

PILOT STUDY ON INTEGRATED EVALUATE METHOD OF MAINTAIN CAPABILITY

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Abstract

In this paper, the six factors which are the parts that compose the maintenance system are analyzed and settled. Some of these factors, such as maintainers, maintain material, maintain equipments, organization management, are used to evaluate the maintain capability of the maintenance organization. Based on the analysis of these factors, the evaluate standard and the calculate method of each aspect are expounded. At the end of this paper, the integrated evaluate method of maintain capability is present.

Key words: maintainability; maintain capability; weighted algorithm

1. Introduction

For the development of science technology, maintenance becomes a most important part in our lives.

The characteristics of equipment such as: reliability, maintainability, testability decide whether the equipment could be used normally, so how to meliorate the characteristic has been an important part during the design process. But when the malfunction happens, maintain capability decide whether the failure could be solved betimes. Whether the repair shop could solve the problem on time can be known by evaluation of the capability of every workshop, so a fit repair shop can be chosen in order to decrease the needless repair steps and reduce the wastage of the sources.

Maintain capability is the competence of fulfilling the repair assignment and insuring the equipment resume the preconcert technical state, reflecting the cooperation level of factors like manpower, material resources, information and the objects needed repair.

The maintain capability of a repair shop lies on the equipment and the maintain system. Every character correlated to maintenance affects the demand from equipment; the kind and quantity of factors which make up of maintain system affect it's maintain capability.

2. Confirmation of evaluation factor of maintain capability

The new concept of quality emphasizes quality is the summation of characteristic and peculiarity which reflected whether service meet demands of maintain, so the productions should not only achieve the preconcert function but keep this capability for a long time when the function degenerate or lose it can resume in a short time. Whether maintain capability is stand or fall lies on

factors make up of repair system. The main factors include men, machine, material, methods, measure and environment (5M1E) [1].

- (1) Men—the operator who handle working procedure;
- (2) Machine—the device used in the repair working;
- (3) Material—include spare parts and expendable;
- (4) Methods—include repair procedure and rationality of methods used;
- (5) Measure—include test methods and scale precision;
- (6) Environment—the condition in the workshop.

In this paper, the factors correlated to repair shop instead of the characters of productions are considered, so the part of measure is ascribed to other parts. The factors considered in this article are men; machine; material; methods and environment (see Figure 1).

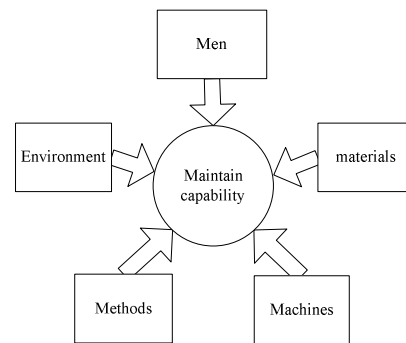


Figure 1: The influential factors of maintain capability.

The influential factors of maintain capability can be divided up into three parts:

- (1) The factor which could be controlled in the repair process, such as men, the spare parts needed, the level of the fix devices;
- (2) The factor which could not be controlled in the repair process, such as the nature lamp-house and the climate during the repair process;
- (3) The factor which could be avoid in the repair process, such as complex repair procedure and methods.

2.1 Men

Men are the principal part of the devices using and repair, they are also the operator of the repair activities. In the workshop which have ability of maintenance, people who have the professional skills should be contain in order to work on the repair of the equipments. And the skills which people have should be consistent to the complex level of technology needed by repair works [2]. The evaluation of factor men in this paper can be considered from two aspects, the quantity of workers and the skill level of them. The skill level of workers can be

measured off into three ranks. High skilled workers can get rid of complex problems, and primary workers can only solve some simple problems. The increasing of the number of workers will enhance the maintain capability of the workshop, but when it reach a definite level, the change of the capability become tiny. So the influence curve of this factor to maintain capability is a curve which rise fast in the beginning and at last reach a definite level (see Figure 2)

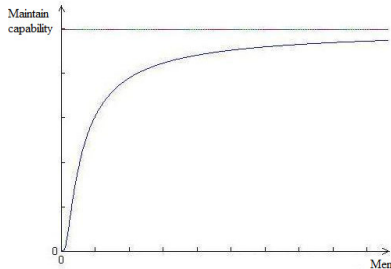


Figure 2: The influence curve of men to maintain capability

2.2 Materials

The repair of equipments need a lot of materials, include spare parts and expendable. Spare parts are used to replace the disabled accessories, expendable are the materials used up in the repair process.

In the repair process, the quantity of spare parts and expendable determine the pitch of maintain process. But if many spare parts and expendable are stored, the charge will increase, and some problems of the quality of these materials will appear.

In this article, the quantity of spare parts and expendable is only considered.

2.3 Machines

Machines are the equipments needed in the process of repair, include tools used to take down or build in accessories and testing devices.

During the repair process, only better equipments could go to failures betimes and repair them, shorten repair time. But the cost will increase when buy a better device, it affects the maintain capability of repair shops.

In this paper, quantity of machines in each rank and how many machines are in good condition are considered.

2.4 Environment

The quality and efficiency of repair work are not only related to the maintainability of production itself or the repair technology, they are also related to environment. Though those factors may not cause loss of repair work immediately, they will accelerate the appearance of workers' tiredness and affect the mind of workers, then influent security of workers.

Environment is the lighting of workshop where repair work happened, the cubage of workshop, temperature, humidity and so on.

So the factors of environment include three kinds:

(1) The factors which could be controlled, such as

lightening, vibrancy and temperature;

(2) The factors which could not be controlled, such as dust and climate;

(3) The factors which could be avoid, such as noises.

The factors which could be controlled are few, so the factor of environment is not considered in this article.

2.5 Methods

This factor is the management carried through to insure the quality of repair work, such as repair techniques, operate rules, information and so on.

A good method could distribute according to need and make a most efficient approach, reduce the waiting time.

An appropriate method could improve the repair rate and affect maintain capability.

In this paper, the management level and technique used are considered.

3. Foundation of evaluation system

Evaluation system is the base of the evaluation of workshops' maintain capability; it could reflect the formation state of maintain capability and the relationship of each factor. In this paper, there are four factors which influent the capability of a workshop, such as men, materials, machines and methods.

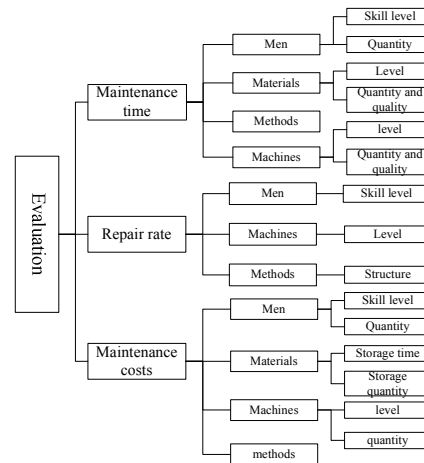


Figure 3: The evaluation system of maintain capability In Figure 3, the evaluate system include three aspects, such as maintenance time, maintenance costs and the repair rate.

3.1 Research of evaluate method about maintenance time

During the repair process of the production, maintenance time is an important element, it considers how much time it will cost to solve a problem, it is very important to the using efficient. Reducing maintenance time will curtail the off time in the life circle of production, so the production could keep on working for long time. Thus maintenance time has become an aspect of evaluation of maintain capability.

In this paper, the evaluation of maintenance time considers aspects followed.

(1) Men

In this part, the skill level and the quantity of workers are

considered.

Enhancement of workers' skill level and increase of the number of workers will decrease maintenance time. So the scores as Table 1:

Table 1: The impact of maintainer on maintenance time

	Primary skilled	Secondary	Higher skilled
scores	S ₁	S ₂	S ₃
quantity	n ₁	n ₂	n ₃

So the integrated score could gain by formula 1:

$$f_1 = \frac{S_1 \times n_1 + S_2 \times n_2 + S_3 \times n_3}{n} \quad (1)$$

Hereinto: f₁ is the integrated score;

n=n₁+n₂+n₃ is the total number of workers.

In this part, the great f₁ is, the short maintenance time is. But in fact, this evaluation should be considered by markers.

(2) Materials

The influence of materials incarnate on the quantity and the quality of spare parts and expendable, the scores as Table 2:

Table 2: The impact of materials on maintenance time

Score	Quantity	Satisfy	Essence	Dissatisfy
Quality				
Excellent		S ₁₁	S ₁₂	S ₁₃
Moderate		S ₂₁	S ₂₂	S ₂₃
Disqualification		S ₃₁	S ₃₂	S ₃₃

Based on the character of materials, material in each rank can gain its score by Table 2. The score of pivotal one is S₁, the score of main one is S₂ and the ecumenical one is S₃. The weight coefficient of three kinds materials are r₁, r₂ and r₃.

So the integrated score could gain by formula 2:

$$f_2 = S_1 \times r_1 + S_2 \times r_2 + S_3 \times r_3 \quad (2)$$

Hereinto: f₂ is the integrated score.

As the same, the great f₂ is, the short maintenance time is. In fact, this score also need to be considered by markers.

(3) Machines

In this part, the great influence factors are the quantity of machines in each level and how many machines are in good condition, the scores as Table 3:

Table 3: The impact of machines on maintenance time

Scores	Quantity	Satisfy	Essence	Dissatisfy
Rate of working				
High		S ₁₁	S ₁₂	S ₁₃
Middle		S ₂₁	S ₂₂	S ₂₃
Low		S ₃₁	S ₃₂	S ₃₃

Based on the character of machines, machine in each rank can gain its score by Table 3. The score of ecumenical one is S₁; the score of pivotal one is S₂. The weight coefficient of two kinds machines are r₁ and r₂.

So the integrated score could gain by formula 3:

$$f_3 = S_1 \times r_1 + S_2 \times r_2 \quad (3)$$

Hereinto: f₃ is the integrated score.

As the same, the great f₃ is, the short maintenance time is.

In fact, this score also need to be considered by markers.

(4) Methods

The influence of methods on maintenance time could be considered by two factors, management and organization structure. The impact as Table 4:

Table 4: The impact of methods on maintenance time

	Description	Rank	Score
Manage system	System and arrangement perfect	S ₁₁	S ₁
	System or arrangement perfect	S ₁₂	
	System or arrangement illogicality	S ₁₃	
	System and arrangement illogicality	S ₁₄	
Maintain process	Structure and process clear	S ₂₁	S ₂
	Structure or process clear	S ₂₂	
	Structure or process confuse	S ₂₃	
	Structure and process confuse	S ₂₄	

So the integrated score could gain by formula 4:

$$f_4 = S_1 + S_2 \quad (4)$$

Hereinto: f₄ is the integrated score;

In this part, the great f₄ is, the short maintenance time is.

3.2 Research of evaluate method about repair rate

The factor of evaluating the maintain capability of a repair shop is the repair rate; it is mostly depends on the production's quality character, and also affect by some other factors. In this paper, the evaluation of repair rate considers aspects followed.

(1) Men

The factor which decides the rate of repair is the skill level of workers. The higher skill level the worker is, more kinds of failure could be solved.

Table 5: The impact of men on repair rate

	Primary skilled	Secondary	Higher skilled
scores	S ₁	S ₂	S ₃
quantity	n ₁	n ₂	n ₃

$$f_1 = \frac{s_1 \times n_1 + s_2 \times n_2 + s_3 \times n_3}{\sum_{i=1}^3 n_i} \quad (5)$$

In this part, the great f₁ is, the high repair rate is.

(2) Machines

If more machines are pivotal, the failure can be found all-around, and the failure can get rid of on time. So the machine level is direct ratio to repair rate.

Table 6: The impact of machines on repair rate

	ecumenical one	pivotal one
score	S ₁	S ₂
quantity	n ₁	n ₂

$$f_2 = \frac{s_1 \times n_1 + s_2 \times n_2}{\sum_{i=1}^2 n_i} \quad (6)$$

(3) Methods

Taking right maintain process could repair production efficiently. And it can avoid some failures which are

led by incorrect maintain process. The calculate method of repair rate is as same as method of maintenance time.

Table 7: The impact of methods on repair rate

	Description	rank	Score
Maintain process	Structure and process clear	S ₁	S
	Structure or process clear	S ₂	
	Structure or process confuse	S ₃	
	Structure and process confuse	S ₄	

The integrated score could gain by formula 7:

$$f_3 = S \quad (7)$$

3.3 Research of evaluate method about maintenance costs

During the maintain process, maintenance costs take the most part of the cost during the whole working time of the production. In this part, maintenance costs is make up of workers' wage, storage cost, spending on buying machines and so on. In this paper, the evaluation of maintenance costs considers aspects followed.

(1) Men

In this part, only workers' wage is considered, because the skill level of the worker decides the salary of him. And if there are lots of workers, more salary will be paid; this will raise the maintenance costs.

Table 8: The impact of men on maintenance costs

	Primary skilled	Secondary	Higher skilled
score	S ₁	S ₂	S ₃
quantity	n ₁	n ₂	n ₃

$$f_1 = \frac{s_1 \times n_1 + s_2 \times n_2 + s_3 \times n_3}{n} \quad (8)$$

The worker's skill level is direct ratio to maintenance costs.

(2) Materials

The storage of materials needs definite cost, the longer storage time and more quantity will cause the increasing of the maintenance costs.

Table 9: The impact of materials on maintenance costs

	Description	rank	Score
Storage time	Long	S ₁₁	S ₁
	Appropriate	S ₁₂	
Quantity	Much more	S ₂₁	S ₂
	Appropriate	S ₂₂	
	Lack	S ₂₃	

$$f_2 = S_1 + S_2 \quad (9)$$

Materials' cost is direct ratio to maintenance costs.

(3) Machines

The kind of maintenance machine decides the purchasing cost and the repair cost; the cost is the main part of the maintenance cost. Cost of machines is direct ratio to maintenance costs.

Table 10: The impact of machines on maintenance costs

	ecumenical one	pivotal one
score	S ₁	S ₂
quantity	n ₁	n ₂

$$f_3 = \frac{n_1 S_1 + n_2 S_2}{n_1 + n_2} \quad (10)$$

(4) Methods

The impact of methods on maintenance cost could be considered by two factors, management and maintain process. An organization which has clear maintenance process will reduce the maintenance costs.

3.4 Integrate evaluation of maintain capability

Based on the analysis up, the evaluation system has been established and the calculation method has been given. In order to get the integrate evaluation of maintain capability, evaluation of factors of maintenance time, repair rate and maintenance costs should be gathered. In this article, weight coefficient of each factor should be given by methods of weighted calculation and prioritizing.

(1) Getting the sequence of the factors.

We can use some questionnaires to get the sequence.

Take maintenance time as an example, the factors, which can affect maintenance time, are men (a₁), materials (a₂), machines (a₃) and methods (a₄). If the sequence of the four factors is a₁>a₂>a₃>a₄, then the weight coefficient of a₁, a₂, a₃, a₄ are 10, 7, 4, 1.

(2) In order to reduce the influence of subjective factors, the sequences should be given by several experts.

For example, the number of the experts is *n*, then

$$s_i = \frac{\sum_{j=1}^n P_j}{n}, i=1,2,3,4 \quad (11)$$

$$r_i = \frac{s_i}{\sum_{i=1}^n s_i}, i=1,2,3,4 \quad (12)$$

P_j is the rank given by the No.*j* expert to the No.*i* factor

s_i is the score of the No.*i* factor

r_i is the weight coefficient of the No.*i* factor

(3) The scores of maintenance time, repair rate and maintenance costs could be calculated by using weighted algorithm.

The weight coefficient of factors in the evaluation of maintenance time is as Table 11:

Table 11: The integrated weight coefficient of factors

Factors	Weight coefficient
Men (f ₁)	r ₁
Materials (f ₂)	r ₂
Machines (f ₃)	r ₃
Methods (f ₄)	r ₄

So the result of evaluation of maintenance time could be given by formula 13.

$$P_{time} = \sum_{i=1}^4 f_i r_i \quad (13)$$

The score of repair rate (*P_{rate}*) and maintenance costs (*P_{costs}*) could get by the same method.

(4) At last, get the weight coefficient of maintenance time, repair rate and maintenance costs by using questionnaires. And get the integrate score by using

weighted algorithm.

$$N = \sum_{i=1}^3 10 \times u_i \times P_i, \sum_{i=1}^3 u_i = 1 \quad (14)$$

N is the integrate score of maintain capability

u_i is the weight coefficient of the No. i factor

P_1 is the score of maintenance time (P_{time})

P_2 is the score of maintenance time (P_{rate})

P_3 is the score of maintenance time (P_{costs})

The evaluation conclusion of maintain capability could be seen in Table 12.

Table 12: Maintain capability

	score	rank
1	<60	D
2	60~79	C
3	80~89	B
4	>90	A

When the failure appears, operator could send the production to the appropriate repair shop by the evaluation score of the repair shop.

4. Example

Take the maintain capability evaluation of airplane repair factory as an example. The factory has 198 workers, the number of engineering technologists is 74, the number of normal maintainers is 95, and the number of workers who have only basic skill is 29. The number of special equipments is 4 and the number of normal equipments is 20. Materials have good quality and the storage is abundant. There are 5 experts who take the questionnaires.

The score of factor men in maintenance time could calculate by the formula:

$$f_1 = \frac{S_1 \times n_1 + S_2 \times n_2 + S_3 \times n_3}{n} = \frac{1 \times 29 + 6 \times 95 + 10 \times 74}{198} = 6.76$$

As the same, we can get the score of the three other factors, the scores of materials, machines and methods are 6.33, 8.15, and 7.00.

Weight coefficient could get by the formula followed:

$$r = \frac{\begin{bmatrix} 10 \\ 7 \\ 4 \\ 1 \end{bmatrix} + \begin{bmatrix} 1 \\ 10 \\ 7 \\ 4 \end{bmatrix} + \begin{bmatrix} 7 \\ 10 \\ 4 \\ 1 \end{bmatrix} + \begin{bmatrix} 7 \\ 10 \\ 4 \\ 1 \end{bmatrix} + \begin{bmatrix} 4 \\ 7 \\ 10 \\ 1 \end{bmatrix}}{5} = \begin{bmatrix} 0.264 \\ 0.400 \\ 0.264 \\ 0.072 \end{bmatrix}$$

The score of maintenance time is as Table 13:

Table 13: Scores of impact factors of maintenance time

Factors	Weight coefficient	Score
Men (f_1)	0.264	6.76
Materials (f_2)	0.400	6.33
Machines (f_3)	0.264	8.15
Methods (f_4)	0.072	7.00

The score of maintenance time is 6.97, the score of repair rate is 7.35, and the score of maintenance costs is 7.92.

The integrate score of the factory's maintain capability is 74.13.

So, the score is logical, the calculate method given by this paper is feasible.

5. Conclusion

In this paper, the impact factors on maintain capability are analyzed, the evaluate system is found, and the calculate methods are given. But the evaluate system is not o perfect that some factors should be measured and circumstantiated, this evaluation should be improved.

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