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Digital geomarketing methods for analyzing the development of the economy of modern urban space

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Abstract. The paper proposes a method for conducting a digital analysis of geocompetition, which allows exploring the competitive environment on digital vector maps. The method includes four stages of analysis: the study of the competitive environment of the city using the function "density of nuclei"; statistical geoprocessing of data using the Clarke-Evans tool; the formation and visualization of the coverage areas of shopping facilities; creation of a polygonal topology based on Thiessen polygons to explore business opportunities for the spatial development of the city. The proposed methodology was tested on the data of the capital of the Republic of Crimea — Simferopol. The purpose of the study is to create a methodology that allows justifying the strategy of placing commercial enterprises based on digital geomarketing technologies. The study shows strong congestion of the city center with trade enterprises, high density of their location, exceeding the standard service areas by two and half times. It identifies the buffer zones around the stores and areas of supersaturated supply, which are the potential "cannibalization zones", that is, areas of potential risk for doing business. Recommendations were made on the use of geo-information technologies as a necessary tool for local authorities to make decisions regarding the issuance of licenses to commercial facilities in the context of the modern development of urban space and the digital economy.

1. Introduction

An increased interest in geographic information systems and their use as a platform for the digital economy was confirmed in August 2018, when at the eighth session of the UN Committee of Experts the creation of the World Geospatial Industry Council was announced. The contribution of geo-information technologies on a global scale in 2017 amounted to about $300 billion. Therefore, the development of innovation, business and entrepreneurship in modern urban spaces in the coming years is connected precisely with new technologies of geospatial analysis. The spatial location of retail facilities is of great importance in the development of modern cities, which has led to the relevance of the chosen research topic.

The purpose of the study is to create a methodology that allows justifying the strategy of placing commercial enterprises based on digital geomarketing technologies. The objectives of the study is to test the proposed methodology on data from Simferopol, to obtain new digital data on the placement of shopping facilities in the city, to identify the central problems associated with areas of increased

competition, to study the competitive environment and to develop recommendations for optimal planning of urban space.

When creating master plans for the cities, there are problems associated with the placement of objects of stationary trade in terms of the validity of decisions to issue licenses. The geoinformational technologies (GIS) are the modern tools to optimize the decision-making process in this area. The use of GIS for solving marketing problems has opened a new area of research called geomarketing. The geomarketing is defined in the work of P. Latour [1] as an integrated data system for decision-making based on specialized software, including statistical and graphical methods for processing digital information. There is the opinion of A. Baviera [2] that geomarketing has a wider toolkit that allows finding ways to meet the needs and desires of consumers in the modern digital space. In general, geomarketing includes such elements as: databases, cartographic information and software environment that allow using special modules to carry out statistical and analytical analysis of geodata.

2. Study methodology

There are two main approaches used in spatial analysis: analysis of geo-competition and analysis of geodetic data. Geodetic research methods include the analysis of geodetic data on trade objects; they are used to search for potential customers on a digital map, taking into account the population density residing in different parts of the city. Geocompetition determines the location of the analyzed objects on a digital vector map and allows to evaluate business competitors and to distinguish them by coverage areas or shopping areas. Note that the study of the essence of shopping areas as a geographic area, where the retail store carries out its sales, began in the works of 1961 by W. Appelbaum [3]. However, in 2012, the definition somewhat changed due to the work of A. Baviera [4], and now it is customary to define them as coverage areas, implying areas of influence of stores and including the territory adjacent to a shopping facility with its own infrastructure. As part of this study, a method of geocompetition analysis is proposed, which allows exploring the competitive environment on a digital map, since it is a key factor determining opportunities for business development.

The research method is implemented according to the following algorithm:

1) Study of the competitive environment of the city using the function "density of nuclei". Identification of competitors on a digital map with the definition of their shopping areas based on geographical coordinates (x, y), taking into account the addresses of shops.

2) Statistical geoprocessing, the calculation of the average nearest neighborhood using the Clarke-Evans tool, which allows determining the type of distribution of objects.

3) Analysis of the spatial location of the stores based on the data of gravity models. Establishment and visualization of the coverage areas of shopping facilities.

4) Creating a polygonal topology on the basis of Thiessen polygons for the study of business opportunities for the spatial development of the city.

The testing of the proposed research algorithm is implemented in a specialized software environment Arcgis. The study was conducted according to the data from Simferopol, the capital of the Republic of Crimea. The initial data were the data obtained from statistical sources [5] and the data of Roskadastr (Cadastral Register in Russia). The area of the studied city is 107.4 km^2. The population of the region is 361,647 people, including 45.4% of men and 54.6% of women. The trade enterprises of the city are represented by different types of objects, among which 3,448 are the stationary units and 7,920 are the kiosks.

Table 1. Number of trade enterprises operating in the city of Simferopol (as of 2017).

No.	Indicator name	Number, items
1	Stationary trading enterprises, including:	3,448
2	Hypermarkets	7
3	Department stores	19
4	Specialized food stores	243
5	Specialized non-food stores	1,671
6	Minimarkets	1,174

3. Results

At the first stage, a study was conducted to estimate the density of nuclei. This concept is associated with a non-parametric estimate of the density function of a random variable proposed by M. Rosenblatt in 1956 [6]. The nucleus density function is aimed at calculating the density of point objects in a given region of space in accordance with the distance between them and their weights. At the same time, there are different types of models describing the density of the nucleus, so A. Moreno [7], R. Vega [8] argue that the choice of the computational model is not important for assessing the quality of the analysis results. The quadratic nucleus function described in the works of B. Silverman [9] is integrated into the GIS software environment. Thus, the main unit of the study is a pixel, which is a square, designed to represent a shopping facility on a digital city map. The circular environment around each pixel on the map is used as its main boundary. At the same time, the centroid of each pixel is the center of the circle. Each point is weighed unevenly, according to the pattern: the closer to the centroid of the pixel, the greater is its weight, the farther from the center – the smaller is the weight. A study of the number of stores in Simferopol per 1 km^2 using the "density of nuclei" function was conducted with a search radius of 150 meters (figure 1) from a point object (commercial enterprise) and 500 meters (figure 2). On the vector digital map of the city 3,448 stationary trade enterprises are marked.
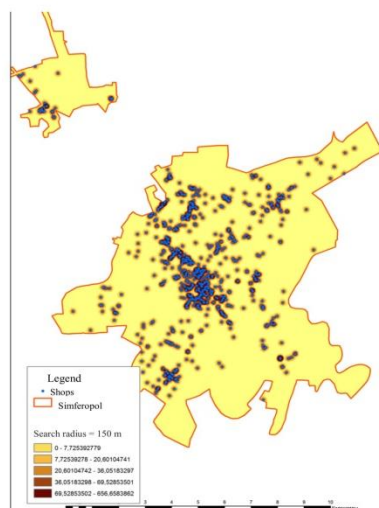

Figure 1. Study of the number of stores per 1 sq km using the function "Density of nuclei". Search radius 150 meters.
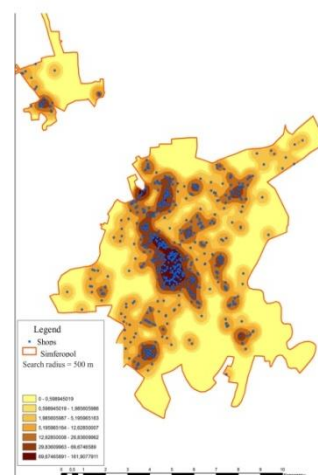
Figure 2. Study of the number of stores per 1 sq km using the function "Density of nuclei". Search radius 500 meters.

Although there exist different types of models when using Kernel estimators (Moreno 1991), Since the competitive environment is the leading factor that determines the location for opening new trading enterprises, the "density of nuclei" function allows visualizing areas of the city with a higher density of stores and areas with low sales offer. The figures show too much congestion in the center of the city, coinciding with the transport arteries and the unbalanced representation of trade enterprises on the periphery. In the work of P. Davis [10] it was shown that the spatial distribution of consumers and sellers influences the channels of distribution, the process of substitution by different types of trading enterprises occurs. This spatial dispersion, visualized with the help of GIS technologies, allows finding potential areas for opening new stores [11], hence the term "business opportunities", which refers to areas of the city with high population density and little commercial competition.

At the second stage of the analysis, statistical geoprocessing was carried out, calculating the average nearest neighborhood using the Clarke-Evans tool, which allows determining the type of distribution of trading objects in the studied space. Spatial statistics allows clarifying, what the distribution of shopping facilities on the map is: clustered, random and scattered, according to the values presented in figure 3.
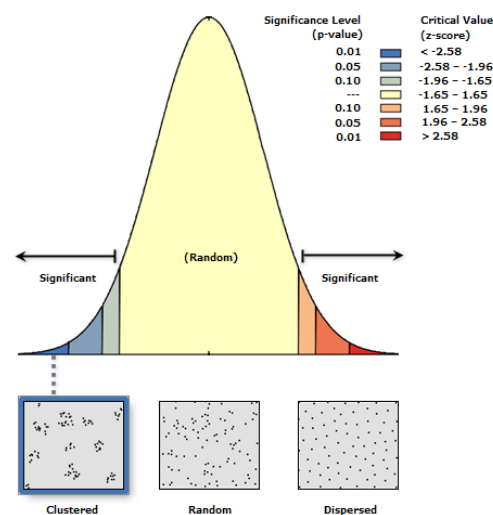

Figure 3. Average neighbor report.

The result of geoprocessing the average summary of the immediate neighborhood between the shopping facilities in Simferopol shows that the actual distance to the nearest store in Simferopol is 113 meters, and the expected − 170 meters. The immediate neighbor ratio is 0.663716, and the given z is the estimate: − 18.139324, which means that there is a probability of less than 1%, that the resulting distribution type is clustered, it is more likely that it is the result of a random choice. Distance method used: manhattan. Note that for the normal operation of a trading facility, the radius of its service should be more than 400 meters, while in the study area it is two and a half times less. This suggests that there is a serious overload with retail space that does not meet the standards of service areas [12].

At the third stage, the establishment and visualization of the areas covered by the trade objects is carried out. After visualizing competitors by geographic location and calculating the distances between them, the group of gravity models of Reilly, Huff, etc. [13] can be applied in the study. They allow calculating the probability of visiting a shopping facility, based on the area of a separate store and the distance between them, which is assumed to be about 8–15 minutes walk, which is equivalent to the maximum distance from 533 m to 1 km. The variation of the distance is related to the area of the store: the larger it is, the stronger is its gravitational force. When two or more service areas overlap due to the proximity between two or more stores, the resulting area has the sum of the corresponding retail space [14]. This means that potential customers living at the intersection have a wider choice of commercial offers of retail properties; these are the areas of rich supply (figure 4).
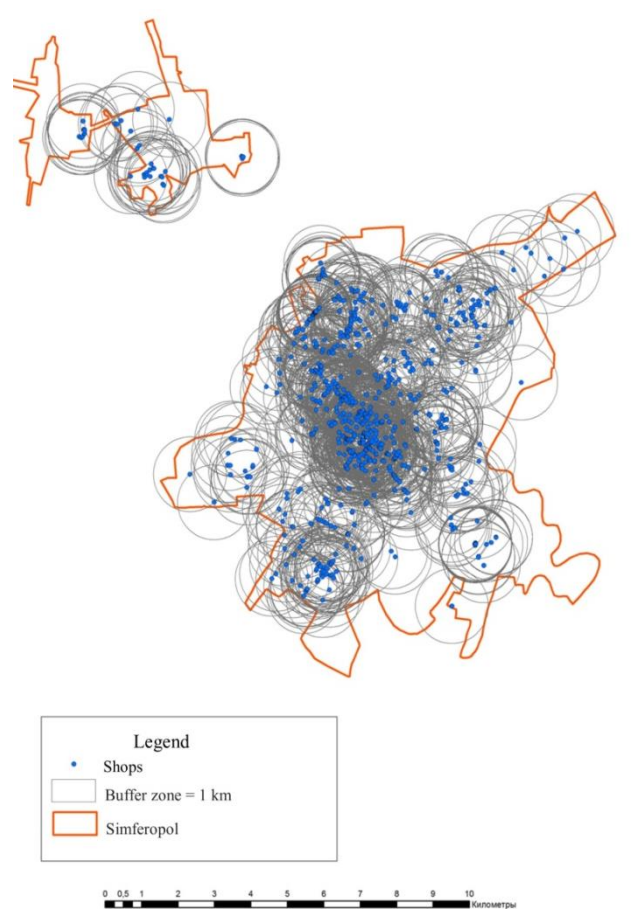
Figure 4. Allocation of buffer zones around trade enterprises with a radius of 1 km.

This process is known in the literature [15] as cannibalization, since commercial enterprises fight for their clients in these areas. According to the works of R. Suarez [16] modern interpretation of cannibalization states that it is the seizure of market share by the new store and the consumption of the existing ones.

At the fourth stage of the research algorithm, it is proposed to create Thiessen polygons to determine the study of business opportunities for the spatial development of the city. The justification of the correct strategy for locating a commercial enterprise in the literature [17] has been discussed since the 1980s, this is a strategy for positioning a commercial facility based on the competitive environment [18], but the opportunity to apply GIS technologies in such an analysis has been actively discussed with the works of A. Murad [19], when geoinformation maps were built for ease of decision making. The Thiessen (Voronoi) polygons integrated into GIS are used as convenient tools for such an analysis are (figure 5).
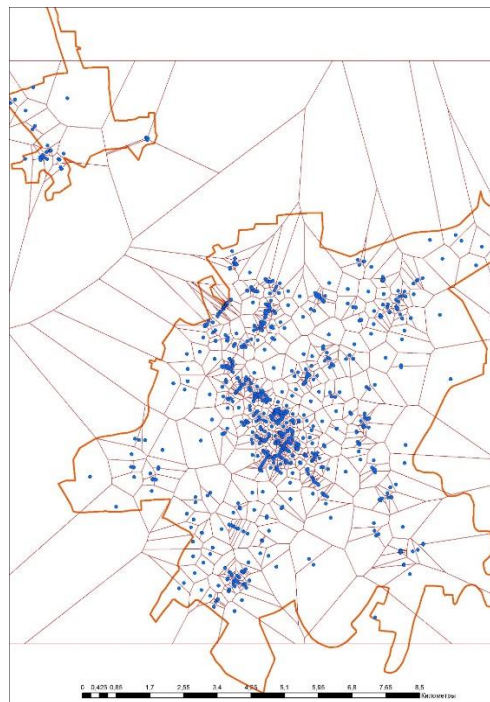
Figure 5. Thiessen polygons.

They have a unique property — they divide all the space between points (trading enterprises) and distribute the point coverage into regions (polygons) [20]. Input point objects are scanned from left to right and from top to bottom and then triangles are created in the Triangon irregular network. The Thiessen polygon is a natural neighborhood around a point; in this case, a commercial enterprise in its economic essence is the area of influence of stores.

4. Conclusions
As a result of the study based on the use of GIS, a competitive environment for the development of trade enterprises has been investigated. For the city under study, a strategy of optimal, rather than congested placement is necessary, which is possible based on scientifically-based service standards of at least 400 m between stores; while now it is 113 m. Statistical data processing using the Clarke-Evans tool showed that shopping facilities are currently randomly located. This, in turn, raises the problem of overlapping service areas and the emergence of areas of rich supply. Allocation of buffer zones around trade enterprises with a radius of 1 km revealed areas of rich supply, which become cannibalization areas, that is, areas of potential risk for doing business.

5. Directions for further research
They are associated with the need to use geo-information technologies as a necessary tool for local authorities to make decisions regarding the issuance of licenses to shopping facilities in the modern development of urban space and the digital economy.

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