A CLASSIFICATION MODEL FOR INVENTORY MANAGEMENT OF SPARE PARTS

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ABSTRACT

This paper presents a developed model for spare parts classification based on Saaty's Analytic Hierarchy Process (AHP) A three-level hierarchy has been defined Five criteria influencing the criticality of spare parts have been specified and four alternative modes for each criterion have been identified The model computes an absolute measure of criticality for each spare part. which is then used to classifying the part as Vital, Essential, Important. or Desirable Unlike other classification models that are based mainly on the annual dollar usage of spare parts. this model considers many other factors that can affect the criticality of the spare parts The developed model has been implemented using Microsoft Excel The classification method described in this paper can be used to optimize the inventory control policies for spare parts

KEYWORDS

Analytic Hierarchy Process (AHP) Spare parts Inventory management - Inventory control – Inventory classification

INTRODUCTION

Companies carry thousands of items in their inventories for various reasons: e.g. tools and supplies, raw materials. Work In Process (WIP), finished parts. spare parts for production and maintenance support, etc Spare parts control plays a vital role in any manufacturing organization Wrong mix of spare parts. e.g. shortage of one type of spare and surplus of another, can have serious implications. Shortage of critical parts not only introduces serious operational risks, but also adds to the operational costs appreciably. On the other hand, surplus parts cause financial waste and may occupy precious space.

Companies must classify items in their inventories and develop effective inventory control polices for each class. In specifying and evaluating the criticality of an item, the specific usage of the different spares must be seriously considered. Factors such as cost of spare part, availability, storage considerations, probability of requirement, etc., are generally considered while classifying spare parts.

Thousands of items may be held in inventory by a typical organization, but only a small portion of them deserve management's close attention and tight control. Many companies are adopting or thinking about adopting analysis that allows organization to classify parts into three classes; class-A (very important), class-B (moderately important), and class-C (less important). Only class-A items deserve management attention.

The classification of an item into the three classes; A, B, or C has generally been based on a single criterion; the annual dollar usage [1-2]; which can be calculated by multiplying the dollar value per unit times the annual usage rate. For many items, there may be some other criteria that represent important consideration for management; e.g. the certainty of supply, the criticality of the item, the effect of stock out, etc. Some of these factors may even be weighted more heavily than the annual dollar usage. Evaluation of the criticality of spares by using quantitative measures is difficult and problematic.

Since Saaty introduced his Analytic Hierarchy Process tool back in 1980 [2], several applications have emerged [3 - 9]. This paper introduces the use of Saaty's Analytic Hierarchy Process for evaluating the criticality of spare parts and classify the spare parts accordingly into four classifications: Vital, Essential, Important, or Desirable. Applicability of the model is demonstrated through a case study in a hospital.

THE ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making tool developed by Saaty. The essence of the AHP is to structure the problem into a three-level hierarchy with the main decision to be made at the top of the hierarchy. At the middle level, the criteria that affect the decision are located. The modes of the criteria are located at the bottom level. For example, in our model the main decision is to evaluate the criticality of spare parts, which is represented at the top level of the hierarchy. At the middle level come the criteria that affect evaluation of the criticality. In our model five criteria have been identified, namely: usage rate, expiration period, lead time, price, and type of the spare. Alternative modes of each criterion are located at the bottom level of the hierarchy. Figure 1 illustrates the hierarchy structure for the VEID analysis.

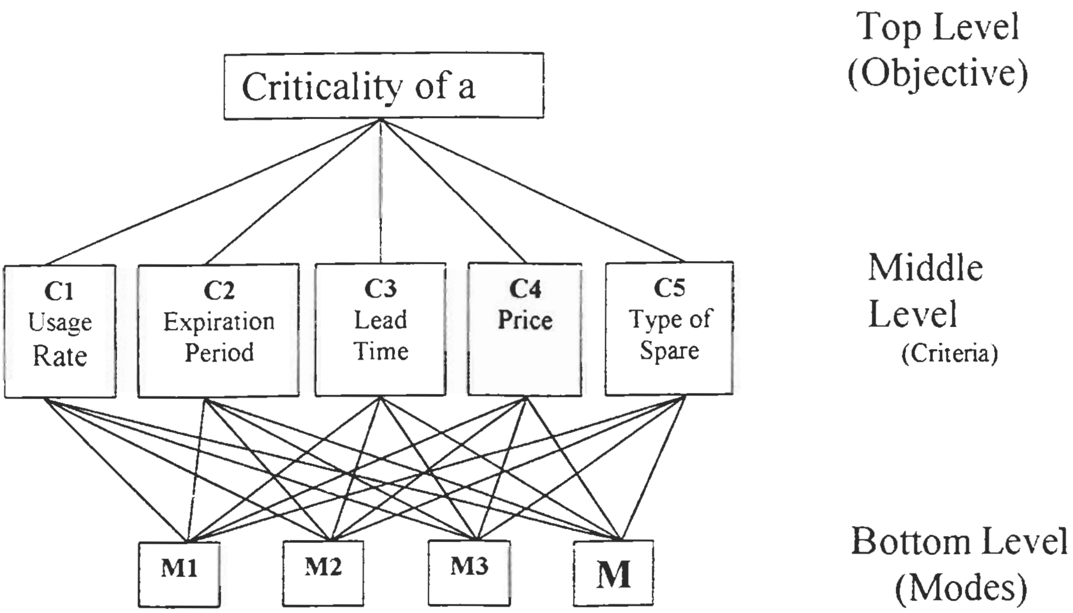

Fig. 1 Hierarchy Structure for the VEID Analysis

Having structured the problem into a hierarchy, pair-wise comparisons of the importance of each criterion with respect to other criteria are to be specified relative to the main decision in hand. These values have to specified by the management after due consideration. The result of this comparison can be formulated as a matrix of order n, where n represents the number of criteria considered. It should be noted that the comparison matrix is a symmetric matrix whose diagonal elements are always equal to 1, and the lower triangular elements are the reciprocal of the upper triangular elements. The normalized principle eigenvector of the criteria comparison matrix reflects the relative importance or weight of each criterion with respect to the main decision.

Similarly, for each criterion, pair-wise comparisons of the importance of each mode with respect to other modes to be determined relative to the criterion considered. The result of this comparison can be formulated as a matrix of order m, where m represents the number of modes for each criterion. The normalized principle eigenvector of each matrix reflects the relative importance or weight of each mode with respect to the criterion under investigated.

Composite weights for each criterion-mode combinations can be calculated by multiplying each normalized principle eigenvector coming from mode comparison by the relative weight of the specific criterion.

An absolute measure of a spare part criticality can be calculated by adding the separate composite weights for all its criterion-modes. The following section illustrates a case study of criticality evaluation of spare parts in a hospital.

A CASE STUDY

A large hospital in Riyadh city was chosen for applying the developed model. To evaluate criticality of spare parts in the hospital, five influencing criteria have been specified by the management of the hospital, and four alternative modes for each criterion have been identified. Details are in order.

The five criteria are:

C1: Usage rate
C2: Expiration Date
C3: Lead/Delivery time
C4: Price
C5: Type of the spare

For each criterion the following modes have been identified:

Usage rate:

M1: High
M2: Moderate
M3: Low
M4: Rare

Expiration Period

M1: Less than 1 year
M2: More than or equal to 1 year & Less than 3 years
M3: More than or equal to 3 years
M4: No expiration

Lead time

M1: More than or equal to 4 months
M2: Less than 4 months & more than or equal to 3 months
M3: Less than 3 months & more than or equal to 1 month
M4: Less than 1 month

Price

M1: More than or equal to $1,000
M2: Less than $1,000 & more than or equal to $100
M3: Less than $100 & more than or equal to $50
M4: Less than $50

Type of spare

M1: Non-standard, and to be fabricated overseas
M2: Non-standard, and to be fabricated locally
M3: Standard, and available in overseas market
M4: Standard, and available in local market

While the pair-wise comparison matrix of the criteria and the normalized eigenvector are depicted in table 1, the pair-wise comparison matrices of modes for criterion 1, 2, 3, 4 and 5, and their corresponding normalized eigenvector are illustrated in tables 2, 3, 4, 5, 6 respectively. These pair-wise comparisons are made using the 9 point comparison scale suggested by Saaty [1]. The eigenvector for each matrix is obtained by using the MathLab software.

Table 1 The pair-wise comparison matrix of criteria & the normalized eigenvecctor

	C1	**C2**	**C3**	**C4**	**C5**	**Normalized Eigenvector**
C1	1	5	2	2	7	**0.4284**
C2	0.2	1	4	5	3	**0.2715**
C3	0.5	0.25	1	2	4	**0.1368**
C4	0.5	0.2	0.5	1	7	**0.1229**
C5	0.1428	0.3333	0.25	0.142	1	**0.0404**

Table 2 The pair-wise comparison matrix of modes for **criterion 1** & the normalized eigenvecctor

	M1	M2	M3	M4	Normalized Eigenvector
M1	1	2	4	6	0.5133
M2	0.2	1	2	4	0.2751
M3	0.25	0.5	1	2	0.1375
M4	0.166	0.25	0.5	1	0.0741

Table 3 The pair-wise comparison matrix of modes for **criterion 2** & the normalized eigenvecctor

	M1	M2	M3	M4	Normalized Eigenvector
M1	1	4	6	8	0.6322
M2	0.25	1	2	4	0.2009
M3	0.166	0.5	1	2	0.1070
M4	0.125	0.25	0.5	1	0.0600

Table 4 The pair-wise comparison matrix of modes for **criterion 3** & the normalized eigenvecctor

	M1	M2	M3	M4	Normalized Eigenvector
M1	1	2	4	6	0.5056
M2	0.5	1	2	4	0.2680
M3	0.25	0.5	1	4	0.1643
M4	0.166	0.25	0.25	1	0.0621

Table 5 The pair-wise comparison matrix of modes for **criterion 4** & the normalized eigenvecctor

	M1	M2	M3	M4	Normalized Eigenvector
M1	1	2	6	8	0.5188
M2	0.5	1	4	9	0.3343
M3	0.166	0.25	1	4	0.1061
M4	0.125	0.111	0.25	1	0.0409

Table 6 The pair-wise comparison matrix of modes for **criterion** 5 & the normalized eigenvecctor

	M1	M2	M3	M4	Normalized Eigenvector
M1	1	2	4	5	**0.5008**
M2	0.5	1	2	4	**0.2799**
M3	0.25	0.5	1	2	**0.1400**
M4	0.2	0.25	0.5	1	**0.0793**

Table 7 summarized the whole process; it shows the relative weight for each criterion (the normalized eigenvector of the pair-wise comparison matrix of the criteria), the relative weight for each criterion-mode combinations (the normalized eigenvectors of the modes for each criterion), and the composite weights for each criterion-mode combinations.

Table 7 Calculation of composite weights for each criterion-mode combinations

	Criterion Weights	Mode Weights				Composite Weights			
		M1	M2	M3	M4	M1	M2	M3	M4
C1	0.4284	0.5133	0.2751	0.1375	0.0741	**0.2199**	**0.1179**	**0.0589**	**0.0317**
C2	0.2715	0.6322	0.2009	0.1070	0.0666	**0.1716**	**0.0545**	**0.0290**	**0.0163**
C3	0.1368	0.5056	0.2680	0.1643	0.0621	**0.0692**	**0.0367**	**0.0225**	**0.0085**
C4	0.1229	0.5188	0.3343	0.1061	0.0409	**0.0638**	**0.0411**	**0.0130**	**0.0050**
C5	0.0404	0.5008	0.2799	0.1400	0.0793	**0.0202**	**0.0113**	**0.0056**	**0.0032**

Obviously, if a spare part for which all the criteria have M1 as the modes, it will be classified as Vital. When all the criteria have M2 as the modes, the spare part will be classified as Essential, and so on. To draw a boundary limits between classification classes, the following points are taken into consideration:

- When a spare part has a high usage rate (M1), and short expiration period (M1), the spare part is classified as **Vital**. In spite of the condition that the spare may have a short lead time (M4), low price value (M4), and is a standard item available in the local market (M4). This serves as a **lower boundary condition for the Vital class of spare parts**. The corresponding total value of the composite weights is calculated as:

  0.2199 + 0.1716 + 0.0085 + 0.0050 + 0.0032 = **0.4082**

- On the other hand, if a spare part has a rare usage rate (M4), and no expiration period (M4); the spare part is classified as **Desirable**. Even though the spare may have a lead time in the range of 1 to 3 months (M3), low price value (M3), and is a non-standard item to be fabricated overseas (M1). This serves as an **upper boundary condition for the Desirable class of spare parts**. The corresponding total value of the composite weights is calculated as:

  0.0317 + 0.0163 + 0.0225 + 0 0130 + 0.0202 = **0.1037**

- Finally, if a spare part has a low usage rate (M3), and a long expiration period (M3); the spare part is classified as **Important**. Even though the spare may have a lead time in the range of 3 to 4 months (M2), moderate price value, in the range of $100 to $1,000, (M2), and is a non-standard item to be fabricated overseas (M1). This serves as an **upper boundary condition for the Important class of spare parts**. The corresponding total value of the composite weights is calculated as:

$$0.0589 + 0.0290 + 0.0367 + 0.0411 + 0.0202 = \mathbf{0.1859}$$

Therefore, the boundary conditions for the VEID classification can be established as follows:

Total of composite weights	**Class**
>= 0.4082	Vital
< 0.4082 & >= 0.1859	Essential
< 0.1859 & >= 0.1037	Important
< 0.1037	Desirable

OUTLINE OF THE DEVELOPED PROGRAM

An Excel program was developed to systematically and reliably classify spare parts. It consists of several related worksheets. Short descriptions for their functionality are in order.

Figure 2 shows the first worksheet which contains the criteria comparison matrix and its eigenvector. Since the comparison matrix is a symmetric matrix with diagonal elements equal to 1, the user should only enter the upper triangular elements. The lower triangular elements will be calculated automatically. The principle eigenvector of the criteria comparison matrix is obtained using the MathLab software. The user should enter the principle eigenvector, and the normalized eigenvector is calculated automatically.

Similar worksheets are developed to contain the mode comparison matrices and eigenvectors for criterion 1, 2, 3, 4, and 5. The user should only enter the upper triangular elements for the mode comparison matrix, and the principle eigenvector. The lower triangular elements and the normalized eigenvectors are calculated automatically.

Another worksheet that summarizes and includes all the calculations done so far are also developed and shown in figure 3. It contains the relative weight for each criterion, the relative weight for each criterion-mode combination, and the composite weights for each criterion-mode combination. The relative weight for each criterion comes from the worksheet depicted in figure 2. The relative weights for each criterion-mode combination come from the similar worksheets developed for criteria 1, 2, 3, 4, and 5. The composite weights for each criterion-mode combinations are calculated automatically. Finally, figure 3 contains also the boundary values that characterize the Vital, Essential, Important, and Desirable categories. These values must be entered by the used after careful analysis as illustrated in the previous section.

Criterion Comparison Matrix:

	C1	C2	C3	C4	C5	Eigenvector	Normalized Eigenvector
C1	1	5	2	2	7	0.7919	0.428448
C2	0.2	1	4	5	3	0.5018	0.271493
C3	0.5	0.25	1	2	4	0.2528	0.136774
C4	0.5	0.2	0.5	1	7	0.2272	0.122924
C5	0.1429	0.3333	0.25	0.1429	1	0.0746	0.040361
						1.8483	1

Figure 2 The criteria comparison matrix and its eigenvector

	Criterion	Mode Weights				Compsite Weights			
	Weights	M1	M2	M3	M4	M1	M2	M3	M4
C1	0.43	0.5153	0.2751	0.1375	0.0741	0.2199	0.1179	0.0589	0.0317
C2	0.27	0.6322	0.2009	0.1070	0.0600	0.1716	0.0545	0.0290	0.0163
C3	0.14	0.5056	0.2680	0.1643	0.0621	0.0692	0.0367	0.0225	0.0085
C4	0.12	0.5188	0.3343	0.1061	0.0409	0.0638	0.0411	0.0130	0.0050
C5	0.04	0.5008	0.2799	0.1400	0.0793	0.0202	0.0113	0.0056	0.0032
						0.5447	0.2615	0.1291	0.0647

Critical Total composite weight Values:

	Value	Class
>=	0.4082	Vital
		Essential
<=	0.1859	Important
<=	0.1037	Desirable

Figure 3 The composite weights for each criterion-mode combination

Figure 4 shows a worksheet that can be used by the user to quickly classify a single spare part. In this worksheet, a list of different modes for each criterion is given as a reminder for the user. The user can enter appropriate codes for the modes that represent the part under consideration. This worksheet looks up the corresponding composite weight for each mode. Then the composite weights are adding together and the resultant is compared with the boundary values that characterize the Vital, Essential, Important, and Desirable categories and appropriate message is displayed for the user.

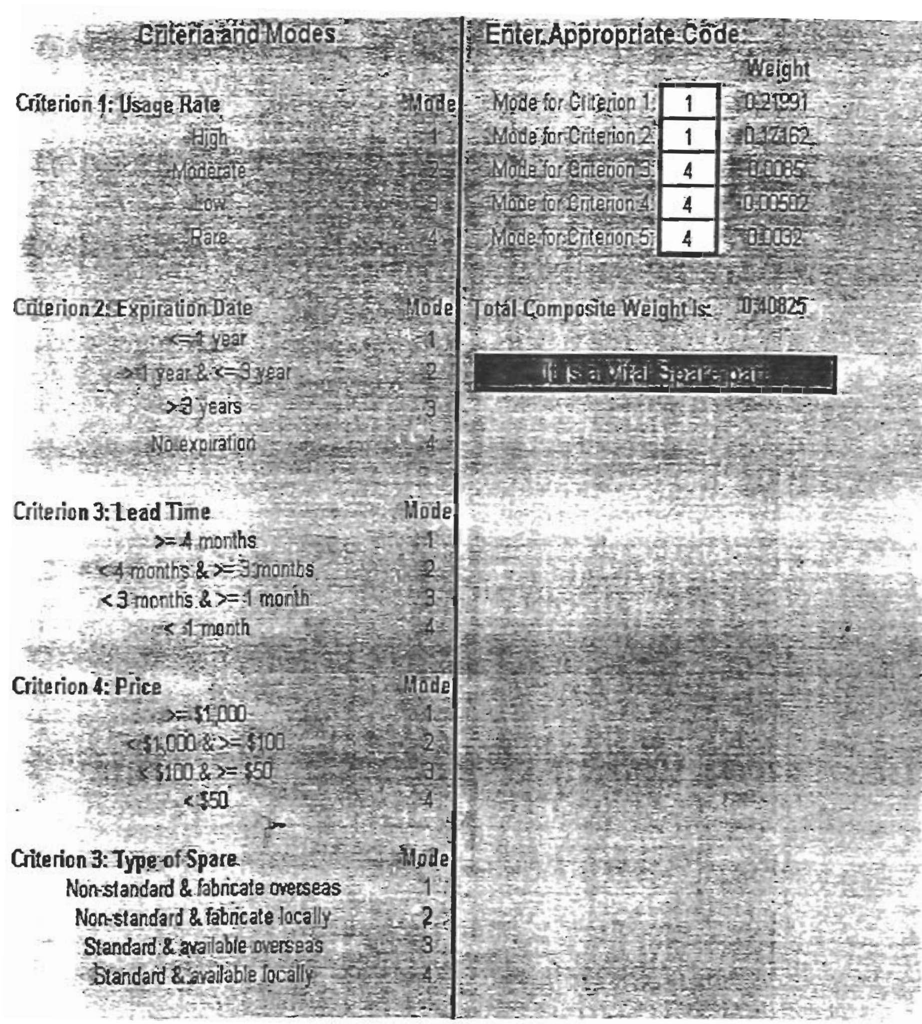

Figure 4 classification of single spare part

If the user would like to classify several spare parts at the same time, the worksheet shown in figure 5 can be used for that task. The mechanism of its working is the same like the previous worksheet.

Criteria & Modes

Criterion 1: Usage Rate	Modes
High	1
Moderate	2
Low	3
Rare	4

Criterion 2: Expiration Dat	Modes
<= 1 year	1
> 1 year & <= 3 year	2
> 3 years	3
No expiration	4

Criterion 3: Lead Time	Modes
>= 4 months	1
< 4 months & >= 3 montl	2
< 3 months & >= 1 mont	3
< 1 month	4

Criterion 4: Price	Modes
>= $1,000	1
< $1,000 & >= $100	2
< $100 & >= $50	3
< $50	4

Criterion 3: Type of Spare	Modes
Non-standard & fabricate overseas	1
Non-standard & fabricate locally	2
Standard & available overseas	3
Standard & available locally	4

Spare Part Classifications

	Part		Modes for criteria					Composite	Part
No.	Name	Number	C1	C2	C3	C4	C5	Weight	Classification
1	Cond.Fan Motor	20	1	4	3	3	4	0.2749	Essential
2	Motor Evapor. Blower	30	1	4	2	2	3	0.3196	Essential
3	Capacitor	150	4	4	3	4	4	0.0787	Desirable
4	Air Flow Switch	190	3	4	3	4	4	0.1059	Important
5	Compressor	290	1	2	1	1	1	0.4276	Vital
6	Contactor	380	2	4	3	4	4	0.1648	Important
7	Time Delay Switch	430	1	2	3	2	2	0.3493	Essential
8	Blower Motor Pulley	460	3	4	2	3	4	0.1281	Important
9	Blower Fan Pulley	490	3	4	2	4	4	0.1201	Important
10	Copmpressor	500	3	4	1	1	3	0.2138	Essential

Figure 5 Classifications of several spare parts

CONCLUSIONS

To properly manage spare parts inventory, the criticality of spare parts has to be evaluated first. In this paper, a classification model for spare parts has been developed based on the Analytic Hierarchy Process (AHP) devised by Saaty. This model classifies spare parts according to their criticality into four categories; Vital, Essential, Important, and Desirable. The developed model has been applied to the inventory of a large hospital in Riyadh City. This classification is better than other classifications based on the annual dollar usage.

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