# AN EXPERIMENT IN COMPUTER-AIDED INSTRUCTION IN REGIONAL ECONOMICS

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## INTRODUCTION

The new generation of time-sharing computers have provided the opportunity to use computer simulation techniques directly in the classroom. In the past, the most frequent application of computer aided instruction in general and time sharing aided instruction, in particular, has been with mathematical or statistical analysis. The main causes for such limited use have been: 1) the long turn-around time associated with batch processing, 2) the forbidding computer languages, and 3) the lack of readily available systems. The introduction of simple time-sharing systems has alleviated the turn-around time problem. The operator has instant communication with and response from the computer. The APL and BASIC languages allow the use of the English lanugage by student operators thus side-stepping the complexities of FORTRAN, PLI or the other standard languages. The remaining problem has been system design.

The computer center at Florida Atlantic University employs an IBM 360/40 via an IBM 2741 remote terminal. Both the APL and BASIC languages are available. Each student has an account number which simply is his telephone number. Stored in his library are all the programs which he will be working on during the term.

In this paper I would like to review the system developed at Florida Atlantic University, to assess the benefits derived, and to contrast such benefits with the associated costs.

## THE URBAN AND REGIONAL COURSE

Urban and Regional Economics is a senior-level course primarily designed for non-economic majors. The only prerequisite is principles. The text is Nourse, Regional Economics,[1] which is supplemented by outside readings. The course not only employs the Nourse text, but also follows the general model set out by Nourse before the members of this association. Prices, capital formation, unemployment, and the entire host of factors of interest to the economist are viewed through a theory of the spatial allocation of resources.[2] The computer-aided system is designed to complement this approach and to accord the student an opportunity to observe and study impacts. This approach is particularly advantageous in that most of the students do not have sufficient background in mathemathics to take impact multipliers or to check for stability. The computer does all the math for them and provides the results of any stock introduced. The student is then required to write a paper using the computer to analyze the impact on spatial allocation of a specified set of changes.

## THE SYSTEM

The system has five major components. Below is a brief discussion of each.

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LEARN

This program contains instructions on how to operate a terminal and how to access a program. It goes into such things as how to correct errors and what to do if things don't work. In addition, LEARN contains a black jack, or 21, game. This is included to give experience in terminal operation, to get over apprehensions about a computer, and to generate interest. The game seems to accomplish all three of these objectives. This program is stored for future reference or for future attempts to "beat" the computer. I might point out that the computer follows Las Vegas rules and generally wins.

LOCATION

This is a simulation version of the Löschian demand cone,[3] and closely follows Nourse.[4] In this model the student must input fixed and marginal cost, an individual elasticity of demand factor, the transportation rate per mile, and a vector of population densities. The model then solves for market area, market price, and quantity supplied. The model is defined in terms of the following:

Parameters

$A$ = fixed cost

$A_1$ = individual quantity demand when $P_{fob} = 0$

$B$ = marginal cost

$B_1$ = elasticity of the individual demand function

$D$ = population density per square mile

$k$ = transportation rate per mile

Variables

$m$ = miles

$P$ = market price

$PFT$ = profit

$Q$ = quantity demanded

$Z$ = sales radius

The problem is to solve for the value of P which maximizes:

$$PFT = P \sum_{m=0}^{Z} (A_1 - B_1 (P+km) D_m) - A + B \sum_{m=0}^{Z} A - B \left( \sum_{m=0}^{Z} A_1 - B_1 (P+km) D_m \right.$$

The value of P is then employed to determine the maximum sales radius, Z:

$$Z = \frac{\frac{A_1}{B_1} - P}{k}$$

where $A_1/B_1$ is the price which will reduce individual quantity demanded to zero.

The student is asked to (1) change marginal cost, (2) change the elasticity of demand, (3) change fixed cost, (4) change the transportation rate, and (5) to alter the vector of densities and to explain the results of these changes in a paper.

LANDUSE

This model is a variation of the concentric zone model but allows for geographic and zoning influences. Heavy reliance has been placed on Muth's approach to land conversion,[5] and upon Alonso's theory of rent.[6] The model calculates the rent bid by all alternative users for each parcel of land. Then the land is allocated among the various users so that the total rent payment is maximized. Six uses of land are employed; central business, heavy manufacturing, light manufacturing, warehousing and non-central commercial, high-density residential, and low-density residential. Agriculture is treated as a residual activity.

The elasticity of demand for the output of each of the land using sectors is entered as a fixed factor. The highest elasticity is for the output of the central business sector and the lowest is for low-density residential. Thus, a hypothetical spatial equilibrium would appear: A rent-bid matrix is calculated for each of the six $\underline{m}$ sectors for each of the $\underline{n}$ prices of land:

$$R = \begin{bmatrix} R_{1,1}, & R_{1,2}, & \ldots & R_{1,n} \\ R_{2,1} & & & \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ R_{6,1}, & R_{6,2}, & \ldots & R_{6,n} \end{bmatrix}$$

where $\quad R_{m,n} = f(C, E_m, D_n)$

and

$C$ = population of the city

$E_m$ = elasticity factor for the output of the $m^{th}$ sector

$D_n$ = distance from center point of the $n^{th}$ piece of land

The center point of the area may be initialized anywhere in the spatial matrix but if the operator does not enter his own point, the system is initialized at the center. The $n^{th}$ parcel of land is selected by a spiraling function radiating out from the center. A matrix A is created which stores the coding of the particular use which will minimize rent.

$A_{i,j}$ is the value of m which corresponds to the maximum of each of the $\underline{n}$ column vectors. In the A matrix, $\underline{i}$ and $\underline{j}$ are initialized at the center and the parcel selected becomes the $n = 1$. An increasing spiral of $\underline{i}$ and $\underline{j}$ is created as $\underline{n}$ is increased in the manner:

$i$ = radius of the curvature x sin $\theta$

$j$ = radius of the curvature x cos $\theta$

where the relevant curve and angle $\theta$ is determined with respect to the $\underline{i}$ and $\underline{j}$ values of the starting point and the current values.

FIG. 1

RENT BID FUNCTION IN LANDUSE

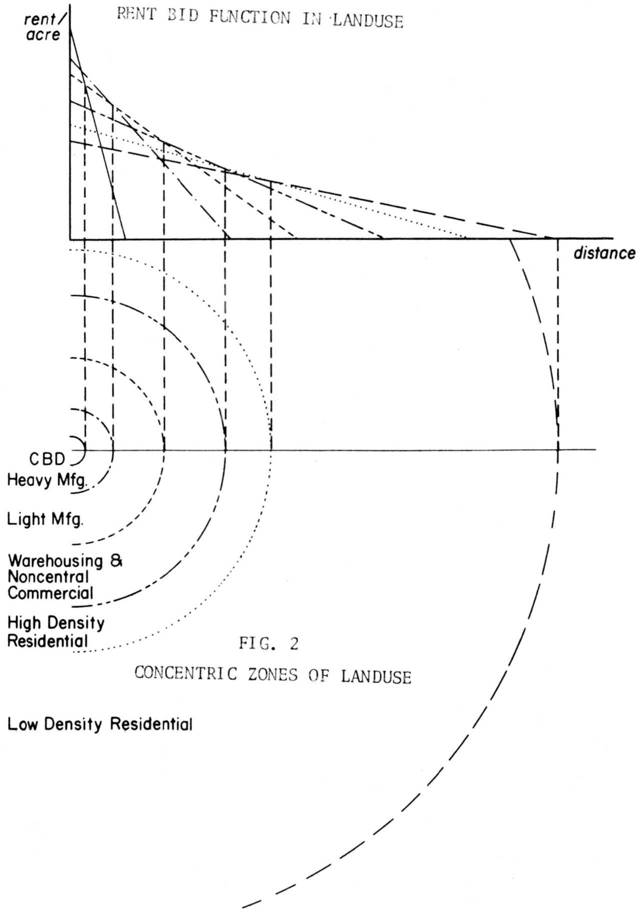


FIG. 2

CONCENTRIC ZONES OF LANDUSE

A third matrix, B, is introduced. B is called the interference matrix which contains both negative interferences, such as bodies of water, swamps, etc. and positive interferences such as railroads, highways, etc. B is introduced between the R and A matricies such that high bidding uses will be biased toward the more attractive parcels of land.

The B matrix involved the entering of a series of ordinal values which describes the city. A simulation of Pittsburgh was done; the B matrix was:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | -10 | 0 | 10 | -20 | 10 | 0 |
| 0 | -10 | 5 | 10 | -20 | 10 | 5 | 0 |
| 0 | 10 | 10 | -20 | 15 | 10 | 5 | 0 |
| 10 | 10 | -20 | 20 | 20 | 20 | 5 | 0 |
| -20 | -20 | -20 | 20 | 20 | 10 | 5 | 0 |
| 15 | 15 | 15 | -20 | -20 | 10 | 5 | 0 |
| 10 | 10 | 10 | 15 | 15 | -20 | 10 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | -20 | 0 |

In this matrix the Monongahela, Allegheny, and Ohio Rivers are coded as -20. This coding accomplishes two things; no activities are placed in the rivers and the riverside is reserved for low-density residential. Due to the small size of the matrix the actual rivers are not shown in the print out. Parcels of land with a high degree of accessability receive positive values with the exact degree of accessability being reflected in the magnitude of the value. Areas with a value of zero are adaptable to any use. The model solves for maximum rent payment by beginning from the center and assigning uses in a spiraling pattern. The solution, or the A matrix which maximizes the total rent payment, was:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | 3 | 4 | 0 | 3 | 1 |
| 3 | 1 | 3 | 4 | 1 | 4 | 3 | 2 |
| 2 | 4 | 5 | 1 | 5 | 5 | 3 | 2 |
| 3 | 4 | 1 | 6 | 6 | 5 | 3 | 2 |
| 0 | 1 | 1 | 6 | 5 | 4 | 3 | 1 |
| 5 | 5 | 5 | 1 | 1 | 3 | 3 | 2 |
| 3 | 3 | 3 | 5 | 5 | 0 | 3 | 1 |
| 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |

where 6 = central business district
5 = heavy manufacturing
4 = light manufacturing
3 = warehousing and non-central commercial
2 = high-density residential
1 = low-density residential
0 = open or agricultural

Those familiar with Pittsburgh who trace out the various land uses will see that this is not a bad fit.

The student is assigned to take a city, simulate it, let it grow, and explain what is going on. A significant aspect of the requirement is to explain the value of the B matrix.

URBAN1

URBAN1 is a simple export base model which was taken from Tiebout[7] and again follows Nourse.[8] The model begins with an identity breaking total employment into basic and non-basic employment.

$$Y = E + X - M$$

$Y$ = total employment

$X$ = basic employment

$E$-$M$ = non-basic employment

$E$ and $M$ are hypothesized to be linear functions of $Y$ and $X$ is exogenously determined.

$$E = A + e\,Y$$

$$M = B + m\,Y$$

$$X = \overline{X}$$

thus

$$Y = \frac{A - B + \overline{X}}{1 - (e - m)}$$

and

$$dY/d\overline{X} = \frac{A - B}{1 - (e - m)} .$$

The equilibrium levels of total, basic and non-basic employment are obtained by solving the model simultaneously. A matrix of multipliers is also obtained. Data is stored for ten cities on the computer and the student can select any of ten cities and input his own growth rate for the output of the basic sector and receive a print out of future levels of total employment.

This model is subjected in class to all of the criticism usually given to the export base model. It is used primarily to introduce the entire concept of regional growth and as an introduction to URBAN2.

The student is assigned a paper to analyze the differences among the available cities and among various growth rates for the basic sector.

URBAN2

URBAN2 is a shift-share growth model which also employs the base-multiplier technique. This model is taken from Perloff[9] and is written so that it is totally consistent with the presentation in Nourse.[10] The basic sector is disaggregated into the ten two-digit manufacturing sectors and each sector is then multiplied by the base multiplier to obtain total employment projections. In essence, this model is simply an extension of URBAN1 and solves for total, basic, and non-basic employment in the same manner. The model is

$$Y_{T+1} = \frac{A - B}{1 - (e-m)} \times \begin{bmatrix} B_1 \\ \cdot \\ \cdot \\ \cdot \\ B_n \end{bmatrix} \times \begin{bmatrix} 1 + g_2 \\ \cdot \\ \cdot \\ \cdot \\ 1 + g_n \end{bmatrix}^T \times S$$

$B_i$ = basic employment in the $i^{th}$ industry at time $T_o$

$g_i$ = national rate of growth of employment in the $i^{th}$ industry

S = share effect which lies between 1.2 and .8 and is arbitrarily selected

T = time interval between T+1 and $T_o$

A business cycle may be introduced by an option which simulates a recession. This is done by altering the $g_i$ for those industries which are sensitive to declines in the rate of growth of GNP.

In this model the share effect is simply a residual value to bring the forecasted value of total employment into accord with the actual. In the future, modifications are planned which will include the share effect within the model.

The assignment in the analysis of this model is to explain the growth of the shift effect, to explain the impact of a recession, and to offer an explanation of the regional shift effect.

## BENEFITS

It has been the experience at Florida Atlantic University that students felt that the above system was both enjoyable and contributed to the overall understanding of the course material. For those students with no previous computer experience, this system tended to destroy the magic of the computer in that they learned something about what a computer can and cannot do.

Given the nature of the students, the major benefit must be considered to be the ability to employ mathematical models and analyze impacts without directly using mathematics. The papers submitted showed that the students were able to attain a high degree of sophistication in their ability to analyze impacts even though they did not know the mathematics behind the models. In addition, the students could find an answer to almost any situation he could think up. Frequently many of these types of questions are never asked in class.

In summary, the benefits to the students were: (1) an opportunity to experiment, (2) a greater depth of understanding, (3) an opportunity to learn something about computers and modeling.

The instructor also received benefits. These models represent a framework around which the course is organizated. Also, the computer seems to have generated interest on the part of the students. The benefit most significant to the author is the ability to employ mathematical techniques in a class where the students do not have a sufficient background.

## NON-PECUNIARY COSTS

There is always the danger when using a system like the above that the proper use of the computer will become the objective. When, of course, the objective is to use the computer to aid in understanding economics. This has been avoided by simply not going into what the computer is doing while concentrating on the theoretical aspects of the particular question at hand. However, this problem must be recognized.

Experience has shown that the student must devote more time to the course. It is not felt that this extra time is out of line, but the student must write four papers which increases the amount of time devoted. In general, the generation of interest tends to counter these costs.

As far as the instructor is concerned the computer is not a labor-saving device. Experience has shown that more instructional time must be devoted to supervision of small groups in a lab. This task, however, may be assigned to a graduate student. The papers assigned to the students must be read and this too takes time. The costs to the instructor, then, are more time but the additional time may be shifted to a graduate student.

No charge is levied for computer use at Florida Atlantic University. Thus, computer time must be considered a non-pecuniary cost in that the computer can only accomodate a limited number of users. Time devoted to my students is time that cannot be used for other purposes.

## PECUNIARY COSTS

In the development and implementation of this system certain advantages were present. First was the availability of research monies to support research assistants and to support a reduced teaching load. Much of the labor time used was devoted to learning the languages and experimenting with design. The few attempts at this type of program which had been discovered did not provide much guidance; thus we were going it alone. Hopefully, my experience can eliminate much of this if any others are interested in such a system. The point I am driving at is that 100% of man hours should not be allocated to development. Even so, my estimate is a minimum of 500 man hours were required to plan, write, and debug the four models. It should be pointed out that the programs were written in two languages. APL and BASIC, and this required extra labor input.

In order to determine user costs which might have some applicability to the general situation, commercial time share rates are employed. The average times of students in Urban and Regional Economics are 6 hours and 47 minutes of connect time and 1 hour and 17 seconds of computer time. Commercial costs are $10 per connect hour and $.12 per computer second. Terminal rental is $60 per month. There is a 50% reduction if non-peak hours of computer and connect time are used. Thus the average cost per student per term is $109.94 if peak-load time is used or $54.97 if off-peak time is used. Commercial times were used because the computer center has provided me, at least up until now, with free time. Moreover, the lack of an imposition of a price system reflected itself in allowing students to have an open-ended account which have been freely used by some. With little effort connect time could be reduced to about 3 hours per term and computer time could be reduced to about 30 seconds. Regardless of the time-saving innovation employed, commercial systems are expensive.

## SUMMARY

Computer-aided instruction is expensive and labor using. The instructor does have the option, however, of shifting the labor burden to a graduate student. The important question is whether or not the benefits justify the bearing of the costs. Inasmuch as most of the benefits are intangible, no precise conclusion can be reduced. No formal test involving a test and control group was undertaken. Thus, only a very general comparison can be made between "before-computer" groups and "after-computer" groups. In my opinion, the computer-using classes have a much better understanding of a regional economy, of regional economic theroy, and of the limitations of regional economic theory. I can cite one piece of evidence to support this opinion; I have had to make the exams harder.

FOOTNOTES

[1]Hugh O. Nourse, Regional Economics, New York, McGraw-Hill, 1968.

[2]Hugh O. Nourse, "Are Regional and Urban Economics Really Different?", The Review of Regional Studies, Vol. I, 1970, p. 25.

[3]August Losch, The Economics of Location, New Haven, Conn., Yale University Press, 1954, pp. 63-66.

[4]Nourse, Regional Economics, Chapter 2.

[5]Richard F. Muth, "Economic Change and Rural-Urban Land Conversion," Econometrica, Vol. 29, 1961, pp. 1-23.

[6]William Alonso, Location and Land Use: Toward A General Theory of Land Rent, Cambridge, Mass., Harvard University Press, 1965.

[7]Charles M. Tiebout, The Community Economic Base Study, Supplementary Paper No. 16, Committee for Economic Development, 1962.

[8]Nourse, Regional Economics, Ch. 7.

[9]Harvey S. Perloff, et. al., Regions, Resources and Economic Growth, Lincoln, Nebraska, University of Nebraska Press, 1965, pp. 63-74.

[10]Nourse, Regional Economics, Ch. 8.