Research on the Supplier Evaluation Based on the Internet of Things

Yamin Ji[1, 2], Dazhuang Wu[1, a, *], and Chunming Yang[1]

[1]University of Chinese Academy of Sciences, Beijing, China

[2]Institutes of Science and Development, Chinese Academy of Sciences, Beijing, China

[a]wudazhuang16@mails.ucas.edu.cn

*Corresponding author

Keywords: Supplier Evaluation, Internet of Things, Life Cycle Cost

Abstract: With the development of new technologies such as the Internet of things, there are more and more studies on the life prediction and fault frequency of equipment through the detection of equipment operating status. Relying on these technologies, it makes the life cycle cost estimate of the materials and goods become possible. At the same time, the objectivity of maintenance data provides the new basis for the evaluation of supplier performance. Under this circumstance, this paper proposes a supplier evaluation system optimization scheme based on the Internet of things.

1. Introduction

Many scholars have expounded the supplier evaluation index system. Dickson put forward 23 indexes [1] of supplier selection through the investigation of 170 enterprises in 1996. Weber studied the literatures from 1967 to 1990, sorted the order of the 23 indexes and discriminated the importance of those indexes. The most important three indexes are price, delivery and quality [2]. William Ho analyzed the journal articles published between 2000 and 2008 and summarized the evaluation indexes of the journal articles. The major evaluation indexes are quality, delivery and price [3]. The other indexes include manufacturing capacity, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, safety and environmental. In addition, with the enhancement of the environmental awareness and the vigorous development of the concept of green supplier in recent years, Govindan summarized the literatures on articles of green supplier selection. Under the concept of green supplier, some new evaluation indexes are put into the supplier evaluation, such as environmental management system. Its secondary evaluation indexes include green image, environmental performance, environmental protection capability, environmental protection design, social responsibility, environmentally friendly materials, environmental protection promotion costs, etc [4].

The theory of life cycle has been widely applied in the engineering construction field and the electric power industry this year. Banar proposed the life cycle cost management theory in 2009, calculated the city waste processing cost by using this theory and then proposed the optimal management strategy on this basis [5]. Laxman improved the cost evaluation method and proposed the new theories [6] of equipment life cycle cost computing by using data such as the mean time between failures (MTBF), mean time to failure (MTTF) and the mean time to repair (MTTR), etc. Other scholars have respectively studied [7-10] the different life cycle costs, cost transmission relation, life cycle cost optimization control, etc. At present, it is generally believed that the cost structure of large-scale equipment during maintenance stage may account for more than one half of the life cycle cost. But it still faces many difficulties on how to apply the maintenance stage cost for estimation. At present, with the development of the Internet of things, artificial intelligence and other technologies, more and more studies focus on the life prediction and fault frequency estimation of the equipment through the detection of equipment operating status. Under this circumstance, it makes the replacement of the life cycle cost with supplier quotation and the replacement of maintenance data with subjective quality evaluation become possible.

In the aspect of analysis method, we need to take into account of various indexes for supplier selection. Therefore, it is multiple decision-making in essence. Previously, typical multi-objective decision method has been used for the solution of these problems, such as analytic hierarchy process (AHP). In recent years, with the emergence of the new and advanced method, more objective methods have been applied to solve this problem. William Ho conducted classification and statistics of the methods with these 78 literatures. The independent methods include data envelopment analysis, mathematical programming, analytic hierarchy process, case-based reasoning, network analysis, fuzzy set theory, genetic algorithms, SMART, etc [3]. Later, Junyi Chai analyzed the 123 journal articles between 2008 and 2012 and listed 7 application environments and three categories (multi-objective decision-making, mathematical programming, and artificial intelligence), 26 decision-making methods, and presented the representative articles of each method [11]. Therefore, under the circumstance of the mature new technologies, such as the Internet of things, it is of a certain practical significance on how to evaluate the supplier objectively by using these new technologies.

2. Multilayer supplier evaluation index system

The state-owned enterprise is taken as an example. At present, the company is mainly responsible for the relevant qualification evaluation of the suppliers and evaluation of the supply quality and compliance by means of the subjective scoring. It monitors the supplier's delivery and material quality put into use by introducing the Internet of things and other emerging technologies, thus re-establishing the supplier evaluation index system by using these data.

2.1 Life cycle cost estimated model

In the aspect of supplier material quotation, the life cycle cost estimated model has been set up by using the operation and maintenance information of the supplier history material supply. The life cycle cost of the supplier materials is estimated and the result is regarded as the supplier's final quotation.

The life cycle cost of the grid equipment can be divided into the following parts, tendering and bidding cost, purchasing cost, warehousing and transportation cost, operation and maintenance cost, failure loss cost and scrap cost. Due to the small differences of the tendering and bidding cost, warehousing and transportation cost, and scrap cost of the supplier's same materials, this model aims to make a comparison of the product life cycle costs of the different suppliers for the consideration of the purchasing cost, operating and maintenance cost and failure loss cost. Based on the construction of the above model, the total cost accounting method of this model is as follows.

$$\mathrm{C} = C_1 + \frac{(C_2 + C_3)[(1+i)^t - 1]}{i(1+i)^t} \tag{1}$$

Among them, C_1 is the purchasing cost, C_2 is the operation and maintenance cost, C_3 is failure loss cost. i is the discount rate. t is the life span of the materials.

$$C_2 = C_0 \times p \tag{2}$$

Among them, C_0 is the equipment investment, which can be replaced by the equipment purchase state-set price range. P is the annual maintenance rate of the equipment.

$$C_3 = \frac{1}{n}\sum_{j=1}^{n}\left(a \times W_j \times T_J + b_j \times RC_J \times MTTR_J\right) \tag{3}$$

Among them, a is the electricity price in this region. W_j is the equipment interruption power of equipment j. T_j is the annual fault interruption time of equipment j. b_j is the mean failure rate of equipment j. RC_j is the mean repair cost of equipment j. $MTTR_j$ is the mean time to repair of equipment j.

2.2 Supplier performance evaluation index system

In the aspect of supplier performance evaluation, the supplier performance evaluation index system is set up in the four stages, i.e., delivery, transportation delivery, installation debugging and production running according to the bidding and purchasing business flow and it is scored by using performance information. It is more objective than the subjective scoring. The specific index system is shown in the table below.

Table.1. Supplier performance evaluation index system

	Index	Index value	Score
Original index	Production running qualification	[0-2)%	(19,20]
		[2-5)%	(17,19]
		[5-10)%	(12,17]
		>10%	(0,12]
	After-sales service	Excellent	(14,15]
		Good	(12,14]
		Medium	(10,12]
		Poor	(0,10]
New index	Running failure time ratio	[0-0.1)%	(19,20]
		[0.1-0.3)%	(17,19]
		[0.3-0.5)%	(12,17]
		>0.5%	(0,12]
	Mean service time	[0,1) day	(14,15]
		[1,2) days	(12,14]
		[2,4) days	(10,12]
		>4 days	(0,10]

3. Example analysis

3.1 Life cycle cost estimated model

The transformer of a certain transformer substation is taken as an example. Currently, the transformer substation has one transformer respectively from supplier A and B. The transformer form supplier A is the conventional transformer. Due to the installation of the vacuum capsule oil storage tank, sealing parts and other upgraded parts, the transformer from supplier B has the low wear and tear and decrease of maintenance cost, but high one-time investment. Now the transformer substation plans to purchase one more transformer according to the history data of the two transformers in operation and the comparison of life cycle cost of the two transformers. The relevant parameters according to the operation and maintenance record are as follows.

Table.2. Transformer life cycle cost estimate parameter information

Parameter name	Supplier A	Supplier B
Supplier quotation /ten thousand yuan	3344	3700
Mean failure rate annually /times	0.61	0.51
Mean failure rate interruption power supply time annually /h	16	13
Mean failure rate interruption power supply power annually /kW	1.2×10^{5}	1.2×10^{5}
Mean time to repair of the equipment /h	9	8
Mean interruption power supply cost /ten thousand yuan /kWh	1.2×10^{-5}	1.2×10^{-5}
Mean repair cost /ten thousand yuan	0.82	0.95

The operation and maintenance costs per year of A and B transformer are respectively calculated according the 3% and 2% of the purchasing cost of the two transformers. The life span of the transformer is 30 years and the discount rate is calculated by 8%.

Table.3. Life cycle cost of the transformer

The unit in the table is ten thousand yuan.

	Purchasing cost C1	Operating and maintenance cost C2	Failure loss cost C3	Total cost C
Supplier A	3344	310.12	1119.57	4773.69
Supplier B	3700	254.43	825.84	4780.27

There are significant decreases of total cost differences of Supplier A and B after the life cycle cost computing due to the increase of upgrading parts of Supplier B and small expenditures of operating and maintenance cost. Life cycle cost can better reflect the total cost of material use. In the existing supplier selection index system, the replacement of the supplier quotation by the life cycle cost estimate result can narrow the scoring differences of the high quality high price supplier and low quality low price supplier and help to select high-quality suppliers on the premise of ensuring the quality of materials.

3.2 Supplier performance evaluation index system

Two suppliers of a certain material are taken as examples. The related data of the new performance index system are shown in the table below according to the statistics of operating and maintenance record.

Table.4. Relevant information of new supplier performance index system.

	Supplier 1	Supplier 2
Total running time in evaluation period (month)	1279	1906
Total failure time in evaluation period (month)	0.02	0.5
Total times of after-sales service	1	4
Total time of after-sales service(day)	0.5	5

The supplier performance scorings of two index systems are calculated respectively according to supplier performance information.

Table.5. Comparison of supplier performance scoring

	Supplier 1		Supplier 2	
	Original index score	New index score	Original index score	New index score
Running fault time ratio	19.96	19.98	19.89	19.74
Mean service time	14.75	14.5	13.21	13.5

The long fault time or postponed after-sales service response caused by the serious quality problems of the supplier’s materials in the supplier performance evaluation index system will reduce the supplier performance scoring. The adjusted performance index system will take into account of bad behaviors of the suppliers, such as the delayed delivery, serious quality problem, etc. The new index system can better reflect the supplier performance when the suppliers have the same times of bad behaviors.

4. Conclusion

This paper puts forward a method of supplier evaluation based on Internet of Things. The relevant information such as the supplier delivery, after-sales service, etc. can be acquired through the supplier chain management and control by using the Internet of things new technologies. These information can be used for supplier evaluation. A more scientific and comprehensive supplier evaluation system can be set up through this method. Under the new supplier evaluation system, we can better evaluate the supplier price, delivery ability and product quality according to the fulfillment of delivery, operating and maintenance data, etc.

Acknowledgments

This work was supported by STATE GRID project - Research on Key Technologies of Optimizing and Promoting Material Supply Chain to Adapt to the New Situation of Electricity Reform and the Development of Emerging Technologies.

References

[1] Dickson G W. An analysis of vendor selection systems and decision [J]. Journal of Purchasing, 1966, 2 (15):1377-1382.W. Strunk Jr., E.B. White, The Elements of Style, third ed., Macmillan, New York, 1979.

[2] Weber C A, Current J R, Benton W C. Vendor selection criteria and methods [J]. European Journal of Operational Research, 1991, 50 (1): 2-18.

[3] Ho W, Xu X, Dey P K. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review [J]. European Journal of Operational Research, 2010, 202 (1): 16-24.

[4] Kannan G, Rajendran S, Sarkis J, Murugesan P, Multi Criteria Decision Making approaches for Green supplier evaluation and selection: A literature review, Journal of Cleaner Production (2013), doi: 10.1016/j.jclepro.2013.06.046

[5] Banar M, Cokaygil Z, Ozkan A. Life cycle assessment of solid waste management options for Eskisehir, Turkey [J]. Waste Management, 2009, 29 (1): 54-62.

[6] Waghmode L Y, Sahasrabudhe A D. Product Life Cycle Cost Modelling? A Suggested Framework [C] // International Conference on Emerging Trends in Engineering & Technology. IEEE, 2008.

[7] Carrubba E R. Integrating life-cycle cost and cost-of-ownership in the commercial sector [C] // Reliability & Maintainability Symposium. IEEE, 1992.

[8] Nahlik M J, Chester M V. Transit-oriented smart growth can reduce life-cycle environmental impacts and household costs in Los Angeles [J]. Transport Policy, 2014, 35:21-30.

[9] Lazzarin R M, Busato F, Castellotti F. Life cycle assessment and life cycle cost of buildings\" insulation materials in Italy [J]. International Journal of Low-Carbon Technologies, 2008, 3 (1): 44-58.

[10] Norris G A. Integrating Life Cycle Cost Analysis and LCA [J]. Int. J. LCA, 2001, 6.

[11] Chai, Junyi, Liu, et al. Application of decision-making techniques in supplier selection: A; systematic review of literature [J]. Expert Systems with Applications, 2013, 40 (10): 3872-3885.