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# Selecting a location for establishing a rail-road intermodal terminal by using a hybrid SWOT/MCDM model

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# Selecting a location for establishing a rail-road intermodal terminal by using a hybrid SWOT/MCDM model

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Abstract. The study proposes a methodology based on the combination of Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis and Multi-Criteria Decision Making (MCDM) methods for selecting the most appropriate location for establishing an intermodal terminal. Analytic Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) are the MCDM methods used in the paper. The methodology contains four steps. In the first step we determine the alternatives variants of the location of intermodal terminal. In the second step the SWOT analysis have been applied to identify strengths, weaknesses, opportunities, and threats related to the surveyed system. The sub-criteria for each SWOT group have been defined. A total of 33 criteria are included in the study. Third step includes determination of weights of main criteria and sub-criteria by applying AHP method. The results of weights given in this step are used in the four step to ranking the alternative variants of the intermodal terminal location by using PROMETHEE method. The methodology has been approved for choosing the location of intermodal terminal in the city of Ruse. Five alternative locations of intermodal terminal have been studied. The results show that main importance of SWOT group has the strengths group criteria (0.471). It was found that the internal factors including the strengths and weaknesses have more important compared to the external factors including the opportunities and threats when studying the location of intermodal terminal. It was found that the main importance of all sub-criteria have the quantity of manipulated containers (9%), connectivity to road infrastructure (6%), rail connection with a port (5%) and average useful length of railway tracks used for loading/unloading activities (5%). The study shows that location that is situated in the place of the suspended Ruse-East railway yard is the best alternative for intermodal terminal location.

#### 1. Introduction

The intermodal transport is a key element of the freight transport system. The essence of the intermodal transport is the organized carriage of a large number of intermodal transport units by rail, inland waterways and/or sea transport over long distances. The first and the last stage of the intermodal transport chains being carried out by road transport that has an auxiliary role. It is a possibility to being used and combined the competitive advantages of different modes of transport to achieve a cost-effective and an environment-friendly intermodal transport chain that is accomplished just in time.

An important efficiency factor of the intermodal transport system is the location of intermodal terminals. The terminals are the main element of this system. It is necessary to set up a network of interoperable intermodal terminals [1, 2] to achieve an efficient, competitive and sustainable intermodal transport system. The intermodal transport development is accompanied by research

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studies directed to different fields of transport science as route selection [3], cost analysis [4], decision-making [5], intermodal terminal location problem [1, 6, 7, 8], transport policy [2], etc.

Selecting a location for establishing a logistic center, incl. an intermodal terminal, depends of different conditions. To take into account the diversity of the conditions in selecting a location for establishing an intermodal terminal different decision-making techniques are used [5]. Widely used methods of selecting a location are MCDM models. Their use is mainly in decision making models when it is necessary to make an optimal decision among multiple alternatives taking into account different, often conflicting criteria [9]. The variety of the criteria allows to be classified into different groups and subgroups. A literature review of the criteria and the sub-criteria used in selecting a location of establishing intermodal terminals and logistic centers has been made in [5, 10, 11]. Three groups of approaches for solving intermodal terminal location problems have been defined in [10]. The authors have written the MCDM methods are considerably less used methods for solving location problems [10].

Widespread used decision criteria for selection of a logistic center location [5] or an intermodal terminal [10] are connected with: costs, natural resources, proximity to transport infrastructure, land use, size of land and suitability to enlargement, proximity to industrial zones, macro-economic criteria, environmental impact, etc. The most commonly used by frequency criteria for selection of a location are: cost-related criteria [10, 12, 13], connectivity and accessibility to railway network, roads and highways or port infrastructure [10, 14], availability of land and expansion possibilities [13, 15], capabilities of environment, environmental impacts [10, 14], macroeconomic indicators, accessibility to labor and distance to residential areas [14], utilities, transportation, logistics, social or investment attractiveness and benefits [12, 14], etc. All these criteria can be summarized in the following groups: location, environmental impact, technical criteria, economic and social factors, etc. The economic criteria are the most frequency used type criteria for decision making analysis in the logistics. The intermodal actors who used cost related criteria in decision making are intensive users of intermodal services in comparison of actors who used both types of criteria - quality and cost criteria [16]. The models consist a multiple criteria with different coefficients of importance their weights is necessary to be determined. One of the most commonly used method for determination of the criteria weights' is AHP method [17, 18].

The variety of the most preferred MCDM techniques used for selection a location for establishing a logistic center have been described in literature [5, 11, 19]. In some research papers a combination between different MCDM methods have been proposed. In [20] a conceptual model based on a combination of the fuzzy-analytical hierarchy process and artificial neural networks methods have been proposed by author to select the most appropriate location. In [21] authors have proposed a method for selecting of a logistic strategy by cooperating of SWOT analysis and AHP model. In addition, a combination of both methods - SWOT analysis and AHP has been used in other research fields and decision-making activities [22, 23, 24]. It can be summarized that the multi-criteria analysis is a suitable method for studying the location of a logistic scenter.

This paper aims to propose an approach for selection the most appropriate location for the intermodal terminal by using multi-criteria methods and taking into account multiple factors relevant for transport. The object of the research is the intermodal terminal in the city of Ruse.

#### 2. Methodology

This paper proposes a new hybrid methodology based on the combination of SWOT analysis, AHP and PROMETHEE methods for selecting the most appropriate location for establishing a rail-road intermodal terminal.

The methodology includes the following steps:

• Step 1: Selection of alternatives of the location of intermodal terminal.

• Step 2: Definition of quantitative and qualitative criteria for the assessment of alternatives. This step of the model uses SWOT analysis as strategic planning technique to identify strengths, weaknesses, opportunities, and threats related to investigated system. It also groups these main criteria

into two categories: internal factors including the strengths and weaknesses and external factors including the opportunities and threats presented by the environment external to the investigated system. The sub-criteria for each main criterion of SWOT group are defined for the evaluation of the alternatives. In this research the following sub-criteria are proposed:

➤ Internal strengths (IS): S1 - Appropriate terrain conditions, coef.; S2 - Part of the main TEN-T network, coef.; S3 - State land ownership, coef.; S4 - Location near the urban area, coef.; S5 - Presence / Using of existing infrastructure, coef.; S6 - Level of access to railway infrastructure. It is measured by the number of railway lines with which the terminal is connected, number; S7 - Length of the longest arrival-departure railway track, m; S8 - Average useful length of railway tracks used for loading/unloading, m; S9 - Connectivity to road infrastructure, m; S10 - Rail connection with a port, m; S11 - Quantity of manipulated twenty-foot equivalent units (TEU), TEU/year.

➤ Internal weaknesses (IW): W1 - High investment costs, million EUR; W2 - High operating costs, 1000 EUR/year; W3 - High net present value (HNPV) of total costs, million EUR; W4 - Size of the site, 1000 m<sup>2</sup>; W5 - Change of land use, coef.; W6 - Lack of direct link between railway tracks used for loading/unloading and arrival-departure railway yard, coef.; W7 - Lack of arrival-departure railway yard in the terminal, coef.; W8 - Crossing of communal infrastructure, coef.; W9 - Impact on protected areas, coef.; W10 - Lack of opportunity for further development, coef.

External opportunities (EO): O1 - Possibilities for upgrading the associated infrastructure as part of TEN-T network, coef.; O2 - Opportunity for two-sided connectivity of arrival-departure railway tracks and railway tracks used for loading/unloading activities, coef.; O3 - Development of freight village, coef.; O4 - Development of additional services, coef.; O5 - Attracting of local cargo traffic, coef.; O6 - Proximity to inland waterway and equipped cargo port (use of the terminal as a Dry port), coef.; O7 - Proximity to sea-borne and equipped cargo port (use of the terminal as a Dry port), coef.

External threats (ET): T1 - Competitive terminals, coef.; T2 - Increase of the percentage of road transport, coef.; T3 - Delay at the border crossings, coef.; T4 - Inappropriate conditions for transport along the river, coef.; T5 - Risk of bad meteorological conditions, coef.

Criteria S6, S7, S8, S9, S10, S11, W1, W2, W3 and W4 are quantitative and values need to be set for them. The other criteria are qualitative. They have to be set with "1" and "0". The value is "1" if the answer is "yes", and "0", otherwise.

• Step 3: Determination the weights of main SWOT criteria and sub-criteria by applying AHP method. This step uses the AHP to derive the relative priorities of each sub-criterion within the SWOT groups. The global criteria weight is obtained by multiplying the factors local weights by the specific group weight.

• Step 4: Ranking the alternative variants of the intermodal transport terminal location by using PROMETHEE method. Choice of an optimal variant.

# 2.1. Determination the weights of criteria by AHP Method

The AHP method is one of the most popular methods of multi-criteria analysis of decision-making. The weights of the criteria are determined by comparing the pairs of the criteria on the basis of the fundamental scale for assessing the criteria (Saaty's scale). Table 1 presents Saaty's scale for pair-wise comparison [25, 26].

Explanation	Intensity of importance	Reciprocal values
Equal importance	1	1
Moderate importance	3	1/3
Strong importance	5	1/5
Very strong importance	7	1/7
Extreme importance	9	1/9
Average intermediate values between two close judgments	2; 4; 6; 8	1/2; 1/4; 1/6; 1/8

Table 1. Saaty's scale for pair-wise comparison.

The evaluation square matrix A (n, n) is formed based on the pairwise comparison on n criteria using Saaty's scale. For the matrix elements are used the following relationships:

$$a_{ii} = 1; \ a_{ij} \neq 0; \ a_{ji} \neq 0; \ a_{ji} = (a_{ij})^{-1}$$
 (1)

The weights of criteria are determined according the following relationship:

$$W = \lambda_{max}.W \tag{2}$$

where  $W = \{w_1, ..., w_n\}^T$  is the normalized right eigenvector;  $\lambda_{max}$  - the largest eigenvalue of the evaluation square matrix A.

$$\lambda_{max} = \sum_{i=1}^{n} \left[ \left( \sum_{j=1}^{n} a_{ij} \right) \cdot w_i \right] \tag{3}$$

In AHP method mathematically are validated the results using the consistency ratio CR.

$$CR = CI.RI^{-1} \le 0.1$$

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where *CI* is the consistency index; *RI* is a random index.

The random matrix is given in [26]. The consistency index is:

$$CI = (\lambda_{max} - n).(n-1)^{-1}$$
 (5)

where  $\lambda_{max}$  is the maximum eigenvalue of the priority matrix; n - the number of elements in the matrix.

Generally, if  $CR \le 0.10$  the consistency of the decision-maker is considered satisfactory. But if CR exceeds 0.10, some revisions of judgements may be required. In order to control the results of the methods, the consistency ratio is used to estimate directly the consistency of pairwise comparisons. The application of consistency index of experts and the conduction of sensitivity analysis of solutions verifies the results.

2.2. Ranking the alternatives variants of intermodal terminal location by using PROMETHEE method A suitable approach to prioritize the alternatives is the outranking method of multi-criteria analysis - PROMETHEE, where the decision matrix and the weights of criteria are set by the decision maker. In the developed methodology, the weights are determined in advance using the AHP method. For each criterion it is necessary to be set the following:

- The type of optimization - maximum or minimum;

- The preference function which characterizes the difference for a criterion between the evaluations obtained by two possible decisions into a preference degree ranking from 0 to 1. Six basic preference functions have been proposed in this method - usual criterion; quasi criterion; criterion with linear preference; level criterion; criterion with linear preference and indifference area; Gaussian criterion.

The explanation and mathematical calculation steps of the PROMETHEE method are summarised below [27]:

• Step 1: This step computes, for each pair of possible decisions and for each criterion, the value of the preference degree.

• Step 2: This step consists of aggregating the preference degrees of all criteria for each pair of possible decisions.

• Step 3: This step includes the computing of the outranking flows. For each possible decision the positive outranking flow  $\varphi^+(a)$  and the negative outranking flow  $\varphi^-(a)$  are computed. The positive outranking flow expresses how much each alternative is outranking all the others. The negative outranking flow expresses how much each alternative is outranked by all the others.

• Step 4: In this step the net outranking flows  $\varphi(a_j)$  of  $a_j$  in the alternatives set *m* of a possible decision are determined as a difference between  $\varphi^+(a_j)$  and  $\varphi^-(a_j)$ .

φ

$$\varphi(a_j) = \varphi^+(a_j) - \varphi^-(a_j) \tag{6}$$

For net outranking flow, the following conditions are valid:

$$(a_j) \in [-1; 1] \tag{7}$$

$$\sum_{j=1}^{m} \varphi(a_j) = 0 \tag{8}$$

The optimal alternative is determined by the maximum value of net outranking flows, which corresponds to the alternative with highest priority:

 $max_{a_j \in S} \varphi_j(a_j) \tag{9}$ 

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where  $\varphi_j(a_j)$  are the net outranking flows for alternative  $a_j$ ; j = 1, ..., m is the number of alternatives.

#### 3. Results and discussion

The methodology is approved for choosing the location of intermodal terminal in the city of Ruse. It is a part of comprehensive TEN-T network. Figure 1 shows the investigated locations.



**Figure 1.** The alternative locations of intermodal terminal in Ruse.

#### 3.1. Alternative places for location of the intermodal terminal

This research uses as alternatives for location of the intermodal terminal the places specified in [28]. The alternatives are as follow: Alternative A - The location is situated near to Ruse railway yard to the north of it; Alternative B - The location is situated in a place on site intended for the construction of Ruse technical railway station; Alternative C - The location is situated in the place of the suspended Ruse-East railway yard; Alternative D - The location is situated to the west of the Ruse-East port; Alternative E - The location is at East of Ruse free zone.

The values of the quantitative criteria for each alternative have been determined by using information given in [28]. Table 2 presents the values of the sub-criteria.

IS	Туре	А	В	С	D	E	IW	Туре	А	В	С	D	Е
<b>S</b> 1	max	1	1	1	1	1	W1	min	21.7	22.2	21.8	24.8	27.9
S2	max	1	1	1	1	1	W2	min	399.0	419.4	423.7	468.2	554.2
<b>S</b> 3	max	0	0	1	0	0	W3	min	29.1	29.8	29.6	33.1	37.3
<b>S</b> 4	max	1	1	1	1	1	W4	max	109.3	109.8	123.4	96.0	112.1
S5	max	0	0	1	0	0	W5	min	0	0	0	0	1
<b>S</b> 6	max	5	5	5	3	4	W6	min	1	1	0	0	1
<b>S</b> 7	max	760	750	774	636	750	W7	min	1	1	0	1	1
<b>S</b> 8	max	470	530	530	470	530	W8	min	1	1	0	1	0
S9	min	1050	220	100	580	850	W9	min	0	0	0	0	1
S10	min	5800	3500	5400	10000	10000	W10	min	0	1	1	0	0
S11	max	30.6	30.7	34.6	26.9	31.4							
EO	Туре	А	В	С	D	Е	ET	Type	А	В	С	D	Е
01	max	1	1	1	1	1	T1	min	1	1	1	1	1
O2	max	0	1	1	0	0	T2	min	1	1	1	1	1
O3	max	0	1	1	0	0	T3	min	1	1	1	1	1
O4	max	1	1	1	1	1	T4	min	1	1	1	1	1
O5	max	1	1	1	1	1	T5	min	1	1	1	1	1
O6	max	1	1	1	1	1							
O7	max	1	1	1	1	1							

Table 2. Sub-criteria values of Decision matrix.

#### 3.2. Determination the weights of criteria

This research uses 10 experts with experience in intermodal transport (academics specialists in freight transportation and managers of transport companies). The experts were asked to perform pairwise comparisons of all main criteria of SWOT group and sub-criteria. Table 3 shows the results of expert assessment for main SWOT group. Table 4, table 5 and table 6 presents expert assessment for sub-criteria. The first and the last column of the tables presents the name of criteria, others columns show the score of each expert. The value of the score is integer if the criterion that is written it the first column of the table is equal or more important than the criterion in the last column in the same row. Otherwise the reciprocal value is recorded, according Saaty's scale.

Expert 2 3 7 9 SWOT 4 8 10 SWOT 1 6 5 2 1/21/51/21/31/42 3 2 2 EO ET 1/41/6 1/31/21/31/41/41/41/3EO 1/2IS EO 1/31/31/31 1/41/31/32 1/51/3IW ET 1/41/5 1/31/21/21/31/41/41/51/3IS 2 3 IW EΤ 1/31/21 1/31/41/51/31 4 3 3 2 IW IS 2 3 2 4 1/23

Table 3. Expert's assessment for the main SWOT group.

IS	1	2	3	4	5	6	7	8	9	10	IS	IS	1	2	3	4	5	6	7	8	9	10	IS
<b>S</b> 1	4	2	1/2	1/2	2	2	1/2	3	1/2	2	S2	S4	1/3	1/2	1/2	1/2	1/2	1/3	1/3	1/4	1/4	1/3	<b>S</b> 7
<b>S</b> 1	1/5	2	2	3	2	1	1/3	3	1/3	1	<b>S</b> 3	<b>S</b> 4	1/4	1/3	1/3	1/2	1/2	1/3	1/4	2	1/4	1/3	<b>S</b> 8
<b>S</b> 1	1/4	3	3	3	2	2	2	2	2	2	S4	S4	1/4	1/3	1/3	1/2	1/2	1/3	1/4	1/4	1/5	1/3	S9
<b>S</b> 1	1/4	2	2	2	2	1	1/3	1/2	1/4	1	S5	<b>S</b> 4	1/2	1/2	1/2	1/2	1/2	1/3	1/3	1/4	1/4	1/3	S10
<b>S</b> 1	1/5	2	2	2	2	1/2	1/4	1/5	2	1/2	S6	S4	1/5	1/4	1/3	1/3	1/2	1/3	1/3	1/5	1/3	1/3	S11
<b>S</b> 1	1/4	2	2	3	2	2	2	3	1	2	<b>S</b> 7	S5	1/3	1/2	1/2	1/2	1/2	1/3	1/4	3	1/3	1/3	S6
<b>S</b> 1	1/4	1/3	1/3	1/2	1/2	2	2	3	1	2	<b>S</b> 8	S5	1/3	1/2	1/2	1/2	1/2	2	1/2	2	2	2	<b>S</b> 7
<b>S</b> 1	1/5	1/3	1/3	1/2	1/2	1/2	1/3	1/3	1/3	1/2	S9	S5	1/4	1/3	1/3	1/2	1/3	1	1/2	2	4	1	<b>S</b> 8
<b>S</b> 1	1/3	1/2	1/2	1	1/2	1/2	1/4	1/4	1/3	1/2	S10	S5	1/3	1/2	1/2	1/2	1/2	1/3	1/2	3	1/3	1/3	S9
<b>S</b> 1	1/4	1/3	1/2	1/2	1/2	1/3	1/3	1/4	1/3	1/3	S11	S5	2	1/2	1/2	1/2	1/2	1/3	1/3	2	1/4	1/3	S10
S2	1/4	2	3	3	3	3	4	3	1	3	<b>S</b> 3	S5	1/5	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	S11
S2	1/4	2	2	3	4	2	3	4	4	2	S4	S6	1/2	1/2	1/2	1/2	1/2	3	3	3	3	3	<b>S</b> 7
S2	1/4	1/2	2	2	1	1	1/2	1	1/3	1	S5	S6	1/5	1/3	1/3	1/2	1/2	3	2	2	3	3	<b>S</b> 8
S2	1/4	2	2	2	1/2	1/2	1/3	1/3	1	1/2	S6	S6	1/2	1/2	1/2	1/2	1/2	1	1	1	1	1	S9
S2	1/4	2	2	2	1/2	1/2	1/2	1	2	1/2	S7	S6	3	2	1	1	2	1	1	1	1	1	S10
S2	1/4	1/3	1/2	1/2	1/2	2	1/2	1	2	2	<b>S</b> 8	<b>S</b> 6	1/4	1/3	1/3	1/2	1/2	1/3	1/3	1/3	1/3	1/3	S11
S2	1/4	1/3	1/3	2	1/2	1/3	1/3	1/4	1/2	1/3	S9	<b>S</b> 7	1	1/2	1/2	1/2	1/2	2	1	1	2	2	<b>S</b> 8
<b>S</b> 2	1/2	1/2	1/2	1/2	1/2	1/3	1/3	1/4	1/2	1/3	S10	<b>S</b> 7	3	1/2	1/2	1/2	1/2	1/3	1/2	1/2	1/3	1/3	S9
<b>S</b> 2	1/5	1/3	1/3	2	1/2	1/3	1	1/2	1	1/3	S11	<b>S</b> 7	3	1/2	1/2	1/2	1/2	1/3	1/2	1/2	1/3	1/3	S10
S3	3	2	2	1/2	1	3	3	1	4	3	S4	S7	1/2	1/3	1/2	1/2	1/2	1/4	1/3	1/4	1/4	1/4	S11
S3	2	1/2	1/2	1/2	1/3	1	1	1/4	1	1	S5	S8	2	2	2	2	2	1/3	1/4	1/4	1/3	1/3	S9
S3	3	1/2	1/2	1/2	1/2	1/2	1	1/3	1/4	1/2	S6	S8	4	3	3	2	2	1/3	1/3	1/3	1/3	1/3	S10
S3	1/3	1/3	1/3	1/2	1/3	1	1	1/2	2	1	S7	S8	1/3	1/2	1/3	1/3	2	1/4	1/3	1/3	1/4	1/4	SII
\$3	1/3	1/4	1/4	1/2	1/3	1	1	1/2	2	1	58	<u>89</u>	4	3	1		3	1	1	1	1	1	S10
\$3	1/3	1/2	1/2	1/2	1/3	1/3	1/3	1/3	1/2	1/3	S9	S9	1/4	1/2	1/2	1/2	1/2	1/3	1/2	1/2	1	1/3	SII
S3	2	2	2	2	2	1/3	1/3	1/3	1/2	1/3	S10	\$10	1/5	1/3	1/2	1/2	1/2	1/3	1/2	1/2	I	1/3	811
55	1/5	1/4	1/4	1/4	1/2	1/3	1/3	1/2	1/3	1/3	511												
S4	1/3	1/2	1/2	1/2	1/2	1/3	1/5	1/4	1/3	1/3	85												
34	1/4	1/3	1/2	1/2	1/3	1/4	1/3	1/4	1/4	1/4	20												

Table 4. Expert assessment for sub-criteria for strengths (IS).

The AHP method has been applied separately for each expert's assessment. Thus, 10 variants of results were obtained. Table 7 presents the value of CR for experts' assessments of main SWOT group, and for sub-criteria. The super decision software have been used to make research [29]. It can be seen that the equation (4) is satisfied for all cases. This shows that each expert's assessment is correct.

IW	1	2	3	4	5	6	7	8	9	10	IW	IW	1	2	3	4	5	6	7	8	9	10	IW
W1	1/3	1/2	1/2	1/2	1	2	1/2	1	1	1/2	W2	W4	2	3	3	3	3	1	2	1	1	2	W5
W1	1/3	1/3	1	1/2	1	3	1/3	1	3	1/3	W3	W4	1/2	3	2	2	3	2	1/2	2	2	1/2	W6
W1	3	3	3	2	3	1/2	3	2	3	3	W4	W4	3	3	3	3	3	1	1	1	1	1	W7
W1	3	3	3	2	4	1	2	2	2	2	W5	W4	3	3	3	3	3	1/2	1/2	2	1/2	1/2	W8
W1	3	2	2	2	2	3	3	3	3	3	W6	W4	1/3	1/3	1/2	1/2	1/2	1/3	1/2	1	1/3	1/2	W9
W1	5	3	3	3	4	3	3	3	3	3	W7	W4	2	2	2	2	2	2	2	1/2	2	2	W10
W1	2	2	2	2	3	2	1/2	1	2	1/2	W8	W5	1/3	1/3	1/2	1/2	1/2	1	1	1/3	1	1	W6
W1	1/3	1/2	1	1	1	2	1/2	1	2	1/2	W9	W5	1/2	1/2	1/2	1/2	1/2	1	1	2	1	1	W7
W1	3	4	4	2	5	3	3	3	3	3	W10	W5	1/2	1/2	1/2	1/2	1/2	1	1	1	1	1	W8
W2	1/3	1/2	1/2	1/2	1	1/3	1/2	1/3	1/3	1/2	W3	W5	1/4	1/3	1/2	1/3	1/2	1/2	1/2	1	1/2	1/2	W9
W2	3	2	2	2	2	2	1/2	3	1	1/2	W4	W5	1/3	1/2	1/2	1/3	1/2	2	1	3	2	1	W10
W2	4	3	3	3	3	2	2	3	3	2	W5	W6	3	3	3	3	1	2	2	2	2	2	W7
W2	4	3	3	3	3	2	3	3	1/2	3	W6	W6	2	1/2	1/2	1/3	1/2	1/2	1/2	1/2	1/2	1/2	W8
W2	4	5	5	3	3	2	3	4	2	3	W7	W6	1/4	1/3	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	W9
W2	5	5	5	3	1	2	1	2	3	1	W8	W6	2	1/3	1/2	1/3	1/2	2	2	2	2	2	W10
W2	1/3	1/3	1	2	1/2	2	1	1	2	1	W9	W7	3	1/3	1/3	1/3	1/2	1/2	1/2	1/2	1/2	1/2	W8
W2	3	4	4	3	3	2	1	3	2	1	W10	W7	1/4	1/3	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	W9
W3	4	3	3	2	2	2	1/2	3	2	1/2	W4	W7	1/3	1/2	1/2	1/3	1/2	2	2	2	2	2	W10
W3	3	3	3	2	3	2	1/2	1/2	3	1/2	W5	W8	1/4	1/3	1/2	1/2	1/2	1/2	1	1	1/2	1	W9
W3	4	4	4	3	3	2	2	1	3	2	W6	W8	1/3	1/2	1/2	1/3	1/2	2	2	2	2	2	W10
W3	4	5	5	3	4	2	2	1	3	2	W7	W9	4	3	3	2	1	3	2	2	3	2	W10
W3	3	3	3	3	2	2	2	1/2	1	2	W8												
W3	1/3	1/2	1	1	1/2	2	1	1	2	1	W9												
W3	4	5	4	4	5	2	2	2	2	2	W10												

Table 5. Expert assessment for sub-criteria for weaknesses (IW).

Table 6. Expert assessment for sub-criteria for opportunities (EO) and threats (ET).

EO	1	2	3	4	5	6	7	8	9	10	EO	ET	1	2	3	4	5	6	7	8	9	10	ET
01	1/3	2	2	3	1/2	2	1/2	1	1	1	02	T1	2	2	2	1/2	1/2	1/2	3	1	1/3	1/3	T2
O1	1/3	2	2	2	1/2	1/2	1/3	3	3	3	O3	T1	4	2	2	2	3	1	2	3	1	1	T3
O1	1/3	1/2	1/2	2	1/2	2	3	4	1	4	O4	T1	4	1/3	2	2	1	2	2	3	3	3	T4
01	1/2	2	1/3	2	1/2	1/3	1/5	1/3	1/4	1/3	05	T1	5	2	3	4	2	2	2	2	2	2	T5
O1	1/3	1/4	1/3	1/2	1/2	1/2	1	2	1	2	06	T2	3	3	3	3	2	3	1/3	1/3	4	4	T3
01	1/3	1/3	1/3	3	1	1/2	1	2	1	2	07	T2	4	1/2	1/2	1/2	1/2	2	1/2	1	3	3	T4
O2	1/2	1/2	1/2	1/2	1/2	1/3	2	3	1/3	3	O3	T2	5	2	3	3	2	1	1/2	1	1	1	T5
O2	1/3	1/4	1/4	1	1/2	3	1/2	2	1/4	2	O4	T3	1/3	1/2	1/2	1/2	1/2	3	2	3	2	2	T4
O2	3	3	1/3	1/2	1/2	1/3	1/3	1/3	1/3	1/3	O5	T3	3	3	3	4	1	1	1	1	1	1	T5
O2	1/3	1/4	1/3	1/2	1/2	1/2	1/2	1/2	1/2	1/2	06	T4	4	4	4	4	2	1	1	1/2	1	1	T5
O2	1/3	1/3	1/3	1/2	1/3	1/2	1/2	1/2	1/2	1/2	07												
03	1/3	1/3	1/3	1/2	1/3	2	2	1	3	1	04												
O3	2	1/2	1/2	1/2	2	1/3	1/3	1/4	1/4	1/4	O5												
O3	1/4	1/4	1/3	1/2	1/2	1/2	1/2	1	1	1	06												
03	2	1/3	1/2	1/2	1	1/2	1/2	1	1	1	07												
O4	3	3	1/2	1/2	1/2	1/3	1/4	1/3	1/3	1/3	O5												
04	1/3	1/3	1/3	1/2	1/2	1/2	1/3	1/2	1/2	1/2	06												
O4	2	1/3	1/3	1/2	1/2	1/2	1/3	1/2	1/2	1/2	07												
05	1/3	1/5	1/3	1	1/3	1	2	2	2	2	06												
05	1/3	1/3	3	3	1/2	1	2	2	2	2	07												
06	5	5	2	2	2	1	1	1	1	1	07												

 Table 7. Consistency ratio (CR).

Expert	1	2	3	4	5	6	7	8	9	10
SWOT group	0.08	0.09	0.03	0.04	0.09	0.08	0.06	0.02	0.03	0.08
IS sub-criteria	0.10	0.07	0.07	0.07	0.07	0.05	0.09	0.09	0.06	0.05
EO sub-criteria	0.09	0.10	0.08	0.05	0.09	0.05	0.09	0.05	0.09	0.05
IW sub-criteria	0.09	0.08	0.06	0.07	0.06	0.07	0.10	0.10	0.07	0.10
ET sub-criteria	0.08	0.08	0.06	0.10	0.05	0.08	0.02	0.09	0.09	0.09

The results of expert's assessments have been summarized. The local weights for each group and the global weights of criteria have been determined as average values of individual scores. The local weights are the normalised weights that show the weight of each sub-criterion in the respective group

of the main criterion. The global weights show the priority of all sub-criteria taking into account the weights of main criteria. Table 8 presents the values of both types of weights.

SWOT			Local	Global	SWOT			Local	Global
group	Weight	Criteria	weight	weight	group	Weight	Criteria	weight	weight
IS	0.471	<b>S</b> 1	0.070	0.033	IW	0.252	W1	0.142	0.036
		S2	0.072	0.034			W2	0.144	0.036
		<b>S</b> 3	0.056	0.026			W3	0.165	0.042
		<b>S</b> 4	0.034	0.016			W4	0.091	0.023
		S5	0.070	0.033			W5	0.058	0.015
		<b>S</b> 6	0.099	0.047			W6	0.066	0.017
		<b>S</b> 7	0.073	0.034			W7	0.048	0.012
		<b>S</b> 8	0.102	0.048			W8	0.081	0.021
		<b>S</b> 9	0.125	0.059			W9	0.146	0.037
		S10	0.106	0.050			W10	0.059	0.015
		S11	0.193	0.091					
EO	0.122	01	0.123	0.015	ET	0.155	T1	0.276	0.043
		O2	0.086	0.010			T2	0.256	0.040
		O3	0.102	0.012			Т3	0.156	0.024
		O4	0.108	0.013			T4	0.190	0.029
		O5	0.210	0.026			T5	0.122	0.019
		O6	0.220	0.027					
		07	0.151	0.018					

Table 8. Local and Global weights of criteria and sub-criteria.

It was found that the main importance of SWOT group has the strengths group criteria. In the second position are the weaknesses group criteria. It can be concluded that the internal factors including the strengths (IS) and weaknesses (IW) have more important compared to the external factors including the opportunities (EO) and threats (ET). The weights of the main criteria opportunities and threats are close.



Figure 2. Overall priority score.

Figure 2 presents the overall priority scores. The lengths of the lines in the different sectors demonstrate that the strengths and weaknesses predominate in comparison to external factors of opportunities and threats. The length of line in each quadrant represents the overall importance of each group. The points in the lines show the overall priority of individual factors. The results show that the main importance have the following sub-criteria: S11 (Quantity of manipulated TEU), S9 (Connectivity to road infrastructure and S10 (Rail connection with a port) of SWOT group – strengths; W3 (HPV of total costs), W9 (Impact on protected areas), W2 (High operating costs) and W1 High investment costs) of SWOT group weaknesses; O6 (Proximity to inland waterway and equipped cargo port), O5 (Attracting of local cargo traffic) and O7 (Proximity to sea-borne and equipped cargo port ) of SWOT group opportunities; T1 (Competitive terminals) and T2 (Increase of the percentage of road transport) of SWOT group threats.

The Pearson correlation coefficient as a measure of the linear correlation between two variables has been determined to assess the difference of value of weights given individual expert's assessments and its average value. Table 9 shows the values of Pearson's correlation coefficient. The values which are larger than 0.7 show presence of a very strong relationship, the values which are between 0.4 and 0.69 present strong relationship. The first column presents the number of experts, the columns indicated with IS-EW show the values of the Pearson's correlation coefficient for local weights in each SWOT group; the column for main weights presents the values of the Pearson's correlation coefficient for the weights of the main SWOT group; the last column in the table presents the values of the Pearson's correlation coefficient for the weights given by individual expert's assessments correlate with average values of weights. For example the value 0.76 in the column IS presents the Pearson's correlation coefficient between the weights given by expert's assessment of the first expert for sub-criteria in IS group and the average value of weights given by all experts. It shows proximity in expert assessments and verifies they results.

		For local	weights		For main weights	For global weights
Expert	IS	IO	ET	EW	-	
1	0.76	0.42	0.88	0.88	0.99	0.84
2	0.87	0.58	0.94	0.94	0.93	0.85
3	0.86	0.94	0.97	0.97	0.99	0.90
4	0.73	0.72	0.91	0.91	0.65	0.58
5	0.76	0.65	0.94	0.94	0.87	0.69
6	0.92	0.85	0.91	0.91	0.98	0.89
7	0.90	0.76	0.90	0.90	0.95	0.82
8	0.78	0.58	0.82	0.82	0.88	0.72
9	0.78	0.67	0.88	0.88	0.57	0.46
10	0.92	0.58	0.90	0.90	0.98	0.86

Table 9. Val	lues of the P	earson's cor	elation coef	ficient by	SWOT	groups
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## *3.3. Ranking the alternatives by using PROMETHEE method*

After determining the weights of the criteria the PROMETHEE method is applied for ranking the investigated location. The weights of the criteria determined by means of AHP method are used in the PROMETHEE method to estimate the alternatives. The Visual PROMETHEE software has been used to make research [30]. The type of optimization is set in table 2. A usual preference functions have been set for the dichotomous variable, which values are 0 or 1. For others variables have been linear preference.

Figure 3 shows the ranking of the investigated location of intermodal terminal using all global criteria. In the first part of the figure is presented the ranking according values of net outranking flows;

the second part shows the global weights of the sub-criteria. It can be seen that the location C which is situated in the place of the suspended Ruse-East railway yard is the best alternative.

Figure 4 presents the ranking by using separately the local weights of each SWOT group. The Location C is the best alternative also when ranking by using strengths group criteria (IS), and when ranking by weaknesses group criteria (IW). The location B is the best alternative when using opportunities group criteria (EO). The net outranking flows for location B and location C have closes values. The value of net outranking flows for all alternatives is equal to zero when applying threats (ET) group criteria. This is due to the equal values of the threats (ET) group criteria for each of the alternatives that can be seen in table 2.

The sensitivity analysis was made for optimal alternative. It was found that the criteria S10 (Rail connection with a port), W2 (High operating costs) and W10 (Lack of opportunity for further development) have small stability intervals of weights: S10 [0-38.96%]; W2 [0-33.13%]; W10 [0-27.22%]. The others criteria have large stability intervals of weights [0-100%].





Figure 3. Ranking the alternatives locations in Visual PROMETHEE using global weights.

Figure 4. Ranking the alternatives locations in Visual PROMETHEE using local weights.

The results of this study in regard to the best location of intermodal terminal in the city of Ruse are identical with the recommendations given in [28].

#### 4. Conclusion

This paper presents a combination of SWOT analysis, AHP and PROMETEE multi-criteria methods into a hybrid model for selecting the most appropriate location for the intermodal terminal. The proposed methodology that combines SWOT analysis with AHP and PROMETHEE methods is the main contributions of this paper. For the first time in this study is deal with the SWOT analysis for the intermodal terminal location problem. The papers that use SWOT analysis and AHP method in different research area do not continue the study to determine the optimal alternative.

The SWOT analysis has been used to define the main factors as strengths, weaknesses, opportunities and threats for investigated system. The sub-criteria for each main criterion of SWOT group are defined for the evaluation of the alternatives. The weights of main SWOT criteria and subcriteria have been determined by applying AHP method. It was found that the main importance of SWOT group has the strengths group criteria (0.471). The results show that the internal factors including the strengths and weaknesses have more important compared to the external factors including the opportunities and threats when studying the location of intermodal terminal. It was found that the main importance of all sub-criteria have the quantity of manipulated TEU (9%), connectivity to road infrastructure (6%), rail connection with a port (5%) and average useful length of railway tracks used for loading/unloading (5%). The important criteria in strengths group are quantity of manipulated TEU (19%), connectivity to road infrastructure (12%) and rail connection with a port (11%); average useful length of railway tracks used for loading/unloading (10%). The important criteria in weaknesses group are HPV of total costs (17%), impact on protected areas (15%), high investment costs (14%) and high operating costs (14%). The main criteria in opportunities group are proximity to inland waterway and equipped cargo port (22%), attracting of local cargo traffic (21%) and proximity to sea-borne and equipped cargo port (15%). The main criteria in threats group are competitive terminals (28%) and increase of the percentage of road transport (26%). The study produces a ranking of alternative locations of intermodal terminal of Ruse using the proposed hybrid model. The research showed that location that is situated in the place of the suspended Ruse-East railway vard is the best alternative for intermodal terminal position. The elaborated methodology in this study could be used for investigations the optimal location of others intermodal terminals. The proposed model could also be applied for solving various problems in transport and different area.

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