Optimization of ABC Classification Method for Automobile Spare Parts based on DEA

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Abstract. In recent years, the prospect of the Vehicle market is worrisome. The development of automotive aftermarket business has become the core of 4s stores. And the spare parts in stock are the key part of the aftermarket. Therefore, it is very important for the development of the aftermarket to make a good classification of spare parts. Aiming at the problem of the variety of spare parts and Improper management, this paper built ABC Classification method for Automobile spare parts based on DEA taking the 4s store of Beijing Citroen brand as an example to optimize the classification method of spare parts in 4s store. The rationality of the method is proved by comparing with the traditional / original method.

1. Introduction
With the rapid development of the automotive industry, the competition among automotive service companies has increased and many companies have made it difficult to make profits. The profits in the aftermarket come mainly from Vehicles’ sales and after-sales maintenance. Due to the competition in the new car market and control from Superior company, new car selling is difficult to earn more profits for the company, thus making automobile maintenance service a main incoming source which only consists 10% income but has a rate of 40% in profit contribution. So now a lot of enterprises focus on the after-sale maintenance as the main profit, and Spare parts and after-sales maintenance is inextricably linked. Extensive inventory management can create adverse effect to the company's operations. The stock backlog occupies a large amount of liquidity, ‘dead inventory’, out of stock and slow response resulting in a decline of customer satisfaction. The traditional ABC classification method is too rigid to consider the influencing factors comprehensively. Using the ABC classification method based on the DEA method can solve the single indicator problem and the inconsistent problem of the numerical dimension between multiple indicators of the traditional ABC classification to identify key spare parts and classify spare parts.

Domestic and foreign scholars have many discussions on the classification of parts and components: Guanghui Song [1] puts the research of 4S spares into the environment of the supply chain, studying the limitations of the traditional ABC taxonomy on auto parts management, and reclassifying auto parts according to the characteristics of 4S spares and giving ordering strategies for various parts and components.
Xiaosheng Ding [2] optimized the traditional ABC classification method, combined with the characteristics of spares, using two-dimensional classification, expounded the application of ABC classification in spares management. Xiaoyong Zou, Yingqiu Xu [3] improved the traditional ABC
method, combining with computer technology, the second use of ABC method to classify spares; Yu Zhao [4] combines AHP and ABC classification, first dividing the automobile parts into five parts: common spare parts, fixed maintenance spare parts, easily damaged spare parts, non-fragile spare parts, main spare parts, establishes the hierarchical structure model, and obtains the combined weight. On this basis, by multiplying the amount of capital occupied with the combined weight to get the weight of the capital occupation, taking the weighted capital occupation as the grade standard, the auto parts and components are divided. Nicola Saccani [5] classified components from the aspects of level of standardization, value, and degree of importance; Mohamed A. Sharaf [6] classified the components from the perspective of price, availability, lead-time spare part type, and life cycle. Xiong Junxing and Xia Fangchen introduced the BP neural network into the ABC classification of parts and components to obtain the BP-ABC classification model. In addition, some scholars introduced the mathematical envelopment analysis (DEA) into the component classification. First, the DEA model was introduced into the component classification, and the ABC classification method based on DEA was proposed. Nanfang Cui [7] first introduced the DEA model into the component classification, and proposed a component-based ABC classification method based on DEA.

2. Method introduction

2.1. ABC Classification

The ABC classification is based on the Pareto law. The most important part is only 20%, and the remaining is 80%. Using the ABC classification method to classify spare parts means that the spare parts are divided into three levels according to the variety and the value of the occupation [8]. Class A is important with the fewest number of types and the largest amount of funds; Class B is general with more varieties and less funds; Class C is secondary with the largest number of types and the least amount of funds.

2.2. DEA Method

Data Envelopment Analysis (DEA) is a systematic analysis method. This method is based on the concept of ‘relative efficiency evaluation’, and extends the concept of single-input-output engineering efficiency to the effectiveness evaluation of similar multi-input and multi-output decision-making units. This method greatly enriches the production function theory and application technology in microeconomics and has Superiority that cannot be underestimated in avoiding simplified algorithms, subjective factors, and reducing errors.

In the DEA model, every decision unit compares with other decision units and calculates an efficiency ratio of the decision unit, which is obtained by the ratio of resource input to product and service output. DEA allows multiple inputs and multiple outputs to get the efficiency ratios. On the one hand, it does not have requirement for the data of input and output. The input can be of any form and the output is only required to be beneficial as long as they are not affected by the data dimension; On the other hand, the model is a quantitative model so it can be transformed into linear programming. Therefore, many decision elements within the considered range can be compared. The complexity of the calculation is only a linear increase. With the support of the calculation software, the calculation efficiency is high. The calculation result is very intuitive and scientific that can actually reflect the comprehensive situation of the evaluation object and its potential competitiveness.

2.3. $C^2R$ Model

$C^2R$ model is the most representative DEA model in the DEA method theory system. The model integrates a group of comparable decision units and corresponding performance metrics into one model to solve the comprehensive efficiency and comparison problems among the group of decision units. The efficiency evaluation index calculation formula is:
The indicators consist of n evaluation units. Each evaluation unit can have m inputs and s outputs. 

\[ x_{ij} \] represents the input amount of the i-th input of the j-th decision unit. 

\[ y_{rj} \] represents the output of the r-th output of the j-th decision unit. 

The input and output of the j-th decision unit are: 

\[ x_j = (x_{ij}, x_{2j}, ..., x_{mj})^T, j = 1,2, ..., n \]

\[ y_j = (y_{ij}, y_{2j}, ..., y_{sj})^T, j = 1,2, ..., n \]

\[ v_i \] represents the measure of the i-th input; 

\[ u_r \] represents the measure of the r-th output.

Looking for a certain combination of n decision units, the output can be reduced as much as possible without lowering the output of the j0th decision unit based on the basic idea of DEA.

The \( C^2R \) model is as follows:

\[
\begin{align*}
\max h_0 &= \frac{u^T y_0}{v^T x_0} = V_p \\
\frac{u^T y_j}{v^T x_j} &\leq l, j = 1,2, ..., n \\
\text{s.t.,} \quad &v \geq 0 \\
&u \geq 0
\end{align*}
\]

\[ v = (v_1, v_2, ..., v_m)^T, u = (u_1, u_2, ..., u_s)^T \]

It is a fractional planning model. After transformation and dual conversion, an equivalent linear programming model can be obtained:

\[
\begin{align*}
\min \theta & \\
\text{s.t.,} \quad &\sum_{j=1}^{n} x_j \lambda_j \leq \theta x_0 \\
&\sum_{j=1}^{n} y_j \lambda_j \geq y_0 \\
&\lambda_j \geq 0, j = 1,2, ..., n
\end{align*}
\]

From the above formula, when evaluating a certain unit, the relative weight between the various indicators of the input and output units are determined by the optimization of the DEA model. Each unit has its goal planning (if there are n units, n goal planning need to be established), and the
corresponding restriction conditions are the same of these goal planning so the efficiency value is based on the same comparison. Therefore the efficiency value obtained by this method is fair and relative.

3. Build the model

3.1. Status of Spare Parts Classification

Beijing Jintai Kaisheng Automobile Sales & Service Co., Ltd. was established in August 2009, with an investment of 15 million yuan and an area of 2,300 square meters. It is the second Citroen 4s store established in Beijing Asian Games Village Market. Authorized by Dongfeng Citroen, it is an automotive service company integrating vehicle sales, spare parts supply, after-sales service, and information feedback. The company currently specializes in several major Citroen C3, C3-XL, C5, C4 Sega, classic Elysee, the new Elysee and other major models. In addition to the above models for the maintenance of models, Citroen, Dongfeng Peugeot 200, Dongfeng Peugeot 206, and Beijing Hyundai are also included [9]. Due to the excessive number of spare parts in stock, the current inventory managers are only empirically classified according to the value of spare parts.

3.2. ABC Classification Application

Considering the current situation, there are some spare parts that are out of date or have no sales. Therefore, the ABC classification is based on the monthly average outbound volume in 2017. The purpose is to directly classify the spare parts according to the demand.

First, monthly average outbound value is 387,366.87 yuan, and the outbound category is 530 and 530 kinds of spare parts are calculated based on the data. According to the value, the ABC classification of spare parts will be obtained as follows.

| Spare parts name                                      | Outbound amount | Number | Category |
|------------------------------------------------------|-----------------|--------|----------|
| Engine Oil 4L TOTAL 7000/5W30                        | 20332.57        | 1      | A        |
| Engine Oil 0W30 A5B5                                 | 18544.33        | 2      | A        |
| Dunlop 255/40R18 Mercedes-Benz                        | 1328.21         | 72     | A        |
| Cylinder cover shroud without hole                   | 1287.26         | 73     | A        |
| Lower skirt                                          | 1281.98         | 74     | A        |
| Rear bumper trim                                     | 1246.24         | 75     | A        |
| Left rear door glass                                 | 1220.51         | 76     | A        |
| Cooling System Cleaner (225ml) 225ML                 | 1196.5          | 77     | B        |
| Bumper stiffener FXT                                 | 1184.6          | 78     | B        |
| Lower trim left                                      | 319.19          | 201    | B        |
| Plating wheel repair                                 | 314.09          | 202    | B        |
| Engine accessory harness                             | 312.61          | 203    | B        |
| Front knuckle Left D82 Reinforced                    | 306.46          | 204    | B        |
| Reed nut M6X1.00                                     | 304.56          | 205    | B        |
| Electronic fan                                       | 296.15          | 206    | C        |
| Tensioner                                           | 294.02          | 207    | C        |
| (MUL) with base nut                                  | 2.2             | 526    | C        |
| Retaining ring D24                                   | 1.97            | 527    | C        |
| Tie                                                  | 1.68            | 528    | C        |
| Timing tensioner pad                                 | 1.01            | 529    | C        |
| Piston ring assembly (3)                             | -381.52         | 530    | C        |
| Total                                                | 387366.87       |        |          |

Summarize the three types of ABC spare parts results as follows:
Table 2. The count of abc classification.

| Spare Parts Category | Spare Parts Value (Yuan) | Value Proportion | The number of Spare Parts Categories | Proportion |
|----------------------|--------------------------|------------------|-------------------------------------|------------|
| A                    | 276552.37                | 71.39%           | 76                                  | 14.33%     |
| B                    | 82114.6349               | 21.20%           | 129                                 | 24.34%     |
| C                    | 28699.8622               | 7.41%            | 325                                 | 61.33%     |
| total                | 387366.87                | 100%             | 530                                 | 100%       |

3.3. Build the DEA Model

The DEA method has outstanding advantages in solving the ABC classification problem. Construct the DEA model of the effectiveness of spare parts, and solve the ABC classification problem of spare parts by classifying the relevant attributes of spare parts [10].

Figure 1. The process of building the model.

1. The value of θ in the model is set as the importance of spare parts. The larger the value of θ is, the more important of spare part is and the more attention should be paid to it.
2. Find indicator attributes related to the importance of spare parts. The unit price of spare parts will affect the occupation of inventory funds. Spare parts mobility represents the size of spare parts turnover. Particularity of spare parts describes the general degree of spare parts or the difficulty of obtaining spare parts. The regularity of spare parts demand indicates the difficulty of forecasting the demand of spare parts. Therefore, these four decision units consider the attributes of spare parts from different perspectives.
3. Determine the input DMU and output DMU. It can be seen that in order to make the efficiency as large as possible, when The smaller the input is and the greater the output is, the larger the value of θ will be, indicating that the decision unit is more effective from the influence of the input index and output index on the value of θ [11]. Therefore, according to this principle, relevant decision units are quantified. Get the answer:
Table 3. Input & output decision unit.

| Input/output | Decision unit | Details |
|--------------|---------------|---------|
| Input        | Particularity of spare parts | The higher the specificity is, the more important the degree of importance is. Spare parts will be assigned as special parts, general parts and standard parts by the spare parts 1, 3, and 5 respectively. |
|              | The regularity of spare parts demand | The smaller the regularity is, the higher the degree of importance is. The values of 1, 3, 5, and 7 are assigned according to the magnitude of regular strength. |
| Output       | The unit price of spare parts | The higher the unit price of parts, the higher the degree of importance. |
|              | The mobility of Spare parts | The larger the turnover, the more important the degree of spare parts. Mobility is defined 1, 3, 5, 7 respectively according to the range of the turnover rate. |

(4) Because 504 spare part categories are not easy to calculate, according to the quantity ratio of ABC method, 7 kinds spare parts of A, 12 kinds spare parts of B and 31 kinds spare parts of C are randomly selected according to the ratio of 14: 24: 62. 50 kinds of spare parts were surveyed and acquired by purchasers and inventory managers. The following results were obtained:

Table 4. Input & output decision unit.

| Spare parts name              | Unit price | Mobility | Particularity | The regularity of demand |
|------------------------------|------------|----------|---------------|--------------------------|
| Oil filter FILTRAUTO         | 30         | 7        | 3             | 7                        |
| Spark plug                   | 19.23      | 5        | 3             | 7                        |
| Pollen filter                | 54.29      | 5        | 3             | 7                        |
| Front lights Right           | 767.95     | 3        | 1             | 3                        |
| Front windscreen             | 762.82     | 3        | 1             | 3                        |
| Engine hood                  | 1014.25    | 3        | 1             | 3                        |
| Goodyear tires               | 578.77     | 5        | 1             | 5                        |
| engine lubricant             | 59.83      | 7        | 3             | 7                        |
| Citroen logo                 | 351.97     | 1        | 1             | 3                        |
| Front fender Left front      | 588.57     | 3        | 1             | 3                        |
| Rear bumper                  | 484.62     | 3        | 1             | 3                        |
| Front cover beam             | 180.98     | 1        | 3             | 1                        |
| Engine air deflector         | 144.19     | 3        | 1             | 3                        |
| Sealing ring 14X24-1.5       | 8.97       | 3        | 3             | 5                        |
| Switches                     | 347.59     | 1        | 3             | 3                        |
| Coolant 2L -35°C             | 28.85      | 5        | 5             | 7                        |
| Main bearing tile            | 46.07      | 1        | 3             | 1                        |
| Timing chain                 | 180.98     | 1        | 3             | 1                        |
| Air filter assembly          | 57.05      | 5        | 3             | 5                        |
| Engine Oil (Mazda)           | 197.44     | 3        | 3             | 5                        |
| Wiper Blade Driving Side     | 59.63      | 3        | 1             | 3                        |
| Machine filter               | 35.9       | 5        | 3             | 5                        |
| Air conditioning filter      | 47.56      | 3        | 3             | 5                        |
| Air filter element           | 28.72      | 3        | 3             | 5                        |
| Item                        | Value | X | Y | Z |
|-----------------------------|-------|---|---|---|
| Button Battery              | 9.23  | 1 | 5 | 3 |
| Bolt                        | 3.95  | 3 | 3 | 3 |
| Gear lever base HZD         | 16.99 | 1 | 3 | 3 |
| Identification Right 1.8   | 16.99 | 3 | 1 | 3 |
| Glass washing nozzle       | 16.68 | 3 | 1 | 5 |
| Fork shaft lock             | 16.45 | 1 | 1 | 1 |
| Electronic fan              | 296.15| 3 | 3 | 3 |
| Tensioner                  | 147.01| 3 | 3 | 3 |
| Door seals                 | 140.06| 1 | 1 | 1 |
| Engine timing gear          | 21.06 | 1 | 3 | 3 |
| Tyres (215/60/R16)          | 272.22| 3 | 1 | 5 |
| Oil seal                   | 235.9 | 3 | 3 | 3 |
| Power steering oil         | 929.49| 3 | 3 | 5 |
| Glass washing nozzle       | 16.68 | 3 | 1 | 5 |
| Fork shaft lock             | 16.45 | 1 | 1 | 1 |
| Electronic fan              | 296.15| 3 | 3 | 3 |
| Tensioner                  | 147.01| 3 | 3 | 3 |
| Door seals                 | 140.06| 1 | 1 | 1 |
| Engine timing gear          | 21.06 | 1 | 3 | 3 |
| Tyres (215/60/R16)          | 272.22| 3 | 1 | 5 |
| Oil seal                   | 235.9 | 3 | 3 | 3 |
| Power steering oil         | 929.49| 3 | 3 | 5 |

5) Substitute the above results into MATLAB and use the programming language. X indicates the value of the input units; Y indicates the value of the output units. Get the θ and sort the θ [12], the following results are obtained:

\[
Y = [\ ];
X = [\ ];
n = size(X', 1); m = size(X, 1); s = size(Y, 1);
epsilon = 10^{-10};
f = [zeros(1, n) -epsilon*ones(1, m+s) 1];
A = zeros(1, n+m+s+1);
b = zeros(1);
LB = zeros(n+m+s+1, 1);
UB = []; 
LB(n+m+s+1) = -Inf;
for i = 1:n;
    Aeq = [X eye(m) zeros(m, s) -X(:, i) Y zeros(s, m) -eye(s) zeros(s, 1)];
    beq = [zeros(m, 1) Y(:, i)];
    w(:, i) = linprog(f, A, b, Aeq, beq, LB, UB);
end
lambda = w(1:n,:)

7
s_minus = w(n+1:n+m,:) 
s_plus = w(n+m+1:n+m+s,:) 
theta = w(n+m+s+1,:) 

Table 5. Input & Output Decision Unit.

| Number | Before using DEA | After using DEA | θ | Number | Before using DEA | After using DEA | θ |
|--------|----------------|----------------|---|--------|----------------|----------------|---|
| 50     | C              | A              | 1 | 36     | C              | C              | 0.64 |
| 7      | A              | A              | 1 | 32     | C              | C              | 0.636 |
| 6      | A              | A              | 1 | 38     | C              | C              | 0.636 |
| 4      | A              | A              | 0.97 | 26     | C              | C              | 0.636 |
| 5      | A              | A              | 0.969 | 46     | C              | C              | 0.636 |
| 10     | B              | A              | 0.947 | 30     | C              | C              | 0.636 |
| 11     | B              | A              | 0.934 | 2      | A              | C              | 0.614 |
| 21     | C              | B              | 0.913 | 3      | A              | C              | 0.614 |
| 28     | C              | B              | 0.913 | 29     | C              | C              | 0.6 |
| 45     | C              | B              | 0.913 | 35     | C              | C              | 0.6 |
| 13     | B              | B              | 0.913 | 37     | C              | C              | 0.564 |
| 1      | A              | B              | 0.86 | 16     | C              | C              | 0.522 |
| 8      | B              | B              | 0.86 | 24     | C              | C              | 0.467 |
| 39     | C              | B              | 0.825 | 20     | C              | C              | 0.467 |
| 40     | C              | B              | 0.822 | 14     | B              | C              | 0.467 |
| 42     | C              | B              | 0.797 | 23     | C              | C              | 0.467 |
| 43     | C              | B              | 0.778 | 17     | B              | C              | 0.38 |
| 19     | B              | B              | 0.778 | 41     | C              | C              | 0.369 |
| 49     | C              | B              | 0.765 | 9      | B              | C              | 0.347 |
| 12     | B              | C              | 0.666 | 15     | B              | C              | 0.343 |
| 18     | B              | C              | 0.666 | 47     | C              | C              | 0.257 |
| 33     | C              | C              | 0.656 | 27     | C              | C              | 0.212 |
| 44     | C              | C              | 0.646 | 34     | C              | C              | 0.212 |
| 31     | C              | C              | 0.645 | 25     | C              | C              | 0.163 |
| 48     | C              | C              | 0.644 | 22     | C              | C              | 0.156 |

3.4. Comparison

It can be concluded that the results of the classification of spare parts using the DEA method are very different from the results of the traditional ABC classification method by comparative analysis. It can be found that the value of θ for some spare parts of C is 1, which proved that the decision unit is valid for DEA, indicating that the importance degree of spare parts is very high. For some spare parts of A that the θ is 0.6, which proved that the decision unit is DEA invalid, indicating that the importance degree of spare parts is low.

For example, the bearings spare parts of No.50 are classified as C according to the traditional ABC classification method, but the value of θ is 1, which proved that the decision unit is valid for DEA. Because the unit price of the bearing is 72.39, the fluidity and particularity are general, but the demand forecast is very difficult, the bearings should be focused. Spare spark plug of No. 2 and spare pollen filter of No. 3 are classified into a according to the outbound value of the spare parts. However, their unit prices are very low and the liquidity and
specificity are general. The demand forecast has strong regularity so it is easy to forecast so they are less important.

From the arrangement of \( \theta \) values, it can be seen that the traditional ABC classification method has certain rationality in a degree. Because the factors considered are relatively single, the classification result is not comprehensive. The ABC based DEA classification method takes into account the various attributes so it is more scientific and reasonable.

4. Concision

This paper uses the DEA-based ABC spare parts classification method to classify the automobile spare parts of Beijing Jintai Kaisheng Automobile Sales and Service Co., Ltd. and compares it with the traditional ABC classification method. The ABC classification method based on the outbound value of spare parts only considers the amount of the spare part occupation liquidity. But the DEA-based ABC classification method comprehensively considers the unit price, liquidity, specificity and demand forecasting rules in terms of capital, turnover rate, availability and difficulty of demand forecasting. Then the input DMU and the output DMU are determined, the related data are collected, the efficiency value is obtained using MATLAB, and classification is finally determined [13]. The selection of special spare parts explains the difference in the results of the two classifications and proves the rationality of the ABC classification method based on DEA. At the same time, this article has some deficiencies. Because of the limited understanding of automotive spare parts, decision-making units are not considered comprehensively. Second, there is a degree of subjectivity on the data obtained by purchasers and Inventory managers.

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