Modelling Supplier Evaluation for an Automobile Company Using Analytical Hierarchy Process

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Abstract: *Importance of efficient supplier evaluation has been discussed to gain competitive advantage in global scenario focusing upon the Indian two wheeler industry. The key factors affecting the sales of motor cycle have been described. Different supplier evaluation and selection models have been investigated and important variables affecting supplier performance have been identified. Analytical Hierarchy Process methodology has been adapted to prepare proposed model to priorities suppliers on the basis of multi criteria decision variables. Its simplicity and flexibility to use have been identified as major advantages of the proposed supplier evaluation model over other exists models.*

Keywords: *Encryption, decryption, Cipher text, Pseudorandom- Noise (P-N), VHDL, CDMA*

1. Introduction

Managing the purchasing task in the supply chain has been considered as major challenge in majority of the corporations all over the world. Therefore, there has been a growing concern for forging effective evaluation process of existing and new suppliers in a supply chain. In the era of increasing global competition, efficient supplier evaluation can provide strategic advantage to buyer and supplier (Bensaou, 1999). For example the buyer can focus on his internal strength and secure the access to external resources that the company needs, while the supplier can plan and use his core competency in the specific production area. Both buyer and supplier can take advantage by putting greater emphasis on the importance of close relationships, so as to derive benefits in the form of lower costs or higher profits.

India is the second largest manufacturer and producer of two-wheelers in the world. It stands next only to Japan and China in terms of the number of two-wheelers produced and domestic sales respectively. This distinction was achieved due to variety of reasons like restrictive policy followed by the Government of India towards the passenger car industry, rising demand for personal transport, inefficiency in the public transportation system etc.

The Indian two wheeler market has a size of over Rs 100,000 million. The Indian two wheeler segment contributes the largest volumes amongst all the segments in automobile industry. Though the segment can be broadly categorized into 3 sub-segments viz; scooters, motorcycles and mopeds; some categories introduced in the market are a combination of two or more segments e.g. scooterettes and step thru's.

2. Current Industry Scenario

Motorcycle sales grew by an annual average of 27% over F1995-2002, and constituted nearly 66% of total two wheeler sales in F2002, up from just 24% in F1995. Average monthly motorcycle sales have increased five-fold since F1995 to almost 250,000 units in F2002. The current share of the leading three companies is shown in the pie chart. And this clearly shows that Hero Honda is the current market leader with a 45% market share. Hero Honda has been an early entrant in the 4 stroke segment of the two wheeler industry.

3. Key Factors Affecting the Sales of Motorcycles

Government policy impact on petrol prices:

Petrol prices determine the running cost of two wheelers expressed in rupees. Improvement in disposable income with the increase in salary levels due to entry of multinationals following liberalization process the disposable income has improved exponentially over the years. This will have a multiplier effect on demand for consumer durables including two wheelers. This is already witnessed in improved demand two wheelers.

Implementation of mass transport system

Many states have planned to implement mass transport systems in state capitals in the future. This will have a negative impact on demand for two wheelers in the long run. But taking into account the delays involved in the implementation of such large infrastructure projects, we expect the demand to be affected only five to seven years down the line.

Availability of credit for vehicle purchase

The availability and cost of finance affects the demand for two wheelers as the trend for increased credit purchases for consumer durables have increased over the past few years.

To survive and get the maximum share in the market, there is tremendous pressure on every company to launch new and attractive models at a reasonable cost and in quick time. In order to achieve this, fast and low cost development with reliable quality and delivery, the company must select good committed suppliers to supply their parts. The Indian auto parts industry is highly distributed in terms of quality, technology, capacity, location, process and infrastructure. To get uninterrupted supplies and development, the supplier selection is one of the key strategic decision to achieve the company objectives.

4. Objectives of the Paper

The main objective of this paper is to model an easy supplier evaluation and evaluation process in automobile industry, so that Xyz Motor India can select the most reliable and profitable supplier for its part supply and development. By achieving this Xyz Motorcycles can be more competitive in the market and they can grab more market share in India.

The paper intends to deal with one of the major strategic issues – the sourcing issue. In the sourcing process, how the suppliers should be evaluated and selected is the major interest of this paper. Right now, no scientific method is used for supplier selection. It depends only on the buyer's perception and their past experience with the supplier. Due to this many strategic issues have arisen before Xyz India. To handle these issues a scientific method should be adopted for supplier selection. The objectives of this paper are :

- To investigate existing supplier evaluation & selection models.
- To identify variables affecting supplier performance.
- To prioritise suppliers on the basis of multi criteria decision variables.

Earlier Supplier Selection/Evaluation Models

A number of studies have been devoted to examining vendor selection methods (Mandal and Deshmukh, 1994). The common conclusion of these studies is that the multiobjective nature of supplier selection decisions (Nydick and Hill, 1992; Ghodsypour and O'Brien, 1998 & 2001; Boer et al., 2001). Weber et al. (1991) reviewed the quantitative approaches to vendor selection problems. According to this study, linear weighting models, mathematical programming models and statistical/probabilistic approaches have been the approaches the most utilized. Nydick and Hill (1992) and Akarte et al. (2001) showed how the AHP can be used to structure the supplier selection process. Addition to traditional AHP, fuzzy analytic hierarchy process approach is proposed by several authors (Zaim, et al., 2003; Kahraman, et al., 2003). Weber and Current (1993) developed a multiobjective programming approach to assist the purchasing manager in making vendor selection decisions. Ghodsypour and O'Brien (1998) proposed an integration of an AHP and linear programming model in choosing the best supplier. Boer et al. (2001) presented a review of decision methods reported in the literature for supporting the supplier selection process. They showed that several suitable Operations Research methods such as data development analysis, total cost approaches, linear programming, linear weighting models, statistical methods; artificial-intelligence-based models have been used so far in the purchasing literature. Bhutta and Huq (2002) presented two approaches (AHP and TCO) related to supplier selection decision and provided a comparison. Handfield et al. (2002) proposed an AHP model that included relevant environmental criteria in supplier selection decision. Cebi and Bayraktar (2003) structured a supplier selection problem using an integrated lexicographic goal programming and AHP model. The activity-based costing approach is also used in the literature (Dogan and Sahin, 2003).

In automobile industry, it is very important for manufacturers to find necessary knowledge and information about suppliers for their systematic evaluation. Earlier research findings indicated that nearly 50% of the companies in different industries have a formal supplier evaluation process (Weber, et al., 2000). The clusters mostly considered in current supplier evaluation methods are quality, facilities, supplier certification, location and channel relationship. Most evaluation methods depend on industry certification or heuristic indicators for supplier performance evaluation, which sometimes may ignore the business synergy, For supplier evaluation, there are four common supplier evaluation models :

- Categorical Model
- The weighted point model
- The cost ratio model
- Dimensional analysis model

Categorical model

In categorical model, the performance of a supplier is divided into different categories. By using this model, the buyers are able to monitor the supplier performance in different product categories. This method is very simple and can be used with no investment & inexpensive technology, however it requires very rich experience buyers with good memory and personal judgement.

The weighted point model

The weighted point model is the most basic of all supplier analysis methods. Buyers normally use this model with small variations. This method is very much in use due to its simplicity, flexibility and effectiveness in decision making process. The key for successful application of this model includes adequate estimation of weights in performance variables and a good understanding of common performance levels in the industry. While using this method, the input for estimating the weights should be taken from the members of cross functional teams, not just from the buyers or the purchasing department.

The cost ratio model

The cost ratio model is complex and less used by buyers. It stresses issues with high influence on buyer's operation costs. Two cost components, the supplier's selling price and the buyer's internal operating cost including quality, delivery and other service elements are the basis for making decisions. To determine the total cost of a purchase, a buyer must know the company's own internal operating cost and obtain accurate information about supplier's prices first, and then convert the internal cost into a cost ratio with respect to the total value of the purchase. The buyer selects the supplier with the lowest adjusted cost after adjusting the selling price with the internal cost ratio or picks the supplier who meets the established cost standard.

Dimensional analysis model

Dimensional analysis model is a response to the disadvantages presented in the previously described models. This method combines multiple criteria into a single unified entity for each supplier. Each supplier is evaluated according to the vendor performance index, which is calculated according to the supplier performance against the standard performance for a set of criteria and the relative importance of the criteria. The key to the successful use of this method is the allocation of weights to each criterion. A buyer must have the ability to establish the relative importance of each criterion considered. Criteria may have positive or negative weights. For example quality could be a positive weight criterion while price represents a negative weight criterion. Another important consideration is the relative importance of each criterion. If a criterion has a importance rated at 4, then it is twice as important as a criterion rated at 2.

The methods discussed above may not effectively address some of the important issues currently driving the automobile industry. The discussion and development of a selection and evaluation model in the following sections aims to wrap up all the critical factors that need to be considered by decision makers in the automobile supply chain activities.

5. Application of AHP in Supplier Selection

Since outsourcing or offloading is an unavoidable trend in cost cutting. Indian automobile industry is doing more and more outsourcing to focus on their core competencies and to cater huge market demand. The implementation of SCM practices aims to establish a close buyer-supplier relationships as a true partnership among companies in a supply chain. It is very important for companies to find reliable and trustworthy suppliers. With the increase in outsourcing activities , purchasing becomes a much more important and critical activity of business in automobile industry. Although outsourcing adds risk to the business process, but it is inevitable to remain competitive in the market on price and delivery front. Analytical Hierarchy Process (AHP) is one of the widely used and discussed supplier selection methods in the existing literatures :

AHP is a robust and simple method that contemplates hierarchical relationships among factors considered by decision makers such as quality, flexibility and cost, but it is weak in determining interrelationships among factors.

So Saaty developed the ANP model to overcome certain difficulties which werein AHP model by including the information of correlations between factors in the decision making process.

Developed by Thomas Saaty, AHP provides a proven, effective means to deal with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision-making process. AHP helps capture both subjective and objective evaluation

measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team thus reducing bias in decision making (Saaty, 1980). Combined with meeting automation, organizations can minimize common pitfalls of team decision making process, such as lack of focus, planning, participation or ownership, which ultimately are costly distractions that can prevent teams from making the right choice.

Methodology for AHP

The first step is for the team to decompose the goal into its constituent parts, progressing from the general to the specific. In its simplest form, this structure comprises a goal, criteria and alternative levels. Each set of alternatives would then be further divided into an appropriate level of detail, recognizing that the more criteria included, the less important each individual criterion may become. Next, assign a relative weight to each one. Each criterion has a local (immediate) and global priority. The sum of all the criteria beneath a given parent criterion in each tier of the model must equal one. Its global priority shows its relative importance within the overall model. Finally, after the criteria are weighted and the information is collected, put the information into the model. Scoring is on a relative basis, not an absolute basis, comparing one choice to another. Relative scores for each choice are computed within each leaf of the hierarchy. Scores are then synthesized through the model, yielding a composite score for each choice at every tier, as well as an overall score.

6. Development of the Supplier Evaluation Model

To make the simple, flexible and easy to use evaluation model ; first we have to list out the variables or clusters that should be considered while selecting a supplier. These clusters should represent the supplier performance as a whole. The supplier who scores the highest amongst all probable suppliers must be selected for supply of parts.

The model is designed according to a hierarchical structure with several layers of decision making activities. The first level of hierarchy includes the most critical areas in sourcing for automobile supply chains. This level consists of six areas that includes delivery, cost, quality, flexibility, reliability and development ability. According to recommendations of Saaty, these areas are called "clusters", which signify grouping factors. Each cluster is assigned a weight, which is assigned by buyers according to their needs. A second level of the hierarchy consists of factors that have significant effect on each cluster.

Again buyers must assign appropriate weights to each factor according to specific situations or needs. Additionally,a desired value must be determined for each factor to provide a benchmark.

We have decided to keep two main characteristics for this model. In first characteristic , we have to obtain a dimensionless index as the result of running the model. The grade that each supplier receives on each factor will be divided by desired value to obtain a dimensionless index that will then be multiplied by its corresponding factor and cluster weight. In this way, it integrates both qualitative and quantitative factors in the evaluation process. So this model can also be classified as a multi-attribute approach. The second characteristic, not considering correlations between factors in the model, is for the sake of simplicity in the use of the model.

The index used in this model to determine a supplier's performance is the total supplier score. This score consists of six cluster scores, the scores for delivery, quality, cost, flexibility, reliability and development capability. It is important to note that some clusters may have negative impact, e.g. high cost score has a negative impact on the total supplier score. Since cost effectiveness is an important factor considered for outsourcing in automobile industry, the cost score will have an important influence over the total supplier score. The following equation shows the supplier evaluation model:

Total supplier score =
Delivery score + Quality score +
Flexibility score + Reliability score +
Development capability score – Cost score

.... (1)

The six scores that determine the total supplier score are from six key supplier performance clusters. To determine these cluster scores we need to determine following:

1. Cluster weights (C)
2. Factor weights (K)
3. Desired value (DV)
4. Value (V), obtained by dividing the score taken from buyer by the factor's desired value (DV)

7. The Clusters for Determining Supplier Performance

As shown in eqn. 1, there are six clusters considered under the supplier performance level. There are further several factors under these clusters. Figure

1 shows the structure of the decision making matrix for supplier evaluation in the proposed approach. The factors affecting the six main clusters are selected based on the most common and significant issues in automobile supply chains.

As shown in the structure in Fig. 1, emphasises that supplier's selling price is not the only factor based on which suppliers are selected. Even in the cost cluster, the cost effect is according to internal cost and the cost associated with ordering and invoicing of part in addition to the selling price. Automobile companies have to evaluate all cost items alongwith all other clusters before deciding on the supplier selection.

Of course, the low product price is very important, but the cost incurred in all other supply chain processes and purchasing process are also equally important. The proposed matrix provides a realistic and easy to use model for automobile companies to evaluate the proposed suppliers.

(i) Delivery Cluster

In the delivery cluster, there are four factors which are important to be considered while evaluating suppliers:

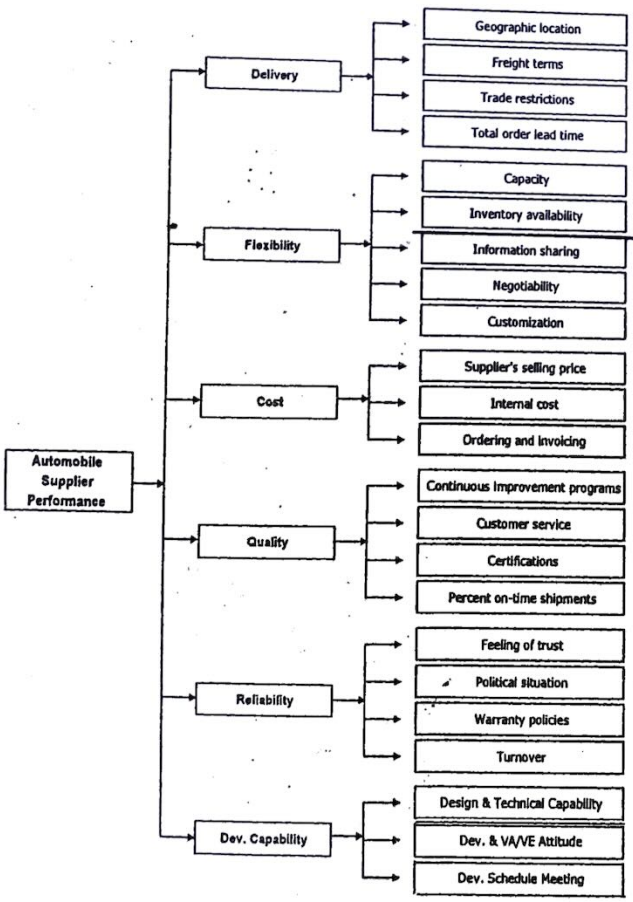

Fig. 1. Supplier Performance Evaluation Matrix Structure

A) Geographic location
B) Trade restrictions (e.g. taxes)
C) Freight terms
D) Total order lead time

A) *Geographic location* is one of important factors, if the vendor is located nearby it is advantageous for supplier and manufaturer from logistic point of view. Like Xyz motor will prefer that their supplier should be located nearby in NCR.

There are four scores assigned to the geographic location factor (K_{gl}) like

- Close proximity with suppliers: within 50 Km (Score 4)
- Suppliers located in the region : 50 to 200 Km (Score 3)
- Suppliers located in the region : 200 to 400 Km (Score 2)
- Suppliers located in the region : Above 400 Km (Score 1)

B) *The next factor under delivery cluster is trade restrictions*

(K_{tr}). It takes into account government regulations like taxes applicable, because it increases the landed cost of product. Some other restrictions like Quota system may also be applicable in some region.

- High trade restrictions : high taxes etc. (Score 4)
- Moderate trade restrictions (Score 3)
- Low trade restrictions (Score 2)
- No trade restrictions : Tax free zones (Score 1)

The high score in this factor will have a negative impact on delivery index. Scores in this category are according to level of restrictions.

C) *The third factor in delivery cluster is the freight terms*

(K_{ft}).This factor refers to the favourability of shipping conditions for the manufacturing company. It is always good for any company that supplier should take all the responsility of material in transit like insurance etc. Scores in this factor are according to following four scales :

- Excellent (Score 4)
- Good (Score 3)
- Fair (Score 2)
- Poor (Score 1)

D) *The last factor influencing delivery performance is the total order lead time (K_{lt}).* The total order lead time is the lead time from the moment a buyer placed an order to the time the customer's designated site received the ordered products. Inefficiencies in production transportation and flow of information between involved supply chain parties may have negative effect on this factor. The buyer may determine the ranges for performance evaluation. For example the ranges may be divided as following:

- Excellent :Total order lead time < 1 day (Score 4)
- Good : Total order lead time 1 to 2 days (Score 3)
- Fair : Total order lead time 2 to 5 days (Score 2)
- Poor : Total order lead time beyond 5 days (Score 1)

The delivery score calculated in equation 2 is according to all factors in delivery cluster :

$$\text{Delivery Score} = C_D[(K_{gl}*V_{gl}) + (K_{ft}*V_{ft}) - (K_{tr}*V_{tr}) + (K_{lt}*V_{lt})] \quad \ldots. (2)$$

In the equation C_D is the weight of the delivery cluster and V_{gl}, V_{ft} , V_{tr} andd V_{lt} represent the value obtained for for each factor after dividing the factor's score by its desired value (DV).

(ii) Flexibility Cluster

The flexibility may be defined as how supplier responds to unexpected customer demands. The flexibility cluster is evaluated in terms of a supplier's capacity to respond to unexpected demands. Previous researches have identified six components of flexibility that include production flexibility, market flexibility, logistiscs flexibilty, supply flexibility, organisational flexibility and information systems flexibility.

Suppliers flexibilty can be evaluated in terms of following five factors :

A) Capacity
B) Inventory availability
C) Information sharing
D) Negotiability
E) Product customisation

A) *Capacity* (K_C) is determined by buyer's knowledge or information obtained from the source itself. This score must display the levels of economic order quantities that a supplier can deal with. Scores on this factor are according to following scales :

- Very High (Score 4)
- High (Score 3)
- Acceptable (Score 2)
- Low (Score 1)

B) The second factor is the inventory availability (K_{iv}) Factor. All buyers want that suppliers should keep certain level of safety stocks. This factor may be measured in terms of weeks of safety stocks available. Small and medium suppliers with make to order production systems are likely to score poorly on this category. Scales for this factor are also as following:

- Very High (Score 4)
- High (Score 3)
- Acceptable (Score 2)
- Low (Score 1)

C) The third factor information sharing (K_{is}) refers to the level of information shared between parties. Buyers want that supplier should give constant updates of inventory levels, production plans and status of orders. While suppliers may require to know the buyer's forecasting data in order to prepare for future production requirements. In today's information technology age buyer and supplier want real time status of above information. The scales used to evaluate information sharing between parties include :

- Very high with real time updates and compatible EDI Technologies (Score 4)
- High with weekly updates and compatible EDI (Score 3)
- Accepatable with updates obtained between one to two weeks and low EDI compatibility (Score 2)
- Low with updates obtained monthy and no EDI compatibility (Score 1)

D) Negotiability (K_n) is the fourth flexibility factor. Negotiability is the mutual trust that exist between supply chain partners and is high in long term relationships.

This category can be evaluated in following scales:

- Very High (Score 4)
- High (Score 3)
- Acceptable (Score 2)
- Low (Score 1)

E) The fifth factor for flexibility cluster is customisation (K_{cu}). This is suppliers capabilities to take orders with special characteristics or specifications. Unusual specifications may require special machine setups, which small and medium suppliers can easily do. Scales in this factor also are same as last factor :

- Very High (Score 4)
- High (Score 3)
- Acceptable (Score 2)
- Low (Score 1)

The flexibility score is computed as in equation 3 with CF as the weight of flexibility cluster :

$$\text{Flexibility Score} = C_F[(K_c * V_c) + (K_{iv} * V_{iv}) + (K_{is} * V_{is}) + (K_n * V_n) + (K_{cu} * V_{cu})] \quad \ldots (3)$$

(iii) Cost Cluster

Cost cluster is most important cluster for supplier evaluation in automobile industry. If a low cost vendor with some quality check is used, the company can get an edge over competitors. No doubt, this cluster influence the most the supplier selection process. The three factors considered in the evaluation of this cluster are:

A) Supplier's selling price (K_{sp})
B) Internal Cost (K_{ic})
C) Invoicing & Ordering Cost (K_{oi})

A) There is always pressure on the buyers to search for less costly products and to get year on year reduction from supplier. Supplier's selling price is evaluated according to the following scales :

- High Prices (Score 4)
- Acceptable Prices (Score 3)
- Low Prices (Score 2)
- Very Low Prices (Score 1)

B) The internal cost factor considers the total cost of each purchase and is adopted from the cost ratio method. In addition to the purchasing price of the product, the other cost related with transport and quality e.g. rectification, waste and plant visits must also be considered. The minimisation of internal cost is every company's target nowadays.

This category is evaluated according to following scales:

- High Internal cost (Score 4)
- Acceptable Internal cost (Score 3)
- Low Internal cost (Score 2)
- Very Low Internal cost (Score 1)

C) The third cost factor, the ordering and invoicing factor is related to the ease in order placing. Every company wants their suppliers to implement online systems in which orders may be posted with less human interactions and real time ordering information. Organisations also need to work on customer driven invoicing systems.

This factor has four ratings :

- Excellent (Score 4)
- Good (Score 3)
- Fair (Score 2)
- Poor (Score 1)

The cost score is calculated by equation 4 with C_c being the weight of cost cluster :

$$\text{Cost Score} = C_c[(K_{sp} * V_{sp}) + (K_{ic} * V_{ic}) - (K_{oi} * V_{oi})] \quad \ldots\ldots (4)$$

(iv) Quality Cluster

The quality cluster includes folloing four factors :

A) Continuous improvement (K_{ip})
B) Quality Certification (K_{ct})
C) Customer Service (K_{cs})
D) On time delivery percentage (K_{ot})

A) Continuous improvement could be in any field which improves the supply chain process. The improvement can be in the field of logistic, lead times, reliability of deliveries and information sharing etc.The continuous improvement score is according to following scale :

High : The supplier constantly presents signs of improvements (Score 4)

Moderate : The supplier occasionally presents signs of improvements (Score 3)

Acceptable : The supplier rarely presents signs of improvements (Score 2)

Poor : The supplier never presents signs of improvements (Score 1)

B) The certifications factor is for the recognition of the supplier's quality level. ISO 9000 certifications or other certifications from recognised organisations or customers have their significance in the evaluation process. Buyers may use supplier

certifications as quality assurance instruments that determines whether or not some suppliers are capable to follow standards in the industry. This category is evaluated as follows :

- Very High : The supplier has ISO 9000 & OHSAS Certificate (Score 4)
- High : The supplier has ISO 9000 Certificate (Score 3)
- Acceptable : The supplier has some Quality Certificate (Score 2)
- Poor : The supplier does not have any certification (Score 1)

C) The third facor is cusomer service. Every industry the customer service given by its supplier. From supply chain point of view, customer service is the responsiveness of supplier to customer requests or complaints. This category may be evaluated as follows:

- Excellent : The supplier always attended complaints or requests promptly (Score 4)
- Good : The supplier always attended complaints or requests promptly most of time. (Score 3)
- Fair : The supplier attended complaints or requests promptly occasionally. (Score 2)
- Poor : The supplier never attended complaints or requests promptly. (Score 1)

D) The last factor, percentage of on-time deliveries (K_{ot}) is important factors that makes the buyer's perception about the supplier. This category is evaluated as follows :

- Very High : More than 95% deliveries are on time (Score 4)
- High : 90 to 95% deliveries are on time (Score 3)
- Moderate : 85 to 90% deliveries are on time (Score 2)
- Poor : Less than 85% deliveries are on time (Score 1)

With these four factors, the quality score is calculated in equation 5 and the coefficient C_Q is the weight of quality cluster.

$$\text{Quality Score} = C_Q[(K_{ip}*V_{ip}) + (K_{cs}*V_{cs}) + (K_{ct}*V_{ct}) + (K_{ot}*V_{ot})] \quad \ldots (5)$$

(v) Reliability Cluster

The reliability cluster for supplier performance evaluation is the reliability of supplier's operations to fulfill supply chain activities. The following factors are used to evaluate supplier's reliability cluster :

A) Feeling of trust (K_t)
B) Political situation (K_{ps})
C) Warranty policy (K_{wp})
D) Supplier turnover (K_{to})

A) The feeling of trust is evaluated according to the buyer's perception of a given supplier regarding sample approval, order delivery. A supplier's reputation in the industry can influence the evaluation result in this category. The evaluation of this factor has the following four levels :

- Very High (Score 4)
- High (Score 3)
- Acceptable (Score 2)
- Low (Score 1)

B) The political situation of the area where supplier is situated is also a factor considered in reliability cluster.

This is a point of concern for buyer , as it is beyond the control of supplier and buyer also. Like in Maharashtra, in some areas the political activists of Shiv Sena are very influential. So the supplier situated in those area may score poorly in this factor.

The evaluation criteria for his factor include four ratings:

- Excellent (Score 4)
- Good (Score 3)
- Fair (Score 2)
- Poor (Score 1)

The Excellent rating shows that the supplier's origin exhibits good short and long term stability and there are no concerns for supply chain operations disturbance. The Good rating provides that the supplier's place has good short and long term political stability. The Fair rating reveals that there are some concerns regarding political stability. Some concerns regarding disruptive events may exist in the supply chain operations. The poor rating shows that the supplier's country of origin exhibits serious concerns regarding political stability and disruptive events in supply chain activities.

C) Now a days companies want their suppliers to give warranty for their parts. From logistic point of view, warranties are associated with on time deliveries. Buyers want compensation in case of late delivery of parts.

The evaluation of this factor is done on following four scales :

- Very Favorable : Supplier takes full responsibility on non-conformities and offer rebates (Score 4)
- Favorable : Supplier takes partial responsibility on non-conformities and offer rebates for delayed delivery only (Score 3)
- Neutral : Supplier only takes partial responsibility on non-conformities (Score 2)
- Non- Favorable: Supplier does not take any responsibilities on non conformities (Score 1)

D) Supplier Turnover is also an indiacation of supplier's financial soundness and its bearing capacity. If the turover is high, according to industry norms then it is excellent. It can be rated on four scales :

- Very High (Score 4)
- High (Score 3)
- Fair (Score 2)
- Low (Score 1)

Eqauation 6 shows the computation for the reliability score. In the equation, C_R is the weight of the reliability cluster :

$$\text{Reliability Score} = C_R[(K_t * V_t) + (K_{ps} * V_{ps}) + (K_{wp} * V_{wp}) + (K_{to} * V_{to})] \quad \text{... eqn. 6}$$

(vi) Development Capability Cluster

Automobile industry is very dynamic now a days. Every now and then new models are launched by competing companies to attract the customers. So it is very important that suppliers should be capable of developing new products very fast and should be reliable also, so that new products are not failed in the market. The following factors must be evaluated while selecting suppliers on the basis of development ability cluster :

A) Design & Technical Capability (K_{dt})
B) Development & VA/VE attitude (K_{dv})
C) Development schedule meeting (K_{ds})

A) Design & Technical capability is very important for developing new products very fast. It can be evaluated on the basis of following four scales :

Excellent : Supplier has its own R&D centre & Technical Collaboration (Score 4)

Good : Supplier has some Design & Technical Collaboration (Score 3)

Fair: Supplier has some proven record of developing Products (Score 2)

Poor : Supplier don't have collaboration and don't have any record of developing products (Score 1)

B) If the supplier has development & value engineering attitude embedded in their culture , the supplier gets high score in this factor. Supplier gives ideas in new development volunteerly to upgrade the product because they are expert in that field. The buyer can give score on the basis of his past experience and supplier reputation. The scale for this factor are following :

- Excellent (Score 4)
- Good (Score 3)
- Fair (Score 2)
- Poor (Score 1)

C) Supplier should give due importance to new development also with the current products regular production. Buyer can give rating on the basis of following four scales :

- Excellent : Supplier always develop products before target date (Score 4)
- Good : Supplier just meets the target schedule (Score 3)
- Fair : Supplier sometimes meet misses the target schedule (Score 2)
- Poor : Supplier never meets the target date (Score 1)

Eqauation 7 shows the computation for the development capability score. In the equation , C_{DC} is the weight of the reliability cluster :

$$\text{Dev. Capability Score} = C_{DC}[(K_{dt} * V_{dt}) + (K_{dv} * V_{dv}) + (K_{ds} * V_{ds})] \quad \text{....eqn. 7}$$

8. Supplier Performance Evaluation Matrix

Xyz motor India has approximately 200 Numbers of Motorcycle parts supplier base, who supply approximately 2000 types of parts. For the purpose of

simplicity, we will choose one type of part and apply this model to select the best supplier from the many probable suppliers.Now we will apply above shown factors through AHP model in a practical example. The major electrical parts used in the two wheeler industry are:

- Headlight
- Tail Light
- Flashers / Indicators

This is an actual study based.on actual suppliers supplying electrical parts to Xyz Motor India. The name of suppliers are not disclosed here for the purpose of company secrecy.The four suppliers are considered here for study.

Selection Procedure

Here we have considered the six clusters and their sub – factors for selection base evaluation. Evaluator will give relative weight for each cluster and factor w.r.t. other cluster and factors for calculation of weight or importance, the evaluator gives to that cluster or factor out of total weight 1. On the basis of relative rating , we first calculate eigen value and then normalise it to get the absolute weightage of each factor.

Then evaluator will also give rating to each potential supplier for each factor . On the basis of cluster weight,factor weight and factor ratings; each cluster index is calculated for every supplier. Then the sum of all cluster indexes is the total score of supplier. On the basis of this total supplier score we can select the best scoring supplier for part development and supply.

The relative weights in the pair wise comparison matrices of AHP have been obtained through the discussion with a group of experts of the supply chain of the case company. The group consists of supply chain experts from the trading partners of the case company.

Rating of SC: Supplier Rating Explanation

Supplier A

Supplier A is located in Pune , which is very far from works location of Xyz Motor India (YMI) , so the evaluator has given him low score (score=1) on geographic location factor. Supplier A also scores badly on freight terms front because the supplier wants that YMI should pay for all transportation cost of supply and insurance (score=2). There are no trade restrictions except some taxes for supplier A (score=2). In the formula for delivery score it is taken as –ve, because high score is not good for this factor. It takes normally more than 5 days for supplier A to deliver the material to YMI after receiving the order (score=1).

In terms of flexibility , supplier A has high capacity for production (score=3) and inventory levels the supplier keeps are in acceptable limits (score=2).In information sharing factor the supplier A does not have efficient information sharing system and there is no EDI compatibility (score=1). Supplier A being 100% subsidary of foreign MNC , works in full control of its parent company and there is very low scope of negotiation, e.g. for mould making the supplier uses its own parent company facility which is very costly (score=1). In customisation also, the supplier does not wants high variation in ordered quantity to keep its packing and forwarding cost to limit (score=2).

In cost cluster factors , the supplier A has high selling price (score=4), high internal cost(score=4) and good ordering and invoicing system (score=3). Being MNC, supplier A has high overheads which adds to it its selling price. YMI has to bear high internal cost due to defects occured during long transit distance. In total supplier score calculation the cost cluster is considered negative, as high score in this cluster has negative impact.

In Quality index, for continuous improvement factor the supplier tries to improve the value addition in each process (score=3). For customer satisfaction, the supplier A is always keen to take every step to satisfy customer (score=4). Supplier A has ISO & OHSAS certification for its plant (score=4). On delivery front, supplier A gives 90 to 95% deliveries ontime for every month orders (score=3).

In reliability index, YMI has high trust in supplier A for its professional working for meeting development and delivery schedule (score=4). The political situation of area of location of supplier A is somewhat stable , except one or two stray incidents of Shiv Sena activist going wild (score=3). Supplier A takes full responsibily for any non conformity in its parts and replaces them free of cost (score=4). The turnover of supplier A is not as high as its competitors so it has got low score in this factor (score=2).

In terms of development capability, supplier A has its own R&D centre and full technical support of its parent company (score=4). Supplier takes development of new parts seriously alongwith regular supply and give value addition in developing new parts (score=). Supplier always meets its development schedule (score=3).

Supplier B

Supplier B is located in Gurgaon within 50 Km distance from the company, so it has got high score in this factor (score=4). Freight terms with the supplier B are good, it supplies the material to YMI without additional cost (score=3). There are only excise & Central Sales Tax applicable with supplier B, so it has got good score (score=2). The total order lead time for supplier B is 1 to 2 days (score=3).

In terms of flexibility, it has enough acceptable capacity and keeps enough inventory availability (score=2). Supplier B also has got low score in terms of information sharing due to many limitation (score=1). Supplier B is somewhat better than supplier B in terms of negotiation (score=2) and they do come on negotiation table if requested. They are highly flexible and customise according to YMI requirements in terms of delivery and product specification (score=4).

In terms of cost cluster factors, supplier B is better than supplier A in terms of selling price (score=3). YMI has low internal cost for the parts supplied by supplier B, as distance is very less between them (score=3). The ordering and invoicing system of supplier B is simple and good (score=3).

The supplier B shows signs of improvement, when it is instructed but it does not do improvements volunteerily, so it has got low score than supplier A (score=2). It most of time attends the complaints promptly (score=3). Supplier B has got ISO certification only, so it has got low score than supplier A (score=3). The supplier B also delivers the material mostly on time (score=3).

In terms of reliability, the evaluator has less trust in supplier B than supplier A, due to their some unprofessional behaviour for long term relationships (score=2). The political situation in Gurgaon is stable and there is no immediate or long term threat (score=4). In warranty policy factor, the supplier resists and does not take full responsility (score=2). The turnover of supplier B is very high in terms of total market (score=4).

In development capability front, the supplier B has proven record of development as it has largest market share but it lacks technical collaboration (score=2). It takes the development activity not so seriously as it is always under pressure for regular supply (score=2). Due to this attitude it sometimes misses development target date also (score=2).

Supplier C

In delivery cluster, Supplier C has got same rating as of supplier B because it is also located in Gurgaon. The evaluator has given him score=4 for geographic location, score=4 for freight terms, score=2 for trade restrictions and score=3 for total order lead time.

In terms of flexibility also, it is almost same as supplier B. The evaluator has rated it score=2 for capacity, score 2 for inventory or safety stock keeping, score=1 for information sharing, score=2 for negotiability. But it has got low score for customisation than supplier B (score=3) because of its less manufacturing capability for all specifications of products.

In cost cluster supplier C has got same rating as supplier B. It has got score=3 for selling price, score 3 for internal cost and score=3 for ordering and invoicing system. In Quality cluster index calculation, the evaluator has rated it as score=2 for continuous improvement, because it does not do improvements volunteerily. In case of customer service, it has got low score (score=2) due to its linient attitude for customer satisfaction. Supplier C has got ISO certification for its operation (score=3). Its delivery rating is not upto mark, it regularly misses the target delivery date for material supply (score=2).

In terms of reliability, supplier C has got same rating as supplier B. It has been rated as Feeling of trust (score=2), political situation (score=4), warranty policies (score=2) and turnover (score=4).

In terms of development capability, it has got more rating than supplier B, as it has technical collaboration with a foreign company (score=3). In Dev. & VA/VE attitude also, it has got low rating due to less product innovation ideas (score=2). In dev. Schedule meeting factor also it has got same rating as supplier B (score=2).

Supplier D

Supplier D is loacted at Sonepat, it has been given score=3 for geographic location. It has got same rating for other factors as supplier B & C has got because there is no difference in conditions of these factors. It has been rated score=4 for freight terms, score=2 for trade restrictions and score=3 for total order lead time.

In terms of flexibility, supplier D has acceptable production capacity right now which can be increased if required (score=2). It keeps some safety stock at its end (score=2). In information sharing also it has got same rating as other suppliers (score=1) because it has no definite information sharing system with YMI. Supplier D has got better negotiability score (score=3) than other suppliers, because it is ready to negotiate on all factors, be it tooling or other cost factors. It has got

good customisation capability for delivery and development (score=3).

In cost cluster factors, supplier D is rated good for selling as compared to other suppliers (score=2). For internal cost burden on YMI, it has been rated best (score=2) for its superior packing and logistic. Its ordering and invoicing system is good (score=3).

For continuous imprivement, its attitude is same as supplier B & C (score=2). It always attended customer complaints promptly and took necessary countermeasures (score=4). It has got ISO and TS certifications for quality and appreciation certificates from foreign customers, so it has been rated high (score=4). It delivers more than 90% deliveries on time (score=3).

Supplier D has gained more trust of evaluator (score=3) than supplier B and C has, because of its technical ability. Political situation in supplier D region is very good (score=4). In terms of warranty policy, supplier takes partial responsibility for failure or non conformity (score=3). The turnover of supplier D is good w.r.t. market (score=3).

The design and technical capability of supplier D is good, it has Japanese technical collaboration also (score=3). Its development and VA/VE atitude is good (score=3) as compared to supplier B and C. It always meets development schedule (score=3).

9. Analysis

The rating of all suppliers on the basis of all factors considered is tabulated in Table 2. on the basis of calculation for all cluster indexes by applying formulas as explained earlier and after that total supplier score calculation, supplier D has got the highest score (Total score=0.287). So it should be selected for part development and supply.

Table 1A and 1B show the calculation of all the cluster and factor weights by calculating eigen value and then normalising it. The sum of weights of all factors of a cluster should be 1. The relative importance is given by evaluator in table 1A on the scale 1 to 9.

e.g. Delievery weight is calculated as

Multiplying all the relative importance ratings in the Delivery row and then taking its root according to no. of values. It will give eigen value , then we can normalise it.

$$\text{Delivery Eigen value} : (1*3*2*3*0.17*0.25)^{1/6} = 0.95$$

Thus we can calculate all eigen values and then sum it as shown in table 1. Then divide the eigen value of delivery by sum of eigen values of all clusters to get the delivery weight.

$$\text{Delivery Weight} : 0.95/7.08 = 0.13$$

Thus we can calculate the weight of all clusters and its factors as tabulated in Table 1-6.

Table 7-13 shows the calculated value of all cluster indexes for all suppliers on the basis of formulas explained earlier.

From the table 12, we see that different suppliers are best in different cluster indexes. Supplier B is best at delivery and flexibility while supplier D is best at cost cluster index. Supplier A is best in terms of quality, reliability and development capability. But overall according to weight of each cluster supplier B has best overall rating , so it should be given preference for future business.

From this analysis, we conclude that pricing is not the only factor in supplier selection and evaluation process other factors also contribute decisively in selection process. Supplier D is best in terms of cost

Table 1

	Delivery	Flexibility	Cost	Quality	RELIABILITY	DEV.CAP.	Normalized
Delivery	1	3	2	3	0.17	0.25	0.13
Flexibility	0.33	1	4	3	3	4	0.27
Cost	0.50	0.25	1	0.20	0.25	0.20	0.05
Quality	0.33	0.33	5	1	0.20	2	0.11
RELIAB	6.00	0.33	4	5	1	2	0.29
DEV. CAP.	4.00	0.25	5	0.50	0.50	1	0.15

Table 2

Delivery	Geographic location	Freight terms	Trade restrictions	Total order lead time	Normalized
Geographic location	1	2	0.25	0.33	0.13
Freight terms	0.5	1	0.33	0.25	0.09
Trade restrictions	4	3	1	2	0.45
Total order lead time	3	4	0.5	1	0.32

Table 3

Flexibility	Capacity	Inventory availability	Information sharing	Normalized
Capacity	1	0.50	0.50	0.09
Inventory availability	2	1	0.33	0.10
Information sharing	2	3	1	0.36
Negotiability	3	4	0.33333333	0.26

Table 4

Quality	Supplier's selling price	Internal cost	Ordering and invoicing	Normalized
Supplier's selling price	1	0.5	2	0.30
Internal cost	2	1	3	0.54
Ordering and invoicing	0.5	0.33	1	0.16

Table 5

Reliability	Feeling of trust	Political situation	Warranty policies	Turnover	Normalized
Feeling of trust	1	3	2	4	0.47
Political situation	0.33333333	1	2	2	0.23
Warranty policies	0.5	0.5	1	4	0.21
Turnover	0.25	0.5	0.25	1	0.09

Table 6

Dev. Capability	Design & Technical Capability	Dev. & VA/VE Attitude	Dev. Schedule Meeting	Normalized
Design & Technical Capability	1	2	0.5	0.31
Dev. & VA/VE Attitude	0.5	1	0.5	0.20
Dev. Schedule Meeting	2	2	1	0.49

which has least weight age, it got second position in all other clusters and overall supplier D is best so it should be selected

10. Limitations of the Model

AHP model developed in this paper has certain limitations. The study through this model is limited to suppliers supplying only one type of component. Softare like EXPERT CHOICE has not been used in the present model. Only limited number of variables have been taker into account while developing the supplier evaluatior model. By using a software package, a new model car be developed by considering more number of variables

11. Conclusion

The supplier evaluation model presented in thi paper has three major advantages over other supplie selection models. The first advantage is that it use

Table 7

	Weight	Factors	Weight	DV	Supplier A	Score	Supplier B	Score	Supplier C	Score	Supplier D	Score
Delivery	0.13	Geographic location	0.13	3	4	1.333333	4	1.333333	3	1	1	0.333333
		Freight terms	0.09	3	4	1.333333	4	1.333333	3	1	2	0.666667
		Trade restrictions	0.45	2	1	0.5	2	1	2	1	1	0.5
		Total order lead time	0.32	4	3	0.75	3	0.75	3	0.75	3	0.75
						0.042069		**0.011469**		**0.001416**		**0.016074**

Table 8

	Weight	Factors	Weight	DV	Supplier A	Score	Supplier B	Score	Supplier C	Score	Supplier D	Score
Flexibility	0.27	Capacity	0.09	2	3	1.5	4	2	2	1	3	1.5
		Inventory availability	0.10	4	2	0.5	3	0.75	2	0.5	2	0.5
		Information sharing	0.36	3	3	1	4	1.333333	2	0.666667	3	1
		Negotiability	0.26	3	1	0.333333	2	0.666667	2	0.666667	3	1
		Customization	0.19	2	1	0.5	2	1	2	1	2	1
						0.195676		**1.861794**		**1.252611**		**1.039076**

Table 9

	Weight	Factors	Weight	DV	Supplier A	Score	Supplier B	Score	Supplier C	Score	Supplier D	Score
Cost	0.05	Supplier's selling price	0.30	2	4	2	3	1.5	3	1.5	2	1
		Internal cost	0.54	2	3	1.5	3	1.5	2	1	2	1
		Ordering and invoicing	0.16	4	4	1	4	1	2	0.5	2	0.5
						0.057482		**0.050598**		**0.041878**		**0.034995**

Table 10

	Weight	Factors	Weight	DV	Supplier A	Score	Supplier B	Score	Supplier C	Score	Supplier D	Score
Quality	0.11	Continuous improvement programs	0.19	3	3	1	4	1.333333	3	1	2	0.666667
		Customer service	0.49	3	3	1	4	1.333333	2	0.666667	1	0.333333
		Certifications	0.17	3	3	1	4	1.333333	3	1	1	0.333333
		Percent on-time shipments	0.16	4	4	1	4	1	2	0.5	3	0.75
						0.10993		**0.140842**		**0.083395**		**0.050622**

Table 11

	Weight	Factors	Weight	DV	Supp-lier A	Score	Supp-lier B	Score	Supp-lier C	Score	Supp-lier D	Score
Reliability	0.29	Feeling of trust	0.47	3	3	1	3	1	3	1	2	0.666667
		Political situation	0.23	3	4	1.333333	3	1	3	1	4	1.333333
		Warranty policies	0.21	4	3	0.75	4	1	3	0.75	2	0.5
		Turnover	0.09	3	3	1	4	1.333333	2	0.666667	2	0.666667
						0.299939		**0.301929**		**0.268906**		**0.2297**

Table 12

	Weight	Factors	Weight	DV	Supp-lier A	Score	Supp-lier B	Score	Supp-lier C	Score	Supp-lier D	Score
Dev. Capability	0.15	Design & Technical Capability	0.31	3	3	1	4	1.333333	3	1	2	0.666667
		Dev. & VA/ VE Attitude	0.20	3	2	0.666667	3	1	3	1	2	0.666667
		Dev. Schedule Meeting	0.49	4	3	0.75	3	0.75	2	0.5	3	0.75
						0.010454		**0.03521**		**0.038105**		**0.103761**

Table 13

	Delivery	Flexibility	Cost	Quality	Reliability	Dev. Capability	Overall Score
Supplier A	0.042069	0.195676	0.057482	0.10993	0.299939	0.010453778	0.1140
Supplier B	**0.011469**	**1.861794**	**0.050598**	**0.140842**	**0.301929**	**0.035210455**	**0.3826**
Supplier C	0.001416	1.252611	0.041878	0.083395	0.268906	0.038104638	0.2686
Supplier D	0.016074	1.039076	0.034995	0.050622	0.2297	-0.004734735	0.2348

hierarchical approach for all major issues like delivery, cost, flexibility, reliability, quality etc. that covers that decision structure. The structure can be used systematically according to company needs.

The second advantage is in its flexibility to use. The buyer can give different weights to different clusters according to his needs and circumstances. For low volume parts or the parts which have volatile demand, the buyer can give more weight to flexibility.

The third advantage is in its simplicity to use because in this model no complex equations are used. This model provides an easy to use supplier evaluation and selection procedure and it gives very useful and practical results without excessive data gathering and analysis.

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