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DETERMINING AN OPTMAL RETAIL LOCATION BY USING GIS

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Abstract: Reengineering of retail networks is a continual process that has been in the forefront of management attention worldwide. The central question is how to achieve positive business results under high costs, but at the same time maintain the attained service quality. This reeingieering process may be implemented successfully only if preceded by detailed preparations concerning, primarily, the analysis of business results, market potentials and **retail outlet location**. GIS tools offer a strong support to this process. Apart from theoretical considerations, this paper will also present the use of GIS as a tool in determining the optimal locations of the Serbian post retail.

Keywords: GIS, location, retail outlet, market zone

1. INTRODUCTION

Location problems, i.e., determining the number and locations of objects in a street network, are strategic in nature. Making decisions on where to locate objects intended for particular purposes is a very complex process bearing high responsibility. Since these decisions may refer to plans for constructng and exploiting objects over a longer time period, they also involve the allocation of considerable amounts of financial resources. The second half of the twentieth century has seen the development of several algorithms for solving location problems based on mathematical programming and graph theory. The specific problem of locating a retail network in urban areas has become a topic of interest in the last decade of the twentieth century. The pratical application of these, as well as the generation of new, algorithms has been promoted by computer technology development. 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).

A brief review of theoretical approaches to solving the multidisciplinary problem of locating retail outlets in urban areas is given in Section 2, whereas Section 3 provides a detailed explanation of the process of solving location problems by using a GIS under conditions matched to the environment in which the project is implemented (Belgrade, Serbia). Finally, Section 4 presents the practical application of the procedure in the form of results obtained by the Analysis of postal retail outlet locations in the City of Belgrade. The analysis of postal retail outlet locations has been performed using the MapInfro software package in Desktop mapping process. Databases on demographic and business populations have also been employed as well as a vector-based map of Belgrade.

2. RETAIL OUTLET LOCATION PROBLEM

Locating retail outlets of profit organizations (in commercially attractive urban areas) has become a discipline in which location problems are approached in a specific way. The growing number of retail traders makes the problem increasingly important and that is why specific expert methods to solve it have been developed. In general, the approach to solving this type of problem is based on the use of GIS tools. According to Prof. Harrington (*James W: Harrington, University of Washington – Seatlle,USA)*, the whole procedure may be divided into a number of steps:

2.1. Defining a strategy of retail service delivery

Before starting to perform it, any analysis has to be matched with the strategy of retail service provision, if this is available; if not, every effort must be made to create and adopt this strategy. We need strategy elements to define numerous procedures forming part of this process. The most important issues that have to be specified are as follows:

1. What areas are target markets? (To provide support to treating these issues, *Ghosh* and *Mclafferty* defined a Market Selection Scale in 1998)
2. How many retail outlets should be served on a selected or desired market ?
3. Where should every single retail outlet be located ?
4. What mix of products and services is optimal for a particular retail outlet ?

Having answered these questions properly, we may proceed to solving the retail outlet location problem.

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2.2. Solving the retail outlet location problem

In general, two approaches are distinguishable within solving this problem:
A nonsystems approach – relies on observing the environment or imitating local competitors' solutions
A systems approach process – takes market zone size and potentials into consideration
The systems approach to process of locating retail outlets involved the following steps:

- Specify the influence of market zone size by
  - using a conventional method
  - forecasting taking into account the existing users (specify the radius of high-quality service). Identify (and preferably rank) preference market zones of known size
  - Consider general "desirable" attributes of market zones - *Ghosh* and *McLafferty* have considered the following parameters: construction of new objects, growth of the number of single users, growth of business or of population gravitating towards these businesses. Taking all these facotrs into account, they have concluded that it is always better to locate a retail outlet in an area under development or construction.
  - Employ analog technique – observe the characteristics of similar market zones containing retail outlets
  - Analyze a market zone – this procedure requires the knowledge of geodemographic and life-style data in a particular market zone.

The previous three techniques ignore the following two very important facts:

- There always exist a certain number of users located out of a market zone who use the services of an outlet in that zone; on the other hand, users located near a boundary of a zone may use the retail services of some other outlet.
- The characteristics of existing market zones do not depend exclusively on the business you are in; rather, they depend on competitors' locations and characteristics.

Identify competition degrees on various markets – To be able to answer this question, we may consider the so-called *saturation index,* I, of a zone. This index expresses the ratio of business "space" planned for retail activities to the maximum value of this space achievable in any market zone.

2.3. Market zone modeling based on competitors' locations

This part of the analysis defines various approaches to estimating competitors' influence, i.e., users' gravitation to a particular market zone. According to one formulation, known in the literature as the ***Reilly law of retail gravitation***, "The attraction of a consumer to a given retailer is directly proportional to the quality of retailer and inversely proportional to the distance to the retailer" [12]. This approach may be used, together with GIS, for generating polygons on a map in which a line of "demarcation" from competitors is shown clearly.

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2.4. Estimating the number of users on each potential location

This is a very important step in which we should forecast the number of potential users according to any point in which a retail outlet exists (or is planned to be located). This step involves the following activities:

- Identify ”the origin and gravitation” of retail service users

This activity is intended to observe, estimate and map ”the origin” of existing users. It may be performed using a variety of sources

- in-house questionnaires
- statistical data from an outlet
- ”reply mail”coupons sent to users’ addresses
- data collected from a postal address code
- the available databases of statistical offices, public utility companies, etc.

Collected data are easy to map using GIS tools, which are also very useful for intra-zone analyses as well as for estimating market ”penetration”.

- *Statistical analyses*

These refer mainly to systematic monitoring of demand and costs for each outlet in order to achieve the best possible business result.

Sale expectations at a point ”j” with users at a point ”i” may be

- Increased through higher outlet attractivity
- Increased through a higher demand generated at a point ”i”
- Decreased by increased distance (distance costs) between them
- Decreased by the number of other destinations ”j” or by competition

- *Geodemographic marketing*

This approach assumes that some retail markets are highly fragmented in a geographical sense. In some cases, certain parts of a retailer’s work area cannot be covered by geographically-targeted promotional activities (e.g., *direct mail*, questionnarires). In such cases we employ an analog geodemographic marketing approach, i.e., we make conclusions based on data collected in”the neighbourhood”.
The following cases are charactristic:

- Mapping of users in order to determine their source
- Identification of the main environmental characteristics
- Identification of the remaining markets with similar general characteristics.

Activities mentioned in this review represent guidelines in solving this complicated multidisciplinary problem. Taking into account environmental characteristics, which refer to the way retail activities are perfomed, user habits and the available statistical databases, a more detailed plan of activities is made. This will be addressed in the following sections.

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3. GIS USED IN SOLVING LOCATION PROBLEMS

The main advantage of GIS, the possibility of integrating spatial and alphanumeric data, has made it widely applicable to a variety of fields. Companies that have made large investments in GIS have achieved considerable cost savings. Some of the fields in which GIS is applied successfully include:

- location analysis
- route and timetable scheduling
- market analysis (demand for various services
- marketing analyses
- urban construction planning
- cost analyses
- cadastral data
- resource allocation.

GIS allows new processing methods to be used and provides high-quality presenation of processed data. These characteristics make it an unavoidable decisionmaking tool in situations 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 a better and more organized analysis of information, which is a prerequisite for making quality decisions.

Our analysis of retail outlet locations is supported by MapInfo software package for Desktop Mapping. We also use vector maps of the urban parts (towns) of Serbia. The required databases are as follows: demographic data, business demography, portions of urban infrastructure databases as well as databases of existing retail outlets.

3.1 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, decisionmaking and management process, we have decided to use MapInfo software with associated programs in solving our task of retail network reeingineering.

- **MapInfo** – software based on GIS technologies, developed by MapInfo Corporation (New York). It provides the following capabilities: data presentation on a map, display of charts and trends, search by various queries, use of maps for database operation, use of mathematical and logical models.
- **MapBasic** – programming language for developing applications in MapInfo. Used to support, in the same sense, certain procedures not supported in standard MapInfo options.
- **Vertical Mapper** – software used to supplement MapInfo. Developed by Northwood Tecnologies, Ottawa. Employs various mathematical models for the creation of graphical attributes, which provide the possibility of analyzing spatial data from several viewpoints.

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3.2. 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: We must note here that precise statistical data on population density on the terrirory of Serbia are not available. Data available from the census relate to territorial units of such size as is not adequate enough for locating retail service users. To form a demographical database, initial databases from the following sources may be used: Serbian Statistics Office, Serbian Electric Power Industry, Telecom, City Water Supply organizations. After a transformation, a demographic database should contain the following attributes: **a 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: Serbian Statistics Office, SerbianTax Administration, Telecom. 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.

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, aveage income, average expenses, the number of employees, ownership.** These data are used to estimate retail outlet profitability. 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.

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 geocoding 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 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 the above mentioned databases are represented on a map in the form of a number of layers:

- City street network – on selecting a street on a map, information on street name and rank is displayed

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- Positions of residential objects – on selecting any building, information on a street, number and the number of inhabitants (household members) is dislayed
- Positions of busines objects – on selecting a firm, information on its name, business activity code, address and the assigned weight is displayed
- Locations of existing retail outlets – on selecting a retail outlet, information on its name, volume of services, income, expenses and ownership is displayed.
- Public transport stations and routes – on selecting a station, all lines passing thorugh it are displayed

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

3.4. Market zones

One among the prerquisites for starting the analysis is to divide a city into the so-called market zones. The population certainly does not gravitate towards the center every day in order to carry out some everyday activities. The aim is to divide the city area into zones that contain some local center towards which the poluation gravitates every day. For the purposes of this research we accept a 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 a parameter. A housing unit is the basic functional unit of urban structure whose size depends on the following factors:

- **Spatial-functional structure and arangement 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 5-6000 inhabitants. With a number (3-4) of such units a center 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 1 km to a retail outlet.

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 6-12000 inhabitants, distances).

3.5. 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 continuity and this permits us to observe the trend of the variation of a value in any map area.

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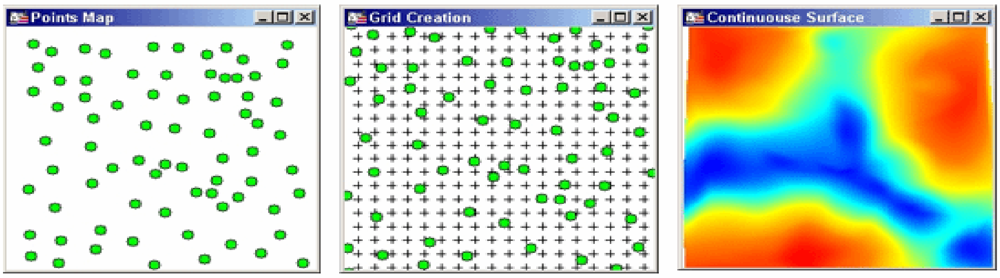

Figure 1: Grid formation [15]

This is a grid of cells (squares) covering some area on a map. Each cell has a node located at its center. 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 present changes in parameter values. To present changes in some quantity between 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 a 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 points of an area in a specified radius are summed and one point is set to represent that area (Fig. 1). In the aggregation of points on the map of Belgrade, a 50 m radius has been used for the central area and 150 m for the remaining parts. A represenative point is located at the geometrical center 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 300 m radius has been used for the central Belgrade zone and a 500 m radius for the remaining parts for purposes of the project “Location Analysis”.

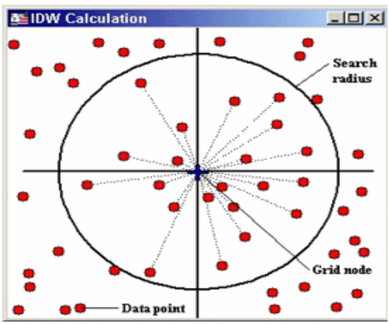

Figure 2 : IDW calculation [15]

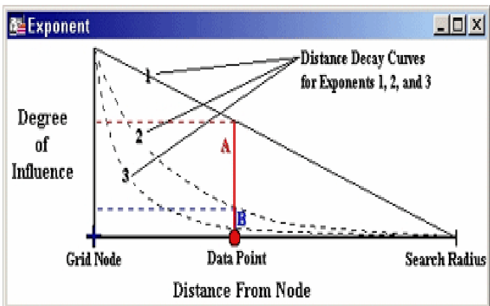

Figure 3 : Degree of influence based on distance from node [15]

An exponential function with exponent 2 is used in summing the values of weight coefficients. This means, practically, that weight values decrease exponentially with an increase in distance from the center. The influence of points (firms, housing objects) located in the vicinity of the best location (point) decreases with an increasing distance within a specified radius. Interpolation of map surface has been used to provide continuity of change in weight values in all map cells.

3.6. Comments on the procedure applied

Location problems arising in practice are, often, not a representative of single theoretical models but of their combination. Locating retail outlets is a multidisciplinary problem. If treating it from the viewpoint of a minimum distance to a retail outlet, we deal with the problem of minimizing a mean distance. On the other hand, users' behaviour and gravitation towards a particular retail outlet is stochastic in nature, whereas input parameters (databases) are variables (a dynamic component).

There are, of course, many other factors we have to take simultaneously into consideration (we observe several layers simultaneously). In some cases the procedure described in the preceding Section is combined with site verification and, possibly, some multicriteria analysis method for selecting an alternative location. All these facts suggest the use of GIS in solving complex strategic location problems. In the following Section we will present the solutions obtained in solving the problem of locating Serbian PTT retail outlets on the territory of Belgrade.

4. CASE STUDY (Results of Location Analysis for Postal Retail Outlets on the Territory of Belgrade)

A wide variety of results may be obtained by applying the procedure described. A part of these results refers to locations (optimal and alternative) and a part to market zones in which optimal locations are positioned. As has been stated, the problem of finding an optimal retail outlet location is multidisciplinary in nature, i.e., in addition to finding the best solutions in the sense of a minimum distance covered it is also necessary to resolve dilemmas regarding optimal market potentials (demand for services) and make decisions on alternative locations within a market zone. The project "Location Analysis" is also intended to provide support to "Franchising in Serbian PTT" Program, which represents a strategic approch to a retail network reengineering process.

The following requirements were a starting point in location analysis for postal retail outlets on the territory of Belgrade:

- Accessibility criterion – a postal retail outlet should be accessible to users within a distance shorter than 1 km
- In each market zone it is necessary to determine the location of at least one postal retail outlet. Criteria for determining a market zone have been referred to in the preceding text.

Reports, i.e., analyses may also be grouped into three categories:

- Reports relating to layers formed on a vector map
- Reports relating to market zones
- SVB – site verification book - visual verification of proposed locations

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4.1. Reports relating to layers formed on a vector map

Using MapInfo and Vertical Mapper and the previously described methods, the following thematic layers have been formed on the vector map of Belgrade:

- street network with the existing postal retail outlets and market zones
- positions and densities of legal and natural persons
- positions of objects and population density
- positions and frequencies of public transport lines
- ideal and potential retail outlet locations
- 1 km radius circles circumscribing postal retail outlets (accessibility criterion)
- forecasted population gravitation towards ideal locations (Huff model).

The layers formed may be combined in various ways for the purpose of analyses needed by network managers.

Example: A layer showing the quality of designed network in the sense of accesibility (distance to the nearest outlet shorter than 1 km)

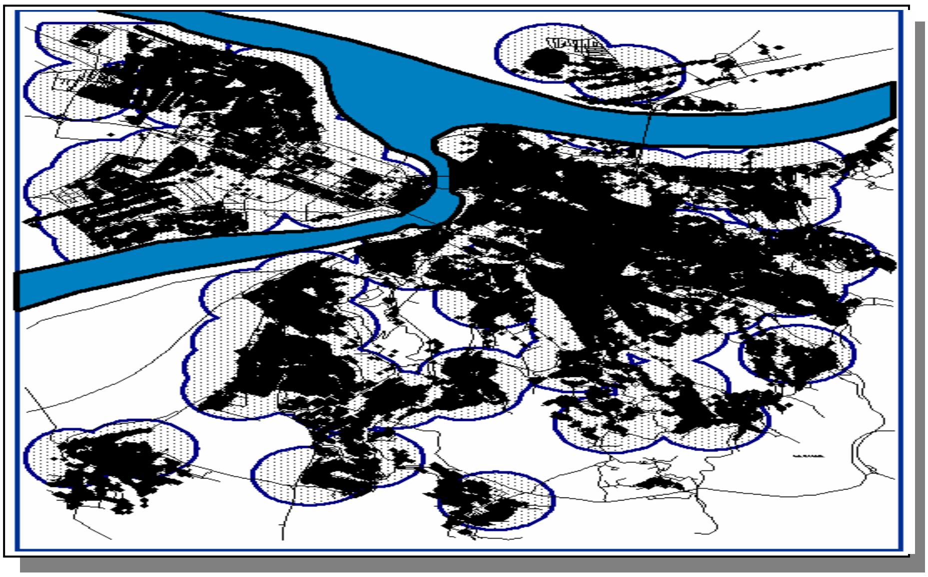

Figure 4: Quality of designed network in the sense accessibility [9]

It may be seen from the presented map that nearly the whole territory of Belgrade is covered by the specified accessibility criterion. The parts of city that are not covered represent areas with minimum population densities or are forest zones, river banks, parks.

The described analyses and reports lead to the following conclusions:

- 116 postal retail outlet locations have been analyzed
- the Belgrade market has been divided into 95 market zones
- 35 (30%) of postal retail outlets are not situated on optimal locations

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- there are 12 market zones (12%) without a postal retail outlet
- 39 retail outlets (36%) are “overloaded”, which results in a poorer quality of service
- 40% of retail outlets do not achieve satisfactory profitability
- 47 (40.5%) retail outlets are rented objects and 59 (59.4%) are owned by PTT [9]

4.2. Reports relating to market zones

In addition to the mentioned documents, it is also possible to create separate reports for each of 95 market zones. These include a graphical presentation made using the Mapbasic software and a report containing the following data: the name and address of proposed location, the number of inhabitants and legal persons.

Example: Market zone in Zemun

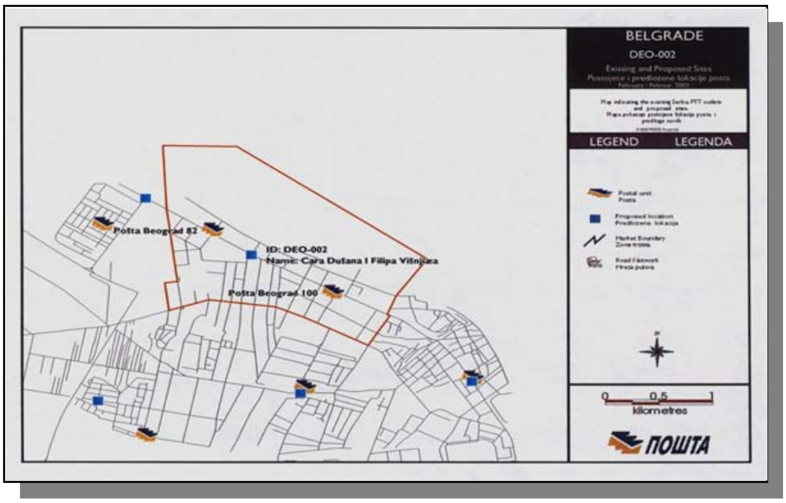

Figure 5 : Market zone in Zemun [9]

In this market zone there are two postal retail outlets and the optimal location is in the middle (a square). Through high-quality capacity design two retail outlets could be substituted by one with considerably higher profitability. There are 122 legal persons (commercial users) and 8952 inhabitants in this zone.

4.3. SVB – Site verification book

SVB is a site report including a graphical presentation of a location and the evaluation of its quality in the sense of object type and purpose, parking place availability, etc. SVB is made for all of the existing and proposed locations. It is often impossible to establish a retail outlet on an optimal location for the following reasons:

- Some general-purpose object (a church, school) or some object with inadequate space is situated on that location
- Parking place unavailable
- Too high rental fee

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The Site verification book also includes alternative locations (2-4) in the vicinity of the optimal one, on which a retail outlet may be established. The choice can be made by applying some multicriteria analysis method. Criteria include: area, rental fee, parking availability, technical conditions, etc. In the project described in this paper the Promethee method and Decision Lab 2000 software package have been used.

5. CONCLUSION

Location theory is a transportation discipline that has recently undergone rapid growth. The basic today's approach to these problems becomes more and more multidisciplinary-oriented. It often proves insufficient to solve a location problem in the sense of solving one of the theoretical models – a variety of other factors have to be included as well, depending on the problem formulated. This is why location models for urban environments have recently been developed. For the problem addressed in this paper, finding optimal retail outlet locations, criteria to be considered include: profitability, quality of service, urban construction criteria. Geographic information systems provide valuable support in this regard. GIS tools will certainly not provide exact results, but will allow us to include a variety of factors into consideration without increasing considerably data processing time. By analyzing and combining the layers formed, we may reach conclusions helpful not only in finding an optimal location but also in retail network management.

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