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Combining GIS and the Analytic Hierarchy Process to Analyze Location of hypermarket

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Abstract. There are many relevant factors for the geographic location selection of hypermarket. Based on the analytic hierarchy process (AHP) method and spatial analysis of GIS, this paper builds the methodology for the process of selecting a supermarket site location. According to the analysis, there are 3 sites that are the right place for new supermarkets in Guiyang city. Each of the sites has its own advantages in such factors as population density, convenience of transportation, market competition and land prices.

1. Introduction
The retail industry is called the industry of location, so the selection of sites is important to retailing. After a systematic consideration, there are five main factors in the location of hypermarket: site, market, economic, population and transportation accessibility. However, the traditional methods of commercial site selection more depend on subjective experience of the operator or the classical mathematical methods. But the methods show a lack of intuitionism and scientific basis[1].

The analytic hierarchy process (AHP) is developed by Saaty and consists of defining a hierarchical model that represents complex problems through criteria and alternatives that are set out initially[2]. This procedure is designed to break a complex problem into a set of simpler decisions, thus making the problem easier to understand and therefore easier to solve[3].

GIS technology has the advantage of data synthesis, simulation and analysis functions. It has access to essential information that it is difficult to obtain by conventional technology[4]. Spatial analysis faculty of GIS has powerful ability, it provides a new way for locating supermarket. One of the reasons for the success of GIS is their capacity to generate visualizations of data, which greatly assist in such a complex decisionmaking process as retail site location[5-6]. In addition, GIS are capable of dealing with large quantities of information and linking digital maps to relational databases. The characteristics described here make GIS indispensable tools in the development of decision processes associated with retail site location selection [7].

This article finds out the major factors of retail location, and then studies locating new hypermarket in Guiyang city, by using spatial analysis of GIS and AHP methodology.

2. Methodology
Applying analytic hierarchy process, we calculate the weights of five main factors. The factors are site, market, economic, population and transportation accessibility. And all the land plots which are
endowed with weights are used to score through spatial analysis of GIS. At last the higher this score, the more the plot is suitable for hypermarket.

2.1 Site factor analysis
All the plots in Guiyang are extracted commercial space, and the spaces with an area less than 2500 square meters are deleted, then we get the distribution of commercial land that suits site for supermarket.

2.2 Market factor analysis
Searching the location of supermarket, it is to map the distribution of competitors.

Based on the central place theory, the market has to satisfy two conditions: profit-maximization and availability of services. The market is determined the rank based on the distance between the market and customers.

Service radius($r$) related to the distance between markets ($D$) was as follows[8]:

$$d = \sqrt{3}r$$

In general, the service radius of the small supermarkets is 500 meters[9]. And so on, through equation(1), the service radius of medium-sized supermarkets is 866 meters. By the same method, the service radius of supermarkets is 1500 meters, and the service radius of hypermarkets is 2598 meters. The each servant region of various kinds of supermarket is assigned grades 1 to 4, the more the radius, the higher the grade.

2.3 Economic factor analysis
In principle, the lower is the land price, the stronger is the willingness of the investors to do business. Therefore, according to the different prices, in accordance with the order from high to low the land price is divided into 4 grades, first grade for the maximum price.

2.4 Population factor analysis
Based on field investigations, we obtained the population of settlements in Guiyang. Then we can use spatial analysis of GIS to draw the map of people distributed. After calculating population density, the density also is divided into 4 grades, first grade for the minimum density.

2.5 Transportation accessibility analysis
The consumer sentiment is mainly affected by walking time. Therefore the influences on transportation accessibility are mainly major roads, bus stops and parking lots. A questionnaire survey shows that walking 2 minutes to 8 minutes to get to the supermarket might be most people agree on. According to the research, we build the buffers of major roads, bus stops and parking lots that buffering distances are 160m, 240m, 400m and 640m respectively. And the ranking is established through assigning 160m radius to 4, 240m radius to 3, 400m radius to 2, and 640m radius to 1.

2.6 Weight definition
In this paper, the weight of the each influence factor is determined by using Analytic Hierarchy Process(AHP)[8]. For convenience, the population density is defined as $c_1$, the buffer of major roads, bus stops and parking lots is defined as $c_2$, $c_3$, $c_4$, respectively, the land price is defined as $c_5$, and the each servant region of various kinds of supermarket is defined as $c_6$.

First of all, the contrast matrix is built.
When $c_i$ is more important than $c_j$, $a_{ij}$ equals 0. When $c_i$ is just as important as $c_j$, $a_{ij}$ equals 1. When $c_i$ is less important than $c_j$, $a_{ij}$ equals 2.

Then the judgment matrix is built.

$$A=(a_{ij}) = \begin{bmatrix}
A & c_1 & c_2 & c_3 & c_4 & c_5 & c_6 \\
c_1 & 1 & 2 & 2 & 2 & 11 & \\
c_2 & 0 & 1 & 2 & 0 & 2 & 7 \\
c_3 & 0 & 0 & 1 & 2 & 3 & r_j \\
c_4 & 0 & 2 & 2 & 1 & 2 & 9 \\
c_5 & 0 & 0 & 0 & 0 & 1 & 1 \\
c_6 & 0 & 0 & 2 & 0 & 2 & 1
\end{bmatrix}$$

$$a_{ij} = \begin{cases}
0, & (i,j=1,2,3,4,5,6) \\
1, & r_i = \sum_{j=1}^{6} a_{ij}
\end{cases}$$

In general, $c_b$ equals 9.

$$r = \frac{r_{\max}}{r_{\min}} = \frac{11}{1} = 11$$

$$M_i = \prod_{j=1}^{6} c_{ij}, \quad W_i = \sqrt[M_i]{M_j}, \quad \omega_i = \frac{W_i}{\sum_{i=1}^{6} W_i}, \quad \sum_{i=1}^{6} W_i = 7.81, \quad \sum_{i=1}^{6} \omega_i = 1$$

Finally, we check the consistency.

If

$$c = c_{ij}$$

Then

$$D = (d_i)_{i=1}^{6} = C \bullet W_i = \begin{pmatrix}
1.77 & 1.17 & 0.54 & 1.47 & 0.19 & 0.86
\end{pmatrix}$$

So

$$\lambda_{\max} = \sum_{i=1}^{6} d_i = \frac{1}{6} \left( \frac{1.77 + 1.17 + 0.54 + 1.47 + 0.19 + 0.86}{0.29 + 0.19 + 0.09 + 0.25 + 0.03 + 0.15} \right) = 6.03$$
The result proves that is a consistent data. So the weights of each evaluation index are shown below.

\[
W_i = (w_1, w_2, w_3, w_4, w_5) = (0.29, 0.19, 0.09, 0.25, 0.03, 0.15)
\]

The grade of each plot is calculated from the values of the weights above. We assume that the grade is Q.

\[
Q = 0.29Q_{e1} + 0.19Q_{e2} + 0.09Q_{e3} + 0.25Q_{e4} + 0.03Q_{e5} + 0.15Q_{e6}
\]

The higher the grade of the plot, the greater the likelihood of the optimal location of hypermarket.

2.7 Spatial analysis

According to the principle of GIS, we build spatial data base and property data base for the location supermarket. The spatial data base includes all the commercial land in Guiyang city, and the property data base has the grades of each impact factors. We make a great location for hypermarket by using overlay analysis of GIS.

3. Results

We find that the possible location for a new hypermarket opening is A, B and C. The population density of A is 23,983 per square kilometer, and it is of convenient transportation. But there is a hypermarket that is 1000 meters distant from A that compete with. The population density of B is 25,071 per square kilometer, but its transportation accessibility is poor. The population density of C is 55,321 per square kilometer, and the region has developed transportation network, but there is competitor nearby.

In general, the three regions are possible new hypermarket sites. According to the grades of the sites, the site of A is most likely to be selected, next is the site of B, the site of C is the last one.

4. Conclusions

This thesis has solved the problem of locations for new supermarkets by using GIS technology and the analysis hierarchy process methodology, and achieved the comprehensive assessment for market
location selection. We have selected 4 of the important factors: market competition, land prices, population density and convenience of transportation to build location model for supermarket according to AHP methodology. Then the best locations for a new supermarket opening are selected by GIS.

Based on the analysis, there are 3 sites that are the right place for new supermarkets in Guiyang city. Each of the sites has its own advantages in such factors as population density, convenience of transportation, market competition and land prices. But ultimately, the operators choose the site that they like.

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References
[1] Fang zhiyuan, Peng Shunfeng, Peng Tao. (2005) Quantitative Method of Location Selecting for Supermarket. Value Engineering. 4:95-99.
[2] Norat Roig-Tierno*, Amparo Baviera-Puig, Juan Buitrago-Vera, Francisco Mas-Verdu. (2013) The retail site location decision process using GIS and the analytical hierarchy process. Applied Geography. 40:191-198.
[3] Arquero, A., Álvarez, M., & Martinez, E. (2009) Decision Management making by AHP (analytical hierarchy process) trough GIS data. IEEE Latin America Transactions, 7(1): 101-106.
[4] Tang Guoan, Zhao Mudan, Yang Xin. (2017) Geographical Information system. The Science Publishing Company, Beijing.
[5] Hernández, T. (2007) Enhancing retail location decision support: the development and application of geovisualization. Journal of Retailing and Consumer Services.14:249-258.
[6] Musyoka, S. M., Mutyauvyu, S. M., Kiema, J. B. K., Karanja, F. N., & Siriba, D. N. (2007) Market segmentation using geographic information systems (GIS). A case study of the soft drink industry in Kenya. Marketing Intelligence & Planning. 25(6):632-642.
[7] Mendes, A. B., & Themido, I. H. (2004) Multi-outlet retail site location assessment. International Transactions In Operational Research. 11: 1-18.
[8] Xu Xueqiang, Zhou Xingyi, Ning Yeumin. (2013) Urban Geography. High Education Press, Beijing.
[9] The blog of urban planning. (2010) The Service Radius of Urban Infrastructures. http://www.xhut.cn/archives/202
[10] Hikmet Erbıyık,Selami Özcan,Kazım Karaboğa. (2012) Retail Store Location Selection Problem with Multiple Analytical Hierarchy Process of Decision Making an Application in Turkey. 8th International Strategic Management Conference.58:1405-1414.
[11] William Applebaum. (1965) Can Store Location Research Be a Science? Economic Geography. 41(3):234-237
[12] E.W.L. Cheng, H. Li, L. Yu (2005) The analytic network process (ANP) approach to location selection: a shopping mall illustration. Construction Innovation. 5:83-97