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Site Location Determination Using Geographic Information Systems: The Process and a Case Study

Arina Mardoukhi
Idaho State University, mardarin@isu.edu

Nima Kordzadeh
Idaho State University, kordnima@isu.edu

SITE LOCATION DETERMINATION USING GEOGRAPHIC INFORMATION SYSTEMS: THE PROCESS AND A CASE STUDY

Arina Mardoukhi
Idaho State University
mardarin@isu.edu

Nima Kordzadeh
Idaho State University
kordnima@isu.edu

ABSTRACT

In this study, we developed a five-step process for GIS-enabled site location determination in different domains. We applied that process to a real case study to examine its feasibility. The case was about determination of a suitable location for a children-oriented store in Bannock County, Idaho. We used ArcGIS 10, went through the decision making process, considered several decision criteria, and determined the best location for that store. The process that we developed in this study can also be used in other contexts such as health care, banking, and tourism.

Keywords

Site location determination, GIS, Bannock County, digital maps

INTRODUCTION

A Geographic Information System (GIS) is a computer-based system that aids in collection, maintenance, storage, analysis, and distribution of spatial (geographical) data and information (Cheng, Li, & Yu, 2007; Roig-Tierno, Baviera-Puig, Buitrago-Vera, & Mas-Verdu, 2013). In other words, GIS applications are used to visualize geographical data on digital maps. Those data represent real objects on the earth such as roads, waterways, trees, restaurants, parks, and shopping malls. Data visualization via GIS applications enables people to easily view, analyze, and understand relationships and patterns in data. In particular, the recent availability of higher resolution images at lower costs have provided a platform that have shown great value and rewards in different contexts, in particular for marketing purposes. For instance, by using the geographical data along with non-spatial data combined with them via GIS applications, managers with not-much technical and geographical knowledge can make informed decisions on location determination for stores, banks, restaurants, hospitals, etc. (Hernandez, 2007; Ozimec, Natter, & Reutterer, 2010). Location determination using GIS-based systems have recently been widely adopted in different domains ranging from environmental modeling and urban planning as well as location analysis and sales territory planning to transportation and route planning, as well as public health. This has also led researchers to examine the capabilities and potentials of GIS applications in determining optimum site locations in those context.

In the context of health care, GIS has been used in health geography and epidemiology research (Graves, 2008) as well as evaluating public and private networks of healthcare facilities and services (Noon & Hankins, 2001). An ultimate goal of using GIS applications in this domain has been to analyze, assess, and potentially enhance accessibility to healthcare services and facilities; and to improve the resulting healthcare outcomes (Graves, 2008). Noon and Hankins (2001) utilized the spatial data visualization features of a GIS application to support decisions on locating medical facilities, specifically related to maternity services, within a large rural healthcare system. They suggested that by using spatial data visualization tools, a cost effective option could be identified and pursued. Hawthorne and Kwan (2012) moved beyond conventional applications of GIS by integrating GIS-based data visualization techniques with interview-based data collected from a lower-income community. They did so to conceptualize and measure perceived satisfaction-adjusted distance to high-quality healthcare facilities.

GIS tools and applications have also been pervasively utilized in finding optimum locations for businesses and retail stores. The major criteria that have been considered for decision making in this context are spatial dispersion of customers and vendors (Davis, 2006). These two criteria are related to the two concepts that include geo-demand and geo-competition, respectively (Roig-Tierno et al., 2013). Customer dispersion can be subdivided into demographic distributions. Vendor dispersion can also be drilled down to specific types of products or services that the vendors provide to the market. GIS tools can be used to visually analyze geo-demand and geo-competition at any desired level.

Some researchers combine visual representation of data with statistical or mathematical models such as Analytic Hierarchy Process (AHP). AHP takes into account the subjective relative importance of a set of criteria as well as a set of alternatives with regard to each criterion (Saaty, 1990). At the end of the process, a weighted average score is assigned to each decision alternative and the one with the highest score is chosen. Roig-Tierno et al. (2013) used a combination of GIS-based analysis and AHP to determine an optimal site location for a retail store in Spain. The criteria that they considered are presented in Figure 1 below.

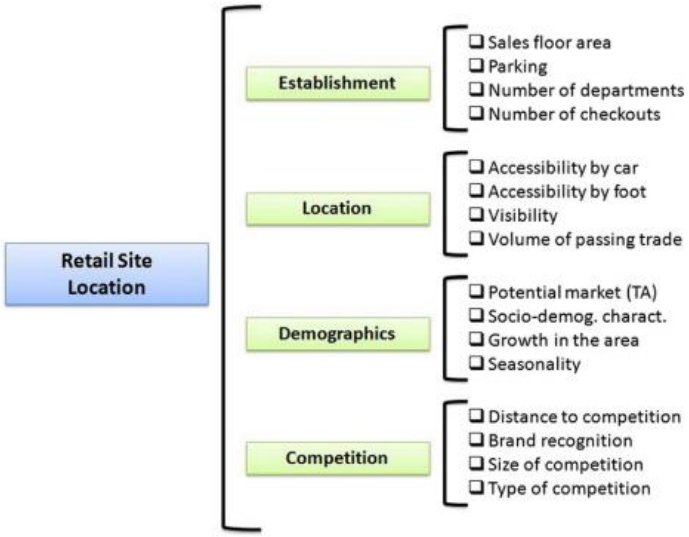

Figure 1. Site Location Determination Criteria for Retail Stores: Adapted from Roig-Tierno et al. (2013)

Cheng et al. (2007) suggested that multi-layer maps and visualized spatial and non-spatial data can be used to find optimal solutions for location identification problems. They used a GIS-based model to find solutions for different problems including minimum distance, maximum demand coverage, maximum income coverage, and optimal center to ultimately determine a suitable location for a shopping mall.

In a more recent study, Liu (2012) integrated GIS-based geographic analysis with a quantitative method named Huff model (Huff, 1964) to find a suitable location for a new Asian supermarket in the state of Minnesota, USA. The Huff model takes into account several factors such as attractiveness of a store and total number of stores in the area to calculate the probability that a customer living at a specific location chooses to buy at a specific store. They conducted spatial data analysis using ArcGIS software and identified 64 potential areas for the supermarket. They ultimately chose the most suitable area based on different criteria such as Asian population in each area.

LOCATION DETERMINATION PROCESS

Collectively, prior studies that fully or partially used GIS tools and data visualization for selecting optimal site locations followed the five generic steps:

1. Formulating the problem
   - The first step is to identify the problem for which a solution should be found. Finding an optimal location for a clinic, a shopping mall, or a bank could be considered a decision making problem for which GIS-tools could be utilized.
2. Setting goals and objectives:
   - The objectives are set based on the context. In the healthcare domain, the objective could be to determine a site location for a diabetes center that can serve at least 1000 individuals a month from low-income families. Whereas, in the retail sector, the objective could be to geo-locate an optimal location for a sporting goods store with a total sales of $50,000 per month.
3. Identifying decision criteria:
   - The decision criteria are identified based on the goals and objectives set at the previous stage. For example, for the healthcare case presented above, the decision criteria could be the average family income as well as the prevalence of diabetes in each region. For the retail sector, however, the criteria may include proximity to Skiing resorts and the number of competitors in each region.

4. Identifying and analyzing alternatives:
   - The alternatives could be assessed, compared, ranked, and selected with regard to the criteria set that were identified at the previous stage. In order to evaluate the decision alternatives, spatial data visualization using GIS applications as well as qualitative (e.g., interviews) and quantitative (e.g., AHP) methods could be employed.
5. Choosing an optimal alternative:
   - The alternative that meets the criteria most effectively will be selected. In this selection process, subjective judgments along with objective measures such as the scores calculated through the AHP procedure may be used.

These steps are also consistent with the generic decision making phases proposed by Simon (1959) that includes intelligence, design, and choice. Accordingly, the intelligence phase includes formulating the problem that calls for a decision. The design phase involves identifying and developing alternatives. The intelligence phase is where the alternatives are evaluated and the most appropriate ones are chosen. In the next section, we apply this GIS-based site location selection process to a real case.

CASE STUDY

Bannock County is located at 42.670° N, 112.220° W in the southeastern part of the state of Idaho (Figure 2). Based on the 2013 census data, this county has a total population of 83,249. Also, according to the same dataset, 16,100 individuals under the age of 14 reside in that area. Therefore, it is critical to address children's needs living in that region. However, as of now, there is no major retail store or shopping area that specifically offers products and services related to children in that range of age. This lack of competition can potentially provide an excellent opportunity for retailers to establish children-oriented stores (such as Toys-R-Us) somewhere in Bannock County. In order to address this issue and to help retailers find an appropriate location to start their business, we utilized the process explained in the previous section and used ArcGIS version 10 to visually locate an optimum site location for such a business.

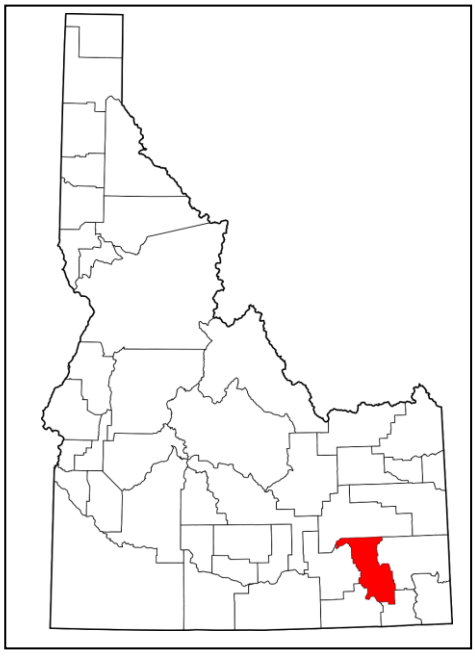

Figure 2. Bannock County, Idaho

The main goal of this decision making problem was to identify a location that can serve the population under 14 residing in that area. Thus, the criteria that we considered for this problem were residential density of the population with the age of 14 and below, proximity to major roads, availability of actual buildings (or shopping malls within which the business can be established), and availability of parking areas. To do so, we used several data sets including census data, Idaho State Boundary and Base Map Imagery with Labels from GIS online as well as transportation data available at insideidaho.org

Considering the decision making problem, goals, and selection criteria in this study, we identified several alternatives in the area, most of which were located in either Pocatello or Chubbuck, the two major cities in Bannock County. At the end of the decision making processes and after comparing all the alternatives, we selected a shopping mall named Pine Ridge mall that is serving the residents of both Chubbuck and Pocatello. Several stores such as J.C. Penney, Herberger's, and Shopko are

currently located at this mall. However, as mentioned earlier, no children-specific store exists in that mall. The location of Pine Ridge mall in Bannock County as well as the two major roads passing through Bannock County (I-15 and I-86) and also the density of population under the age of 14 are depicted in Figures 3 and 4. The census block groups with higher population density (e.g., 421 – 1294 persons per square kilometer) are presented in darker colors in Figure 3.

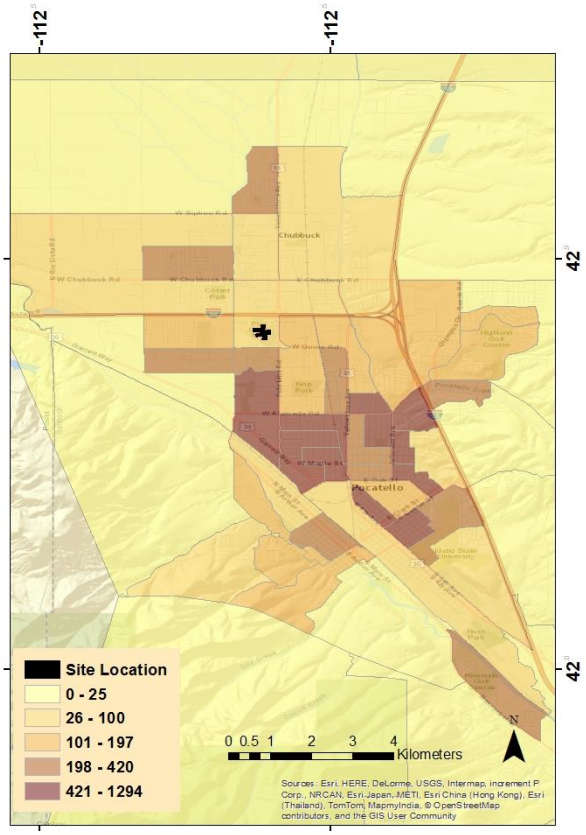

Figure 3: Population Density and Optimum Site Location

Figure 4: Optimum Site Location: Pine Ridge Mall

CONCLUSION

Using the GIS-enables site location determination approach that we introduced in this study, we were able to locate a suitable location for a children-specific store in Bannock County, Idaho. This five-step process could, however, be customized in different domains. For instance, in the area of public health and based on the best practices, one can identify the major decision criteria that researchers and practitioners can use. Also, in the context of banking, the main objectives that are typically considered for determination of a location for a bank can be identified and incorporated into our process. This contextualization can make this approach more effective and efficient in those domains. All in all, the approach introduced in this study can help decision makers systematically select suitable locations in various contexts.

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