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Application of Optimal Combination Weights in Supplier of Ship Industry

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Abstract

Manufacturers of ship industry always have more than one supplier evaluation index systems, which are still not standard in China. Based on the principle of observation, through the theoretical research and field investigation, we build a supplier evaluation index system made up of 21 tertiary indicators of ship industry. We adopt the optimal combination weight which composes of G1, G2, entropy value weight and deviation to investigate the case study. We find that the lead indicators of ship industry to choose suppliers are technology design, research and development, technical service and support, competitive price and quick response ability.

Keywords: *optimal combination weight; ship industry; supplier evaluation*

1. Introduction

Shipbuilders in China have not formed a complete system of supplier management physique, but also there is no uniform supplier evaluation index system [1]. The selection of suppliers should be based on a variety of criteria to evaluate, rather than a simple factor of cost [2]. There are few papers investigate supplier selection index in shipbuilder industry, but is a large number of scholars has carried on the index system of supplier and supplier evaluation weight in supply chain management. Meng Chen (2014) consider that making order preference similarity was proposed for the ideal solution (TOPSIS) supplier selection model to determine the combination of supplier evaluation index weights [3]. Xianwu Hu (2013) establish the evaluation index system based on AHP small and medium-sized enterprise and then use AHP decide the weight of each evaluation index [4]. Chen Zhizong provides a weight dependent on super efficiency DEA model with integrated advantages context-dependent DEA and super efficiency DEA [5]. Mou-Yuan Liao adopts fuzzy inference to deal with testing of cpk. Jianyong Bai constructs a supplier evaluation index system from four aspects such as customer satisfaction, enterprise operating condition, the financial condition of enterprise and enterprise development prospect, using principal component analysis for the index system application [6]. Xuhui Duan uses AHP to comprehensively evaluate the system which was established including four primary index and seven sub-indicators [7]. Ma Shihua chooses quality, cost and delivery time to build supplier evaluation of gray correlation model [8]. Huang Bo presents an optimal combination determining weights weight for supplier evaluation which contains of minimize the weighted and sum of squared deviations criterion [9]. The scholars are using a single weight or a simple combination of the two weights for supplier evaluation studies, thus we have two problems to be solved. (1) the ship industry supplier evaluation to be determined, (2) the improvement of the evaluation weight in the shipbuilder industry suppliers.

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2. Index System Construction

2.1. Foundation and Basis of Shipping Industry Supplier Evaluation Index System

Xiong Ye builds supplier evaluation index system of Chinese ship enterprises in 2003. Based on it, we modify and construct ship industry supplier evaluation system. The system, which is built by Xiong Ye [1] is shown in Figure 1.

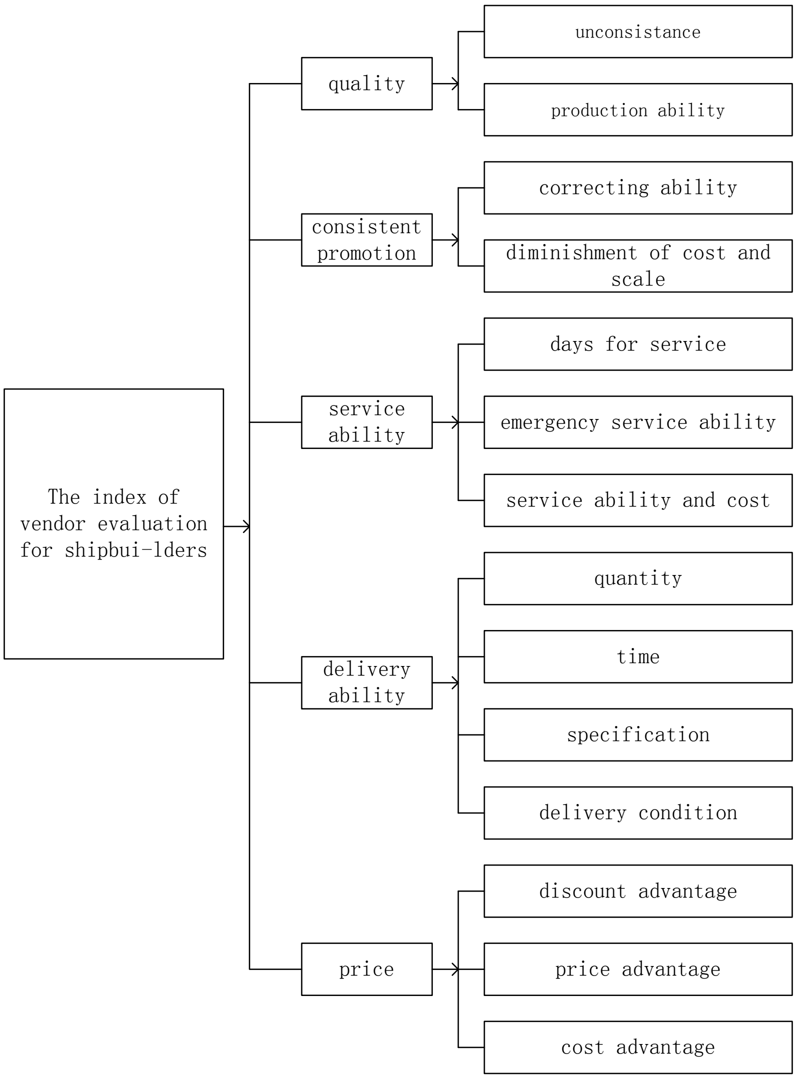

Figure 1. Supplier Evaluation Index System of Chinese Ship Enterprises

Based on principles of observation, we build a suppliers evaluation index system which applies to shipbuilder industry with considering current realities in ship industry development and the ship enterprise supplier evaluation system.

2.2. Shipbuilder Industry Supplier Evaluation Index System Construction

We build three-level indicators from five aspects which are technical level, quality, price, deliver, and service. The specific indicators are shown in Table 1.

Table 1. Ship Industry Supplier Evaluation Index System

first class	second class	third class index	index explanation
technology	design and R&D	R/D investment	annual investment on R&D （ten thousand yuan）
		products quantity	quantity of products
	service and support	quantity of technology service	quantity of service provided by supplier
		number of service staff	number of workers of on-site technical service
		service level	
quality	product quality	qualified rate	qualified material lot/total material lot
		inspection tolerance	factual specification/design specification
		rate of complaint	number of complaint/total number of product
	work quality	quality of quality certificates	the number of certificates justified by classification society
		matching degree	factual certificates/total certificates
price	price competitiveness	discount	discount on the quantity
		price	1 for high-end and 0 for low-end
	price tendency	change with industry price	supplier price/average price in industry
		change with macro-economy	rate of price change/rate of PPI
delivery	arrive on time	products arrive on time	quantity of arrived material/quantity of material on plan
		certificates arrive on time	quantity of arrived certificates/quantity of certificates on plan
	Flexible delivery capabilities	emergency	[(quantity of material for emergent purchase/actual quantity of material provided)+(time of material for emergent purchase/actual time of material provided)]*1/2
service	Non-service rapid response capability	emergency	emergent on-site service time/actual time
		not emergency	not emergent on-site service time/actual time
	after-sale service	service time	1 for quick service time and 2 for others
		service cost	1 for low service cost and 2 for others

Technical design and development. We examine all product development and design capability of the supplier about whether they meet the industry requirements.

Technical service and support. Shipbuilder's need for the production and use of devices require on-site or remote technical service and support. This ability is mainly on whether the supplier can provide their products with a positive and effective technical service and support.

Product quality. We test pass rate to test the tolerance of the product and the product history of complaints percentage. Then we provide a test to examine the supplier's product quality issues.

Work quality. Suppliers quality is reflected in the quality of work, including two kinds of indicators which are the product quality and work quality.

Price competitiveness. Prices directly affect the cost of ship. We study the important indicators about quantity discounts as well as its bid to evaluate the price competitiveness.

Price tendency. Price stability will indirectly affect ship costs. Supplier product prices changes with the industry price and the economic situation. When price stability is high, it will be more conducive for the shipyard to purchase.

Arrive on time. All business operations are orders of ship enterprises, because of its strict deadlines require the shipyard has a very detailed plan of production. The procurement plan is also in accordance with the detailed planning of the production plan. Therefore, the delivery time will affect the shipyard's delivery. We use the arriving time of certificates and goods to calculate the supplier arrival rate.

Flexible delivery capabilities. Due to design changes or other reasons, the shipyard will make some urgent procurement. We look at supplier's ability to deliver flexible fit.

Non-service rapid response capability. Shipyard ship will require the supplier to provide on-site service and technical support for be some devices, this indicator examines the emergency and non-emergency services provided by suppliers of rapid response capabilities.

After-sales service，we consider the service capacity of ship industry suppliers from two aspects of time and cost of service.

3 Evaluation Weights Selection

We use the weight which is used by Chi Guotai to evaluate the index combination. This weight uses G1, G2, entropy weights and dispersion index weighting weight. And different weights with different weight coefficients obtain combination weighting, and finally obtain the supplier evaluation scores. Optimal combination determining weights weight could be reflected from the subjective and objective aspects to evaluate accurately.

Determine the weight of G1. Firstly we use G1 weight to determine the index of the order. Experts assign rational values r_k of the importance of adjacent indicators x_{k-1} and x_k, then we use formula 1 to obtain the m index of G1 weights, obtain the weights of other indicators from weight w_m) by the formula [10-11] $w_{k-1} = r_k w_k, (k = m, m-1, \cdots, 1)$.

$$w_m = (1 + \sum_{k=2}^{m} \prod r_k)^{-1} \tag{1}$$

Determine the weight of G2. We use G2 weight to determine the index of the order. Only one of the most important targets in mind for x_m is given by experts and then we get the level of importance a_k between indexes x_k and x_m. The index weights are shown in the formula 2 [10].

$$w_k = a_k / \sum_{k=1}^{m} a_k \tag{2}$$

Principle of entropy weight.

$$w_k = \frac{1-e_j}{n-\sum_{i=1}^{n} e_i} = \frac{1+\frac{1}{\ln(n)}\times\sum_{i=1}^{n}[x_{ik}/\sum_{i=1}^{n}x_{ik}]\times[\ln(x_{ik}/\sum_{i=1}^{n}x_{ik}]}{\sum_{k=1}^{m}\{1+\frac{1}{\ln(n)}\times\sum_{i=1}^{n}[x_{ik}/\sum_{i=1}^{n}x_{ik}]\times[\ln(x_{ik}/\sum_{i=1}^{n}x_{ik}]\}} \tag{3}$$

$f_{ij} = x_{ij} / \sum_{i=1}^{n} x_{ij}$ is j share of feature in the i system index, x_{ij} is j index data in the i system, $\sum_{i=1}^{n} x_{ij}$ is j index sum of all the observations of the system.

Determine the weight of the maximizing deviation weight.

$$w_i = \frac{\sum_{j=1}^{n}\sum_{k=1}^{n}|p_{ij}-p_{ik}|}{\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{n}|p_{ij}-p_{ik}|} \tag{4}$$

Determine the combination weight[10-11].

$$a_k = \frac{\exp\{-[1+\mu\sum_{i=1}^{n}\sum_{j=1}^{m} w_j^k(1-z_{ij})/(1-\mu)]\}}{\sum_{k=1}^{l}\exp\{-[1+\mu\sum_{i=1}^{n}\sum_{j=1}^{m} w_j^k(1-z_{ij})/(1-\mu)]\}} \tag{5}$$

Calculate the final scores of ship industry.

$$R = W^T \times X = (r_1, r_2, r_3, \cdots, r_n) \tag{6}$$

4. Case Study

4.1. Data Selection

We select a sample of ten suppliers of ship material, based on actual research to obtain the following data, as shown in Table 2.

Table 2. Initial Data of NN Supplier for MM Shipbuilder

No.	Index	SR	GL	LG	H8	CW	JG	SG	XG	WG	BC
1	S_1	380	260	400	386	271	200	507	253	461	327
2	S_2	807	536	782	671	508	426	1056	400	867	723
3	F_1	256	327	463	382	213	200	578	203	435	387
4	F_2	2	3	3	3	2	2	4	3	4	4
5	F_3	0.8	0.75	0.85	0.8	0.7	0.7	0.85	0.8	0.8	0.85
6	C_1	0.92	0.98	0.97	0.95	0.94	0.9	0.93	0.9	1	0.95
7	C_2	0.95	0.93	0.92	0.95	0.9	0.93	0.9	1	0.9	0.94

8	C_3	0.07	0.03	0.08	0.1	0.04	0.08	0.06	0.1	0.1	0.09
9	G_1	3	3	2	3	2	4	3	2	3	3
10	G_2	0.98	0.95	0.9	0.92	0.95	0.92	0.97	1	1	0.93
11	J_1	0.85	0.9	0.85	0.85	0.9	0.95	0.85	0.9	0.9	0.9
12	J_2	1	1	0	1	1	1	0	1	1	0
13	Q_1	0.92	0.9	0.93	0.85	0.95	0.97	0.9	0.9	1	0.95
14	Q_2	0.87	0.83	0.88	0.9	0.95	0.87	0.82	0.9	0.9	0.9
15	H_1	0.96	0.97	0.97	0.95	0.95	0.9	0.94	1	1	0.95
16	H_2	0.9	0.92	0.93	0.95	0.93	0.96	0.95	1	0.9	0.95
17	T_1	0.85	0.84	0.8	0.85	0.9	0.85	0.87	0.9	0.9	0.87
18	K_1	0.7	0.72	0.78	0.75	0.75	0.71	0.75	0.8	0.8	0.78
19	K_2	0.82	0.83	0.85	0.82	0.85	0.85	0.83	0.9	0.9	0.81
20	W_1	1	1	0	1	1	0	1	0	1	1
21	W_2	1	0	1	0	0	1	1	0	1	1

4.2. Data Standarization

Due to the unstandardized data, normalization is required to evaluate operations and normalize the index. The metrics data is as shown in the following table. Furtherrmore, as the limited paper space. This paper only gives out the major data.

Table 3. Standard Data of NN Supplier for MM Shipbuilder

No.	Index	SR	GL	LG	H8	CW	JG	SG	XG	WG	BC
1	S_1	0.586	0.195	0.651	0.606	0.231	0.000	1.000	0.173	0.850	0.414
2	S_2	0.620	0.207	0.582	0.413	0.165	0.040	1.000	0.000	0.712	0.492
3	F_1	0.148	0.336	0.696	0.481	0.034	0.000	1.000	0.008	0.622	0.495
4	F_2	0.000	0.500	0.500	0.500	0.000	0.000	1.000	0.500	1.000	1.000
5	F_3	0.667	0.333	1.000	0.667	0.000	0.000	1.000	0.333	0.667	1.000
6	C_1	0.250	1.000	0.875	0.625	0.500	0.000	0.375	0.250	0.625	0.625
7	C_2	0.000	0.400	0.600	0.000	1.000	0.400	1.000	0.000	0.800	0.200
8	C_3	0.429	1.000	0.286	0.000	0.857	0.286	0.571	0.286	0.429	0.143
9	G_1	0.500	0.500	0.000	0.500	0.000	1.000	0.500	0.000	0.500	0.500
10	G_2	1.00	0.62	0.00	0.25	0.62	0.25	0.87	0.62	1.00	0.37

		0	5	0	0	5	0	5	5	0	5
11	J_1	1.000	0.500	1.000	1.000	0.500	0.000	1.000	0.500	1.000	0.500
12	J_2	0.000	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000
13	Q_1	0.538	0.385	0.615	0.000	0.769	0.923	0.385	0.615	1.000	0.769
14	Q_2	0.385	0.077	0.462	0.615	1.000	0.385	0.000	0.538	0.615	0.615
15	H_1	0.750	0.875	0.875	0.625	0.625	0.000	0.500	0.625	1.000	0.625

4.3. Data Calculation

Require experts to order ten secondary indexes (s for X_1,F for X_2,C for X_3,G for X_4,J for X_5,Q for X_6,H for X_7,T for X_8,K for X_9,W for X_{10}) . Then we obtain a subjective order of precedence ordering, which as follows. $X_1 > X_2 > X_3 > X_4 > X_5 > X_6 > X_7 > X_8 > X_9 > X_{10}$.

According to expert opinion, the criticality RJ between adjacent secondary indicators Xk-1 and Xk is concluded.,R_2= X_1/X_2=1.2, R_3= X_2/X_3=1.1, R_4= X_3/X_4=1.1, R_5= X_4/X_5=1.1, R_6= X_5/X_6=1.1, R_7= X_6/X_7=1.1, R8= X_7/X_8=1.1, R_9= X_8/X_9=1.1, R_{10}= X_9/X_{10}=1.1.

We insert X_{k-1} and the adjacent secondary indicators X_k and R_J (j=2,3 ... 10) into formula 1 to calculate G_1 weights. Similarly three indicators can be obtained for secondary indicators. Three indicators on the target layer are obtained by weighting listed in Table 4.

Table 4. G_1-weight Weight of Standard Data of NN Supplier for MM Shipbuilder

number	index	weight	number	index	weight
1	S_1	--	12	J_2	J_1/J_2=1.6
2	S_2	S_1/S_2=1.2	13	Q_1	--
3	F_1	--	14	Q_2	Q_1/Q_2=1.6
4	F_2	F_1/F_2=1.2	15	H_1	--
5	F_3	F_2/F_3=1.1	16	H_2	H_1/H_2=1.4
6	C_1	--	17	T_1	--
7	C_2	C_1/C_2=1.4	18	K_1	--
8	C_3	C_2/C_3=1.3	19	K_2	K_1/K_2=1.3
9	G_1	--	20	W_1	--
10	G_2	G_1/G_2=1.5	21	W_2	W_1/W_2=1.5
11	J_1	--			

Employs other weights, we get other weights in Table 5.

Substitute the weights in Table 5 to get the coefficients ai, then we combine the above weights and result combinations into the formula $w_i = \sum_{k=1}^{l} x_k w^k$, listed in table 5 the 8th column.

Table 5. Weights and Combined Weight of Standard Data

number	second class index	third class index	G1	G2	entropy	deviate	Combined weight
1	S	S_1	0.082	0.084	0.074	0.061	0.073
2		S_2	0.069	0.056	0.081	0.076	0.074
3	F	F_1	0.049	0.044	0.076	0.067	0.064
4		F_2	0.041	0.041	0.077	0.093	0.071
5		F_3	0.037	0.032	0.092	0.085	0.073
6	C	C_1	0.05	0.044	0.074	0.082	0.069
7		C_2	0.036	0.036	0.08	0.075	0.065
8		C_3	0.028	0.030	0.063	0.079	0.058
9	G	G_1	0.062	0.061	0.069	0.07	0.067
10		G_2	0.042	0.041	0.079	0.083	0.069
11	J	J_1	0.058	0.056	0.082	0.063	0.069
12		J_2	0.036	0.038	0.077	0.064	0.061
13	Q	Q_1	0.053	0.083	0.073	0.078	0.072
14		Q_2	0.033	0.035	0.083	0.087	0.069
15	H	H_1	0.046	0.060	0.065	0.091	0.069
16		H_2	0.033	0.034	0.064	0.071	0.057
17	T	T_1	0.071	0.086	0.079	0.077	0.078
18	K	K_1	0.036	0.050	0.084	0.086	0.072
19		K_2	0.028	0.061	0.091	0.087	0.075
20	W	W_1	0.035	0.041	0.061	0.073	0.058
21		W_2	0.024	0.037	0.063	0.062	0.053

Substitute weights obtained in table 5 and standardized values in Table 3 into formula 6, we obtain each secondary index score and rank, as shown in Table 6.

Table 6. Grades and Rank for Suppliers

No.	score		grades and rank									
			SR	GL	LG	H8	CW	JG	SG	XG	WG	BC
1	total	score	0.526	0.608	0.822	0.632	0.668	0.423	0.931	0.666	0.947	0.777
		rank	9	8	3	7	5	10	2	6	1	4
2	S	score	0.089	0.03	0.091	0.075	0.029	0.003	0.147	0.013	0.115	0.067
		rank	4	7	3	5	8	10	1	9	2	6
3	F	score	0.058	0.081	0.153	0.115	0.002	0	0.208	0.06	0.159	0.176
		rank	8	6	4	5	9	10	1	7	3	2
4	C	score	0.042	0.153	0.116	0.043	0.149	0.043	0.124	0.034	0.12	0.064
		rank	9	1	5	7	2	7	3	10	4	6
5	G	score	0.104	0.078	0	0.052	0.043	0.086	0.095	0.043	0.104	0.06
		rank	1	5	10	7	8	4	3	8	1	6
6	J	score	0.069	0.035	0.13	0.069	0.035	0	0.13	0.035	0.069	0.096
		rank	4	8	1	4	8	10	1	7	4	3
7	Q	score	0.065	0.033	0.076	0.042	0.124	0.093	0.028	0.081	0.114	0.098
		rank	7	9	6	8	1	4	10	5	2	3
8	H	score	0.052	0.079	0.089	0.091	0.072	0.057	0.082	0.091	0.069	0.091
		rank	10	6	4	1	7	9	5	1	8	1
9	T	score	0.039	0.031	0	0.039	0.078	0.039	0.055	0.07	0.078	0.055
		rank	6	9	10	6	1	6	4	3	1	4
10	K	score	0.009	0.037	0.11	0.054	0.083	0.047	0.064	0.128	0.12	0.072
		rank	10	9	3	7	4	8	6	1	2	5
11	W	score	0	0.053	0.058	0.053	0.053	0.058	0	0.111	0	0
		rank	7	4	2	4	4	2	7	1	7	7

4.4. Data Analysis

From the figure above, we find that for MM, WG, SG, and LG are the top 3 suppliers, which are consist with the results of current evaluation. For the current evaluation weight is naively weight, it can be concluded that evaluation weight is more comprehensive and accurate.

After analyzing each second index in the analysis of scoring and sorting, we can see that technology design and research and development (S), technical service and support (F), price competitiveness (J) and rapid response ability (K) are of the top three scores ranking and total score ranking. It also reflects the characteristics of shipping industry. The ship industry requires high security. S and F two indicators show good technology development and technical support to ensure the high security of the ship. The price competitiveness (J) embodies the demand of ship industry to control costs. The last of after-sales quick reaction capability meet the requirement of the shipping industry (K) just in time delivery order demand. Only a quick response makes the shipyard timely delivery to the owner. After-sales service (W) ranks different, because the shipyard will be delivered to the ship owner and the use of geographic range is very wide. So the shipyard for important equipment suppliers generally chooses the foreign suppliers, decreasing the importance of after-sale.

5. Conclusion

The index which is selected in this paper is a combination of theory and practice, more closely to the actual situation. And results are also able to provide the basis for shipping industry to choose suppliers, which indicates that the established supplier evaluation weight is more objective, scientific. After our preliminary site investigation and in-depth theoretical study, we have established a supplier evaluation index system composed of 21 tertiary indexes in the ship industry. We use the optimal combination weight to study the problem, and the method including G1, G2, entropy value weight and deviation. Through empirical research, we find that technology design, research and development, technical service and support, competitive price and quick response ability are the lead indicators when the Chinese ship industry chooses suppliers.

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