DOI 10.20544/TTS2021.1.1.21.p30
UDC••656.13.025.4:004.891
Professional paper

Evaluation of criteria for performing oversized transport using Fuzzy PIPRECIA method

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Abstract – **Oversized transport is an organizationally and infrastructurally demanding way of performing transport activities. It is a very important factor in an overall economic system. Since it is a mode of transport that has specific requirements in terms of organization and infrastructure, this paper evaluates the factors for its execution. The Fuzzy PIvot Pairwise RElative Criteria (Fuzzy PIPRECIA) method was used to determine the significance of ten criteria. The purpose of this paper is to analyze the necessary conditions for adequate and safe oversized transport.**

Keywords – **oversized transport, Fuzzy PIPRECIA**

I. Introduction

Oversized or special transport is considered to be transport of all cargoes with dimensions or masses exceed certain prescribed limits. More specifically, it is a cargo that exceeds legally permissible dimensions. Considering the language of certain area and depending on the legal regulations of a country, there are several identified names for oversized transport. This mode of transport is carried out exclusively by means of transport of specific construction, which largely depends on the type of cargo. Oversized transport requires special approvals of a competent institution and mandatory security measures. The design and implementation of an oversized cargo chain is a multi-level logistical process that focuses on preparation of cargo, as well as traffic infrastructure, for the safe movement of cargo on a particular part of a route or the complete route along which transport is performed.

The organization of oversized transport, effectively following regulations and prescribed conditions by each segment of transport, is a very specific job that requires good organizational skills and an excellent knowledge of laws governing such services. Its specificity is based on the size of structural elements, equipment or machines that require a special and individual approach. The appropriate choice of means of transport in relation to the cargo carried is the most important element in the overall planning process. It is due to the fact that the persons responsible for transport planning tend to minimize the occurrence of risk for all road participants.

Road transport in B&H is currently the most frequently used transport sector due to its wide availability, speed, flexibility and affordable service costs. For the same reasons, it is also most frequently the problematic area of transport due to many legal regulations and inadequately prepared roads for the transport of heavy cargo. It is known that very often there are not many options when choosing the mode of transporting oversized cargo. Long, wide, high and heavy loads are transported to new facilities, wind farms, production halls, buildings and roads, and often the cargo itself by its structure determines the mode of transport. The transport of oversized cargo is more complicated due to the regulations and procedures it has to comply with, and is more expensive financially because of required permits and supporting documentation.

The purpose of this paper is to analyze the necessary conditions for adequate and safe oversized transport. The criteria for successful oversized transport were analyzed. Ten criteria, which are explained in detail in the following section, were considered and evaluated using the Fuzzy PIPRECIA method. The transport of cargo of greater length (pipes, trees ...) can be accomplished in a way that the load by its one end is set on a towing vehicle and by the other on a trailer. Thus, the load plays a role of a link between the towing vehicle and the trailer. A large number of vehicles for this purpose are equipped with cranes, which can be equipped with various gripping devices: hook, rake, etc. [1]. Oversized transport includes cargoes such as: [2] construction machinery, urban infrastructure elements, elements of the power, chemical, mining and metallurgical industries.

II. Methods

The main advantage of the PIPRECIA method is that it allows criteria to be evaluated without sorting criteria by significance first, which is not the case with the SWARA method [3,4]. The Fuzzy PIPRECIA method was developed by Stević et al. [5]. It consists of 11 steps shown below.

Step 1. Forming the required benchmarking set of criteria and forming a team of decision-makers. Sorting the criteria according to marks from the first to the last, which means they need to be sorted unclassified. Therefore, in this step, their significance is irrelevant.

Step 2. In order to determine the relative importance of criteria, each decision-maker individually evaluates the pre-sorted criteria by starting from the second criterion, Eq. (1).

$$\overline{s_j^r} = \begin{cases} > \bar{1} & if \quad C_j > C_{j-1} \\ = \bar{1} & if \quad C_j = C_{j-1} \\ < \bar{1} & if \quad C_j < C_{j-1} \end{cases} \quad (1)$$

$\overline{s_j^r}$ denotes the evaluation of the criteria by a DM *r*. In order to obtain a matrix $\overline{s_j}$, it is necessary to perform the averaging

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of matrix $\overline{s_j^r}$ using a geometric mean. Decision-makers evaluate the criteria by applying the linguistic scales developed and defined in [5,6].

Step 3. Determining the coefficient $\overline{k_j}$

$$\overline{k_j} = \begin{cases} =\bar{1} & if \quad j=1 \\ 2-\overline{s_j} & if \quad j>1 \end{cases} \tag{2}$$

Step 4. Determining the fuzzy weight $\overline{q_j}$

$$\overline{q_j} = \begin{cases} =\bar{1} & if \quad j=1 \\ \dfrac{\overline{q_{j-1}}}{\overline{k_j}} & if \quad j>1 \end{cases} \tag{3}$$

Step 5. Determining the relative weight of the criterion $\overline{w_j}$

$$\overline{w_j} = \frac{\overline{q_j}}{\sum_{j=1}^{n} \overline{q_j}} \tag{4}$$

In the following steps, it is necessary to apply the inverse methodology of the fuzzy PIPRECIA method.

Step 6. Evaluation of the applying scale defined above, but this time starting from a penultimate criterion.

$$\overline{s_j^r}' = \begin{cases} >\bar{1} & if \quad C_j > C_{j+1} \\ =\bar{1} & if \quad C_j = C_{j+1} \\ <\bar{1} & if \quad C_j < C_{j+1} \end{cases} \tag{5}$$

$\overline{s_j^r}'$ denotes the evaluation of the criteria by a decision-maker *r*. It is again necessary to average the matrix $\overline{s_j^r}$ by applying a geometric mean.

Step 7. Determining the coefficient $\overline{k_j}'$

$$\overline{k_j}' = \begin{cases} =\bar{1} & if \quad j=n \\ 2-\overline{s_j}' & if \quad j>n \end{cases} \tag{6}$$

n denotes a total number of criteria. Specifically, in this case, it means that the value of the last criterion is equal to fuzzy number one.

Step 8. Determining the fuzzy weight $\overline{q_j}'$

$$\overline{q_j}' = \begin{cases} =\bar{1} & if \quad j=n \\ \dfrac{\overline{q_{j+1}}'}{\overline{k_j}'} & if \quad j>n \end{cases} \tag{7}$$

Step 9. Determining the relative weight of the criterion $\overline{w_j}'$

$$\overline{w_j}' = \frac{\overline{q_j}'}{\sum_{j=1}^{n} \overline{q_j}'} \tag{8}$$

Step 10. In order to determine the final weights of the criteria, it is first necessary to perform the defuzzification of the fuzzy values $\overline{w_j}$ and $\overline{w_j}'$

$$\overline{w_j}'' = \frac{1}{2}(w_j + w_j') \tag{9}$$

Step 11. Checking the results obtained by applying Spearman and Pearson correlation coefficients.

III. Evaluation of Criteria by the Fuzzy PIPRECIA Method

The determination of criteria and their mutual evaluation have been performed by managers of Hes-Komerc company, which is a carrier in charge of oversized (special) cargoes. Table 1 lists all the criteria that affect the selection of an optimal transport route, as well as their description.

TABLE I

CRITERIA AFFECTING THE SELECTION OF OPTIMAL TRANSPORT ROUTE

C1	Cargo dimensions
C2	Number of countries in transit
C3	Cost of international permits
C4	Police escort
C5	Tolls
C6	Bridges, tunnels and viaducts along the route
C7	Roundabouts
C8	Crossing of roads and railway lines
C9	Cost of motor fuel
C10	Transport identification plates

On the basis of practice and experience, the most dominant criterion is considered to be the one that directly affects the choice of route since it dictates: the choice of a customs crossing due to dimension constraints; choice of means of transport; (im)possibility of passing through tunnels or over bridges; determines whether police escort is required, and with all of this directly affecting transport costs.

An important factor in obtaining oversized transport permits is that the more countries through which transport is carried out, the greater the number of required permits or approvals of competent authorities, and costs and the length of the route are also increased, which proportionally increases the time for performing the transport.

The cost of international permits depends on C2, i.e. the number of countries in transit.

The necessity of police escort increases the duration of obtaining a transport permit and increases costs. All local police stations need to be contacted on the territory of B&H for consent to transit through a certain place, as well as obtaining permits for police escort from the Ministry of Interior of the countries in transit.

By optimizing a transport route, the cost of tolls reduces, which directly affects the overall costs and time of transport.

The possibility of avoiding bridges, tunnels, viaducts, etc. on a transport route is important, as otherwise the statistical load carrying capacity of bridges or other structures must be checked and a safety analysis regarding the height and width of the cargo being transported must be carried out.

Transport of cargo of great width or length requires stopping traffic in a roundabout to remove traffic signs and warn other traffic participants in order to perform the transport without damaging or endangering any traffic participant as well as the carrier itself along with the cargo.

The authority managing the railway must carry out controls on all dimensions of cargo and a road transport vehicle in order to decide on whether it is possible to approve the oversized transport over the crossing of road and railway lines.

It influences the overall transport costs, which further affects the optimization of the transport route.

If there are many countries in transit where different transport identification plates are required by legal regulations, it is necessary to posses transport indication plates in accordance with requirements of each country in transit.

The evaluation was performed using a linguistic scale that includes quantification into fuzzy triangle numbers. Table 2 shows the evaluation of the criteria for fuzzy PIPRECIA and Inverse fuzzy PIPRECIA by the decision-maker and the values are used for further calculation.

TABLE II

EVALUATION OF THE CRITERIA BY THE DECISION-MAKER FOR THE FUZZY PIPRECIA AND INVERSE FUZZY PIPRECIA METHOD

PIPR.	C2			C3			...	C9			C10		
DM	0.400	0.500	0.667	0.500	0.667	1.000	...	1.000	1.000	1.000	0.500	0.667	1.000
PIPR-I	C10			C9				C2			C1		
DM	1.100	1.150	1.200	1.000	1.000	1.000	...	1.100	1.150	1.200	1.200	1.300	1.350

Based on the evaluation of the criteria, Equation (1), a matrix *sj* is formed. By applying Equation (2), these values are subtracted from number two. Following the rules of operations with fuzzy numbers, the matrix *kj* is obtained as follows: According to Equation (2), the value $\overline{k_1} = (1.000, 1.000, 1.000)$

$$\overline{k_2} = (2-0.667,\ 2-0.500,\ 2-0.400) = (1.333, 1.500, 1.600)$$

By applying Equation (3), the values of *qj* are obtained as follows: $\overline{q_1} = (1.000, 1.000, 1.000)$

$$\overline{q_2} = \left(\frac{1.000}{1.600}, \frac{1.000}{1.500}, \frac{1.000}{1.333}\right) = (0.625, 0.667, 0.750)$$

By applying Equation (3), the relative weights are calculated:

$$\overline{w_1} = \left(\frac{1.000}{7.750}, \frac{1.000}{3.969}, \frac{1.000}{3.264}\right) = (0.129, 0.252, 0.306)$$

$$\overline{w_2} = \left(\frac{0.625}{7.750}, \frac{0.667}{3.969}, \frac{0.750}{3.264}\right) = (0.081, 0.168, 0.230)$$

In order to determine the final weights of the criteria, it is necessary to apply Equations (5)–(9), i.e. the methodology of the inverse fuzzy PIPRECIA method. Based on the evaluation performed by the decision-maker, a matrix *sj'* is obtained.

By applying Equation (6), the values of the matrix *kj'* are obtained:

$$\overline{k_{10}}' = (1.000, 1.000, 1.000)$$

$$\overline{k_9}' = (2-1.200,\ 2-1.150,\ 2-1.100) = (0.800, 0.850, 0.900)$$

By applying Equation (7), the following values are obtained:

$$\overline{q_{10}}' = (1.000, 1.000, 1.000)$$

$$\overline{q_9}' = \left(\frac{1.000}{0.900}, \frac{1.000}{0.850}, \frac{1.000}{0.900}\right) = (1.111, 1.176, 1.250)$$

etc.

After that, it is necessary to apply Equation (8) to obtain the relative weights for the fuzzy Inverse PIPRECIA method.

$$\overline{w_{10}}' = \left(\frac{1.000}{25.244}, \frac{1.000}{19.228}, \frac{1.000}{14.973}\right) = (0.040, 0.052, 0.067)$$

$$\overline{w_9}' = \left(\frac{1.111}{25.244}, \frac{1.176}{19.228}, \frac{1.250}{14.973}\right) = (0.044, 0.061, 0.083)$$

The results of the inverse fuzzy PIPRECIA method are presented in Table 4. By applying Equation (9), the final weights of the criteria are obtained. Before applying this equation, it is necessary to defuzzify the values of the criteria obtained by applying Equations (1)–(9). *Table* shows the complete previous calculation, and the last column presents the defuzzified values of the relative weights of the criteria.

TABLE III.

CALCULATION AND RESULTS OBTAINED BY FUZZY PIPRECIA AND INVERSE FUZZY PIPRECIA

P.	sj			kj			qj			wj			DF
C1				1.000	1.000	1.000	1.000	1.000	1.000	0.129	0.252	0.306	0.241
C2	0.400	0.500	0.667	1.333	1.500	1.600	0.625	0.667	0.750	0.081	0.168	0.230	0.164
C3	0.500	0.667	1.000	1.000	1.333	1.500	0.417	0.500	0.750	0.054	0.126	0.230	0.131
C4	1.000	1.000	1.000	1.000	1.000	1.000	0.417	0.500	0.750	0.054	0.126	0.230	0.131
C5	0.500	0.667	1.000	1.000	1.333	1.500	0.278	0.375	0.750	0.036	0.094	0.230	0.107

C6	0.500	0.667	1.000	1.000	1.333	1.500	0.185	0.281	0.750	0.024	0.071	0.230	0.090
C7	0.500	0.667	1.000	1.000	1.333	1.500	0.123	0.211	0.750	0.016	0.053	0.230	0.076
C8	0.500	0.667	1.000	1.000	1.333	1.500	0.082	0.158	0.750	0.011	0.040	0.230	0.067
C9	1.000	1.000	1.000	1.000	1.000	1.000	0.082	0.158	0.750	0.011	0.040	0.230	0.067
C10	0.500	0.667	1.000	1.000	1.333	1.500	0.055	0.119	0.750	0.007	0.030	0.230	0.059
SUM							3.264	3.969	7.750				1.133
P-I	sj'			kj'			qj'			wj'			DF
C1	1.200	1.300	1.350	0.650	0.700	0.800	2.352	3.788	5.869	0.093	0.197	0.392	0.212
C2	1.100	1.150	1.200	0.800	0.850	0.900	1.882	2.651	3.815	0.075	0.138	0.255	0.147
C3	1.000	1.000	1.000	1.000	1.000	1.000	1.694	2.254	3.052	0.067	0.117	0.204	0.123
C4	1.100	1.150	1.200	0.800	0.850	0.900	1.694	2.254	3.052	0.067	0.117	0.204	0.123
C5	1.100	1.150	1.200	0.800	0.850	0.900	1.524	1.916	2.441	0.060	0.100	0.163	0.104
C6	1.100	1.150	1.200	0.800	0.850	0.900	1.372	1.628	1.953	0.054	0.085	0.130	0.087
C7	1.100	1.150	1.200	0.800	0.850	0.900	1.235	1.384	1.563	0.049	0.072	0.104	0.074
C8	1.000	1.000	1.000	1.000	1.000	1.000	1.111	1.176	1.250	0.044	0.061	0.083	0.062
C9	1.100	1.150	1.200	0.800	0.850	0.900	1.111	1.176	1.250	0.044	0.061	0.083	0.062
C10	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	0.040	0.052	0.067	0.052
SUM							14.973	19.228	25.244				1.047

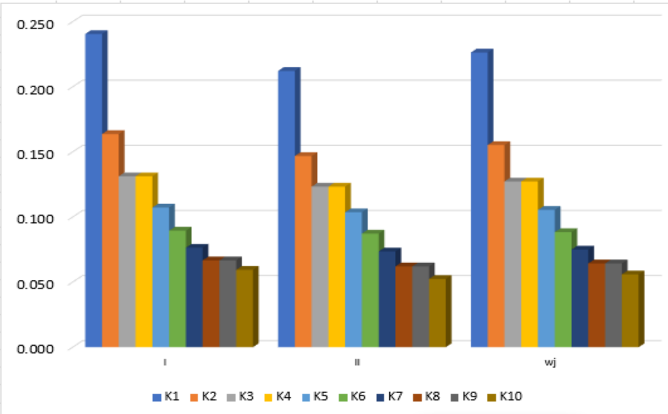

FIG 1. FINAL VALUES OF CRITERIA OBTAINED BY THE FUZZY PIPRECIA METHOD

The calculated statistical tests indicate a complete correlation of the Fuzzy PIPRECIA and the Inverse Fuzzy PIPRECIA method. Spearman's correlation coefficient is 1.000 and Pearson's correlation coefficient is 0.999. From Figure 1, we can see that C1 (Cargo dimensions) is dominantly more significant than C10 (Transport identification plates), and in the optimization of the transport route, it is dominant and dictates the choice of route. The most significant criteria for performing this type of transport is the criterion related to the dimensions of the cargo. In addition, the number of countries in transit and the cost of the required permits are criteria of paramount importance in performing this mode of transport.

IV. CONCLUSION

The organization and realization of road transport of oversized cargo is a complex activity and requires the expertise and good organizational skills of the person who realizes it. This mode of transport is much more complex than road transport of standard-size cargo since, due to the over-sized cargo, the transport itself endangers other traffic participants to some extent, causes congestion and sometimes requires the complete closure of a certain part of the route used for transport. The most significant criteria for performing this type of transport is the criterion related to the dimensions of cargo. In addition, the number of countries in transit and the cost of the required permits are the criteria of paramount importance in carrying out this mode of transport. A total of ten criteria were considered and their exact significance values were determined using the Fuzzy PIPRECIA method. As coefficients of validity, statistical tests were applied: Spearman's correlation coefficient of 1.000, and Pearson's correlation coefficient of 0.999.

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