Modeling University Enrollments with ArcGIS

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Abstract

Many universities are using GIS to visualize student enrollment. Simply looking at the numbers of students enrolled in a university, however, does not provide an analytical result. Areas with low populations and at long distances from a university, for example, can be expected to provide fewer students than areas with higher population and in close proximity to the university. Therefore, it would be helpful to understand which areas provide more (or fewer) students to the university than would be expected, given their population and distance from the university. In this presentation, market penetration index and gravity model are employed to analyze student enrollment.

1. Introduction

Colleges and universities have always competed with one another for a certain number of qualified high school graduates. Beginning with 1970s, however, the competition has become more intense as institutions of higher education struggled to maintain their enrollment levels. Such competition has inevitably focused more attention on institutional marketing strategies and source areas of potential students (Marble et. al. 1995). As a result, admission planning becomes one of the most important activities in almost every colleges and universities.

Increasingly, GIS (Geographic Information Systems) technology has been employed by universities to analyze student enrollment (Zhou and Wu, 2000; Smith et. al. 2002). Many universities use GIS to map locations of current students and visualize demographic distribution. Simply looking at the numbers of students enrolled in a university, however, does not provide an analytical result. For example, areas with low populations and at long distances from a university can be expected to provide fewer students than areas with higher population and in close proximity to the university. Therefore, it would be helpful to understand which areas provide more (or fewer) students to the university than would be expected, given their population and distance from the university. To better understand student enrollment and improve a higher education institution's recruit capability, it is necessary to combine GIS with certain spatial analysis techniques.

There were several theoretical researches on university student enrollment by geographers since 1960s (Smith et. al. 2002). McConnel (1965), for example, examined source areas for Bowling Green State University (BGSU) of Ohio using 1962-63 enrollment data. Kariel (1968) focused on the 1962 freshmen class at Western Washington State College in Bellingham. Both researchers used gravity spatial interaction model to explain geographic patterns of student enrollment. Maps, however, were missing from both studies due to perhaps technology limitations. In their monograph, Hayes and Fotheringham (1984) did produce a map showing prediction of student enrollment at Indiana University based on gravity model. Also, Spinelli and Smith (1985) employed market penetration index (MPI) to study college student recruitment.

In this paper, the authors attempt to combine these earlier theoretical studies with current GIS technology to study student enrollment patterns. Specifically, two spatial analysis methods, market penetration index (MPI) and gravity model, are tested. The data used in this study is from Ohio Board of Regents' 2003 enrollment of Ohio's public institutions of higher education (OBOR, 2005). The dataset provides number of Ohio residents enrolled in 13 four-year state universities (Figure 1) from each of county. ArcGIS is used in analysis and mapping.

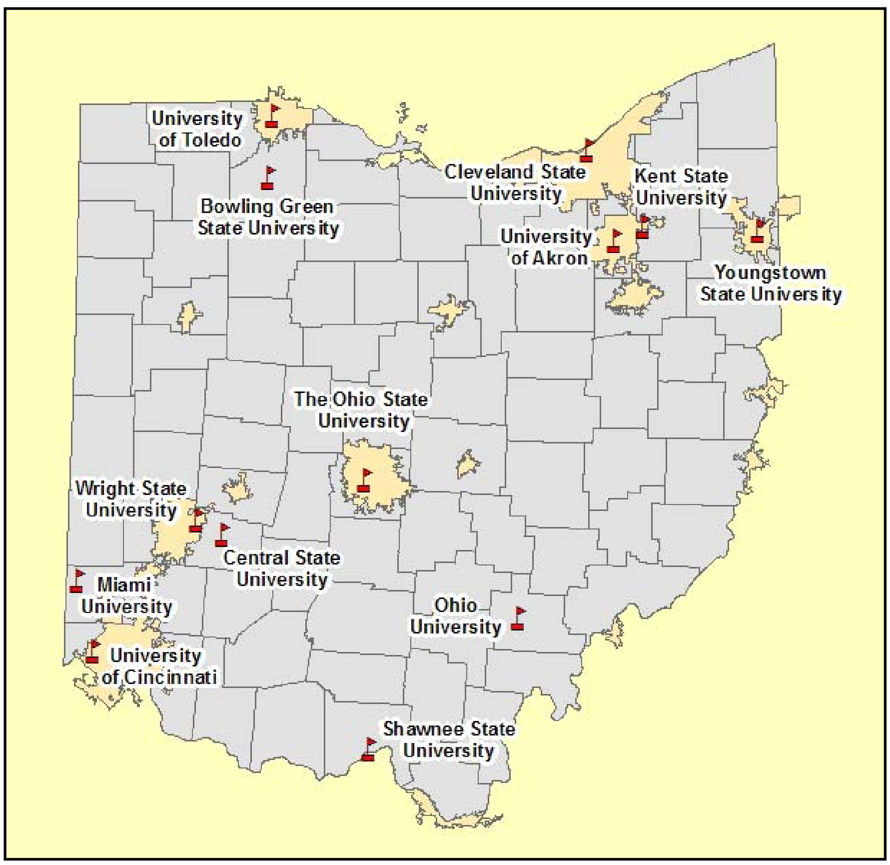

Figure 1. Location Map of Ohio's State Universities

2. Analyzing Student Enrollment with Market Penetration Index

Figure 2 is a map showing distribution of Ohio residents enrolled in 13 state universities from each county in 2003. This choropleth map displays the number of student from each county. The map, however, does not provide any indication of enrollment pattern.

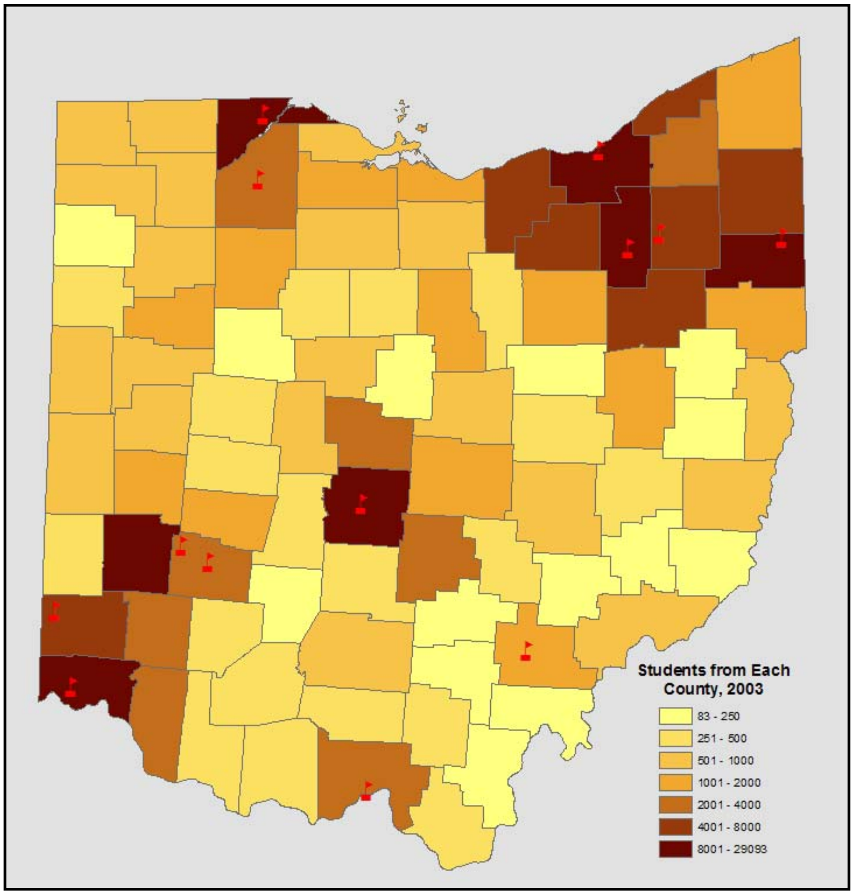

Figure 2. Enrollment of Ohio Residents in 13 State Universities, 2003

One technique can be used to study the enrollment pattern is *Market Penetration Index* (MPI), a measurement developed by geographers for studying manufacture and sales distribution (Spinelli and Smith, 1985). A MPI is defined by formula

$$MPI = \frac{X_{i,j} / \sum_{i=1}^{n} X_{i,j}}{\sum_{j=1}^{m} X_{i,j} / \sum_{i=1}^{n} \sum_{j=1}^{m} X_{i,j}}$$

where i represents a state university, j represents a county, n is the total number of state universities (13), m is the total number of counties in Ohio (88), and $X_{i,j}$ is the number of students from County j enrolled at University i .

The MPI assesses the strength of attraction power of each state university. The index presumes that each university's proportional share of the total Ohio-resident enrollment will be found operating in each of the 88 counties. Basically, if the MPI of a university in a specific county is less than 1.00, the university is attracting fewer students than its proportional share from the county. Conversely, if the MPI is greater than 1.00, the university is attracting more than its "fair share." Figure 3 is a map showing MPI values of each county related to the student enrollment at Bowling Green State University (BGSU). The impact of distance on enrollment is evident on the map.

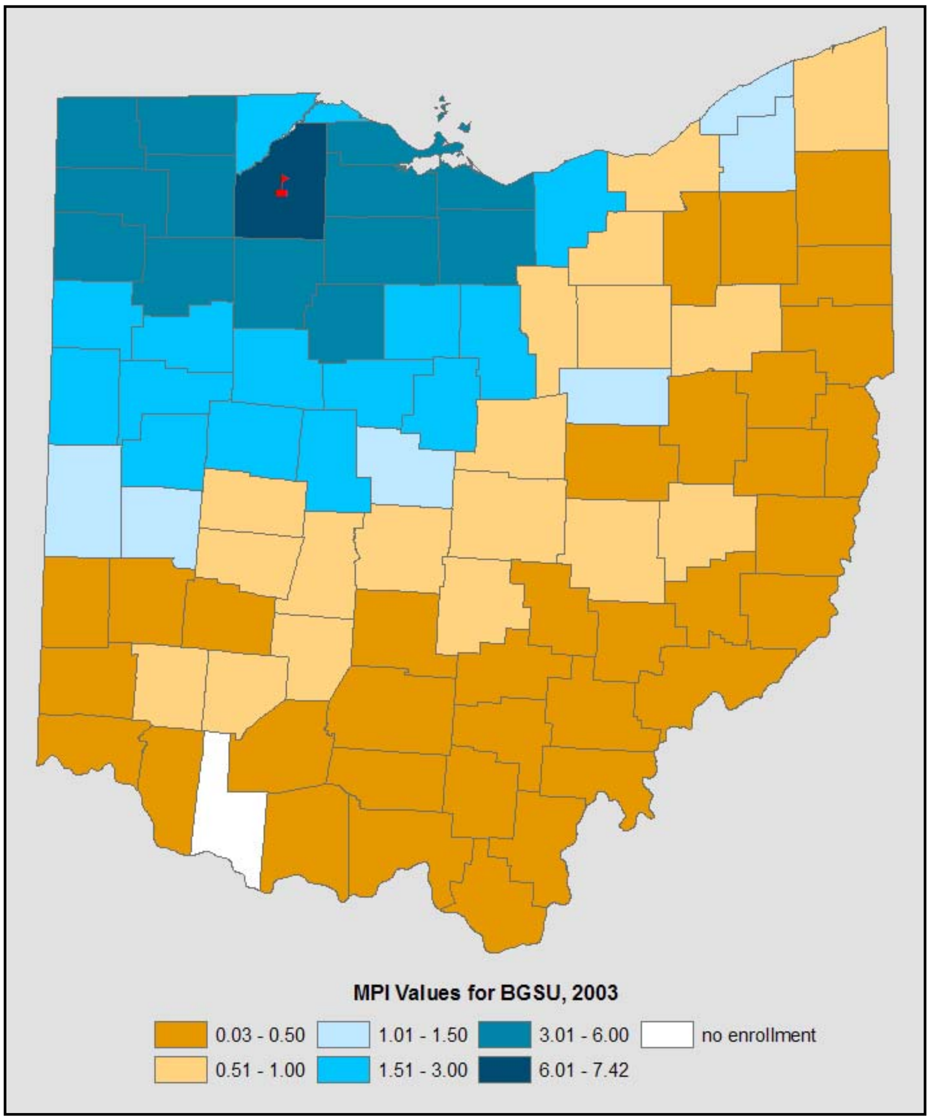

Figure 3. MPI Values of 88 Counties for Bowling Green State University

MPI method provides a useful mechanism for analyzing the geographic pattern of a university's source area. The method, however, does not provide a complete picture. A county with low student number and at long distance from a university, for example, can be expected to provide fewer students than counties with large number of students and in close proximity to the university. However, it would be useful to know which counties provide more (or fewer) students to the university than would be expected given their population and distance from the university. This can be done by gravity model (Hayes and Fotheringham, 1984).

3. Modeling Student Enrollment with Gravity Model

The gravity model offers a good application of the spatial interaction. It is named so because it uses a similar formulation than Newton's gravity model, which implies that the attraction between two objects is proportional to their mass and inversely to their respective distance. Consequently, the general formulation of spatial interactions can be adapted to reflect this basic assumption to form the elementary formulation of the gravity model:

$$T_{i,j} = k \frac{P_i^{\lambda} P_j^{\alpha}}{d_{i.j}^{\beta}}$$

where $\boldsymbol{P_i}$ is the importance of the location of origin (in this case, county), $\boldsymbol{P_j}$ is the location of destination (university in this case), $\boldsymbol{d_{i,j}}$ is the distance between the location of origin and destination, and $\boldsymbol{k}$ is a proportionality constant. The exponent values, $\boldsymbol{\alpha}$, $\boldsymbol{\lambda}$, and $\boldsymbol{\beta}$, are optional parameters to insure that the estimated results are similar to the observed flow.

In the formula, the calculated $\boldsymbol{T_{i,j}}$ represents the interaction between counties and universities. With total number of students in each county, total number of students in each university, and proportionality constant $\boldsymbol{k}$, expected number of students from each county at a university can be calculated.

With data provided by OBOR (2005), a matrix was built for finding the proportionality constant $\boldsymbol{k}$. In the matrix, the rows are 88 counties and the columns are 13 state universities. Each row and column is then summed up. Row number 18, for example, is Cuyahoga County, where the city of Cleveland is located. In 2003, the county had 29,093 residents enrolled in 13 state universities. The top five universities attracting the county's residents were Cleveland State University (12,430), Kent State University (3,751), The Ohio State University (3,419), University of Akron (1,877), and Ohio University (1,851). Column number 2 is Bowling Green State University (BGSU) located in northwest Ohio. In 2003, there were 16,448 Ohio residents enrolled to the University. The top five providers were Lucas (2,119), Wood (2,018), Cuyahoga (1,757), Franklin (743), and Lorain (589). Distance is an important parameter in the gravity model. The distances between each university and 88 counties, therefore, are measured. Since a county is a polygon, the population center of each county is used for the measurement.

Suppose all three exponent values, α, λ, and β, are 1, the value of k in the model can be determined. With the elementary formulation of the gravity model, the predicted interactions between a university and a county can be established. Figure 4 is a map showing the expected number of students from each county enrolled to Bowling Green State University.

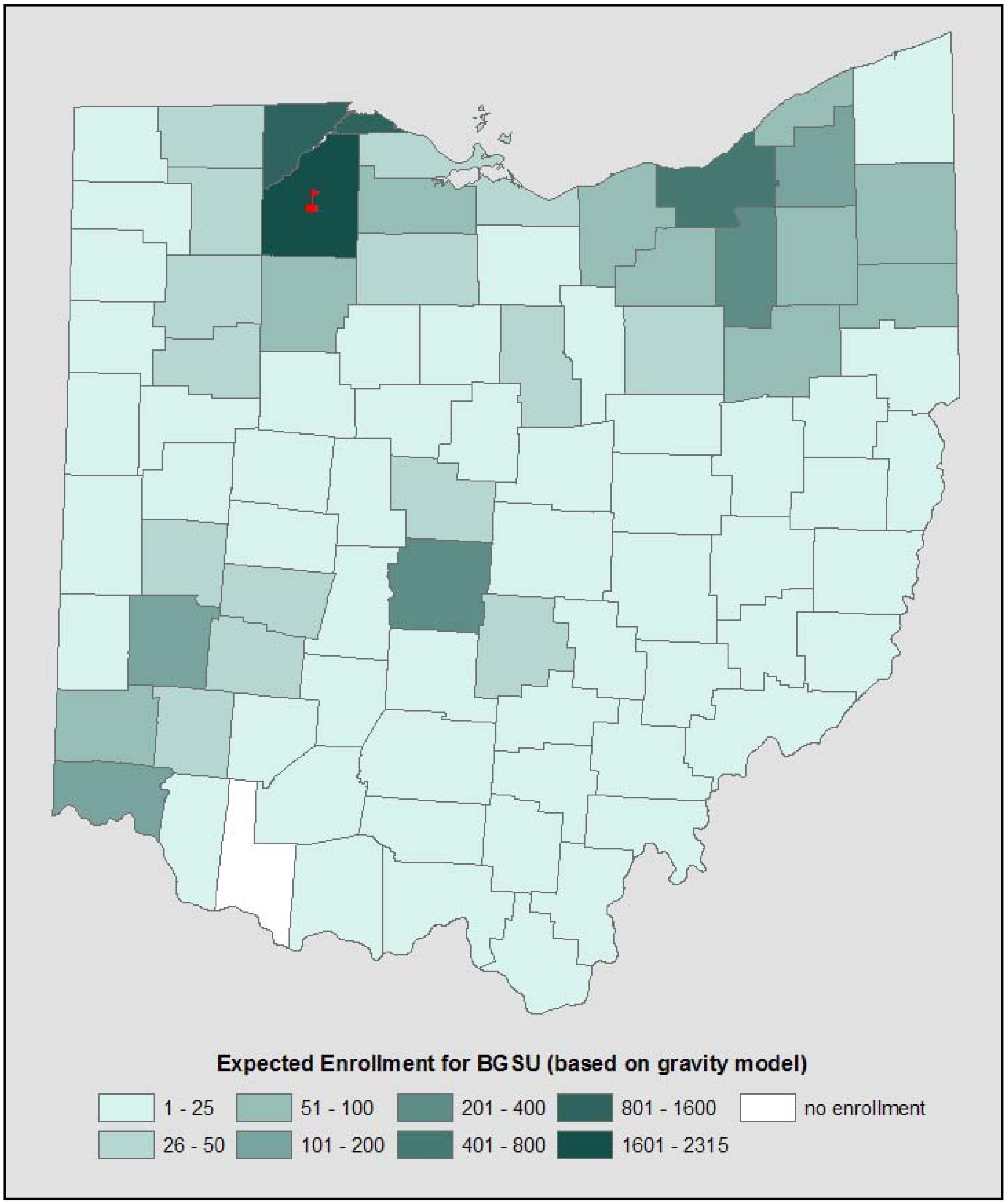

Figure 4. Expected Enrollment for BGSU Based on Gravity Model

The difference between the actual student enrollment and the expected enrollment from gravity model is called ***residual***. Residual can provide information on enrollment performance from particular counties. A positive residual indicates the county providing more students to the university than would be expected given their total number of students and distance from the university. Negative residuals indicate the counties from which fewer students attend the university than would be expected.

Figure 5 is a map depicts residuals from an analysis of student enrollment at Bowling Green State University. It appears that the university receives more students than would be expected from most counties, especially from northern part of the state and major urban centers, while it receives fewer students than expected from southern part of the state and Wood County, where the university is located.

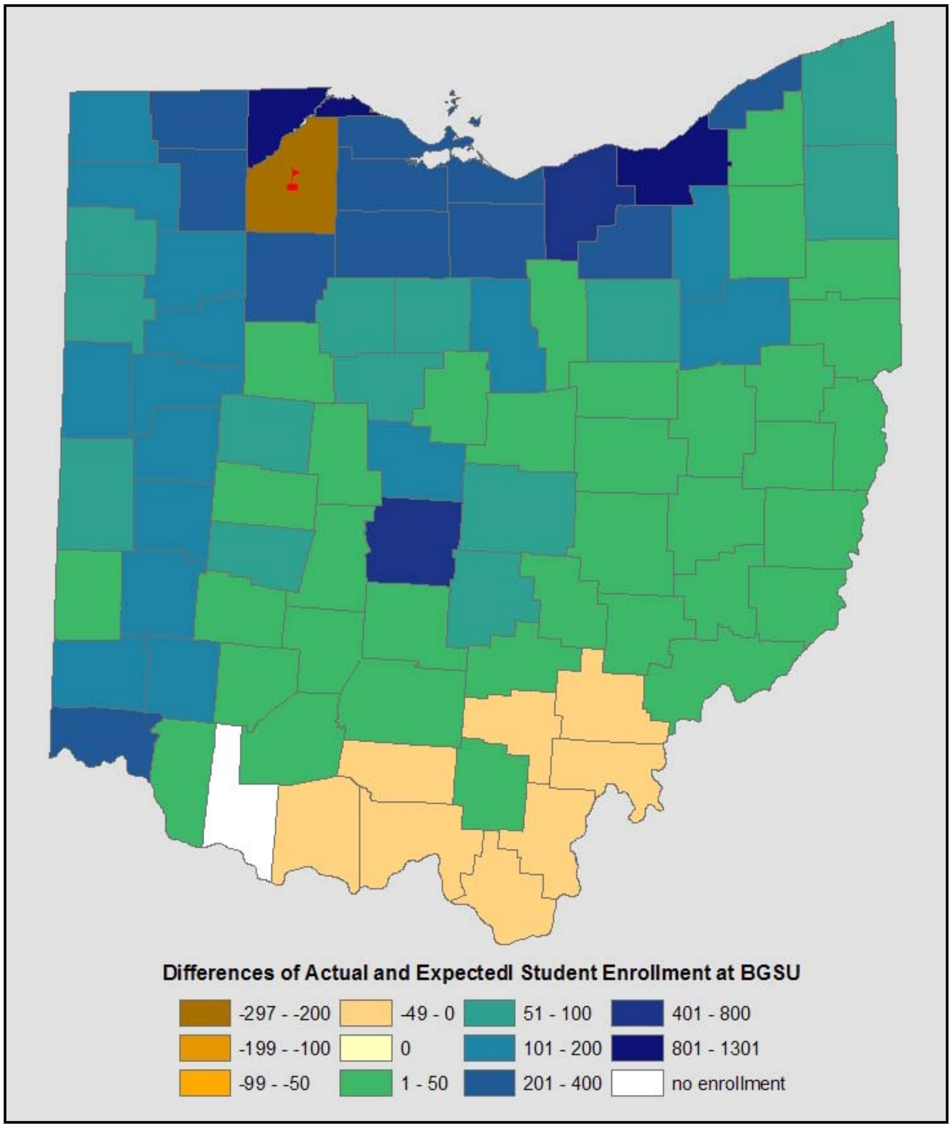

Figure 5. Differences of Actual and Expected Student Enrollment

4. Discussion

In this paper, two methods have been employed to analyze university student enrollment. The first method, market penetration index, provides a useful mechanism for analyzing the spatial pattern of a university's recruiting source area. It can also used to compare regions of competing institutions. The method, however, does not utilize the distance, an important parameter, in the analysis. The function of distance is completely missing in the formulation of MPI.

The importance of distance, however, is emphasized in the gravity model. The model has been applied widely in transportation, marketing, retailing, urban, and many other spatially-related fields. In this case, gravity model is successfully implemented in the analysis of university student enrollment. The gravity model used in this paper, however, is only in its simplest format. Three important parameters, α (potential to attract movement, or attractiveness), λ (potential to generate movements, or emissiveness), and β (transportation friction), are not calibrated in the study. Altering the value of α, λ, and β will certainly influence the estimated spatial interactions. Furthermore, the value of the parameters can be different with different users. All of these factors have to be considered in the future study.

5. References

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