The Selection of Logistic Centers Location Using Multi-Criteria Comparison: Case Study of the Balkan Peninsula

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Abstract: This paper focuses on finding the most suitable location for the logistic centers in the area of the Balkan Peninsula (BP). Strategic global logistic center location decisions involve many environmental factors that may be conflicting in nature, and can pose a difficult selection problem. This paper uses the environment–strategy–performance (E–S–P) paradigm as a means to understand the relevance of environment complexity on logistic centers, while proposing that an environmental analysis properly represents a multi-criteria decision-making problem. Aiming at a more precise analysis of the environmental influence for finding suitable location of logistic centers, mathematical methods such as Greedy heuristic algorithm and Analytic Hierarchy Process (AHP) are used in this paper. Implementation of the Greedy heuristic algorithm in AHP improves the existing methodology for finding the most suitable location for logistic centers. Besides location selection, this is an illustrative method that evaluates logistic capabilities for individual countries in BP.

Keywords: Logistic center; environmental analysis; location decisions; multi-criteria comparison

1 Introduction

For over a century, many methods for finding the most suitable location for factories, airports, warehouses, logistic centers (LC) have been developed and this methodology has been improved. The quality of transport services and the total costs of transporting system depend on the position of important objects in the distribution network. The number and location of LC in the distribution network have a direct influence on the cost of the final product.

One of the crucial factors for a highly efficient distribution network is a suitable choice of LC location. The main aim of this paper is to find the most suitable location for the LC in the area of the Balkan Peninsula (BP) which would improve logistic flaws in distribution network between Central Europe and Asia Minor region. Between these two regions lies the BP area, known throughout history to be the gate connecting the Eastern and Western market, but today BP is known by its insufficiently used geographical position in the global distribution network. Part of the reasons for this insufficiently used geographical position in the BP is the constant oscillation of environmental criteria (for example: safety, political stability, inflation, etc.), so the investors are reserved in making decisions about new LC.

Mathematical methods such as Greedy heuristic algorithm [1] and Analytic Hierarchy Process (AHP) [2] are used in this paper as a support in making LC location decisions. We use Greedy heuristic algorithm to find a suitable geographical position of LC, such that the average (total) distance traveled by those who visit or use these LC is minimized. In order to find a suitable LC location it is necessary to analyze all important criteria that influence on the location choice. AHP analysis is a method of multi-criteria decision-making problem, and it is applied in this research to analyze criteria which affect LC location decision. In addition to AHP metod, environment–strategy–performance (E–S–P) paradigm as a means to understand the relevance of environment complexity is applied [3]. The E–S–P paradigm assumes a hierarchical view on strategy and advocates a fit between firm strategy (in this case LC strategy), its environment and performance.

Implementation of these methods improves the existing methodology by Kinra and Kotzab [3] for supply chain environment evaluation. By applying Greedy heuristic algorithm on AHP analysis with support of the E-S-P paradigm, a mathematical method for choosing the most suitable LC location is obtained. Finally, solution to find the most suitable location for the LC which would significantly improve the quality of distribution network among Europe, BP and Asia Minor region is suggested.

2 Literature Review

During the last three decades, a great number of methods that solve location problems have been developed. Depending on the complexity of the problem, the exact and heuristic methods can be distinguished. Implementation of exact methods for solving location problems is limited to relatively simple problems, while more complex problems can be solved using heuristic methods. Solutions for location problems are first mentioned by Weber [4], later, Cooper [5], [6] and in recent times, many other researchers found solutions and improved methods for solving location problems [7].

During the creation of a supply chain network, traditional solutions are done with the aim of minimizing supply costs of LC [8]. A drawback of this solution is the fact that in this case suppliers are given greater significance compared to consumers [9], so suppliers are given an advantage over consumers. Modern location solutions consider maximum profit increase of LC with the focus shifted to consumers and meeting their needs [10], [11]. Besides that, researchers pay special attention to the effect of environmental complexity (survival factors) which has indirect influence on the existence of all participants (for example: LC, factories, stores, airports, ports, warehouses…) in a distribution network [3], [12].

A great deal of operational-strategy literature uses macro-institutionalized environmental criteria such as government rules, economic policy regulations, political stability, etc [13], [14] when applying environmental uncertainty to evaluate the E-S-P paradigm when applied to a distribution network [15].

AHP method, invented by Saaty [2], has been widely used in measuring environmental complexity. Kinra and Kotzab [3] used the E-S-P paradigm in combination with AHP method as a means to understand the relevance of environmental complexity facing supply chain operations. They proposed that an environmental analysis would represent a multi-criteria decision-making problem. Inspired by this idea, in this paper, the results of the E-S-P paradigm are put into an AHP analysis in order to find the suitable LC location in the BP.

Besides the AHP method and E-S-P paradigm, many researchers have applied heuristic methods to solve location problems. Greedy heuristic algorithm [1] which was later efficiently applied by Whitaker [16] and Hidaka [17], has also been developed for solving location problems. In this paper, by implementing Greedy heuristic algorithm into AHP method, the existing method by Kinra and Kotzab [3] for supply chain environment evaluation is improved.

3 Europe and Balkan Peninsula Logistics Overview

The Europe enlargement, outsourcing in economy, development of LCs and their progressing towards Eastern European countries, as well as expansion of cargo flows between Western Europe and Asia, create new challenges for the BP region. As a consequence of permanently increasing cargo flows, there is a trend of building LCs to reduce transportation time and cost and to improve customer service. Georgijevic at al. [18], point to BP as the weakest link in the distribution network between Central Europe and Asia Minor region.

We confirm this claim by a graphic presentation of the present LCs in Europe and BP (Figure 1).

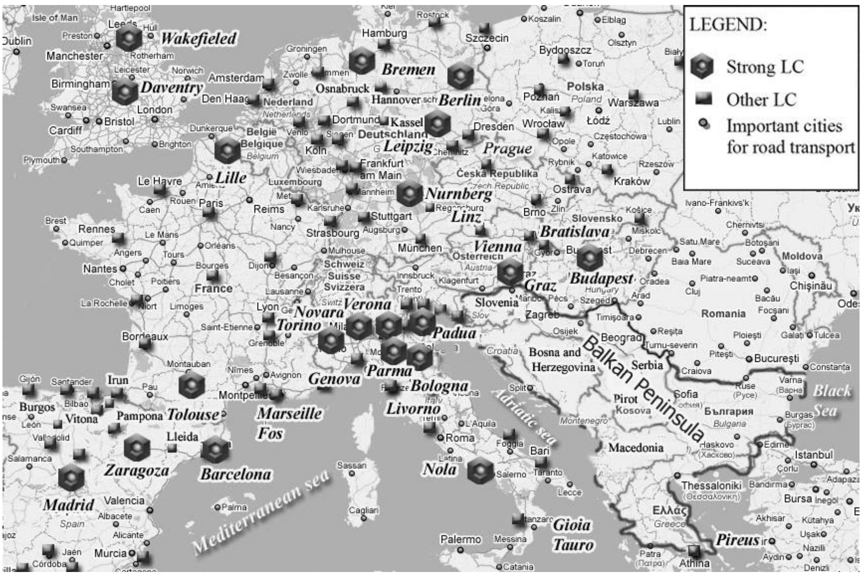

Figure 1
Important LCs in Europe – the basis of present logistic area model

The information necessary for creating a map of LCs (Figure 1), was taken from published papers and projects which contributed to the development of LCs. Thus, the Center for Advanced Infrastructure and Transport [19] published a study in which all important LCs with a strong influence on global transport are described clearly and in detail. The project carried out under the European Commission (EC) called "Sutranet" [20], gave the list of the most influential LCs in Europe in the final report. Furthermore, in the creation of the LCs map in Figure 1, the information from worldwide logistic companies and their associations including European platforms, the association of European freight villages, Association of Spain Transport Centers (ACTE), the Association of Danish Transport Centers (FDT), the Association of German Freight Villages (DGG), and the Association of Italian Freight Villages (UIR), was used.

Regarding the previously presented researches, Germany can be designated as the most advanced logistic country which has the most developed infrastructure with modern LCs. This outcome is also confirmed by Arvis at al. [21] who compared countries according to Logistics Performance Index (LPI). The LPI index was created to help countries to evaluate their logistic performance. On the basis of qualitative and quantitative indicators of LPI index, Germany is evaluated with the highest mark and represents the leading European country in the field of logistics, while the countries of the BP were among the least developed. Also, according to this research (Figure 1), in the area of the BP, there are only a few moderately developed LCs, while none of them are on the list of the most influential in Europe. This way, the BP is completely omitted in the distribution network between Central Europe and Asia region. This is also a proof for bad global economic situation on the BP, presented by Miroljub at al. [22].

Further in the paper, the methodology selecting the most suitable location for LC in the BP with the aim of strengthening logistic network through Europe and Asia region is shown.

4 Methodology

In this paper, the method for finding the most suitable location for LC on the BP is suggested. Many criteria affect LC location selection. One of the most influential criteria is also the geographical position of LC. The geographical position of LC should be such that average (total) distance traveled between objects in distribution network is minimized. Greedy heuristic algorithm is used for minimization of average distance between objects. Since the geographical position as one of the criteria is not the only aspect that influences the decision making process when choosing the most suitable location of LC, the rest of the relevant criteria such as political stability, safety, legislation etc, must be taken into account. Using E-S-P paradigms, the rest of the important criteria, are identified. After that, complex analysis of criteria is done by using AHP method [2], [23] and data from the World Bank [24], [21]. As a result, logistic comparison of the BP countries is done, and the most suitable LC location is found.

4.1 P-Median Problem and Greedy Heuristic Algorithm

In order to transport goods through the BP with minimal costs, the LC would be located on the crossroads of railway, air and highway traffic. One way to measure the efficiency and effectiveness of LC is by evaluating the average distance between the customers and the LC. When the average distance decreases, the accessibility and response times of the LC increase. This is known as the p-median problem (PMP) [25]:

$$min = \sum_{i=1}^{n} \sum_{j=1}^{m} c_i \cdot d_{ij} \cdot x_{ij} \quad (1)$$

subject to:

$$\sum_{j \in J} x_{ij} = 1, \quad \forall i \in I , \quad (2)$$

$$\sum_{j \in J} y_j = p, \quad \forall j \in J , \quad (3)$$

$$d_{ij} x_{ij} \le K. \quad \forall i \in I , \ \forall j \in J \quad (4)$$

$$x_{ij} \le y_j . \quad (5)$$

$$x_{ij} \in \{0,1\}; \quad y_j \in \{0,1\}; \quad (6)$$

where $I = \{1,...m\}$ is the set of demand points (locations); $J = \{1,...n\}$ is the set of candidate sites for LC, d_{ij} is the shortest distance between location i and location j, $x_{ij}=1$ if the customer at location i is allocated to the LC at location j and 0 otherwise, $y_j=1$ if an LC is established at location j and 0 otherwise, K is the maximum distance to be traveled by customers, p is the number of LC's to be established and c_i is the population at the demand point (location) i.

The objective function (1) is to minimize the total distance from customers or clients to their nearest LC. Constraint (2) shows that the demand of each customer or client must be met. Constraint (3) shows the number of LC to be located is p. Constraint (4) imposes a maximum distance to be covered by each customer. Constraint (5) shows that customers must be supplied from an open LC, and constraint (6) restricts the variables to 0, 1 values.

For solving PMP we used Greedy heuristic algorithm [1]. The Greedy heuristic algorithm starts with an empty set of LC, and then the first-median problem of n such problems are solved and added to this set. LCs are then added one by one until the number p is reached; each time, the location which most reduces the total cost is selected [26]. An efficient implementation is given by Whitaker [16].

4.1.1 Method Application and Results

Assuming that each citizen in any country of BP has the same requirements for certain goods, then the number of requirements is proportional to the number of citizens c_i in each country of the BP. By applying Greedy heuristic algorithm the most suitable LC location (called Median) in the BP is selected. Candidate sites for LC locations are the capitals of the BP countries. Within this research, we limit the set of possible solutions to the main cities of the BP. An illustrative example is also applicable to a wider set of solutions. The result in table 2 shows that the first median (highway traffic costs) is located in Belgrade. This location is confirmed because transport costs per kilometer are the lowest in relation to other cities. During this analysis, distances between cities are measured only on highways. By air traffic analysis, the distances between cities over air traffic routes are used as the assessment criterion. The first median is also located in Belgrade because transport costs per kilometer by plain are lowest. With railway traffic, the results of median analysis show that that the lowest costs of transport are in Bucharest. During this analysis, transport duration between cities is used, not the mileage as with other ways of transport. Railway transport duration between cities is obtained according to the evidence of the InterRail railway map. The InterRail railway map uses all the European railways, thus including the railways in the BP such as Serbian, Croatian, Bulgarian, Romanian, Macedonia, Bosnian, Greek, Albanian, Montenegrin and Slovenian railways. Additionally, Budapest (Hungary) has been included in Table 2 due to its strong influence onto the strategy of the overall BP logistics towards Europe. Hence, Budapest is a kind of logistics gate between LCs in the BP and Europe and it is treated that way in this research. Due to these reasons, Budapest should be treated as an integral part of the logistics network of BP, although geographically it actually does not belong to BP.

Table 2

Results of medians analysis

Higway traffic		Air traffic		Railway traffic	
City	Average Distance [km]	City	Average Distance [km]	City	Average travel hours [h]
Belgrade	31,822,926,491.0	Belgrade	23,361,770,017.0	Bukurest	581,165,875.9
Sofia	32,188,617,927.0	Sofia	25,254,781,728.0	Sofia	700,917,022.6
Skopje	37,846,948,229.0	Bucharest	26,631,877,464.0	Belgrade	717,115,113.9
Bucharest	35,273,951,137.0	Skopje	27,431,437,085.0	Zagreb	781,007,518.7
Thessaloníki	49,005,449,252.0	Sarajevo	29,160,273,980.0	Ljubljana	859,339,272.5
Budapest	37,316,007,790.0	Podgorica	30,160,161,396.0	Budapest	953,208,979.5
Podgorica	47,418,576,427.0	Budapest	31,029,996,417.0	Sarajevo	1,006,369,208.4
Tirana	50,088,069,735.0	Tirana	32,303,305,363.0	Thessaloníki	1,067,945,758.4
Sarajevo	45,436,154,063.0	Thessaloníki	35,371,385,840.0	Skopje	1,070,980,455.5
Zagreb	47,418,828,022.0	Zagreb	37,913,428,104.0	Podgorica	1,270,553,216.2
Ljubljana	55,685,302,780.0	Ljubljana	44,677,140,064.0	Tirana	1,350,950,458.4

On the basis of those data, according to geographical parameters, the most suitable location for the LC is the city of Belgrade which is situated on the crossroads of the main highway and air tracks. The lowest railway transport costs will be achieved if LC is located in Bucharest. On the basis of railway transport, the most suitable location for the LC is the city of Bucharest.

For final LC location decision, additional analysis is required. In section 4.2, we combine both the AHP analysis and E-S-P paradigm. In this way all important criteria that influence the choice of LC location selection on the BP are taken into account and an efficient approach to selecting suitable LC location is obtained.

4.2 Multi-Modal Access to LC Location Selection

In order to reach the final decisions on LC location, besides the geographical criteria, it is necessary to analyze the rest of the criteria that influence the choice of LC location. The suggested method for LC location selection, takes the following steps (Figure 2). The AHP starts by decomposing a complex, multi-criteria problem into a hierarchy where each level consists of a few manageable elements (criteria C_i) which are then decomposed into another set of elements (sub-criteria $C_{i\text{-}j}$). Later, these criteria ($C_{i\text{-}j}$) are mutually compared in order to get the priority of each criterion in hierarchy. Finally, all alternatives are compared in relation to the set of criteria ($C_{i\text{-}j}$) and in this way the comparison of alternatives is obtained.

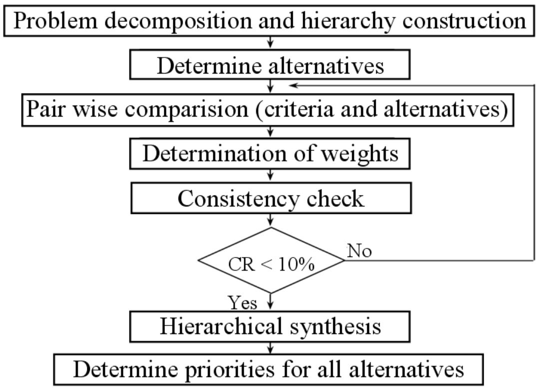

Figure 2
AHP methodology [27]

In order to get the final result, first it is necessary to compare sub-criteria mutually in order to get gradation of influence for each sub-criterion. The comparison of any two criteria C_i and C_j with respect to the goal is made using the questions of the type: of the two criteria C_i and C_j which is more important and how much. Saaty [2], suggests the use of a nine-point scale to transform the verbal judgments into numerical quantities representing the values of a_{ij}. During comparison of sub-criteria C_i with sub-criteria C_j by Saaty's scale, numerical coefficient a_{ij} is determined and set on position a_{ij} in matrix **A**. Matrix **A** is called a symmetrically reciprocal (SR) matrix and can be defined as:

$$\mathbf{A}=[a_{ij}], \quad i,j=1,2,3...n. \tag{7}$$

$$a_{i,j}>0, \quad a_{ji}=\frac{1}{a_{ij}}, \qquad a_{ij}a_{ji}=1 \quad for \quad i\neq j \;\; and \quad a_{ii}=1, \quad i=1,2,3,...,n \tag{8}$$

The intuition behind the AHP is that the pairwise comparison matrix **A** would be identical to the following matrix:

$$\mathbf{A}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \cong \begin{bmatrix} \frac{W_1}{W_1} & \frac{W_1}{W_2} & \cdots & \frac{W_1}{W_n} \\ \frac{W_2}{W_1} & \frac{W_2}{W_2} & \cdots & \frac{W_2}{W_n} \\ \vdots & & & \vdots \\ \frac{W_n}{W_1} & \frac{W_n}{W_2} & \cdots & \frac{W_n}{W_n} \end{bmatrix} \tag{9}$$

where W_i is the relative weight of element *i.*

Here an entry a_{ij} from R^n represents a ratio, i.e, a_{ij} indicates the strength with which alternative A_i dominates alternative A_j with respect to a given sub-criterion $C_{i\text{-}j}$, $i,j=1,2, ...,m$. Such a matrix is called a pairwise comparison matrix (PCM) and is usually constructed by eliciting experts' judgments. The basic objective is to derive implicit weights (priority scores), $W_1,W_2, ...,W_m$, with respect to each criterion $C_{i\text{-}j}$. *A* vector of the weights, $\mathbf{W}=[W_i]$, $W_i>0$, $i=1,...,n$, may be determined by using the eigenvalue formulation $\mathbf{AW}=\lambda_{max}\mathbf{W}$, λ_{max} is the principal eigenvalue of the matrix **A**. Since the single sub-criteria are usually not equally important, therefore, a vector of the weighting factors of each sub-criterion, $\mathbf{s}=[s_{i\text{-}j}]$, should also be determined, where $s_{i\text{-}j}$, $i,j=1,2, ...,m$ is often normalized so that $0<s_{i\text{-}j}<1$.

In the transitive case the eigenvector method provides the true relative dominance of the alternatives. In reality, however, an individual cannot give his/her estimates such that they would conform to perfect consistency. Recognizing this fact, Saaty [2] proposed a measure for the inconsistency of a PCM: $\mu=(\lambda_{max}-n)/(n-1)$, where n is the matrix size. Results might be accepted if $\mu\leq 0.08$. Otherwise the problem should be reconsidered and the associated PCM must be revised. For all details of mathematical concept, see [2] or [23].

This vector of weights is then multiplied with the weight factor of the higher level element which was used as the criterion in making the pairwise comparisons. The procedure is repeated by moving downwards along the hierarchy. The best alternative is the one with the greatest composite weight.

4.2.1 Multi-Modal Method Application and Results

This study conducts a survey on the macro-institutional competitive factors (environment complexity) which affect the LC location decisions. In this paper, taking into consideration that macro-institutional constrains are relevant for logistics operation [28], we summarized criteria from previous studies on LC location selection, as the outcomes of the literature review, in order to more precisely understand the influence of environment complexity on LC location selection. Finally, a graph of six most influential criteria (C_i) and twenty nine sub-criteria ($C_{i\text{-}j}$) and ten alternatives (A_i) is shown in Figure 3 and Figure 4, and this represents the basic structure of AHP method.

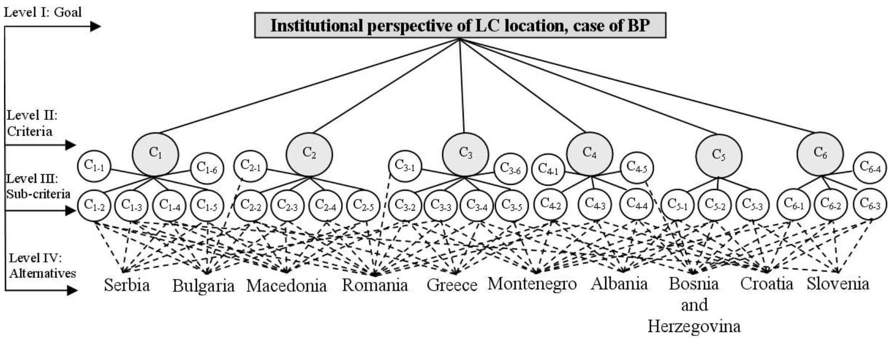

Figure 3

AHP method implementation on LC location selection

E-S-P paradigm

Code		Name of criteria / sub-criteria	Code		Name of pod sub-criteria
		Criteria:			
C_1		Physical flows	C_{1-2}	Strong influence	Quality of a railway infrastructure
C_2		Economics flows	C_{1-3}		Development and number of airports
C_3		Institutional or ownership flows	C_{6-1}		The size of domestics suppliers
C_4		Goods flows	C_{2-2}		Taxes and dues
C_5		Information flows	C_{3-1}		Legal and judicial efficiency
C_6		Other flows	C_{2-4}		Salary and worker productivity
	Sub	-criteria list of hierarchy priority:	C_{4-1}		Antimonopoly politics
C_{3-2}	Very strong influence	Safety in country	C_{4-2}		Local competition of LC
C_{3-3}		Political stability in country	C_{4-5}		Supply chain development
C_{1-5}		Geographical position +	C_{4-3}		Total country import
		Result of Greedy algorithm.	C_{4-4}		Total country export
C_{2-3}		Inflation rate	C_{6-2}	Low influence	Logistics competence
C_{2-5}		The presence of trade barriers	C_{6-3}		Cluster development
C_{1-1}		Road infrastructure	C_{5-1}		Telecommunication technology
C_{2-1}		Facility of getting a bank credit	C_{5-3}		Presence of distribution companies
C_{3-4}		Bribery and corruption	C_{3-6}		Bureaucracy (paper work)
C_{1-4}		Development of ports	C_{5-2}		The availability of new technologies
C_{1-6}		Infrastructure (energy, facilities)	C_{6-4}		Quality of education
C_{3-5}		The complexity of customs procedures			

Figure 4

List of sub-criteria with their priority for LC location selection

In this paper, two leading logistic companies and three scientific institutions in the BP ranked these sub-criteria (C_{i-j}) according to their influence on LC location selection. The results of this ranking are represented below in matrix **A** where safety and stability in country (C_{3-2}) represents the most influential sub-criteria while quality of education represents the least influential (C_{6-4}).

A =

	C_{1-1}	C_{1-2}	C_{1-3}	C_{1-4}	C_{1-5}	C_{1-6}	C_{2-1}	C_{2-2}	C_{2-3}	C_{2-4}	C_{2-5}	C_{3-1}	C_{3-2}	C_{3-3}	C_{3-4}	C_{3-5}	C_{3-6}	C_{4-1}	C_{4-2}	C_{4-3}	C_{4-4}	C_{4-5}	C_{5-1}	C_{5-2}	C_{5-3}	C_{6-1}	C_{6-2}	C_{6-3}	C_{6-4}
C_{1-1}	1	3	3	2	1/3	2	1	3	1/2	4	1/2	4	1/3	1/3	1	2	7	4	4	5	5	5	6	7	6	3	6	6	7
C_{1-2}	1/3	1	2	1/3	1/5	1/2	1/3	2	1/4	3	1/4	3	1/5	1/5	1/3	1/2	6	3	3	4	4	4	5	6	5	2	5	5	6
C_{1-3}	1/3	1/2	1	1/2	1/5	1/2	1/3	1	1/4	2	1/4	2	1/5	1/5	1/3	1/2	5	2	2	3	3	3	4	5	4	1	4	4	5
C_{1-4}	1/2	3	2	1	1/4	2	1/2	3	1/3	4	1/3	4	1/4	1/4	1/2	2	7	4	4	5	5	5	6	7	6	3	6	6	7
C_{1-5}	3	5	5	4	1	4	3	5	1	6	1	6	1/2	1	3	4	9	6	6	7	7	7	8	9	8	5	8	8	9
C_{1-6}	1/2	2	2	1/2	1/4	1	1/2	2	1/3	3	1/3	3	1/4	1/4	1/2	1	6	3	3	4	4	4	5	6	5	2	5	5	6
C_{2-1}	1	3	3	2	1/3	2	1	3	1/2	4	1/2	4	1/3	1/3	1	2	7	4	4	5	5	5	6	7	6	3	6	6	7
C_{2-2}	1/3	1/2	1	1/3	1/5	1/2	1/3	1	1/4	2	1/4	2	1/5	1/5	1/3	1/2	5	2	2	3	3	3	4	5	4	1	4	4	5
C_{2-3}	2	4	4	3	1	3	2	4	1	5	1	5	1/2	1/2	2	3	8	5	5	6	6	6	7	8	7	4	7	7	8
C_{2-4}	1/4	1/3	1/2	1/4	1/6	1/3	1/4	1/2	1/5	1	1/5	1	1/6	1/6	1/4	1/3	4	1	1	2	2	2	3	4	3	1/2	3	3	4
C_{2-5}	2	4	4	3	1	3	2	4	1	5	1	5	1/2	1/2	2	3	8	5	5	6	6	6	7	8	7	4	7	7	8
C_{3-1}	1/4	1/3	1/2	1/4	1/6	1/3	1/4	1/2	1/5	1	1/5	1	1/6	1/6	1/4	1/3	4	1	1	2	2	2	3	4	3	1/2	3	3	4
C_{3-2}	3	5	5	4	2	4	3	5	2	6	2	6	1	2	3	4	9	6	6	7	7	7	8	9	8	5	8	8	9
C_{3-3}	3	5	5	4	1	4	3	5	2	6	2	6	1/2	1	3	4	9	6	6	7	7	7	8	9	8	5	8	8	9
C_{3-4}	1	3	3	2	1/3	2	1	3	1/2	4	1/2	4	1/3	1/3	1	2	7	4	4	5	5	5	6	7	6	3	6	6	7
C_{3-5}	1/2	2	2	1/2	1/4	1	1/2	2	1/3	3	1/3	3	1/4	1/4	1/2	1	6	3	3	4	4	4	5	6	5	2	5	5	6
C_{3-6}	1/7	1/6	1/5	1/7	1/9	1/6	1/7	1/5	1/8	1/4	1/8	1/4	1/9	1/9	1/7	1/6	1	1/4	1/4	1/3	1/3	1/3	1/2	1	1/2	1/5	1/2	1/2	1
C_{4-1}	1/4	1/3	1/2	1/4	1/6	1/3	1/4	1/2	1/5	1	1/5	1	1/6	1/6	1/4	1/3	4	1	1	2	2	2	3	4	3	1/2	3	3	4
C_{4-2}	1/4	1/3	1/2	1/4	1/6	1/3	1/4	1/2	1/5	1	1/5	1	1/6	1/6	1/4	1/3	4	1	1	2	2	2	3	4	3	1/2	3	3	4
C_{4-3}	1/5	1/4	1/3	1/5	1/7	1/4	1/5	1/3	1/6	1/2	1/6	1/2	1/7	1/7	1/5	1/4	3	1/2	1/2	1	1	1	2	3	2	1/3	2	2	3
C_{4-4}	1/5	1/4	1/3	1/5	1/7	1/4	1/5	1/3	1/6	1/2	1/6	1/2	1/7	1/7	1/5	1/4	3	1/2	1/2	1	1	1	2	3	2	1/3	2	2	3
C_{4-5}	1/5	1/4	1/3	1/5	1/7	1/4	1/5	1/3	1/6	1/2	1/6	1/2	1/7	1/7	1/5	1/4	3	1/2	1/2	1	1	1	2	3	2	1/3	2	2	3
C_{5-1}	1/6	1/5	1/4	1/6	1/8	1/5	1/6	1/4	1/7	1/3	1/7	1/3	1/8	1/8	1/6	1/5	2	1/3	1/3	1/2	1/2	1/2	1	2	1	1/4	1	1	2
C_{5-2}	1/7	1/6	1/5	1/7	1/9	1/6	1/7	1/5	1/8	1/4	1/8	1/4	1/9	1/9	1/7	1/6	1	1/4	1/4	1/3	1/3	1/3	1/2	1	1/2	1/5	1/2	1/2	1
C_{5-3}	1/6	1/5	1/4	1/6	1/8	1/5	1/6	1/4	1/7	1/3	1/7	1/3	1/8	1/8	1/6	1/5	2	1/3	1/3	1/2	1/2	1/2	1	2	1	1/4	1	1	2
C_{6-1}	1/3	1/2	1	1/3	1/5	1/2	1/3	1	1/4	2	1/4	2	1/5	1/5	1/3	1/2	5	2	2	3	3	3	4	5	4	1	4	4	5
C_{6-2}	1/6	1/5	1/4	1/6	1/8	1/5	1/6	1/4	1/7	1/3	1/7	1/3	1/8	1/8	1/6	1/5	2	1/3	1/3	1/2	1/2	1/2	1	2	1	1/4	1	1	2
C_{6-3}	1/6	1/5	1/4	1/6	1/8	1/5	1/6	1/4	1/7	1/3	1/7	1/3	1/8	1/8	1/6	1/5	2	1/3	1/3	1/2	1/2	1/2	1	2	1	1/4	1	1	2
C_{6-4}	1/7	1/6	1/5	1/7	1/9	1/6	1/7	1/5	1/8	1/4	1/8	1/4	1/9	1/9	1/7	1/6	1	1/4	1/4	1/3	1/3	1/3	1/2	1	1/2	1/5	1/2	1/2	1

Gradations of influence for all sub-criteria are also shown in Figure 4 above. This list of sub-criteria and their weight coefficients is specifically defined for BP and it is not valid for LC locations selection outside the BP. It means that for other locations outside the BP some sub-criteria would be omitted, or more likely, there would be some changes in their weight coefficients. For example, safety in Europe is much more stable and does not change due to national conflicts as it is the case with the BP, so the same criteria for European Union (EU) may be less important, while in BP its weight is much higher.

These sub-criteria were then compared according to each alternative and the composite priorities computed (Table 3), as recommended by Farkas [23]. In order to get realistic results of comparisons we used real data for all sub-criteria, which are obtained by the World Bank [24], [21]. For some sub-criteria, as in the case with C_{1-5}, besides the results from the World Bank, previously obtained results of Greedy heuristic algorithm, were also considered. This way, the criterion (geographical position), which is ranked as the most influential, is more effectively evaluated. As the result of the previously described method, a unique list of sub-criteria and their weights, (Table 3) is obtained. Results of the inconsistency test of the comparison matrix from the available interview and previous data are all ≤ 0.05, indicating ‘consistency’. Data analysis and matrix calculation for all countries were conducted by software Expert Choice® [29] (Figure 5), as recommended by Kinra and Kotzab [3] or Farkas [23], with the aim to verify the solution.

Table 3
The results of given alternatives for weight coefficients

Criteria	Sub-criteria	Weight	Serbia	Bulgaria	Macedonia	Romania	Greece	Montenegro	Albania	Bosnia and Herzegovina	Croatia	Slovenia
C_1	C_{1-1}	0.054	0.039	0.026	0.063	0.026	0.132	0.044	0.092	0.019	0.320	0.239
	C_{1-2}	0.032	0.028	0.188	0.042	0.061	0.096	0.087	0.016	0.028	0.247	0.206
	C_{1-3}	0.025	0.030	0.065	0.027	0.053	0.279	0.065	0.197	0.016	0.124	0.145
	C_{1-4}	0.047	0.046	0.099	0.013	0.184	0.134	0.075	0.080	0.020	0.177	0.233
	C_{1-5}	0.097	0.254 0.149 0.247 0.067	0.254 0.149 0.177 0.018	0.111 0.057 0.111 0.013	0.159 0.235 0.154 0.188	0.032 0.057 0.042 0.192	0.044 0.037 0.064 0.098	0.028 0.014 0.064 0.046	0.055 0.057 0.097 0.017	0.044 0.133 0.030 0.183	0.019 0.112 0.014 0.178
	C_{1-6}	0.037	0.030	0.045	0.068	0.022	0.140	0.045	0.098	0.016	0.249	0.287
C_2	C_{2-1}	0.054	0.042	0.116	0.020	0.074	0.074	0.378	0.042	0.029	0.053	0.170
	C_{2-2}	0.024	0.062	0.093	0.304	0.036	0.024	0.149	0.036	0.149	0.093	0.054
	C_{2-3}	0.077	0.014	0.080	0.195	0.022	0.123	0.039	0.080	0.225	0.080	0.142
	C_{2-4}	0.017	0.043	0.105	0.137	0.200	0.018	0.091	0.281	0.016	0.031	0.079
	C_{2-5}	0.077	0.045	0.022	0.052	0.114	0.143	0.188	0.114	0.031	0.075	0.216
C_3	C_{3-1}	0.017	0.022	0.035	0.056	0.078	0.090	0.307	0.124	0.017	0.040	0.232
	C_{3-2}	0.110	0.023	0.015	0.074	0.074	0.027	0.231	0.157	0.062	0.106	0.231
	C_{3-3}	0.102	0.031	0.031	0.134	0.024	0.047	0.354	0.168	0.031	0.047	0.134
	C_{3-4}	0.054	0.042	0.028	0.151	0.151	0.028	0.102	0.068	0.020	0.048	0.361
	C_{3-5}	0.037	0.026	0.022	0.130	0.050	0.083	0.130	0.058	0..026	0.083	0.391
	C_{3-6}	0.006	0.094	0.060	0.187	0.118	0.060	0.094	0.172	0.013	0.040	0.162
C_4	C_{4-1}	0.017	0.017	0.034	0.080	0.115	0.174	0.115	0.049	0.023	0.067	0.325
	C_{4-2}	0.017	0.027	0.089	0.089	0.138	0.135	0.037	0.056	0.019	0.056	0.354
	C_{4-3}	0.011	0.030	0.091	0.204	0.028	0.016	0.270	0.062	0.178	0.032	0.091
	C_{4-4}	0.011	0.070	0.148	0.044	0.229	0.223	0.017	0.023	0.044	0.101	0.101
	C_{4-5}	0.011	0.028	0.070	0.108	0.041	0.108	0.163	0.020	0.041	0.051	0.371
C_5	C_{5-1}	0.008	0.026	0.135	0.019	0.051	0.206	0.179	0.036	0.014	0.237	0.096
	C_{5-2}	0.006	0.020	0.030	0.074	0.030	0.173	0.064	0.045	0.020	0.232	0.313
	C_{5-3}	0.008	0.027	0.044	0.089	0.036	0.125	0.196	0.144	0.016	0.044	0.278
C_6	C_{6-1}	0.024	0.067	0.132	0.136	0.047	0.177	0.030	0.020	0.020	0.030	0.339
	C_{6-2}	0.008	0.048	0.209	0.146	0.099	0.099	0.018	0.025	0.018	0.048	0.290
	C_{6-3}	0.008	0.027	0.043	0.074	0.043	0.074	0.043	0.027	0.167	0.074	0.425
	C_{6-4}	0.006	0.036	0.055	0.119	0.055	0.018	0.311	0.119	0.024	0.036	0.229

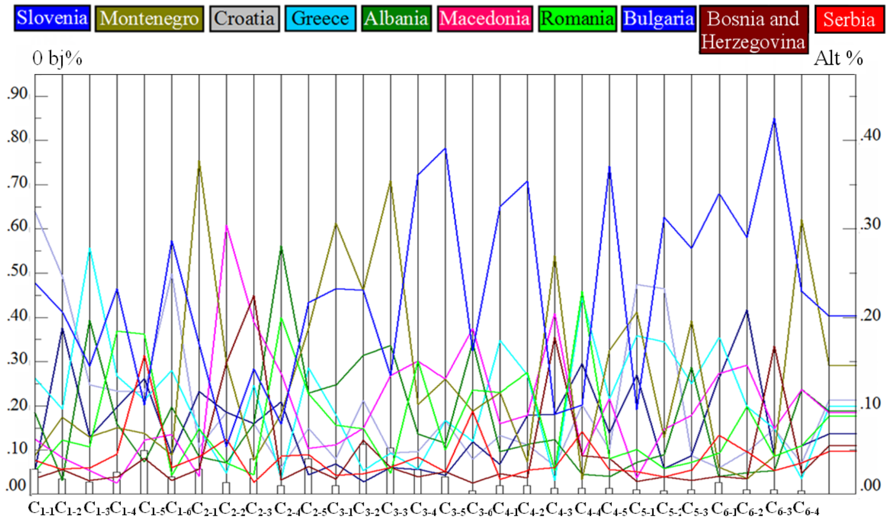

Figure 5
Alternatives performance sensitivity

Finally, according to the presented method, the resulting weights of suggested alternatives are determined in Table 4, by summing the weights throughout the hierarchy in Table 3. Priority hierarchy of suggested alternatives helps decision makers to find the suitable LC location. As it is noticed, all vectors are in range 0 to 1, and their sum always equals 1. For example, Slovenia alternative has the highest value (0.202), and as such, will represent the country which offers the most suitable conditions for LC, while Serbia with the lowest value (0.049) offers the poorest conditions. These results show that Slovenia has four times better conditions for LC development than Serbia. Similarly, as Slovenia is compared with Serbia, all other countries in BP can be compared, as well.

Table 4
Final results of alternative significance

Alternatives	Slovenia	Montenegro	Croatia	Greece	Albania	Macedonia	Romania	Bulgaria	Bosnia and Herzegovina	Serbia
Results	0.202	0.146	0.106	0.099	0.094	0.092	0.088	0.069	0.055	0.049

6 Analysis of Results

The final result obtained in table 4 shows the aim of this research, where Slovenia is the first on the priority list for LC location, followed by Montenegro, Croatia, Greece, Albania, Macedonia, Romania, Bulgaria, Bosnia, and Serbia as the last competitive country, respectively. These results are obtained on the basis of six most influential criteria, twenty nine sub-criteria and ten alternatives.

According to these criteria, Slovenia is potentially the most competitive place for the future LC development. According to previous data, the priority of LC location in Slovenia is given to the existing port Kopar. Besides strengthening LC in Slovenia, it is necessary to develop a logistic network through the whole BP with the aim of more flexible and faster distribution through this region. So, development of LCs in Montenegro, as the second ranked country, is recommended also. Montenegro has the Bar port, as one of the potential locations for further investments. According to these results, it can be concluded that these two countries offer the best conditions to the investors for LC development.

We can conclude that countries such as Serbia, Bulgaria, and Bosnia and Herzegovina, did not use their natural geographical dominance over the rest of the countries, as it was previously presented by Greedy heuristic algorithm. This research presents how environmental performance influences LC and how less important criteria can override the strongest criteria. All criteria except geographical position are dynamic, and their change over time is possible, which causes frequent change of results. Geographical position stands for one of the most influential criteria for LC location decisions. By implementation of Greedy heuristic algorithm into the AHP method, it is possible for this criterion to be evaluated more precisely. This way, final results achieved through AHP analysis are more realistic and represent the basis for decision making processes during the selection of the most suitable LC location. Besides LC location selection, these results might also represent a comparison of logistic performance for individual countries in the BP.

Conclusion

This research provides an analysis of potentials and obstacles in the process of BP integration in the Europe logistic system. The idea of this paper is to give the methodology of selecting and ranking suitable LC locations in the BP using the multi-modal method access. A special part of the research belongs to the Greedy heuristic algorithm and AHP method, and to their implementation during location problems solving. Using these methods, alternatives are efficiently evaluated while subjective mistakes of decision makers are avoided. Finally, using these methods the aim is reached, a logistic comparison of the BP countries is done, and the most suitable LC location is recommended.

This research also demonstrates managerial implications in the form of a generic decision-making problem. Further, this research not only explains how environmental performance influences LC, but also its possibility of applying this model in other fields, such as decisions in supply chains, decision in management or decisions that may arise in everyday life. In making such decisions it is recommended that decision makers use this mathematical model to find the suitable solution.

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