NIKOLA TRUBINT, Ph.D
E-mail: nikola.trubint@rapus.rs
Republic Agency for Postal Services
Omladinskih brigada 1, 11070 Belgrade, Serbia

Traffic and Space
Review
Accepted: Dec. 16, 2010
Approved: Mar. 14, 2012

A GIS APPLICATION TO EXPLORE POSTAL RETAIL OUTLET LOCATIONS

ABSTRACT

The use of GIS in solving a wide variety of problems in postal operations is expanding. This approach provides the development and usage of new methods in spatial data analysis, as support in achieving a better quality of the decision-making process. The use of location analysis model based on GIS software is implemented in solving the Belgrade postal retail outlet problem. One of the most important experiences of model implementation is that the local environmental conditions have a significant impact on strategic as well as operational approach. A portion of the material included in the paper has resulted from the Serbian PTT and CPC (Canada Post Corporation) joint project Location Analysis.

KEYWORDS

Location, Retail, GIS, Postal outlet

1. INTRODUCTION

Location planning, i.e., determining the number and locations of objects in a street network, is strategic in nature. Making decisions on where to locate the objects intended for particular purposes is a very complex process bearing high responsibility. Since these decisions may refer to plans for constructing and exploiting objects over a longer time period, they also involve the allocation of considerable amounts of financial resources. The aim of this paper is to present the modern approach to solving this multidisciplinary problem which relies on the support of a Geographical Information System (GIS) and to show the impact of local environmental conditions on the solution.

A brief review of theoretical approaches to solving the problem of locating facilities is given in Section 2, whereas Section 3 provides a brief explanation of the process of solving postal location problems by using a GIS. Section 4 presents the practical application of the procedure under conditions matched to the environment in which the project is implemented (Belgrade, Serbia) with the brief comparisons with the Canadian experience. Finally, Section 5 is devoted to the conclusion.

2. FACILITY LOCATION PLANNING

The algorithms for solving location problems were rapidly developed in the last two decades of the 20th century, although the first significant result in this area is attributed to the French mathematician Fermat (19th century). The location of facilities depends on the type of service which is in relation with the optimization criteria (function). When a police station, fire department or emergency unit are to be located, the solution is based on minimizing the distance to the farthest user. However, if we want to locate an airport facility, the criterion will be the optimal distance from the airport. Optimal distance (in this case) means neither too near, in order to meet ecological and safety conditions, nor too far, because of passenger service quality. The location of postal retail outlets is determined by the accessibility to a wide variety of users, which means a minimal distance from a residential place or locations which users frequent: shopping malls, supermarkets, administrative centres... The basic elements which have to be defined prior to solving location problems are:

- the number, location and capacity of the existing outlets,
- strategic approach i.e. number of new outlets and network expansion,
- urban areas (market zones) where establishing a retail outlet is possible.

2.1 Taxonomy of Facility location problems

As stated above, location models can be presented differently. The classification used in this paper is based on research done by Daskin, Brandeau, Karup and Pruzan [1].

- *Classical location models*: In this section we outline three classes of objectives that are typically used in facility location modelling. This group of

location problems contains: Covering model, Average distance model and Undesirable facility location models.
- *Continuous vs. Network location models*: The main difference between these two types of location models is that the significant characteristics of the latter are service demands and possible spots in nodes or links of the network. In most cases of network location models service demands are located in nodes of the network.
- *''Tree'' model* represents a special class of location problems
- *Static vs. Dynamic location models*: location models based on the premise that incoming demands such as costs, distances or databases are not functions of time are static location problems. All the classical location models (covering models, average distance models and undesirable facility location models) are static models.
- *Deterministic vs. Stochastic location models*: Models for which the incoming data can be precisely predicted without any uncertainty are deterministic models. All classical location models belong to the deterministic class.
- *Single vs. Multi-objective location models*: The majority of location models are single objective. However, since facility location problems are strategic in nature, there are likely to be a number of different constituents interested in the location decisions. Erkut and Neuman (1989) argue that the location of undesirable facilities is an inherently multi-objective problem [2].

Location problems which arise in practice rarely follow the theory approach, but are a combination of the above mentioned. If we start solving the problem of locating postal retail outlets by some of the mentioned models, we will face serious problems. One type of problems involves the fact that each address point on an urban territory is a potential location that should be examined. Since practically none of the above listed models (software) can handle such a large number of potential locations, the use of classical location methods does not offer an efficient problem-solving procedure. Problems including such a large number of data and alternatives are referred to as 'NP hard' ones in literature. On the other hand, in the case of a postal retail outlet the location problem is multidisciplinary. If it is considered in the sense of a minimal average distance from a retail outlet, a classical location problem is solved; on the other hand, the users' behaviour and gravitation to the existing outlets is of stochastic nature, while the incoming parameters (databases) are dynamic. Therefore, the conclusion is that the given task is not to be solved by theoretical location methods, but by a heuristic approach which requires simultaneously multi objective monitoring [3]. The facts mentioned above emphasize the necessity of using GIS as a support in solving these complex strategic problems (matching problems) because of its flexibility and visualisation of solutions, which is of great assistance in the decision-making process.

3. LOCATION ANALYSIS MODEL BASED ON GIS

The main advantage of GIS, the possibility of integrating spatial and alphanumeric data, has made it widely applicable to a variety of fields. GIS allows new processing methods to be used and provides high-quality presentation of the processed data. These characteristics make it an unavoidable decision-making tool in a situation when data relevant to a decision include a spatial component. GIS is by no means a system that will give a final solution to a user, but it will provide the possibilities for better and more organized analysis of information, which is a prerequisite for making quality decisions [4]. Our analysis of retail outlet locations is supported by MapInfo software package for Desktop Mapping. The main components of postal retail outlet location model are: external and internal databases, software package for desktop mapping, vector maps and spatial data display.

3.1 External and internal Databases

Geographical information systems can be developed successfully only with today's database management systems. Database management is described as linking topology data and attributes to geographical elements (a point, line, polygon). In location analysis and retail outlet capacity design, we use databases relating to the number of inhabitants on a territory and the number of legal persons on the same territory. In addition, we must take into account the fact that other companies located in the neighbourhood of the outlet may also attract potential users' attention.

Demographical data: To form a demographical database, initial databases from the following sources may be used: Statistics Office, Electric Power Industry, Telecommunication companies, City Water Supply organizations. After transformation, a demographic database should contain the following attributes: street code, house number, number of persons on house number.

Business demography: This database refers to legal persons located on a particular territory segment. For each database record, we have to specify: name, business activity code, street code and number. Possible initial data sources are: Statistics Office, Tax Administration, Telecommunication companies. When forming this database, we must keep in mind the fact

that, depending on a firm's activity, a certain number of inhabitants gravitate towards the area in which it is located. More precisely, certain activities such as trade (supermarkets) and services (agencies, crafts) attract the largest number of potential users to a retail outlet zone. The business demography database should also include a column representing a weight W that ranges from 1 to 10, with the exception of some extreme cases when its value is incomparably higher [5].

Database on existing retail outlets: To analyze the position of an existing outlet and find alternative locations, it is necessary to collect the following data for each outlet: the number of services, average income, average expenses, the number of employees, ownership of the building. These data are used to estimate the retail outlet profitability. The data on the number of services and income are usually in correlation, although they can also be considered separately, because an increase in the number of services without a capacity revision leads inevitably to a lower quality of service.

To collect and process data so various in nature is a very complex task. As initial databases are of different formats, it is necessary, first of all, to convert them into the same format (Microsoft Access has been used for this purpose in our project) to permit a successful process of linking. After that, it is necessary to determine a unique attribute of each database record according to which pairing is performed. In our analysis we have used the postal address code, a digital code linked to the application 'Territory' by means of which each address point on the territory of Serbia has been geo-referenced. This should be accompanied by performing the already mentioned corrections in the 'legal entities' database, i.e., specifying 'the effect' ('weight' on a 1-10 scale) of certain types of business activities. Since this procedure is very complex and represents one among the essential factors in building a GIS infrastructure, it has to be carried out very carefully. To succeed in pairing about 85% of data, what we have achieved in our project, is regarded to be a satisfactory result [6, 7].

3.2 Software package for Desktop Mapping

A number of software packages based on GIS technologies and relying on different computer platforms are available worldwide. Because of the advantages reflected in the analysis of spatial data and in certain logical and mathematical models supporting planning, decision making and management process, we have decided to use MapInfo software with associated programs (Map Basic and Vertical Mapper) in solving our task of retail network reengineering. We have chosen Mapinfo software because it is simple to use (compared with, say, Arcview software) and yields better data visualization, which facilitates considerably the process of further analysis. The Vertical mapper software, produced by Northwood Technologies, Inc., a Marconi Company, offers a wide range of analytical tools operating in GIS environment. Vertical Mapper features modelling tools and a full suite of interpolators based on all standard estimation principles that let you build continuous surfaces, or grids, from existing point files or unmapped tables, regardless of data type. This software has robust spatial analysis capabilities that help us gain a new insight from grid data.

3.3 Vector maps

A vector map has been made on the basis of geodesic survey data sets and positioning of points using a GPS receiver. The position of the existing retail outlets, i.e., legal persons, on a city map has been determined by a geo-coding procedure. Firms and retail outlets have been positioned on a city map by connecting the coordinates and addresses of objects on a vector map, on the one hand, and a database with the addresses of firms and outlets, on the other. On the other hand, information on the number of inhabitants living in an object has been associated to each object. Data from databases are represented on a map in the form of a number of layers:

- Rank of City street network;
- Positions of residential objects – *building, information on a street, number and the number of inhabitants* (*household members*);
- Positions of business objects – *information on its name, business activity code, address and the assigned ''business weight''* (*W*);
- Locations of existing postal retail outlets – *information on its name, volume of services, income, expenses and real estate ownership*;
- Public transport stations and routes – *on selecting a station, all lines passing through it are displayed.*

The stated layers represent the basis for forming additional layers that will be used in the analysis.

3.4 Spatial data display

Data display (presentation) on a map is provided by MapInfo software. MapInfo uses three basic data types: polygons, lines and points. These objects may be used to present discrete values of spatial data. A problem arising in data application and analysis lies in that their presentation does not show how values vary from one location to another. A solution to this problem is offered by Vertical Mapper software which creates a new type of spatial data known as *a grid*. It provides the possibility of presenting data in con-

tinuity and this permits us to observe the trend of the variation of a value in any map area. This is a grid of cells (squares) covering some area on a map. Each cell has a node located at its centre. A cell can be assigned a value and a colour representing this value. If there are several cells between two known locations (between points or contours), changes in colour represent changes in parameter values. To present changes in some quantity between the known locations, it is necessary to apply some techniques to estimate these values. Interpolation with inverse distance weighting (IDW) has been applied in the analysis of retail outlet location. The application of IDW method requires previous aggregation of points on a map. *Aggregation* is a mathematical process of reducing the number of points on a map and is performed in cases when a large number of points is grouped on some locations. To shorten the calculation time, the values of all the points of an area in a specified radius are summed and one point is set to represent that area. In the aggregation of points on the map of Belgrade, a 50m radius has been used for the central area and 150m for the remaining parts. We have accepted these parameters because of the higher density of address points per square unit in central city zones compared with peripheral ones, and the processing time is much shorter. If the analysis is performed on a less restricted space, smaller aggregation parameter values are taken. In our analysis we have tested the use of other values (60 and 140m) of aggregation parameters, but we recorded no serious effects on the final result.

A representative point is located at the geometrical centre of the original group of points. Having completed the aggregation procedure, we proceed to applying interpolation with inverse distance weighting. This method estimates the value of each cell as the average sum of weight coefficients at points covered by a specified radius. A 300m radius has been used for the central Belgrade zone and a 500m radius for the remaining parts for purposes of the postal retail outlet "Location Analysis" [8].

We have accepted these parameter values for two reasons. First, we have estimated that the potential users located in the covered zone (those who either live there or spend there a larger part of the day) will gravitate, with high probability, to the associated retail outlet. In principle, the choice of these values depends on the type of analysis. If we wish to locate, for example, a store selling food products to which users gravitate every day (unlike a post office), we will use shorter radius values. On the other hand, we have tested different values of IDW parameters and their effect on the formation of grid line in the sense of colour nuances transforming gradually from darker to lighter ones. This visualization is very important in the locating process and it is the clearest when 300 and 500m radius are used.

4. AMBIENT AND LOCAL CONDITIONS IN LOCATION ANALYSIS OF POSTAL RETAIL OUTLETS APPROACH

The elements of location analysis model have to be adapted to local environmental conditions and users behaviours. Their characteristics in case of retail service of the Republic of Serbia are [9]:

- A growing number of distributing retail chains with a wide variety of services;
- Significant participation of cash in retail money transactions;
- Insignificant participation of alternative electronic services such as ATM and e-banking;
- Unequal accessibility based on retail location;
- Insufficiently researched micro market potential;
- Undeveloped data market necessary for the analysis.

The parameters for location analysis of postal retail outlets model are defined based on the above mentioned premises.

4.1 The nature of postal retail business

The postal retail segment is a part of postal system communicating directly with individual users. The main features specific of this service may be systematized as follows:

- Provision of a part of payment operations and trading services (in addition to the basic postal services);
- Sharp competition with banks and trading & distribution companies;
- Requirement of being physically accessible on the whole territory of a country regardless of market potentials;
- Different approaches in rural and urban areas (this paper addresses the problem in an urban area);
- Severe accessibility criterion in urban areas (no more than 1,000m to any user);
- High establishment and maintenance costs.

The highest of all fixed costs of postal operations is incurred by this segment; reengineering is therefore aimed at making this segment profitable taking into account the mentioned constraints. Budget allocated to these activities is designed to satisfy the mentioned criteria, but any savings (achieved through franchising, for example) may be redirected to more profitable activities, such as distribution of commodities or direct mail. On the other hand, retail service quality has to be improved constantly because users require rather high quality standards. The accessibility criterion is satisfied by establishing at least one retail outlet per

market zone. If the potentials of that micro-market are respectable, additional outlets are established, mainly through franchising tools. As postal retailing faces the same challenges and goals as any other retail sector, the procedures required to be performed are specific and are not related closely to the basic postal (distributive) activity.

4.2 Accessibility criterion

The accessibility criterion specifies the requirement each postal operator has to satisfy concerning the coverage of the entire operator's business territory by a retail network.

Accessibility criterion in urban areas can be defined in different ways such as:

- The maximum distances to the nearest postal retail outlet covered by the user;
- ''Minute zone'' criterion which defines the minutes of walking to the nearest retail outlet;
- Territory in which it is necessary to establish at least one postal retail outlet.

For the purposes of the analysis, we have chosen the maximum distance to the nearest postal retail outlet covered by the user. By using GIS we can locate almost all users of postal retail services and calculate the covered distance to the nearest postal outlet by each of them. We define the accessibility criterion so that the maximum distance cannot exceed 1km. By defining this criterion environmental conditions are users' behaviours (most of them demand services within their residential areas). The daily migration of inhabitants which is on a lower level than in other countries. On the other hand CPC (Canada Post Corporation) define accessibility criterion as 2km cover distance taking into consideration the large territory of their cities and higher daily migrations (from residential to business parts of the cities and vice versa). In *Figure 1* the accessibility criteria for Belgrade postal retail service market are presented. These criteria are defined in accordance with the previous facts of a maximum cover distance to the nearest postal retail outlet (1km) [9].

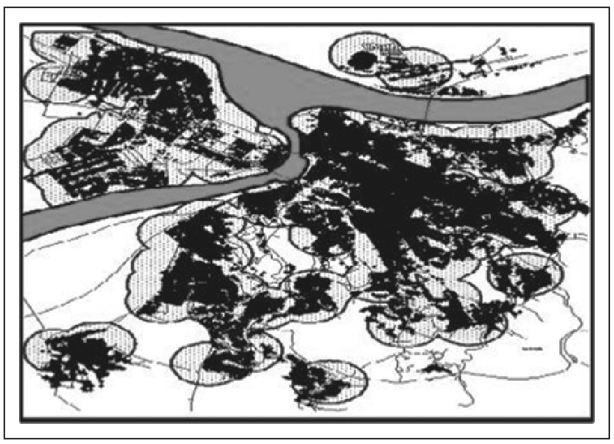

Figure 1 - Fulfilled accessibility criteria for Belgrade post retail market [10]

In the shaded grid areas (inside the circle within 1km radius) the accessibility criteria are fulfilled, as opposed to the external zones. The parts of Belgrade out of the grid shaded areas (circles) are mostly parks and industrial zones with a low retail market potential.

4.3 Creating market zone process

A market zone represents a micro-zone of retail services to which a certain number of inhabitants and legal entities belong, on the one hand; on the other, that area is a whole according to urbanistic criteria.

The population certainly does not gravitate towards the centre every day in order to carry out some everyday activities. The aim is to divide the city area into zones that contain a local centre towards which the population gravitates every day. For the purposes of this research we accept the criterion stating that at least one retail outlet should be positioned in each market zone. In determining the market zones the boundaries of housing units have been used as a parameter. A housing unit is the basic functional unit of urban structure whose size depends on the following factors:

- *Spatial-functional structure and arrangement of objects* – Depends on the type of construction and objects. These factors define the number of inhabitants as an important factor in defining a market zone.
- *Social organization concept* – As far as this aspect is concerned, the smallest unit for which accompanying facilities are constructed consists of 5-6,000 inhabitants. With a number (3-4) of such units a centre of a more complex structure is planned, which may be the location of a potential retail outlet.
- *Functional concept of traffic* – This factor also affects the sizing of a housing unit territory. An optimally shaped and sized housing unit would be a 1x2 rectangle. Centrally placed accompanying functions would permit distances shorter than 1km to a retail outlet [11, 12].

Market zones required for the purposes of our analysis have been formed taking into account factors that affect the creation of the boundaries of housing units (position, gravitation of 6-12,000 inhabitants, distances). In CPC model the market zones are defined in frames bordered by highly frequented streets with retail centres within each frame, but without defined territory or number of inhabitants in the frame and market zone. An example of defined market zones in New Belgrade is presented in *Figure 2*.

As we can see in *Figure 2*, the New Belgrade market is divided into the market zones according to the

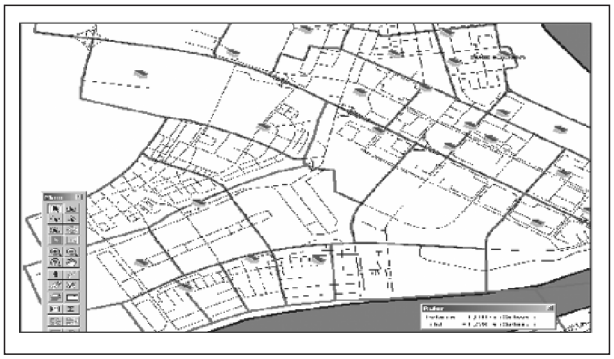

Figure 2 - Market zones in New Belgrade [10]

previously defined criteria (market zones are bordered with the bold lines on the map). In each of them it is necessary to establish at least one or more postal retail outlets on the optimal locations, depending on the micro-market potential. The existing postal retail outlets are marked with the square symbol.

4.4 The influence of location of consumers, commercial users and public transportation routes on the proposed model

The resulting layer of GIS helps us to determine the optimal retail outlet location in the defining market zone. Special data are displayed as a grid line. Darker parts in the grid line represent better locations for postal retail outlet. In Canadian model the resulting model is mostly influenced by location of commercial users and administration. Namely, common Canadian users demand this kind of service at the locations which they frequently cover during the day (shopping malls, business areas, administrative areas, school centres...) i.e. they do not need postal services in the vicinity of the residential area, as most of the requirements are satisfied from home through the internet, for example. However, Serbian users have slightly different requirements since, as mentioned before, the daily migrations are low. Therefore, it is necessary to provide retail postal services in the vicinity of the residential area. Opposite to ''North American'' city concept, residential and business areas are not strictly divided. Most inhabitants use public transportation, so the public transportation routes should be taken into the resulting layer of GIS. For the purposes of ''Commercial users layer'' it is necessary to perform certain preparations. These preparations are related to determining the different ''type of business weights'' depending on their business classification. For that reason we have classified ''type of business weight'' of 1,427 business activities in Serbia. The weight criteria range from 1 to 10 with the exception of major city malls (Rodic, Maxi, Vero...) which have been assigned 100. The sum of the ''weights'' represents the values of cells on the vector map. The resulting GIS layer is the result of aggregation of commercial users, consumers and public transportation routes in proportion 4:2:1 which means that the commercial users level is twice as important as the consumer level, and four times more influential than public transportation route level [13, 14].

In the following Figures 3 and 4 the grid lines of different grey levels are presented. The high grey level with concentrated circles marks the areas with a significant potential of consumers and commercial users respectively, as well as the locations where common people use most of the daily retail activities.

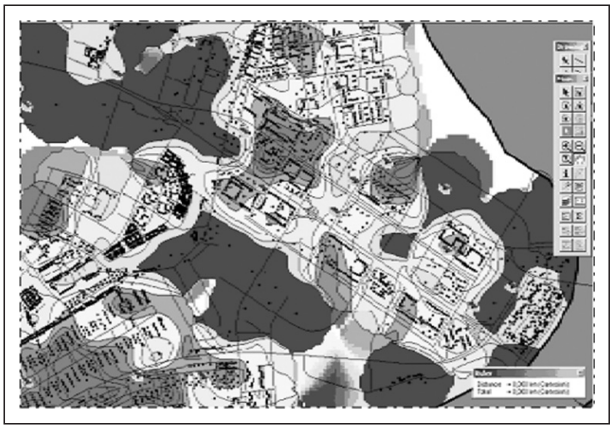

Figure 3 - Consumers layer [10]

Figure 4 - Commercial users layer [10]

In *Figure 5* the public transportation routes layer is shown. We are able to collect more quality information about the consumers' daily migration through the public transportation routes and stations from the GIS data.

The resulting GIS layer for Location analysis of retail postal outlets in Belgrade is presented in *Figure 6*.

The optimal location of postal retail outlets process consists of several steps. Firstly, the ideal locations in each market zone are marked with the grey level with highest density of concentrated circles. Secondly, the spots with a lower grey level with concentrated circles are determined. For the start, the market zones with-

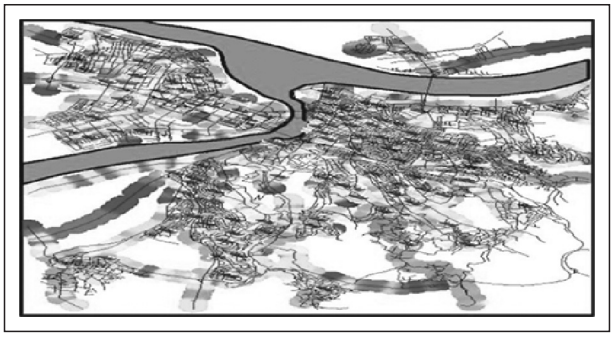

Figure 5 - Public transportation routes layer [10]

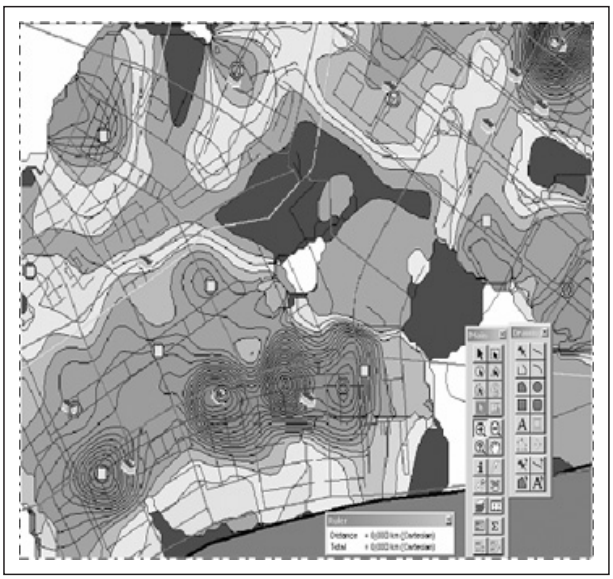

Figure 6 - Resulting GIS layer (consumers, commercial users and public transportation routes) for Belgrade market [10]

out existing postal outlets are considered, in the sense of locating an outlet at the best location. In the next phase, new sites in the highly potential market zones are determined in the sense of unburdening the existing postal retail outlet. During these activities it is necessary to pay attention to the spots of the existing postal outlets in the neighbouring market zones with the existing postal outlets to avoid nearby locations. In the rented facilities with a low level of revenue, it is necessary to suggest the best alternative location.

5. CONCLUSION

The procedure of retail outlet location analysis is a very important stage of the process of retail network reengineering, as witnessed by the fact that large retail chains attach greatest attention to this problem. On the other hand, the position of postal retailing, as an activity of public importance, is somewhat specific. It is necessary to cover a whole urban area according to rather severe accessibility criteria (no more than 1,000m to each user) achieving at the same time a certain profitability level. By consequent reengineering of the postal retail network, which involves, in addition to location analysis, the analysis of business results, the analysis of market potentials of a micro-market, the analysis of competitors and the implementation of a franchising program, postal retailing is turning more and more into a commercial activity rather than an administrative service. Data required for these analyses are generated using a GIS and processed by appropriate software tools. As the postal retail network is used by almost all citizens of a country, the process of reengineering, which also includes location analysis, is strongly influenced by local ambient conditions and user behaviour. The strong influence of these factors is especially present in the description of daily population migration; this is illustrated by the example of different approaches employed by the Canadian and Serbian Post.

Experience gained through the process of postal retail network reengineering is particularly important for further restructuring of the complete postal activity, which is now in progress in the majority of transition countries.

Dr **NIKOLA TRUBINT**
E-mail: nikola.trubint@rapus.rs
Republička agencija za poštanske usluge
Omladinskih brigada 1, 11070 Novi Beograd, Srbija

REZIME

ODREĐIVANJE LOKACIJE POŠTANSKOG MALOPRODAJNOG PUNKTA PRIMENOM GIS APLIKACIJE

Upotreba Geografskog informacionog sistema (GIS) je sve više prisutna u rešavanju široke lepeze problema u poštanskom saobraćaju. Ovakav pristup omogućava razvoj i primenu novih metoda analize prostornih podataka, u cilju podrške donošenju kvalitetnih poslovnih odluka. Primena modela Analize lokacije bazirane na GIS aplikaciji je implementirana u rešavanju problema optimalne lokacije poštanskog maloprodajnog punkta na teritoriji grada Begrada. Kao jedinstveno iskustvo u projektovanju i implementaciji modela izdvaja se snažan uticaj lokalnih faktora okruženja kako na strateškom , tako i na operativnom nivou. Deo materijala prezentovanog u radu proističe iz zajedničkog projekta Pošte Srbije i Kanadske pošte (Canadian post corporation) ''Analiza Lokacije''

KLJUČNE REČI

Lokacija, Maloprodaja, GIS, Poštanski punkt

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