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Research Article

Based on the AHP Small and Medium-Sized Enterprise Supply Chain Supplier Evaluation Research

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Abstract: In this study, we establish the evaluation index system based on the AHP small and medium-sized enterprise and then use AHP decide the weight of each evaluation index. Moreover, we use Linear Weighting Method to study supplier performance from perspective of quantitative research and give the measurement process. The empirical research, to validate the method is scientific and feasible.

Keywords: AHP, decision method, hybrid intelligent system, index system, supply chain, performance evaluation

INTRODUCTION

Many famous scholars from home and abroad put forward their own ideas about research on supply chain performance evaluation from different points of view respectively. The study lists only some representative views.

PRTM, a research institute of supply chain, has put forward 11 indexes, which are delivery performance, order fulfillment, the perfect order fulfillment, response time of supply chain, production flexibility, total logistics management cost, value-added productivity, warranty cost, cash flow turnaround time, inventory turnover days of supply chain and asset turnover, to measure supply chain performance. Bemano has established the system of supply chain performance evaluation from 3 aspects. Resource indexes include: total cost, distribution cost, manufacturing cost, inventory cost and return on investment; output indexes include: sales, profits, order fulfillment rate, on-time delivery, stockout, customer response time, manufacturing lead time, shipping errors and customer complaints; flexibility indexes include: time flexibility, quantity flexibility, product flexibility and mix flexibility. Brewer and Speh (2000) review supply chain performance from 4 aspects, which are targets of supply chain management, the interests of end customers, financial benefits and the development of supply chain management. Professor Roger (1999) thinks customer service quality is the most important index to evaluate overall performance of supply chain. Supply chain performance evaluation is conducted from 10 aspects. Supply indexes: reliability of the supplier and supplier's lead time; transformation indexes: process reliability, processing time and completion status against schedule; transport indexes: order fulfillment rate, replenishment lead time and transport days; demand management indexes: the total inventory cost of supply chain. Mercer, a management consulting company, suggests adopting the following 7 indexes to evaluate performance of the third-party logistics and the third-party suppliers. Those indexes are on-time transportation; on-time delivery; transport accuracy; order fulfillment rate; project fulfillment rate; inventory accuracy and damage rate. Schultz (2003) has a research of keeping SCOR on the supply chain. Beamon (1999) have a research of the measuring supply chain performance. Brewer and Speh (2000) use balanced scorecard to measure supply chain performance. Roger (1999) studies the measurement for measure. Camm *et al*. (1997) analyse the chorman blending OR/MS.

The purpose of this study is to research performance evaluation systems and methods based on the existing domestic and international theories of supply chain performance evaluation. According to features of SMEs' participation in supply chain operation, evaluation index system of supplier selection in supply chain has been established. Finally theories and methods of supply chain performance evaluation of SMEs have been applied to some small enterprise and the result has provided some decision support for upstream partner selection of supply chain of the small enterprise.

ESTABLISH THE HIERARCHICAL MODEL OF SUPPLIER'S PERFORMANCE EVALUATION

In the operating environment with keen competition, the complete supply chain management is an important tool for SMEs to increase their competitiveness. An ideal supplier will bring huge benefits to the supply chain organization. Quality of suppliers will have direct influence over the operating cost of supply chain organization. The daily issue of supply chain management faced by SMEs is to set up an objective and targeted evaluation index system as well

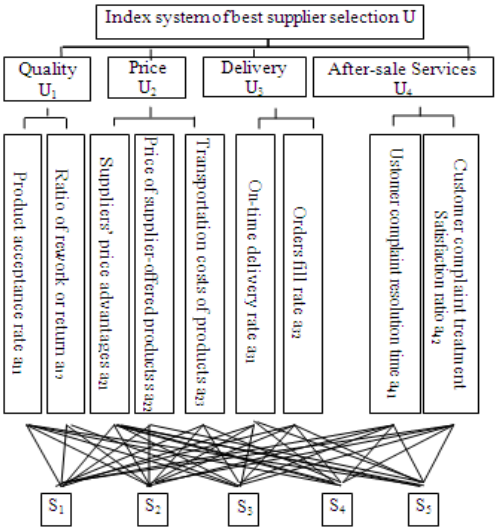

Fig. 1: The hierarchical model of supplier's performance evaluation

as an evaluation model with comprehensive evaluation capacity so as to evaluate good suppliers and develop long-term partnership with them.

Hierarchical model of supplier performance evaluation fit for SMEs as in Fig. 1 has been built according to empirical research on supplier selection of the supply chain of SMEs as well as the hierarchical model of supplier performance evaluation based on the balanced scorecard. Evaluation indexes of SMEs on suppliers generally focus on several parameters such as quality, price, delivery, after-sales service, etc., which can be regarded as the first-class evaluation indexes. Accordingly, second-class evaluation indexes include Product acceptance rate, Ratio of rework or return, suppliers' price advantages, Price of supplier-offered products, transportation cost of products, on-time delivery rate, order fill rate, Customer complaint resolution time, customer complaint treatment satisfaction ratio, etc.

SUPPLIER SELECTION EVALUATION BASED ON AHP AND LINEAR WEIGHTING METHOD

Index systems of performance evaluation above are taken into consideration to calculate weights relative to targets hierarchically and to build hierarchical judgment matrix. Moreover, by matrix multiplication, evaluation on the degree of implementation of the target is made hierarchically from low level to high level, from the index to the criteria and finally to the highest goal. Consistency check on hierarchical sequencing and judgment matrix should be conducted repeatedly until the result is satisfying. Evaluation value of supply chain performance is the sum of product of relative priority ordering of all kinds of indexes considered or the weight of supply chain performance evaluation and the corresponding index.

EMPIRICAL RESEARCH ON SUPPLIER SELECTION EVALUATION

Hangzhou Tianshun Urban Landscape Engineering Co., Ltd. is a professional construction enterprise with the second-class Qualification of Urban Landscape Greening Enterprises. The company has the administrative and finance department, quality and safety department, project management department, landscape design department, business department, nursery base, etc. and there are almost 100 permanent staff who engage in landscape greening design, construction, maintenance and management, etc. For supplier selection evaluation, 5 nursery stocks suppliers are selected as samples to be compared and analyzed. The questionnaire is designed according to established index system and AHP software yaahp Version 0.5.1 is adopted to process some data of empirical research.

Suppose some enterprise adopts 4 indexes, quality, price, delivery and after-sales service, to evaluate suppliers. Alternative suppliers are S1, S2, S3 and S4. Among them,

S1: Hangzhou Xiaoshan Xinjie Qingfang Horticultural Farm
S2: Hangzhou Xiaoshan Xinjie Colorful Horticultural Farm
S3: Zhejiang Yuyao Siming Honest Landscaped Field
S4: Hangzhou Runtu Horticultural Technology Co., Ltd.
S5: Shengzhou Shengda Landscaped Sales Department

1~9 scaling methods are adopted here to determine the relative importance of index (Table 1).

If the result of comparison is between two scales, 2, 4, 6 and 8 can be adopted.

The following calculation can be made first according to data gained to determine weight of each index. Calculate all the following data to three decimal places.

- First figure out sum of each column of pairwise comparison matrix to get the following Table 2, 3, 4, 5 and 6.

Table 1: 1~9 grading scales

Score	Meaning
1	Two targets are of equal importance.
3	One target is more important than the other one.
5	One target is obviously more important than the other one.
7	One target is much more important than the other one.
9	One target is extremely more important than the other one.

Table 2: Total computation table

U	U_1	U_2	U_3	U_4
U_1	1	1/2	2	2
U_2	2	1	3	3
U_3	1/2	1/3	1	1
U_4	1/2	1/3	1	1
∑	4.000	2.167	7.000	7.000

Table 3: Quality computation table

U_1	a_{11}	a_{12}
a_{11}	1	3
a_{12}	1/3	1
$\sum$	1.333	4.000

Table 4: Price survey

U_2	a_{21}	a_{22}	a_{23}
a_{21}	1	2	4
a_{22}	1/2	1	3
a_{23}	1/4	1/3	1
$\sum$	1.750	3.333	8.000

Table 5: Delivery computation table

U_3	a_{31}	a_{32}
a_{31}	1	3
a_{32}	1/3	1
$\sum$	1.333	4.000

Table 6: After-sales service survey

U_4	a_{41}	a_{42}
a_{41}	1	3
a_{42}	1/3	1
$\sum$	1.333	4.000

Table 7: Total computation tables

U	U_1	U_2	U_3	U_4	Weight
U_1	0.250	0.231	0.286	0.286	0.263
U_2	0.500	0.462	0.429	0.429	0.455
U_3	0.125	0.154	0.143	0.143	0.141
U_4	0.125	0.154	0.143	0.143	0.141

Table 8: Quality computation table

U_1	a_{11}	a_{12}	Weight
a_{11}	0.750	0.750	0.750
a_{12}	0.250	0.250	0.250

Table 9: Price survey

U_2	a_{21}	a_{22}	a_{23}	Weight
a_{21}	0.571	0.600	0.500	0.557
a_{22}	0.286	0.143	0.300	0.100
a_{23}	0.375	0.125	0.320	0.123

Table 10: Delivery computation table

U_3	a_{31}	a_{32}	Weight
a_{31}	0.750	0.750	0.750
a_{32}	0.250	0.250	0.250

Table 11: After-sales service survey

U_4	a_{41}	a_{42}	Weight
a_{41}	0.750	0.750	0.750
a_{42}	0.250	0.250	0.250

- Calculate the mean value of each column of standard pairwise comparison matrix with each element of pairwise comparison matrix divided by the sum of corresponding column. These mean values are weights of all programs in upper hierarchy as in Table 7, 8, 9, 10 and 11.
- Consistency check

First, multiply the pair wise comparison matrix being tested by its Eigen vector, the result of which is called weighted sum vector. For example:

$$\begin{bmatrix} 1 & \frac{1}{2} & 2 & 2 \\ 2 & 1 & 3 & 3 \\ \frac{1}{2} & \frac{1}{3} & 1 & 1 \\ \frac{1}{2} & \frac{1}{3} & 1 & 1 \end{bmatrix} \begin{bmatrix} 0.263 \\ 0.455 \\ 0.141 \\ 0.141 \end{bmatrix} = \begin{bmatrix} 1.055 \\ 1.827 \\ 0.565 \\ 0.565 \end{bmatrix}$$

Secondly, divide component of each weighted sum vector by component of the corresponding Eigen vector respectively:

$$\frac{1.055}{0.263} = 4.011 \quad \frac{1.827}{0.455} = 4.015 \quad \frac{0.565}{0.141} = 4.007$$

$$\frac{0.565}{0.141} = 4.007$$

Then, calculate the mean value of result of the second procedure:

$$\lambda_{\max} = \frac{4.011 + 4.015 + 4.007 + 4.007}{4} = 4.010$$

Next, calculate the coincidence index CI:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} = \frac{4.010 - 4}{4 - 1} = 0.003$$

Finally, figure out the coincidence rate CR. CR = CI/RI

Saaty gives RI, the mean value of consistency check. Figure out the arithmetic mean value of 1000 maximum eigen value of random judgment matrix to gain the following mean random indexes of consistency check, as in Table 12.

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = \frac{0.003}{0.89} = 0.003 < 0.1$$

So judgment matrix is proved to be acceptable. Similarly, other judgment matrixes are also acceptable.

- **Hierarchical total sequencing:** Weights corresponding to each index of supply chain performance evaluation are:

Suppliers' price advantages a_{21}:

$$0.557 \times 0.455 = 0.253$$

Product acceptance rate a_{11}:

$$0.750 \times 0.263 = 0.197$$

Table 12: Indexes of consistency check

Order number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	0	0	052	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58

Price of supplier-offered products a_{22}:

$$0.320\times0.455 = 0.146$$

On-time delivery rate a_{31}:

$$0.750\times0.141 = 0.106$$

Customer complaint resolution time a_{41}:

$$0.750\times0.141 = 0.106$$

Return rate a_{12}:

$$0.250\times0.263 = 0.066$$

Transportation cost of products a_{23}:

$$0.123\times0.455 = 0.056$$

Orders fill rate a_{32}:

$$0.250\times0.141 = 0.035$$

Customer complaint treatment satisfaction ratio a_{42}:

$$0.250\times0.141 = 0.035$$

The above calculation is manual calculation while the following result is gained from processing by the AHP software yaahp Version 0.5.1.

It shows that weights of price and quality are heavier. Customers relatively pay more attention to suppliers' price advantages, Product acceptance rate, Price of supplier-offered products, on-time delivery rate and Customer complaint resolution time.

Weight vector corresponding to index layer:

$$\omega=\left(a_{11}a_{12}a_{21}a_{22}a_{23}a_{31}a_{32}a_{41}a_{42}\right)^T$$
$$=\left(0.197\ 0.066\ 0.253\ 0.146\ 0.056\ 0.106\ 0.035\ 0.106\ 0.035\right)^T$$

Evaluation formula:

$$y = 0.197\times1+0.066\times2+0.253\times3+0.146\times4+0.056\times5+0.106\times6+0.035\times7+0.106\times8+0.035\times9$$

EVALUATION RESULTS

Scores and the calculated result equal to 3.7220 of Hangzhou Xiaoshan Xinjie Qingfang Horticultural Farm Scores and the calculated result equal to 3.2878 of Hangzhou Xiaoshan Xinjie Colorful Horticultural Farm Scores and the calculated result equal to 3.4836 of Zhejiang Yuyao Siming Honest Landscaped Field Scores and the calculated result equal to 3.3839 of Hangzhou Runtu Horticultural Technology Co., Ltd. Scores and the calculated result equal to 3.1463 of Shengzhou Shengda Landscaped sales department it shows the performance evaluation rank.

Hangzhou Xiaoshan Xinjie Qingfang Horticultural Farm> Zhejiang Yuyao Siming Honest Landscaped Field> Hangzhou Runtu Horticultural Technology Co., Ltd>Hangzhou Xiao Shan Xinjie Colorful Horticultural Farm> Shengzhou Shengda Landscaped Sales Department

CONCLUSION

Main conclusions of this study are: According to actual situation, there are a lot of problems. The project manager of Hangzhou Tianshun Urban Landscape Engineering Co., Ltd. pointed out deficiency of 1~9 scales when filling in the questionnaire. There is fuzziness and uncertainty in comparison of index and score chart and some adjustment has been done later. It shows that much improvement of traditional AHP need to be done.

Researching supplier selection evaluation of SMEs from the angle of partnerships and coordination, setting up a set of indexes of objectivity and accuracy referring to the balanced scorecard, adopting AHP to determine the index weight and choosing the supplier by simple linear weighting are feasible. By empirical analysis on supplier selection in landscaped projects, it is found that suppliers' price advantages, Product acceptance rate, Price of supplier-offered products, on-time delivery rate and Customer complaint resolution time are valued.

When conducting supplier selection evaluation, enterprises often consider many evaluation indexes and different enterprises pay attention to different indexes. Referring to the balanced scorecard, this research divides supplier evaluation standard into 4 aspects, quality, price, delivery and after-sales service, including 9 quantitative and qualitative evaluation indexes. Selection and definition of each evaluation index can be reference for relevant future research.

Data processing function of the AHP software yaahp Version 0.5.1 brings convenience to writing and plays a role in the process of supplier selection. At last, Hangzhou Xiaoshan Xinjie Qingfang Horticultural Farm, which relatively conforms to the purchase situations in actual operation, has been selected.

At present theoretical researches on supply chain performance evaluation are relatively dispersive and there is no systematical theory. Researches on supply chain evaluation methods are relatively fewer. Research

on supply chain performance evaluation of SMEs can not only promote further enrichment and improvement of supply chain theory but also provide decision support for supply chain management of SMEs.

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