Decision Making: Applications in Management and Engineering
Vol. 1, Number 1, 2018, pp. 38-50
ISSN: 2560-6018
DOI: https://doi.org/10.31181/dmame180138r

SPATIAL ANALYSIS OF LOGISTICS CENTER LOCATION: A COMPREHENSIVE APPROACH

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Received: 13 November 2018;
Accepted: 26 January 2018;
Published: 15 March 2018.

Original scientific paper

Abstract. *To select a suitable logistic center (LC) location it is necessary to do a comprehensive spatial analysis. Geographic information systems (GIS) are ideal for this type of spatial analysis which provides functionality to capture, store, and query, as well as analyze geographic information. The paper presents novel methodology for a LC location analysis based on GIS and SWOT analyses. The proposed method uses a GIS for data collection, spatial analysis, generating alternatives, and producing maps for further analysis. We used the GIS to support decision-making and for an analysis of the location attributes, including a number of relevant factors, namely spatial position, intermodal connections (road, water, air and rail transport), the size of the available location, topography, local traffic connections, environment, ecological aspect of the location, ownership structure, equipment of communal infrastructure, constraints in the area, etc. We used the SWOT analysis to determine strengths, weaknesses, opportunities, and threats of the local area for attracting capital, knowledge and innovation. Experimental results on real-world problems, i.e., application of the proposed comprehensive methodology in a case study of a location analysis for the logistic center in the Municipality of Apatin, Vojvodina, Serbia, show that the proposed methodology provides upstanding results in the spatial analysis.*

Key words: *Geographic Information Systems, Location Analysis, Logistic Center, Spatial Analysis, Spatial Data Mining, SWOT Analysis key.*

1. Introduction

The recent development of logistics management in companies has caused the need for streamlining business operations in the most efficient way, which implies cost

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reduction and service quality improvement in order to satisfy the growing customers' demands.

The Council of Supply Chain Management Professionals defines the term logistics management as follows: "Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements" (CSCMP, 2012).

Thus, the importance of logistics centers (LC) is reflected in linking economic activities both locally and globally, where LCs become places of circulation of production, storage and transportation of goods. The LC is a separate entity operating in a secured area, within which all logistics activities (transportation and forwarding, material handling, warehousing, inventory management, cross-docking, intermodal trans-shipment, physical distribution of goods) are carried out on a commercial basis (Żak & Weglinski, 2014).

According to the European Transport Ministers' Conference (ECMT) the following criteria relating to site selection are common to all LCs (ECMT, 1996):

- the specific location of a LC reflects the need to optimize the quantity and quality of local and long-distance traffic, so that flows can be efficiently grouped together in terms of traffic volume. Of utmost importance is that the location is able to optimize the inevitably broken local and long-distance flow by achieving a cluster effect. Topographical factors are important in this context, as is the possibility of using existing infrastructure developed by different transport modes.
- the size of logistics centers must be given considerable thought. Firms looking for a location to generate or organize transport operations regard networked traffic nodes as highly attractive. In all events, a sufficient area of land must be set aside for the centre so that any future growth in traffic can be absorbed.
- existing infrastructure has already been identified as an important factor when choosing the site of a logistics centre. In the case of the European inland transport, centers must at least offer the possibility of linking up with the combined transport network of road/rail services. Links with other transport modes, such as the inland waterways, air transport or, in coastal areas, maritime transport, can of course also be incorporated. The attractiveness of these logistics nodes will depend mainly on the quality of the existing infrastructure, in other words, available capacity and, in particular, the possibility of extending capacity where necessary.
- another important factor for developing a network of logistics centers is compatibility, particularly at the level of transshipment procedures, containers, etc. A certain amount of standardization of technical equipment is therefore required. In addition, telematics networks of information and communications systems are needed so that firms can have on-line access to any important data required for rapid decision-making (e.g. data on consignments, stocks, status, etc.).

A LC location is a strategic decision and a critical point of the entire supply network, from the manufacturer to the consumer, whereby one of the main factors determining the location is the transportation cost. According to Rikalovic et al., the transportation costs, taxes, salaries, raw materials, renting costs, etc. are directly under the influence of the location and can make up 25% of the purchase product price. When all costs are summarized the location may change the overall operating costs by 50% (Rikalović et al., 2014). As a result, the optimal location of a LC may lead to reduced transportation costs, promote synchronization between production and consumption, ensure a

balanced development of transportation systems, and achieve better overall benefits (Gao & Dong, 2012; Lium et al., 2009).

Many mathematical approaches to solving a LC location problem have been reported, including: mathematical programming (Klose & Drexl, 2005), evaluation and ranking of considered sites (Özcan, et al., 2011; Awasthi et al., 2011; Żak & Weglinski, 2014). The location problem plays a crucial role in logistics, where it refers to finding the most desirable (proper) location of LC (Thai & Grewal, 2005; Kayikci, 2010).

Recent developments in the field of decision-making have led to dramatic improvements in the capabilities of GIS for a LC location analysis. Geographic information systems (GIS) are powerful tools designed for spatial analysis which provides functionality to capture, store, query, analyze, display and output geographic information (Bolstad, 2002). The power of geographic information systems is reflected in their simultaneous analysis of the geographic space and the information (attributes) linked to the space (Rikalović et al., 2014).

To address all of the above aspects we propose a novel comprehensive methodology for a location analysis based on GIS, which provides for an innovative approach to finding a desirable location efficiently. This paper is organized as follows. In Section 2 we summarize the literature overview in the field of logistics centers, pointing out the role of a multi-criteria decision analysis and the geographic information systems in the location analysis. In Section 3 we present innovative comprehensive methodology for a spatial analysis of the logistics center location, with a study case to show implementation choices. In Section 4 we present a SWOT analysis of the competitiveness of the local area for attracting capital, knowledge and innovation. Section 5 presents a discussion and analysis of the application of the proposed approach. Section 6 derives some conclusions and directions for future research.

2. Background

The location problem consists in determining proper placement of an infrastructural component (ground, site, facility) in a considered area, taking into account the decision-maker's preferences and existing constraints (Owen & Daskin, 1998; Farahani & Hekmatfar, 2009). One of the typical logistics location problems refers to the proper placement of a LC (Thai & Grewal, 2005; Kayikci, 2010).

Logistics centers should be located at the intersection of large streams of flow, or very close to major transport links, especially in order to take advantage of multimodality. The advantage of multimodal transport in addition to optimizing transport times and reducing transport costs represents greater justification regarding environmental protection (Gao & Dong, 2012).

Decisions related to a LC location have an impact on operating costs and revenues. For instance, a poor choice of location might result in excessive transportation costs, a shortage of qualified workers, loss of competitive advantage, inadequate supplies of raw materials, or some similar condition that would be detrimental to operations (Stevenson, 1993). While the optimal location selection in the logistics sector decreases transportation costs, it increases the job performance, competitive capacity and profitability of companies (Thai & Grewal, 2005). Lee et al. (2009) point out the need to consider geographic, topographic, and hydrological aspects of the available land for the logistics center installation.

In the literature the site selection processes generally disaggregate the problem into several levels. Zelenović (2003) distinguishes macro and micro locations. The

macro location is the geographical area, which can meet the basic requirements for construction and development of the LC with minimal operating costs. The micro location is the specific place in the macro location that meets technical, infrastructural and working process requirements (Zelenović, 2003).The basic criteria for analyzing the LC micro-location include an analysis of all the parameters from the micro and macro aspect with the coordination of all the entities in the multimodal transportation process. The factors that influence the LC location selection, mentioned in the literature, can be divided into two categories: factors that influence the selection of a macro location of a facility and factors that influence the selection of the micro-location. In the selection of the macro location of facilities, the factors are considered that are related to the role of the facilities in the logistic system – market characteristics, type and characteristics of goods in the distribution chain, transport possibilities and the availability of the expert personnel. In determining the micro-location of the facility, the following characteristics are considered (Fig. 1.): the area of the terrain, fitting of the location into urban plans, condition of the traffic infrastructure in the observed area, price of the land, attitudes and exemptions for the local community, etc. (Pašagić-Škrinjar et. al., 2012).

(a) (b)

Figure 1. Micro location (from the urban plan): (a) land use and (b) infrastructure

In the modern concepts of 3PL and 4PL the LC plays an important role of a logistics service integrator that provides customers with a comprehensive and high quality service besides connecting all possible transportation modes (road, rail, water and air). The concept of a location planning is based on the technological-functional requirements of the work organization such as a multimodal transport node (Rushton et al., 2006). Also, the transport and technological requirements of goods flows and the global and domestic experience in determining the technology, structure and size of individual subsystems of the LC have a significant influence on the planned solution. The development of multimodal transport corridors and logistics services are promoted as part of the overall development transport strategy (World Bank, 2008).

With the development of information technology, spatial databases have become an irreplaceable tool in management systems. It has been estimated that 80% of data used by managers and decision-makers are geographical (spatial) in nature (Worral, 1991). A large number of decisions have geographic (spatial) character, and finding a winning formula for the optimal location selection is the challenge for engineers and scientists. Besides a standard spatial analysis, GIS is increasingly used in the decision-making process. Experts in the field of industry and trade consider a spatial analysis using GIS technology as a reliable approach in the location analysis as well as in overall

marketing strategy of the company (Beaumont, 2000). Several studies have used this type of GIS function for a location analysis. One of the papers in which the GIS methodology is applied is the role of GIS in the industrial site of analysis (Rikalović et al., 2014).

Previous research on the location analysis has determined that GIS provides a methodological framework for a quality, reliable and efficient decision-making and development of the overall strategy for the development of a certain space or within a particular company.

3. Spatial analysis of logistics center location: a comprehensive approach

In this section we introduce an innovative approach to the logistics center analysis: a GIS based approach.

The proposed comprehensive method uses a GIS for generating location alternatives and spatial data mining. We used GIS to support decision-making and for the analysis of the location attributes, including a number of relevant factors: spatial position, intermodal connections (road, water, air and rail transport), the size of the available location, topography, local traffic connections, environment, ecological aspect of the location, ownership structure, equipment of communal infrastructure, constraints in the area, etc.

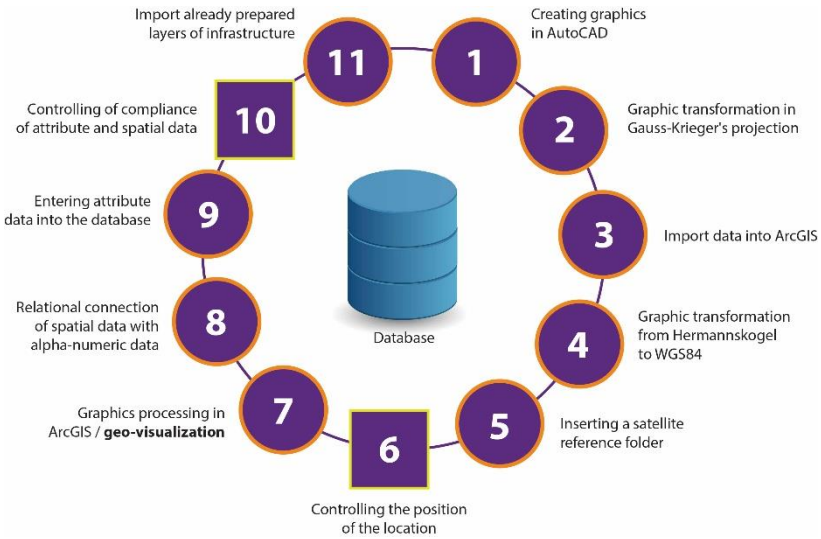

Figure 2. Process of creating a database

We have divided the proposed methodology into eleven phases (Fig. 2):

1. Creating (preparing) graphics in AutoCAD in relevant layers
2. Graphic transformation in Gauss-Krieger's projection (Hermannskogel's date)
3. Controlling the graphics before entering ArcGIS - import data into ArcGIS
4. Transformation of graphics from Hermannskogel to WGS84 (World Geodetic System - Worldwide Reference Date-Applied by Google) using Geocentric Translation
5. Inserting a satellite reference folder (which is in WGS84)

6. Controlling the position of the brownfield location relative to the reference map
7. Graphics processing in ArcGIS / geo-visualization
8. Relational connection of spatial data with alpha-numeric data
9. Entering attribute (alpha-numeric) data into the database
10. Controlling of compliance of attribute and spatial data
11. Importing already prepared layers of infrastructure (traffic, electricity, thermal power, water management, etc.) on the territory of the province of Vojvodina, Serbia, in the form of information (Fig. 3):
    - review and analysis of infrastructure data in the territory of the province of Vojvodina, Serbia, created in the process of drafting the Regional spatial plan of the province of Vojvodina,
    - graphic transformation from Hermannskogoel to WGS84 (World Geodetic System - world reference date-applied by Google) using geocentric translation,
    - control of compliance of spatial and attribute data, and,
    - final control.

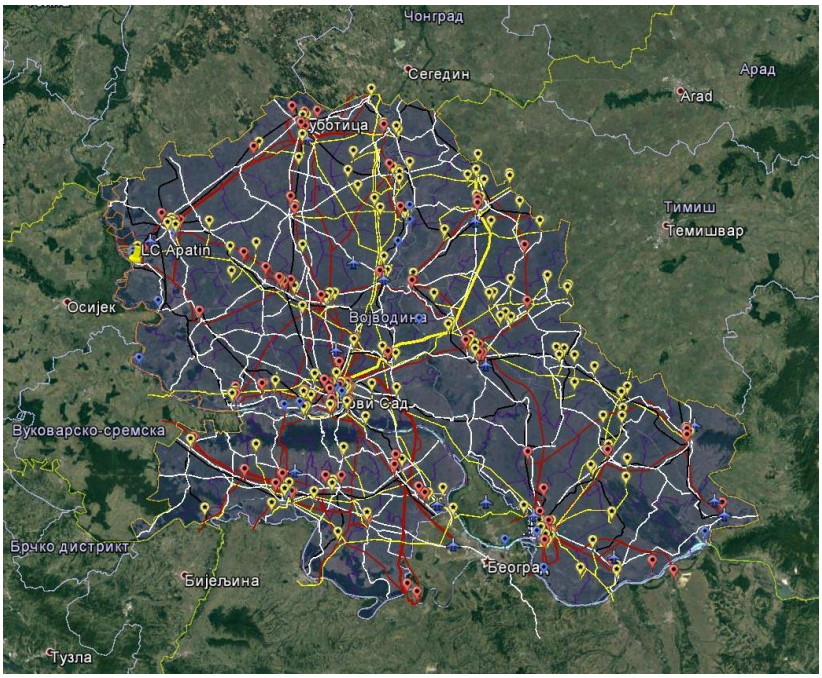

Figure 3. Traffic, electricity, thermo power and water management layer on the territory of the province of Vojvodina - macro view

GIS techniques & procedures have an important role in analyzing decision problems in the form of a spatial decision support system for location analysis especially in the screening phase. In the screening phase the role of GIS is to analyze feasible alternatives that will be later considered in the evaluation phase. The first step is the collection, input and processing of data such as: geographical characteristics, urban parameters, ecological aspect of the site, ownership structure, infrastructure facilities, architectural heritage and other relevant data.

The analysis and assessment based on the collected data are extremely important because they represent the basis which enables us to determine the extent of the potential and risk posed by the location of logistic centre. Based on the information provided by the municipality as well as spatial plans, we are able to look at and adequately address the spatial-technical-technological aspects of the site and set up the database. For generating location alternatives and spatial analyses we develop a GIS, using the ArcGIS infrastructure.

To provide a useful set of location alternatives, we have developed a GIS to mine data and generate location alternatives. Our GIS is based on the spatial database that contains data for all the selected features in the region of interest. The spatial data mining process focuses on the process of discovering interesting and potentially useful patterns for generating industrial locations alternatives from a spatial dataset by using a multilayer framework, i.e., an infrastructure where the spatial database is organized in multiple layers (thematic maps) that represent the selected features layer by layer (map by map) (Fig 4.). Using our GIS, we can separately analyze each layer of the spatial data in the region of interest and of the overlapping specific layers in order to obtain useful information as well.

In Fig. 4 we are presenting application of the proposed methodology, i.e., spatial data mining process in a case study of a location analysis for the logistic center in the Municipality of Apatin, Vojvodina, Serbia in Google Earth environment.

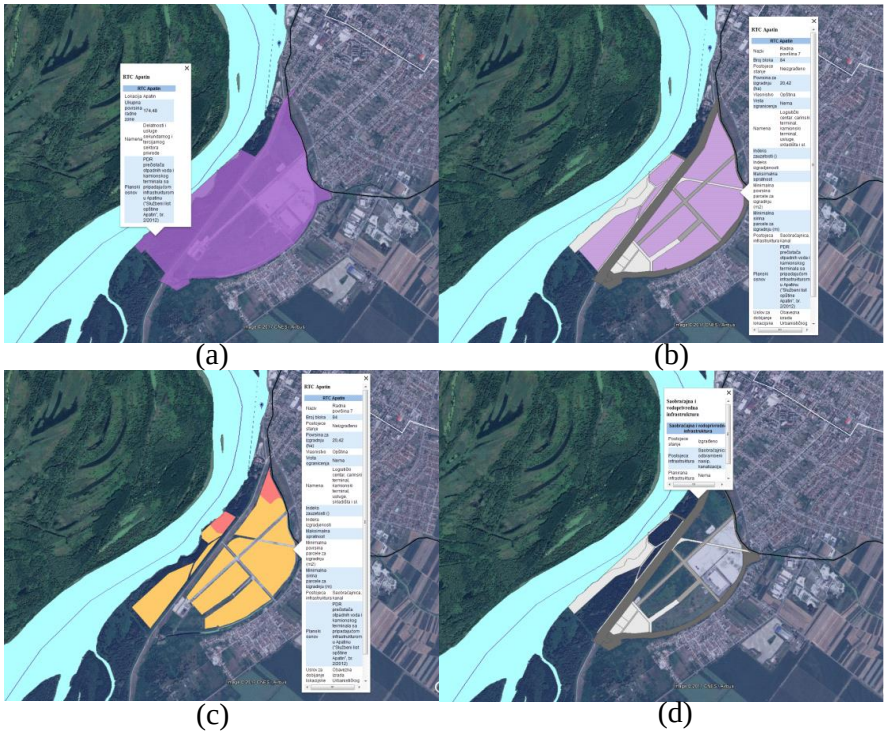

Figure 4. Spatial data mining process: (a) zone of logistic centre, (b) land use, (c) property and (d) infrastructure

4. SWOT analysis

The analysis includes a quantitative and qualitative approach to data processing, but the stakeholder involvement in identifying, analyzing and ranking the problem is essential.

The analysis of the situation encompasses the following sources: reports, information, studies, plans, earlier analysis, strategic documents, analysis questionnaires, interviews with key experts. After collecting data and analyzing the situation, the SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) is established.

The SWOT analysis is a method that gives the opportunity to establish a balance between internal capabilities and external possibilities. It is a set of analytical methods based on which the comparison of their strengths and weaknesses with opportunities and threats in the environment is conducted.

A SWOT analysis (Table 1) of the competitiveness of the local area for attracting capital, knowledge and innovation as key determinants for entering the upward path of sustainable development provides a synthesis of the established state of endogenous factors and processes in their interaction with external events.

Table 1. SWOT analysis of the LC location in Apatin[1]

INTERNAL FACTORS	
Strengths	Weaknesses
A favorable traffic and strategic position of the LC (easy access to Pan-European Corridors X and Vc, the position on Pan-European Corridor VII - Danube River) and higher intermodal transport potentials -by water, rail, road, air Multiple natural potentials (land, water, climate) as motors for economic development Good infrastructure network Growing public-private sector partnership Relatively trained, affordable and low-cost labor (tradition and quality) The realization of the project of constructing Apatin port complex with dock is in progress Completion of work on the Corridor V (Budapest - Ploce) section Good electrical connection Good telecommunication network, mobile, cable distribution systems, internet, wireless Tradition in the manufacturing industry, wholesale and retail trade A trend of increasing exports Relatively favorable business expenses	Negative demographic trends Lack of new innovative and information technologies, know-how and their slow integration into business flows Information and innovative technologies are not sufficiently integrated into business flows and productive sectors Obsolete technology and equipment Poor cross-sectoral links between enterprises and scientific and research facilities and other development institutions at the regional level Insufficient marketing activities Poor condition of the railway infrastructure Lack of regional/state roads of the highest rank Insufficient utilization of the Danube River Lack of a resource database - preparation for land and plant purposes The lack of institutions dealing with scientific-research activities in the field of economy, as well as low level of cooperation with scientific-research facilities and development institutions

[1] In the SWOT analysis were used the data from the Strategy of sustainable development of Apatin Municipality 2009-2019, (2009).

EXTERNAL FACTORS	
Opportunities	Threats
The Danube River (Corridor VII) as the most important European river roadway, as well as a better use of the potentials of Corridor IV, Vc and X	Unstable economic and political situation
Access to trade and other integration models	Strengthening the competitive advantages of the EU market
Strengthening of cooperation with other regions in order to promote socio-economic development and create a regional brand	Absence of interregional cooperation in the field of goods and services flow planning with the goal to exploit potential economic capacities
Institutional and investment support in the development and modernization of existing capacities	Migration movements of highly educated people from the area
Openness of the municipal administration towards potential investors, through making of higher-order planning documents	Postponement of the beginning of the construction of a road bypass around Apatin
Construction of the highway Vc (Budapest - Ploce)	Undefined role of the airport in the traffic vision of the region
Development of freight transport facilities and associated content related to Corridor VII; reconstruction of the passenger harbor, construction of a marina for the reception of smaller vessels	Complicated administrative procedures
Revitalization of the railroads and establishment of regular traffic on the SO-Apatin factory -Sonta route - this would enable the inclusion of Apatin on the railway corridor X; further construction of industrial tracks and free zone	
The existence of the logistic concept for AP Vojvodina, West Bačka County and Municipality of Apatin, as well as spatial planning documents	
Construction of a road bypass around the city	
Existing plans for improvement of the existing production which have the goal to create better and more competitive products	
EU market proximity	
Participation in the cross-border cooperation programs	
Openness of the municipal administration to potential investors	
Establishing of a cluster network of businesses	
Improvement of cooperation with scientific-research institutions	
Lower labor costs in relation to prices in the EU	
Tax and financial incentives for foreign investors	
Potentials for the development of a specialized business incubator - transport logistics	

In the near future, the Municipality of Apatin recognizes itself as a micro-regional, multimodal transport hub, with well-developed water management, electricity, gas and telecommunications infrastructure.

In this sense, the first goal is to ensure all the necessary conditions for the development and continuous improvement of the infrastructure capacities, contents and supporting elements. The realization of this goal, the accompanying measures and

projects are in the function of more complete and better utilization of local economic potentials.

In addition to the difficult transport of goods and transport of people, the marginal role of the railway can be a potential bottleneck in the functioning of the multimodal traffic system in the territory of the Municipality of Apatin. The expressed interest of the local community for the revitalization of the Sombor-Apatin factory-Sonta route, for the development of commodity terminals and for the construction of industrial tracks in the logistics center Apatin, gives this measure a priority status.

Due to its natural characteristics, the Danube is invaluable, not only for the observed location, but also for a wider environment. The construction, completion and smooth functioning of the LC in its vicinity can open the doors to all the major European metropolises located on the Danube coast. By implementing this measure, the Municipality of Apatin would, in a short period of time, experience direct and positive impacts of better and more extensive commodity traffic.

5. Discussion and analysis

The significance of the LC is reflected in the geographical position, infrastructure and traffic connections in the distribution chain. Logistics today is one of the most important factors that arise in the market economy. Companies use LC services to speed up the process of starting up goods while reducing transportation costs.

The possibility of connecting with the environment, as well as that of communal equipping, are very important parameters for the LC functioning. We used GIS for data mining, generating alternatives, spatial analysis and presentation of the layers obtained by analysis in the form of maps.

After analyzing the geo-traffic position and infrastructure, as the most important factors for the development of a LC, in the case of the Municipality of Apatin we can state:

- the direct support of the LC to the Danube aquarium, which represents the most important river road in Europe (by commissioning the Rhine-Main-Danube channel, all the Danube countries, with good interconnections, the exit to the Black Sea and the North Sea) provides an excellent geo-traffic position of the LC. Apatin is located in the central part of this waterway, and it is also the first convenient location for the formation of a freight transport center, downstream of the Hungarian border, through which the entire central and north-western area of Bačka can reach an exit to this important international river road, known as the Pan-European corridor VII;
- railway line Apatin factory - Sonta in Sonta comes to the main road Szeged (Hungary) -Subotica, Sombor (Serbia) -Vinkovci, Osijek (Croatia), so it has a direct connection with European corridors VII, X, IV and V;
- Apatin is not directly connected with neighboring Croatia because the Danube River and Kopački Rit represent a natural obstacle for the construction of road and railroads, and the traffic connection with Croatia is realized in the hinterland over the state road (Sombor-Apatin bridge over the Danube near Bogojevo);
- the Apatin settlement has an eccentric position in relation to the area of the Municipality of Apatin, and also to the wider hinterland where the main landing traffic routes are located, which in some way makes it separate; yet this is usually a common position for coastal settlements and can be completely compensating for the activation of river transport potentials and the formation

of an appropriate network of road and railroads, through which they will be linked with their immediate, but also wider environments.

A direct access to the international waterway - the Danube River, as a Pan-European corridor VII, an indirect rail link with the main railway line through the local railway line, an exit by road connection to the state road IIa of order no. 107, are elements that give this space extraordinary spatial-traffic predispositions for smooth development, especially in the domain of integral transport.

In addition to the analyzed infrastructure from the aspect of traffic, the subject location is also analyzed from the aspect of the utility equipment, which is assessed as suitable for placing space in function since the infrastructure of electricity, water supply, gas pipelines and electronic communication infrastructure has been built.

6. Conclusion

This paper proposes an innovative approach to a logistics center analysis that adopts a GIS based approach. The proposed methodology uses a developed GIS for generating location alternatives and spatial data mining. We used a GIS for data collection, spatial analysis, generating alternatives and producing maps for further analysis.

The results of the location analysis in the study case of the Municipality of Apatin, Vojvodina, Serbia show that a suitable geostrategic position is the biggest advantage for Apatin's future development priority in the field of economy, infrastructure and logistics development. The position of the LC, on the very bank of the Danube, provides an unhindered access from the corridor of the waterway and service of all sub-systems and sub-stations of the LC. The international port gives a quality basis to enable dispatch and delivery of all types of products across Europe through the Danube (international waterway) with the maximum application of an integral transport system. The Apatin intermodal hub, as a sublimate of all available, natural and infrastructural benefits, with water transport as the carrier of the entire system, will contribute to increasing system efficiency, reducing transport costs, increasing the level of transport services, applying modern transport technologies with ecologically minimal negative impacts and integrating all traffic types. The LC in Apatin will enable the rationalization of the distribution of all types of product on the micro and macro plan, including all modes of transport in the observed area, which will contribute to reducing the cost of shipping - delivery and overall reduction in transport costs.

In further research the comprehensive method for industrial site selection will be studied at the micro-location level.

The results show that our comprehensive methodology constitutes an efficient and highly accurate tool for spatial decision support. In future research, our methodology will be tested on different cases with larger datasets. Moreover, we plan to study strategies such as the use of intelligent systems to improve the decision support effectiveness.

Acknowledgments

The authors would like to thank the Urban Institute of Vojvodina, Novi Sad, Serbia, which provided highly valuable data of LC locations in Vojvodina. The authors would also like to thank J. Lovric and D. Moraca for their expert advice on performing LC locations analysis.

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