A hybrid performance evaluation model of TPL providers in agricultural products based on fuzzy ANP-TOPSIS

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Abstract

With the development of China agricultural industry, the third-party logistics (TPL) of agricultural products has achieved a rapid growth, and has received much consideration from academic and company in recent years. However, there is lack of appropriate performance evaluation method. In the article, based on the characteristics of agricultural products logistics, we established an evaluation index system including six criteria dimensions on TPL providers in agricultural products for the present situation and existing problems in agricultural products logistics in China, and then constructs a hybrid multi-criteria evaluation model. Finally, with the application of Super Decisions software, this research conducts an application study with the fuzzy analytical network process (ANP) and fuzzy technique for order preference by similarity to an ideal solution (TOPSIS) method to verify the validity of the model. The ultimate results show that the proposed hybrid model is efficacious on the performance evaluation of TPL providers in agricultural products.

Keywords: Third party logistics (TPL). Agricultural products logistics. Performance evaluation. Fuzzy ANP-TOPSIS

1. Introduction

After several years of development, China Agricultural Logistics evolved out of a variety of logistics mode, these modes played an important role in solving the problem difficulty in selling agricultural products (Shi, 2012). At present, agricultural logistics mode is divided into three categories, the first category is the most primitive self-logistics mode that farmers transport their own agricultural products to the farmers market for sales, this kind of
mode can’t form economies of scale, and waste a lot of time and transportation costs in the logistics process. The second category is ‘the agricultural company and farmer’ logistics mode that the company undertakes sales of agricultural products packaged by farmers, the kind of mode adds new middlemen, results in higher prices of agricultural products, increases consumers’ spending. The third category is ‘farmer collaborators, the company and third party logistics (TPL) providers’ logistics mode that it combines the latest development in logistics and agricultural products logistics. The agricultural products logistics (Xu and Ding, 2014; Yang and Xiong, 2011) has received much consideration from academic and company in recent years.

Along with the professionalization and increasing personalized demands of enterprises on logistics services, TPL has attained a rapid development, and also has changed into an emerging sunrise industry in China. TPL in agricultural products refers to the use of subcontracted specialized logistics companies to perform logistics functions that can encompass the entire agricultural products logistics process or selected activities within that process and that have traditionally been performed by farmers or agricultural organization. Within the agricultural products supply chain, TPL can cut down the agricultural logistics channels and processing part, reduce logistics costs and consumption during transportation, while the TPL providers can use the quickest way to transport the agricultural products to the designated locations because of their more advanced technology and information. Therefore, there are a few values to evaluate the performance of TPL providers: it is not only an important means of reducing costs of the entire agricultural supply chain, improving the efficiency of agricultural product logistics, improving the added-value of agricultural products, increasing farmers' income through high-quality and efficient services, but also the key to building the TPL value idea based on performance. TPL provider becomes an increasingly important issue (Liu and Wang, 2009). However, on the whole, few research on performance evaluation of TPL providers in agricultural products.

2. Literature Review of TPL Performance Evaluation

There is plenty of literature on the provider (or supplier) evaluation for supply chain. Since 1966, Dickson (1966) proposed 23 different evaluation criteria being used to select provider based on survey using questionnaire. Weber et al. (1991) reviewed 74 articles addressed the provider evaluation issues. Shipley (1985) suggested that price, quality and
delivery lead time should be used to select provider. Ellra (1990) proposed that companies should consider four criteria, namely, quality, price, time, and service quality in the provider evaluation process. Ghodsypour and O’Brien (1998) researched an automobile company and twenty providers of automobile parts, and indicated that evaluating provider criteria should include quality, price, flexibility, time, and so on. Zhou et al. (2003) researched the fuzzy estimation approach for logistics corporations based on competitive capability, business capacity. Pi et al. (2005) established an approach for estimating provider. Chen et al. (2006) suggested that provider evaluation should consider five criteria, namely, the profit ability of provider, relationship degree conformance quality, technological ability, and conflict resolution. Wei and Chai (2007) established an evaluation criteria system for logistics providers including four first-level criteria, and 23 second-level criteria. Saen (2010) proposed an approach for selecting third-party reverse logistics provider. Shaw et al. (2012) built a provider evaluation criteria system, including the criteria of carbon emission for developing the low carbon manufacturing supply chain in Indian.

Over the years, some techniques have been used to evaluate and select the providers. These techniques include linear programming, date envelopment, cost-based methods, neural networks, AHP, fuzzy sets theory, analytic network process, and TOPSIS. Recently, researchers have been integrating different methodologies to solve provider evaluation issues in SCM literature. Ha et al. (2008) used an integrated model including AHP, EDA and NN to evaluate the providers. Liao et al. (2010) established an integrated fuzzy TOPSIS and MCGP method to deal with the provider evaluation. Performance evaluation of TPL providers in agricultural products involves combined evaluation of various factors, is a MCDM problem, MCDM has some obvious merits that it can estimate various options according to criteria. Another obvious merit of MCDM is that it has the ability to analyze both qualitative and quantitative estimation criteria together (Bozbura et al., 2007). For these merits of the MCDM techniques, the integrated methods of fuzzy ANP and fuzzy TOPSIS were adopted in this article. Decision makers have to think over a number of complex factors when they evaluate performance of TPL providers. Many traditional MCDM assumed that all factors are independent of each other. In fact, under many situations, these criteria are not completely independent (Shee et al., 2007). The analytic network process (ANP) is a suitable theory that deals with dependence and feedback (Saaty 1996). It has been successfully applied in a number of research fields (Chang et al., 2007; Saaty 2007). Wijnmalen (2007) analyzed four factors with the AHP/ANP, including benefits, opportunities, costs, and risk. Gencer et al.
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(2007) proposed a method by using ANP to select provider with a feedback systematic. Demirtas et al. (2008) integrated ANP and OR for purchasing decisions. Wu et al. (2009) integrated both tangible and intangible factors for optimizing. Vinodh et al. (2011) applied the fuzzy ANP method to select the manufacturing supplier in an Indian company. In addition, TOPSIS is a classical MCDM approach that is applied to deciding alternatives. It is able to provide the basis for handling uncertainty properties. It is understandable and rational, and the computation isn’t complicated (Shyur, 2006).

In the total decision-making process, decision-makers have to deal with a variety of uncertain and vague information from subjective perceptions and experiences (Ertuğrul and Karakasoğlu, 2006). The practice proved that fuzzy set theory is an effective approach in handling uncertainty and vagueness problems. In the real life, we have to model a variety of situations to find out some issues, the model may not be sufficient as the data aren’t exact or available, the nature of data is uncertain, imprecise and vague (Sarami et al., 2009). In order to modeling these vague situations, we introduced fuzzy sets theory to describe the linguistics terms which will be used during decision making process. In this article, considering the features of performance evaluation of TPL providers in agricultural products, an integrated fuzzy ANP-TOPSIS model is built. Firstly, based on linguistics values described in triangular fuzzy numbers, fuzzy ANP method is used to compute weights of performance evaluation criteria. Secondly, TOPSIS approach is used to compute the ratings order of the potential alternatives.

This article aims to build an integrated multi-criteria model of performance evaluation of TPL providers in agricultural products. This article is organized as follows. Section 2 reviews literature. Then in section 3 explains the basic definitions of triangular fuzzy numbers (TFNs) and its relative linguistic variables. In section 4, the fuzzy ANP method and fuzzy TOPSIS model is built, the calculating steps are summarized. In section 5, a practical case is given to express the integrated approach and the application results. At last, the conclusions and findings are presented in section 6.

3. Triangular Fuzzy Sets Theoretical Analysis

Zadeh (1965) introduced the fuzzy theory to handle vagueness of human thought. We use fuzzy sets theory being powerful mathematical tools to model uncertain and vague issues. We may apply them to explaining complex phenomena, which we have difficult in describing
by old-fashioned mathematical ways, specially while our aim is to advance a suitable solution, it is the most appropriate way to use fuzzy sets theory (Bojadziev and Bojadziev, 1998; Ertuğrul and Tus, 2007; İrfan and Nilsen, 2008).

3.1. Linguistic variables

The linguistic variable isn’t a specific figure in a natural language. For an example, height is a linguistic variable, Variables labeled high, not high, very high, not very high etc. not the number 1, 2, 3, 4. In the real life, if we have no way to express complex phenomena or undefined problems in quantitative terms, the concept of the linguistic variables is the most appropriate ways (Zadeh, 1975; Bellman and Zadeh, 1977).

3.2. Triangular fuzzy numbers

The expression of a fuzzy number is possibly different according to applied situation (İrfan and Nilsen, 2008). According to Deng’s and Chang’s definitions (Deng, 1999; Chang, 1996), we can determine a triangular fuzzy number (TFN) \( M \) on \( \mathbb{R} \) using a triplet \((l, m, u)\), then, value of the membership function \( u_{M}(x): \mathbb{R} \to [0,1] \) will be:

\[
\begin{align*}
  u_{M}(x) &= \begin{cases} 
    \frac{x - l}{m - l}, & x \in [l, m] \\
    \frac{x - u}{m - u}, & x \in [m, u] \\
    0, & \text{otherwise}
  \end{cases}
\end{align*}
\]

The parameters \( l, m \) and \( u \) respectively express the lower limit of possibility, the most possible value, and the upper limit of possibility.

There are several calculation principles on TFN. Here, we only introduce some relevant principles. If we define two positive TFNs \( M_1 = (l_1, m_1, u_1) \) and \( M_2 = (l_2, m_2, u_2) \) then:

\[
M_1 \oplus M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)
\]

\[
M_1 \odot M_2 = (l_1 l_2, m_1 m_2, u_1 u_2)
\]

\[
(\lambda l, \lambda m, \lambda u) \odot M_i = (\lambda l_i, \lambda m_i, \lambda u_i), \quad \lambda > 0, \quad \lambda \in \mathbb{R}
\]

\[
M_i^{-1} = (l_i, m_i, u_i) = (1/u_i, 1/m_i, 1/l_i)
\]
We can calculate the distance between \( M_1 \) and \( M_2 \) by using vertex method [50]:

\[
d_i(m_1, m_2) = \sqrt[3]{\left[ (l_i - l_2)^2 + (m_i - m_2)^2 + (u_i - u_2)^2 \right]}
\]  

(6)

In this study, for calculating each criteria weight, we used Chang’s extent analysis methods (Chang, 1996). We let \( \{X_1, X_2, \ldots, X_n\} \) be a goal set, and \( \{G_1, G_2, \ldots, G_k\} \) be an aim sets. Then we can calculate \( m \) analysis values for each goal, the following signs:

\[
m_i = \left( \sum_{j=1}^{n} M_{i,j} \right) \left( \sum_{j=1}^{n} M_{i,j}^{-1} \right)^{-1}
\]  

(7)

The fuzzy calculation of \( m \) degree analysis values for an especial matrix is accomplished as:

\[
\sum_{j=1}^{n} M_{i,j} = \left( \sum_{j=1}^{n} m_j \sum_{j=1}^{n} u_j \right)
\]  

(8)

\[
\left( \sum_{j=1}^{n} M_{i,j}^{-1} \right)^{-1} = \left[ \frac{1}{\sum_{j=1}^{n} m_j} \frac{1}{\sum_{j=1}^{n} u_j} \right]
\]  

(9)

**Step 1:** we define the normalized values of fuzzy comprehensive degree with regard to the \( i \)th goal as

\[
S_i = \sum_{j=1}^{n} M_{i,j} \otimes \left( \sum_{j=1}^{n} M_{i,j}^{-1} \right)^{-1}
\]

**Step 2:** The possibility of \( M_1 \geq M_2 \) is calculated as:

\[
d_i(m_1, m_2) = \sqrt[3]{\left[ (l_i - l_2)^2 + (m_i - m_2)^2 + (u_i - u_2)^2 \right]}
\]  

(10)

Where a pair \((x, y)\) exits such that \( x \geq y \) and \( u_{x,y} = u_{y,x} \) then we believe \( V(M_1 \geq M_2) = 1 \).

As \( M_1 \) and \( M_2 \) are TFNs we have that:

\[
V(M_1 \geq M_2) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_2 \geq u_2 \end{cases}
\]  

(11)

\[
V(M_1 \geq M_2) = hgl(M_1 \cap M_2) = \mu_{M_1}(d)
\]  

(12)

Where \( f \) is the ordinate of the cross-point \( H \) between \( \mu_{M_1} \) and \( \mu_{M_2} \). When \( M_1 = (l_1, m_1, u_1) \) and \( M_2 = (l_2, m_2, u_2) \), the ordinate of \( D \) is expressed by:

\[
V(M_1 \geq M_2) = hgl(M_1 \cap M_2) = \frac{l_2 - \mu_{M_2}}{m_2 - u_2}
\]  

(13)

In order to comparing \( M_1 \) and \( M_2 \) the values of \( V(M_1 \geq M_2) \) and \( V(M_1 \geq M_1) \) should be obtained.

The possibility for a TFN is bigger than \( k \) TFNs \( M_i = (l_i, m_i, u_i) \) can be defined by:
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\[ V(M \geq M_1, M_2, \cdots, M_k) = \min \{ V(M \geq M_i, \text{for } i = 1, 2, \cdots, k) \} \]

Supposing:
\[ d(A_i) = \min V(S_i \geq S_j) \]

For \( k = 1, 2, \cdots, n; k \neq i \). Then the weight vector is calculated by:
\[ W = (d(A_1), d(A_2), \cdots, d(A_n))^T \]

Where \( A_i (i = 1, 2, \cdots, n) \) are \( n \) factors. By normalization of data, the normalized vectors of weights are as following:
\[ W = (d(A_1), d(A_2), \cdots, d(A_n))^T \]

Where \( W \) isn’t a fuzzy number.

4. Constructing Model of Integrated Fuzzy ANP-TOPSIS
4.1. Fuzzy ANP

Van Larrhoven and Pedryez proposed the first study of fuzzy AHP (Van and Pedrcyz, 1993). Chang (1996) conducted a fuzzy AHP analysis. Saaty (1996) suggested that ANP is a general type of AHP. The ANP is a network system that takes the place of single direction influences via alternation and feedback. Complex interrelationships are used by ANP among decision (Dağdeviren and Yüksel, 2010). Figure 1 gives the structure of ANP. A node describes an object (or cluster) with inside factors, a straight line describes A affects B, Loop describes internal dependence of the factors within an object.

Figure 1: Structure of a hierarchy network process
We may use the ANP approach to handle interdependence within factors, and obtain the criteria weights by building a super-matrix (Saaty and Vargas, 1998). A super-matrix is a subdivided matrices, whose sub-matrix is consisted of a set of relations between a pair of goals. Through entering the priorities calculated by fuzzy ANP into the corresponding columns, we can construct an initial super-matrix.

An ANP approach is implemented by following four steps:

**Step 1:** GLPS criteria and sub-criteria identification, and then, The ANP model with hierarchical structure is constructed like AHP.

**Step 2:** A pair-wise comparison matrices will be built between criteria and sub-criteria, and priority vectors will be obtained. Pair-wise comparison is acted in a matrix, and then a local weights vector will be calculated.

**Step 3:** Formulating and analyzing super-matrix. Supposing the criteria are causally connected, then a network relationships will substituent the hierarchy.

**Step 4:** Calculating weighted criteria for a variety of criteria and sub-criteria. TOPSIS will use them to evaluate the alternatives.

### 4.2. Fuzzy TOPSIS

Chen et al. originally proposed the TOPSIS approach (Chen and Hwang, 1992; Yoon and Hwang, 1995). The core thought of TOPSIS means that the alternatives should be the shortest from the positive ideal solution and the farthest from negative ideal solution (Wang and Elhag, 2006; Gülcin and Gizem, 2012). Under many situations, data being used are insufficient to model decision issues. Consequently, in order to enhance the efficiency of the traditional TOPSIS, researcher introduced the fuzzy sets to improve TOPSIS approach. Fuzzy TOPSIS methodology needs the weights of the criteria. We use $w_i$ to express the weight of each criteria. The weight of criteria is calculated by the above fuzzy ANP approach.

The TOPSIS approach is made up of six steps as follows (Wu et al., 2010):

**Step 1:** Computing the normalized decision matrix and values $r_{ij}$:

$$r_{ij} = X_{ij} / \sqrt{\sum_{j=1}^{n} X_{ij}^2}, \forall i, j$$  \hspace{1cm} (18)

**Step 2:** Computing the value $v_{ij}$ being weighted and normalized: $v_{ij} = w_i r_{ij}, \forall i, j$

Where $w_i$ is the weight of the $i^{th}$ criteria, here $\sum_{i=1}^{n} w_i = 1$. 

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Step 3: Determining the positive-ideal and negative-ideal point:

\[ A^+ = \left[ v_i^+, \ldots, v_n^+ \right] = \left(\max_{j \in C_C} v_{ij}, \min_{j \in C_C} v_{ij}\right) \]

\[ A^- = \left[ v_i^-, \ldots, v_n^- \right] = \left(\min_{j \in C_C} v_{ij}, \max_{j \in C_C} v_{ij}\right) \]

(19)

(20)

Where \( C_C \) is related with profit factors and \( C_C \) is related with cost factors.

Step 4: Measuring the distance on the m-dimensional Euclidean space from the positive-ideal point for the alternatives:

\[ d_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v^+_{ij})^2}, \quad \forall i \]  

(21)

Similarity, Measuring the distance from the negative-ideal for the alternatives:

\[ d_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v^-_{ij})^2}, \quad \forall i \]  

(22)

Step 5: The relative factor value of the alternative \( A_i^+ \) to \( A^+ \) is calculated:

\[ RC_i^+ = \frac{d_i^-}{d_i^+ + d_i^-}, \quad \forall i (i = 1, 2, \ldots, n) \]  

(23)

Step 6: Ranking the priority.

The values range of \( RC_i^+ \) will be \((0, 1]\). The largest value states the closer to positive-ideal point for alternatives.

5. Application Study

The case came from agricultural products logistics industry in Jilin Province of China. With evaluating TPL performance in agricultural products, we desire to find their performance status. There are eight alternatives (P1-P8). A committee of decision-makers is organized before the evaluation project started, there are several main decision-makers in the committee who are from agricultural logistics management sector and technology sector.
5.1. Evaluation criteria system for fuzzy ANP process

The process starts with identification and evaluation of GLPS criteria based on the precious related work and literature analysis. The evaluation criteria system in this study consists of six indicators dimensions. The criteria system is shown in Figure 2.

In Figure 2, six indicators dimensions includes twenty-seven sub-indicators: Technology Ability indicators dimensions include five sub-indicators, which are packaging ability, agricultural products deep processing ability, tracking ability, standards development. Information Ability indicators dimensions include four sub-indicators, which are infrastructure status, information management level, information sharing level, information systems support capability. Service Ability indicators dimensions include five sub-indicators, which are customer satisfaction, average delivery time, service price, flexibility and agility, contract execution rate. Management Ability indicators dimensions include four sub-indicators, which are management costs, shipping and distribution costs, warehousing and handling costs, human resources costs, order processing time. Economic Performance indicators dimensions include four sub-indicators, which are management ability, TPL development potential, the degree of organization of farmers, agricultural products supply chain management. Social Performance indicators dimensions include five sub-indicators, which are carbon emissions control, use of recycled materials, social project investment, noise and pollution control, innovative ideas number.
5.2. Triangular Fuzzy ANP Application

Firstly, the linguistic variables were used to describe the importance degree of indicator by decision-makers in Table 1. We use twelve linguistic terms to express the different degrees of influence, and the equivalent fuzzy membership is shown in Figure 3.

Table 1: Linguistic variables with regard to TFNs

<table>
<thead>
<tr>
<th>Linguistic Variable</th>
<th>Triangular Fuzzy Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (N)</td>
<td>(0, 0, 0.1)</td>
</tr>
<tr>
<td>Very low (VL)</td>
<td>(0, 0.1, 0.2)</td>
</tr>
<tr>
<td>Low (L)</td>
<td>(0.1, 0.2, 0.3)</td>
</tr>
<tr>
<td>Fairly Low (FL)</td>
<td>(0.2, 0.3, 0.4)</td>
</tr>
<tr>
<td>More or Less (ML)</td>
<td>(0.3, 0.4, 0.5)</td>
</tr>
<tr>
<td>Equation (E)</td>
<td>(0.5, 0.5, 0.5)</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>(0.4, 0.5, 0.6)</td>
</tr>
<tr>
<td>More or less good (MG)</td>
<td>(0.5, 0.6, 0.7)</td>
</tr>
<tr>
<td>Fairly good (FG)</td>
<td>(0.6, 0.7, 0.8)</td>
</tr>
<tr>
<td>Good (G)</td>
<td>(0.7, 0.8, 0.9)</td>
</tr>
<tr>
<td>Very good (VG)</td>
<td>(0.8, 0.9, 1.0)</td>
</tr>
<tr>
<td>Excellent (E)</td>
<td>(0.9, 1.0, 1.0)</td>
</tr>
</tbody>
</table>

Figure 3: Triangular fuzzy membership functions for linguistic values

Every decision-maker has been asked to answer a series of pair-wise comparisons by using TFNs. The fuzzy judgment matrix  is built as follows:
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\[
\tilde{A} = \begin{bmatrix}
\tilde{a}_{11} & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\
\tilde{a}_{21} & \tilde{a}_{22} & \ldots & \tilde{a}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\tilde{a}_{m1} & \tilde{a}_{m2} & \ldots & \tilde{a}_{mn}
\end{bmatrix}
\]

Where \( \tilde{a}_{ij} = (i_j, m_j, u_j) \) describes the importance among the indicators (importance of \( i \) with regard to \( j \)) where \( i = 1, 2, \ldots, n \), \( j = 1, 2, \ldots, n \), in Table 2, we gives the examples of linguistic and fuzzy evaluations between collaboration sustainability dimensions and goal. Other evaluations are calculated in the same way.

<table>
<thead>
<tr>
<th>Matrix 1. The Linguistic Evaluation Matrix with regard to Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
</tr>
<tr>
<td>C1</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>C3</td>
</tr>
<tr>
<td>C4</td>
</tr>
<tr>
<td>C5</td>
</tr>
<tr>
<td>C6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Matrix 2. The Corresponding Fuzzy Evaluations Matrix with regard to Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
</tr>
<tr>
<td>C1</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>C3</td>
</tr>
<tr>
<td>C4</td>
</tr>
<tr>
<td>C5</td>
</tr>
<tr>
<td>C6</td>
</tr>
</tbody>
</table>

As a sample, we give a calculation procedure of indicators weights with regard to goal by using those data from table 2. By using formula (7), we have.

\[
S_{C1} = (3.3,3.8,4.3) \odot (1/21,1/18,1/15) = (0.16,0.21,0.29) \\
S_{C2} = (2.3,2.8,3.3) \odot (1/21,1/18,1/15) = (0.11,0.16,0.22) \\
S_{C3} = (2.6,3.1,3.6) \odot (1/21,1/18,1/15) = (0.12,0.17,0.24) \\
S_{C4} = (1.6,2.1,2.6) \odot (1/21,1/18,1/15) = (0.08,0.12,0.17) \\
S_{C5} = (2.7,3.2,3.7) \odot (1/21,1/18,1/15) = (0.13,0.18,0.25) \\
S_{C6} = (2.5,3.0,3.5) \odot (1/21,1/18,1/15) = (0.12,0.17,0.23) \\
\]

Using formula (11), (12), and (13), and these bellowing values are calculated.

\[
V(S_{C1} > S_{C2}) = 1.00 \cdot V(S_{C1} > S_{C3}) = 1.00 \cdot V(S_{C1} > S_{C4}) = 1.00 \cdot V(S_{C1} > S_{C5}) = 1.00 \cdot V(S_{C1} > S_{C6}) = 1.00 \\
V(S_{C2} > S_{C3}) = 0.55 \cdot V(S_{C2} > S_{C4}) = 0.91 \cdot V(S_{C2} > S_{C5}) = 1.00 \cdot V(S_{C2} > S_{C6}) = 0.82 \cdot V(S_{C2} > S_{C6}) = 0.81 \\
\]

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At last, by using formula (14), we can calculate the values.

\[ d(C_1) = \min V(S_{C_3} \geq S_{C_4}, S_{C_5} \geq S_{C_6}) \]
\[ d(C_2) = \min V(S_{C_1} \geq S_{C_2}, S_{C_4} \geq S_{C_5}, S_{C_6}) \]
\[ d(C_3) = \min V(S_{C_1} \geq S_{C_2}, S_{C_4} \geq S_{C_5}, S_{C_6}) \]
\[ d(C_4) = \min V(S_{C_1} \geq S_{C_2}, S_{C_4} \geq S_{C_5}, S_{C_6}) \]
\[ d(C_5) = \min V(S_{C_1} \geq S_{C_2}, S_{C_4} \geq S_{C_5}, S_{C_6}) \]
\[ d(C_6) = \min V(S_{C_1} \geq S_{C_2}, S_{C_4} \geq S_{C_5}, S_{C_6}) \]

Therefore, priority weights from \( W^* = (1.00, 0.55, 0.67, 0.10, 0.75, 0.64)^T \).

Through normalization, and we have obtained the interdependence weights vector that it is with regard to the main goal of the evaluation indicators using fuzzy ANP are as follows:

\[ W = (0.27, 0.15, 0.18, 0.03, 0.20, 0.17)^T \]

After all above calculations, we are go on calculating with the internal dependence matrix. In table 3, the results with regard to \( C_1 \) is shown. The internal dependence matrices are respectively shown in tables 4, 5, 6, 7 and 8.

**Table 3: The internal dependence matrix of the elements with regard to \( C_1 \)**

<table>
<thead>
<tr>
<th>Matrix 1. The Linguistic Evaluation Matrix with regard to ( C_1 )</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>*</td>
<td>NE</td>
<td>NE</td>
<td>NE</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>C3</td>
<td>NE</td>
<td>*</td>
<td>NE</td>
<td>MI</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>C4</td>
<td>NE</td>
<td>NE</td>
<td>*</td>
<td>NE</td>
<td>MI</td>
<td>NE</td>
</tr>
<tr>
<td>C5</td>
<td>NE</td>
<td>NE</td>
<td>NE</td>
<td>*</td>
<td>M</td>
<td>NE</td>
</tr>
</tbody>
</table>
| C6 | NE | NE | ME | NE | * | *

<table>
<thead>
<tr>
<th>Matrix 2. The Corresponding Fuzzy Evaluations Matrix with regard to ( C_1 )</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C3</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.5,0.6,0.7)</td>
<td>(0.0,0.0,0.1)</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.5,0.6,0.7)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.4,0.5,0.6)</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.3,0.4,0.5)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

The interdependence weights vector with regard to \( C_1 \) of the evaluation indicators using fuzzy ANP are as follows:

\[ W_{C_1} = (0.08, 0.25, 0.25, 0.22, 0.20)^T \]
A hybrid performance evaluation model of TPL providers in agricultural products based on fuzzy ANP-TOPSIS

Zhang, S.; Li, X.

Table 4: The Internal dependence matrix of the factors with regard to C2

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C2</td>
<td>(0.4,0.5,0.6)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C3</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.2,0.3,0.4)</td>
</tr>
<tr>
<td>C4</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.7,0.8,0.9)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.4,0.5,0.6)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.6,0.7,0.8)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>W^T</td>
<td>0.00</td>
<td>0.16</td>
<td>0.07</td>
<td>0.51</td>
<td>0.26</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: The internal dependence matrix of the factors with regard to C3

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C2</td>
<td>(0.5,0.6,0.7)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C3</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.3,0.4,0.5)</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.2,0.3,0.4)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.6,0.7,0.8)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>W^T</td>
<td>0.07</td>
<td>0.26</td>
<td>0.20</td>
<td>0.17</td>
<td>0.30</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: The internal dependence matrix of the factors with regard to C4

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C2</td>
<td>(0.3,0.4,0.5)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C3</td>
<td>(0.7,0.8,0.9)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C4</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.5,0.6,0.7)</td>
<td>*</td>
<td>(0.6,0.7,0.8)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.4,0.5,0.6)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>W^T</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: The internal dependence matrix of the factors with regard to C5

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C2</td>
<td>(0.6,0.7,0.8)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C3</td>
<td>(0.4,0.5,0.6)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C4</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.4,0.5,0.6)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.4,0.5,0.6)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>W^T</td>
<td>0.07</td>
<td>0.28</td>
<td>0.22</td>
<td>0.21</td>
<td>0.22</td>
<td></td>
</tr>
</tbody>
</table>

Table 8: The internal dependence matrix of the factors with regard to C6

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C2</td>
<td>(0.5,0.6,0.7)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C3</td>
<td>(0.4,0.5,0.6)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
</tr>
<tr>
<td>C4</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td>(0.0,0.0,0.1)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.0,0.0,0.1)</td>
<td>(0.2,0.3,0.4)</td>
<td>(0.0,0.0,0.1)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>W^T</td>
<td>0.11</td>
<td>0.30</td>
<td>0.27</td>
<td>0.11</td>
<td>0.21</td>
<td></td>
</tr>
</tbody>
</table>

After calculating all weights of the indicators internal dependence matrices, the global weights of the indicators are calculated as follows:
A hybrid performance evaluation model of TPL providers in agricultural products based on fuzzy ANP-TOPSIS

Zhang, S.; Li, X.

Custos e @gronegócio on line - v. 11, n. 3 – Jul/Sep - 2015. ISSN 1808-2882
www.custoseagronegocioonline.com.br

After a weighted normalized fuzzy decision matrix is formed, the fuzzy integrated evaluation values are shown in Table 9. Fuzzy positive ideal solution (FPIS) and fuzzy negative ideal (FNIS) are determined as in the following:

\[ A^+ = \{v^+_1, v^+_2, \ldots, v^+_n\} \quad A^- = \{v^-_1, v^-_2, \ldots, v^-_n\} \]

Where \[ v^+_i = (1,1,1) \quad v^-_i = (0,0,0) \]

Table 9. The linguistic alternatives evaluation matrix from decision-makers and the corresponding integrated weighted values for each alternative

Matrix 1. The linguistic alternatives evaluation matrix from three decision-makers

<table>
<thead>
<tr>
<th>Indicators</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternatives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1 M</td>
<td>MG</td>
<td>MG</td>
<td>ML</td>
<td>FL</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>P2 FG</td>
<td>M</td>
<td>G</td>
<td>M</td>
<td>M</td>
<td>ML</td>
<td>FL</td>
</tr>
<tr>
<td>P3 ML</td>
<td>M</td>
<td>MG</td>
<td>FL</td>
<td>L</td>
<td>MG</td>
<td>ML</td>
</tr>
<tr>
<td>P4 G</td>
<td>FG</td>
<td>M</td>
<td>M</td>
<td>MG</td>
<td>M</td>
<td>FL</td>
</tr>
<tr>
<td>P5 FL</td>
<td>ML</td>
<td>MG</td>
<td>ML</td>
<td>ML</td>
<td>M</td>
<td>FL</td>
</tr>
<tr>
<td>P6 MG</td>
<td>ML</td>
<td>M</td>
<td>MG</td>
<td>G</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>P7 G</td>
<td>MG</td>
<td>FG</td>
<td>ML</td>
<td>MG</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>P8 FL</td>
<td>ML</td>
<td>FL</td>
<td>FL</td>
<td>FL</td>
<td>FL</td>
<td>M</td>
</tr>
</tbody>
</table>

Matrix 2. The corresponding integrated weighted values for each alternative

<table>
<thead>
<tr>
<th>Indicators</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternatives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1 ((0.023,0.028,0.033))</td>
<td>((0.054,0.072,0.090))</td>
<td>((0.078,0.096,0.114))</td>
<td>((0.057,0.074,0.091))</td>
<td>((0.107,0.130,0.153))</td>
<td>((0.076,0.095,0.114))</td>
<td></td>
</tr>
<tr>
<td>P2 ((0.028,0.033,0.038))</td>
<td>((0.066,0.084,0.102))</td>
<td>((0.048,0.066,0.084))</td>
<td>((0.085,0.102,0.119))</td>
<td>((0.115,0.138,0.161))</td>
<td>((0.057,0.076,0.095))</td>
<td></td>
</tr>
<tr>
<td>P3 ((0.020,0.025,0.030))</td>
<td>((0.048,0.082,0.099))</td>
<td>((0.072,0.090,0.108))</td>
<td>((0.074,0.091,0.108))</td>
<td>((0.123,0.146,0.161))</td>
<td>((0.082,0.101,0.120))</td>
<td></td>
</tr>
<tr>
<td>P4 ((0.028,0.033,0.038))</td>
<td>((0.078,0.096,0.114))</td>
<td>((0.054,0.072,0.090))</td>
<td>((0.096,0.113,0.130))</td>
<td>((0.123,0.146,0.161))</td>
<td>((0.082,0.101,0.120))</td>
<td></td>
</tr>
<tr>
<td>P5 ((0.017,0.022,0.027))</td>
<td>((0.060,0.078,0.096))</td>
<td>((0.048,0.066,0.084))</td>
<td>((0.074,0.091,0.108))</td>
<td>((0.069,0.092,0.115))</td>
<td>((0.057,0.076,0.095))</td>
<td></td>
</tr>
<tr>
<td>P6 ((0.020,0.025,0.030))</td>
<td>((0.096,0.114,0.132))</td>
<td>((0.054,0.072,0.090))</td>
<td>((0.079,0.096,0.113))</td>
<td>((0.084,0.107,0.130))</td>
<td>((0.101,0.120,0.139))</td>
<td></td>
</tr>
<tr>
<td>P7 ((0.030,0.035,0.040))</td>
<td>((0.072,0.090,0.108))</td>
<td>((0.078,0.096,0.114))</td>
<td>((0.091,0.108,0.125))</td>
<td>((0.084,0.107,0.130))</td>
<td>((0.070,0.089,0.108))</td>
<td></td>
</tr>
<tr>
<td>P8 ((0.012,0.017,0.022))</td>
<td>((0.048,0.066,0.084))</td>
<td>((0.060,0.078,0.096))</td>
<td>((0.091,0.108,0.125))</td>
<td>((0.084,0.107,0.130))</td>
<td>((0.082,0.101,0.120))</td>
<td></td>
</tr>
</tbody>
</table>

According to formula (21), (22), and (23), the distance of each alternative from FPIS and FNIS with regard to each indicator is calculated, and is shown in Table 10.
Table 10: Positive-negative distances with regard to each indicators

<table>
<thead>
<tr>
<th>Distance</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td></td>
<td>0.9720</td>
<td>0.9670</td>
</tr>
<tr>
<td></td>
<td>0.9281</td>
<td>0.9161</td>
</tr>
<tr>
<td></td>
<td>0.9041</td>
<td>0.9341</td>
</tr>
<tr>
<td></td>
<td>0.9261</td>
<td>0.8981</td>
</tr>
<tr>
<td></td>
<td>0.8702</td>
<td>0.8622</td>
</tr>
<tr>
<td></td>
<td>0.9051</td>
<td>0.9241</td>
</tr>
<tr>
<td></td>
<td>0.0283</td>
<td>0.0333</td>
</tr>
<tr>
<td></td>
<td>0.0735</td>
<td>0.0853</td>
</tr>
<tr>
<td></td>
<td>0.0971</td>
<td>0.0676</td>
</tr>
<tr>
<td></td>
<td>0.0753</td>
<td>0.1029</td>
</tr>
<tr>
<td></td>
<td>0.1313</td>
<td>0.1393</td>
</tr>
<tr>
<td></td>
<td>0.0963</td>
<td>0.0776</td>
</tr>
</tbody>
</table>

The closeness coefficient for the alternative is shown in Table 11. According to the closeness coefficient of four alternatives, the ranking order of eight alternatives is determined as \( P4 > P6 > P3 > P7 > P2 > P1 > P8 > P5 \). The fourth alternative is determined as the most appropriate TPL provider in agricultural products. Namely, the fourth alternative is closer to the FPIS and farther from the FNIS.

Table 11: Final performance values of TPL Alternatives in agricultural products

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>Ranking order</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d^+ )</td>
<td>5.5056</td>
<td>5.5016</td>
<td>5.4717</td>
<td>5.4326</td>
<td>P4&gt;P6&gt;P3&gt;P7&gt;P2&gt;P1&gt;P8&gt;P5</td>
</tr>
<tr>
<td>( d^- )</td>
<td>0.5018</td>
<td>0.5060</td>
<td>0.5369</td>
<td>0.5740</td>
<td></td>
</tr>
<tr>
<td>( RC^- )</td>
<td>0.0835</td>
<td>0.0842</td>
<td>0.0894</td>
<td>0.0956</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>P6</td>
<td>P7</td>
<td>P8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d^+ )</td>
<td>5.5756</td>
<td>5.4666</td>
<td>5.4756</td>
<td>5.5236</td>
<td></td>
</tr>
<tr>
<td>( d^- )</td>
<td>0.4330</td>
<td>0.5403</td>
<td>0.5313</td>
<td>0.4842</td>
<td></td>
</tr>
<tr>
<td>( RC^- )</td>
<td>0.0721</td>
<td>0.0899</td>
<td>0.0884</td>
<td>0.0806</td>
<td></td>
</tr>
</tbody>
</table>

6. Conclusion

In this article, we proposed a novel integrated model of hybrid performance evaluation of TPL in agricultural products logistics based on the integrated methods of both fuzzy ANP and fuzzy TOPSIS. For solving our issues and avoiding improper decisions, we use linguistic variable approaches.

The contributions of our research lie in the proposed integration of the fuzzy ANP approach and the fuzzy TOPSIS approach and the practical implementation that will enable...
the integrated model to be used by decision-maker in agricultural logistics industries for evaluating the TPL. Firstly, based on the literature survey, we given the TPL evaluation framework, proposed an indicators system. We evaluated these indicators to decide the order of TPL provider alternatives. Secondly, based on the analysis of the fuzzy sets theory and triangular fuzzy numbers, we proposed a novel hybrid evaluation method of TPL in agricultural products. Using fuzzy ANP, decision-makers can make mutual comparisons for the indicators and alternatives. Then we can transform these comparison values into TFNs. The weights of indicators are calculated by using fuzzy ANP method. Using fuzzy TOPSIS, we can not only construct the decision matrix but also establish the fuzzy weighted normalized decision matrix. Based on TFPIS and TFNIS, the closeness factor of each alternative was obtained respectively. Based on the closeness factor of alternatives, we can decide the ranking order of each alternatives. The results present the constructed approach offered a more accurate analysis by merging interdependent relationships among indicators.

In future studies, the proposed integrated model can be improved. And also the proposed methods may be useful for various MDCM issues like project management, agricultural logistics facility location, new products development, personnel evaluation, machine evaluation of companies and marketing activities under data vague and uncertain situations.

7. References


A hybrid performance evaluation model of TPL providers in agricultural products based on fuzzy ANP-TOPSIS
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