Logistics service provider selection using TOPSIS and VIKOR methods

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Abstract
Choosing a transportation provider is one of the most important choices for a successful business. Forwarding companies rely on past relationships and managerial skills to choose a logistics service providers. There is a number of criteria that need to be taken into account when evaluating a transportation service provider, which are, i.e. one criterion should be as high as possible and the other as low as possible. Multi-criteria decision making methods are commonly used to solve this problem. This article uses VIKOR and TOPSIS multi-criteria decision making methods. 10 transport service providers are ranked, the results of the methods are compared and the expert opinion is compared with the criteria calculated from the actual data. The ranking results are similar for both methods, but differ the ranking of experts and criteria is based on actual data.

Keywords
Logistic service provider, MCDM, ranking, TOPSIS, VIKOR

1. Introduction

In today's business world, it is very difficult to develop products without partners. The company should take care of the entire supply chain of the product, from the selection of raw materials, production, packaging, promotion, storage, and transportation to the customer. It is difficult for a company to be competitive. As a result, companies buy services from other companies that specialize in a particular area. One of the most common areas of cooperation is transportation because transporting their own products would require considerable costs and investment in vehicles and human resources to manage them. Most companies choose to cooperate with transportation service providers. But there is another problem of choosing the most suitable one from a large number of transport service providers.

According to data provided by the Ministry of Transport and Communications of the Republic of Lithuania, the transport sector continues to grow [1]. 2017 was a big leap in logistics, and 2018 was a big leap forward. growth slowed but persisted. 2018 Exports of domestic transport services grew by 21.5% and revenue by over 18%. As the transport sector grows, competition between transport service providers increases. For both small businesses and forwarding companies, choosing the right transportation provider is important.

Different criteria for choosing a logistics provider are important for different loads and types of cargo. For companies that want to bring their food products, the most important thing is the delivery time, the quality of the cargo storage or the undamaged cargo and price. And when it comes to transporting large quantities of non-food items, the key is low price, fleet capabilities, and quality delivery. And in companies, the manager is still deciding which company to choose as a logistics provider, considering all the criteria. It is a job that requires a lot of experience and skills, and many aspects need to be evaluated. A person with many years of experience still can make mistakes. Mathematical estimation methods are used to eliminate human errors and subjective judgment when choosing a transportation service provider.

2. Literature review

Literature reviews considering logistics provider selection problems from a broader standpoint have already been published [2, 3, 4]. The paper [2] reviews 67 articles and distinguishes the most important evaluation criteria: price, relationship, service, and quality. The next article [3] reviewed 140 articles broken down by supply chain functions: supplier selection, manufacturing, warehousing, logistics. The results showed that *Fuzzy Analytical Hierarchal Process* (FAHP), *Fuzzy Technique for Ordering Preference by Similarity to the Ideal Solution* (FTOPSIS) and fuzzy, FAHP with other methods are mainly used to solve the problem of logistics service providers.

Often several methods or several combinations of

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methods are used in scientific works. For example, a combination of AHP and TOPSIS techniques [5, 6], the AHP method evaluates expert consistency and criterion weights, and the TOPSIS ranking. The integration of AHP, *Data Envelopment Analysis* (DEA) and Linear Programming results in an efficient and effective methodology, which can consider a huge number of relevant information [7]. Mathematical estimation methods are used to eliminate human errors and subjective judgment when choosing a transportation service provider. Assessment methods can be divided into 5 groups: MCDM techniques, statistical approaches, artificial intelligence, mathematical programming, and hybrid methods [2, 8, 9].

3. Methodology

As it is mentioned above, there is a number of ranking methods. In this paper, we experiment with TOPSIS [10] and VIKOR [11] methods. These methods are based on an aggregating function representing "closeness to the ideal", which originated in the compromise programming method. In VIKOR linear normalization and TOPSIS vector normalization is used to eliminate the units of criterion functions [12]. We chose these methods because they are quick and easy to use [2] and the results of the methods are easy to interpret and compare.

3.1. TOPSIS

Technique for Ordering Preference by Similarity to the Ideal Solution (TOPSIS) of the multi-criteria decision-making (MCDM) methods most commonly used to rank logistics companies [3]. The essence of this method is to find the solution (alternative) closest to the ideal solution and farthest from the worst solution geometrically [5]. To apply this method, follow these steps:

1. Construct a decision matrix and determine criteria weights.
   Let $X = (x_{ij})$ be a *decision matrix*. It consists of m alternatives and n criteria. Then we have a matrix of size $X_{m \times n} = (x_{ij})$ $m \times n$. We also have a vector of weights $W = (w_1, w_2, \dots, w_n)$, where the sum of the elements of the vector equals $w_1 + w_2 + \dots + w_n = 1$. Criteria of the functions can be: *benefit functions*, when more is better or *cost functions*, when less is better [5, 6].
2. Calculate the normalized decision matrix.
   The elements of the normalized decision matrix r_{ij} are given by the following equation:
   $$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1, 2, \dots, m, \; j = 1, 2, \dots, n. \tag{1}$$
3. Calculate the weighted normalized decision matrix.
   Calculate the weighted normalized matrix elements v_{ij} using the following expression:
   $$v_{ij} = r_{ij} \cdot w_j, \quad i = 1, 2, \dots, m, \; j = 1, 2, \dots, n. \tag{2}$$
4. Determine the ideal and negative-ideal solution.
   The *ideal positive solution* is the solution that maximizes the benefit criteria and minimizes the cost criteria whereas the *negative ideal solution* maximizes the cost criteria and minimizes the benefit criteria. [13].
   Expression of a positive ideal solution A^+:
   $$A^+ = \{v_n^+\} = \{(\max_i v_{ij} \mid j \in I^{'}), \; (\min_i v_{ij} \mid j \in I^{''})\} \tag{3}$$
   Expression of a negative ideal solution A^-:
   $$A^- = \{v_n^-\} = \{(\min_i v_{ij} \mid j \in I^{'}), \; (\max_i v_{ij} \mid j \in I^{''})\}, \tag{4}$$
   where I' relates to the benefit criterion and I'' relates to the cost criterion [5].
5. Calculate the separation measures, using the n-dimensional Euclidean distance.
   The separation of each alternative from the ideal solution is given as:
   $$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, \quad i = 1, 2, \dots, m \tag{5}$$
   Similarly, the separation from the negative-ideal solution is given as:
   $$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \quad i = 1, 2, \dots, m \tag{6}$$
6. Calculate the relative closeness to the ideal solution.
   The relative closeness of the i-th element to the positive ideal solution can be calculated using the formula:
   $$C_i = \frac{d_i^-}{d_i^- + d_i^+}, \tag{7}$$
   where $0 \leqslant C_i \leqslant, \quad i = 1, 2, \dots, m.$
7. Rank the preference order.
   Items C_i are ordered in descending order. The highest number indicates the best solution.

3.2. VIKOR

The VIKOR [11] was introduced as one applicable technique to implement within MCDM. It focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria, and on proposing compromise solution (one or more) [14]. The compromise ranking algorithm VIKOR has the following steps [12, 14]:

1. Determine the best f_i^* and the worst f_i^- values of all criterion functions, $i = 1, 2, \dots, n$. If the ith function represents a benefit then:

$$f_i^* = \max_j f_{ij},\ f_i^- = \min_j f_{ij}. \tag{8}$$

2. Compute the values S_j and R_j, $j = 1, 2, \dots, J$, by the relations

$$S_j = \sum_{i=1}^{n} w_i (f_i^* - f_{ij})/(f_i^* f_i^-), \tag{9}$$

$$R_j = \max_i [w_i (f_i^* - f_{ij})/(f_i^* f_i^-)], \tag{10}$$

where w_i are the weights of criteria, expressing their relative importance.

3. Compute the values $Q_j, j = 1, 2, \dots, J$, by the relation

$$Q_j = v(S_j - S^*)/(S^- - S^*) + (1 + v)(R_j - R^*)/(R^- - R^*) \tag{11}$$

where

$$S^* = \min_j S_j, S^- = \max_j S_j, \tag{12}$$

$$R^* = \min_j R_j, R^- = \max_j R_j, \tag{13}$$

and v is introduced as weight of the strategy of "the majority of criteria" (or "the maximum group utility"), here $v = 0.5$.

4. Rank the alternatives, sorting by the values S, R and Q, in decreasing order. The results are three ranking lists.
5. Propose as a compromise solution the alternative (a') which is ranked the best by the measure Q (minimum) if the following two conditions are satisfied:

C1. Acceptable advantage:

$$Q(a'') - Q(a') \geqslant DQ \tag{14}$$

where a'' is the alternative with second position in the ranking list by Q; $DQ = 1/(J - 1)$; J is the number of alternatives.

C2. Acceptable stability in decision making: Alternative a' must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be: "voting by majority rule" (when $v > 0.5$ is needed), or "by consensus" $v \approx 0.5$, or "with veto" ($v < 0.5$). Here, v is the weight of the decision making strategy "the majority of criteria" (or "the maximum group utility") [12].

Table 1
Expert evaluation

Alternative	Documents	Communication	Quality	Price
P1	6	7	8	5
P2	5	7	5	4
P3	6	7	7	8
P4	7	7	6	4
P5	5	6	8	8
P6	6	7	8	7
P7	6	7	7	6
P8	6	6	7	6
P9	5	1	7	6
P10	5	5	7	6

4. Data Set

We use real data collected by the logistic company, which includes companies, trucks, trailers, cargo orders, trip data. Data were collected from January 2, 2015, to May 10, 2019. Companies that provide transportation services were selected from this data. We estimated from data:

1. number of company trucks,
2. number of trailers,
3. number of trips,
4. number of orders,
5. average daily payment period for purchase document,
6. average loading time for purchase documents.

We also have an expert evaluation of logistic providers. The expert rated the logistic provider on a ten-point scale where 1 is very bad and 10 is very good. The expert evaluated according to 4 criteria:

1. speed of sending documents of the company,
2. communication,
3. quality of services and
4. price.

This data can be used to rank logistic providers based on expert judgment and actually calculated criteria. In

Table 2
Actual data evaluation

Alternative	Truck	Trailer	Trip	Order	Payment period	Documents
P1	28	3	16852	1904	43.55	202.36
P2	21	13	868	51	30.10	48.60
P3	14	1	245	35	30.22	97.44
P4	65	30	454	225	43.39	112.98
P5	95	12	959	2	26.12	85.79
P6	22	1	133	11	35.83	64.50
P7	46	8	489	849	42.40	81.75
P8	36	15	597	171	38.47	36.03
P9	4	0	211	928	31.90	16.39
P10	113	76	545	905	29.50	272.27

Table 3
TOPSIS ranking

Alternative	Expert evaluation		Data based evaluation	
	Score	Rank	Score	Rank
P1	0.67	6	0.54	1
P2	0.53	9	0.28	8
P3	0.84	**1**	0.21	**10**
P4	0.59	7	0.33	5
P5	0.74	3	0.33	4
P6	0.83	2	0.25	9
P7	0.73	4	0.32	6
P8	0.68	5	0.31	7
P9	0.29	10	0.33	3
P10	0.57	8	0.48	2

Table 4
VIKOR ranking

Alternative	Expert evaluation		Data based evaluation	
	Q	Rank	Q	Rank
P1	0.36	5	0.00	1
P2	1.00	10	0.58	5
P3	0.02	2	0.92	10
P4	0.70	7	0.42	4
P5	0.59	6	0.85	8
P6	0.00	1	0.90	9
P7	0.13	**3**	0.41	**3**
P8	0.17	4	0.41	2
P9	0.96	9	0.84	7
P10	0.81	8	0.67	6

the analysis, we will compare expert judgment with factual evaluation. For this purpose, we randomly selected 10 transport service providers for which we have an expert judgment (see table 1) and actual data (see table 2).

Table 5
Correlation matrix

	TOPSIS expert	TOPSIS data	VIKOR expert	VIKOR data
TOPSIS expert	1	0.42	**1**	**0.53**
TOPSIS data		1	0.42	0.39
VIKOR expert			1	**0.53**
VIKOR data				1

5. RESULTS

Both of these methods used the same criteria weights to compare the results of the methods. In the TOPSIS method *higher score* means *higher rank*. The reverse is true for the VIKOR method. In VIKOR method smaller Q coefficient means higher rank. Table 3 shows the results of the TOPSIS model and table 4 shows the results of the VIKOR model.

First of all, we calculated the correlation matrix (see tabel 5) to compare the obtained methods. Correlation matrix values closeness to these values indicate relationships between rankings:

1. 1 if the agreement between the two rankings is perfect; the two rankings are the same,
2. 0 if the rankings are completely independent,
3. -1 if the disagreement between the two rankings is perfect; one ranking is the reverse of the other.

As can be seen from the correlation matrix, the experts evaluated TOPSIS ranking is completely identical with VIKOR expert assessment. This correlation equal to 1. Other correlation values are greater than 0, that means rankings are slightly similar.

The two methods of expert assessments offered by the best P3 and P6 logistics providers. When evaluating 3PL suppliers based on actual data, both methods gave P1 provider as the best alternative.

Comparing the results of each method on its own, it can be seen that expert judgment in the vast majority of places does not coincide with evaluations of criteria calculated from actual data. This is because different criteria have been chosen for the evaluation. The experts evaluated the sending of the documents, we evaluated the speed of the loading of the documents according to the data. But it is difficult to evaluate communication, quality of service and price from the data e.g. as the price depends on the number of kilometers and type of cargo.

The results calculated by the VIKOR method coincide with estimates made by experts and factual data. Supplier P7 took 3rd place. But looking at other suppliers, the P3 and P6 are ranked high by experts: 2 and 1 respectively. And according to the actual data low: 10 and 9 places. The analysis should combine expert judgment with criteria calculated from actual data, thus better describing the logistics providers.

According to VIKOR and TOPSIS models and actual data, P1 is the best choice and P3 the worst from this ten providers. If we included other logistics service providers in the ranking, the results would change.

6. Conclusions

The choice of a transport service provider is one of the most important cooperation (outsourcing) solutions to increase the competitiveness of the company. With a large supply of logistics providers, it is difficult to choose the best partner. The goal of this research is application and comparison of TOPSIS and VIKOR multicriteria decision making methods, to determine which transportation supplier is the best. These logistics service provider were analyzed for the period from 2nd January 2015 to 10th May 2019.

The main results of this article:

1. Overview of transportation service providers issues.
2. Comparison of the TOPSIS and VIKOR methods.
3. Evaluation of both methods.

Conclusions:

1. Expert judgment and evaluation of data-based criteria are more correlated in the VIKOR method than in the TOPSIS.
2. According to expert assessments, both methods offered the same ranking of logistics services providers.
3. Approach of The VIKOR method better reflected expert judgment in the evaluation of actual data.

In future, we plan to perform sensitivity analysis of criteria weights obtained by the VIKOR method, as well as adapting other logistics provider choices MCDM techniques, statistical approaches, artificial intelligence.

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