APPLICATION OF THE ORESTE METHOD FOR SOLVING DECISION MAKING PROBLEMS IN TRANSPORTATION AND LOGISTICS

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Complexity of transportation and logistics processes and systems as well as necessity to make right decision in right time imposes the use of different mathematical methods and techniques decision making process support. Decision making in transportation and logistics domain is a complex process due to the fact that a wide range of diverse criteria, stakeholders and possible solutions are embedded into this process. In order to help decision makers in solving these decision making problems a number of multi-criteria decision making (MCDM) methods have been proposed. This paper introduces the use of an almost unexplored MCDM method, i.e. the ORESTE (Organization, Rangement Et Synthese De Donnes Relationnels) method. The main motivation of the application of the ORESTE method is that it is not necessary to determine criteria weights as in other MCDM methods, rather it is only required to specify ordinal criteria importance. Applicability and detailed computational procedure of the ORESTE method has been demonstrated while solving two decision making problems, evaluation and selection of transportation companies and suppliers.

Keywords: Transportation, logistics, multi-criteria decision making, ORESTE.

1. Introduction

In today's modern industry, transportation and logistics services are inevitable tool in order to satisfy ever changing customer demands. Logistics deals with the analysis, design and management of flows of goods, information, people and energy, and involves a wide range of activities such as: transportation (internal and external), handling, packaging, storage, scheduling and inventory management, purchasing, energy supplies, service, maintenance, life cycle cost management, customer relationship management, etc. Logistics manage these activities whether it is the case of the basic flow of goods and services (from producers to consumers) or the return flow when the used product or packaging is returned to the manufacturer for reuse, recycling, destruction or safe disposal [1].

Being described shortly as 'the set of activities for managing resources, in broad sense)', logistics aims to ensure efficient flow of supplies from the point of origin to the customers. The whole concept of logistics is based on the concept of 7R [2]: to move right materials/products, in right quantity, in right condition, at

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the right time, to the right place, at the right cost, and to the right customers/associates/suppliers/stockholders [3]. These objectives must be satisfied in a highly volatile and uncertain logistic environment, sensitive to dynamic changes, human errors and unexpected events [4] and this imposes a number of challenges in modern logistics. Since logistics costs account for nearly 30% of the sales of a company [3], optimization and improvement of logistics processes/systems is very important aspect for each company. One of the key elements in logistics is transportation as it is required in the entire production process, from manufacturing to delivery to the final consumers and returns as well as it occupies more than one-third of the amount of the logistics costs [3].

Complexity of transportation and logistics processes is reflected through [4]: many evaluation criteria (economical, technical, environmental, social,...), many stakeholders (customers, operators, employees, local communities,...), and many trade-offs such as cost vs. quality, contradictory interests, strong interaction and dynamics between stakeholders. Above all, transportation and logistics need quick and reliable decisions in every moment.

Consequently, several concepts, methodologies and approaches emerged into existence to meet transportation and logistics challenges of the 21st century. Among others, multi-criteria decision making (MCDM) methods especially stands out as one of the most widely used set of mathematical tools. MCDM is one of the most popular areas in decision making theory and its main objective is to evaluate a number of, previously known, alternatives (solutions) with respect to a number of criteria. In a MCDM process for solving decision problems, goals, criteria, alternatives and criteria weights are defined, upon which evaluation matrix is determined. Subsequently, an appropriate MCDM method for determination of a decision rule, i.e. evaluation and ranking of alternatives is applied and finally the best alternative is determined and implemented [5, 6]. This process is often accompanied by auxiliary activities, such as data normalization, determination of criteria weights, change in the nature of criteria, conversion of linguistic variables into the crisp values, etc.

MCDM methods have become preferential choice for solving real life complex transportation and logistics problems. These methods allow decision makers to determine compromise solution taking into the account different criteria, type of information (quantitative and qualitative), interest of stakeholders, relative significance of criteria as well as decision maker preferences. By using these methods, starting from the decision matrix, which is developed by decision maker considering the available data and information, through step-by-step procedure a decision rule is generated upon which evaluation and ranking is performed. Most MCDM methods incorporate subjective preference of decision makers, particularly in determining relative significance of the criteria, but still represent a solid mathematical apparatus for systematical procedural problem

solving and generating improvement. However, one need to mention that there are objective methods such as a novel MCDM method, i.e. performance selection index (PSI) which determines criteria weights only by using information provided in the decision matrix, i.e. it uses objective approach to determine criteria weights like standard deviation or entropy method.

Different MCDM methods have been previously applied to solve various transportation and logistics problems, including: selection of transportation services/modes, evaluation of logistics/transportation projects, facility location selection, crew assignment and scheduling, route selection, supplier evaluation and selection, etc. The purpose of this paper is to present the application methodology of an almost unexplored MCDM method, i.e. ORESTE (Organization, Rangement Et Synthese De Donnes Relationnels) method for solving transportation and logistics decision making problems. The ORESTE method is a more general method in operational research that applies in situations where no quantitative data are available and avoids the necessity of determining criteria weights [11]. To the best authors knowledge, the method has not been previously applied for solving decision making problems in the transportation and logistics domain.

2. Overview of MCDM

In MCDM alternatives represent different possibilities that are available for decision maker. In a MCDM model alternatives form the set of a finite number of elements to be analyzed, evaluated and ranked. Criteria represent different dimensions (aspects) which are used for evaluation of alternatives, wherein the relative significance or importance of the criteria may be different. The fact that multiple-criteria of multiple-stakeholders are considered it seems very useful, especially within the context of logistics planning, where multiple stakeholders, conflicting interests and criteria represent the nature of such issues [7]. Real MCDM problems in most cases do not consider criteria of the same importance. Accordingly, when solving decision making problems decision makers must determine the degree of significance of each criterion. In MCDM models this is accomplished by assigning appropriate weight coefficients to each criterion. In doing so it applies that the sum of weight coefficients is equal to one, wherein higher weight coefficient value implies a greater relative significance of a given criterion.

MCDM methods for solving decision making problems aims at evaluating m alternatives A_i ($i=1,2,...,m$) with respect to n criteria C_j ($j=1,2,...,n$) by considering alterative's attribute values x_{ij} (performance values) with respect to each criterion as well as relative significance of criteria given by weight coefficients w_j ($j=1,2,...,n$). Accordingly, it is clear that evaluation and ranking of

alternatives is based, on the one hand, considering alternative's attribute values, and on the other hand, taking into account preferences of decision makers about the relative significance of criteria. The central and most important element in an MCDM analysis is decision matrix, which in different contexts is also called performance matrix or decision table. Decision matrix is essentially a particular MCDM model that fits poorly structured problems and has the following general mathematical formulation [1]:

$$\text{Max } \{C_1(x), C_2(x), ..., C_n(x)\}, \quad m, n \geq 2$$
$$\text{Subject to} : x \subset A = [a_1, a_2, ..., a_m] \tag{1}$$

Previous formulation can be interpreted as follows: apply the decision rule for selecting the best alternative from a set of possible alternatives taking into the account the performances of alternatives in relation to the considered criteria.

MCDM methods have been developed as mathematical tools to support decision makers involved in the process of solving decision making problems. They are based on scientific principles that enable effective and efficient way of determining the "compromise" solution that takes into account the trade-off between criteria and preferences of decision makers. Although MCDM analysis, as a scientific discipline, has a relatively short history of about 50 years, until today over 70 different MCDM methods were developed and literature continuously records the development of new ones. For example, Zavadskas and colleagues [8], proposed WASPAS (Weighted Sum Aggregated Product Assessment) method in 2012, whose effectiveness is well documented in the literature. Recently, this MCDM method was augmented to deal with fuzzy and grey numbers so WASPAS-F and WASPAS-G methods were proposed.

Existence of a large number of MCDM methods implies that the decision maker has a large possibility in terms of choosing the particular MCDM method for solving a given decision making problem, but at the same time it can create confusion within decision makers in sense of selection of a MCDM method. In essence, the choice of a MCDM method for solving a specific decision making problem is in itself a kind of MCDM problem [9]. One of the most important classifications of MCDM methods that is seen in the literature and which was carried out by type and essential characteristics of the information provided by decision maker, was proposed by Hwang and Yoon [10]. The classification of MCDM methods was carried out in three phases: the first phase specifies the type of attribute (criteria) information or alternative, which is required from the decision maker, the second phase refers to the essential characteristics of the information, and in the third phase the main MCDM methods that can be applied are given. According to the proposed classification, unless there is no information from the decision makers, as a method to be chosen, one can select for example domination method. In the case of ordinal information of criteria preferences, as a method for decision making problem solving one can select the ORESTE method.

In the case of cardinal information of criteria preferences, one may select a number of MCDM methods including TOPSIS, VIKOR, ELECTRE, PROMETHEE, etc.

3. ORESTE method

The ORESTE method is a general MCDM ranking method based on outranking relation. The method was proposed by Roubens [12] and was later popularized by Pastijn and Leysen's [13]. Evaluation and ranking of alternatives is made on the basis of preferences of decision makers, the data in the decision matrix and Besson's ranking of criteria and alternatives [12, 13]. In many MCDM problems in which quantitative and qualitative attributes coincide, this method is particularly suitable given that it does not require the existence of accurate numerical values of attributes and/or criteria weight coefficients [14]. The main advantage of the ORESTE method is that it uses only ordinal ranking of criteria, which speeds up the decision making process. The ORESTE method is composed of three phases. In the first phase projection of the decision matrix is calculated. In the second phase, global ranking are assigned to the projections. In the third phase by adding the global rankings, the mean rankings are calculated.

The basic procedure of the ORESTE method application can be summarized in the following steps [1, 14]:

Step 1: Identify the set of criteria on the basis of which the evaluation of alternatives is to be performed.

Step 2: Create decision matrix in which the performance of all alternatives in relation to each criterion are given.

Step 3: Determine the global (weak) ranking of criteria which shows their relative significance:

$c_1 P c_2 I c_3 P c_4 \dots c_n$

Previous expression shows that the most important criterion is c_1, c_2 and c_3 are of the same importance, but less significant in comparison with c_1, while the least significant criterion is c_n.

Step 4: With respect to each criterion determine the weak ranking of alternatives, as in step 3:

$c_1 : a_1 P a_2 P a_3 \dots a_m$

$c_2 : a_1 P a_2 I a_3 \dots a_m$

...

$c_n : a_1 I a_2 P a_3 \dots a_m$

Step 5: Determine Besson's ranking of alternatives and criteria. When using the ORESTE method each alternative takes Besson's ranking based on performances compared to other alternatives with respect to all the criteria. Also, each criterion receives Besson's ranking based on its ranking. Application of the

ORESTE method allows that alternatives or criteria can have the same significance. In this case Besson's ranking is applied by which values of ranking of alternatives or criteria, are determined by taking into account the sums of integers ranks. So, if one has two alternatives, which are according to a given criterion ranked in fifth position, then they will obtain Besson's ranking (5+6)/2=5.5 (i.e. average rank of first two places held in the order of alternatives). Similarly, if two criteria have the same values of weight coefficients, which are also the largest, then Besson's ranking of criteria is (1+2)/2=1.5. Besson's ranking of alternative a_i in relation to the criteria j is denoted as $r_j(a_i)$ and Besson's ranking of criterion j is denoted as rc_j.

Step 6: Calculate projection distances. Distance projections correspond to the relative distance of Besson's rankings of alternative with respect to arbitrary point O and are defined as $d(O, a_i)$. There are different types of projections, but linear orthogonal projection is mostly used and it may be expressed by the following equation:

$$d_j(O, a_i) = \frac{1}{2} \cdot \left(rc_j + r_j(a_i) \right) \tag{2}$$

Based on previous equation when an alternative a_i is more preferable in comparison to other alternative a_2 ($a_1 P a_2$) with respect to criterion j, then $d_j(a_1) < d_j(a_2)$, i.e. the lower projection distance is, the better is the position of alternative in the rank.

Step 7: Rank projections and determine global Besson's ranks of distance projection of alternatives in relation to criteria. Global Besson's rank $r_j(a_i)$ is assigned to all projection distances from the smallest to the largest. The lower value of $r_j(a_i)$ shows a better position of certain alternative in ranking.

Step 8: Calculate the mean global Besson's ranks $r(a_i)$ for alternatives by summarizing their global Besson's rankings for the entire set of criteria using the following equation:

$$r(a_i) = \sum_{j=1}^{n} r_j(a_i) \tag{3}$$

Mean global Besson's ranks are then sorted in ascending order and one obtains the complete ranking of alternatives. An alternative that has the lowest mean global Besson's ranking is the best alternative.

4. Case studies

In order to demonstrate computational procedure and applicability of the ORESTE method for solving transportation and logistics decision making problems, two case studies were considered, evaluation and selection of transportation companies and suppliers.

4.1. Supplier selection

Supplier selection is a complex MCDM problem which may include both qualitative and quantitative attributes of alternatives and a number of conflicting criteria. Let us consider a hypothetical example of supplier selection. Suppose one need to select one of three possible suppliers (a_1, a_2, a_3) based on the following four criteria: delivery time in days (c_1), after sale service (c_2), reliability (c_3) and price in EUR (c_4). Let us consider that the price is the most important criterion followed by delivery time, reliability and after sale service, respectively. The evaluation of alternatives (suppliers) in relation to the selected criteria is given in Table 1. Note that alternative performances in relation to criteria c_2 and c_3 are given using Likert's 9 point scale.

Table 1

Decision matrix for supplier selection

Alternatives	Criteria			
	c_1	c_2	c_3	c_4
	min	max	max	min
a_1	9	9	5	124
a_2	7	5	3	135
a_3	12	5	7	150

The detailed computational procedure of the ORESTE method for solving this decision making problem is as follows. The global (weak) ranking of criteria is $c_4 P c_1 P c_3 P c_2$. Weak ranking of alternatives in relation to each criterion is:

c_1 : $a_2 P a_1 P a_3$

c_2 : $a_1 P a_2 I a_3$

c_3 : $a_3 P a_1 P a_2$

c_4 : $a_3 P a_1 P a_2$

Besson's rankings of criteria and alternatives are given in Tables 2 and 3, respectively.

Table 2

Besson's ranking of criteria

Criteria	c_1	c_2	c_3	c_4
rc_j	2	4	3	1

Table 3

Besson's ranking of alternatives

	c_1	c_2	c_3	c_4
a_1	2	1	2	1
a_2	1	2.5	3	2
a_3	3	2.5	1	3

By applying Eq. 2 the projection distances of alternatives in relation to the considered criteria are determined (Table 4).

Projection distances

	c_1	c_2	c_3	c_4
a_1	2	2.5	2.5	1
a_2	1.5	3.25	3	1.5
a_3	2.5	3.25	2	2

Global Besson's ranks of distance projections of alternatives in relation to the criteria are given in Table 5.

Global Besson's rankings of projection distances

	c_1	c_2	c_3	c_4
a_1	5	8	8	1
a_2	2.5	11.5	10	2.5
a_3	8	11.5	5	5

Finally, by applying Eq. 3 mean Besson's ranks of alternatives, $r(a_i)$, are determined upon which the complete ranking was obtained (Table 6).

Complete ranking of suppliers

Alternative	$r(a_i)$	Rank
a_1	22	1
a_2	26.5	2
a_3	29.5	3

4.2. Selection of transportation company

Kulović [15] applied fuzzy TOPSIS method for evaluating the transportation companies. Presented method takes into account both quantitative and qualitative attributes. The paper analyzed the hypothetical example of selecting the best transportation company among three possible (a_1, a_2 i a_3) taking into account the five criteria: reliability (c_1), competence (c_2), responsibility (c_3), trust (c_4) and flexibility (c_5). Evaluation of alternatives (transportation companies) in relation to the selected criteria is given in Table 7.

Decision matrix for transportation company selection

Alternatives	Criteria				
	c_1	c_2	c_3	c_4	c_5
	max	max	max	max	max
a_1	0.5	5.6	0.75	0.25	0.25
a_2	0.75	4.2	0.5	0.5	0.75
a_3	0.5	4.8	0.75	0.75	0.5

On the basis of three expert opinions and application of the AHP method, Kulović [15] determined criteria weights as $w = [0:32, 0.26, 0.19, 0.13, 0.11]$, and by using the fuzzy TOPSIS method, a_2-a_3-a_1 ranking of alternatives was obtained.

The detailed computational procedure of the ORESTE method for solving this decision making problem is as follows. Based on given criteria weight coefficients the global (weak) ranking of criteria is $c_1Pc_2Pc_3Pc_4Pc_5$. So c_1 is the most important criterion while the least important criterion is c_5. Weak ranking of alternatives in relation to each criterion is:

$c_1 : a_2Pa_1Ia_3$
$c_2 : a_1Pa_3Pa_2$
$c_3 : a_1Ia_3Pa_2$
$c_4 : a_3Pa_2Pa_1$
$c_5 : a_2Pa_3Pa_1$

Besson's ranking of criteria and alternatives are given in Tables 8 and 9, respectively.

Besson's ranking of criteria

Criteria	c_1	c_2	c_3	c_4	c_5
rc_j	1	2	3	4	5

Besson's ranking of alternatives

	c_1	c_2	c_3	c_4	c_5
a_1	2.5	1	1.5	3	3
a_2	1	3	3	2	1
a_3	2.5	2	1.5	1	2

By applying Eq. 2 the projection distances of alternatives in relation to the considered criteria are determined (Table 10).

Table 10

Projection distances

	c_1	c_2	c_3	c_4	c_5
a_1	1.75	1.5	2.25	3.5	4
a_2	1	2.5	3	3	3
a_3	1.75	2	2.25	2.5	3.5

Global Besson's ranks of distance projections of alternatives in relation to the criteria are given in Table 11.

Table 11

Global Besson's rankings of projection distances

	c_1	c_2	c_3	c_4	c_5
a_1	3.5	2	6.5	13.5	15
a_2	1	8.5	11	11	11
a_3	3.5	5	6.5	8.5	13.5

Finally, by applying Eq. 3 mean Besson's ranks of alternatives, $r(a_i)$, are determined upon which the complete ranking was obtained (Table 12).

Table 12

Complete ranking of transportation companies

Alternative	$r(a_i)$	Rank
a_1	40.5	2
a_2	42.5	3
a_3	37	1

Based on the obtained results one can conclude that the alternative a_3 (transportation company 3) is the best alternative, i.e. the most favorable option for transportation. However, it should be noted that there is small difference in mean global Besson's rank values of alternatives. The comparison between obtained alternatives ranking with the one obtained by Kulović [15] is not objective since the ORESTE method uses only ordinal type of information.

5. Conclusions

This paper introduced the application of an almost unexplored MCDM method, i.e. the ORESTE method for solving the decision making problems in transportation and logistics domain. The detailed computational procedure of the ORESTE method was demonstrated while solving two case studies related to evaluation and selection of transportation companies and suppliers. The main advantage of the ORESTE method is that it can work with data in an ordinal scale, i.e. it can handle situations in which performances of alternatives with respect to

given criterion cannot be expressed quantitatively (numerically). This feature is particularly important when dealing with intangible aspects in decision making process. Also the application of this method does not necessarily need assessment of criteria significance through determination of criteria weights, rather only simple specification about relative significance. Consequently the decision making process is accelerated since decision makers do not spend time on selection and application of different methods for criteria weights estimation, either subjective or objective. Moreover, the implementation of the ORESTE method does not necessarily requires strong background in mathematics and operational research as well the use of specialized software packages since it can be easily implemented in MS Excel.

In conclusion, the ORESTE method may be a useful auxiliary decision making tool for solving transportation and logistics decision making problems. In decision making situations where one need to consider imprecision and indetermination in the structure of a MCDM model, the ORESTE method can be efficiently applied in a preliminary analysis. Also, since this outranking approach is very efficient and flexible, one may use it for MCDM model dimension reduction, i.e. elimination of the lowest ranked alternatives from initial set.

Main scope of future work will be application and comparative analysis of the ORESTE and PSI methods for solving decision making problems in transportation and logistics and design of an decision support system with a graphical user interface to ease the decision making process.

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