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DETERMINING CRITERIA SIGNIFICANCE IN SELECTING REACH STACKERS BY APPLYING THE FUZZY PIPRECIA METHOD

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Abstract: *Handling facilities play the essential role in the work of the complete transport chain, especially when performing operations at ports or container terminals. In this paper, a list of 15 criteria for the evaluation and selection of a reach stacker for the container terminal in Belgrade were formed in a double hierarchical structure, with an equal number of the elements. There are three main groups of the criteria: economic, technological and technical, each containing a total of the five sub-criteria. The survey involved 15 decision-makers, who evaluated all the criteria. To determine the individual significance of each criterion, the Fuzzy PIvot Pairwise RElative Criteria Importance Assessment (i.e. fuzzy PIPRECIA) method was applied. The results showed that the most essential criteria belong to the technology group.*

Key words: *reach stacker, container terminal, Fuzzy PIPRECIA*

1. Introduction

"Railway Integral Transport" (RIT) Limited Liability Company (*ŽIT d.o.o.*) Belgrade was founded in 1983 as a subsidiary of ŽELEZNICE SRBIJE (JSC Serbian Railways), when a container terminal was built in the area of the former Belgrade Central Railway Station. During 2016, the RIT terminal has been relocated to the new location at the Belgrade Marshalling Yard. One of the Company's primary activities is the provision of terminal services in the international container transportation of cargo, such as the handling, loading and containerization of goods, and the transportation of loaded and empty containers. Due to limited space, the maximum dispatch and distribution capacity of the terminal is about 15,000 intermodal units (containers) annually

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The main technological process of the transhipment of containers from the rail mode to the road transportation mode and *vice versa*, as well as the storage of loaded and empty containers in the area of the terminal itself, is carried out by the reach-stacker-type container handlers Belloti (the load capacity being 45 t) and Kalmar (the load capacity being 42 t). It should be noted that both reach stackers are over 20 years old.

In order to perform the primary operations at the terminal, two tracks of a length of 250 m and a shunting track for shunting units of 250 m in length are available. At the terminal, there are also three tracks in the shunting and dispatching groups of the Belgrade Marshalling Yard used by cranes and for the movements of trains from the terminal, as well as the storage of spare wagons.

The construction of the Phase 2 of the container terminal, i.e. the expansion to the fifth marshalling group of the Belgrade Marshalling Yard, would enable the conditions for the RIT Terminal to process over 80,000 containers per year, or about 120,000 TEU units. According to the analysis conducted in the period from 2016 to 2019, the RIT terminal processes about 40% of all the containers arriving by rail, which is about 15% of all the containers arriving in Serbia. Of this, about 90% of the containers processed by the RIT Terminal come from the Rijeka – Belgrade–Rijeka line (three trains running on that route weekly). The completion of the Phase 1 of the new terminal is expected to introduce the fourth pair of trains, and the fifth pair of trains in the year 2021.

This paper aims to evaluate and determine the significance of the criteria by which the reach stacker selection will be made. All of the above data indicate the need to expand the range of the handling equipment, for which reason buying at least one reach stacker is a necessity.

The rest of the paper is structured into several chapters. In Chapter Two, a brief description of the volume of business at the container terminal and some forecasts for this year and for next year are given. In Chapter Three, the Fuzzy PIPRECIA method applied in the paper in order to determine the significance of the criteria is presented in detail. Chapter Fur of the paper deals with a case study, detailing the input parameters and the calculation procedure. In Chapter Five, the conclusion concerning the continuation of this research is presented.

2. A Short Description of the Extent of Work for the Terminal

Taking into account the expected increase in the scope of work (Figure 1), it is necessary that new reach stackers should be purchased, since the installation of a bridge crane for the transhipment of intermodal units is not foreseen in the first phase of the construction and operation of the terminal. Given the state of the existing two reach stackers, it is necessary to procure two new ones so as to ensure the reliability and continuity of the performance of the basic technological operations at the terminal.

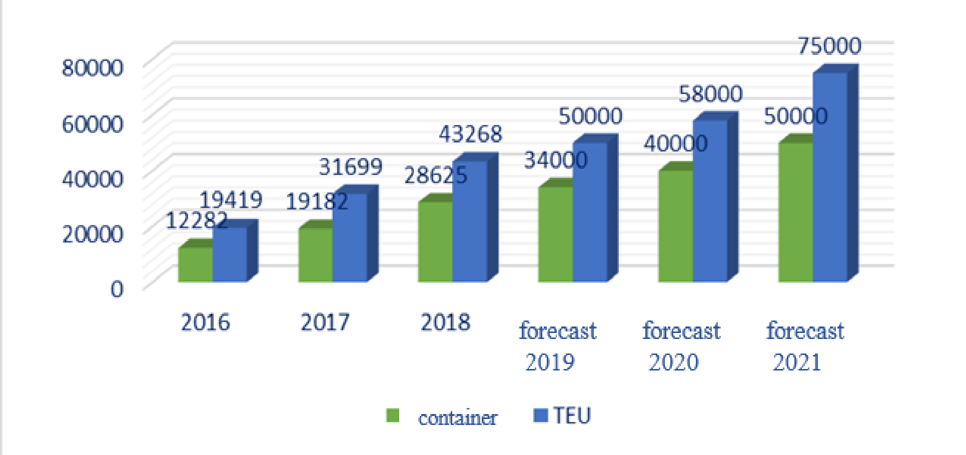

Figure 1. The achieved and the planned scopes of work at the RIT Terminal

By constructing a large logistics centre (Figure 2), which is planned to be operated in the Makiš Field, the workload might also double.

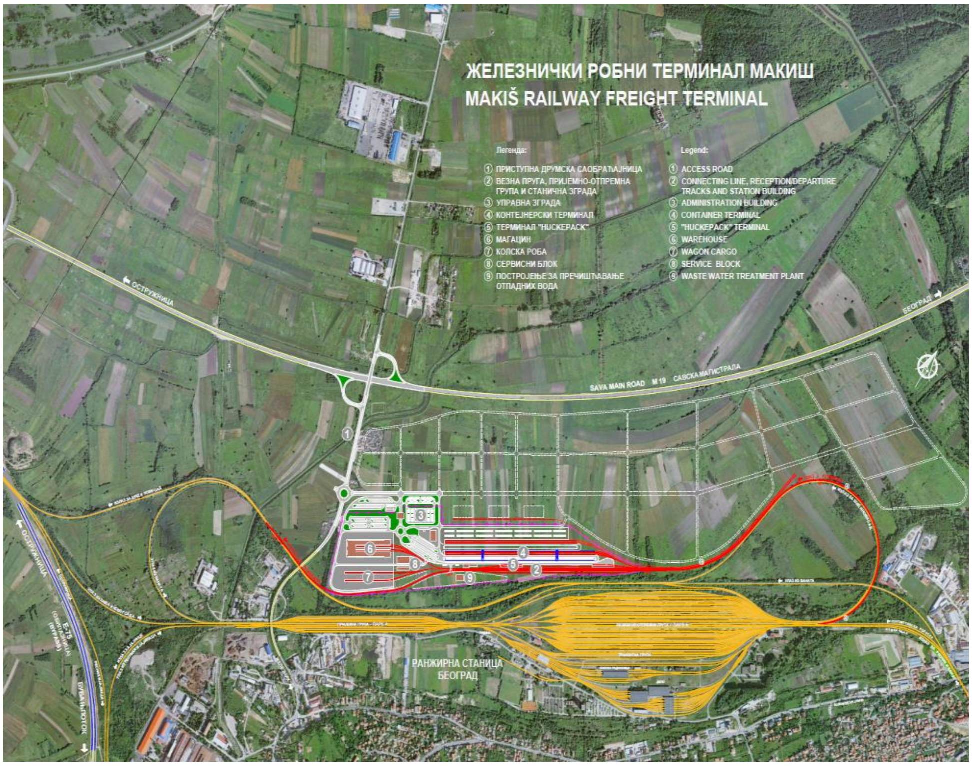

Figure 2. The plan for the construction of the new RIT Terminal

3. Methods

3.1. Operations on fuzzy numbers

A fuzzy number $\overline{A}$ on R to be a TFN if its membership function $\mu_{\overline{A}}(x)$: R→[0,1] is equal to the following Equation (1):

$$\mu_{\overline{A}}(x) = \begin{cases} \frac{x-l}{m-l} & l \le x \le m \\ \frac{u-x}{u-m} & m \le x \le u \\ 0 & otherwise \end{cases} \tag{1}$$

From equation (1), *l* and *u* denote the lower and the upper bounds of the fuzzy number $\overline{A}$, and *m* is the modal value for $\overline{A}$. The TFN can be denoted by $\overline{A} = (l, m, u)$.

The operational laws of TFN $\overline{A} = (l_1, m_1, u_1)$ and $\overline{A} = (l_2, m_2, u_2)$ are displayed as the following equations.

Addition: $\overline{A} = (l_1, m_1, u_1)$

$$\overline{A_1} + \overline{A_2} = (l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{2}$$

Multiplication:

$$\overline{A_1} \times \overline{A_2} = (l_1, m_1, u_1) \times (l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \tag{3}$$

Subtraction:

$$\overline{A_1} - \overline{A_2} = (l_1, m_1, u_1) - (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \tag{4}$$

Division:

$$\frac{\overline{A_1}}{\overline{A_2}} = \frac{(l_1, m_1, u_1)}{(l_2, m_2, u_2)} = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2} \right) \tag{5}$$

Reciprocal:

$$\overline{A_1}^{-1} = (l_1, m_1, u_1)^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1} \right) \tag{6}$$

3.2. The Fuzzy PIvot Pairwise RElative Criteria Importance Assessment (i.e. fuzzy PIPRECIA) method

The PIPRECIA method in a crisp form has been developed in (Stanujkić et al., 2017). The fundamental advantage of the PIPRECIA method lies in the fact that it allows criteria to be evaluated without their prior sorting by importance, which is not the case with the fuzzy SWARA method. Today, the largest number of the problems of multicriteria decision-making are solved by applying group decision-making. In such cases, especially with an increase in the number of the decision-makers involved in the fuzzy model, PIPRECIA achieves its advantages. The fuzzy PIPRECIA method consists of the 11 steps that are shown below (Stević et al., 2018; Đalić et al. 2020).

Step 1. Forming the required benchmarking set of criteria and forming a decision-making team. Sorting the criteria according to the marks from the first to the last, which means that they need to be sorted unclassified. Therefore, their significance does not play any role at all in this step.

Step 2. In order to determine the relative importance of the criteria, each decision-maker individually evaluates the pre-sorted criteria by starting from the second criterion, as in Equation (7).

$$\overline{s_j^r} = \begin{cases} > \bar{1} & if \quad C_j > C_{j-1} \\ = \bar{1} & if \quad C_j = C_{j-1} \\ < \bar{1} & if \quad C_j < C_{j-1} \end{cases} \tag{7}$$

where $\overline{s_j^r}$ denotes the criteria assessment made by the decision-maker *r.*

In order to obtain a matrix $\overline{s_j}$, it is necessary to perform the averaging of the matrix $\overline{s_j^r}$ by using the geometric mean. The decision-makers evaluate the criteria by applying the scales defined in Tables 1 and 2.

The second and third steps of the developed method are closely dependent on one another, and new fuzzy scales are defined in order to meet the second and third steps of the fuzzy PIPRECIA method. If the facts that the nature of fuzzy number operations and that, in the third step, the values $\overline{s_j}$ are subtracted from number two are taken into consideration, then it is required that these scales be defined. It is important to note that, by defining these scales, the appearance of number two is avoided, which might cause difficulties and lead to wrong results in the case of calculation. Therefore, no other previously developed fuzzy scales, but only the scales defined in this paper, may be used.

Table 1. The Criteria Assessment Scale 1-2

			l	m	u	DFV
An almost equal value	**Scale 1-2**	1	1.000	1.000	1.050	1.008
Slightly more significant		2	1.100	1.150	1.200	1.150
Moderately more significant		3	1.200	1.300	1.350	1.292
More significant		4	1.300	1.450	1.500	1.433
Much more significant		5	1.400	1.600	1.650	1.575
Dominantly more significant		6	1.500	1.750	1.800	1.717
Absolutely more significant		7	1.600	1.900	1.950	1.858

When a criterion has greater importance concerning the previous one, an assessment is made by using the above scale (Table 1). In order to make it easier for the decision-makers to evaluate the criteria, the table shows the defuzzified value (DFV) for each comparison.

Table 2. The Criteria Assessment Scale 0-1

	l	m	u	DFV	
Scale 0-1	0.667	1.000	1.000	0.944	Slightly less significant
	0.500	0.667	1.000	0.694	Moderately less significant
	0.400	0.500	0.667	0.511	Less significant
	0.333	0.400	0.500	0.406	Really less significant
	0.286	0.333	0.400	0.337	Much less significant
	0.250	0.286	0.333	0.288	Dominantly less significant
	0.222	0.250	0.286	0.251	Absolutely less significant

When a criterion is of less importance compared to the previous one, an assessment is made by using the above scale (Table 2).

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

$$\overline{k_j} = \begin{cases} = \bar{1} & if \quad j = 1 \\ 2 - \overline{s_j} & if \quad j > 1 \end{cases} \tag{8}$$

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

$$\overline{q_j} = \begin{cases} \underline{= \bar{1}} & if \quad j = 1 \\ \dfrac{q_{j-1}}{\overline{k_j}} & if \quad j > 1 \end{cases} \tag{9}$$

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

$$\overline{w_j} = \frac{\overline{q_j}}{\sum_{j=1}^{n} \overline{q_j}} \tag{10}$$

In the following steps, the inverse methodology of the fuzzy PIPRECIA method needs to be applied.

Step 6. Performing the assessment of the above-defined applied scale, this time starting from the penultimate criterion.

$$\overline{s_j^r}' = \begin{cases} > \bar{1} & if \quad C_j > C_{j+1} \\ = \bar{1} & if \quad C_j = C_{j+1} \\ < \bar{1} & if \quad C_j < C_{j+1} \end{cases} \tag{11}$$

where $\overline{s_j^r}'$ denotes the criteria assessment made by the decision-maker *r.*

It is, again, necessary to perform the averaging of the matrix $\overline{s_j^r}$ by applying a geometric mean.

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

$$\overline{k_j}' = \begin{cases} = \bar{1} & if \quad j = n \\ 2 - \overline{s_j}' & if \quad j > n \end{cases} \tag{12}$$

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

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

$$\overline{q_j}' = \begin{cases} = \bar{1} & if \quad j = n \\ \dfrac{\overline{q_{j+1}}'}{\overline{k_j}'} & if \quad j > n \end{cases} \tag{13}$$

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

$$\overline{w_j}' = \frac{\overline{q_j}'}{\sum_{j=1}^{n} \overline{q_j}'} \tag{14}$$

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 $\overline{w_j}'$ as follows:

$$\overline{w_j}'' = \frac{1}{2}(w_j + w_j') \tag{15}$$

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

4. Determining Criteria Significance When Selecting a Reach Stacker by Applying the Fuzzy PIPRECIA Method

For the evaluation and selection of a reach stacker, a total of the 15 criteria formed into the two levels of the hierarchical structure were applied. As it is essential to obtain objective results, the hierarchical structure should be balanced. This means that each major criterion has an equal number of criteria. This problem was to some extent addressed in (Markovic et al., 2020), where it was found that it was necessary to form a hierarchical structure with an equal number of the elements at the lower levels of the hierarchy. Therefore, this paper approached the formation of a group of criteria in this manner, with the three main criteria inclusive of the five sub-criteria in each group.

CE - Economic:

CE1 – The cost

CE2 – The supply of spare parts

CE3 – Fuel consumption when manipulating one hour of operation

CE4 – The tire type and price

CE5 – Maintenance costs

CTH - Technological:

CTH1 – Life expectancy

CTH2 – The capacity

CTH3 – The number of the TEUs processed as per unit of time,

CTH4 – Manipulative abilities,

CTH5 – The lift height

CTR - Technical Solutions:

CTR1 – The engine type

CTR2 – The gross mass (the net mass)

CTR3 – The engine power

CTR4 – The lift speed

CTR5 – The driving speed

As already pointed out, the three main criteria are economic (CE), technological (CTH) and applied technical solutions (CTR). These three criteria cover the whole aspect of the operation of a reach stacker, i.e. the performance of the necessary technological activities at the terminal.

The first set of the economic criteria, which describe the financial and economic aspects of the acquisition and exploitation of a reach stacker, include the following sub-criteria:

- The purchase price on the market (CE1) is expressed as a numerical value. The goal of every terminal operator is to achieve the top-notch performance of a reach stacker for minimum investment. CE1 → min.
- The supply of spare parts (CE2) is essential for the reliable operation of a reach stacker and the quality maintenance system. This parameter is represented as a linguistic variable, and the same can be wrong, good, very good or excellent. CE2 → max.
- Manipulation fuel consumption (CE3) is expressed as per hour of operation. This parameter directly affects the exploitation cost. CE3 → min.
- The tire type (CE4) directly influences its price, and as such is classified into this parameter group. The purchase and replacement of tires are a significant source of the operation cost. CE4 → min.
- Maintenance costs, if the result of the technological process of the maintenance process can significantly affect the choice of a type of a reach stacker. They cover all the aspects of the maintenance process (both current and investment) and are expressed every year. CE5 → min

The second group consists of the technological criteria, which describe the technological parameters and characteristics of a reach stacker, the sub-criteria being as follows:

- The expected service life (CTH1) is expressed as a numerical value. The manufacturer proposes the expected service life in quality maintenance conditions, but the value of this parameter is also determined by customers' experience at the terminals. CTH1 → max.
- The reach stacker capacity (CTH2), i.e. the maximum payload declared by the manufacturer, is essential for operators, as it may be a limiting factor in processing certain types and intermodal units and their loads. CTH2 → max.
- The number of the TEUs processed as per unit of time (CTH3) represents the output, i.e. the processing power of a reach stacker, thus determining the processing power and capacity of the terminal. CTH3 → max.
- Manipulative abilities (CTH4) are an essential parameter for the operation of a reach stacker, especially so in confined spaces. This parameter is presented as a linguistic variable, and the same can be weak, satisfactory, good and excellent. CTH4 → max.
- The lift height (CTH5) is a parameter declared by the manufacturer and expressed in meters or in the number of the containers that can stack the height for the first and second stack orders. CTH45 → max.

The third group is represented by the applied technical solutions in a reach stacker, namely including the following sub-criteria:

- The motor type (CTR1) is expressed as a linguistic value. Usually, diesel engines are the EURO3, EURO4 or EURO5 type. The engine type affects fuel consumption, thus also making an influence on the environment. The negative impact of this parameter by engine type is high, medium and low, while the lowest negative environmental impact is desirable. CTR1 → min.
- The reach stacker gross mass (CTR2) is a parameter declared by the manufacturer. It is desirable that this parameter should be as high as possible for the purpose of the stability of operation, i.e. for the purpose of lifting heavy intermodal units. CTR2 → max.
- The engine power (CTR3) is a parameter declared by the manufacturer. It is desirable for this parameter to be as high as possible, because of the reliability of the work, i.e. the low load of a reach stacker. CTR3 → max.
- The lifting speed (CTR4) is a parameter declared by the manufacturer. This parameter is expressed in m/s and is given for the following lifting conditions: empty/full. In the model, the value of lifting a full container is considered. CTR4 → max.
- The driving speed (CTR5) is a parameter declared by the manufacturer. This parameter is expressed in km/h and is given for the conditions of the movement of a reach stacker with empty/full intermodal units. In the model, the value of the maximum driving speed with full intermodal units is considered. CTR5 → max. CTR5 – The travel speed (km/h) empty/full

The evaluation of the criteria was performed by using a linguistic scale involving quantification into fuzzy triangle numbers. Table 3 shows the evaluation of the criteria for fuzzy PIPRECIA and inverse fuzzy PIPRECIA carried out by the decision-maker.

There are a total of 15 decision-makers, whose structure is viewed from the following three aspects:

- the profession, i.e. what activity (function) the expert performs,
- the expert’s competence field,
- the expert’s work experience.

When the expert’s occupation is in question (Figure 3), three occupational groups are covered. The largest number of the experts, i.e. 47% of them in total, belong to the group of traffic and mechanical engineering university professors, only to be followed by those employed in the economic sector (practitioners), accounting for 33%, and finally, the employed in design institutions in the transportation field, accounting for 20%.

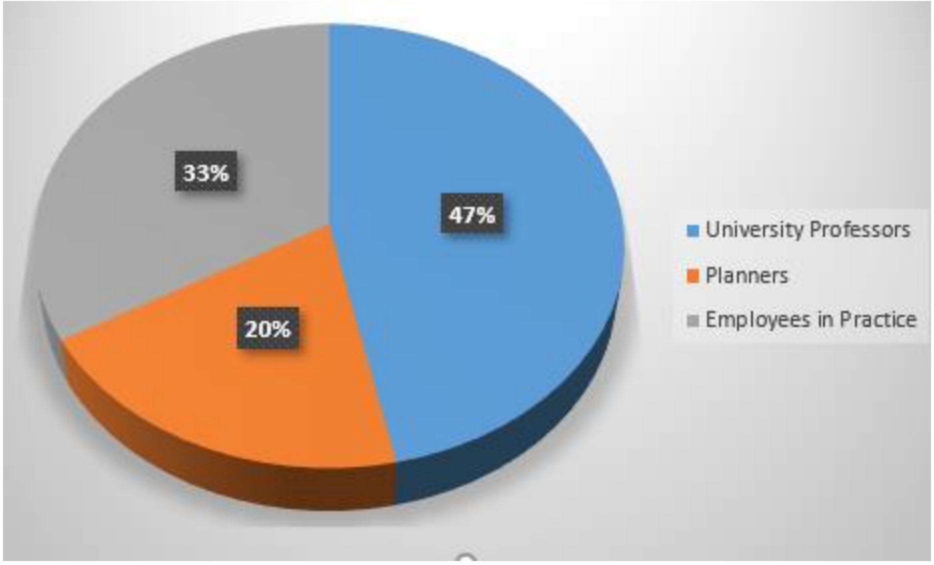

Figure 3. The structure of the experts by occupation

The structure of the experts in the competence field is shown in Figure 4. The survey included 47% of the experts in railway transport, 20% of the experts employed in logistics and mechanical engineering, and 13% of the experts working in road transportation.

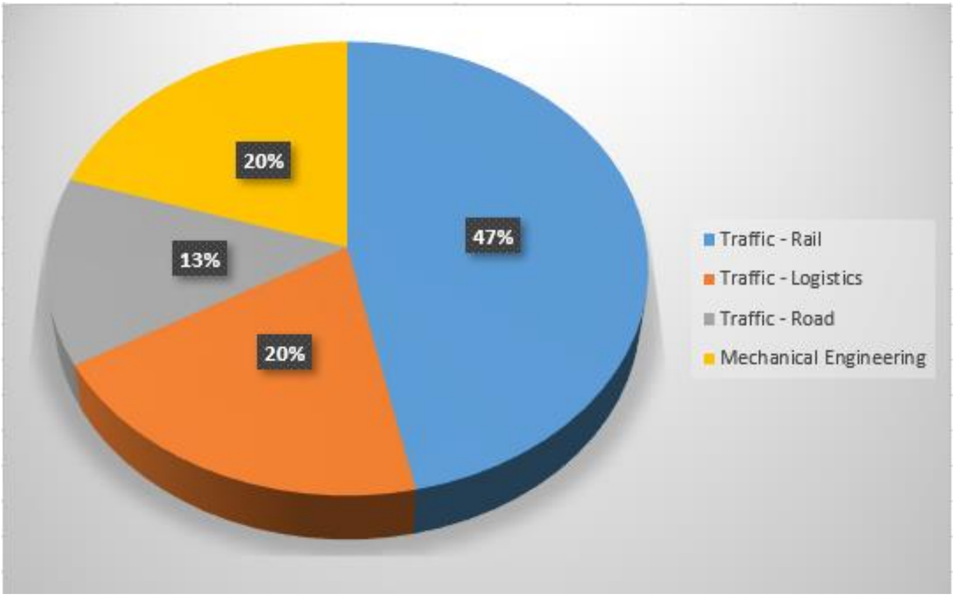

***Figure 4**. The structure of the experts by the competence field*

The last analysis refers to the experience (the experts' work experience) and is shown in Figure 5. The largest number of the experts included in the survey, i.e. 40% of them, have a work experience ranging from 21 to 30 years; a total of 27% have a work experience ranging from 11 to 20 years, and 20% of the experts have a work experience exceeding 30 years. The smallest number of the experts, actually 13% of them, have a work experience of less than ten years.

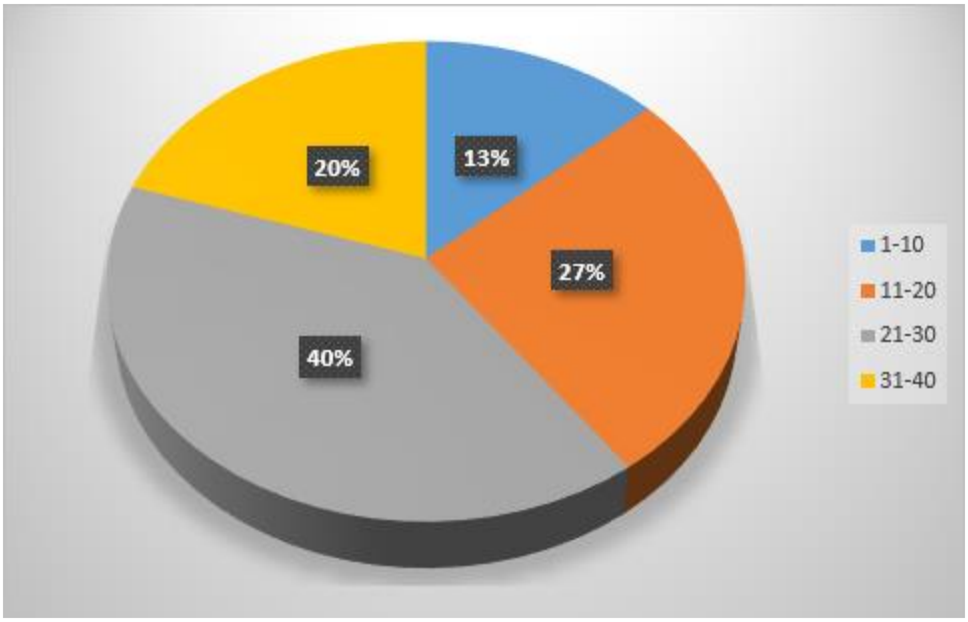

Figure 5. The structure of the experts by work experience

Table 3. The criteria ratings for fuzzy PIPRECIA and inverse fuzzy PIPRECIA for the main criteria

PIPR.		C2			C3		PIPR-I		C2			C1	
DM1	1.200	1.300	1.350	0.250	0.286	0.333	DM1	1.500	1.750	1.800	0.400	0.500	0.667
DM2	1.000	1.000	1.000	1.000	1.000	1.000	DM2	1.000	1.000	1.000	1.000	1.000	1.000
DM3	1.200	1.300	1.350	0.286	0.333	0.400	DM3	1.400	1.600	1.650	0.400	0.500	0.667
DM4	1.000	1.000	1.000	1.200	1.300	1.350	DM4	0.400	0.500	0.667	1.000	1.000	1.000
DM5	1.200	1.300	1.350	0.286	0.333	0.400	DM5	1.400	1.600	1.650	0.400	0.500	0.667
DM6	1.000	1.000	1.000	0.400	0.500	0.667	DM6	1.200	1.300	1.350	1.000	1.000	1.000
DM7	1.400	1.600	1.650	1.000	1.000	1.000	DM7	1.000	1.000	1.000	0.286	0.333	0.400
DM8	1.300	1.450	1.500	1.100	1.150	1.200	DM8	0.500	0.667	1.000	0.333	0.400	0.500
DM9	1.300	1.450	1.500	1.000	1.000	1.000	DM9	1.000	1.000	1.000	0.333	0.400	0.500
DM10	1.000	1.000	1.000	1.000	1.000	1.000	DM10	1.000	1.000	1.000	1.000	1.000	1.000
DM11	1.100	1.150	1.200	0.250	0.286	0.333	DM11	1.500	1.750	1.800	0.500	0.667	1.000
DM12	1.200	1.300	1.350	0.500	0.667	1.000	DM12	1.100	1.150	1.200	0.400	0.500	0.667
DM13	1.500	1.750	1.800	1.000	1.000	1.000	DM13	1.000	1.000	1.000	0.250	0.286	0.333
DM14	1.100	1.150	1.200	1.000	1.000	1.000	DM14	1.000	1.000	1.000	0.500	0.667	1.000
DM15	1.300	1.450	1.500	0.286	0.333	0.400	DM15	1.400	1.600	1.650	0.333	0.400	0.500
AV	1.187	1.280	1.317	0.704	0.746	0.806	AV	1.093	1.194	1.251	0.542	0.610	0.727

Note: As has been shown in the method steps, it ranges from the second criterion for the fuzzy PIPRECIA method, and the penultimate criterion for the inverse fuzzy PIPRECIA method, i.e. C2 in the first column and also C2 in the third column.

Based on the evaluation of the criteria and Equation (7), the matrix s_j is formed.

$$s_j = \begin{bmatrix} & \cdots & \\ 1.187 & 1.280 & 1.317 \\ 0.704 & 0.746 & 0.806 \end{bmatrix}$$

Applying Equation (8), these values are subtracted from number two. Following the rules of operations with the fuzzy numbers of the k_j matrices, the following is obtained:

$$k_j = \begin{bmatrix} 1.000 & 1.000 & 1.000 \\ 0.683 & 0.720 & 0.813 \\ 1.194 & 1.254 & 1.296 \end{bmatrix}$$

According to Equation (8), the value $\overline{k_1} = (1.000, 1.000, 1.000)$

$$\overline{k_2} = (2 - 1.317, 2 - 0.280, 2 - 1.187) = (0.683, 0.720, 0.813)$$

Applying Equation (9) to the value of q_j

$$q_j = \begin{bmatrix} 1.000 & 1.000 & 1.000 \\ 1.230 & 1.389 & 1.463 \\ 0.949 & 1.107 & 1.225 \end{bmatrix}$$

the following is obtained:

$$\overline{q_1} = (1.000, 1.000, 1.000)$$

$$\overline{q_2} = \left(\frac{1.000}{0.813}, \frac{1.000}{0.720}, \frac{1.000}{0.683}\right) = (1.230, 1.389, 1.463)$$

After that, the values for q_j are summed up and the following are obtained: 3.178; 3.496 and 3.689, respectively.

Applying Equation (10), the relative weights are calculated in the following manner:

$$\overline{w_1} = \left(\frac{1.000}{3.689}, \frac{1.000}{3.496}, \frac{1.000}{3.178}\right) = (0.271, 0.286, 0.315)$$

$$\overline{w_j} = \begin{bmatrix} 0.271 & 0.286 & 0.315 \\ 0.333 & 0.397 & 0.460 \\ 0.257 & 0.317 & 0.386 \end{bmatrix}$$

Then, the following equation must be applied: $df_{crisp} = \frac{l + 4m + u}{6}$ so as to get crisp value: 0.288; 0.397 and 0.318

In order to determine the final weights of the criteria, it is necessary to apply Equations (11)-(15) and the methodology of the inverse fuzzy PIPRECIA method. The matrix sj' was obtained from the decision-maker.

$$s_j' = \begin{bmatrix} 0.542 & 0.610 & 0.727 \\ 1.093 & 1.194 & 1.251 \end{bmatrix}$$

Applying Equation (12), the values of the matrix kj' are obtained as follows:

$$k_j' = \begin{bmatrix} 1.273 & 1.390 & 1.458 \\ 0.749 & 0.806 & 0.907 \\ 1.000 & 1.000 & 1.000 \end{bmatrix}$$

$\overline{k_3}' = (1.000, 1.000, 1.000)$

$\overline{k_2}' = (2 - 1.251, 2 - 1.194, 2 - 1.093) = (0.749, 0.806, 0.907)$ itd.

Applying Equation (13), the following values are obtained:

$$q_j = \begin{bmatrix} 0,757 & 0,893 & 1,049 \\ 1.103 & 1,241 & 1,335 \\ 1,000 & 1,000 & 1,000 \end{bmatrix}$$

$\overline{q_3}' = (1.000, 1.000, 1.000)$

$\overline{q_2}' = \left(\frac{1.000}{0.907}, \frac{1.000}{0.806}, \frac{1.000}{0.749}\right) = (1.103, 1.241, 1.335)$ itd.

After that, the values for q_j are summed up and the values obtained are as follows: 3.178, 3.496 and 3.689, respectively.

After that, it is necessary to apply Equation (14) so as to obtain the relative weights for the fuzzy inverse PIPRECIA method.

$$\overline{w_j}' = \begin{bmatrix} 0.224 & 0.285 & 0.367 \\ 0.326 & 0.396 & 0.467 \\ 0.296 & 0.319 & 0.350 \end{bmatrix}$$

$\overline{w_3}' = \left(\frac{1.000}{3.689}, \frac{1.000}{3.496}, \frac{1.000}{3.178}\right) = (0.296, 0.319, 0.350)$

Then, the equation $df_{crisp} = \frac{l + 4m + u}{6}$ must be applied in order to obtain the crisp values 0.288, 0.396 and 0.320, after which the obtained w_j values are aggregated and the final weighted values for the main criteria are obtained: 0.288, 0.397 and 0.319.

The results of the methodology applied are presented in Table 4.

Table 4 shows the complete previous calculation, and the last column shows the deficient values of the relative weights of the criteria.

Table 4. The calculation of the weights and values of the main criteria

P		sj			kj			qj			wj		DF	Rang
c1				1.000	1.000	1.000	1.000	1.000	1.000	0.271	0.286	0.315	0.288	3
c2	1.187	1.280	1.317	0.683	0.720	0.813	1.230	1.389	1.463	0.333	0.397	0.460	0.397	1
c3	0.704	0.746	0.806	1.194	1.254	1.296	0.949	1.107	1.225	0.257	0.317	0.386	0.318	2
SUM							3.178	3.496	3.689					
P – I		sj			kj			qj			wj			
c1	0.542	0.610	0.727	1.273	1.390	1.458	0.757	0.893	1.049	0.224	0.285	0.367	0.288	3
c2	1.093	1.194	1.251	0.749	0.806	0.907	1.103	1.241	1.335	0.326	0.396	0.467	0.396	1
c3				1.000	1.000	1.000	1.000	1.000	1.000	0.296	0.319	0.350	0.320	2
SUM							2.860	3.135	3.384					

The Spearman correlation coefficient (Erceg et al., 2019) for the obtained ranks is 1.00, which means that these ranks are in absolute correlation. The Pearson correlation coefficient (Stevic et al., 2018) was also calculated for the criterion weights of 0.985.

Table 5 presents the final weight results by using the fuzzy PIPRECIA method.

As can be seen from the application of the complete methodology and the results obtained in Table 5, the technological criteria group represents the most important group for the selection of a reach stacker, because the three priority criteria belong to this group: CTH4 – manipulative abilities, CTH5 – the lift height and CTH3 – the number of the processed TEU in the unit of time. Of the economic criteria group, the most important is CE4 – the tire and price types, which ranks fourth in the overall ranking.

Table 5. The criteria ranking by applying the FUZZY PIPRECIA method

ECONOMIC	Local value	Global value	Rank
CE1	0.184	0.043	19
CE2	0.187	0.049	17
CE3	0.228	0.061	13
CE4	0.152	0.073	4
CE5	0.281	0.071	7
TECHNOLOGICAL			
CTH1	0.150	0.059	15
CTH2	0.171	0.068	10
CTH3	0.211	0.084	3
CTH4	0.253	0.100	1
CTH5	0.246	0.098	2
TECHNICAL			
CTR1	0.228	0.073	6
CTR2	0.185	0.059	16
CTR3	0.214	0.068	9
CTR4	0.206	0.066	11
CTR5	0.195	0.062	12

5. Conclusion

In this paper, the fuzzy PIPRECIA method for the determination of the significance of the reach stacker selection criteria for a rail container terminal is presented. A total of 15 criteria were considered, those criteria being divided into the three groups: economic, technological and technical. The survey involved 15 decision-makers of different structures, which is presented in detail in the paper. The results show that the most essential criteria belong to the technology group. Continued research would imply drafting a list of potential reach stackers, collecting quantitative and qualitative data and evaluating those data. Some of the classical MCDM methods can be applied for evaluation and selection (Stevic et al., 2020; Zavadskas and Turskis, 2010; Pamučar and Ćirović) individually or in combination with uncertainty theories (Stojić et al., 2018; Stanujkić and Karabašević, 2018; Stevic et al., 2019; Kahraman et al., 2017).

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