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The evaluation of the effectiveness of modular outfitting of engine room machinery

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Abstract

Modular outfitting plays an important role in shipbuilding to improve the effectiveness, save man-hours and have bigger competitive in the world. But the advantages above mentioned are benefit to shipbuilder for the most part. We don't know whether it has brought a convenience for crew to operate it or a benefit to owner. Now we want to use effectiveness to evaluate its' convenience to crew in this paper. How to determine the effectiveness of modular outfitting is an interesting project because modular ship is built through a new method of shipbuilding and there are not yet enough data to evaluate it. Traditionally, effectiveness' evaluation is carried out on a precise data. In many cases, however, there are some difficulties with application of traditional method to calculate it because lack of evidence or due to the inability of the expert to make firm evaluation. Therefore fuzzy set is attempted to resolve this problem in this paper and got an appropriate result.

1 Introduction

Modular outfitting method play an important role in shipbuilding to improve the effectiveness, save man-hours and have bigger competitive in the world. Based on literatures, there are a 20% reduction in build time, a 52% improvement in man-hours[4,5], 54% reduction in overhead cost and 18% reduction in material costs in Yarrow Shipbuilders Ltd.(This is a result of ship outfitting). In Hitachi Ariake shipyard (in Japan)[5] design time was reduced

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from 509h to 355h, onboard time was reduced from 594h to 515h(only in engine room) etc. therefore it has been used in shipyard all in the world. But the advantages above mentioned are benefit to shipbuilder for the most part, we don't know whether it has brought an convenience for crew to operate it or a benefit to owner. Now we try to use effectiveness to evaluate its' benefit to crew in this paper.

It is an interesting project how to determine the effectiveness of modular ship because modular ship is built through a new method of shipbuilding and there are not yet enough data to evaluate it. In this paper a new method is used to resolve this problem.

2 The method of effectiveness's assessment

The purpose of effectiveness's assessment is to check its working condition of modular ship. It may be difficult to evaluate it only using technology data. For example, generator sets can be used as an example, generators were assembled one by one in the past, now assembled together as a module in engine room. Maybe there are not any changes in technology data, such as power, voltage, current, frequency and so on because they are yet original generator sets. But there may be some changes in operation, vibration, reliability, etc because the assembly technology and bed plate is different. Therefore here we want to use vibration, noise, operation, inspection, reliability, maintenance and satisfied degree to assess it, i.e. the effectiveness = f (vibration, noise, operation, inspection, reliability, maintenance and satisfied degree).

Traditionally, effectiveness' assessment is carried out on a precise data. In many cases, however, there are some difficulties with application of traditional method to calculate it because lack of evidence or due to the inability of the expert to make firm assessments. For example, we must list a table 1 to calculate it in old method if we want to calculate the effectiveness of generator sets. Each term in table is

Table 1 The assessment of Generator set

Items		Vibration	Noise	Operation	Inspection	Reliability	Maintenance degree	Satisfied degree	Total
Generator set	Before	9	8	8	8	8	8	7	56
	After	10	9	7	8	8	7	8	57

Note: "before"-------no modular ship
"after" ------modular ship

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represented by special data, such as 10, 9, ···, 1,etc. The contrast of sum represents the result of evaluation. The bigger the sum is, the better the effectiveness is.

But there are some troubles in this method, such as:

1) It is difficulty to select the special data of the condition of modular ship and no-modular ship. For example, why and how do we select the value if we select the condition of vibration of modular ship as 10, no-modular ship as 9
2) The judgment of contrast result is very difficult. For example, how to judge which is better or bad if the assessment result of modular ship is 57, no-modular ship is 56.

Therefore fuzzy set is attempted to resolve this problem. We can use linguistic variables such as 'very good', 'good', average' and 'poor' to represent it.

In fuzzy theory[1,2,3], linguistic variables can be characterized by their membership functions to a set of categories which describe the degrees of property about ship. For instance, if U=(1,2,3,···,n-1,n) represent a set of categories, the linguistic variables 'very good', 'good', 'average' and 'poor' may be modeled by:

'very good'={0/1,···,0/n-3,0/n-2,0.75/n-1,1.0/n}

'good'={0/1,···,0.5/n-3,1/n-2,0.25/n-1,0/n}

'average'={0/1,0.25/2,1/3,···,0/n-2,0/n-1,0/n}

'poor'={1.0/1,0.75/2,0/3,···,0/n-2,0/n-3,0/n}

Where the integers in the numerators of each term within the brackets represent the categories and the real numbers in the denominators stand for the membership degrees.

The membership values for the components in U belonging to each of the linguistic variables 'very good', 'good', 'average' and 'poor' can be denoted as follows if n=7:

Table 2 The membership values for the components

Linguistic μ	1	2	3	4	5	6	7
Very good	0	0	0	0	0	0.75	1
Good	0	0	0	0.5	1	0.25	0
Average	0	0.25	1	0.5	0	0	0
Poor	1	0.75	0	0	0	0	0

Table 3 The membership value of operation

Linguistic	1	2	3	4	5	6	7
Very good	0	0	0	0	0	0.75	1
Good	0	0	0	0.5	1	0.25	0
Average	0	0.25	1	0.5	0	0	0
Poor	1	0.75	0	0	0	0	0

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As mentioned above, the effectiveness is a result considering vibration, noise, operation, reliability, maintenance degree, satisfied degree. Each element of them can be represented such as table 2, for example, operation can be represented by table 3 and alternative set (defined effectiveness set) can be represented with μ_d and as shown in table 4.

Table 4 The membership value of alternative set

Linguistic μ_d	1	2	3	4	5	6	7
Very good	0	0	0	0	0	0.75	1
Good	0	0	0	0.5	1	0.25	0
Average	0	0.25	1	0.5	0	0	0
Poor	1	0.75	0	0	0	0	0

The assessment matrix can be shown:

$$\mu_r = \begin{bmatrix} viberation \\ noise \\ operation \\ inspection \\ reliability \\ ma\,\mathrm{int}\,eance\,\mathrm{deg}\,ree \\ satisfied\,\mathrm{deg}\,ree \end{bmatrix}$$

The factors of assessment matrix are represented by linguistic variables. For example, it also can be selected as a middle value between [0/1, 0/2, 0/3, 0/4, 0/5, 0.75/6,1/7] and [0/1, 0/2, 0/3, 0.5/4, 1/5, 0.25/6, 0/7] if the factor is between very good and good.

The different weight must be given because each factor has a different affection to effectiveness of modular ship. The comparison method in rank is used to determine the weight of factor.

Suppose factor set may be represented with $\mu_a = (\mu_{a1}, \mu_{a2}, \cdots, \mu_{ai}, \cdots, \mu_{an})$. After It had been in rank according its importance , $\mu_{ai+1,I} \in [0,1]$ (I=1,2, $\cdots$,n-1) can be got when the (I+1)th factor is compared with the Ith factor. We can get the result at last:

$$Ai = \frac{\bar{\mu}_{ai}}{\sum_{i=1}^{n} \bar{\mu}_{ai}} \qquad (\mathrm{I}=1,2, \cdots ,n-1)$$

Here: $\bar{\mu}_{a1} = 1$; $\bar{\mu}_{a2} = \mu_{a2,1}$; $\cdots$; $\bar{\mu}_{ai} = \mu_{a2,1} \times \mu_{a3,2} \times \cdots \times \mu_{ai,I-1}$; $\cdots$; $\bar{\mu}_{an} = \mu_{a2,1} \times \mu_{a3,2} \times \cdots \times \mu_{an,n-1}$. It can be shown in table 5:

Table 5 The weight of factors

Factor μ_a	Comparison in rank		$\bar{\mu}_{ai}$	Weight Ai
Reliability	1	---	1 .00	0.21
Maintenance degree	0.9	1	0.90	0.19
Inspection	1	0.8	0.72	0.15
Operation	0.9	1	0.65	0.14
Vibration	1	0.8	0.52	0.11
Noise	0.9	1	0.47	0.10
Satisfied degree	1	---	0.47	0.10

The assessment result (μ_c) can be got with factor set • assessment matrix。 But here we only consider the affection of a module or considering engine room as a whole. The affection of all modules must be considered when assessment of the ship is done because there are many modules in actual engine room. Suppose there are m modules in ship, the assessment result of each module can be obtained:

$$\mu_{cj} = \mu_{aj} \bullet \mu_{rj} \qquad (j=1,2, \cdots , m)$$

the matrix can be obtained:

$$\mu_c = (\mu_{c1}, \mu_{c2}, \cdots, \mu_{cm})^T$$

The weight of each module must be considered because each module has a different important degree in ship. The weight can be obtained based on the ranking of modular importance degree in literature 2 and the method to determine the weight above mentioned. It can be represented with μ_y:

$$\mu_y = (\mu_{y1}, \mu_{y2}, \cdots, \mu_{ym}).$$

Table 6 The weight of modules

Module	Comparison in rank		$\bar{\mu}_{aj}$	Weight μ_y
Generator set module	1	---	1.00	0.11
Main engine module	1	1	1.00	0.11
Integrated cable module	1	0.9	0.90	0.10
Fuel oil module	0.9	1	0.81	0.09
Starting and con. Module	1	1	0.81	0.09
Lub. Oil module	1	1	0.81	0.09
H.T. fresh water module	1	0.8	0.65	0.07
Integ. ventilation module	0.9	1	0.59	0.06
Sea water module	1	0.9	0.53	0.06
Engine control module	1	1	0.53	0.06
L.T. fresh water module	1	0.9	0.48	0.05
Boiler module	0.8	1	0.38	0.04
Air compressor module	1	1	0.38	0.04
Ballast water module	1	0.7	0.27	0.03
Fresh water module	0.7	1	0.19	0.02

The assessment result can be obtained after considering all modules and all factors of importance degree. It can be represented with μ_e:

$$\mu_e = \mu_y \bullet \mu_c$$

It may be known that the effectiveness is belonged to good or bad after the result is compared with alternative set μ_d.
Because the assessed result is not right equal to the value of alternative set the best –fit method may be used to resolve this problem.

3 The classification of modular effectiveness

The method uses distance between μ_e and each of the effectiveness expression to represent the degree to which μ_e is belong to each of them[1,2,3]. The distance can be defined as follows:

$$d_1(\mu_e, \text{very}) = \left[\sum_{l=1}^{7}\left(\mu_e^l - \mu_{very}^l\right)^2\right]^{1/2}$$

$$d_2(\mu_e, \text{good}) = \left[\sum_{l=1}^{7}\left(\mu_e^l - \mu_{good}^l\right)^2\right]^{1/2}$$

$$d_3(\mu_e, \text{average}) = \left[\sum_{l=1}^{7}\left(\mu_e^l - \mu_{average}^l\right)^2\right]^{1/2}$$

$$d_4(\mu_e, \text{poor}) = \left[\sum_{l=1}^{7}(\mu_e^l - \mu^l{}_{poor})^2\right]^{1/2}$$

The smaller the d is ,the closer the μ_e is. The μ_e is just same as the jth expression of alternative set if d is equal to zero.
Suppose D is the smallest among the obtained distances and let η_1, η_2, η_3 and η_4 represent the reciprocals of the relative distances between the identified fuzzy effectiveness description μ_e and each of defined alternative set with reference to D. η_j can be defined as follows:

$$\eta_j = \frac{1}{d_j / D} \qquad j = 1, 2, 3, 4$$

then η_j cab be normalized by:

$$\theta_j = \frac{\eta_j}{\sum_{m=1}^{4}\eta_m} \qquad j = 1, 2, 3, 4$$

Each θ_j represents the extent to that μ_e belongs to the jth defined alternative set expression if μ_e completely belongs to the jth expression then θ_j is equal to 1 and others are to 0. The sum of values of these indices for μ_e is equal to 1,i.e. $\sum_{j=1}^{4}\theta_j = 1$. Thus θ_j can be viewed as a degree of confidence that μ_e belongs to the jth effectiveness expression.

4 The result of evaluation

SYOU YOU MARU is a vessel of 1600 ton built in 1997, partly used modules in engine room. Now we use fuzzy function to assess its effectiveness.
Sea water module, ballast water module, high temperature fresh water module, fresh water system module, air compressor module and lubricating oil purifier module are used in SYOU YOU MARU, we get the Table7 and Table 8 about modular ship and no-modular ship through investigation.

Table 7 The investigated result of SYOU YOU MARU

Items	Sea water module	Ballast water module	High temperature fresh water module	Fresh water system module	Air compressor module	Lube. Oil purifier module
Vibration	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.1 0.4 0.5 0.6 0.15 0
Noise	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.25 0.5 0.85 0.20 0
Operation	0 0 0 0.5 1 0.25 0	0 0 0 0.3 0.6 0.2 0.4	0 0.1 0.25 0.5 0.85 0.20 0	0 0 0 0.5 1 0.25 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0 0 0.4 0.80 0.2 0.2
Inspection	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.25 1 0.5 0 0 0	0 0.1 0.25 0.5 0.85 0.20 0
Reliability	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.2 0.75 0.5 0.25 0.1 0
Maintenance degree	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.25 1 0.5 0 0 0	0 0.1 0.4 0.5 0.6 0.15 0
Satisfied degree	0 0.1 0.25 0.5 0.85 0.20 0	0 0 0 0.4 0.80 0.2 0.2	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.1 0.25 0.5 0.85 0.20 0

We can get the result of effectiveness evaluated based on mentioned above method using these data.
The result of no-modular ship is [(0.1832, 'very good'), 0.2362,'good'], (0.3900,'average'), (0.1905,'poor')].
The result of modular ship is [(0.1856, 'very good'), 0.4090,'good'],

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(0.2266,'average'),(0.1789,'poor')].
Therefore the effectiveness of modular ship can be evaluated as "good" and the effectiveness of no-modular ship can be evaluated as "average".

Table 8 The investigated result of no-modular ship

Items	Sea water module	Ballast water module	High temperature fresh water module	Fresh water system module	Air compressor module	Lube. Oil purifier module
Vibration	0 0.25 1 0.5 0 0 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.15 0.55 0.5 0.45 0.15 0
Noise	0 0.2 0.75 0.5 0.25 0.1 0	0 0.1 0.25 0.5 0.85 0.20 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.1 0.4 0.5 0.6 0.15 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.1 0.4 0.5 0.6 0.15 0
Operation	0 0.2 0.75 0.5 0.25 0.1 0	0.45 0.60 0.45 0.20 0 0 0	0 0.25 1 0.5 0 0 0	0 0.25 1 0.5 0 0 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.25 1 0.5 0 0 0
Inspection	0 0.15 0.55 0.5 0.45 0.15 0	0.2 0.35 0.85 0.40 0 0 0	0 0.25 1 0.5 0 0 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.25 1 0.5 0 0 0	0 0.25 1 0.5 0 0 0
Reliability	0 0.2 0.75 0.5 0.25 0.1 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0
Maintenance degree	0.2 0.35 0.85 0.40 0 0 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.2 0.75 0.5 0.25 0.1 0	0 0.1 0.4 0.5 0.6 0.15 0	0.2 0.35 0.85 0.40 0 0 0
Satisfied degree	0 0.2 0.75 0.5 0.25 0.1 0	0.2 0.35 0.85 0.40 0 0 0	0.2 0.35 0.85 0.40 0 0 0	0 0.15 0.55 0.5 0.45 0.15 0	0 0.15 0.55 0.5 0.45 0.15 0	0.6 0.45 0.4 0.2 0 0 0

5 Conclusion

The modular effectiveness of SYOU YOU MARU is better than no-modular ship through above calculation. But now we couldn't say the effectiveness of modular ship is better than no-modular ship because part of modules are only used in SYOU YOU MARU, we must evaluate an all modularized ship if we want to get an accurate result of modular effectiveness.
The method proposed in this paper can also be used in other engineering evaluations.

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