A Case Study on Function Evaluation of Air Tool

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A Case Study on Function Evaluation of Air Tool

Luheng ZHAO*, Yasufumi KUME** and Fumio HASHIMOTO**

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Function analysis is an important phase in Value Analysis. In this phase, Function Analysis System Technique (FAST) can be used to analyze and evaluate the functions for a value analysis object. It is useful to represent the interrelationship of all functions visually. FAST can graphically help in defining, classifying and evaluating the functions, and discriminating the importance for all functions. The function evaluation methods can be used to calculate the coefficients of function importance which can describe the importance levels of the functions for all items of the value analysis object. In this paper, a new method (Function Distribution Evaluation Method) is proposed and applied to the function evaluation of a chipping hammer.

1. Introduction

The concept of Value Analysis was originated and developed by Miles who was an employee of the purchase department at General Electric (U.S.A.)[1]. He made use of the alternative which could not change the function required and indicated that the product was not required but the function was required indeed by the user, and that the money was paid by the user depending on the needs of the function required. Based on above-mentioned idea, methods of function analysis, function definition and function evaluation have been established, and a systematic technique was named "Value Analysis".

The term "Value Analysis" is used interchangeable with "Value Engineering". Traditionally, "Value Engineering" is used at the design stage or before the fact, whereas "Value Analysis" is used to an existing product or after the fact.

A well-known and powerful technique of function analysis used by value analysis practitioners is Function Analysis System Technique (FAST) developed by Bytheway[2]. The FAST diagram is a tree figure. It can help in defining and classifying the functions, and represent the graphical interrelationship of all functions for a value analysis object.

Function evaluation is an important phase in Value Analysis. Many function evaluation methods were introduced and every one has its own unique advantage. In this paper, a new method named Function Distribution Evaluation Method (FDEM) is proposed and applied to the function evaluation of a chipping hammer.

FDEM can be used to determine the coefficient of function importance. After deciding the coefficient of function importance f_i and the cost coefficient c_i, the Value Index is calculated. According to f_i and c_i, the items whose value must be improved can be selected from a lot of items by means of Value Graph. It has been discussed in our previous paper[3].

* Visiting Researcher, Department of Industrial Engineering, College of Engineering.
** Department of Industrial Engineering, College of Engineering.

2. Function Evaluation Methods

There are numerous function evaluation methods which can be used to decide the coefficient of function importance, such as Forced Decision method (FD)[4], Decision Alternative Ratio Evaluation (DARE)[5] and so on.

2.1. Forced decision method (FD)

In Forced Decision method, a paired comparison matrix is used. By assigning scores to all possible pairs and subsequently summing these scores associated with each item (function or component), it is possible to quantify the relationships of the function importances for all items. Table 1 shows a simple example of paired comparison matrix. The procedure is performed by the team members who know well the value analysis object. If the item A is more important than item B, the column of item B has a score of "1" in the row of item A, and the column of item A has a score of "0" in the row of item B at the same time. The scores in the row of each item are summed up and the coefficients of function importance f_i for all items can be decided by

$$f_i = \frac{P_i}{\sum_{i=1}^{n} P_i} \qquad (i = 1, 2, \cdots, n), \tag{1}$$

where

P_i : the score of a item i,
n : the number of items.

Table 1 A paired comparison matrix of 0–1 FD

item	A	B	C	D	E	F	score	coefficient of function importance f_i %
A	*	1	0	0	0	0	1	6.7
B	0	*	1	1	0	0	2	13.3
C	1	0	*	1	0	1	3	20.0
D	1	0	0	*	0	0	1	6.7
E	1	1	1	1	*	1	5	33.3
F	1	1	0	1	0	*	3	20.0
totals							15	100.0

This method is especially called 0–1 Forced Decision method. Although this method can discriminate which one is more important in paired items, it can not decide the difference in importance between paired items. For this reason, a method called 0–3 Forced Decision method is used to compute the coefficient of function importance. This method needs a same paired comparison matrix used in the 0–1 Forced Decision method, but the scores are decided as follows: 0 = "no difference in importance"; 1 = "minor difference in importance"; 2 = "medium difference in importance"; 3 = "major difference in importance". Table 2 gives a result of function evaluation for a chipping hammer by using the 0–3 Forced Decision method.

Table 2 Paired comparison matrix for a chipping hammer with 0 – 3 FD

No.	compared component	1 valve	2 valve lifter	3 valve spring	4 spring cover	5 packing	6 valve lever	7 valve lever pin	8 cap	9 hose joint	10 spring washer	11 cylinder	12 chisel bush	13 cylinder cover	14 damper	15 chisel holder	16 chisel holder spring	17 clasp ring	18 piston	evaluation score of importance	coefficient of function importance f_i %
1	valve	*	1	1	1	2	0	2	0	0	2	0	0	0	1	0	0	1	0	11	4.3
2	valve lifter	0	*	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	3	1.2
3	valve spring	0	0	*	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	3	1.2
4	spring cover	0	1	1	*	1	0	1	0	0	1	0	0	0	0	0	0	0	0	5	2.0
5	packing	0	0	0	0	*	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.4
6	valve lever	0	1	1	0	2	*	2	0	0	2	0	0	0	1	0	0	1	0	10	3.9
7	valve lever pin	0	0	0	0	0	0	*	0	0	1	0	0	0	0	0	0	0	0	1	0.4
8	cap	3	3	3	3	3	3	3	*	3	3	0	2	2	3	1	2	3	1	41	16.1
9	hose joint	0	1	1	1	2	0	2	0	*	2	0	0	0	1	0	0	1	0	11	4.3
10	spring washer	0	0	0	0	1	0	0	0	0	*	0	0	0	0	0	0	0	0	1	0.4
11	cylinder	3	3	3	3	3	3	3	1	3	3	*	2	2	3	1	2	3	1	42	16.5
12	chisel bush	2	2	2	2	2	1	2	0	2	2	0	*	0	2	0	0	2	0	21	8.3
13	cylinder cover	1	2	2	2	2	0	2	0	1	2	0	0	*	1	0	0	1	0	16	6.3
14	damper	0	0	0	0	1	0	1	0	0	1	0	0	0	*	0	0	0	0	3	1.2
15	chisel holder	3	3	3	3	3	2	3	0	3	3	0	2	1	3	*	1	3	0	36	14.2
16	chisel holder spring	1	1	1	1	2	0	2	0	1	2	0	0	0	1	0	*	1	0	13	5.1
17	clasp ring	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	*	0	3	1.2
18	piston	2	3	3	2	3	2	3	0	2	3	0	2	1	3	0	1	3	*	33	13.0
	totals																			254	100.0

2.2. Decision alternative ratio evaluation (DARE)

Decision Alternative Ratio Evaluation is a method in which scores are assigned to adjoining two items in direct ratio to the function importance that the items possess. The procedure may be modelled on the following example as Table 3 and the calculating steps are shown as follows:

(1) The items of value analysis object are written in the column ⟨1⟩.

(2) The ratio is decided to adjoining two items from top to bottom one by one, e.g. if the team members perceive that the importance of item A seems 2 times higher

Table 3 DARE

⟨1⟩ item	⟨2⟩ temporary weighted coefficient	⟨3⟩ corrected weighted coefficient	⟨4⟩ coefficient of function importance f_i %
A	2.0	4.50	32.7
B	0.5	2.25	16.4
C	3.0	4.50	32.7
D	1.5	1.50	10.9
E	–	1.00	7.3
totals	–	13.75	100.0

* The dotted lines show the determination procedures of the corrected weighted coefficients.

than item B, 2 is put down in the column⟨2⟩which is temporary weighted coefficient in the row of item A. If the importance of item D seems 1.5 times higher than the last item E, 1.5 is put down in the column⟨2⟩in the row of item D. Then, the decision of temporary weighted coefficients is completed.

(3) The temporary weighted coefficients are converted to the corrected weighted coefficients and these scores are put down in the column ⟨3⟩. Firstly, 1.00 is assigned to the column⟨3⟩of the last item. In this example, the last item is E. The importance of item D which is the predecessor of item E seems 1.5 times higher than item E, so 1.50 is assigned to the column⟨3⟩in the row of item D (1.0 × 1.5 = 1.50). However, the item C seems 3.0 times higher than the item D, then 4.50 is assigned to the column ⟨3⟩in the row of item C (1.5 × 3.0 = 4.50). The procedure is continued until all columns⟨3⟩are filled with corrected weighted coefficients for every item.

(4) The coefficients of function importance f_i for all items can be computed by

$$f_i = \frac{W_i}{\sum_{i=1}^{n} W_i} \quad (i = 1, 2, \cdots, n), \tag{2}$$

where

W_i : the corrected weighted coefficient of i-th item,
n : the number of items.

In the case of chipping hammer, the items are so many then it is difficult to decide the temporary weighted coefficients.

2.3. Function distribution evaluation method (FDEM)

In above-mentioned two methods, the items (components or functions) are compared with one another. Generally, a value analysis object such as a product consists of many components. One component may have a lot of functions and one function can be accomplished by many components. In order to determine the coefficient of function importance of every component, the score of function importance must be distributed to all functions which the component possesses. That is, the score is assigned to every function individually. Then, the score of every component is summed up. Finally, they are converted to individual percentages by Eq. (1). Thus, the coefficients of function importance are calculated. Based on this idea, a new method named Function Distribution Evaluation Method is proposed. As a practical example, the application of this method to the function evaluation of chipping hammer is presented in Table 4, and the procedure of this method can be shown as follows:

(1) At first, by using the Function Analysis System Technique, the functions of components are defined as a FAST diagram shown in Fig. 1. Then, all functions of every component (including the structural and assembling functions) are listed in Table 4 in more detail. Note that the listed functions must not overlooked and overlapped. In order to make the FAST diagram concise and the function analysis effective, it is unnecessary to list all functions in the FAST diagram. For example, the structural and assembling functions are both not always listed in the FAST diagram.

Table 4 The function, evaluation score and coefficient of function importance for a chipping hammer

No.	component	function	score	coefficient of function importance f_i %
1	Valve	pass through compressed air	3	
		check compressed air	3	5.3
2	Valve lifter	open valve	4	3.5
3	Valve spring	close valve	4	3.5
4	Spring cover	press valve spring	2	
		press spring washer	2	3.5
5	Packing	prevent compressed air leaking	2	1.8
6	Valve lever	give valve lifter force	4	3.5
7	Valve lever pin	hold valve lever	3	2.7
8	Cap	pass through compressed air	3	
		check compressed air	3	
		hold hose joint	2	
		hold spring cover	1	
		hold packing	1	
		hold lever pin	1	
		hold spring washer	1	
		guide valve lifter	1	11.5
9	Hose joint	pass through compressed air	3	
		connect hose	3	5.3
10	Spring washer	give packing pressure	2	
		prevent spring cover turning	1	2.7
11	Cylinder	pass through compressed air	3	
		produce pressure	5	
		exhaust used gas	2	
		hold clasp ling	1	
		hold cap	2	
		hold cylinder cover	1	
		hold chisel cover	2	
		hold chisel bush	1	
		guide piston	3	17.7
12	Chisel bush	guide chisel	2	
		limit position of chisel	1	
		exhaust used gas	2	4.4
13	Cylinder cover	hold damper	2	
		produce pressure	5	6.2
14	Damper	absorb vibration	4	3.5
15	Chisel holder	guide chisel	2	
		press chisel holder spring	4	
		exhaust used gas	2	
		hold chisel holder spring	2	8.9
16	Chisel holder spring	give chisel force	5	4.4
17	Clasp ring	fix position of chisel holder	2	1.8
18	Piston	produce pressure	5	
		exhaust used gas	2	
		give chisel force	4	9.8
		totals	113	100.0

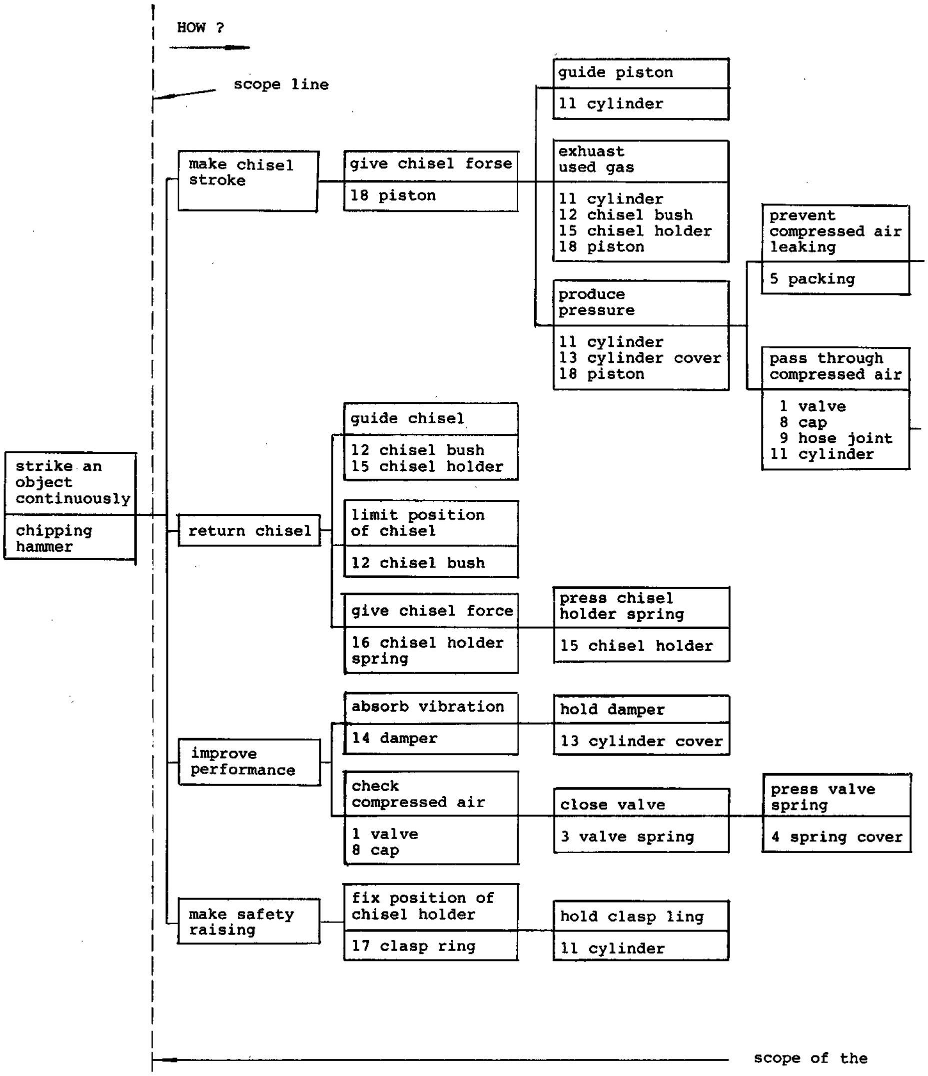
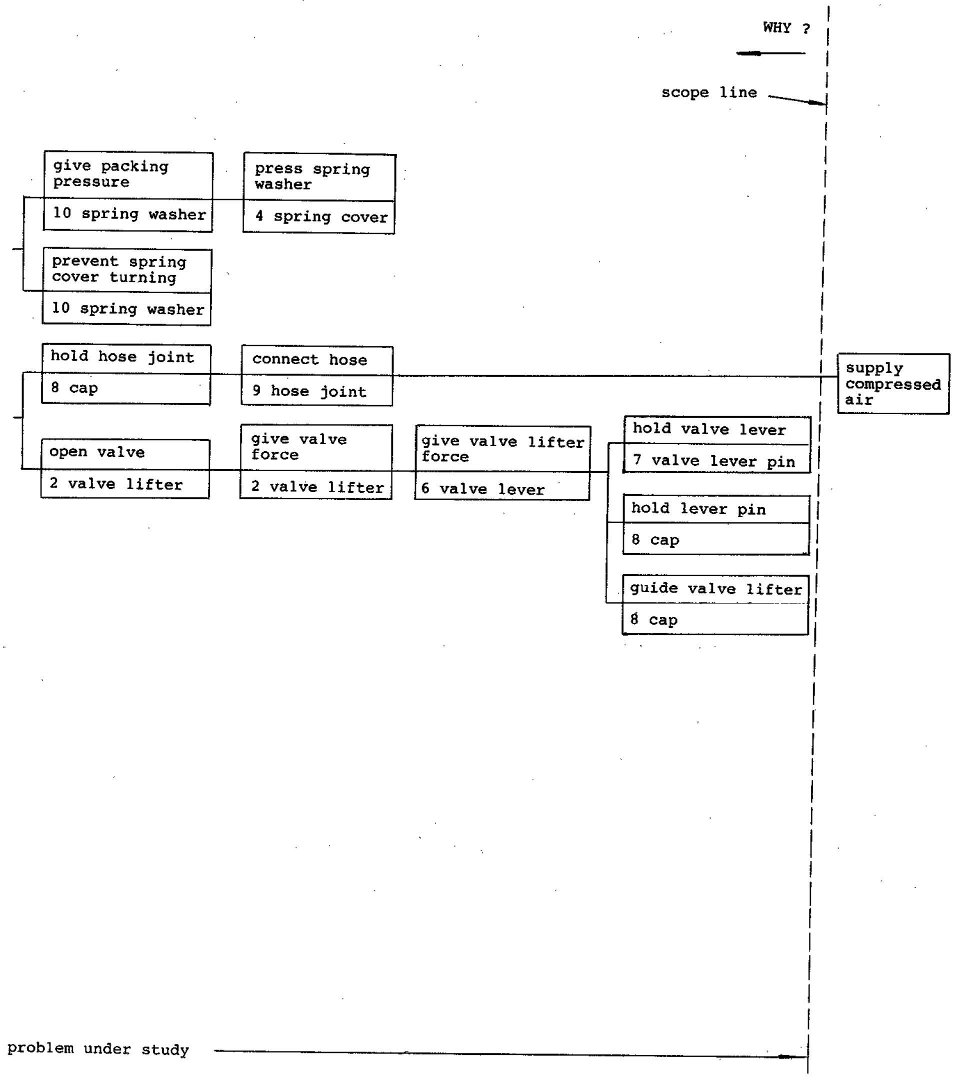


Fig. 1 A FAST diagram for a chipping hammer

(2) The evaluation score is assigned to all functions by the team members. The score can be taken as follows: 5 = "most important"; 4 = "very important"; 3 = "moderately important"; 2 = "slightly important"; and 1 = "little important". In this example, the function "produce pressure" is considered as the most important function, therefore, 5 is assigned to it. Then, the score of 5 is given to this function which the components possess. Generally, the structural and assembling functions only display the relationships among the components, so the score of 3 or less than 3 is assigned to them.

(3) The scores are summed up for every component and the total score of value analysis object is calculated. Finally, the coefficient of function importance for every component can be computed by Eq. (1).

The right side of Table 4 shows the evaluation scores and the coefficients of function importance by means of this method for the chipping hammer.



3. Discussion of Function Evaluation Methods

Both of the 0-1 Forced Decision method and the 0–3 Forced Decision method use a paired comparision matrix which compares the one item with the others for all possible pairs. The former can discriminate the rank of importance of all items, but it can not decide the differences in importance among the functions. The latter is more correct and useful than the former. Paired comparision has high discrimination for the priority of function importance among items. If the number of items is less than 20, the Forced Decision method can be used effectively. A weakness of this method is cumbersome to determine many columns for the paired comparision matrix.

The Decision Alternative Ratio Evaluation (DARE) is based on paired comparision method, but the number of comparisons is less than that of the Forced Decision methods. On the other hand, DARE has no fundamental defect, because the ratios are used to indicate the relationship of the function importances for all items. In principle, any object can be evaluated by this method. However, it may be impractical if there are many items to be evaluated, because the ratios among all items can not be decided correctly. In this case, the Forced Decision method may be recommended.

Although the Forced Decision methods and the Decision Alternative Ratio Evaluation can be used to discriminate the differences in importance among functions, but they are somewhat complicated. The use of the Function Distribution Evaluation Method proposed in this paper can compute the coefficients of function importance concisely and correctly. This method takes account of the importance for every function, and of the differences in importance among the functions. Furthermore, this method takes notice of the structural and assembling functions for every component, so it is a more suitable method.

It is necessary that the members of the value analysis team must have sufficient knowledge for the value analysis object, and for the functions of every item regardless of function evaluation methods to be used.

4. Conclusion

In this paper, a new method (Function Distribution Evaluation Method; FDEM) is proposed. The use of this method can determine the coefficient of function importance for a value analysis object concisely and correctly. The main merit of this method is that the members of a value analysis team take account of the number of functions, the difference in importance among the functions, and the structural and assembling functions for every item. An application of the FDEM to the function evaluation of a chipping hammer is illustrated and it is clarified that the cylinder and cap for the chipping hammer have higher function importance than the others.

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