Exploration of Distribution Network for Indian Automobile Industries:
AHP Approach

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Abstract. In a world of shrinking margins, controlling the cost of the product with good serviceability is a factor which puts your supply chain ahead of your competitors. In supply chain, distribution network design plays a key role to control the adoptive cost and service factor. Effective supply chain distribution network design needs to consider various performance dimensions of the cost and service factors. This paper describes a framework for designing the various distribution networks in a supply chain. Various factors influencing the choice of distribution network in supply chain are described for Indian automobile industries. Further, an analytic hierarchy process (AHP) multi-criteria decision-making methodology is use to explore the various distribution networks for Indian automobile industries.

Keywords: Analytic hierarchy process; Distribution network; Supply chain; Multi-criteria decision-making.

1. Introduction

The automotive industry in India is one of the larger markets in the world. It had previously been one of the fastest growing globally, but is currently experiencing flat or negative growth rates [1]. India's passenger car and commercial vehicle manufacturing industry is the sixth largest in the world, with an annual production of more than 3.9 million units in 2011[2].

Logistics distribution network design is one of the major decision problems arising in contemporary supply chain management. The decision involves many quantitative and qualitative factors that may be conflicting in nature [3]. The distribution environment for automobiles in India is quite different from that of most advanced countries. Such differences exist in type and size of dealers, number of dealers, car supermarkets, vertical integration, functions of dealer, bookings, financing, manufacturer-dealer relationship, number of cars sold per dealer, margins, and market environment. Having operated for years in a supply-constrained industry, most dealers in India would need to adjust to a situation where the customer has a wide choice.

With increased competition, established automobile manufacturers in India are becoming more conscious about technology and quality. These companies are incorporating ISO 9000 certification and Total Quality Management as explicit corporate goals. Network design drives profitability by directly affecting supply chain cost and the customer experience. Further, choice of distribution network can achieve supply chain objectives from low cost to high efficiency.

This paper applies an integrated multiple criteria decision making approach to explore distribution network for automobile industries. In this approach, the analytic hierarchy process (AHP) is used to determine the relative importance weightings or priorities of different distribution networks so that industries gain maximum profit and provide their customers best service options. In the section 2 of this paper we have explored regarding background and basic plot of this paper.

2. Background

At the highest level, performance of a distribution network should be evaluated along two dimensions [4]:
1. Customer needs that are met
2. Cost of meeting customer needs

The customer needs that are met influence the company's revenues, which along with cost decide the profitability of the delivery network. While customer service consists of many components, we will focus on those measures that are influenced by the structure of the distribution network. These include:

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• Response time
• Product variety

Response time is the time between when a customer places an order and receives delivery. Product variety is the number of different products / configurations that a customer desires from the distribution network.

Changing the distribution network design affects the following supply chain costs:
• Inventories
• Transportation
• Facilities and handling

As the number of facilities in a supply chain increases, the inventory and resulting inventory costs also increase. As long as inbound transportation economies of scale are maintained, increasing the number of facilities decreases total transportation cost. If the number of facilities is increased to a point where there is a significant loss of economies of scale in inbound transportation, increasing the number of facilities increases total transportation cost. A distribution network with more than one warehouse allows producer to reduce transportation cost relative to a network with a single warehouse. Facility costs decrease as the number of facilities is reduced because a consolidation of facilities allows a firm to exploit economies of scale. When considering distribution between any other pair of stages, such as supplier to manufacturer, many of the same options still apply. According to Chopra and Meindl [4] there are two key decisions when designing a distribution network:

1. Will product be delivered to the customer location or picked up from a preordained site?
2. Will product flow through an intermediary (or intermediate location)?

There are six types of distribution channel which we will be analyzing for above two raised questions, using AHP [4].

1. Manufacturer storage with direct shipping
2. Manufacturer storage with direct shipping and in-transit merge
3. Distributor storage with package carrier delivery
4. Distributor storage with last mile delivery
5. Manufacturer / distributor storage with customer pickup
6. Retail storage with customer pickup

3. Analytical Hierarchy Process

Because the optimization techniques with a single criterion or objective are not suitable for the design of logistics distribution network, multiple criteria decision making (MCDM) techniques have been used in recent years. One of the most prevalent MCDM techniques is the analytic hierarchy process (AHP). A number of research papers were found in the last decade. [5][6]

The analytic hierarchy process (AHP) is a technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty. AHP provides a method to connect that can quantify the subjective judgment of the decision maker in a way that can be measured. It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. [7] The procedure for using the AHP can be summarized as [7].

4. Application of AHP

The step by procedure for using the AHP has been proposed to explore the distribution network in automobile industries as follows:

Step 1: Define the problem in terms of Hierarchy. Define goal, Criteria. Sub criteria of problem.
Decompose the decision criteria in the form of a hierarchy of from the top (i.e. the goal) through intermediate levels (criteria and sub-criteria on which subsequent levels depend) to the lowest level (i.e. the alternatives).

Here the goal of the problem to explore the distribution network. Then two evaluation criteria (Cost Factor and Service factor) and five evaluation sub-criteria are incorporated. Each criterion is defined in terms of performance. Figure 1 schematically illustrates the developed AHP model for performance metrics hierarchy.

To explore the distribution network

Cost Factor

Service Factor

Inventory

Transportation

Facilities & Handling

Response Time

Product Variety

Manufacturer storage with direct shipping

Manufacturer storage with direct shipping and in-transit merge

Distributor storage with package carrier delivery

Distributor storage with last mile delivery

Manufacturer / distributor storage with customer pickup

Retail storage with customer pickup

Step 2: Establish each factor of the pair-wise comparison matrix.

In this step the elements of a particular level are compared pair-wise, with respect to a specific element in the immediate upper level. A judgment matrix is formed and used for computing the priorities of the corresponding elements. First, a criterion is compared pair-wise with respect to the goal. The comparison of any two criteria with respect to the goal is made using the questions of the type: of the two criteria, which is more important and how much. Relative importance scale is presented. The decision maker is supposed to specify their judgments of the relative importance of each contribution of criteria towards achieving the overall goal. Here all calculations regarding Eigen Value (λmax) have been obtained using MATLAB. Table 2.1 shows the pair wise comparison matrix of determinants/ criteria. Table 2.2 and table 2.3 show the pair wise comparison matrix of dimensions/ sub-criteria. Further, Pair wise comparison matrix between alternatives for inventory have been shown in Table 2.4

<table>
<thead>
<tr>
<th></th>
<th>Service Factor</th>
<th>Cost Factor</th>
<th>Eigen Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Factor</td>
<td>1</td>
<td>7</td>
<td>0.875</td>
</tr>
<tr>
<td>Cost Factor</td>
<td>0.14</td>
<td>1</td>
<td>0.125</td>
</tr>
</tbody>
</table>

λmax= 1.9899; RI= 0 ; CR= NA ; CI= NA
Table 2.2: Pair wise comparison matrix of dimension/ Sub - Criteria Cost Factor

<table>
<thead>
<tr>
<th></th>
<th>Inventory</th>
<th>Transportation</th>
<th>Facilities And Handling</th>
<th>Eigen Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>0.57</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.25</td>
<td>1</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Facilities And Handling</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>0.19</td>
</tr>
</tbody>
</table>

$\lambda_{max} = 3.0536; \ RI = 0.58; CR = 0.026807; CI = 0.0268$

Table 2.3: Pair wise comparison matrix of dimension/ Sub - Criteria Service Factor

<table>
<thead>
<tr>
<th></th>
<th>Response Time</th>
<th>Product Variety</th>
<th>Eigen Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Time</td>
<td>1</td>
<td>8</td>
<td>0.89</td>
</tr>
<tr>
<td>Product Variety</td>
<td>0.13</td>
<td>1</td>
<td>0.11</td>
</tr>
</tbody>
</table>

$\lambda_{max} = 2.0198; \ RI = 0; CR = NA; CI = NA$

Table 2.4: Pair wise comparison matrix between alternatives for inventory

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>Eigen Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>0.242</td>
</tr>
<tr>
<td>A2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>0.242</td>
</tr>
<tr>
<td>A3</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>0.5</td>
<td>3</td>
<td>0.137</td>
</tr>
<tr>
<td>A4</td>
<td>0.33</td>
<td>0.33</td>
<td>0.5</td>
<td>1</td>
<td>0.33</td>
<td>2</td>
<td>0.083</td>
</tr>
<tr>
<td>A5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>0.242</td>
</tr>
<tr>
<td>A6</td>
<td>0.25</td>
<td>0.25</td>
<td>0.33</td>
<td>0.5</td>
<td>0.25</td>
<td>1</td>
<td>0.054</td>
</tr>
</tbody>
</table>

$\lambda_{max} = 6.0304; \ RI = 1.24; CR = 0.004903; CI = 0.00608$

Similarly, pair wise comparison matrix between alternatives for other sub-criteria have been calculated and the priorities/Eigen vectors of these alternatives for each sub-criteria are summarized in Table 2.5

Table 2.5: Priorities/Eigen-vectors of these alternatives for each sub-criteria

<table>
<thead>
<tr>
<th>Sub-criteria</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory</td>
<td>0.242</td>
<td>0.242</td>
<td>0.137</td>
<td>0.083</td>
<td>0.242</td>
<td>0.054</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.071</td>
<td>0.112</td>
<td>0.180</td>
<td>0.047</td>
<td>0.295</td>
<td>0.295</td>
</tr>
<tr>
<td>Facilities and Handling</td>
<td>0.380</td>
<td>0.249</td>
<td>0.160</td>
<td>0.102</td>
<td>0.065</td>
<td>0.043</td>
</tr>
<tr>
<td>Response time</td>
<td>0.063</td>
<td>0.063</td>
<td>0.148</td>
<td>0.247</td>
<td>0.063</td>
<td>0.416</td>
</tr>
<tr>
<td>Product Variety</td>
<td>0.242</td>
<td>0.242</td>
<td>0.137</td>
<td>0.083</td>
<td>0.242</td>
<td>0.054</td>
</tr>
</tbody>
</table>

Step 3: Calculate the eigenvalue and eigenvector.

To obtain the relative weight of the criteria Eigen value of the n normalized matrix should be calculated. The equation $A.W = \lambda_{max}. W$ should be verified, Where, A is pair wise comparison matrix, W is Eigen vector; $\lambda_{max}$ is highest Eigen value. The alternative with the highest coefficient value is chosen as the best alternative

Step 4: Perform the consistency test.

The eigenvector method yields a natural measure of consistency. Saaty [7] defined the consistency index (CI) as $CI = (\lambda_{max} – n)/(n-1)$,

Where $\lambda_{max}$ is the maximum eigenvalue and n is the rank of the matrix. Accordingly, Saaty [T.L. Saaty (1990)] defined the consistency ratio (CR) as $CR = CI/RI$

Where RI represents the average consistency index over numerous random entries of same order reciprocal matrices

RI is selected from below table according to the rank of the matrix.

<table>
<thead>
<tr>
<th>Matrix rank</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>1.12</td>
<td>1.24</td>
<td>1.35</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
<td>0.58</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

As mentioned above CI should be always less than 0.1.

Consistency tests should be performed for all the criteria, sub-criteria and alternative matrices. The values are shown in from Table 2.1 to Table 2.4.

Step 5: Calculate the overall level hierarchy weight/ performance weighted index (PWI)

The composite priorities of the alternatives are then determined by aggregating the weights throughout the hierarchy. Performance weighted index (PWI) is the product of criteria weightage, sub-criteria weightage, and alternatives weightage for each alternative. PWI of each factor have been shown in Table 2.6.
Table 2.6 : Performance weighted index for various alternatives

<table>
<thead>
<tr>
<th>Sub-criteria</th>
<th>Alternatives and its Calculated Weightage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Criteria Weightage * Sub-criteria Weightage * Alternatives Weightage)</td>
</tr>
<tr>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>Inventory</td>
<td>0.0163</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.0010</td>
</tr>
<tr>
<td>Facilities and Handling</td>
<td>0.0166</td>
</tr>
<tr>
<td>Response Time</td>
<td>0.0491</td>
</tr>
<tr>
<td>Product Variety</td>
<td>0.0233</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0.1063</td>
</tr>
</tbody>
</table>

A1: Manufacturer storage with direct shipping.
A2: Manufacturer storage with direct shipping and In-transit merge.
A3: Distributor storage with package carrier delivery.
A4: Distributor storage with last mile delivery.
A5: Manufacturer/Distributor storage with consumer pickup.
A6: Retail storage with consumer pickup.

5. Results:
Initially, the discussions have been made for results of the proposed model. Later, few suggestions made for prospective users of this model and discuss the managerial implications of this model with some generalization of results.

For the case undertaken in this study, the results indicate that Retail storage with consumer pickup is the first choice of the distribution network, which is followed by Distributor storage with last mile delivery and Distributor storage with package carrier delivery.

In the automobile industry, distribution planning can lead to enhanced competitiveness. It is relevant to discuss here the priority values of the determinants of cost and service phenomena, which influence this decision. From Table 2.1, it is seen that service factor (87.5%) is the most important determinant for the distribution network. Similarly, From Table 2.1, it is seen that inventory (57%) is most important dimensions among the different cost factors and Table 2.3 shows that response time dominate the product variety.

6. Conclusion:
The major contribution of this research lies in the development of a distribution network, which incorporates diversified issues for distribution network for automobile industries. The model considers a balanced view on two perspectives namely cost factor and service factor. The proposed AHP model in this paper, not only guides the decision makers to explore the distribution networks but also enable them to visualize the impact of other factor in the arrival of the final solution.

7. References: