CONSTRAINTS AND POSSIBILITIES IN USING GEOGRAPHICAL INFORMATION SYSTEMS TO THE ANALYSIS ON PROVISION AND ALLOCATION OF SOCIAL SERVICES[1]

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ABSTRACT

This paper is aimed to asses the value of Geographical Information Systems in formulating policies for planning social services (especially, their allocation and further use). Above all, we pretend to recognize the possibilities in introducing information about sociological or perceptual features and individual behavior in a G.I.S.. Besides, we try to identify the possibility of using this kind of information combined with other different data.

INTRODUCTION

The Geographical Information System (GIS) are important for the correct formulation of location of public or private facilities (Jong, Ritsema y Toppen, 1991).

The purpose of this paper is to show the usefulness of using the perceptual data in this processes; particular remark is made about the use of cognitive distances among points in the space. An operative procedure is defined to include this kind of distances in the database of a GIS used to determine location of social facilities.

LOCATION OF FACILITIES. ELEMENTS AND MODELS TO BE CONSIDERED

Several steps may be defined in the formulation of policies for the location of social facilities (Moreno, 1987 and 1988): diagnosis of actual situation, definition of the new supply made by the Administration and evaluation of the results. A GIS can play an important role in each of these steps.

The Diagnosis

The evaluation of the concrete situation of the facilities requires the study of the following aspects:

- First the spatial distribution of the demand of commodities and services provided by the actual facilities (Moreno y López de los Mozos, 1989). That is, the geographical situation of the population using each type of facilities as well as their demographic, economic and social characteristics. All these circunstances modify their relationships with the commodities and services studied (age, sex, cultural level, etc)

- In a second place, the spatial distribution of the facility supply: the geographical location and relative size of each center of services and each facility.

- In the third place, it is essential to know the transport system and communication (network of streets and roads) and their characteristics (speed of traffic, directions...). Through this system the demand approaches the supply, located in concrete places.

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The combination of these three aspects allows one to determine the spatial opportunities of the population demanding services and the more important problems of the actual situation as well (Fernández y Bosque, 1991).

The New Supply of Commodities and Services

The definition of new supplys of commodities and services consists of determining the new location of the facilities. Using several mathematical models (especially those called location-allocation, Bosque y Moreno, 1990; Moreno y López de los Mozos, 1989), is possible to determine new places where the facilities can be located with the maximum benefit for the demand and supply and a minimum travel cost for the users. Different criteria can be used to guide the location of facilities, specially that of efficiency (minimum value of the total displacements) and that of spatial justice (to make sure that there are not large differences of accessibility among the users living in different places).

In these two steps and, in general, in the whole process of location of facilities, the concepts of distances between places (say, supply and demand centers) and accessibility play an important role. Any of the more usual methods depend on the use of the distance.

Normally these distances and accessibilities are of physical and "objective" kind, that is, the values employed for the distance are measured in units of length (meters, Km, etc), in units of time (seconds, hours, etc), or in units of travel cost or physical cost of going from a point to another.

THE PERCEPTUAL INFORMATION AND ITS ROLE IN THE LOCATION OF FACILITIES

As shown by Capel (1975), one of the more interesting discoverings of the social sciences during the last decades is the existence of perceptions and personal representations about the space that do not coincide with the actual facts.

In Geography, this fact yields to maps or mental representations which differ from the actual and objectives maps normally used by geographers. The consequences derived from taking into account these personal representation are of great importance. Thus, the spatial decisions and therefore the behavior derived from them depends on the personal subjective space reflected in mental maps rather than in the actual and objective space.

In the mental map, as in any other map, the concept of distance is an important element.

The cognitive distance of mental maps do not coincide with the actual distance (Cauvin, 1984a) measured with any kind of unit (time of travel, meters, etc). To illustrate this, Fig 1 shows the actual and cognitive distances of a set of urban travels made in Alcala de Henares (Madrid, Spain). The cognitive distances have been obtained from a survey, (Escobar Martinez, 1991a) and the actual distances from direct measurement. To emphasize the importance of the differences, the figure shows the ordinal rank of actual and perceived distances. As observed in the graph only in four cases the perceived and actual distances follow the same ordering. In other words, not only the magnitudes are different but even the ranging from the larger to the smaller distance are different.

Given the importance of the differences existing between these kind of distances, the inclusion of the subjective distances is needed in the diagnosis step as well as in the determination of new locations. Otherwise, the results could be right from the "objective" point of view but the results could not be satisfactory from the perspective of the direct users.

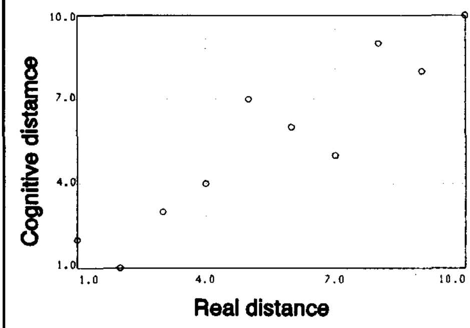

Figure 1

PERCEIVED DISTANCES AND GIS

The location of facilities may be carried out with a GIS which uses a network of communications where nodes and links are defined. The links are associated to numbers which measure their length and/or cost for "going through them" in "objective" values (Lupien, Moreland, and Dangermond, 1987). In this case, the problem is how to include a subjective perception of the length of each link in a GIS. The problem to be solved consists of three questions:

a) First, the obtention of the perceived distances by the group of population who demand the services. Normally, using surveys to the population and to the users of the facilities to be studied. There are several formulations for the surveys (Escobar Martinez, 1991a). The final result with any of them is a numerical value for each trip between two known points in the town, asked in the survey. Table 1 shows an example, the average of the distances among the five points of figure 2, derived from a survey applied to a wide number of persons resident in the city of Alcalá de Henares (Escobar Martínez, 1991a). The difficulty is that a properly formulated survey cannot include so many trips as the links that normally exist in a communication network; otherwise the survey would be impossible to answer. For this reason, it appears necessary the use of some procedure to obtain a general view about the subjective space of the area under study in which all the elements of the communications network employed are placed.

Table 1
Mean Values of Perceived Distances in Alcala

	CERV	ELVA	CEME	MAZA	CAJA
CERV	0	27.4809	31.4138	23.1892	36.2445
ELVA	27.48	0	47.5767	31.3192	38.4962
CEME	31.4	47.57	0	39.5149	42.3821
MAZA	23.18	31.31	39.51	0	48.9380
CAJA	36.24	38.49	42.38	48.93	0

b) Thee determination of the subjective space generated from the perceived distances. To accomplish this, the Multidimensional Scaling technique (MDS) allows to generate a space of one, two o three dimensions where the perceived distances fit appropriately (Kruskal, 1964; García Ballesteros and Bosque Sendra, 1989). This way, the observed and calculated perceived distances are very similar.

An usual task in Geography consists of measurements of distances among points of known locations.

- Let a number of points defined by their coordinates (X,Y), distributed in the space. The measurement of the distance between each pair of points constitutes a direct operation ($D_{ij}=\sqrt{(X_i-X_j)^2+(Y_i-Y_j)^2}$) and this generates a matrix of distances.

The MDS carries out the process inversely: Let a matrix of distances among n points. The MDS find the appropriate locations for each point providing its coordinates (X,Y). Fig 3 shows, as an example, the rebuilding of the space of Alcalá carried out by the MDS from the matrix of distances shown in Table 1.

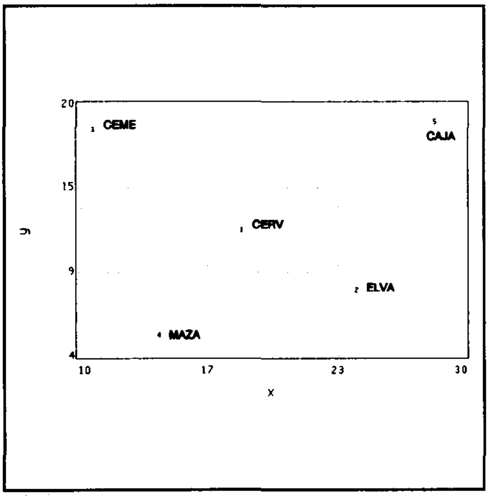

Figure 2

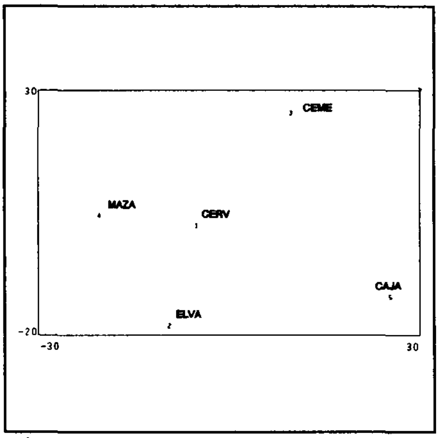

Figure 3

The "stress", a measure of the differences between the two kind of distances (the observed and the calculated one) is 0.013, corresponding to a pseudo-R^2 value between the observed and the calculated distances of 0.71. Although the system of perceptual coordinates does not have the same scale as the actual coordinates and there is a rotation of about 90 degrees in one of the coordinate system (the actual one), it can be seen that the relative position of the five points is not equal but it is similar. The differences indicate a certain failure of correspondence between the actual and subjective space, which we explicitly propose that should be included within the analytical processes for the location of services and facilities.

c) It appears necessary a procedure to extend the MDS results to the whole area studied, since the number of distances obtained from the survey is much smaller than the number of links of the network. In order to carry out a realistic study of facility locations, we should know the subjective distances for all trips. To accomplish this, two procedures are possible: the bidimensional regression technique and a simple afin transformations of the two systems of coordinates.

Bidimensional Regression

The bidimensional regression, proposed by Tobler (1978) and developed by Cauvin in France (1984b), allows to quantitatively compare two surfaces. The first surface consists of points included in the survey of distances and the second surface includes the locations of the same points after the MDS. All the points are over an original frame that allows, after analysis, the knowledge of the deformation in all the places of the area studied.

This way, we are able to obtain a distorted surface as a function of the perceived distances where all the possible trips through the area are included.

The basis of the method is as follows:

- We have an original surface, **Z**, with n points defined by their coordinates (X_i, Y_i), actual locations of the points included in the surveys.

- After application of MDS, we also have a surface image, **W**, with n homologous points determined by the coordinates (U_i, V_i), perceived configuration.

- Then we find the best fit of the function **W** = f(**Z**) using least squares. This way, we have a fit of the two surfaces, minimizing the deviations between the observed **W** surface and the fitted **W*** surface.

The method nor only gives a fit based on the selected points. The method includes a second step - the interpolation- which allows to extent the results obtained for homologous points to the whole area under study. This way, the deformations can be known and measured over any point of the surface.

The DARCY program, designed by Waldo Tobler, allows the inclusion of a base map that will be distorted at the same time that the interpolation step is done. This way, all the transport network is included in the study of facility location giving the perceived distances for all the link of the network.

After application of the method, we have four homologous surfaces:

- Original surface **Z**
- Observed surface **W**
- Fitted image **W***
- Interpolated image **W****

Figs 4, 5, 6 and 7 show an example of these surfaces applied to the city of Burdeos, France (Escobar Martínez, 1991b).

Fig. 4 shows the original surface **Z** where the links forming the transport network are included in addition to the actual location of the points of the survey. Fig. 5 includes the perceived locations of the points of the survey together with the observed surface **W**. Figure 6 shows the fitted image **W***, which is the product of the first step of the bidimensional regression applied to the observed surface **W**. Finally, in Fig. 7 the interpolated image **W**** of the surface under study appears distorted after interpolation of the bidimensional regression.

<u>Afin Transformation</u>
When an afin transformation of the two systems of coordinates is used (Cauvin, 1984b), two equations should be obtained using the perceptual coordinate system as the dependent variable and the actual ones as explanatory variables. This provides an analytical procedure to find the perceived coordinates in any point of the actual map.

For Alcalá de Henares and starting with Figures 2 y 3, the least squares fit is:

$$XPERC^* = -47.16 + 0.71 \times XREAL + 2.74 \times YREAL \quad R^2 = 0.983$$
$$YPERC^* = 29.15 - 2.29 \times XREAL + 1.18 \times YREAL \quad R^2 = 0.994$$

From these perceived coordinates (calculated), it is possible to draw the lineal links binding these points and the length of each of them. These values can be included easily into the database of the GIS to give the location of new facilities to be placed. Table 2 lists the length of the links existing in a simplified example of the communication network of Alcalá

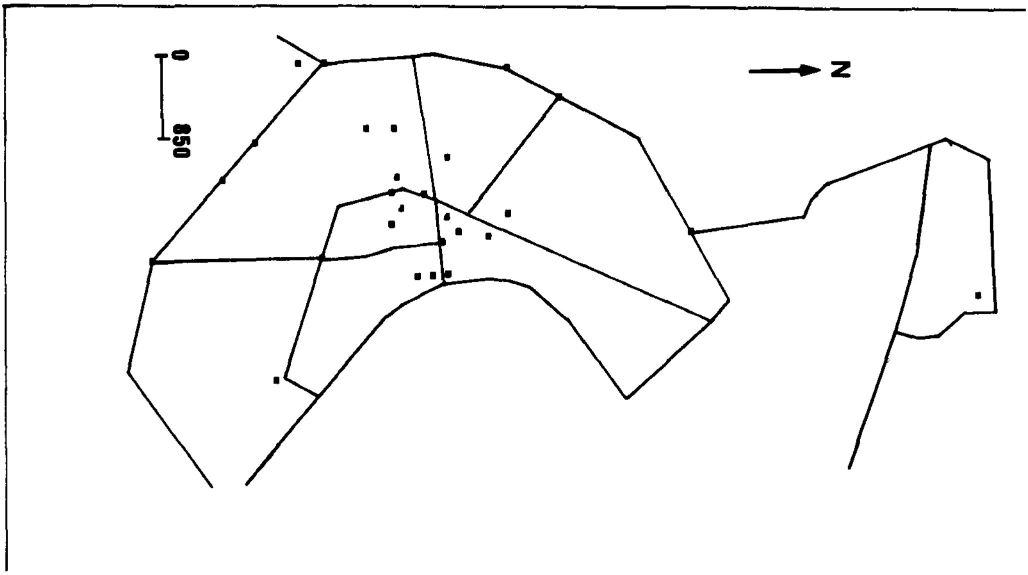

Figure 4

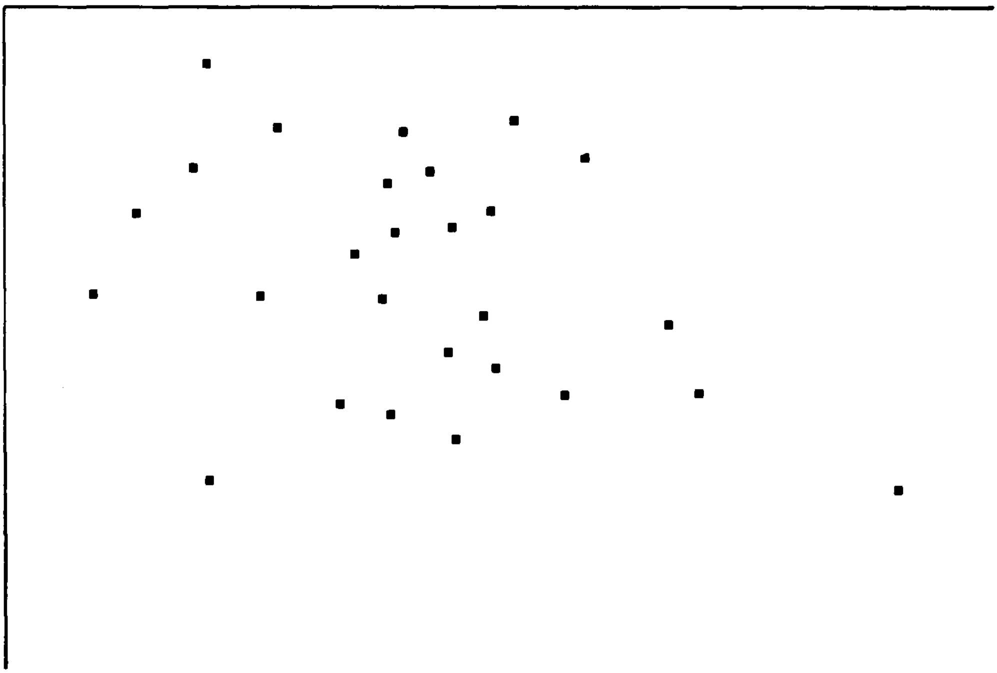

Figure 5

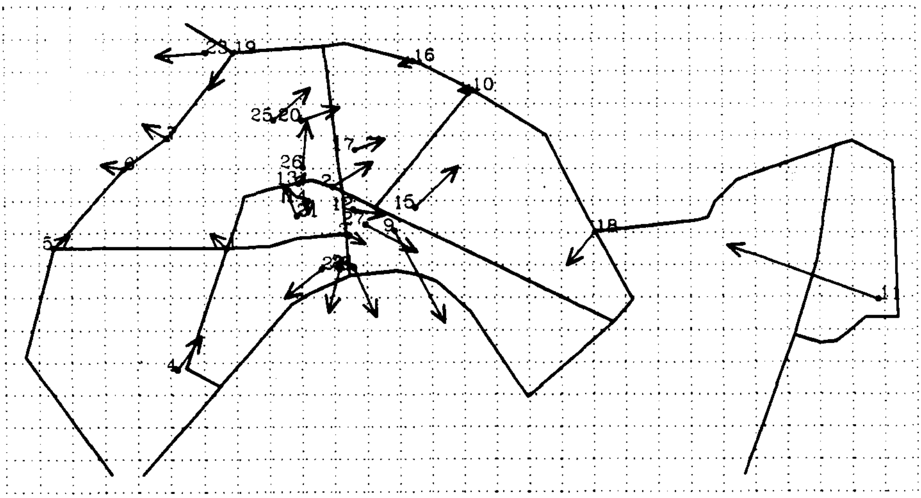

Figure 6

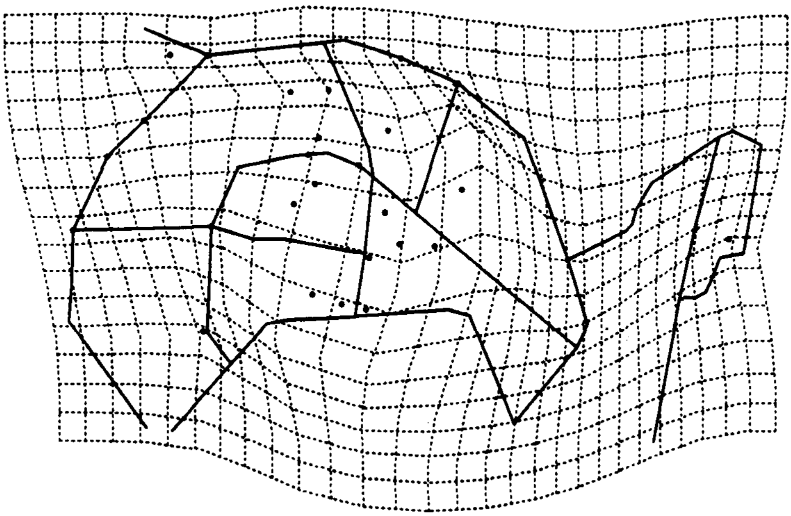

Figure 7

de Henares. Fig. 8 shows the actual placement of the street network and Fig. 9 the perceived location calculated from the two earlier equations.

Table 2
Actual and Perceived Length of the Links in the Transport Network of Alcalá de Henares

Link	Real L.	Perc. L.	Link	Real L.	Perc. L
1-2,	13.00	33.82	5-11,	18.68	44.29
1-8,	23.43	62.27	6-16,	17.12	40.61
1-10,	8.25	20.68	7-11,	16.28	46.98
1-15,	14.00	42.41	9-16,	22.00	52.75
2-16,	16.55	43.53	9-17,	21.93	63.16
3-14,	26.68	63.18	11-12,	41.23	121.16
3-17,	21.19	50.47	12-13,	18.68	44.29
4-8,	10.00	27.70	13-14,	7.21	21.38
4-13,	25.50	61.53	16-17,	17.46	49.69
5-10,	12.37	31.02			

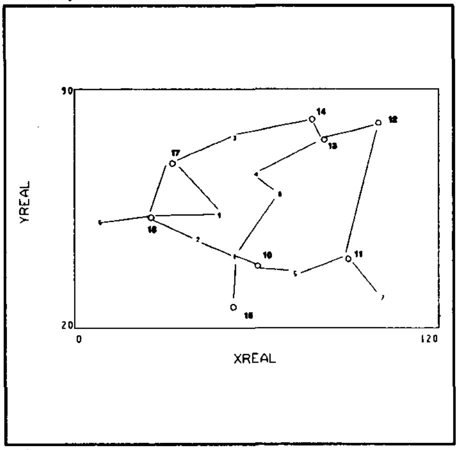

Figure 8

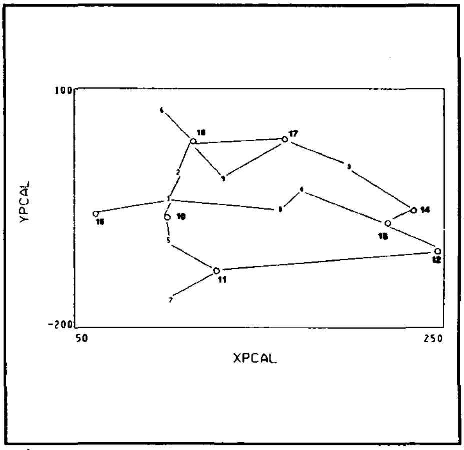

Figure 9

The units on the perceived distance are arbitrary but it is not a problem because the determination of locations is based on the measured distance in any type of unit as long as the unit be the same for all the existing links.

CONCLUSIONS

This study uses "soft data", obtained from surveys within a GIS.

The Multidimensional Scaling is needed to determine the subjective space and the mental maps of the surveyed elements. On the other hand, the bidimensional regression or an afin transformations is used to generalize the subjective space to all the elements of the area. This way, it is possible to calculate the perceived link lengths of a transport network. The lengths can then be employed to determine and to analyze facility locations.

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