3PL selection using hybrid model of 
AHP-PROMETHEE

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Abstract: This research paper aims to give a new dimension to the decision 
maker by proposing a hybrid model of analytic hierarchy process (AHP) 
and preference ranking organisation method for enrichment evaluation 
(PROMETHEE) in 3PL selection. It uses an integrated approach of 
AHP-PROMETHEE as a selection methodology to select an efficient and 
requisite 3PL firm for a manufacturer. A relatively new and user interactive 
software, visual PROMETHEE has been used to solve the problem. The hybrid 
model of AHP-PROMETHEE is a sound technique for 3PL selection. AHP 
easily performs the cumbersome process of weighting diverse criteria, whereas 
PROMETHEE ranks various alternatives according to their performance on the 
basis of these criteria. Application of hybrid model of AHP-PROMETHEE is 
an important tool for multi-criteria decision making (MCDM). Further research 
work on this method and its variants like fuzzy AHP and PROMETHEE VI 
may enlighten a new path for the decision makers. Moreover development of 
accurate and user-friendly software may prove very helpful in the selection 
process. However, types of criteria, their number and their importance may 
vary from firm to firm. So, it becomes extremely difficult to generalise the 
view of the 3PL selection process.

Keywords: 3PL; analytic hierarchy process; AHP; preference ranking 
organisation method for enrichment evaluation; PROMETHEE; multi-criteria 
decision making; MCDM.

Reference to this paper should be made as follows: Bansal, A. and Kumar, P. 

Biographical notes: Ankit Bansal is an undergraduate student in the 
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University, Delhi. His research interest is in the area of supply chain and 
logistics management, operations research.
A 3PL company is an independent firm that provides logistics services under a contract to a primary manufacturer, vendor, or user of a product or service (Aguezzoul, 2008). In comparison to traditional transportation and warehousing services, 3PLs are more complex, encompass a broader number of functions, and are characterised by longer-term, more mutually beneficial relationships (Large et al., 2011). 3PL is usually associated with the offering of multiple, value added services, rather than just isolated transport or warehousing functions (Leahy et al., 1995). Some of the possible 3PLs are summarised in Table 1.

<table>
<thead>
<tr>
<th>Logistic function</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Shipping, forwarding, (de)consolidation, contract delivery, freight bill payment/audit, cross-docking, household goods relocation, load tendering, brokering.</td>
</tr>
<tr>
<td>Warehousing</td>
<td>Storage, receiving, (re)assembly, return goods and kitting.</td>
</tr>
<tr>
<td>Inventory management</td>
<td>Forecasting, location analysis, network consulting and slotting/layout design.</td>
</tr>
<tr>
<td>Order processing</td>
<td>Order entry/fulfilment, consignee management and call centre.</td>
</tr>
<tr>
<td>Information systems</td>
<td>EDI/VANS, routing/scheduling, artificial intelligence, expert systems, bar-coding, RFID, web-based connectivity, tracking and tracing.</td>
</tr>
<tr>
<td>Value-added activities</td>
<td>Design and recycling of packaging, marking/labelling, billing, call centre activities and customisation.</td>
</tr>
<tr>
<td>Reverse logistics</td>
<td>Collection and transportation of used products after their useful life.</td>
</tr>
</tbody>
</table>

Customer-oriented 3PL firms are specialist in providing a wide range of logistics activities and are well-recognised as key enablers of their customers’ service-related competitive advantages in developed economies (Tian et al., 2010). As a result outsourcing logistics functions to third party logistics (3PL) service providers has been a source of competitive advantage for many companies. Employing 3PL provides companies greater flexibility, operational efficiency, improved customer service levels, and a better focus on their core business (Göl and Çatay, 2007). This implies that the relation with a 3PL can be of strategic importance for the supply chain of a company, not just of tactical value (Wolf and Seuring, 2010). Thus, the selection of a requisite 3PL vendor selection is a crucial decision for any firm to be successful.

The selection of an efficient 3PL involves many criteria, techniques and methods. There is a need to develop a systematic process for identifying and prioritising relevant
criteria and evaluating the trade-off between different criteria (Zhang et al., 2004). Thus, to address the above problem, an integrated approach of analytic hierarchy process (AHP) and preference ranking organisation method for enrichment evaluation (PROMETHEE) have been proposed in this research paper. It is an exclusive study of 3PL selection method using hybrid model of AHP-PROMETHEE giving an all-together relatively new dimension to the important managerial decision.

Remaining part of this paper have been arranged as: Section 2 presents the literature review, Section 3 presents criteria for 3PL selection, Section 4 explores the proposed methodology, Section 5 presents the numerical illustration of the proposed methodology and Section 6 presents the result, discussion of managerial implications of the research work and conclusion.

2 Literature review

In the contemporary business world, a large number of companies are outsourcing their logistic operations in order to focus their efficiencies on core competences by employing a 3PL firm. According to Göl and Çatay (2007), outsourcing logistics functions to 3PL providers has been a source of competitive advantage for most companies. These companies cite greater flexibility, operational efficiency, improved customer service levels, and a better focus on their core businesses as part of the advantages of engaging the services of 3PL providers. 3PL alliances began with companies outsourcing some or all of their transportation and distribution functions. 3PL providers can also contribute to improved customer satisfaction and provide access to international distribution networks (Bask, 2001).

Bounfour (1999) proposed that the main reasons of an enterprise to outsource some of its functions were: concerned with core business or process, reduced technological complexity, reduced costs and development of new competitive approaches, through innovation. According to Gunasekaran and Ngai (2008), nowadays 3PL has become very popular for disposing products to market as soon as possible and also for the one-time delivery of products to the customers. Due to the increasing importance of logistic services, enterprises need to carefully evaluate and select their service providers. Logistics outsourcing offers many cost-related advantages such as reduction in asset investment and labour and equipment maintenance costs (Bardi and Tracey, 1991). 3PL may serve multiple customers at a time and are able to utilise capacity better and spread logistics costs, thus achieving economies of scale (van Damme and Ploos van Amstel, 1996). Operational advantages of employing a 3PL service provider include reduction in inventory levels, order cycle times, lead times and improvement in customer service (Bhatnagar and Viswanathan, 2000; Daugherty et al., 1996; Wong et al., 2000).

Examining the importance of 3PL selection, there has been a surge of academic interest and publications in the 3PL study making the decision process more efficient day by day. There are a number of references analysing different attributes (criteria) and methodologies as determinants for 3PL firm selection and they discover the variance in the importance of the different attributes and methodologies corresponding to changing economic conditions and technical advancements.
2.1 Methodology for 3PL selection

Aguezzoul et al. (2006) addressed the problem of 3PL selection by choosing main and secondary criteria according to the situation in a flexible selection method where user can introduce desirable criteria and weights and then using ELECTRE to solve the multi-criteria problem for 3PL selection. The extended version of the AHP, the analytic network process (ANP) has also been used widely to solve more complex problems for example Jharkharia and Shankar (2007) used ANP as a tool to classify the 3PL criteria selection into three levels. Chen and Wu (2011) combined the Delphi method and analytical network process (ANP), to develop a decision-making method which help the electronic companies that need to evaluate and select the logistics service provider.

Efendigil et al. (2008) proposed an integrated conceptual framework combining artificial intelligence and fuzzy logic to assist managers in determining the most appropriate 3PL. Gupta et al. (2010) integrated fuzzy Delphi and fuzzy TOPSIS method to choose the best service provider by finding the closeness to the positive ideal solution (PIS). In addition of these criteria, some of the methodologies and their descriptions have been summarised in Table 2.

Table 2 Literature review of various methods proposed for 3PL selection

<table>
<thead>
<tr>
<th>Authors</th>
<th>Methodology for 3PL selection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rao (2007)</td>
<td>3PL vendor selection in a supply chain using analytic hierarchy process and genetic algorithm methods</td>
<td>The proposed procedure of AHP and genetic algorithm methods has been found capable to handle realistic situations and provides a decision-making tool for the 3PL vendor selection decision in a supply chain.</td>
</tr>
<tr>
<td>Perçin (2009)</td>
<td>A two phase method comprising analytical hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS).</td>
<td>AHP is applied for weighing different criteria and TOPSIS for final ranking of the attributes.</td>
</tr>
<tr>
<td>Qureshi et al. (2009)</td>
<td>A combined approach of AHP and graph theory</td>
<td>AHP and graph theory is employed to develop a logistics service provider index which evaluates and ranks 3PL service providers.</td>
</tr>
<tr>
<td>Liu and Wang (2009)</td>
<td>An integrated fuzzy approach for 3PL selection</td>
<td>Fuzzy Delphi method is used to identify important evaluation criteria fuzzy inference method is applied to eliminate unsuitable 3PL providers and then fuzzy linear assignment approach is developed for the final selection.</td>
</tr>
</tbody>
</table>
Table 2  Literature review of various methods proposed for 3PL selection (continued)

<table>
<thead>
<tr>
<th>Authors</th>
<th>Methodology for 3PL selection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gupta et al. (2010)</td>
<td>Integrated fuzzy Delphi and fuzzy TOPSIS method</td>
<td>Fuzzy Delphi method is used to shortlist the most important criteria and most probable service providers and fuzzy TOPSIS is employed to choose the best service provider by finding the closeness to the positive ideal solution (PIS).</td>
</tr>
<tr>
<td>Muralidharan et al. (2011)</td>
<td>Integrated analytic hierarchy process (AHP) and quality function deployment (QFD) method for 3PL selection.</td>
<td>A three-phase analytical model with the integration of analytic hierarchy process (AHP) and quality function deployment (QFD) method has been developed to handle the voice of customer and internal and external business metrics for evaluation and selection of 3PL service provider.</td>
</tr>
<tr>
<td>Sreekumar and Mahapatra (2011)</td>
<td>Fuzzy multi-criteria decision-making approach for supplier selection.</td>
<td>Fuzzy multi-criteria decision making approach in group decision making environment is proposed to solve a highly complex supplier selection problem which involves a number of qualitative and quantitative factors having interdependencies among themselves.</td>
</tr>
<tr>
<td>Ye and Liu (2011)</td>
<td>An integrated method of goal programming and balanced scorecard.</td>
<td>The balanced scorecard is used to define the evaluation systems of 3PL enterprise and final ranking is obtained by adopting the goal programming method from the, which systematically integrates the special and relative ability assessment on the 3PL enterprise.</td>
</tr>
<tr>
<td>Li et al. (2012)</td>
<td>3PL supplier selection using fuzzy sets</td>
<td>Using fuzzy sets, an indicator system and a data integration method has been proposed to evaluate and rank 3PL service providers.</td>
</tr>
</tbody>
</table>

2.2 Evaluation criteria for selecting 3PL providers

Vendor/3PL selection is a multi-criteria problem and hence a complex process because it involves various criteria such as price, quality, delivery, etc. (Aguezzoul, 2008). By establishing a set of selection criteria, a company will be better able to select a 3PL provider that will best fit its needs and existing operations (Bhatnagar et al., 1999). The study conducted by McGinnis et al. (1995) and Menon et al. (1998) in the USA explores that both the firm’s competitiveness strategy and external environmental affect the selection criteria. They also stated eight important attributes for 3PL selection which are on-time shipment and deliveries, superior error rates, financial stability, creative management, ability to deliver as promised, availability of top management, responsiveness to unforeseen occurrences and meet performance and quality requirements before price discussions occur.
Efendigil et al. (2008) used 12 performance indicators in their proposed model. These indicators are: on time delivery ratio, confirmed fill rate, service quality level, unit operation cost, capacity usage ratio, total order cycle time, system flexibility index, integration level index, increment in market share, research and development ratio, environmental expenditures and customer satisfaction index. Dapiran et al. (1996) and Bhatnagar et al. (1999) found that service quality, work force capability and cost are the most important criteria for a 3PL selection.

Survey conducted by the International Warehouse Logistics Association in 2003 comprising 550 logistic companies of North America found that the periodic change in the importance of criteria for 3PL evaluation could be given as: price was ranked at number 11 in 1994 in the importance list and it climbed to fourth position in 1999 to the first position in 2003 while on the other hand service quality dropped from the first position in 1994 to the third position in 2003.

Moberg and Speh (2004) observed the four most influential attributes for 3PL selection which were: responsiveness to service requirements, quality of management, track record of ethical importance and ability to provide value-added services.

Wolf and Seuring (2010) studied environmental impacts as criteria for 3PL selection and found that, while 3PL reports an increasing interest in environmental issues, buying decisions are still made on traditional performance objectives, such as price, quality and on-time delivery. Environmental concerns have not been incorporated.

Thus, all the above mentioned studies show that 3PL selection process is a multi-criteria problem and some of these criteria are client-based and some are general. Consideration of a criteria and their importance totally depend on the needs and prevailing economic conditions of the buyer firm. Table 3 shows various criteria chosen for 3PL selection literature.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Criteria chosen for 3PL selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spencer et al. (1994)</td>
<td>On-time service delivery, service quality, communication, reliability, service speed and flexibility</td>
</tr>
<tr>
<td>McGinnis et al. (1995) and Menon et al. (1998)</td>
<td>On-time shipment and deliveries, superior error rates, financial stability, creative management, ability to deliver as promised, availability of top management, responsiveness to unforeseen occurrences and meet performance and quality requirements before price discussions occur</td>
</tr>
<tr>
<td>Dapiran et al. (1996) and Bhatnagar et al. (1999)</td>
<td>Service quality, work force capability and cost</td>
</tr>
<tr>
<td>Moberg and Speh (2004)</td>
<td>Responsiveness to service requirements, quality of management, track record of ethical importance and ability to provide value-added services</td>
</tr>
</tbody>
</table>

3 3PL selection criteria used in this model

Before choosing a 3PL, companies must define the goals and objective for outsourcing and then establish their criteria for selection. Selection process of 3PL starts with the stringent research to collect data regarding the services required, market availability and
The selected 3PL firm should ensure a full customer satisfaction to his clients. Major criteria for 3PL selection used in this paper are:

1. **Logistic cost (LC):** Cost of service is an important criterion for the selection of 3PL. In this ultra-competitive environment, shippers are looking for more for less cost by demanding value-added services like tracing and tracking, short lead time, bundled services, etc. Hence the cost of service has become an important concern for both (Milligan, 2000).

2. **Quality of service (QS):** It plays an important role in providing product differentiation by adding values (Qureshi et al., 2008). This factor has significantly contributed to the development of measurement systems that have in turn contributed significantly to the expansion of 3PL alliances (Van Hoek, 2001).

3. **Compatibility (CP):** This criterion measures the degree of synchronisation between the company and the service provider. CP of culture and values is one of the keys to build a successful partnership which can result in long-term relationship (Bowersox and Daugherty, 1990). Thus, the cultural, technological and social CP leads to strong outsourcing partnership.

4. **Information technology capability (IT):** It is an important criterion to be considered in selection of 3PL service providers. IT capability may be increased by adopting sophisticated software, for instance, enterprise resource planning (ERP), electronic data interchange (EDI), simulation software, vehicle routing packages, carrier loading optimisation tools, consolidation packages, etc. Hardware like servers, networking and internet/intranet connections, radio frequency identification devices (RFID), bar code printers and scanners, global positioning system (GPS), satellite tracking devices etc may be used to ease up operations and to raise the productivity (Qureshi et al., 2008). Enhanced IT capability may also lead to the reduction of cost of service in long run (Vaidyanathan, 2005).

5. **Delivery performance (DP):** On-time delivery and high quality service plays a pivotal role in the strength of supply chain. DP of 3PL effects shippers’ reputation and market share as high DP enhances the market share and vice versa (Qureshi et al., 2008). Flexibility in operations and delivery enhances DP of a 3PL services provider. It is important to see, how far the 3PL services providers tailor the services according to shipper’s changing need in constantly evolving marketplace (Qureshi et al., 2008). Thus, DP is a vital attribute to be considered in selection of 3PL service provider.

6. **Trust factor (TF):** Trust can be defined as reliance on, and confidence in, another party, and represents a key element in relational exchanges. Trust has been an important element since the infancy of third-party logistics and today trust continues to be the bedrock of many successful 3PL arrangements (Knemeyer and Murphy, 2005).

7. **Geographical range of services (GR):** 3PL service providers with greater geographical coverage are more desirable as they help the shippers to expand their businesses around the globe. Thus, allowing them to evolve from a regional to a national to a multinational firm.
8 Number of value added services (VS): In today’s world, along with traditional transportation and warehousing of freight, a wide range of services like inventory management, tracing and tracking etc are provided by a 3PL. Broad the spectrum of such services, less the pressure on the buyer firm and more favourable is the 3PL service provider.

9 Environmental sustainability (ES): The major global 3PL service providers have made important commitments to ES during the past several years. The companies have made capital expenditures, implemented organisational changes and modified operating practices to address such issues. While the reasons for making these commitments vary from company to company, the most commonly cited reasons have been an organisational desire to do the right thing with respect to environmental concerns and pressure from customers. In pursuing sustainability goals, many of the 3PL have closely worked with customers, transportation companies, trade associations, non-governmental organisations, and government agencies. Interestingly, in many instances, their efforts have resulted in significant cost savings for the companies (Lieb and Lieb, 2010). Thus, ES has become an important modern-day criterion to be chosen for 3PL selection.

4 Proposed methodology

Although AHP and PROMETHEE were proposed and developed around 20 years their hybrid has been seldom used in the field of decision making and management. Babic and Plazibat (1998) used combined approach of AHP and PROMETHEE for selection of enterprises and thus answer about the financial standing of each enterprise. Đagdeviren (2008) utilised this methodology for equipment selection to enhance productivity, precision and productivity of a manufacturing system. Alp et al. (2011) used hybrid of fuzzy AHP and PROMETHEE to select bus garage location to minimise dead kilometres travelled by a bus. This research paper aims to add another feather to the cap of AHP-PROMETHEE hybrid literature by employing this methodology for 3PL selection. The detail of the methodology has been mentioned in the following subsections.

4.1 Integrated approach of AHP and PROMETHEE

In this paper, AHP-PROMETHEE has been proposed to an integrated approach of AHP-PROMETHEE to solve a 3PL selection problem. AHP will be used to find the weights of the criteria and PROMETHEE will be used to find the complete ranking of alternatives (3PLs).

4.2 Analytic hierarchy process

The AHP is a theory of measurement through pair wise comparisons of criteria to rank order alternatives (Saaty, 1980).

There is a two step process to find the weights of the criteria using AHP: find the priority vector and verify the consistency of the priority vector.
4.2.1 Priority vector

Priority vector is calculated by setting up a comparison matrix which compares various criteria for 3PL selection over one another using a 9 point scale rating devised by Saaty (1980) as shown in Table 4.

Table 4 Nine-point rating scale

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two factors contribute equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Somewhat more Important</td>
<td>Experience and judgment slightly favour one over the other.</td>
</tr>
<tr>
<td>5</td>
<td>Much more Important</td>
<td>Experience and judgment strongly favour one over the other.</td>
</tr>
<tr>
<td>7</td>
<td>Very much more Important</td>
<td>Experience and judgment very strongly favour one over the other.</td>
</tr>
<tr>
<td>9</td>
<td>Absolutely more Important</td>
<td>The evidence favouring one over the other is of the highest possible validity.</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate Values</td>
<td>When compromise is needed.</td>
</tr>
</tbody>
</table>

Now, $C_1$, $C_2$, $C_3$, ..., $C_n$ be $n$ criteria for 3PL selection to be compared. The relative ‘weight’ (priority or significance) of $C_i$ with respect to $C_j$ is denoted which by $a_{ij}$ forms a square matrix $A = (a_{ij})$ of order ‘$n$’ with the constraint that $a_{ij} = 1/a_{ji}$ for all $i \neq j$ and for $i = j$, $a_{ii} = 1$ for all $i$ as shown in Table 5.

Table 5 Pair-wise comparison among various criteria

<table>
<thead>
<tr>
<th></th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>.</th>
<th>.</th>
<th>$C_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>1</td>
<td>$a_{21}$</td>
<td>$a_{31}$</td>
<td>.</td>
<td>.</td>
<td>$a_{1n}$</td>
</tr>
<tr>
<td>$C_2$</td>
<td>$a_{12}$</td>
<td>1</td>
<td>$a_{32}$</td>
<td>.</td>
<td>.</td>
<td>$a_{2n}$</td>
</tr>
<tr>
<td>$C_3$</td>
<td>$a_{13}$</td>
<td>$a_{23}$</td>
<td>1</td>
<td>.</td>
<td>.</td>
<td>$a_{3n}$</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>$C_n$</td>
<td>$a_{1n}$</td>
<td>$a_{2n}$</td>
<td>$a_{3n}$</td>
<td>.</td>
<td>.</td>
<td>1</td>
</tr>
</tbody>
</table>

The relative priority vector is given by the right eigenvector ($w$). Let the corresponding highest eigenvalue be $\lambda_{\text{max}}$ and we know that from vector calculus that:

$$AW = \lambda_{\text{max}} W.$$  

4.2.2 Consistency check

The weights are consistent if they are transitive, i.e., $a_{ik} = a_{ij}a_{jk}$ for all $I, k$ and $j$. A consistent matrix has rank 1 and $\lambda_{\text{max}} = n$. In that case, weights can be obtained by normalising any of the rows and column of $A$. 

4.2.3 Consistency check can be done by calculation

CR (consistency ratio) = Consistency Index (CI) / Random Consistency Index (RI)

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]

\[ CR = \frac{CI}{RI} \]

CR is given by Table 6:

<table>
<thead>
<tr>
<th>N</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0.9</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
</tr>
</tbody>
</table>

- if \( CR < 0.1 \) then the priority vector is consistent
- and if \( CR > 0.1 \) then priority vector is inconsistent and should be recalculated.

4.3 PROMETHEE

PROMETHEE is an outranking method for a finite set of alternative actions to be ranked and selected among criteria, which are often conflicting (Behzadian et al., 2010). PROMETHEE is also a quite simple ranking method in conception and application compared with the other methods for multi-criteria analysis (Brans et al., 1986). The PROMETHEE family of outranking methods has six different forms of PROMETHEE including PROMETHEE I for partial ranking of the alternatives and the PROMETHEE II for complete ranking of the alternatives which are used in this paper to select the requisite 3PL device provider for a company.

Algorithm of PROMETHEE I and II has been stated in the following steps:

4.3.1 Determining the weights of the criteria

Let \( j = 1, 2, \ldots, n \) be the criteria for 3PL selection and \( w_j \) is the weight for \( j^{th} \) criteria, showing the relative importance of each criterion over one another. These weights are allocated by the buyer company and can be effectively calculated using various methods developed. It has been observed that allocating weights to criteria is also an intriguing multi criteria decision problem. In this paper, AHP is used to allocate weights to criteria. Let \( C = \{ g_1(), g_2(), g_3(), \ldots, g_j(), \ldots, g_n() \} \) be the set of criteria for 3PL selection and \( (w_1, w_2, w_3, \ldots, w_j, \ldots, w_n) \) be the corresponding weights of the criteria calculated by AHP using Sub-Section 4.2 as shown in Table 7.

Table 7 Weights of criteria

<table>
<thead>
<tr>
<th>Criteria ((C))</th>
<th>(g_1())</th>
<th>(g_2())</th>
<th>(g_3())</th>
<th>(\ldots)</th>
<th>(g_i())</th>
<th>(\ldots)</th>
<th>(g_n())</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights ((w))</td>
<td>(w_1)</td>
<td>(w_2)</td>
<td>(w_3)</td>
<td>(\ldots)</td>
<td>(w_j)</td>
<td>(\ldots)</td>
<td>(w_n)</td>
</tr>
</tbody>
</table>

where

\[ \sum_{j=1}^{k} w_j = 1 \]

\[ w_j < 1 \]
4.3.2 Development of evaluation table

Evaluation Table 8 rates the performance various 3PL firms against a particular criterion. Let \( A = \{a_1, a_2, a_3, a_4 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots an\} \) be the set of 3PL service providers and \( g_j(a) \) is the performance of 3PL service provider \( a_i \) with respect to \( j^{th} \) criteria.

### Table 8  
The evaluation of alternatives with respect to criteria

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Criteria</th>
<th>( g_1(.) )</th>
<th>( g_2(.) )</th>
<th>( g_3(.) )</th>
<th>( g_4(.) )</th>
<th>( \ldots )</th>
<th>( g_j(.) )</th>
<th>( \ldots )</th>
<th>( g_k(.) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>( g_1(a_1) )</td>
<td>( g_2(a_1) )</td>
<td>( g_3(a_1) )</td>
<td>( g_4(a_1) )</td>
<td>( \ldots )</td>
<td>( g_j(a_1) )</td>
<td>( \ldots )</td>
<td>( g_k(a_1) )</td>
<td></td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( g_1(a_2) )</td>
<td>( g_2(a_2) )</td>
<td>( g_3(a_2) )</td>
<td>( g_4(a_2) )</td>
<td>( \ldots )</td>
<td>( g_j(a_2) )</td>
<td>( \ldots )</td>
<td>( g_k(a_2) )</td>
<td></td>
</tr>
<tr>
<td>( a_3 )</td>
<td>( g_1(a_3) )</td>
<td>( g_2(a_3) )</td>
<td>( g_3(a_3) )</td>
<td>( g_4(a_3) )</td>
<td>( \ldots )</td>
<td>( g_j(a_3) )</td>
<td>( \ldots )</td>
<td>( g_k(a_3) )</td>
<td></td>
</tr>
<tr>
<td>( a_4 )</td>
<td>( g_1(a_4) )</td>
<td>( g_2(a_4) )</td>
<td>( g_3(a_4) )</td>
<td>( g_4(a_4) )</td>
<td>( \ldots )</td>
<td>( g_j(a_4) )</td>
<td>( \ldots )</td>
<td>( g_k(a_4) )</td>
<td></td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td></td>
</tr>
<tr>
<td>( a_n )</td>
<td>( g_1(a_n) )</td>
<td>( g_2(a_n) )</td>
<td>( g_3(a_n) )</td>
<td>( g_4(a_n) )</td>
<td>( \ldots )</td>
<td>( g_j(a_n) )</td>
<td>( \ldots )</td>
<td>( g_k(a_n) )</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3.2.1 Development and allocating of preference functions to each criteria

PROMETHEE involves pair wise comparison of all the 3PL service providers on the basis of each criterion. Pair wise comparison is undertaken by calculation of the deviations between the evaluations of 3PL service providers with respect to each criterion.

\[
d_j(a, b) = g_j(a) - g_j(b)
\]

where \( a \) and \( b \) are two different 3PL service providers.

It is clear that larger the deviation, better the performance of the 3PL service provider in that particular criteria.

Then, these deviations are normalised by generating a preference function \( P_j(a, b) \).

\[
P_j(a, b) = f_j(d_j(a, b))
\]

and

\[
0 \leq P_j(a, b) \leq 1
\]

There are six types of generalised criteria or preference functions proposed by Brans and Mareshal which are stated in Table 9.
Table 9 Preference functions

<table>
<thead>
<tr>
<th>Preference function</th>
<th>Definition</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 *Usual Criterion*</td>
<td>$P(d) = \begin{cases} 0 \rightarrow d \leq 0 \ 1 \rightarrow d &gt; 0 \end{cases}$</td>
<td>-</td>
</tr>
<tr>
<td>Type 2 *U shape Criterion*</td>
<td>$P(d) = \begin{cases} 0 \rightarrow d \leq q \ 1 \rightarrow d &gt; q \end{cases}$</td>
<td>$q$</td>
</tr>
<tr>
<td>Type 3 *V-Shape Criterion*</td>
<td>$P(d) = \begin{cases} 0 \rightarrow d \leq 0 \ d/p \rightarrow 0 &lt; d \leq p \ 1 \rightarrow d &gt; p \end{cases}$</td>
<td>$p$</td>
</tr>
<tr>
<td>Type 4 *Level Criterion*</td>
<td>$P(d) = \begin{cases} 0 \rightarrow d \leq q \ q/p \rightarrow q &lt; d \leq p \ 1 \rightarrow d &gt; p \end{cases}$</td>
<td>$p, q$</td>
</tr>
</tbody>
</table>
where q is the threshold of indifference, i.e., the largest deviation considered to generate full preference; p is the threshold of strict preference, i.e., the smallest deviation considered to generate full preference, s is an intermediate value of p and q, however it is rarely used.

Selection of type of preference function and thresholds (p, q and s) depends upon the nature of the criteria and the buyer firm. Some guidelines to choose the correct preference function according to the nature of the criteria are discussed below as:

1 The V-shape (type 3) and Linear (type 5) preference functions are best suited for quantitative criteria (e.g., prices, costs, power, etc.). The choice will depend on the use of indifference threshold. V-shape is a special case of the linear one.

2 The Usual (type 1) and Level (type 4) preference functions are best suited for qualitative criteria. In case of a small number of levels on the criteria scale (e.g., yes/no criteria or up to five-point scale) and if the different levels are considered quite different from each other, the Usual preference function is the good choice. If we want to differentiate smaller deviations from larger ones, the Level preference function is more adequate. The U-shape (type 2) preference function is a special case of the Level one and is less often used.

3 The Gaussian (type 4) preference function is less often used as it is more difficult to parameter (the s threshold value is somewhere between the q indifference threshold and the p preference threshold).
4.3.3 Aggregated preference indices and aggregated preference table

PROMETHEE procedure is based on pair wise comparisons. \( API(\pi(a, b)) \) measures the degree by which 3PL service provider ‘a’ is preferred over 3PL service provider ‘b’ on all criteria and vice-a-versa.

Let \( a, b \in A \) where \( A \) is the set of 3PL service providers in contention for selection. Then API is given by:

\[
\pi(a, b) = \sum_{j=1}^{k} P_j(a, b)w_j
\]

\[
\pi(b, a) = \sum_{j=1}^{k} P_j(b, a)w_j
\]

where \( w_j \) are the relative weights of criteria devised by AHP and \( P_j(a, b) \) is the preference functions as discussed in above sub-section. In this way, API for all the 3PLs with respect to all criteria can be calculated as shown in Table 10.

### Table 10  Aggregated preference index

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>( a_1 )</th>
<th>( a_2 )</th>
<th>( a_3 )</th>
<th>.</th>
<th>.</th>
<th>.</th>
<th>( a_n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>0</td>
<td>( \pi(a_1, a_2) )</td>
<td>( \pi(a_1, a_3) )</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>( \pi(a_1, a_n) )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( \pi(a_2, a_1) )</td>
<td>0</td>
<td>( \pi(a_2, a_3) )</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>( \pi(a_2, a_n) )</td>
</tr>
<tr>
<td>( a_3 )</td>
<td>( \pi(a_3, a_1) )</td>
<td>( \pi(a_3, a_2) )</td>
<td>0</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>( \pi(a_3, a_n) )</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>( a_n )</td>
<td>( \pi(a_n, a_1) )</td>
<td>( \pi(a_n, a_2) )</td>
<td>( \pi(a_n, a_3) )</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>0</td>
</tr>
</tbody>
</table>

Following self explanatory properties hold for API

1. \( \pi(a, a) = 0 \)
2. \( 0 \leq \pi(a, b) \leq 1 \)
3. \( 0 \leq \pi(b, a) \leq 1 \)
4. \( 0 \leq \pi(a, b) + \pi(b, a) \leq 1 \).
   - if \( \pi(a, b) \rightarrow 0 \) then, ‘a’ has weak global preference over b
   - and if \( \pi(a, b) \rightarrow 1 \) then, ‘a’ has strong preference over b.

4.3.4 Calculation of outranking flows

Outranking flows shows the amount by which a 3PL service provider outperforms the competitors or by how much a 3PL service provider is being outperformed by competitors.

Positive and negative outranking flows are given by:

\[
\phi^+(a) = \left( \sum_{x \in A} \pi(a, x) \right) / n - 1
\]
3PL selection using hybrid model of AHP-PROMETHEE

\[ \phi^-(a) = \left( \sum_{i=0}^{n} \pi(x, a) \right) / n - 1 \]

where \( \pi(a, x) \) and \( \pi(x, a) \) are the aggregated preference indices (API) and \( n \) are the number of criteria considered for 3PL selection.

Positive outranking flow shows the outranking character of 3PL service provider ‘\( a \)’. Greater the \( \phi^+(a) \) better the performance of 3PL service provider. Negative outranking flow shows the degree by which a 3PL service provider has been outranked by others. Lesser the \( \phi^-(a) \), better the performance of 3PL service provider. Outranking flows are shown in Table 11.

**Table 11** API with outranking flows

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>( a_1 )</th>
<th>( a_2 )</th>
<th>( a_3 )</th>
<th>.</th>
<th>.</th>
<th>( a_n )</th>
<th>( \phi^+(a) )</th>
<th>( \phi^- (a) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>0</td>
<td>( \pi(a_1, a_2) )</td>
<td>( \pi(a_1, a_3) )</td>
<td>.</td>
<td>.</td>
<td>( \pi(a_1, a_n) )</td>
<td>( \phi^+(a_1) )</td>
<td>( \phi^- (a_1) )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( \pi(a_2, a_1) )</td>
<td>0</td>
<td>( \pi(a_2, a_3) )</td>
<td>.</td>
<td>.</td>
<td>( \pi(a_2, a_n) )</td>
<td>( \phi^+(a_2) )</td>
<td>( \phi^- (a_2) )</td>
</tr>
<tr>
<td>( a_3 )</td>
<td>( \pi(a_3, a_1) )</td>
<td>( \pi(a_3, a_2) )</td>
<td>0</td>
<td>.</td>
<td>.</td>
<td>( \pi(a_3, a_n) )</td>
<td>( \phi^+(a_3) )</td>
<td>( \phi^- (a_3) )</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>( a_n )</td>
<td>( \pi(a_n, a_1) )</td>
<td>( \pi(a_n, a_2) )</td>
<td>( \pi(a_n, a_3) )</td>
<td>.</td>
<td>.</td>
<td>0</td>
<td>( \phi^+(a_n) )</td>
<td>( \phi^- (a_n) )</td>
</tr>
<tr>
<td>( \phi^+(a) )</td>
<td>( \phi^+(a_1) )</td>
<td>( \phi^+(a_2) )</td>
<td>( \phi^+(a_3) )</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>( \phi^+(a_n) )</td>
<td>( \phi^- (a_n) )</td>
</tr>
</tbody>
</table>

**4.3.5 PROMETHEE I partial ranking**

The PROMETHEE I \((P^I, I^I, R^I)\) is obtained from positive and negative outranking flows where

\( P \) is the symbol of strict preference of one 3PL service provider over another

\( I \) is the symbol of indifference, i.e., the two 3PL service providers have the same preference

\( R \) is the symbol of incomparability, i.e., the two 3PL service providers cannot be compared.

**Case 1**

If

\( \phi^+(a) > \phi^+(b) \) and \( \phi^-(a) < \phi^-(b) \) or

\( \phi^+(a) = \phi^+(b) \) and \( \phi^-(a) < \phi^-(b) \) or

\( \phi^+(a) > \phi^+(b) \) and \( \phi^-(a) = \phi^-(b) \)
Then 3PL service provider ‘a’ is preferable over 3PL service provider ‘b’ or $aP^I b$.

**Case 2**

If

\[ \phi^+(a) = \phi^+(b) \text{ and } \phi^-(a) = \phi^-(b) \]

Then 3PL service provider ‘a’ is indifferent to 3PL service provider ‘b’ and vice-a-versa, i.e., $a\equiv b$ or $b\equiv a$.

**Case 3**

If

\[ \phi^+(a) > \phi^+(b) \text{ and } \phi^-(a) > \phi^-(b) \text{ or } \]
\[ \phi^+(a) < \phi^+(b) \text{ and } \phi^-(a) < \phi^-(b) \]

Then, 3PL service provider ‘a’ and 3PL service provider ‘b’ incomparable, i.e., $aR^I b$. Incomparability makes PROMETHEE I inefficient to use.

### 4.3.6 PROMETHEE II complete ranking

PROMETHEE II ($P^{II}$, $I^{II}$) is complete ranking method and gives a definite solution. In this method net outranking flow $\phi(a)$ is considered.

\[ \phi(a) = \phi^+(a) - \phi^-(a) \]

It is the balance between positive and negative outranking flow. Greater the net outranking flow better the performance of the 3PL service provider.

If $\phi(a) > \phi(b)$ then $aP^{II} b$

and

If $\phi(a) = \phi(b)$ then $aI^{II} b$.

and

\[ -1 \leq \phi(a) \leq 1 \]
\[ \sum_{a\in A} \phi(a) = 0 \]

When $\phi(a) > 0$, 3PL service provider ‘a’ is more outranking, and $\phi(a) < 0$, 3PL service provider ‘a’ is more outranked.

In this method, incomparability is completely eliminated and all 3PL service providers are comparable but a lot of data and information is lost due to subtraction.

Final PROMETHEE table with API, outranking flow, and net outranking flows are shown in Table 12.
3PL selection using hybrid model of AHP-PROMETHEE

Table 12 Net outranking flows

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>$a_1$</th>
<th>$a_2$</th>
<th>$a_3$</th>
<th>. . .</th>
<th>$a_n$</th>
<th>$\phi^+(a)$</th>
<th>$\phi^-(a)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>0</td>
<td>$\pi(a_1, a_2)$</td>
<td>$\pi(a_1, a_3)$</td>
<td>. . .</td>
<td>$\pi(a_1, a_n)$</td>
<td>$\phi^+(a_1)$</td>
<td>$\phi^-(a_1)$</td>
</tr>
<tr>
<td>$a_2$</td>
<td>$\pi(a_2, a_1)$</td>
<td>0</td>
<td>$\pi(a_2, a_3)$</td>
<td>. . .</td>
<td>$\pi(a_2, a_n)$</td>
<td>$\phi^+(a_2)$</td>
<td>$\phi^-(a_2)$</td>
</tr>
<tr>
<td>$a_3$</td>
<td>$\pi(a_3, a_1)$</td>
<td>$\pi(a_3, a_2)$</td>
<td>0</td>
<td>. . .</td>
<td>$\pi(a_3, a_n)$</td>
<td>$\phi^+(a_3)$</td>
<td>$\phi^-(a_3)$</td>
</tr>
<tr>
<td>. . . . . .</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>$a_n$</td>
<td>$\pi(a_n, a_1)$</td>
<td>$\pi(a_n, a_2)$</td>
<td>$\pi(a_n, a_3)$</td>
<td>. . .</td>
<td>0</td>
<td>$\phi^+(a_n)$</td>
<td>$\phi^-(a_n)$</td>
</tr>
<tr>
<td>$\phi^+(a)$</td>
<td>$\phi^+(a_1)$</td>
<td>$\phi^+(a_2)$</td>
<td>$\phi^+(a_3)$</td>
<td>. . .</td>
<td>$\phi^+(a_n)$</td>
<td>$\phi^+(a_n)$</td>
<td>$\phi^+(a_n)$</td>
</tr>
<tr>
<td>$\phi^-(a)$</td>
<td>$\phi^-(a_1)$</td>
<td>$\phi^-(a_2)$</td>
<td>$\phi^-(a_3)$</td>
<td>. . .</td>
<td>$\phi^-(a_n)$</td>
<td>$\phi^-(a_n)$</td>
<td>$\phi^-(a_n)$</td>
</tr>
</tbody>
</table>

5 Numerical illustration

Let us consider four 3PL service providers $A_1, A_2, A_3, A_4$ whose performance and ranking has to be calculated on the basis of nine attributes discussed in Section 3 using the AHP-PROMETHEE hybrid model. First relative weights of all the nine criteria is calculated using AHP and then final ranking of all the four 3PL service provider is obtained using PROPMETHEE. A relatively new and user-interactive software visual PROMETHEE has been used to solve PROMETHEE.

5.1 AHP

We will first assign weights to the criteria using the AHP. So the required pair wise comparison square $9 \times 9$ matrix showing the relative importance of each criteria shown in Table 13.

Table 13 Relative importance of all the criteria considered

<table>
<thead>
<tr>
<th>Criteria</th>
<th>LC</th>
<th>QS</th>
<th>CP</th>
<th>IT</th>
<th>DP</th>
<th>TF</th>
<th>GR</th>
<th>VS</th>
<th>ES</th>
<th>Weightage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>0.274</td>
</tr>
<tr>
<td>QS</td>
<td>1/2</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>0.221</td>
</tr>
<tr>
<td>CP</td>
<td>1/5</td>
<td>1/5</td>
<td>1</td>
<td>2</td>
<td>1/4</td>
<td>1/4</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>0.068</td>
</tr>
<tr>
<td>IT</td>
<td>1/6</td>
<td>1/6</td>
<td>1/5</td>
<td>1/4</td>
<td>1/4</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>0.051</td>
<td></td>
</tr>
<tr>
<td>DP</td>
<td>1/2</td>
<td>1/2</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>0.169</td>
</tr>
<tr>
<td>TF</td>
<td>1/3</td>
<td>1/2</td>
<td>4</td>
<td>5</td>
<td>1/2</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>3</td>
<td>0.139</td>
</tr>
<tr>
<td>GR</td>
<td>1/9</td>
<td>1/9</td>
<td>1/5</td>
<td>1/4</td>
<td>1/8</td>
<td>1/8</td>
<td>1</td>
<td>1/3</td>
<td>3</td>
<td>0.022</td>
</tr>
<tr>
<td>VS</td>
<td>1/7</td>
<td>1/7</td>
<td>1/3</td>
<td>1/2</td>
<td>1/6</td>
<td>1/6</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0.031</td>
</tr>
<tr>
<td>ES</td>
<td>1/8</td>
<td>1/7</td>
<td>1/6</td>
<td>1/6</td>
<td>1/4</td>
<td>1/3</td>
<td>1/3</td>
<td>1/2</td>
<td>1</td>
<td>0.022</td>
</tr>
</tbody>
</table>

5.1.1 Consistency check

- $\lambda_{max} = 9.95106$
- $CI = 0.118883$
390  A. Bansal and P. Kumar

- $RI$ for $n = 9$ is equal to 1.45
- $CR = 0.081988 < 0.1$

Thus, the found priority vector is consistent and can be further used.

5.2 PROMETHEE

Now, PROMETHEE and visual PROMETHEE software has been used to solve the illustrated numerical problem of the 3PL selection. Table 14 gives the weights, scale, type, preference functions of the different criteria chosen.

Table 14  Scale and preference functions of selection criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weightage</th>
<th>Units/scale</th>
<th>Max/Min</th>
<th>Preference function</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC</td>
<td>0.274</td>
<td>$$/km/kg</td>
<td>Min</td>
<td>Linear</td>
</tr>
<tr>
<td>QS</td>
<td>0.221</td>
<td>Five-point</td>
<td>Max</td>
<td>Level</td>
</tr>
<tr>
<td>CP</td>
<td>0.068</td>
<td>Five-point</td>
<td>Max</td>
<td>Level</td>
</tr>
<tr>
<td>IT</td>
<td>0.051</td>
<td>Five-point</td>
<td>Max</td>
<td>Level</td>
</tr>
<tr>
<td>DP</td>
<td>0.169</td>
<td>Five-point</td>
<td>Max</td>
<td>Level</td>
</tr>
<tr>
<td>TF</td>
<td>0.139</td>
<td>%</td>
<td>Max</td>
<td>Level</td>
</tr>
<tr>
<td>GR</td>
<td>0.022</td>
<td>Kilometre</td>
<td>Max</td>
<td>Linear</td>
</tr>
<tr>
<td>VS</td>
<td>0.031</td>
<td>Numerical count</td>
<td>Max</td>
<td>Linear</td>
</tr>
<tr>
<td>ES</td>
<td>0.022</td>
<td>Five-point</td>
<td>Max</td>
<td>Level</td>
</tr>
</tbody>
</table>

The preference functions are chosen according to the nature of the criteria as explained earlier.

- **quantitative**: the V-shape (type 3) and Linear (type 5)
- **qualitative**: the Usual (type 1), Level (type 4) and U-shape (type 2).

The preference functions have been randomly chosen from available choices in the two categories and one can select the other choices available in the respective categories to get different set of results. It depends on the choices of the buyer firm buying services from 3PL service provider. Table 15 is the evaluation table for all four 3PL service providers and eight criteria.

Table 15  Evaluation of alternatives

<table>
<thead>
<tr>
<th>3PL firms</th>
<th>LC</th>
<th>QS</th>
<th>CP</th>
<th>IT</th>
<th>DP</th>
<th>TF</th>
<th>GR</th>
<th>VS</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>$7$</td>
<td>High</td>
<td>V. Good</td>
<td>V. Good</td>
<td>High</td>
<td>30%</td>
<td>15,000 km</td>
<td>9</td>
<td>Good</td>
</tr>
<tr>
<td>$A_2$</td>
<td>$6$</td>
<td>V. High</td>
<td>Good</td>
<td>Good</td>
<td>V. High</td>
<td>60%</td>
<td>10,000 km</td>
<td>7</td>
<td>V. Good</td>
</tr>
<tr>
<td>$A_3$</td>
<td>$5$</td>
<td>Low</td>
<td>Bad</td>
<td>Average</td>
<td>V. Low</td>
<td>10%</td>
<td>2,500 km</td>
<td>4</td>
<td>V. Bad</td>
</tr>
<tr>
<td>$A_4$</td>
<td>$3$</td>
<td>Moderate</td>
<td>Average</td>
<td>Bad</td>
<td>High</td>
<td>20%</td>
<td>5,000 km</td>
<td>2</td>
<td>Average</td>
</tr>
</tbody>
</table>
• **Logistic cost (LC):** Has been calculated in terms of cost (in $) per kg of load per kilometre to be travelled. Being quantitative criteria linear preference function has been chosen. Values of $q$ and $p$ are $8$ and $2$ respectively.

• **Quality of service (QS):** Has been ranked on a five-point scale as provided by visual PROMETHEE software. Being a qualitative criteria Level preference function has been chosen. Values of $q$ and $p$ are $2$ and $4$ respectively.

• **Compatibility (CP):** Has been ranked on a five-point scale as provided by visual PROMETHEE software. Being a qualitative criteria Level preference function has been chosen. Values of $q$ and $p$ are $1$ and $4$ respectively.

• **Information technology capability (IT):** Has been ranked on a five-point scale as provided by visual PROMETHEE software. Being a qualitative criteria Level preference function has been chosen. Values of $q$ and $p$ are $1$ and $4$ respectively.

• **Delivery performance (DP):** Has been ranked on a five-point scale as provided by visual PROMETHEE software. Being a qualitative criteria Level preference function has been chosen. Values of $q$ and $p$ are $2$ and $4$ respectively.

• **Trust factor (TF):** Has been measured in terms of percentage by which the 3PL firm is trusted by the buyer. Being a qualitative criteria Level preference function has been chosen. Values of $q$ and $p$ are $20\%$ and $80\%$ respectively.

• **Geographical range of services (GR):** Has been quantified as the maximum distance up to which the 3PL firm can provide its services. Being quantitative criteria linear preference function has been chosen. Values of $q$ and $p$ are $1,000$ km and $10,000$ km respectively.

• **Number of value added services (VS):** Has been quantified as number of value added services provided. Being quantitative criteria, linear preference function has been chosen. Values of $q$ and $p$ are $2$ and $10$ respectively.

• **Environmental sustainability (ES):** Has been ranked on a five-point scale as provided by visual PROMETHEE software. Being a qualitative criteria Level preference function has been chosen. Values of $q$ and $p$ are $2$ and $4$ respectively.

**5.2.1 PROMETHEE I – partial ranking**

Using visual PROMETHEE software we get the PROMETHEE I rankings of all the four 3PL service providers by comparing their respective positive and negative outranking flows as shown in Figure 1. As shown in Figure 1, the scale on the left hand side gives the relative comparison of positive outranking flows ($f^+$) of all the four 3PL service providers and the scale on left hand side gives the relative comparison of negative outranking flows ($f^-$) of all the four 3PL service providers. In this figure, the alternatives are shown by $A_1, A_2, A_3, A_4$ are same as $a_1, a_2, a_3, a_4$ as shown in Table 8.

Greater the positive outranking flow ($f^+$) better is the performance of 3PL service provider as $f^+$ shows how much an alternative is outranking the other alternatives while on the other hand lesser is the negative outranking flow better the alternative as $f^-$ shows by how much an alternative is being outranked by others.
• on $\phi^+$ scale it is clear that $\phi^+(A_2) > \phi^+(A_1) > \phi^+(A_4) > \phi^+(A_3)$
• on $\phi^-$ scale it is evident that $\phi^-(A_2) > \phi^-(A_1) > \phi^-(A_4) > \phi^-(A_3)$.

Pair wise comparisons:

$A_1/A_2 - \Gamma^+(A_2) > \Gamma^+(A_1)$ and $\Gamma^-(A_2) > \Gamma^-(A_1)$ thus, we get $A_1P^lA_2$.

$A_1/A_3 - \Gamma^+(A_3) > \Gamma^+(A_1)$ and $\Gamma^-(A_3) > \Gamma^-(A_1)$ thus, we get $A_1P^lA_3$.

$A_1/A_4 - \Gamma^+(A_4) > \Gamma^+(A_1)$ and $\Gamma^-(A_4) < \Gamma^-(A_1)$ thus, we get $A_1P^lA_4$.

$A_2/A_3 - \Gamma^+(A_3) > \Gamma^+(A_2)$ and $\Gamma^-(A_3) < \Gamma^-(A_2)$ thus, we get $A_2P^lA_3$.

$A_2/A_4 - \Gamma^+(A_4) > \Gamma^+(A_2)$ and $\Gamma^-(A_4) < \Gamma^-(A_2)$ thus, we get $A_2P^lA_4$.
Thus, from the above pair wise comparisons we get the preference order as $A_2 > A_1 > A_3 > A_4$. Unlike the simple case discussed above there may be situations where incomparability creeps and PROMETHEE I rankings become inefficient so its is evident to calculate PROMETHEE II rankings for complete and trustworthy rankings as shown in next subsection.

5.2.2 PROMETHEE II – complete ranking

From visual PROMETHEE software we get the PROMETHEE II rankings of all the 3PL service providers with their net outranking flows and their relative comparisons as shown in Figure 2.

**Figure 2** PROMETHEE II rankings with net outranking flows (see online version for colours)
The values of net outranking flows are shown in Table 16.

**Table 16** Net outranking flows

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Net outranking flow ($\Phi$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_2$</td>
<td>+0.1476</td>
</tr>
<tr>
<td>$A_1$</td>
<td>+0.0574</td>
</tr>
<tr>
<td>$A_4$</td>
<td>-0.0257</td>
</tr>
<tr>
<td>$A_3$</td>
<td>-0.2169</td>
</tr>
</tbody>
</table>

$\phi(A_1) > \phi(A_2) > 0$, which implies $A_2$ outranks $A_1$ and $\phi(A_3) > \phi(A_4) > 0$, which implies $A_4$ outranks $A_3$. Thus, $A_3$ is most outranked. As we can analyse, $\phi(A_2) > \phi(A_1) > \phi(A_4) > \phi(A_3)$.

Therefore, from the above method we get the final PROMETHEE II rankings which are $A_2^{PIIA} A_1^{PIIA} A_4^{PIIA} A_3^{PIIA}$. From these rankings it can analysed that $A_2$ outperforms all the other three 3PL service providers on the basis of all the nine criteria and should be employed by the buyer while 3PL service provider $A_3$ has very poor performance on the basis of nine criteria considered and should be least preferred by the buyer.

6 Conclusions

It has been observed that hybrid model of AHP-PROMETHEE is an effective, understandable and easier Tool for 3PL selection. AHP allows the buyer firm to categorise and rate their priorities in a favourable manner and finally scaling various criteria according to their importance to the buyer firm.

PROMETHEE on the other hand is an efficacious method to categorise and scale diverse criteria by their nature and effect by providing different types of preference functions. PROMETHEE uses the weighed criteria processed by AHP and performance of various alternatives on requisite criteria to produce final trustworthy rankings of contenders. Moreover, usage of contemporary, user-interactive software like visual PROMETHEE makes it quite over-generous for the decision maker as it makes her work limited to just filling few input tables. The model is relatively complex compared to other MCDM but preference ranking of alternatives is unique output of PROMETHEE.

This model may help the decision makers to solve the other types of multi-criteria decision making problems such as selection of vendors, selection of machine tools, selection of facility location, etc. In future, to incorporate the linguistic vagueness fuzzy AHP may be integrated with PROMETHEE.

References


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