A Method of Supply Chain Performance Evaluation Based on Principal Component Analysis

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Abstract: Supply chain performance evaluation is an important topic and many researchers focus on investigating the methods to evaluate the performance of supply chain as reasonable as they can. In this paper, the fundamental principle of principal component analysis was introduced, which followed by the practical operating process. Then, the advantage of the method was indicated. Subsequently, the model is obtained by empirical analysis, using the statistical software SPSS. At last, some empirical results, supported the new method's validity, bring this paper into close.

Keywords: supply chain; performance; principal component analysis

I. Introduction

With the development of social，the competition is not only the competition between the enterprises ,but between the supply chains. In order to enable the supply chain develop healthily and evaluate the operating performance of the supply chain systematically, we need to consider all aspects of supply chain operating conditions, which need evaluate the efficiency of enterprises with multiple indicators. But it is difficult for our study, because of the relations between different indicators. What's more, the information reflected from the indicators has a certain degree of overlap.

There are many methods of supply chain performance evaluation, such as neural network, balanced scorecard and so on. In this paper, I will consider supply chain performance by principal component analysis. The method is an objective method which is not dependent on the judgments of experts. So we can rule out the interference and influence of human factors in the evaluation process.

II. Basic principles of principal component analysis

Principal component analysis is a method to simplify the complex relationship between various variables. We use principal component analysis to reduce the high-dimensional to the low with the principle of minimum information loss.

In the study, many indicators must be considered for analyzing and researching the problem comprehensively and systematically. These indicators reflect the characteristics of our study from different aspects. However, there are information- overlaps in some degree. In other words, there is correlation between the indicators, which brings us a lot of difficulties. Principal component analysis makes the study more convenient and the result more clear.

The steps of principal component analysis:

Standardizing the original data: Standardize the original data with Z-score algorithm. Let

$$y_{ij} = \frac{x_{ij} - \overline{x}_j}{S_j} \tag{1}$$

Solving the correlation coefficient matrix between the indicator data:We get the correlation coefficient matrix by computing the correlation coefficient between every two Indicator variables in normalized matrix;

Solving the Eigenvalues and Eigenvectors of correlation coefficient matrix;

Computing the variance proportion and cumulative variance proportion of principal component: variance proportion:

$$\omega_j = \frac{\lambda_j}{\sum_{j-1}^{p} \lambda_j} \tag{2}$$

cumulative variance proportion:

$$\omega = \sum_{j=1}^{m} \omega_j \tag{3}$$

Computing the load capacity of principal component;

Solving principal components;

III. Application research of the supply chain performance evaluation based on principal component analysis

Data sources

The text data (in table I) include 18 groups of samples with 16 Indicators.

Process of principal component analysis

First, in order to get the correlation coefficient matrix, we deal with the indicators of supply chain performance evaluation by factor analysis with the software of SPSS13.0. Known from the correlation coefficient matrix, we should emove the three variables: V8, V15, V16.Thus, there is significant correlation between the other indicators. Now, I mark the indicators as follows:Return on capital of supply chain(x1),Inventory days of supply chain（x2）,Cash

Table I Quantization table of Sampled data

indicator	1	2	3	4	5	6	7	8	9
Return on capital of supply chain	0	0.96	0.94	0.967	0.925	0.846	0.654	0.991	0.983
Inventory days of supply chain	0.853	1	0.853	0.603	0.873	0.631	0.539	0.561	0.763
Cash turnover ratio	0.067	0.071	0	0	0.175	0.18	0.065	0.481	0.105
Customer sales growth	0	0.849	0.689	0.501	0.613	0.709	0.891	0.981	0.815
Effective Lead	0.625	0	0.25	0.75	0.25	0.5	0.375	0.375	0.375
Time Flexibility	1	0.259	0.331	0.389	0.35	0.901	0.528	0.711	0.115
Ratio of being target cost	0.5	0.5	1	0.5	1	0.5	0.5	0.5	0
Sales rate of new product	1	1	1	1	1	1	1	1	1
Holding costs of supply chain	0.535	0.359	0.529	1	0.41	0.771	0.32	0.309	0.051
Final assembly point of product	1	1	1	1	1	0	1	1	0
Information sharing rati	0.511	0.561	0.538	0.553	0.475	1	0.527	0.611	0.244
Team participation	0.609	0.7	0.698	0.803	0.683	1	0.413	0.221	0.223
Total cycle time of order	0.969	0.7	0.735	0.78	0.703	0.43	1	0.325	0.261
Customer recognition of flexibility	1	0.14	0.093	0.083	0.096	0.205	0.07	0.021	0.005
Customer Value Rate	1	1	1	1	1	1	1	1	1
Customer retention	1	1	1	1	1	1	1	1	1

Continued

indicator	10	11	12	13	14	15	16	17	18
Return on capital of supply chain	0.99	0.981	1	0.991	0.919	0.995	0.997	0.993	1
Inventory days of supply chain	0.735	0.907	0.781	0.093	0.939	0.41	0	0.411	0.339
Cash turnover ratio	1	0.413	0.071	0.071	0.344	0.995	0.997	0.993	1
Customer sales growth	0.97	1	0.963	0.963	0.813	0.961	0.971	0.957	0.948
Effective Lead	0	0.25	0.191	0.311	0.88	0.061	0.25	0.25	0.269
Time Flexibility	0.093	0	0.151	0	0.061	0.109	0.217	0.061	0.07
Ratio of being target cost	0.5	0.5	0.5	0	0	0.5	0	0	0
Sales rate of new product	1	1	1	1	1	1	1	1	1
Holding costs of supply chain	0.048	0.191	0.191	0	1	0.411	0.221	1	1
Final assembly point of product	1	0	0	1	1	0	1	1	1
Information sharing rati	0	0.248	0.239	0.211	0	0.247	0	0	0
Team participation	0	0.223	0.227	0.225	0	0.301	0.225	0.22	0.211
Total cycle time of order	0.329	0.491	0.485	0	0.095	0.271	0.327	0.325	0.331
Customer recognition of flexibility	0	0.021	0.003	0.002	0.003	0.003	0.003	0.005	0.004
Customer Value Rate	1	1	1	1	1	1	1	1	1

Customer retention	1	1	1	1	1	1	1	1	1

turnover ratio(x3),Customer sales growth(x4),Effective Lead(x5),Time Flexibility(x6),Ratio of being target cost(x7),

Holding costs of supply chain(x8), Final assembly point of product(x9),Information sharing ratio(x10),Team participation(x11),Total cycle time of order(x12),Customer recognition of flexibility(x13).

Second, we choose five factors for reaching 85% of cumulative variance proportion. Then, the cumulative variance proportion accounts to 86.631% which reflects the information of original variables better. The eigenvalues, variance proportion and cumulative variance proportion are listed in table II.

Table II Eigenvalues and variance proportion

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.750	44.230	44.230	5.750	44.230	44.230
2	2.117	16.285	60.516	2.117	16.285	60.516
3	1.296	9.972	70.488	1.296	9.972	70.488
4	1.106	8.511	78.999	1.106	8.511	78.999
5	.992	7.632	86.631	.992	7.632	86.631
6	.728	5.600	92.231			
7	.377	2.904	95.135			
8	.276	2.127	97.262			
9	.221	1.703	98.965			
10	.081	.623	99.587			
11	.029	.220	99.808			
12	.013	.099	99.906			
13	.012	.094	100.000			

Table III Component Matrix

	Component				
	1	2	3	4	5
X1	-.756	.396	.459	.154	.040
X2	.487	.342	.068	-.318	.653
X3	-.661	-.281	-.220	.345	-.115
X4	-.873	.325	.104	.084	-.094
X5	.419	-.605	.477	-.349	.051
X6	.839	-.088	-.041	.074	-.389
X7	.584	.623	-.048	.291	.221
X8	.202	-.550	.627	.256	.164
X9	.107	-.479	-.101	.639	.314
X10	.774	.392	.278	.054	-.348
X11	.779	.255	.328	.255	-.227
X12	.796	.161	-.167	.291	.197
X13	.794	-.345	-.417	-.133	-.061

Third, input the data of Component Matrix to SPSS, and compute the Eigenvalues according to Transform/Compute, in which input

$$z_{ij} = a_{ij} \Big/ \sqrt{\lambda_j} \qquad (4)$$.

The result is listed in table IV.

Table IV Eigenvector matrix

	Z1	Z2	Z3	Z4	Z5
1	-0.315	0.272	0.403	0.146	0.040
2	0.203	0.235	0.060	-0.302	0.656
3	-0.276	-0.193	-0.193	0.328	-0.115
4	-0.364	0.223	0.091	0.080	-0.094
5	0.175	-0.416	0.419	-0.332	0.051
6	0.350	-0.060	-0.036	0.070	-0.391
7	0.244	0.428	-0.042	0.277	0.222
8	0.084	-0.378	0.551	0.243	0.165
9	0.045	-0.329	-0.089	0.608	0.315
10	0.323	0.269	0.244	0.051	-0.349
11	0.325	0.175	0.288	0.242	-0.228
12	0.332	0.111	-0.147	0.277	0.198
13	0.331	-0.237	-0.366	-0.126	-0.061

$$\begin{aligned} F1 = & -0.315X1+0.203X2-0.276X3-0.364X4+0.175X5 \\ & +0.350X6+0.244X7+0.084X8+0.045X9+0.323X10 \\ & +0.325X11+0.332X12+0.331X13 \end{aligned} \qquad (5)$$

$$\begin{aligned} F2 = & 0.272X1+0.235X2-0.193X3+0.223X4-0.416X5 \\ & -0.060X6+0.428X7-0.378X8-0.329X9+0.269X10 \\ & +0.175X11+0.111X12-0.237X13 \end{aligned} \qquad (6)$$

$$\begin{aligned} F3 = & 0.403X1+0.060X2-0.193X3+0.091X4+0.419X5 \\ & -0.036X6-0.042X7+0.551X8-0.089X9+0.244X10 \\ & +0.288X11-0.147X12-0.366X13 \end{aligned} \qquad (7)$$

$$\begin{aligned} F4 = & 0.146X1-0.302X2+0.328X3+0.080X4-0.332X5 \\ & +0.070X6+0.277X7+0.243X8+0.608X9+0.051X10 \\ & +0.242X11+0.277X12-0.126X13 \end{aligned} \qquad (8)$$

$$\begin{aligned} F5 = & 0.040X1+0.656X2-0.115X3-0.094X4+0.051X5 \\ & -0.391X6+0.222X7+0.165X8+0.315X9-0.349X10 \\ & -0.228X11+0.198X12-0.061X13 \end{aligned} \qquad (9)$$

So, the expression of F is obtained.

$$\begin{aligned} F &= \lambda_1 F_1 \Big/ \sum_{i=1}^{m} \lambda_i + \cdots + \lambda_m F_m \Big/ \sum_{i=1}^{m} \lambda_i \\ &= 0.442F_1 + 0.163F_2 + 0.1F_3 + 0.085F_4 + 0.076F_5 \end{aligned} \qquad (10)$$

It is observed that X4, X11, X12 have higher load on the first principal component. They are customer sales growth, team participation and total cycle time of order respectively.F1 shows sales factor.

X7 has a higher load on the second principal component. X7 is ratio of being target cost. F2 shows achievement factor.

X1, X8, X13 have higher load on the third principal component. They are return on capital of supply chain, holding costs of supply chain and customer recognition of flexibility respectively.F3 shows market factor.

X3, X5, X9 have higher load on the forth principal component. They are cash turnover ratio, effective Lead and final assembly point of product respectively.F4 shows operation factor.

X2, X6, X10 have higher load on the fifth principal component. They are inventory days of supply chain, time Flexibility, and information sharing ratio respectively.F5 shows effectiveness factor.

Discussion

Compute the result by putting the Standardized data into F1, F2, F3, F4, F5 and F, which be ranked in table V.

We can know from table 5 that F1 retain 44.2% information of original indicators, which is more similar to the composite score than other four principal components. The coefficient of customer sales growth is the largest, which reflects that the stimulation of consumption is closely related to supply chain performance. And this coincides with the current policy.

F2 retain 16.3% information of original indicators. The coefficient of ratio of being target cost is the largest, which reflects that the supply chain performance is closely related to the ability of task.

We can also draw the appropriate conclusions from the contribution rate of other Principal components and the coefficient of each indicator. And we can control the supply chain accordingly.

Table V Composite Score Table

	F1		F2		F3		F4		F5		F	
1	1.842	1	-0.335	15	0.241	17	0.819	11	0.521	10	0.893	1
2	0.547	7	0.723	3	0.773	9	1.156	9	0.765	5	0.593	6
3	0.795	4	0.711	4	0.936	4	1.277	4	0.833	2	0.733	2
4	0.880	3	0.044	13	1.434	1	1.195	6	0.638	6	0.690	5
5	0.745	5	0.681	5	0.808	7	1.276	5	0.824	3	0.692	4
6	1.002	2	0.605	6	1.383	2	0.658	13	-0.233	18	0.718	3
7	0.665	6	0.376	9	0.644	14	1.157	8	0.496	12	0.556	7
8	0.203	8	0.331	11	0.779	8	1.130	10	0.278	14	0.339	8
9	-0.131	11	0.558	8	0.760	10	0.047	18	0.349	13	0.140	11
10	-0.479	16	0.363	10	0.203	18	1.184	7	0.778	4	0.028	14
11	-0.099	10	0.816	2	0.695	12	0.387	16	0.607	7	0.238	10
12	0.011	9	0.867	1	0.734	11	0.344	17	0.508	11	0.287	9
13	-0.422	14	0.130	12	0.636	15	0.787	14	0.208	15	-0.019	15
14	-0.153	12	-0.481	18	1.248	3	0.618	15	1.056	1	0.112	12
15	-0.381	13	0.564	7	0.654	13	0.811	12	0.142	16	0.069	13
16	-0.577	18	-0.159	14	0.443	16	1.289	3	0.127	17	-0.117	18
17	-0.477	15	-0.353	16	0.899	5	1.338	2	0.588	8	-0.020	16
18	-0.487	17	-0.380	17	0.899	5	1.356	1	0.542	9	-0.031	17

V. Conclusion

PCA eliminates the overlap between indicators, and evaluate supply chain performance excellently with fewer indicators. We can know which indicators are more important than the others according to diverse contribution rates. Moreover, we can point out the advantages and disadvantages of our supply chain by the rank of principal components. Thus, it is clear for the future direction of effort. Above all, it is feasible for us to evaluate supply chain performance Based on Principal Component Analysis.

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Appendices and References Available Upon Requests