Abstract

The automobile industry frequently uses rubber in the body structure of its components. The rubber parts contribute around 20% of the entire body structure. Storing the inventory of the rubber components is the main problem in the automobile industry. A Multi Criteria Inventory Classification (MCIC) is one of the effective inventory classification techniques. In MCIC, various criteria and sub criteria are also considered for classification of the inventory. In this paper, the MCIC method has been proposed for the classification of the inventory of an automobile rubber components manufacturing industry. An Analytic Hierarchy Process (AHP) has been utilized for estimating the value of the inventory system. In the AHP, complex problems are categorized into various sub problems, which have been identified by using the hierarchical structure based on the criteria and attributes. Using the AHP, better inventory classification was identified for the automobile rubber components manufacturing industry. Further, this paper discusses the effective inventory control system of the automobile rubber components manufacturing industry.

Keywords: Multi Criteria Inventory Classification; AHP; Automobile Rubber Components Manufacturing Industry; Inventory classification

1. Introduction

An inventory is one of the primary drivers in a supply chain management. The inventory may be in the form of raw material, work in progress, finished goods, warehouse items etc. between the supplier and customer, throughout the supply chain network. Managing these inventories is essential for any type of industry.

Nomenclature

| MCIC | Multi Criteria Inventory Classification |
| ADU  | Annual Dollar Usage |
| AHP   | Analytic Hierarchy Process |

The automobile industry deals with many different types of components. 20% of the overall components are composed of rubber parts. The Indian rubber industry manufactures a wide range of rubber products such as of tyres, tubes, automobile parts etc. The rubber industry in India is basically divided into two sectors: tyre and non tyre sectors. In the non tyre sector automobile rubber parts have made a major contribution. These sectors comprise of small scale, medium scale and micro-scale units. Managing the inventory in these industries is a difficult task due to the absence of an inventory manager and enterprise resource planning. To overcome these issues, a simple inventory classification should be developed. Normally, The ABC analysis is used to classify the inventory items based on the ADU. It is based on the Pareto principle. In the ABC analysis, A class items contribute the majority (70-80%) of the total inventory value of the items. B class
contributs (10-15%) and C class consist 5 % of the total inventory value of the items. However, it is not appropriate for a single criterion now a day. The inventory of an firm depends on various criteria, such as unit price, annual demand rate, critical nature, scarcity, durability etc.In the past studies, the annual demand value of a product and critical nature of the product were used to classify the items [1]. Then the criteria extended to lead time[2].The Analytic hierarchy process was used to classify the spare parts of a large manufacturing organization, based on the criticality of the parts which depends on criteria like availability, spare demand and lead time for spares procurement [3].The Genetic algorithm was used to classify the inventory items based on various criteria, like ADU, number of requests, lead time, reparability for a university stationary inventory and unit price, number of requests, lead time, scarcity, durability, substitutability, reparability, order size, and stock ability for an explosive inventory[4].In a pharmaceutical company, the Artificial neural network was used to classify the randomly selected inventory items based on the criteria, unit price, ordering cost, demand range and lead time[5].A weighted linear optimization model was proposed for the classification of inventory items based on the various criteria[6].A web based MCIC was proposed and validated with inventory records obtained from an electrical appliances company. The classification is based on criteria such as price, annual demand, blockage effect, availability, lead time and common use [7].

Hadi proposed a nonlinear programming model for MCIC considering fewer criteria, unit cost, ADU and lead time [8]. Rezari et al. Proposed a fuzzy rule based approach for the MCIC based on the criteria, like unit price, annual demand, lead time and durability. The approach was validated with the set of 54 stock keeping units [9]. A Hadi et al. proposed a fuzzy AHP-DEA approach for the ABC classification considering the criteria of ADU, lead time, average lot cost and limitations of warehouse space[10]. Chaeen proposed an inventory classification, based on the items peer estimation value. The approach estimates the subjective nature, and considered only three criteria, like ADU, annual unit cost and lead time [11]. Torabi et al. proposed an MCIC based on qualitative and quantitative criteria [12]. However warehouse space and shape of the items are ignored in the decision making process of the inventory classification. The warehouses of an industry have space constraints, and accessibility of item constraints in accommodating all the inventory items.

In this paper, a multi criteria inventory ABC classification has been proposed, for an automobile rubber components manufacturing industry. The classification is based on the criteria of demand, unit price, annual consumption value, unit weight, and shape of the component. An Analytic Hierarchy Process (AHP) has been utilized for estimating the value of the inventory system. The classification is based on the bin allocation of the inventory items. Further, this paper will discuss the effective inventory control system of an automobile rubber components manufacturing industry.

The rest of the paper is organized as follows: Section 2 presents the methodology applied in this paper. Section 3 contains the industry details, data collection from the industry and data analysis. Section 4 deals with the results obtained from the analysis and their discussion. Section 5 concludes the paper.

2. Methodology

2.1. Analytic hierarchy process

In 1980 Saaty developed the AHP to solve complex problems [13]. AHP is widely used for the multi-criteria decision making process. The values of the criteria are tabulated below in table 1.

| Value aij | Description |
|-----------|-------------|
| 1         | Criteria i and j are equally important |
| 3         | Criteria i is slightly more important than criteria j |
| 5         | Criteria i is more important than criteria j |
| 7         | Criteria i is most important than criteria j |
| 9         | Criteria i is absolutely most important than criteria j |
| 2, 4, 6, 8| Middle values |

It disintegrates a complex problem into sub problems in the form of a hierarchical structure. Experts judgment plays an important role in the decision making process. The AHP process normally consists of four steps; they are

1. The complex problem is disintegrated into a hierarchical structure, based on objectives, criteria, sub criteria and alternatives.
2. The criteria and alternatives are compared pair wise, with respect to the importance of the objective, criteria, sub criteria and alternatives, at each level of the hierarchy. Saaty’s scale is used for the quantification of the pair wise comparison.
3. The pair wise comparison results of n criteria can be summarized in a n*n comparison matrix A, using formula 1.

\[ A = (a_{ij}), \text{ where } i, j=1, 2, 3,..., n. \] (1)

Using the following equation 2 the priority weights are calculated for the comparison matrix

\[ \omega = \lambda_{max} \omega \] (2)

where A is a n dimensional comparison matrix, \( \lambda_{max} \) is the biggest eigen value of A and \( \omega \) is the eigen vector corresponding to \( \lambda_{max} \).

4. The consistency index (CI) can be calculated to evaluate the consistency of the matrix by using equation 3.

\[ CI = (\lambda_{max} - n)/(n - 1) \] (3)

To measure the degree of CI the consistency ratio CR is calculated using the equation 4.
where RI is the random index

The value of CR should be below 0.10; otherwise the procedure should be repeated to improve the consistency.

3. Industry and Data collection

3.1 Industry

The industries studied in this study were manufacturers of rubber components, particularly for automobiles. The company is located in Chennai. The company is one of the leading suppliers of rubber components for major automobile industries. The various components manufactured in the industry were covers, grommets, boots, protectors etc, each product having sub groups or part families. These sub groups vary slightly in shape, part weight, manufacturing processes, colour, and their unit price.

Usually, the rubber components are lesser in weight. In the rubber component manufacturing industry, the unit weight of each component is essential for inventory classification. Usually, the rubber components are stored or handled only in various sizes of bins. Managing the components in the warehouse area is a difficult task due to the space constraint. All the inventory items in the industry were handled by three types of bins. Based on the bin usage, the inventory items were classified.

3.2 Data Collection

The monthly data of all the components were obtained from the industry for a period of one year. In the automobile rubber components manufacturing industry, the criteria of demand, unit price, annual consumption value, unit weight, and shape of the component were the important criteria for inventory control. The demand rate, unit price, unit weight and shape of all the components have been obtained from the inventory supervisor. The shape of the component was categorised into three, namely, regular, irregular, Awkward. The shape of the component would play a major role in bin selection, and allocating bins for the inventory items. Three types of bins were alternatives, which is used for inventory classification.

3.3 Data Analysis

The data collected has been analyzed using the Excel sheet. The overall data of the components were interpreted, and summarized based on the various criteria of the component. Saaty’s 9 point scale is used for analytic purposes. Inventory supervisor knowledge is applied in this process for decision making. Various criteria are analyzed and compared pairwise with the other criteria. After obtaining the criteria and sub criteria weights, the values were compared with the alternatives; the comparison resulted in the final weights of the bin. The bins were ranked based on the high values of the weights.

3.4 Pareto Diagram

Pareto analysis is a statistical technique for decision making, which is used for selecting the limited number of tasks, which provide the significant overall effect. Pareto charts are used to display the pareto principle in arranging data from the largest frequency to the smallest, which shows the few vital factors that can be concentrated on and many trivial factors that can be ignored. Thus, the Pareto diagram is a powerful quality improvement tool. The ABC analysis was carried out using the Pareto principle. The analysis was based on the single criterion, annual usage value in rupees. The ABC analysis is the traditional method used for inventory classification.

![Fig.1. Hierarchy Structure of AHP](image-url)
3.5. Hierarchy Structure of AHP

The hierarchy structure of AHP is shown in the Fig.1. The objective of level I is inventory classification. The criteria used for the classification of the inventory items were placed in level II. They are

(a) Annual demand of the items was quantified as the number of items.
(b) Unit price of the item.
(c) Annual usage value of the item in Indian Rupees.
(d) Unit weight of the component
(e) Shape of the component

The shape of the component is categorized into three types at level III. They are

(a) Regular shaped inventory items. These items could easily be accommodated in the bins.
(b) Irregular shape d inventory items; the storage and utilization of these items in the bin was not done fully due to their structure.
(c) Awkward shaped inventory items. The items have a low occupancy rate in the bin.

The alternatives are at level IV. It consists of different types of bins, they are

(a) Bin B1 having a cubic volume of 0.0237 m³. The inventory items handled by bin B1 are mentioned in Table 3.
(b) Bin B2 having a cubic volume of 0.04875 m³. The inventory items handled by bin B2 are mentioned in Table 3.
(c) Bin B3 having a cubic volume of 0.039 m³. The inventory items handled by bin B3 are mentioned in Table 3.

4. Results and Discussion

The pair wise matrix is formulated using the AHP judgment values of the various criteria and it is structured in table 2 using (1). From the comparison matrix the weights of the various criteria were obtained.

The relative weights of different types of criteria are calculated using (2) and tabulated in table 2. The weight of annual usage was the highest and next was the unit weight then followed by shape, demand and unit price. From the result, it is seen that the annual usage value of the item is the highest contributor to the inventory classification. After finding the relative weights of the criteria, the weight of the sub criteria was obtained, using the same procedure. The consistency index was calculated using (3), and the $\lambda_{max}$ value the level I matrix was 5.327. The consistency index value was 0.0819, and using (4) the consistency ratio was calculated as 0.079. The consistency ratio is less than 0.10 and the matrix was found to be consistent. The same procedure was applied to the other pair-wise comparison matrices and the final results were obtained.

Table 2. AHP matrix for level I

| Criteria        | Annual usage | Unit price | Demand | Unit weight | Shape | Relative weight |
|-----------------|--------------|------------|--------|-------------|-------|----------------|
| Annual usage    | 1            | 6          | 5      | 2           | 3     | 0.425          |
| Unit price      | 1/6          | 1          | 1/4    | 1/3         | 1/2   | 0.059          |
| Demand          | 1/5          | 4          | 1      | 1/4         | 1/2   | 0.106          |
| Unit weight     | 1/2          | 3          | 4      | 1           | 3     | 0.279          |
| Shape           | 1/3          | 2          | 2      | 1/3         | 1     | 0.130          |

Table 3. Final bin weights

| S.No | Bin | Weights | Rank | Class of items |
|------|-----|---------|------|----------------|
| 1    | B1  | 0.526098| 1    | A              |
| 2    | B2  | 0.225171| 3    | C              |
| 3    | B3  | 0.248731| 2    | B              |

The final weights of the three types of bins are mentioned in table 3. The weight of bin B1 was the highest, followed by B3 and B2. From the bin weight results, the inventory items are categorized into A, B, C classes, where A class items are important and should have tight control on them. B class items are less important items and C class items are of very low importance.
| S.No | Item | Demand of the components in numbers | Unit price in Rupees (Rs) | Annual usage in Rupees (Rs) | Unit Weight in kg | Shape of the Component | Bin Allocation | ABC Classification | AHP Classification |
|------|------|----------------------------------|--------------------------|-----------------------------|------------------|------------------------|----------------|-------------------|--------------------|
| 6    | R12  | 27000                            | 0.33                     | 8910                        | 0.0091           | Regular                | B1             | C                 | A                  |
| 7    | R13  | 4700                             | 1.6                      | 7520                        | 0.00808          | Regular                | B1             | C                 | A                  |
| 8    | R16  | 3200                             | 3.22                     | 10304                       | 0.0098           | Regular                | B1             | C                 | A                  |
| 9    | R20  | 20000                            | 1.33                     | 26600                       | 0.00353          | Regular                | B1             | C                 | A                  |
| 10   | R21  | 200                              | 2.65                     | 530                         | 0.00343          | Regular                | B1             | C                 | A                  |
| 11   | R22  | 2900                             | 0.66                     | 1914                        | 0.0037           | Regular                | B1             | C                 | A                  |
| 12   | R23  | 19700                            | 0.12                     | 23640                       | 0.00693          | Regular                | B1             | C                 | A                  |
| 13   | R25  | 35000                            | 0.11                     | 3850                        | 0.00696          | Regular                | B1             | C                 | A                  |
| 14   | R32  | 50500                            | 2                       | 101000                      | 0.0032           | Regular                | B1             | B                 | A                  |
| 15   | R33  | 2500                             | 0.88                     | 2200                        | 0.00451          | Regular                | B1             | C                 | A                  |
| 16   | R34  | 11000                            | 0.1                      | 1100                        | 0.00074          | Regular                | B1             | C                 | A                  |
| 17   | R39  | 49000                            | 1.75                     | 85750                       | 0.00675          | Regular                | B1             | B                 | A                  |
| 18   | R40  | 56017                            | 1.11                     | 62178.87                    | 0.01481          | Regular                | B1             | B                 | A                  |
| 19   | R41  | 162                              | 0.79                     | 127.98                      | 0.00826          | Regular                | B1             | C                 | A                  |
| 20   | R42  | 34279                            | 0.22                     | 7541.38                     | 0.004            | Regular                | B1             | C                 | A                  |
| 21   | R43  | 243473                           | 0.055                    | 13391.02                    | 0.00873          | Regular                | B1             | C                 | A                  |
| 22   | R49  | 500                              | 1.134                    | 567                         | 0.00539          | Regular                | B1             | C                 | A                  |
| 23   | R50  | 3000                             | 2.99                     | 8970                        | 0.00517          | Regular                | B1             | C                 | A                  |
| 24   | R52  | 74500                            | 0.31                     | 23095                       | 0.00509          | Regular                | B1             | C                 | A                  |
| 25   | R56  | 38150                            | 0.23                     | 8774.5                      | 0.00539          | Regular                | B1             | C                 | A                  |
| 26   | R57  | 6000                             | 1.134                    | 6804                        | 0.0075           | Regular                | B1             | A                 | A                  |
| 27   | R62  | 222000                           | 0.087                    | 19314                       | 0.00009          | Regular                | B1             | C                 | A                  |
| 28   | R64  | 151600                           | 0.44                     | 66704                       | 0.00111          | Regular                | B1             | B                 | A                  |
| 29   | R65  | 4000                             | 1.56                     | 6240                        | 0.00435          | Regular                | B1             | C                 | A                  |
| 30   | R68  | 16500                            | 2.1                      | 34650                       | 0.00114          | Regular                | B1             | C                 | A                  |
| 31   | R5   | 824000                           | 0.1                      | 82400                       | 0.0107           | Irregular              | B2             | B                 | C                  |
| 32   | R6   | 434500                           | 0.22                     | 95590                       | 0.00655          | Irregular              | B2             | B                 | C                  |
| 33   | R9   | 139630                            | 0.025                    | 3490.75                     | 0.00836          | Irregular              | B2             | C                 | C                  |
| 34   | R14  | 70000                            | 3.25                     | 227500                      | 0.00017          | Irregular              | B2             | A                 | C                  |
| 35   | R18  | 272221                           | 2.8                      | 762218.8                    | 0.0086           | Irregular              | B2             | A                 | C                  |
| 36   | R19  | 37000                            | 1.13                     | 41810                       | 0.00355          | Irregular              | B2             | B                 | C                  |
| 37   | R24  | 33550                            | 1.76                     | 59648                       | 0.00074          | Irregular              | B2             | B                 | C                  |
| 38   | R27  | 689750                           | 0.98                     | 675955                      | 0.00664          | Irregular              | B2             | A                 | C                  |
| 39   | R28  | 2500                             | 2.689                    | 6722.5                      | 0.00432          | Irregular              | B2             | C                 | C                  |
| 40   | R29  | 287437                           | 1.444                    | 415059                      | 0.0038           | Irregular              | B2             | A                 | C                  |
| 41   | R31  | 7000                             | 1.9                      | 13300                       | 0.00425          | Irregular              | B2             | C                 | C                  |
| 42   | R36  | 132500                           | 0.34                     | 45050                       | 0.00353          | Irregular              | B2             | B                 | C                  |
| 43   | R37  | 67000                            | 1.9                      | 127300                      | 0.00435          | Irregular              | B2             | A                 | C                  |
| 44   | R44  | 114797                            | 0.01                     | 1147.97                     | 0.0078           | Irregular              | B2             | C                 | C                  |
| 45   | R45  | 8650                             | 2.4                      | 20760                       | 0.0075           | Irregular              | B2             | C                 | C                  |
| 46   | R47  | 30860                            | 1.44                     | 44438.4                     | 0.00534          | Irregular              | B2             | B                 | C                  |
| 47   | R48  | 112298                           | 0.23                     | 25828.54                    | 0.00111          | Irregular              | B2             | C                 | C                  |
| 48   | R54  | 114900                           | 2.4                      | 275760                      | 0.00804          | Irregular              | B2             | A                 | C                  |
| 49   | R66  | 182700                           | 1.56                     | 285012                      | 0.00018          | Irregular              | B2             | A                 | C                  |
| 50   | R67  | 113200                           | 1.9                      | 215080                      | 0.00268          | Irregular              | B2             | C                 | C                  |
| 51   | R69  | 94690                            | 5.33                     | 504697.7                    | 0.0125           | Irregular              | B2             | C                 | C                  |
In this study, the multicriteria inventory ABC classification is proposed, for an automobile rubber components manufacturing industry. Due to improper material allocation and inefficient inventory handling process, storing the inventory of the rubber components in a proper location and in the proper bin is the main problem in the automobile rubber components industry. The criteria, unit weight of the component, and shape of the product, are used along with the other traditional criteria for the inventory classification. The Analytic Hierarchy Process (AHP) has been utilized, for estimating the judgment of the inventory system. By analyzing the various criteria, sub criteria and alternatives, the weights are obtained for the different types of bins. Based on the usage of the bin, the inventory items are classified as A, B, C items. The resulting bin classification has easy accessibility in the warehouse. The bin traceability and utilization has also improved.

Acknowledgements

The authors thank the reviewers of this research paper. This research was funded and supported by Anna University, Chennai under Anna Centenary Research Fellowship CR/ACRF/Jan 2012/6.

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| S.No | Item | Demand of the components in numbers | Unit price in Rupees (Rs) | Annual usage in Rupees (Rs) | Unit Weight in kg | Shape of the Component | Bin Allocation | ABC Classification | AHP Classification |
|------|------|-----------------------------------|--------------------------|-----------------------------|------------------|-----------------------|-----------------|-------------------|-------------------|
| 52   | R70  | 464655                            | 2.45                     | 1138405                     | 0.00099          | Irregular             | B2              | A                 | C                 |
| 53   | R2   | 31855                             | 1.25                     | 39818.75                    | 0.01982          | Awkward               | B3              | B                 | B                 |
| 54   | R4   | 70485                             | 1.9                      | 133921.5                    | 0.018            | Awkward               | B3              | A                 | B                 |
| 55   | R11  | 167000                            | 0.66                     | 110220                      | 0.01353          | Awkward               | B3              | A                 | B                 |
| 56   | R15  | 209650                            | 1.45                     | 303992.5                    | 0.02122          | Awkward               | B3              | A                 | B                 |
| 57   | R17  | 86557                             | 1.33                     | 115120.8                    | 0.02144          | Awkward               | B3              | A                 | B                 |
| 58   | R26  | 28000                             | 0.5                      | 14000                       | 0.01598          | Awkward               | B3              | C                 | B                 |
| 59   | R30  | 96775                             | 1.45                     | 14023.8                     | 0.01363          | Awkward               | B3              | A                 | B                 |
| 60   | R35  | 438500                            | 0.45                     | 197325                      | 0.00451          | Awkward               | B3              | A                 | B                 |
| 61   | R38  | 201000                            | 1.11                     | 223110                      | 0.00478          | Awkward               | B3              | A                 | B                 |
| 62   | R46  | 320                               | 2.55                     | 816                         | 0.04432          | Awkward               | B3              | C                 | B                 |
| 63   | R51  | 28194                             | 0.23                     | 6484.62                     | 0.04684          | Awkward               | B3              | C                 | B                 |
| 64   | R53  | 90620                             | 0.22                     | 199386.4                    | 0.03559          | Awkward               | B3              | C                 | B                 |
| 65   | R55  | 226075                            | 2.55                     | 576491.3                    | 0.05159          | Awkward               | B3              | A                 | B                 |
| 66   | R58  | 9500                              | 2.99                     | 28405                       | 0.00435          | Awkward               | B3              | C                 | B                 |
| 67   | R59  | 37640                             | 0.99                     | 37263.6                     | 0.03281          | Awkward               | B3              | B                 | B                 |
| 68   | R60  | 16600                             | 1.2                      | 19920                       | 0.03269          | Awkward               | B3              | C                 | B                 |
| 69   | R61  | 100540                            | 0.56                     | 56302.4                     | 0.03537          | Awkward               | B3              | B                 | B                 |
| 70   | R63  | 1100                              | 0.09                     | 99                          | 0.03545          | Awkward               | B3              | C                 | B                 |

4. Conclusion

In this study, the multicriteria inventory ABC classification is proposed, for an automobile rubber components manufacturing industry. Due to improper material allocation and inefficient inventory handling process, storing the inventory of the rubber components in a proper location and in the proper bin is the main problem in the automobile rubber components industry. The criteria, unit weight of the component, and shape of the product, are used along with the other traditional criteria for the inventory classification. The Analytic Hierarchy Process (AHP) has been utilized, for estimating the judgment of the inventory system. By analyzing the various criteria, sub criteria and alternatives, the weights are obtained for the different types of bins. Based on the usage of the bin, the inventory items are classified as A, B, C items. The resulting bin classification has easy accessibility in the warehouse. The bin traceability and utilization has also improved.