CSCanada
Management Science and Engineering
Vol. 6, No. 4, 2012, pp. 94-97
DOI:10.3968/j.mse.1913035X20120604.ZT0411

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

Effectiveness-Based Method for Equipment Maintenance Evaluation

HU Ruiping[a],*; YANG Honghua[b]; HU Beijia[c]

[a] Department of Command Zhenjiang Watercraft College, Zhenjiang, China.
[b] School of Business, Jiangnan University, Wuxi, China.
[c] Jinling College, Nanjing University, Nanjing, China.
*Corresponding author.

Received 21 August 2012; accepted 5 December 2012

Abstract

In a modern war on the high-tech conditions, an exertion of military equipment effectiveness impacts on results of the war. The quality of equipment maintenance determines the exertion of military equipment effectiveness. The method for equipment maintenance evaluation guides the equipment maintenance. Current equipment effectiveness rests with designing performance and the quality of equipment maintenance. For some homotypical and homocronous equipments used on the same conditions, current equipment effectiveness reflects the quality of equipment maintenance in the past period. An effectiveness-based Method for Equipment Maintenance Evaluation is illuminated by a case of certain equipment. A program for solving problems using this method by computer has being implemented. The rationality, maneuverability and serviceability of this method are satisfactory.

Key words: Equipment effectiveness; Equipment maintenance; Evaluation method

HU Ruiping, YANG Honghua, HU Beijia (2012). Effectiveness-Based Method for Equipment Maintenance Evaluation. *Management Science and Engineering*, *6*(4), 94-97. Available from: http://www.cscanada.net/index.php/mse/article/view/j.mse.1913035X20120604.ZT0411
DOI: http://dx.doi.org/10.3968/j.mse.1913035X20120604.ZT0411

INTRODUCTION

A technical status of equipment reflects past equipment management quality. An evaluation method of equipment management reflects an idea, objective and measure. An active evaluation method is usually to list some items and more enumerations, and give score for each, than synthesize them by weighted sum[1][2]. This method has some obvious shortages: Firstly, lacks the all and the one concept of equipment system. A functional performance of any part of equipment system can not determine its technical status. Secondly, too much more enumerations are loaded down with trivial details for check-up. Sun Xiangchuan etc.[3] put forward the DEA evaluation method of naval equipment management with its relative validities. This method has definite rationality, but military benefits are weighted by indirect indexes, such as launch-out quantity and training subject score, lacking scientific score for the technical status of equipment. Herein this article puts forwards a method for equipment management evaluation based on reliability-centered quality management mode and Equipment effectiveness, and expatiates on the method with an example of a watercraft.

1. THEORY OF EQUIPMENT EFFECTIVENESS

Ultimately, the developer must determine the individual and combined effects of all equipment attributes when choosing between alternative equipment and equipment designs. The equipment effectiveness is measured at both the mission and the battle levels. Of these two levels, the mission level provides the most direct means for relating equipment attributes to system effectiveness. This argument is supported by the abundance of models which link equipment attributes to equipment effectiveness at the mission level, and the lack of models which link these attributes to equipment effectiveness at the battle level. These models will be sub-divided into two categories, multiplicative and additive. The multiplicative models are the Weapons Systems Effectiveness Industry Advisory

Committee (WSEIAC), Habayeb, Ball, OPNAVINST 3000.12, Marshall and Giordano models[4]. One additive model is the Georgia Tech Aerospace Systems Design Laboratory (ASDL) model. All of the models develop mission-specific measures of effectiveness through the combination of a few key equipment attributes into mathematical equations involving attribute measures. There are two basic types of these equations. The first method involves the multiplication of key attribute measures, leading to a single overall measure of effectiveness. The second method involves applying weighting coefficients to various key attribute measures which reflect the relative importance of those attributes and then adding the weighted attribute value, leading to a single overall measure of effectiveness. The multiplicative models are based on the premise that equipment's effectiveness in accomplishing a particular mission is a product of a few key equipment attributes. These attribute measures are expressed as probabilities, and they all must be present, in some degree, for an equipment to be considered effective. The most effective equipment, using these models, is the one with the highest probability of mission accomplishment over time.

1.1 Equipment Effectiveness

As the ADC model proposed by Weapons System Effectiveness Industry Advisory Committee (WSEIAC, 1965), authors think that an equation identifying three key equipment attributes, Availability (*A*), Dependability (*D*), and Capability (*C*), was presented for overall equipment effectiveness (*E*) evaluation: $E^t = A^tDC$. Where *E* is the measure of the extent to which equipment can be expected to achieve a set of specific mission requirements, and is a function of availability, dependability and capability. If equipment has *n* quality factors, $E^t = (e_1,\dots, e_k,\dots e_n)$. Where e_k stands for the measure of the extent of k^{th} quality factor (requirement) that the equipment can be expected to have for achieving a specific missions. For example, a set of quality factors of the landing craft may be chosen as follows:

1) Load ability, the maximal capacity vessel can take human or cargo on board;

2) Endurance, the extreme range vessel can run at provision sailing speed with full of fuel under usual voyage conditions;

3) Ability of resistance wind, the highest wind power Vessel is able to suffer and be control safely;

4) Navigating area, the different water or sea region is partitioned on which vessel can navigate on different safety according to hydrology and weather condition;

5) Self-control ability, hours in which seamen can live on fresh water and food that Vessel reserved;

6) Convolution diameter, the diameter of turning circle the vessel steers with full speed and rudder;

7) Speed, sailing velocity at which Vessel steer on still water;

8) Landing gradient;

9) Gate got up close hour;

10) Protective potential;

11) Unsinkable ability: A vessel is still able to float on surface safely even one or a few influent cabin.

1.2 Availability

The *A* is an availability vector, which presents the possible states of equipment condition at the start of the mission and is a function of the relationships among hardware, personnel and procedures. It is a set of probability of several important states at the start. If an equipment has *m* stats, $A^t = (a_1,\dots a_2,\dots a_m)$. Where a_i stands for a probability of i^{th} important state at the start.

So called the equipment state is a distinguish equipment status at pre-serve or in serve time. For example, the four states of a landing craft are defined as the follows:

State 1 Waiting for voyage (in a state of berth, await orders put out to sea)

State 2 Underway (take superior mission upon, in a state of mission)

State 3 Finishing (corrective maintenance, personnel rest and recuperation)

State 4 Went wrong

So an availability vector of the landing craft is denoted as: $A^t = (a_1, a_2, a_3, a_4)$. Where:

$$a_1 = \frac{Total \quad Waiting \quad Hour \quad for \quad Voyage}{Serve \quad Hour \quad in \quad Life \quad Cycle}$$

Serve Hour in Life Cycle is defined as deploy time of the life cycle of a landing craft, it is chosen between green line and red line period on alleged "bathtub curve". Total Waiting Hour for Voyage is defined as an accumulative waiting hour of the landing craft at its post waiting for mission.

$$a_2 = \frac{Total \quad Underway \quad Hour}{Serve \quad Hour \quad in \quad Life \quad Cycle}$$

Total Underway Hour includes both starting hour and mission hour. The starting hour is defined as a length of time required for leading landing craft launch to mission. It is calculated from the point of command coming to hand. The mission hour is defined as time of the landing craft executing mission.

$$a_3 = \frac{Total \quad Finishing \quad Hour}{Serve \quad Hour \quad in \quad Life \quad Cycle}$$

Total Finishing Hour includes check-up hour and maintenance hour. The check-up hour is time required for test landing craft status. The maintenance hour is time required for maintain landing craft.

Identify applicable sponsor/s here. (Sponsors)

$$a_4 = \frac{Total \quad Went \quad Wrong \quad Hour}{Serve \quad Hour \quad in \quad Life \quad Cycle}$$

Total Went Wrong Hour is defined as time in which the landing craft went wrong and can not work, includes preparing hour, fault location hour, obtaining spare part hour, removing malfunction hour, adjusting and calibrating hour and clearing hour, but do not include off line time required for repairing any subrogation parts, also do not include delay causing by dining and administration and so on. The preparing hour is defined as time required for obtaining maintaining handbook and test equipments and fixing them. The fault location hour is time required for both examining and analyzing the landing craft, in order to hunt malfunction out. The obtaining spare part hour is time required for gaining spare part from repository on the spot. The removing malfunction hour is time required for eliminating malfunction, in this segment there are three repair approaches: 1) Repair on the spot, 2) takeoff and install after fixing, and 3) substitute with analogous spare part. The adjusting and calibrating hour in which the repair job is proved is content. The clearing hour is time required for tiding the landing craft restore scene.

1.3 Dependability

D is a dependability square matrix, which presents the probability that the equipment 1) will enter and/or occupy any one of its significant states during the specific mission, and 2) will perform the functions associated with those states. D is expressed as probability from a state turning to another state after accomplishing a mission. If equipment has m availability states, D is $m \times m$ square matrix, likely:

$$D = \begin{pmatrix} d_{11} & d_{12} & \cdots & d_{1m} \\ d_{21} & d_{22} & \cdots & d_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mm} \end{pmatrix}$$

Where d_{ij} is probability that equipment is working in j^{th} state and starts mission at j^{th} state. For example, the above landing craft has dependability square matrix:

$$D = \begin{pmatrix} d_{11} & d_{12} & d_{13} & d_{14} \\ d_{21} & d_{22} & d_{23} & d_{24} \\ d_{31} & d_{32} & d_{33} & d_{34} \\ d_{41} & d_{42} & d_{43} & d_{44} \end{pmatrix}$$

Where d_{12} is probability of the landing craft is on waiting for voyage, and once receives order then go underway; d_{13} is probability of the landing craft is on Waiting for voyage, and has voyaged for mission but turn to finishing; and so on. The value of elements of D can be given on statistics from The Log of Landing Craft.

1.4 Net Value of Single Equipment Effectiveness

1) Value of Single Equipment Effectiveness ($E^{\wedge}$) is defined as a weighted sum of all compounds of equipment effectiveness vector, namely $E^{\wedge} = E^t Z$, where $Z^t = (z_1, \cdots, z_k, \ldots, z_n)$ and z_k is the weight of k^{th} quality factor, can be given by Delphi method or Analytic Hierarchy Process.

2) Taking a mean value of some homotypical and homocronous equipments effectiveness as the equipment effectiveness standards. Then enact "Afterwards Serve Years/Effectiveness Standard".

3) The net value of single equipment effectiveness is defined as an increment between the current effectiveness and the effectiveness standard, namely:

The net value of single equipment effectiveness = current effectiveness – effectiveness standard.

1.5 Example (Take Certain Landing Craft as an Example)

By stating history data, give out availability vector of certain landing craft: $A^t = (0.5, 0.3, 0.1, 0.1)$

Through looking up "Voyage Log", gain dependability matrix:

$$D = \begin{pmatrix} 0 & 0.7 & 0 & 0.3 \\ 0 & 0.8 & 0 & 0.2 \\ 0.7 & 0.2 & 0 & 0.1 \\ 0.1 & 0.1 & 0 & 0.8 \end{pmatrix}$$

Through technical appraisement of the landing craft existing status, obtain capability matrix:

$$C = \begin{pmatrix} 5 & 0 & 4 & 0 & 5 & 0 & 0 & 2 & 3 & 4 & 3 \\ 4 & 3 & 4 & 3 & 4 & 4 & 3 & 2 & 3 & 3 & 2 \\ 0 & 0 & 3 & 0 & 5 & 0 & 0 & 2 & 3 & 4 & 3 \\ 0 & 0 & 2 & 0 & 2 & 0 & 0 & 0 & 2 & 3 & 2 \end{pmatrix}$$

So current effectiveness vector of the landing craft is $E^t = A^t DC$ = (2.88, 1.86, 3.4, 1.86, 3.48, 2.48, 1.86, 1.4, 2.7, 3.08, 2.08).

If Z^t = (0.15, 0.1, 0.1, 0.05, 0.1, 0.05, 0.15, 0.1, 0.05, 0.05, 0.1), then $E^{\wedge} = 2.439$.

2. METHOD FOR EQUIPMENT MAINTENANCE QUALITY EVALUATION BASED ON EFFECTIVENESS

Current equipment effectiveness rests with designing performance and the quality of equipment maintenance. For some homotypical and homocronous equipments used on the same conditions, current equipment effectiveness reflects the quality of equipment maintenance in past period.

For any twain equipment x and y, suppose they have net value of effectiveness respectively: $\varepsilon_x(t_1)$ and $\varepsilon_y(t_1)$ at time t_1, $\varepsilon_x(t_2)$ and $\varepsilon_y(t_2)$ at time t_2. Then the increments $[\varepsilon_x(t_2)-\varepsilon_x(t_1)]$ and $[\varepsilon_y(t_2)-\varepsilon_x(t_1)]$ reflect the quality of equipment maintenance in $[t_1, t_2]$ for equipment x and y respectively. The larger is the net value, the higher is the level of the quality of equipment maintenance.

Induction upwards analyses, give out the Method of Equipment Maintenance Quality Evaluation as follows:

Step 1 by reviewing history data of each single equipment, get availability vector, dependability matrix and capability matrix;

Step 2 according to the formula ($E^t = A^t DC$), gain the effectiveness vector of each single equipment;

Step 3 using Delphi method or Analytic Hierarchy Process, present weight vector of the equipment quality factor. By the formula ($E^{\wedge} = E^t Z$), find out the value of each single equipment. It reflects the technical status of single equipment;

Step 4 reckoning the mean of some homotypical and homocronous equipments used on the same conditions ($\bar{E}$), enact "Afterwards Serve Years/Effectiveness Standard";

Step 5 by formula $\varepsilon = E^{\wedge} - \bar{E}$, obtain the increment of the net value of each equipment effectiveness in time between t_2 and t_1: $[\varepsilon(t_2)-\varepsilon(t_1)]$;

Step 6 sort these increments. The sequence of those increments from big to small is a sequence of the quality of equipment maintenance from high to low in a period of evaluation.

3. EPILOGUES

In this paper, based on the effectiveness concept, a method for Equipment Maintenance Evaluation is proposed. Firstly, value of single equipment effectiveness is defined as a weight sum of all compounds of equipment effectiveness vector. Secondly, the net value of single equipment effectiveness is defined as an increment between the current effectiveness and the effectiveness standard. Thirdly, an increment of the net value of equipment effectiveness in the period of evaluation is defined as an increment between the end net effectiveness and the beginning net effectiveness. The bigger this increment is, the higher quality the equipment maintenance has. A sequence of those increments from big to small is a sequence of the quality of equipment maintenance from high to low in the period of evaluation. The method is illuminated by a case of certain equipment (landing craft). A program for solving problems using this method by computer has being implemented. The rationality, maneuverability and serviceability of this method are satisfactory.

REFERENCES

[1] ZHANG, Zenglei *et al.* (2007). Synthesis Account Method of Evaluation Standards for Equipment Management. *Ordnance Industry Automation*, *26*(2).

[2] ZHANG, Ru *et al*. (2006). Hierarchy Description and Synthesis Account for Equipment Management Evaluation System. *Ordnance Industry Automation*, *25*(3), 22-23.

[3] SONG, Xiangchuan (2006). Naval Equipment Management Evaluating Method Based on DEA Model. *Journal of Dalian Naval Academy*, *29*(1), 53-55.

[4] Brown, Kevin W. (1995). *Measuring the Effectiveness of Weapons Systems in Term of System Attributes* (Master's thesis). Naval Postgraduate School.

