)
Low	L	(0,0.1,0.3)
	M L	(0.1,0.3,0.5)
Medium	M	(0.3,0.5,0.7)
	M H	(0.5,0.7,0.9)
	H	(0.7,0.9,1.0)
High	V H	(0.9,1.0,1.0)

Table 2 Linguistic variables for the rating

Variable	Depiction	TFNs
	V P	(0,0,1)
Poor	P	(0,1,3)
	M P	(1,3,5)
Fair	F	(3,5,7)
	M G	(5,7,9)
Good	G	(7,9,10)
	V G	(9,10,10)

Step 3: Determine the weighted normalized decision matrix in fuzzy environment $\tilde{v}_{ij}$

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}$$

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_{ij}^*}, \frac{b_{ij}}{c_{ij}^*}, \frac{c_{ij}}{c_{ij}^*}\right) \quad where\ c_{ij}^* = \max c_{ij}$$

$$\tilde{v}_{ij} = \tilde{w}_j . \tilde{r}_{ij} \quad where \quad j = 1,2,3, \ldots .m \quad and \quad i = 1,2,3, \ldots ..n$$

Step 4: Determine the FPIS and FNIS

$$\text{FPIS} \quad A^* = \{ \tilde{v}_1^*, \tilde{v}_2^*, \tilde{v}_3^*, \ldots\ldots\ldots\ldots\tilde{v}_m^* \}$$

$$\text{FNIS} \quad A^- = \{ \tilde{v}_1^-, \tilde{v}_2^-, \tilde{v}_3^-, \ldots\ldots\ldots\ldots\tilde{v}_m^- \}$$

$$where\ \tilde{v}_j^* = (1,1,1)\ and\ \tilde{v}_j^- = (0,0,0) \quad , j = 1,2,3, \ldots .m$$

Step 5: Measure the separation of each option from A^* and A^- . The separation between two TFNs is equal to the Euclidean distance.

Step 6: Determine the closeness co-efficient

Step 7: Rank the alternatives accordingly

5. METHODOLOGY

Customer service factors and cost factors are taken to evaluate the distribution network designs. A questionnaire was created to understand the relative importance of these factors in supply chain of consumer food products. As a part of the survey, telephonic interviews were conducted with managers from few FMCG and logistic companies. Fuzzy TOPSIS method along with AHP is used to evaluate the configurations or alternatives shown in figure 1. The criteria are summarized in Table-3 and alternatives in Table- 4.

Table 3 Summary of the Criteria/Factors (Chopra, 2003)

Type	Criterion	Depiction
Customer service factors	Response time	Fa1
	Product variety	Fa2
	Product availability	Fa3
	Customer experience	Fa4
	Order visibility	Fa5
	Returnability	Fa6
Cost Factors	Transportation costs	Fa7
	Inventory costs	Fa8
	Facility & Handling costs	Fa9
	Information costs	Fa10

Table 4 Summary of the alternatives

Alternative	Depiction
Manufacturer Direct To Retail Store	Z1
Manufacturer Via Own Distribution Operations To Retail Store	Z2
Manufacturer Via Retail Distribution Center To Retail Store	Z3
Manufacturer Via Wholesaler To Retail Store	Z4
Manufacturer Via 3pl To Retail Store	Z5

AHP analysis is conducted to obtain the corresponding weights for the variables.. As a part of it, criteria are compared pair wise and a matrix is created. (shown in Table 5). The matrix is normalized and consistency analysis is done. CR = 0.016 is within the acceptable limit (CR < 0.1) as suggested by Saaty (1980).

Table 5 Pair-wise comparison matrix for criterion

	Fa1	Fa2	Fa3	Fa4	Fa5	Fa6	Fa7	Fa8	Fa9	Fa10
Fa1	1	3	0.5	2	4	6	1	2	3	5
Fa2	0.33	1	0.25	0.5	2	4	0.33	0.5	1	3
Fa3	2	4	1	3	5	7	2	3	4	6
Fa4	0.5	2	0.33	1	3	5	0.5	1	2	4
Fa5	0.25	0.5	0.2	0.33	1	3	0.25	0.33	0.5	2
Fa6	0.17	0.25	0.14	0.2	0.33	1	0.17	0.2	0.25	0.5
Fa7	1	3	0.5	2	4	6	1	2	3	5
Fa8	0.5	2	0.33	1	3	5	0.5	1	2	4
Fa9	0.33	1	0.25	0.5	2	4	0.33	0.5	1	3
Fa10	0.2	0.33	0.17	0.25	0.5	2	0.2	0.25	0.25	1

The criteria weights were summarized. Using the linguistic variables mentioned in Table 1, the corresponding triangular fuzzy numbers (TFNs) were defined for the weights (Table 6).

Table 6 Weights and fuzzy weights

Fa1	Fa2	Fa3	Fa4	Fa5	Fa6	Fa7	Fa8	Fa9	Fa10
0.163	0.065	0.248	0.103	0.042	0.021	0.163	0.103	0.065	0.029
M H	M L	V H	M	L	L	M H	M	M L	L
(0.5, 0.7, 0.9)	(0.1, 0.3, 0.5)	(0.9, 1, 1)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0, 0.1, 0.3)

The distribution network configurations are rated for the different criteria. Data is normalized and the corresponding decision matrix is constructed as viewed in Table 7

Table 7 Rating of alternatives for each criterion

	Fa1	Fa2	Fa3	Fa4	Fa5	Fa6	Fa7	Fa8	Fa9	Fa10
Z1	5	9	9	5	5	3	3	8	9	4
Z2	7	8	9	5	7	5	6	7	7	5
Z3	9	7	7	9	9	9	8	6	7	7
Z4	9	5	5	9	9	7	9	5	5	8
Z5	7	8	8	7	7	7	9	7	7	5
	Data after AHP evaluation									
Z1	0.296	0.534	0.519	0.309	0.296	0.205	0.182	0.535	0.565	0.298
Z2	0.414	0.475	0.519	0.309	0.414	0.342	0.364	0.468	0.440	0.373
Z3	0.533	0.416	0.404	0.557	0.533	0.616	0.485	0.401	0.440	0.523
Z4	0.533	0.297	0.288	0.557	0.533	0.479	0.546	0.334	0.314	0.597
Z5	0.414	0.475	0.461	0.433	0.414	0.479	0.546	0.468	0.440	0.373

The TFNs are defined for the linguistic variables and the fuzzy decision matrix is normalized and with the assistance of weights calculated above, a fuzzy weighted normalized decision matrix is built (see Table-8).

Table 8 Fuzzy weighted normalized decision matrix

	Fa1	Fa2	Fa3	Fa4	Fa5	Fa6	Fa7	Fa8	Fa9	Fa10
Z1	(0.15,0.35,0.63)	(0.09, 0.3, 0.5)	(0.81, 1, 1)	(0.09, 0.25, 0.49)	(0, 0.05, 0.21)	(0, 0.03, 0.15)	(0.05, 0.21, 0.45)	(0.27, 0.5, 0.7)	(0.09, 0.3, 0.5)	(0, 0.05, 0.21)
Z2	(0.25,0.49,0.81)	(0.07, 0.27, 0.5)	(0.81, 1, 1)	(0.09, 0.25, 0.49)	(0, 0.07, 0.27)	(0, 0.05, 0.21)	(0.15, 0.35, 0.63)	(0.21, 0.45, 0.7)	(0.05, 0.21, 0.45)	(0, 0.07, 0.27)
Z3	(0.45,0.7, 0.9)	(0.05, 0.21, 0.45)	(0.45, 0.7, 0.9)	(0.27, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.1, 0.3)	(0.35, 0.63, 0.9)	(0.15, 0.35, 0.63)	(0.05, 0.21, 0.45)	(0, 0.09, 0.3)
Z4	(0.45, 0.7, 0.9)	(0.03, 0.15, 0.35)	(0.27, 0.5, 0.7)	(0.27, 0.5, 0.7)	(0, 0.1, 0.3)	(0, 0.07, 0.27)	(0.45, 0.7, 0.9)	(0.09, 0.25, 0.49)	(0.03, 0.15, 0.35)	(0, 0.1, 0.3)
Z5	(0.25, 0.49,0.81)	(0.07, 0.27, 0.5)	(0.63, 0.9, 1)	(0.15, 0.35, 0.63)	(0, 0.07, 0.27)	(0, 0.07, 0.27)	(0.45, 0.7, 0.9)	(0.21, 0.45, 0.7)	(0.05, 0.21, 0.45)	(0, 0.07, 0.27)

Determine the FPIS and FNIS and determine the separation measure. Finally obtain the closeness co-efficient of each configuration (see in Table- 9).

Table 9 Closeness Co-efficient

Alternatives	S_i^*	S_i^-	Closeness Co-efficient
Z1	7.05	3.51	0.333
Z2	6.85	3.81	0.358
Z3	6.55	4.15	0.388
Z4	6.87	3.75	0.353
Z5	6.56	4.12	0.386

6. RESULTS

Based on fuzzy TOPSIS analysis, the ratings for different logistics distribution network configurations for consumer food products supply chain are obtained. From the closeness co-efficient calculations (shown in Table 11), the configurations are ranked as shown in Figure 2.

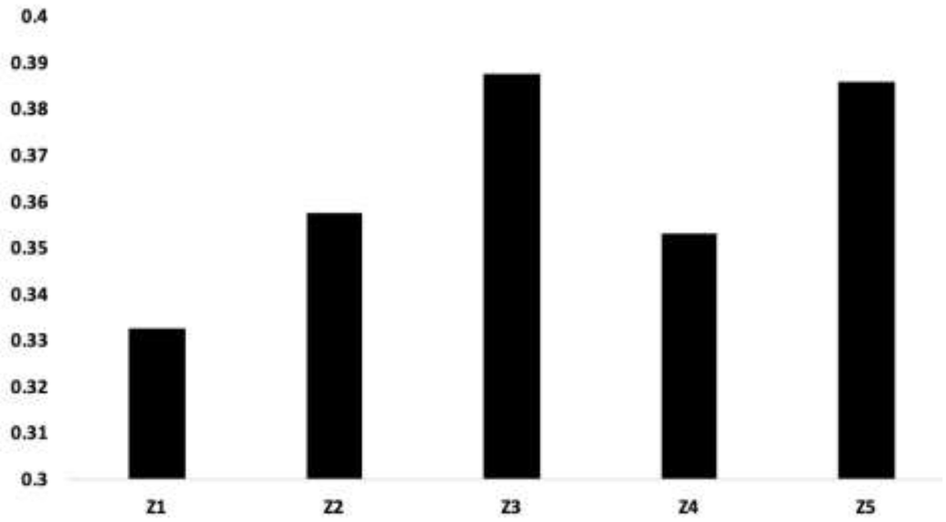

Figure 2. Relative Closeness Measure

Ranking:

Z3[0.388] > Z5 [0.3865] > Z2 [0.358] > Z4 [0.353] > Z1 [0.333]

7. CONCLUSION

In this study, the logistics network configurations are evaluated based on customer service factors and cost factors. The weightage for the factors is determined in view of consumer food products industry and they may differ for other categories within the FMCG industry.

From the closeness co-efficient calculations of fuzzy TOPSIS analysis, we observe that configuration Z3 (Manufacturer via retail distribution center to retail store) is optimal for consumer food products distribution. We also observe that the closeness co-efficient of configuration Z5 (Manufacturer via third party logistics to retail store) is very close to Z3, making it the best alternative to Z3.

Evaluating the configurations by taking service factors and cost factors individually may have given different solutions altogether. Considering service factors and cost factors together will take both customer and management perspective and provide a holistic way of evaluating distribution network configurations.

SCOPE FOR FURTHER RESEARCH

This study is limited to consumer food products industry. The fuzzy TOPSIS analysis carried out to determine optimal network configuration can be extended not only to other categories of FMCG but to other industries as well.

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