



Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Ho, W.;Bennett, DJ;Mak, KL;Chuah, KB;Lee, CKM;Hall, MJ

Title:

Strategic logistics outsourcing: An integrated QFD and AHP approach

Date:

2009-12-01

Citation:

Ho, W., Bennett, D. J., Mak, K. L., Chuah, K. B., Lee, C. K. M. & Hall, M. J. (2009). Strategic logistics outsourcing: An integrated QFD and AHP approach. Ieem 2009 IEEE International Conference on Industrial Engineering and Engineering Management, pp.1434-1438. IEEE. <https://doi.org/10.1109/IEEM.2009.5373059>.

Persistent Link:

<https://hdl.handle.net/11343/118705>

Strategic Logistics Outsourcing: An Integrated QFD and AHP Approach

W. Ho¹, D. J. Bennett¹, K. L. Mak², K. B. Chuah³, C. K. M. Lee⁴, M. J. Hall¹

¹Operations & Information Management Group, Aston Business School, Aston University, Birmingham, UK

²Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Hong Kong

³Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong, Hong Kong

⁴Division of Systems and Engineering Management, Nanyang Technological University, Singapore

w.ho@aston.ac.uk

Abstract – Third-party logistics service providers (3PLs) play a vital role in contemporary supply chain management. Evaluation and selection of the right 3PLs depends on a wide range of quantitative and qualitative criteria rather than cost-based factors. Although various multi-criteria decision making approaches have been proposed, they have not considered the impact of business objectives and requirements of company stakeholders on the evaluating criteria. To enable the “voice” of company stakeholders is considered, this paper develops an integrated approach for selecting 3PL strategically. In the approach, multiple evaluating criteria are derived from the requirements of company stakeholders using a series of house of quality (HOQ). The importance of evaluating criteria is prioritized with respect to the degree of achieving the stakeholder requirements using analytic hierarchy process (AHP). Based on the ranked criteria, alternative 3PLs are evaluated and compared with each other using AHP again to make an optimal selection.

Keywords – Logistics outsourcing, third-party logistics service providers, evaluation, selection, analytic hierarchy process, quality function deployment

I. INTRODUCTION

Logistics outsourcing or third-party logistics is regarded as using external companies to perform some or all logistics functions, including transportation, distribution, warehousing, inventory management, order processing, and material handling, that have traditionally been performed within an outsourcing firm [1–3]. Those logistics functions can be treated as non value-added activities because they are critical to the smooth running of the business, but not a unique ingredient of the overall product [1]. Because of this reason, firms tend to outsource those activities to the external companies or 3PLs, and focus on value-added activities to develop sustainable competitive advantage.

Evaluation and selection of 3PL is a critical step in the logistics outsourcing process because an appropriate 3PL will help the outsourcing firms to reduce capital investment in facilities, equipment, information technology and manpower, increase the flexibility of outsourcing firms in adapting to changes in the market, reduce inventory and improve inventory turnover rate, improve on-time delivery, reduce the transportation cost, and so on [3–4].

Choosing the right 3PLs involves much more than scanning a series of price list, and choices will depend on a wide range of factors which involve both quantitative and qualitative. Various individual and integrated multi-criteria decision making approaches have been proposed for the 3PL selection, such as AHP, analytic network process (ANP), artificial neural networks (ANN), case-based reasoning (CBR), data envelopment analysis (DEA), rule-based reasoning (RBR), technique for order preference by similarity to ideal solution (TOPSIS), and so on. Although these approaches can deal with multiple and conflicting criteria, they have not taken into consideration the impact of business objectives and requirements of company stakeholders on the evaluating criteria. In reality, the weightings of 3PL evaluating criteria depend a lot on business priorities and strategies. In cases where the weightings are assigned arbitrarily and subjectively without considering the “voice” of company stakeholders, the selected 3PL can not provide what the company exactly wants.

To enable the “voice” of company stakeholders is considered, this paper develops an integrated approach for selecting 3PL strategically. HOQ, a technique of quality function deployment (QFD), is responsible for translating the requirements of company stakeholders into evaluating criteria. AHP is responsible for the assignment of importance ratings and relationship weightings in the HOQs so that inconsistencies due to subjective judgments can be avoided. Based on the ranked criteria, alternative 3PLs are evaluated and compared with each other using AHP again to make an optimal selection.

II. LITERATURE REVIEW

Various multi-criteria decision making approaches have been proposed to tackle the logistics outsourcing problem. Menon et al. [5] proposed nine criteria for the 3PL evaluation and selection, including price, on-time delivery, error rate, financial stability, creative management, meet or exceed promises, availability of top management, responsive to unforeseen problems, and meet performance and quality requirements.

Meade and Sarkis [6] applied ANP to select the best third-party reverse logistics service provider. The decision factors and clusters considered in the ANP model include location of product in its lifecycle, the organizational performance criteria, the reverse logistics process

functions required by the organization, and the organizational role of reverse logistics.

Bottani and Rizzi [7] developed a fuzzy TOPSIS approach to rank and select the most suitable 3PL with respect to nine criteria, including compatibility, financial stability, flexibility of service, performance, price, physical equipment and information systems, quality, strategic attitude, and trust and fairness.

Işıklar et al. [2] presented an integrated approach, combining CBR, RBR, and compromise programming, to deal with the 3PL selection problem. The evaluating criteria include cost, quality, technical capability, financial stability, successful track record, service category, personnel qualification, information technology, comparable culture, region, and so on.

Jharkharia and Shankar [8] deployed the ANP approach to select the optimal 3PL with respect to four major determinants or criteria, such as compatibility, cost, quality, and reputation.

Göl and Çatay [9] adopted the AHP approach to select an appropriate 3PL. In the AHP hierarchy, there were five evaluating criteria (general company considerations, capabilities, quality, client relationship, and labor relations), in which multiple sub-factors were proposed.

Efendigil et al. [10] proposed an integrated approach, combining fuzzy AHP and ANN, to select the best third-party reverse logistics provider. 12 factors were considered, including on-time delivery, fill rate, service quality, unit operation cost, capacity usage, total order cycle time, system flexibility index, integration level, increment in market share, research and development, environmental expenditures, and customer satisfaction.

Zhou et al. [11] utilized the DEA to measure the efficiencies of Chinese 3PLs. There were four inputs (net fixed asset, salaries and wages, operating expenses, and current liabilities) and one output (operating income) variables in the DEA model.

Qureshi et al. [12] developed an interpretive structural modeling based approach to identify and classify the key criteria, and to study their role in the assessment of 3PLs. There were 15 criteria – service quality, size and quality of fixed assets, quality of management, IT capability, delivery performance, information sharing and trust, operational performance, compatibility, financial stability, geographic spread and range, long-term relationship, reputation, optimum cost, surge capacity, and flexibility in operation and delivery.

Liu and Wang [4] presented a three-stage approach for the evaluation and selection of 3PLs. At the first stage, a fuzzy Delphi method was used to identify important evaluation criteria. Then, a fuzzy inference method was applied to estimate unsuitable 3PLs. At the final stage, a fuzzy linear assignment approach was developed for the final selection.

There are two drawbacks in the above approaches. First, they fail to consider the impact of business objectives and the requirements of company stakeholders into the identification of evaluating criteria. The selected 3PL can not provide what the outsourcing firms exactly

need. To overcome this problem, the proposed approach provides a platform for stakeholders in various functional departments to express their objectives and requirements explicitly, and then translate the requirements into various criteria for performance measurement. Thus, the evaluating factors are related to the strategic intent of company through the involvement of concerned stakeholders. This ensures successful strategic outsourcing because the selected 3PL can achieve the business objectives. Second, natural disasters, accidents, and volatility of the financial market have made the supply chain vulnerable nowadays. Thus, identifying, analyzing, and responding to risk events proactively are critical in minimizing disruption and losses in supply chains. However, risk-based factors were not considered in the above approaches.

III. METHODOLOGY

The integrated QFD and AHP approach comprises of three HOQs, including HOQ1 – linking company stakeholders with their requirements (steps 1 to 5), HOQ2 – relating stakeholder requirements to evaluating criteria (steps 6 to 9), and HOQ3 – benchmarking alternative 3PLs with respect to various criteria (steps 10 to 13).

Step 1: Identify the company stakeholders who have a say in the 3PL selection process.

Step 2: Determine the importance rating of each stakeholder category using AHP (steps 2.1 to 2.7).

Step 2.1: AHP pairwise comparison

Construct a pairwise comparison matrix,

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix},$$

where n denotes the number of elements (i.e., number of stakeholder categories), and a_{ij} refers to the comparison of element i to element j with respect to each criterion. The 9-point scale, shown in Table I, can be used to decide on which element is more important and by how much.

TABLE I
AHP PAIRWISE COMPARISON SCALE

Intensity	Importance	Explanation
1	Equal	Two activities contribute equally to the object
3	Moderate	Slightly favors one over another
5	Strong	Strongly favors one over another
7	Very strong	Dominance of the demonstrated in practice
9	Extreme	Evidence favoring one over another of highest possible order of affirmation
2, 4, 6, 8	Intermediate	When compromise is needed
Reciprocals of the above numbers		For inverse comparison

Step 2.2: AHP synthesization

Divide each entry (a_{ij}) in each column of matrix A by its column total. The matrix now becomes a normalized pairwise comparison matrix,

$$A' = \begin{bmatrix} \frac{a_{11}}{\sum_{i \in R} a_{i1}} & \frac{a_{12}}{\sum_{i \in R} a_{i2}} & \cdots & \frac{a_{1n}}{\sum_{i \in R} a_{in}} \\ \frac{a_{21}}{\sum_{i \in R} a_{i1}} & \frac{a_{22}}{\sum_{i \in R} a_{i2}} & \cdots & \frac{a_{2n}}{\sum_{i \in R} a_{in}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{a_{n1}}{\sum_{i \in R} a_{i1}} & \frac{a_{n2}}{\sum_{i \in R} a_{i2}} & \cdots & \frac{a_{nn}}{\sum_{i \in R} a_{in}} \end{bmatrix},$$

where R denotes the set of stakeholder categories, that is, $R = \{1, 2, \dots, n\}$.

Step 2.3: Compute the average of the entries in each row of matrix A' to yield column vector,

$$C = \begin{bmatrix} c_{1k}^1 \\ \vdots \\ c_{nk}^1 \end{bmatrix} = \begin{bmatrix} \left(\frac{\frac{a_{11}}{\sum_{i \in R} a_{i1}} + \frac{a_{12}}{\sum_{i \in R} a_{i2}} + \cdots + \frac{a_{1n}}{\sum_{i \in R} a_{in}}}{n} \right) \\ \vdots \\ \left(\frac{\frac{a_{n1}}{\sum_{i \in R} a_{i1}} + \frac{a_{n2}}{\sum_{i \in R} a_{i2}} + \cdots + \frac{a_{nn}}{\sum_{i \in R} a_{in}}}{n} \right) \end{bmatrix},$$

where c_{ik}^1 denotes the importance ratings of stakeholder category i .

Step 2.4: AHP consistency verification

Multiply each entry in column i of matrix A by c_{ik}^1 . Then, divide the summation of values in row i by c_{ik}^1 to yield another column vector,

$$\bar{C} = \begin{bmatrix} \bar{c}_{1k}^1 \\ \vdots \\ \bar{c}_{nk}^1 \end{bmatrix} = \begin{bmatrix} \frac{c_{1k}^1 a_{11} + c_{2k}^1 a_{12} + \cdots + c_{nk}^1 a_{1n}}{c_{1k}^1} \\ \vdots \\ \frac{c_{1k}^1 a_{n1} + c_{2k}^1 a_{n2} + \cdots + c_{nk}^1 a_{nn}}{c_{nk}^1} \end{bmatrix},$$

where \bar{C} refers to a weighted sum vector.

Step 2.5: Compute the averages of values in vector \bar{C} to yield the maximum eigenvalue of matrix A ,

$$\lambda_{\max} = \frac{\sum_{i \in R} \bar{c}_{ik}^1}{n}.$$

Step 2.6: Compute the consistency index,

$$CI = \frac{\lambda_{\max} - n}{n - 1}.$$

Step 2.7: Compute the consistency ratio,

$$CR = \frac{CI}{RI(n)},$$

where $RI(n)$ is a random index of which the value is dependent on the value of n , shown in Table II. If CR is greater than 0.1, go to step 2.1. Otherwise, go to step 3.

TABLE II
LIST OF RANDOM INDEX VALUE

n	2	3	4	5	6	7	8	9
$RI(n)$	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Step 3: Identify the stakeholder requirements.

Step 4: Determine the relationship weightings of stakeholder requirement i and its corresponding stakeholder k using AHP (steps 2.1 to 2.7), that is, c_{ik}^2 .

Note that R denotes the set of stakeholder requirements, that is, $R = \{1, 2, \dots, n\}$, whereas S denotes the set of stakeholder categories, that is, $S = \{1, 2, \dots, m\}$.

Step 5: Compute the importance rating of each stakeholder requirement,

$$w_i^1 = \sum_{k \in S} c_k^1 c_{ik}^2,$$

where c_k^1 are the importance ratings of stakeholder k .

Step 6: Copy the stakeholder requirements (step 3) and their corresponding importance ratings (step 5) into HOQ2.

Step 7: Identify the 3PL evaluating factors.

Step 8: Determine the relationship weightings between evaluating factors i and its corresponding stakeholder requirements k , c_{ik}^3 , using AHP (steps 2.1 to 2.7). Note that, in HOQ2, R denotes the set of evaluating factors, that is, $R = \{1, 2, \dots, n\}$, whereas S denotes the set of stakeholder requirements, that is, $S = \{1, 2, \dots, m\}$.

Step 9: Compute the importance rating of each evaluating factor,

$$w_i^2 = \sum_{k \in S} w_k^1 c_{ik}^3.$$

Step 10: Copy the evaluating factors (step 7) and their corresponding importance ratings (step 9) into HOQ3.

Step 11: Identify alternative 3PLs.

Step 12: Determine the relationship weightings between 3PL i and its corresponding evaluating factors k , c_{ik}^4 , using AHP (steps 2.1 to 2.7). Note that, in HOQ3, R denotes the set of alternative 3PLs, that is, $R = \{1, 2, \dots, n\}$, whereas S denotes the set of evaluating factors, that is, $S = \{1, 2, \dots, m\}$.

Step 13: Finally, calculate the total score of each 3PL,

$$w_i^3 = \sum_{k \in S} w_k^2 c_{ik}^4.$$

IV. CASE STUDY

Company A is a Hong Kong based enterprise that supplies hard disk components all over the world. The enterprise has manufacturing plants in China and regional offices in US, Japan, Korea, and Singapore. Recently, the company has decided to outsource three logistics functions, including freight forwarding, out-bound transportation, and inventory management.

The reasons for outsourcing these functions are as follows. First, the company is not capable of handling the

freight forwarding operation. In general, air freight forwarders rent the air containers from the airlines, and consolidate all customers' shipments and pack in the air containers to achieve cost effectiveness. Firms seldom contact airlines directly as air freight forwarders can help the shippers to prepare shipping documents, tender shipments to the airlines, and provide pick and pack services.

Second, the company has to provide the hard disk components regularly to meet the urgent needs of customers. The company reveals that it is more efficient if the products are shipped directly from manufacturing plants in China by the 3PL rather than the internal logistics team. It is because the 3PL will help the company to save time in handling the custom clearances, especially in small batch production. Due to this reason, Company A prefers outsourcing the cross-border transportation to shipping by the internal logistics team.

Third, the company intends to request the 3PL to manage the inventory, including the determination of the appropriate inventory level for each product type, and the appropriate inventory policies.

To evaluate and select the best 3PL for the above three services, the company stakeholders who have a say in selection process are identified first. In this case, there are four categories: finance, logistics/transportation, manufacturing, and marketing. Then, the importance rating of each stakeholder category is determined using AHP. A stakeholder with a higher importance rating means that s/he has more impact on the selection process. The first step is to construct a pairwise comparison matrix (Fig. 1). For synthesization, a normalized comparison matrix is constructed (Fig. 2). Based on matrix A' , a column vector showing the importance ratings of stakeholders is constructed (Fig. 3). To verify the consistency, a weighted sum vector is constructed (Fig. 4). Then, the maximum eigenvalue of matrix A , consistency index, and consistency ratio are computed.

$$A = \begin{bmatrix} 1 & \frac{1}{4} & 5 & 4 \\ 4 & 1 & 7 & 6 \\ \frac{1}{5} & \frac{1}{7} & 1 & \frac{1}{2} \\ \frac{1}{4} & \frac{1}{6} & 2 & 1 \end{bmatrix}$$

Fig. 1. Pairwise comparison matrix.

$$A' = \begin{bmatrix} 0.183 & 0.160 & 0.333 & 0.348 \\ 0.734 & 0.641 & 0.467 & 0.522 \\ 0.037 & 0.092 & 0.067 & 0.043 \\ 0.046 & 0.107 & 0.133 & 0.087 \end{bmatrix}$$

Fig. 2. Normalized pairwise comparison matrix.

$$C = \begin{bmatrix} 0.256 \\ 0.591 \\ 0.060 \\ 0.093 \end{bmatrix}$$

Fig. 3. Column vector.

$$\bar{C} = \begin{bmatrix} 4.196 \\ 4.388 \\ 4.058 \\ 4.021 \end{bmatrix}$$

Fig. 4. Weighted sum vector.

$$\lambda_{\max} = \frac{4.196 + 4.388 + 4.058 + 4.021}{4} = 4.166$$

$$CI = \frac{4.166 - 4}{4 - 1} = 0.055$$

$$CR = \frac{0.055}{0.90} = 0.061$$

Because CR is less than 0.10, the pairwise comparison is consistent.

In the third step, the stakeholder requirements are identified. According to the results of questionnaire, there are eight requirements, "Reduce total logistics costs", "Reduce cycle time", "Assure quality in distribution", "Provide customized logistics services", "Increase customer satisfaction", "Possess state-of-the-art hardware and software", "Able to provide guidance on time", "Able to resolve problems effectively". To calculate the importance ratings of stakeholder requirements, the relationship weightings between the stakeholders and their requirements are determined using AHP (HOQ1 is not shown here because of page limit).

After completing HOQ1, both stakeholder requirements and their corresponding importance ratings are copied into HOQ2, which links the requirements and evaluating factors. In this case, there are 20 evaluating factors that the 3PL should possess in order to achieve the stakeholder requirements. Similar to HOQ1, AHP is used to calculate the relationship weightings between the stakeholder requirements and evaluating factors in HOQ2. Certainly, the size of each pairwise comparison matrix is varied, and is dependent on the number of evaluating factors that will achieve a particular requirement. After determining all relationship weightings between the nine stakeholder requirements and their related evaluating factors, the importance ratings of each factor can be computed in HOQ2 (Again, HOQ2 is not shown here because of page limit).

At the last stage, both evaluating factors and their corresponding importance ratings are copied into HOQ3, which evaluates the 3PLs with respect to the 20 evaluating factors. In this case, there are four potential

3PLs to be evaluated. AHP is used again to calculate the relationship weightings between the evaluating factors and 3PLs in HOQ3. After determining all relationship weightings, the importance ratings of each 3PL can be computed in HOQ3 as shown in Fig. 5. According to HOQ3, the performance of the third 3PL is the best, followed by A1, A4, and A2. Therefore, Company A should select the third 3PL for the freight forwarding, out-bound transportation, and inventory management services.

Evaluating factors	Importance rating	Alternative 3PLs			
		A1	A2	A3	A4
1. Pro-active in cost reduction	0.043	0.083	0.427	0.255	0.235
2. Responsibility for warranty cost	0.023	0.112	0.123	0.274	0.492
3. Sustainable low cost through	0.043	0.089	0.488	0.190	0.233
4. Accuracy of quantity fulfilment	0.062	0.150	0.066	0.544	0.240
5. Delivery condition	0.064	0.121	0.068	0.313	0.497
6. On-time delivery	0.110	0.124	0.058	0.520	0.297
7. Compatibility with the users	0.088	0.242	0.159	0.537	0.062
8. Flexibility in increasing production capacity	0.006	0.198	0.299	0.422	0.081
9. Service category	0.053	0.240	0.112	0.576	0.072
10. Perfect rate	0.047	0.113	0.053	0.391	0.443
11. References from current customers	0.002	0.100	0.059	0.510	0.330
12. Reliability of quality	0.028	0.163	0.062	0.539	0.236
13. TQM program implemented	0.009	0.134	0.107	0.273	0.486
14. Information system capabilities	0.101	0.598	0.070	0.162	0.170
15. Optimization capabilities	0.083	0.488	0.113	0.332	0.067
16. Physical equipment	0.105	0.474	0.134	0.320	0.072
17. Ability in identifying and preventing potential problems	0.050	0.150	0.240	0.544	0.066
18. Accessibility of contact persons in emergency	0.030	0.445	0.080	0.315	0.160
19. Financial stability	0.023	0.072	0.134	0.474	0.320
20. Risk mitigating skills	0.032	0.128	0.255	0.552	0.065
Importance ratings of alternative 3PLs		0.264	0.140	0.396	0.201
Ranking		2nd	4th	1st	3rd

Fig. 5. HOQ3 – benchmarking alternative 3PLs with respect to various criteria.

V. CONCLUSION

This paper developed an integrated multiple criteria decision making approach to measure the performance of alternative 3PLs. A case study was given to demonstrate how it works. In the approach, QFD was used to translate the hard disk components manufacturing company stakeholder requirements into multiple evaluating factors, which were used to benchmark the 3PLs. AHP was used to determine both importance ratings and relationship weightings in HOQs consistently. The major advantage of this integrated approach is that the evaluating factors are of interest to the stakeholders. This ensures that the selected 3PL will achieve the business objectives and satisfy the stakeholders most. Another advantage is that the approach can guarantee the benchmarking to be consistent and reliable. Furthermore, the integrated approach involves a team of people representing various functional departments that have involvement in 3PL selection: finance, logistics/transportation, manufacturing, and marketing. The active involvement of these departments can lead to a balanced consideration of the

requirements or “what’s” at each stage of this translation process, and provide a mechanism to communicate implicit knowledge - knowledge that is known by one individual or department but may not otherwise be communicated through the company. Therefore, the proposed approach outranks the conventional approaches to strategic logistics outsourcing. In the immediate future, a sensitivity analysis should be carried out in order to check the effect of changes in the importance levels of various factors on final outcome.

REFERENCES

- [1] H. L. Sink and C. J. Langley, “A managerial framework for the acquisition of third-party logistics services,” *Journal of Business Logistics*, vol. 18, no. 2, pp. 163–189, 1997.
- [2] G. Işıklar, E. Alptekin and G. Büyükoçkan, “Application of a hybrid intelligent decision support model in logistics outsourcing,” *Computers & Operations Research*, vol. 34, pp. 3701–3714, 2007.
- [3] M. A. Razzaque and C. C. Sheng, “Outsourcing of logistics functions: A literature survey,” *International Journal of Physical Distribution & Logistics Management*, vol. 28, no. 2, pp. 89–107, 1998.
- [4] H. T. Liu and W. K. Wang, “An integrated fuzzy approach for provider evaluation and selection in the third-party logistics,” *Expert Systems with Applications*, vol. 36, pp. 4387–4398, 2009.
- [5] M. K. Menon, M. A. McGinnis and K. B. Ackerman, “Selection criteria for providers of third-party logistics services: An exploratory study,” *Journal of Business Logistics*, vol. 19, no. 1, pp. 121–137, 1998.
- [6] L. Meade and J. Sarkis, “A conceptual model for selecting and evaluating third-party reverse logistics providers,” *Supply Chain Management: An International Journal*, vol. 7, no. 5, pp. 283–295, 2002.
- [7] E. Bottani and A. Rizzi, “A fuzzy TOPSIS methodology to support outsourcing of logistics services,” *Supply Chain Management: An International Journal*, vol. 11, no. 4, pp. 294–308, 2006.
- [8] S. Jharkharia and R. Shankar, “Selection of logistics service provider: An analytic network process (ANP) approach,” *Omega*, vol. 35, pp. 274–289, 2007.
- [9] H. Göl and B. Çatay, “Third-party logistics provider selection: Insights from a Turkish automotive company,” *Supply Chain Management: An International Journal*, vol. 12, no. 6, pp. 379–384, 2007.
- [10] T. Efindigil, S. Önüt and E. Kongar, “A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness,” *Computers & Industrial Engineering*, vol. 54, pp. 269–287, 2008.
- [11] G. Zhou, H. Min, C. Xu and Z. Cao, “Evaluating the comparative efficiency of Chinese third-party logistics providers using data envelopment analysis,” *International Journal of Physical Distribution & Logistics Management*, vol. 38, no. 4, pp. 262–279, 2008.
- [12] M. N. Qureshi, D. Kumar and P. Kumar, “An integrated model to identify and classify the key criteria and their role in the assessment of 3PL service providers,” *Asia Pacific Journal of Marketing and Logistics*, vol. 20, no. 2, pp. 227–249, 2008.