# Research on Selection of theThird-Party Logistics Service Providers

Huimin Zhang[1], Guofeng Zhang[2], ,and Bin Zhou[1]
1 Henan University of Technology, College of Management, Zhengzhou 450052, P.R.China, zhm76@126.com,
2 Henan Business College, Department of Business Management

**Abstract**. At present, the supply chain is the last field, which can make enterprise reducing cost and improving flexibility. How to construct the supply chain successfully has received much attention and logistics outsourcing has become common among large manufacturers. The information age and globalization are forcing companies to place a premium upon collaboration as a new source of competitive advantage, so companies are facing significant challenges to evaluate and select appropriate third-party logistics (3PL) providers. This paper will choose a set of indicators, construct a framework for performance measures and introduce an evaluation method which proceeds as follow: (1) choosing principal components applying principal components analysis; (2) ranking the 3PL providers applying grey relational analysis.

## 1 Introduction

Since competition is no longer between organizations but among supply chains, effective supply chain management has become a potentially valuable way of securing competitive advantage and improving organization performance. In order to make core business outstanding and improve efficiency, more and more large manufacturers outsourced their logistics. Being the most important mode of logistics outsourcing, the third-party logistics services have become an important option for large manufacturers to develop supply chain strategies. 3PL providers offer such companies a broad range of services, both in domestic and in international markets.

According to a recent report from Datamonitor, the global spend on 3PLs in 2005 finished at $227.2 million, fueled by increased trade between Asia and the U.S [1]. The third-party logistics providers continue to see strong demand for their services, although operational efficiency can be the differentiator between long-term success and being put on the block.

On the other hand, large quantity of third-party logistics providers come into the world and inevitably the bad become mixed with the good. It is important to both

3PL providers and users of their services to facilitate the development of corporate supply chain strategy. The 3PL industry continues to evolve, executives considering the use of such services are faced with many puzzles, whose key is how to evaluate and select the appropriate 3PL providers.

## 2 Evaluation System Construction

A performance evaluation system will be of great interest to manufacturers and distributors with potentially high costs and delays across complex operations, or to enterprises recognizing the need to reduce costs and improve levels of customer service. These systems are designed to enable management to pay attention to deriving business benefits in areas such as improvements in delivery reliability, increased levels of greater flexibility, customer responsiveness, reductions in operational costs, effective asset management.

Selecting performance indicators is the premise of 3PL provider's evaluation, comprehensive and reasonable indicator system is the key of ensuring correct performance evaluation. Indicator system construction should follow the rules: all sidedness, versatility, comparability and operability. Many researchers have adopted several components or multiple dimensions to evaluate the performance of 3PL. For example, Xuefen Ma suggested evaluating 3PL's performance from four aspects: development potential, logistic technology, logistic equipment and level of service [2]. Two surveys [3, 4] identified the following as significant outsourcing functions: transportation, warehousing, freight consolidation and distribution, labeling, packaging, inventory management, traffic management and fleet operations, freight payments and auditing, order management, carrier selection, rate negotiation and so on. These functions can be divided into four categories: warehousing, transportation, customer service, and inventory and logistics management. Evaluation framework can be constructed on the foundation of these four categories.

The traditional evaluation system pays much attention to cost cutting and the evaluation system commits itself to earn a profit. The evaluating indicators always deal with delivery reliability, delivery costs, management efficiency and so on. But the environment of competition today is a departure from yesterday. Firstly, the environment is filled with uncertainty and the demands of customers diversified day by day. Enterprises must become more flexible to meet individualized demand. Secondly, increasing attention is devoted to suppliers' social responsibility with a particular focus on environmental protection, fair and legal use of natural resources. Green supply chain management is emerging to be an important approach for enterprises to improve performance. We should think highly of environmental performance when evaluate 3PL. Thirdly, information technology develops rapidly. To implement 3PL, real-time information flow is essential. IT links members of a supply chain, such as manufacturers, distributors, transportation firms, and retailers, as it automates some element of the logistics workload, such as order processing, order status inquiries, inventory management, or shipment tracking. So the evaluation system must pay enough attention to flexibility, environment protection, information sharing.

### 2.1 Flexibility

Nowadays, the environment's rate of change is more rapid than at any previous time. Enterprises have continuously devoted their efforts to keeping flexible or agile in order to maintain a competitive advantage over its rivals. Agility is firstly used in manufacturing industry. The manufacturing environment has undergone several transitions, from the craft industry, to mass production, and now the newest paragon, agility. Agile-based competition is destined to displace mass-production based competition as the norm for global commerce [5]. Flexibility can be regarded as a critical compete factor. Being flexible means having the capability to provide products/services that meet the individual demands of customers [6].

More or less the same, we can evaluate the flexibility or agility of enterprises in service trade. A 3PL service provider with flexibility is one whose processes are designed to respond effectively to unanticipated change. Flexibility of 3PL provider can be measured from response capability to quantitative change of demand, time response capability, capability of adopt new technology, capability of expanding and so on. These indicators aid in monitoring the capability of a process to respond to unanticipated change.

### 2.2 Environmental Management

Today, competition has intensified and globalized, many governments impose standards that set the lower boundary of customers' expectations regarding environmental compliance, which results in higher pressure and drivers for enterprises to improve environmental performance. Environmental issues in construction typically include soil and ground contamination, water pollution, construction and demolition waste, noise and vibration, dust, hazards emissions and odors, wildlife and natural features demolition, and archaeological destruction [7]. Environmental pollution is a serious problem, it is reported that road vehicles are responsible for more than 25% of Britain's greenhouse gas emissions, according to the government's Transport White Paper, 24000 people each year die prematurely due to air pollution.

With the increasing acceptance of ISO 14001 environmental standards, there is a greater role for enterprise in organizational environmental practice. Many enterprises take up measures to improve environmental performance, but these control and management appear to be very qualitative. So we should select the quantitative indicators to evaluate 3PL service providers' environmental performance. These quantitative approaches are useful for indicating, reducing and mitigating pollution level.

### 2.3 Information Communication

A supply chain is dynamic in nature and involves the constant flow of product, cash and information between different stages. It is the coordination or integration of the activities of all the members of a supply chain. Modern information technology, through its power to provide timely, accurate, and reliable information, has led to a

greater integration of modern supply chains than possible by any other means [8]. Timely and accurate information communication can highly improve the forecast precision of management and the flexibility to unanticipated change, so we should pay enough attention to information activity when measure the level of cooperation among the members. We can evaluate the information activity from four aspects: informatization level, information accuracy rate, ratio of information activity in time and information sharing level.

By measuring performance across several business areas using a set of performance indicators, for example: financial, non-financial, customer, operational, leading and lagging, it is possible to coordinate and optimize supply chain performance to achieve strategic competitive advantage. Performance measurement systems provide significant impact when used to support a program to monitor key performance indicators that have been aligned to critical business issues. They will reduce decision-making cycle times by notifying key decision-makers through workflow or event management, to initiate corrective action before problems escalate into major issues. This is often difficult to achieve when existing management information systems fail to provide real time performance data.

On the basis of the discussion above, the paper selects 17 indicators from 5 aspects, refers to table 1.

## 3 Evaluation Method

After the construction of evaluation system, an appropriate method may be used to evaluate and select 3PL providers. In this paper, the evaluation method can divide into two stages: firstly, choose principal components applying principal components analysis, then rank the 3PL providers applying grey relational analysis. The specific steps proceed as follow.

### 3.1 Principal Components Analysis

Principal components analysis [9]–[11] (PCA) is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data which transforms a number of correlated variables into a smaller number of uncorrelated variables called principal components. The main advantage of PCA is that once you have found these patterns in the data, and you compress the data, by reducing the number of dimensions, without much loss of information.

#### 3.1.1 Standardized process of raw data

The larger the target value the better:

$$y_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \qquad (1)$$

The smaller the target value the better:

**Table 3.** Indicator system for 3PL provider's evaluation

| Indicator classification | Indicator | Quantitative description of indicator |
|---|---|---|
| $X_1$: Transportation activity | $X_{11}$:Transportation cost | Transportation cost/the value of goods delivered |
| | $X_{12}$:Correct transportation ratio | Times of correct transportation /total times of transportation |
| | $X_{13}$:Delivering loss rate | Value of delivering loss/ inventory value delivered |
| $X_2$: Warehousing activity | $X_{21}$:Inventory turnover rate | Cost of goods sold/average inventory |
| | $X_{22}$:Inventory defection rate | Value of inventory defection/ total inventory value |
| | $X_{23}$:Warehousing cost per ton | Warehousing cost/ average inventory |
| | $X_{24}$:Warehouse utilization rate | Inventory level/storage capacity |
| $X_3$: Information activity | $X_{31}$:Information accuracy rate | Times of accurate information activity / total times of information activity |
| | $X_{32}$:Ratio of information activity in time | Times of information activity in time/total times of information activity |
| | $X_{33}$:Information sharing level | Given through benchmarking |
| | $X_{34}$:Informatization level | The level of hardware and software, given through benchmarking |
| $X_4$: Environmental performance | $X_{41}$:Pollutants released | Pollutants released/quantity of goods delivered |
| | $X_{42}$: Energy consumption | Energy consumption /quantity of goods delivered |
| $X_5$: Flexibility | $X_{51}$:Response capability to quantitative change of demand | Quantity delivered according to buyer's rectification/quantity rectified on buyer's demand |
| | $X_{52}$:Time response capability | Times of adjusted delivering on buyer demand /times of delivering with schedule adjusted |
| | $X_{53}$:Capability of expanding | Kinds of new service/ kinds of service |
| | $X_{54}$:Response capability to consumer's change | Number of new client/number of client lost |

$$y_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (2)$$

The closer to the target value the better:

$$y_{ij} = \frac{1}{1 + OB - x_{ij}} \quad (3)$$

OB: the target value

### 3.1.2 Calculate the covariance matrix

After the Standardized process of raw date, we get a matrix, and then calculate the covariance matrix of the matrix. Covariance is always measured between 2 dimensions. If we have a data set with more than 2 dimensions, there is more than one covariance measurement that can be calculated. For an n-dimensional data set, we can calculate $\frac{n!}{(n-2)*2}$ different covariance values and put them in a matrix.

**3.1.3 Calculate the orthorhombic eigenvectors and eigenvalues of the covariance matrix**

Since the covariance matrix is square, we can calculate the eigenvectors and eigenvalues for this matrix. These are rather important, as they tell us useful information about our data. By this process of taking the eigenvectors of the covariance matrix, we have been able to extract lines that characterize the data.

$$\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_i \geq \cdots \geq \lambda_n \geq 0 \qquad (4)$$

$$u_j = (u_{11}, u_{12}, u_{13}, \cdots u_{ij} \cdots u_{54}) \qquad (5)$$

$\lambda_i$ : The ith eigenvalue of the covariance matrix

$u_j$ : The jth eigenvectors of the covariance matrix

**3.1.4 Calculate accumulative variance' contribution ratio of eigenvalue**

Once eigenvectors are found from the covariance matrix, the next step is to order them by eigenvalue, highest to lowest. Then calculate the contribution ratio.

$$E = \frac{\sum_{i=1}^{m} \lambda_i}{\sum_{i=1}^{n} \lambda_i} \qquad (6)$$

$m$ : The minimum integer when $E \geq 85\%$

**3.1.5 Choosing principal components**

Choose certain principal components, from large to small, let $E \geq 85\%$.

$$y_k = \sum_{j=1}^{n} u_{kj} X_j \quad (k = 1,2,\cdots,m) \qquad (7)$$

$y_k$ : The kth principal component

## 3.2 Grey Relational Analysis

Grey relational analysis was pioneered by Deng Julong in 1984, which aim at analyzing the relationships among things [12]. GRA, in fact, might be reckoned as a contrasting way, in wholeness, equipped with reference for contrasting. Differing from the traditional mathematical analysis, GRA provides a simple scheme to analyze the series relationships or the system behavior, even if the given information is few.

In the former part of the paper, we have got the principal components which can be taken as the input of GRA. What follows are the steps needed to perform a GRA on a set of data.

**3.2.1 Standardized process of principal components**

According to the algorithm of principal components, calculate and standardize the principal components.

**3.2.2 Establish the reference series for GRA**

The series consist of the best dates of the principal components after standardized process above.

$$y^0 = (y^0_1 \ldots y^0_j \ldots y^0_m)$$

**3.2.3 Calculate the grey relational coefficient**

The algorithm on grey relation coefficient is as follows:

$$\xi_{ij}(y^0_j, y_{ij}) = \frac{\min_i \min_j \left|y^0_j - y_{ij}\right| + \rho \max_i \max_j \left|y^0_j - y_{ij}\right|}{\left|y^0_j - y_{ij}\right| + \rho \max_i \max_j \left|y^0_j - y_{ij}\right|} \qquad (8)$$

$\rho$ : distinguishing coefficient, $\rho \in [0, 1]$, usually, $\rho$ =0.5

**3.2.4 Establish the weights of indicators**

We can take the variance contribution ratio as weights, refers to Table 3.

$$W = (w_1, w_2, w_m)$$

**3.2.5 Calculate the monolayer Grey Relational Grade**

$$\gamma_i = \sum_{k=1}^{m} w_k \xi_{ik} \qquad (9)$$

According to the value of grey relational grade, the 3PL provider can be ranked.

## 4 Case Studies

In order to illustrate the evaluation method, the paper selects a manufacturer whose products are quick-frozen foods and its five 3PL providers. The indicators used are those which are listed in table 1 and the indicator value is listed in table 2. The paper evaluates the performance and gives the numerical value for every indicator, then ranks these 5 enterprises according to their performance, MATLAB7.0.1 being the computational aids.

**Table 2.** The raw data of indicators for 5 enterprises

| Indicator | A | B | C | D | E |
|---|---|---|---|---|---|
| $X_{11}$ | 0.10 | 0.12 | 0.28 | 0.20 | 0.09 |
| $X_{12}$ | 0.98 | 0.99 | 0.97 | 0.95 | 0.85 |
| $X_{13}$ | 0.10 | 0.01 | 0.20 | 0.03 | 0.05 |
| $X_{21}$ | 1.90 | 3.55 | 3.50 | 4.00 | 2.50 |
| $X_{22}$ | 0.08 | 0.01 | 0.13 | 0.04 | 0.02 |
| $X_{23}$ | 2.40 | 4.20 | 3.50 | 1.50 | 4.00 |
| $X_{24}$ | 0.78 | 0.95 | 0.70 | 0.90 | 0.88 |
| $X_{31}$ | 0.85 | 0.70 | 0.65 | 0.95 | 0.99 |
| $X_{32}$ | 0.12 | 0.40 | 0.25 | 0.89 | 0.99 |
| $X_{33}$ | 1 | 5 | 6 | 8 | 9 |
| $X_{34}$ | 2 | 6 | 5 | 7 | 9 |
| $X_{41}$ | 0.10 | 0.01 | 0.20 | 0.03 | 0.02 |
| $X_{42}$ | 0.35 | 0.12 | 0.30 | 0.20 | 0.19 |
| $X_{51}$ | 0.62 | 0.85 | 0.80 | 0.70 | 0.98 |
| $X_{52}$ | 0.58 | 0.90 | 0.88 | 0.59 | 0.97 |
| $X_{53}$ | 0.01 | 0.12 | 0.08 | 0.02 | 0.05 |
| $X_{54}$ | 0.18 | 0.05 | 0.41 | 0.11 | 0.48 |

The raw data in table 2 are standardized and the covariance matrix is calculated, then the orthorhombic eigenvectors and eigenvalues of the covariance matrix are also calculated. The paper chooses 3 principal components to model according to $E \geq 85\%$. These 3 principal components are listed in table 3, eigenvalue, variance contribution ratios and accumulative contribution ratios are also calculated.

**Table 3.** The contribution ratios and eigenvectors of eigenvalue

| Eigenvalue | 1.3723 | 0.7144 | 0.4542 |
|---|---|---|---|
| Variance contribution ratio | 46.81% | 24.37% | 15.49% |
| Accumulative contribution ratio | 46.81% | 71.88% | 86.67% |
| $u_{11}$ | 0.0223 | -0.0245 | 0.0057 |
| $u_{12}$ | -0.1008 | 0.0366 | -0.0832 |
| $u_{13}$ | 0.1152 | 0.0065 | -0.0114 |
| $u_{21}$ | 0.0789 | 0.0701 | 0.0151 |
| $u_{22}$ | 0.1183 | 0.0281 | 0.0360 |
| $u_{23}$ | 0.0433 | -0.1384 | -0.1868 |
| $u_{24}$ | 0.1197 | 0.0368 | 0.0190 |
| $u_{31}$ | 0.1353 | -0.1258 | -0.0564 |
| $u_{32}$ | 0.1860 | -0.0310 | 0.0423 |
| $u_{33}$ | 0.1378 | 0.0216 | 0.0861 |
| $u_{34}$ | 0.1331 | 0.0345 | 0.0993 |
| $u_{41}$ | 0.1283 | 0.0044 | 0.0073 |
| $u_{42}$ | 0.1134 | 0.0945 | 0.0897 |
| $u_{51}$ | 0.0582 | 0.0885 | 0.1699 |
| $u_{52}$ | 0.0038 | 0.1456 | 0.2243 |
| $u_{53}$ | -0.0301 | 0.1677 | 0.1456 |
| $u_{54}$ | 0.1894 | -0.0301 | 0.0038 |

The principal components can be expressed as follows:

$y_1=0.0223X_{11}+0.1008X_{12}+0.1152X_{13}+0.0789X_{21}+0.1183X_{22}+0.0433X_{23}+0.1197X_{24}+0.1353X_{31}+0.1860X_{32}+0.1378X_{33}+0.1331X_{34}+0.1283X_{41}+0.1134X_{42}+0.0582X_{51}+0.0038X_{52}-0.0301X_{53}+0.1894X_{54}$

$y_2=-0.0245X_{11}+0.0366X_{12}+0.0065X_{13}+0.0701X_{21}+0.0281X_{22}-.1384X_{23}+0.0368X_{24}-0.1258X_{31}-0.0310X_{32}+0.0216X_{33}+0.0345X_{34}+0.0044X_{41}+0.0945X_{42}+0.0885X_{51}+0.1456X_{52}+0.1677X_{53}-0.0301X_{54}$

$y_3=0.0057X_{11}-0.0832X_{12}-0.0114X_{13}+0.0151X_{21}+0.0360X_{22}-0.1868X_{23}+0.0190X_{24}-0.0564X_{31}+0.0423X_{32}+0.0861X_{33}+0.0993X_{34}+0.0073X_{41}+0.0897X_{42}+0.1699X_{51}+0.2243X_{52}+0.1456X_{53}+0.0038X_{54}$

From the expressions above we can see that $y_1$ pay more attention to ratio of information activity in time, information sharing level and response capability to change of consume; $y_2$ pay more attention to time response capability and capability of expanding; $y_3$ pay more attention to response capability to quantitative change of demand, time response capability and capability of expanding.

According to algorithm 8, we get the grey relational coefficients, $\rho$ =0.5, shown in table 4.

**Table 4.** Grey relational coefficient

| Coefficient | A | B | C | D | E |
|---|---|---|---|---|---|
| $\xi_{11}$ | 0.3333 | 0.5182 | 0.5301 | 0.7021 | 1.0000 |
| $\xi_{12}$ | 0.3333 | 0.4199 | 0.4736 | 1.0000 | 0.4829 |
| $\xi_{13}$ | 0.3333 | 0.4169 | 0.5012 | 1.0000 | 0.9188 |

At last, grey relational grade is calculated, refers to algorithm 9.

$\gamma_1$=0.2889, $\gamma_2$=0.4095, $\gamma_3$=0.4412, $\gamma_4$=0.7273, $\gamma_5$=0.7281

Optimally selected schemes are as follows:

$E \succ D \succ C \succ B \succ A$

## 5 Conclusion

This paper integrates PCA with GRA, chooses principal component with PCA and takes them as key indicators which leave the complex for the easy, then takes the key indicators as the input of GRA and ranks the 3PL providers according to the value of grey relational grade. PCA is a powerful tool for analyzing data, PCA can reduce the number of dimensions and find the key factors influencing performance easily, without much loss of information. Moreover there also exists uncertainty of less date, incomplete information and devoid of experience in 3PL providers evaluation, GRA is a useful tool to deal with such grey system.

The evaluation framework presented in this article improved previous evaluation system; it can help management evaluate outsourcing logistics services in new competitive situations. Using this framework and the factors essential to quantify outsourcing, we have established a set of indicators for 3PL provider selection. It is worth mentioning, the indicator system is flexible and different enterprise may select different indicators. But the indicator selected should be easy to quantify for example by using benchmarking and the information systems should provide real time performance data. Overall, this study provided additional insight into the growing field of 3PL evaluation. Clearly, the field has ample space to grow in terms of research and practice.

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