Multi-criteria Decision Making for the Needs of Layout of Haulage Parks

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ABSTRACT— ***Problem solving layout and location of road infrastructure elements are unique but necessary for not only technical but also economic and operational. Difficulty of the optimization procedure is highlighted by the diversity of determining entry criteria. Methods for the layout of regional development are built mainly for solving the distribution character with such disregarding energy requirements built parking lots, toll booths and the like. For this purpose it is necessary to apply other analytical methods, e.g. multi-criteria decision making, which complicates the solution procedure and does not lead to satisfactory results and is also easily influenced by a particular solver thus judgment may also be biased. The aim of the new layout method, focusing on elements of the transport is to achieve the desired result in one comprehensive solution, yet degrade the shortcomings of existing methods and procedures.***

Keywords— location, layout, freight transport, parking area

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1. INTRODUCTION

In Central and Eastern Europe we are witnessing a constant, huge increase in cars on the road. More than 16 million new cars sold in Europe per year [1]. Road infrastructure (its construction and renovation) is progressing very slowly, and despite seeing an increase in the services sector as a unit is still weak compared with the developed European countries. Projects of the European Union are helping a lot in this cause to the countries of Eastern and Central Europe [2] by which they are built and funded by elements of road transport infrastructure serving the monitoring, security services and the motorists.

If you establish a business, or if we want to extend the operation of existing firm into other regions, or we want to increase the effectiveness of existing shops, it is important the correct choice of location for the position of a company, a distribution centre, or a warehouse. This topic deals with the definitions of the allocation in literatures. A large number of scientists, researchers have dealt with the allocation problems (Table 1) and it describes the amount of authors with their works. The most known are the theories of allocation and layout by Weber, Launhard, Tyunen, Kristaller and Lesh.

The correct position of a company in area has a major impact to transport costs, the time that is needed to distribute and to all activities associated with the distribution. The allocation is dependent on a number of factors, which are necessary to consider when choosing a right place. There can be used two approaches to solve the allocation problems:

- the principle of multi-criteria decision making,
- the principle of mathematical and geometrical.

Table 1: Definitions of the allocation and the authors' views about the allocation

The author	Year	The view to the allocation
A. Weber [3]	1909	He assumed that the production in terms of the allocation will choose positions that are least costly in terms of its operation and development. Transport costs are proportional to the weight of the goods and the distance that raw materials or finished products have to overcome.
A. Lesh [4]	1940	The allocation has a balanced state, which has the following conditions: • the location of each enterprise is characterized by the maximum possible benefits to consumers and producers, • enterprises are positioned in the way that the area is fully used, • there is equality of prices and costs, • all areas of market have a minimum size in the shapes of hexagons.
D. Malindžák [5]	1997	Under the allocation it is understood: • the location of a manufacturing process, an enterprise, • the location of a distribution centre, • the location of manufacturing operations to workstations, • the location of an one-purpose machine or equipment.
M. Straka [6]	2013	The allocation can be defined as a process, which result is a determined particular position to the location of a warehouse, a company, a machine, a manufacture process, people, animals, things and other activities in a particular area, respectively in area that best suits for the defined conditions and restrictions on such requirements e.g. supplies, production, distribution or trade, strategy and tactics.

2. THE ALLOCATION AND MULTI-CRITERIA DECISION MAKING

The importance of the allocation for the needs of logistics distribution is greater, if companies and enterprises want to remain competitive in the market, respectively they try to reduce and minimize costs, which the appropriately allocated warehouse helps them to. The decision on building a warehouse and where to place it has the strategic importance and that is why the logistics distribution uses the methodological apparatus of a multi-criteria decision making in its favour [7].

If the choice of the location of a manufacturing process, a distribution or an operating centre is dependent on a number of factors and some of them can be economically evaluated and some not, it is suitable any method of multiple-criteria decision making.

The procedure for solution of multi-criteria decision-making tasks consists of the following steps:

- to define the criteria that various variants are evaluated by,
- to determine the weights for each criterion (non-standardized k_i, respectively standardized form α_i),
- the calculation of the overall usefulness of the particular variants,
- the selection, determination of the optimal variant, efficiency of variants sometimes as a proportion of total usefulness and price (cost).

In case of multi-criteria decision-making it is necessary to define the criteria by which they evaluate various variants of solutions and their ability, respectively the possibility to fulfill the defined criterion is expressed by the from the cardinal scale of evaluation (there are methods that do not require the ratio transfer of values to the cardinal scale, for example the method of a distance from the fictional variant, where it works with real values).

The expression of the achievement, respectively failure of defined criterion can be assessed in two ways [7]:

- maximizing - the better variant meets defined criteria, the more points of cardinal scale it gets,
- minimize - the better variant meets defined criteria, the less points of the cardinal scale it gets.

Weights for each criterion can be determined in two ways [6,7]:

- Direct methods for determining the weights of criteria - are methods where weights of each criterion are evaluated, defined by the decisive entity itself, they are called non-objectified weights (very simple, very subjective).
- Indirect methods for determining the weights of criteria - are more complex and values of weights are determined by mutual comparison of all defined criteria among themselves, they are called objectified weights, attempt to remove, reduce subjectivity.

"Subjectivity cannot be completely removed, it can only be minimized [6,7]." Various open questions remain that have subjective character for each of the methods: "Why were the following criteria defined?", "Why were these solutions chosen?", "Why was this method chosen?", "Why did a group of experts consist of such number?", "Why was a real representation of an expert missing in the expert group?"...

Objectifying of criteria weights (the reduction of subjectivity) can be made by:

1) A group determination of the criteria weights, the expert approach - a group of experts will define the criteria weights according to their experience – the heuristic approach.

2) An application of indirect methods for determining the weights of criteria - mathematical approach.

3) Gradual change of values of the weights of individual criteria, respectively using of different methods and their comparison – it multiplies a number of solutions - combination approach.

Standardization of criteria weights:

Values of criteria weights at particular methods are in nonstandard form. If we want to compare the values of weights obtained from different methods, it is necessary to convert them into the standardized form, while it is valid that and the sum of standardized criteria weights is equal to one (1) [6,7].

$$\sum_{i=1}^{n} \alpha_i = 1 \tag{1}$$

α_i – the weight of i^{th} standardized criterion.

The values of weights of non-standard form are possible convert to a standard form by the formula (2):

$$\alpha_i = \frac{k_i}{\sum_{i=1}^{n} k_i} \qquad i = 1,2,...,n \tag{2}$$

k_i – the weight of i^{th} non-standard criterion,
n – the number of criterion.

The direct methods for determining the criteria weights include for example:

a) the classification of criteria into groups,
b) the assignment of points to criteria from the specified point scale,
c) the Metfessel's allocation,
d) the preferential ranking of criteria,
e) the rating scale, …

The indirect methods for determining the criteria weights include for example:

a) the pair-wise comparisons – the Fuller's triangle,
   - with a permission for equal value weights of criteria,
   - with no permission for equal value weights of criteria,
b) the Saaty's method, …

3. PROBLEMS OF TRADITIONAL MULTI-CRITERIA DECISION MAKING METHODS

The solutions of deployment of elements in the space will in most cases require sensitive consideration of multi-criteria and not only take into account cost items [8]. The problem is that some of the criteria on which the layout is created, are measurable, can be expressed numerically (cost, path length, time, work time, vehicle capacity) and some are not measurable and can be only expressed as description (customer satisfaction, the catchment area of the region, the social aspects of the deployment, the impact of demographic developments) [6]. Another problem that arises when considering these criteria is their diversity while there is an effort to compare and put together the various areas that are fundamental, resp. a certain influence on the layout solution. The criteria for solving the layout are from areas that are in everyday life very difficult to compare with each other because they are completely out of other areas for example economy, manufacturing, statistics, transport, urban planning and demography, sociology, and other industries [6].

For this reasons is necessary to design of new approach for solution of layout elements of distribution space, so that was taken into consideration not only cost site of solution but also criteria, which is not possible immediately mathematically to express, but has permanent impact for cost-page [9,10]. Also is advantage, that solution is graphically displayed, so the researcher immediately know where is necessary to allocate of required places and how looks total layout of defined positions. Method which combines all aspects is so System Blocks Criteria Decision - SB method.

The procedure for solving the deployment of elements of the distribution system by SB method consists of the following steps:

1. defining the space within which the layout will be implemented,
2. division of space into smaller parts (if the dimension of space is required),
3. the gradual application of the criteria graphical layout method of multi-criteria decision making,
4. determine the final design layout solution elements (the result may be several suitable options).

4. LAYOUT PARKING FOR FREIGHT TRANSPORT IN CONCRETE COUNTRY OF EUROPEAN UNION

The establishment of parking lots for road freight transport is in the interest the Slovak Republic as well as the European Union, correct allocation of parking places has a major impact on transport costs, the time needed to distribute and to all activities associated with the distribution of products. Parking lots will be used for Lorry Vehicles (LV) as a service, recreational, technical, medical, catering and security centers, which will be used according to the needs of truck drivers to carry out its activities [11,12]. Network optimization of parking lots is dependent on the quality of road infrastructure and the traffic intensity in the studied sections. It is therefore important choice of an appropriate methodology for the design and subsequent assessment of the suitability of selected sites [13,14]. Since the deployment of parking lots in the area is dependent to several important criteria for solving the layout will be used SB method, which combines multi-criteria decision making with graphical representation of the solution and this is a suitable method for establishing a network of parking places in Slovak Republic (SR).

Deployment of parking lots space for trucks is defined by the Slovak Republic (Figure 1), and for possible solutions are peripheral parts of the area not excluded. In terms of resolution process is necessary followed the basic principles of the logistics, orderliness, method, algorithm steps and global assessment [15,16]. SB method is principally designed to exclude the possibility that the allocation of parking lots has been placed in unsuitable environments, e.g. middle of the lake, at the top of peaks and so.

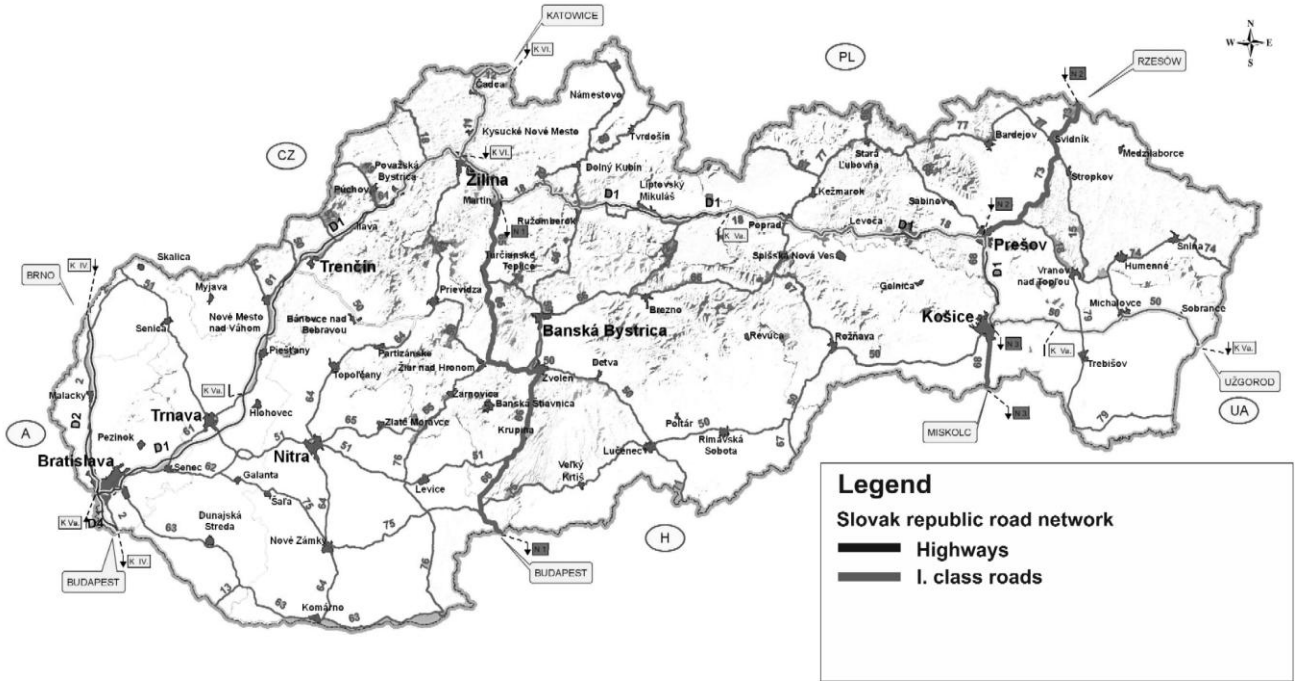

Figure 1: Defining the space for solving the allocation of parking

The irregular shape of the geographical area of Slovak Republic, especially in the East - West direction is greater than allowed by the implementation standards for driving without a break, is essential to a defined area divided into smaller parts (Figure 2) [17]. The criterion for division of space is a circle with a diameter of about 200 km where it is assumed that all the trucks (with costs) are capable of up to 4 hours (limit for one journey and the realization breaks) circuit to overcome this and appear at the parking lot where they planned implement , forced break. This way the territory of Slovakia is divided into three circles, the diameter and cross intersections respect the geographic diversity of the area and quality of transport infrastructure in terms of possible stoppings truck across the parking lots [18,19].

In the production lines and splitting the space does not overlap different circuits with each reflecting a relationship to the quality and intensity of the given locality as an additional reserve in terms of time between deployments of parking lots space. The space, located at intersection of circles, will be processed in terms of solutions considered in each circuit, in each part.

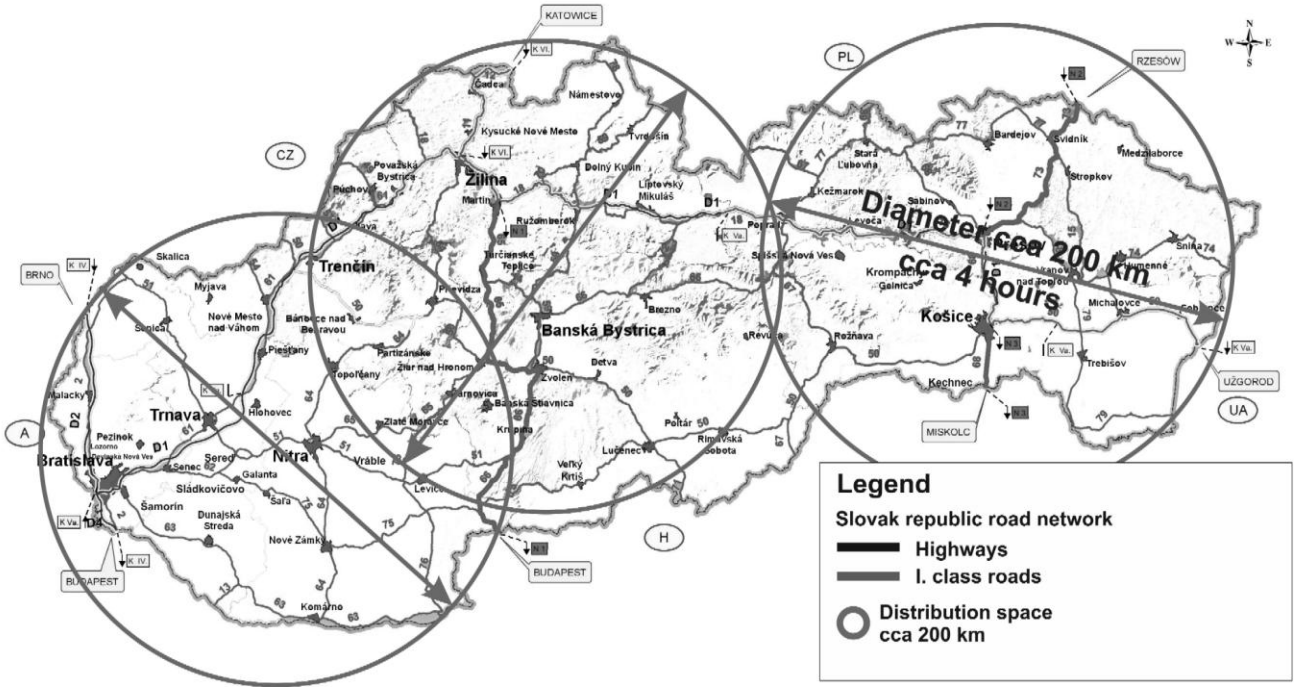

Figure 2: Breakdown of the solution space into smaller parts

5. THE APPLICATION OF CRITERIA LAYOUT BY A GRAPHICAL METHOD OF MULTI-CRITERIA DECISION

In the framework of multi-criteria decision making is necessary to correctly define and select the criteria that have a major impact on the total solution and drawing up the decisions [20,21]. For the solution of deployment parking lots, following criteria were defined:

a) structure of the road network and traffic flow at the given locality,
b) technical and industrial zones in the given locality,
c) large industrial enterprises in the given locality,
d) demographic potential sites,
e) technical and maintenance services for freight transport in the locality.

Definition of main roads of the road network within specified parts of the area is important for the allocation of parking spaces. Into account the structure of the road network will ensure the building of parking spaces in parts which are significant in terms of international freight transport and to exclude the situation when the site was too far from the road network which would provide a link for the required additional funds.

Traffic intensity in a given area is one of the most important criteria, and for this reason the more expensive vehicles passing a given section, the greater the likelihood that the vehicle will have to park somewhere and will need a driver for each vehicle and specific services [22]. The circles are defined road sections and their intensity is considered separately, i.e. traffic intensity in the first circuit does not affect the assessment of intensity in other circuits. The aim is to mark the site with the highest traffic intensity in the defined range, whereas in each circuit must be allocated separate parking areas for trucks (Figure 3) [23].

Determination of technical and industrial zones within the defined lines is important for the assumption that these areas are largely frequented by trucks and therefore they should be placed near the parking area. The circuits were technical and industrial zones recorded by region (Figure 3) [24,25].

Definition of major industrial enterprises is defined in the circuit based on the development of industry in Slovakia and its allocation in certain locations. Large industrial companies are separate entities and are not part of the technical and industrial zones, in this context are recorded separately. The assumption is that the supply and distribution companies are now conducted primarily transport vehicles whose increased concentration is in these companies and therefore are more likely to need for a parking space on these sites (Figure 3) [26].

The demographic potential of the site as a criterion takes into account the number of residents in the locality. A prerequisite is that the larger demographic force in the locality, the greater the demand for supply, more reason to implement heavy vehicle traffic and is the reason to place the parking area for trucks to this site (Figure 3).

For the operation of large-scale parking areas for trucks is necessary to provide services related to the technical side

of cars. Not all sites in Slovakia provide quality and professional service trucks because of the need for large investments for equipment of service areas. It is therefore necessary to take into account technical and servicing service parking lots (Figure 3) [27,28].

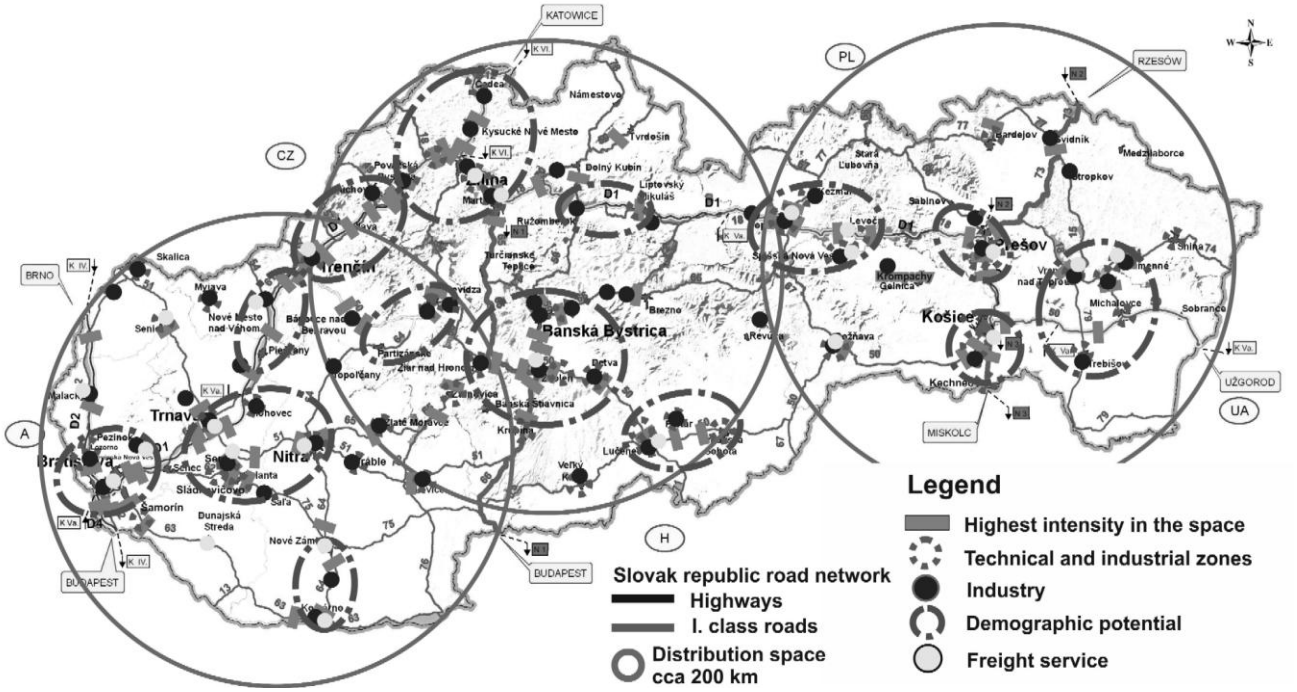

Figure 3: Showing criteria by graphical method of multi-criteria decision making

6. DETERMINATION OF THE FINAL DESIGN SOLUTION DEPLOYMENT PARKING WITH SB METHOD

Definition of the specific of parking area network structure for trucks is the last step in the application of SB method. Due to the unique remittance of a variety for the results of the network structure parking areas opportunities arising from the application of the SB method described as a separate chapter.

The application of SB method for allocation of parking lots for trucks has a number of possible solutions. The solution with the minimum number of parking spaces in the structure is represented by three parking spaces (Figure 4). These three positions are for locations that best meet the defined criteria. Under the heading "East" is a good place for the location of parking areas in the LV of Prešov and its surroundings. The advantage of this point is that the position will cover the transport of Prešov in the north - south and east - west for main international routes. Place meets all expectations in terms of defined criteria and in terms of allocation of the geometrical center of the defined location. Within the range of "center" is a suitable location for the allocation of parking space for LV and around Zilina. It covers transport in the north - south and east - west for main international routes and over the position and surroundings of Banská Bystrica has the advantage of built highways and high intensity of traffic within the site. The radius of the "West" is a suitable location for the allocation of parking space for LV Bratislava and its surroundings. The choice of this site show high intensity in the region and cover the connections in the north - south direction and the border with the Czech Republic.

The distance between the positions of Prešov and Žilina is about 220 km which corresponds to the criterion of compliance with required breaks drivers of trucks. The distance between the positions of Žilina and Bratislava is about 200 km which corresponds to the criteria for compliance with required breaks drivers of trucks.

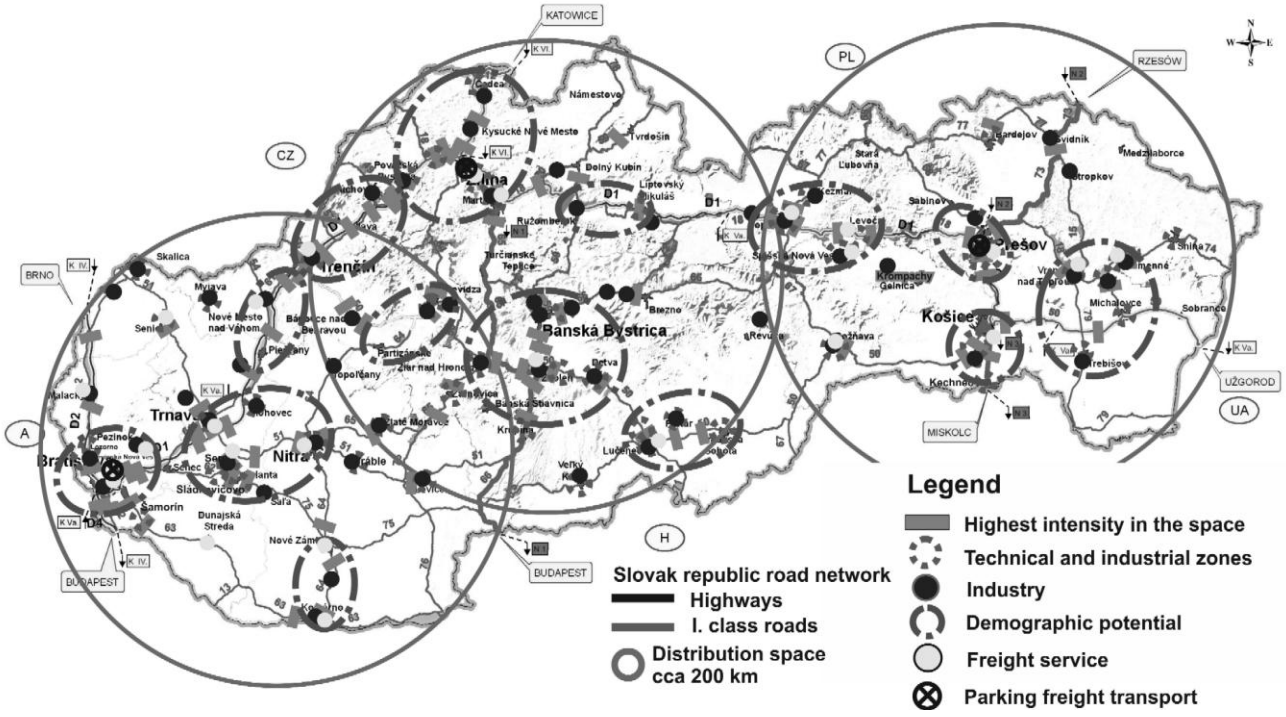

Figure 4: Parking lots structure with a minimum number of positions in the network

The solution to the expansion of the parking spaces in the structure is represented by placing additional parking spaces (Figure 5) to a minimum network structure parking area networks. The extended version is amended by sites that meet the essential defined criteria. Sites also take into account the specifics of the geographical terrain of the Slovak Republic, such as location around Zvolen. Added position Poprad and has the advantage built around the highway network, a high intensity of traffic at the transport and continuity to Poland. This position gives the perspective of regional development with a link to Poprad districts such as Spišská Nová Ves, Kežmarok and Stará Ľubovňa. The advantage of the position around Nitra and surroundings are I. class crossroads, highway and heavy traffic at that point.

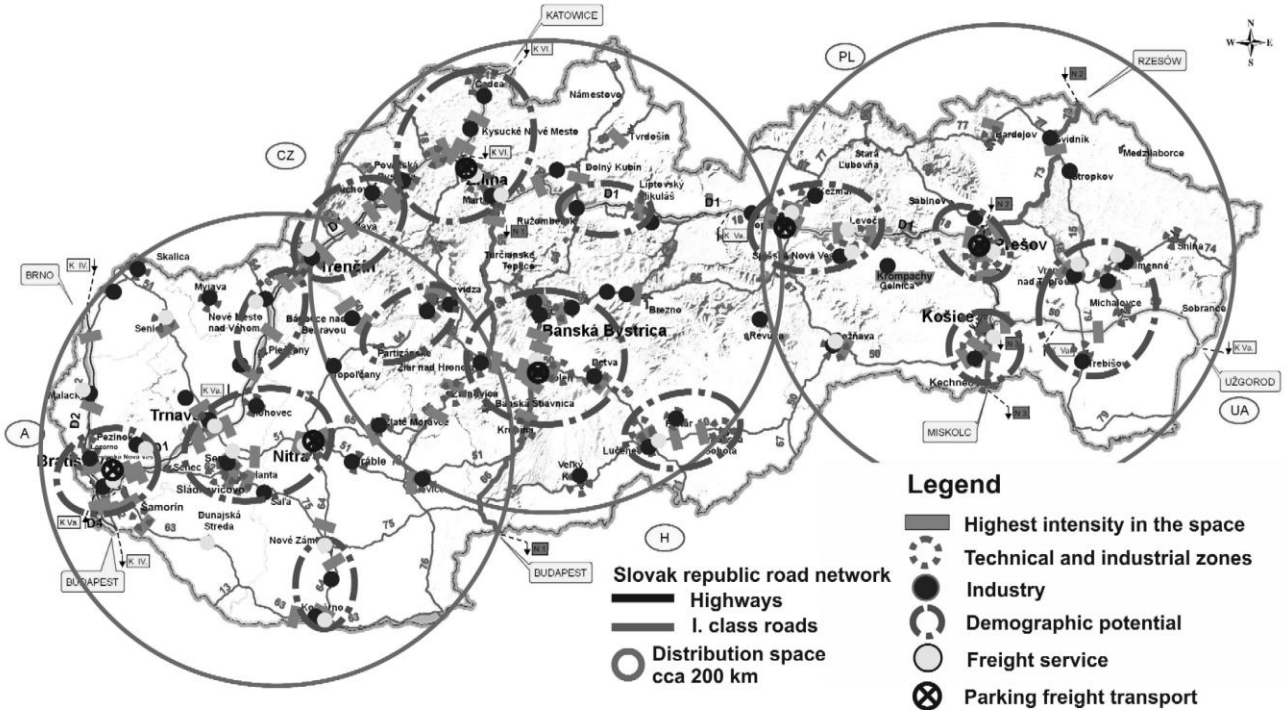

Figure 5: Parking structure with an extended number of positions in the network

The solution with the maximum number of parking spaces in the national structure is represented by each point that meets defined criteria from the application of SB method (Figure 6). Parking area network positions that were added to

the network over the previous version are in the range of "East" and Strážske Košice, within a "center" Liberty and Trenčín and circle the "West" Trnava. The positions are justified as Strážske and expressway construction R8, Košice in connection with an industrial park Kechnec, while the major transportation hub of eastern Slovakia, Trenčín and Liberty are the hubs of their sites and the like Trnava, which has high traffic volumes within the node.

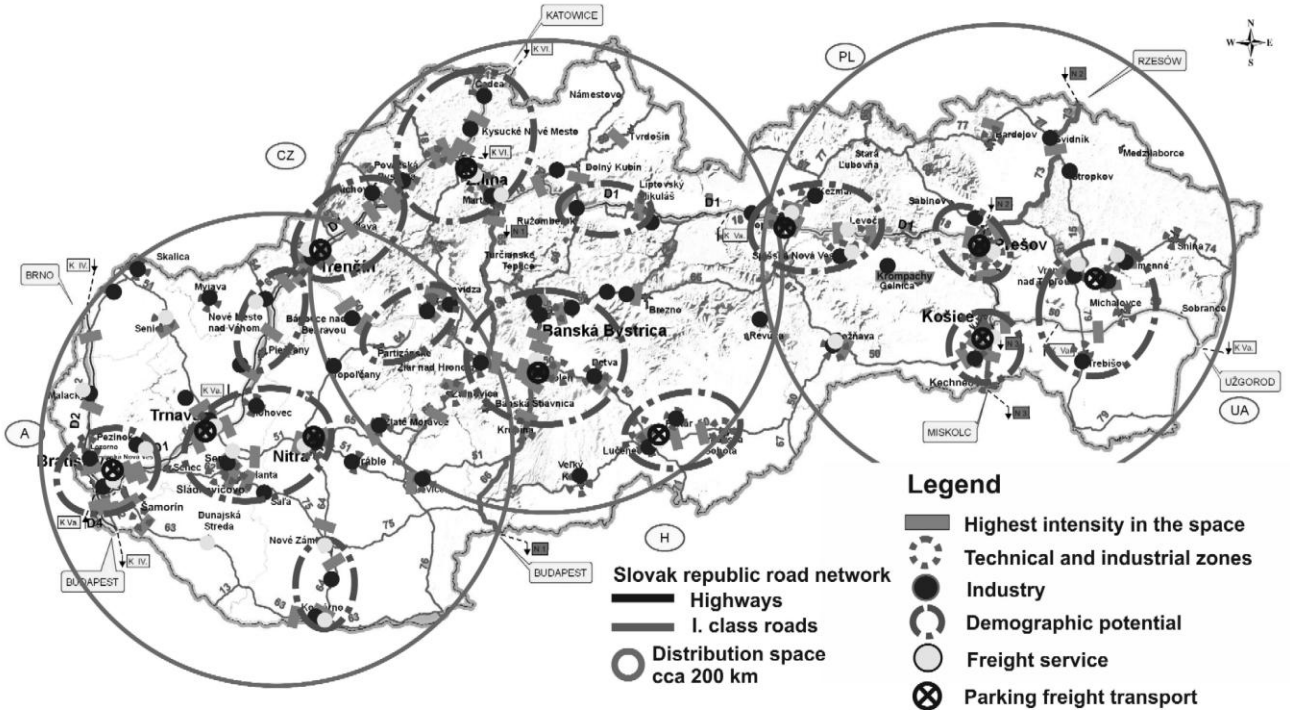

Figure 6: Parking structure with maximum number of positions in the network

7. RESULTS AND DISCUSSION

Since the applicable variant includes the allocation of positions in terms of parking 11 points, in terms of its eventual implementation construction stages would be appropriate (Figure 7).

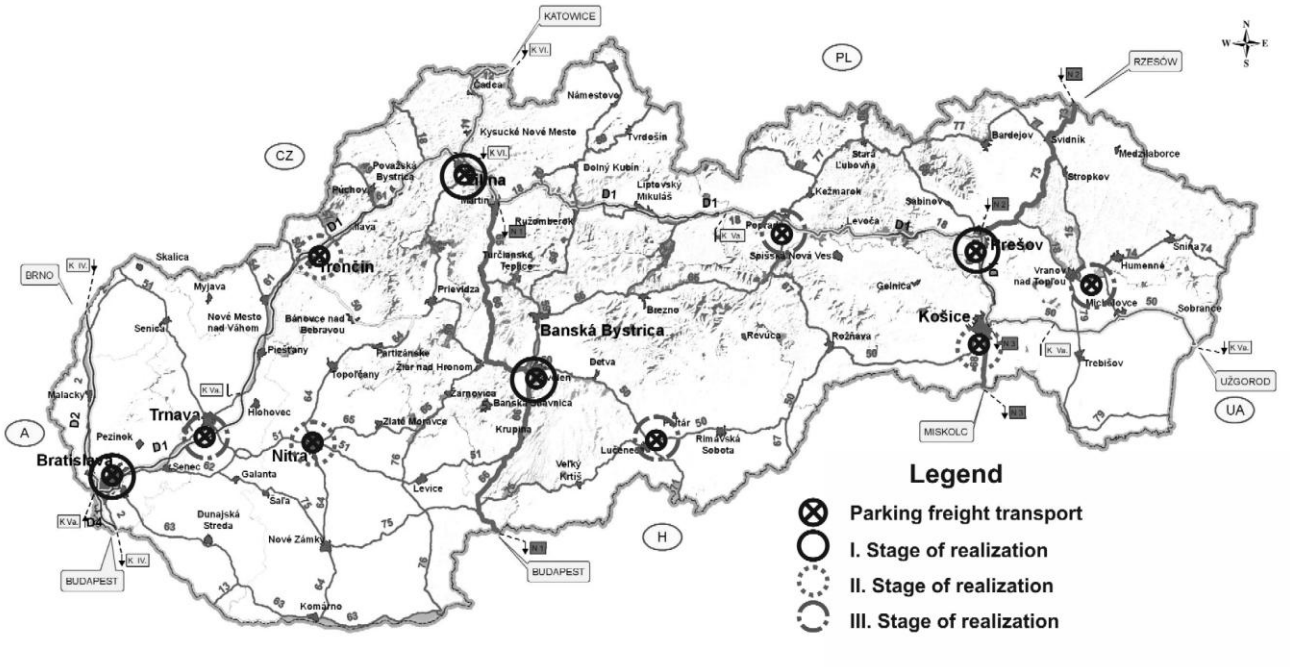

Figure 7: The final network design parking for trucks according to the stages of building

In the first stage it is necessary to build a truck parking position in the locations Prešov, Žilina, Zvolen and Bratislava. Location is understood wider neighborhood destination dependent on the connection to the road infrastructure and

construction opportunities in the defined area. The second step is to build a position in the truck parking locations Košice, Nitra and Trenčín. In the final stage it is necessary to build a truck parking position in the locations Strážske, Poprad, Lučenec and Trnava.

The resulting solution from the first phase of the construction truck parking position meets logic, logistics and quality requirements for parking layout positions. Each additional stage of building parking lots increases the quality of services provided and defined by the network.

In terms of property and the feasibility of parking network can be divided into the proposed parking lots into three groups:

- parking at border crossings,
- parking in privately owned,
- parking areas that will need to build new ones.

Parking lots at border crossings, currently owned by the National Highway Company are from the point of implementation not very difficult, but morally and physically worn out and in terms of implementation challenging for investment. Parking lots which are privately owned are in terms use instantly available and classifiable into the network structure for parking trucks. In terms of capacity, which parking lots provide due to the demands of the market, investment into capacity and technical completion is needed. The current owners of car parks expect help from either the state or the EU. The only drawback is agreement between the owner and the state.

Economically and time least favorable in terms of networking is to build parking lots in areas of existing industrial parks, where other than setting aside land possible utilities and there is nothing. In these cases, the State or the EU will have to invest a considerable amount of funding.

Even these mentioned aspects show the correctness of phased networking truck parks in Slovakia. In the first stage of building positions in Bratislava, Žilina, Zvolen and Prešov it is possible to use the facilities at the border crossings and in privately owned parking lots that already exist in the current economic situation, this procedure is useful and real for state.

8. CONCLUSION

For solution of parking layout of freight transport in Slovak Republic was applied SB method, which is building on the graphic, expert and analytical apparatus. SB method appropriately combines of graphic displaying with multi-criteria decision making. With the SB method variant solution was developed which meets the minimum, enhanced and maximalist number of elements in a network of intelligent parking of trucks in the SR. Number of parking lots in the proposed network in terms of its construction, allows to introduce an element to stage, which is an advantage in the gradual release of funds in terms of building parking of trucks at the time.

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