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Personal Geographies in GIS:
New Approaches to Analyse Accessibility to Public Services

Francisco J. Escobar[1]

Maria J. Salado[2]

[1] Senior Lecturer
Department of Geospatial Science
RMIT University
GPO Box 2476V, Melbourne 3001, VIC, Australia
Email: Francisco.Escobar@rmit.edu.au

[2] Associate Professor
Department of Geography
University of Alcalá de Henares
Calle Colegios 2, Alcalá de Henares 28801, Spain
Email: mariaj.salado@uah.es

ABSTRACT

This paper presents the results of two complementary studies undertaken in the city of Alcalá de Henares, Spain. The main objective was to analyse accessibility to public services from the users' personal circumstances and perception of the environment.

The paper provides information on the methodology adopted to include cognitive distances and time budgets into a GIS database. It summarises both cartographic and numeric results and concludes with a discussion on future developments in this area.

The main outcomes of the study include: (a) the demonstration that personal geographies can be handled and analysed using GIS technology, (b) a personal approach to the analysis of spatiotemporal accessibility, and (c) the development of a set of innovative cartographic representations.

INTRODUCTION

The most common approach to the study and analysis of accessibility is based on distances, whether they are length, time or cost-based. However, in the analysis of the accessibility to public services there are important aspects that are disregarded by this approach.

The term Personal Geographies has been adopted to refer to those studies focussing on individuals and the way they interact with the environment, as opposed to traditional Geography where the environment itself is the main object of study.

Personal Geographies include Cognitive and Time Geographies. Both streams have encountered great difficulties when attempting to adopt GIS technology in their analysis. Even though Cognitive Geography was developed in the 1960s and Time Geography in the 1970s, we had to wait until the late 1990s to witness some results in the integration of Personal Geographies with GIS.

This paper presents the results of two complementary studies undertaken in the city of Alcalá de Henares, Spain. The main objective of such studies was to analyse accessibility to public services from the users' personal circumstances and perception of the environment.

Information related to personal time budgets and individual and aggregated estimations of street distances as well as locational and descriptive information related to selected services (health centres and kindergartens) were integrated with the actual street network in a GIS environment.

Using this information, GIS was then applied to the analysis of the accessibility to the above-mentioned services. The main outcomes of the study included: (a) the demonstration that personal geographies can be handled and analysed using GIS technology, (b) a personalised approach to the analysis of spatiotemporal accessibility, and (c) the development of a set of innovative cartographic representations.

The paper summarises the principles of both Time Geography and Cognitive Geography and provides detailed information on the methodology adopted to include cognitive and temporal information into a GIS database. It summarises both cartographic and numeric results and concludes with a discussion on future developments in this area.

COGNITIVE GEOGRAPHY AND ACCESSIBILITY

Studies on Cognitive Geography undertaken in the 1970s demonstrated that spatial behaviour is based on the image individuals have about their environment rather than the physical characteristics of this environment (Capel, 1973). Since the accessibility to public services aims at minimising distances between location of services and location of users (normally residential address), it is imperative to consider cognitive distances in their analysis. The rational for this is related to the fact that short but long perceived distances would have a negative impact in the accessibility to such services.

Although a large range of methods to obtain and represent cognitive environments was developed in the 1960s and 1970s (Golledge, 1976; Bailly, 1977), they have only been some isolated attempts to analyse these environments using GIS technology. This is perhaps due to the difficulties that GIS encounters to analyse qualitative and personal information.

The analysis of cognitive environments constitutes a complex task. Since distances are the most relevant factor in accessibility, only cognitive distances are considered for the purposes of this research. Cognitive distances in cognitive spaces are the equivalent to geometric distances in physical spaces (Escobar, 1996).

The following sections summarise the method adopted for the obtention and integration in a GIS of cognitive intra-urban distances and their role in the analysis of accessibility.

Obtention and Representation of Cognitive Distances

In Cognitive Geography research some kind of survey is needed. In our case, a survey amongst a sample of 284 users of public health services was undertaken. Users were asked to estimate the distance that separates 17 well-known locations within the built area in the city and a matrix of 136 distances was obtained. This matrix would then become the main input in a combined analysis based on Multidimensional Scaling and Bi-dimensional Regression techniques.

Multidimensional Scaling (MDS) and Cognitive Configurations

Multidimensional Scaling (MDS) was first developed by psychologists. Torgerson (1958) expressed the objectives of MDS as "Given a set of stimuli (= cases or locations) which number of dimensions is unknown, determine (a) the minimum dimension for the set and (b) the stimuli projections over each of the dimension". For the psychologists the emphasis resides on the number of dimensions while for geographers, who later on adopted the method, the main interest resides on the projections or mapping-like configurations.

In our case, the set of stimuli would be the matrixes of estimated and actual distances and the projection would be a cartographic-like configuration of the 17 locations based on the estimated distances. In simple terms, what MDS offers to geographers is the possibility to invert the common procedure of measuring distances between known locations to obtain locations that best fit a matrix of given distances (Gould, 1972).

Figure 1 shows the actual location of the 17 chosen places and the configuration obtained by the MDS for the same points based on the estimations of distances.

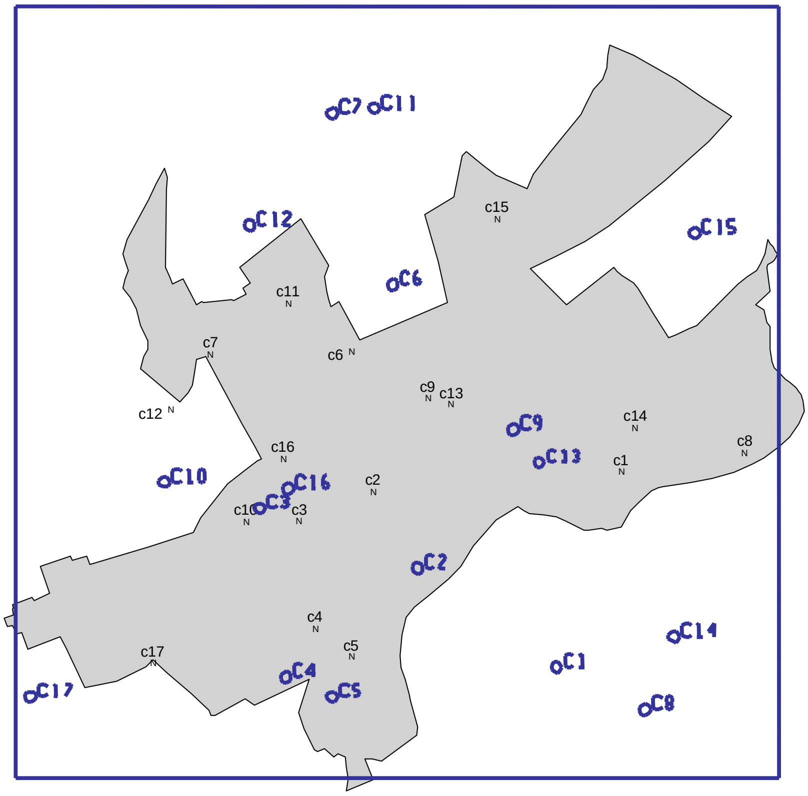

Figure 1. Actual (black) and perceived location (blue) of 17 well-known places within the city of Alcalá de Henares.

Bi-dimensional regression and Cognitive Mapping

Once the initial configuration for the 17 places was obtained by the MDS, some kind of interpolation technique was needed in order to extent to the whole intra-urban street network the deformations found in the perceived location of the considered places.

The technique adopted is based on the work published by Tobler (1977, 1978, 1994) and by Cauvin (1984a, 1984b). These authors adopted the bi-dimensional regression, which was originally established for the comparison of animal shapes in their different stages of growth, to the comparison of maps produced under different projection systems and to the comparison of actual and cognitive mapping configurations.

The principle is simple; having two spatial repartitions of homologue points (actual and perceived configurations presented in figure 1), it consists on extending the deformations associated to the perceived configuration to the whole street network.

The method is based on two consecutive phases; an adjustment between the homologue points and an interpolation that permits to know the deformations in any areas of the considered space and not only on the location of the points (Cauvin, 1984a).

Figure 2 summarises the main phases in the bi-dimensional regression. It shows how a direct comparison between the original map (actual location of the 17 points) and the observed configuration (perceived location of the points obtained by the MDS) is impossible. Through a transformation in terms of scale, translation and rotation, the observed configuration is adjusted to fit the parameters of the original map. The adjusted configuration can then be compared to the original configuration and the elements included in the later be interpolated based on the deformations of the cognitive image.

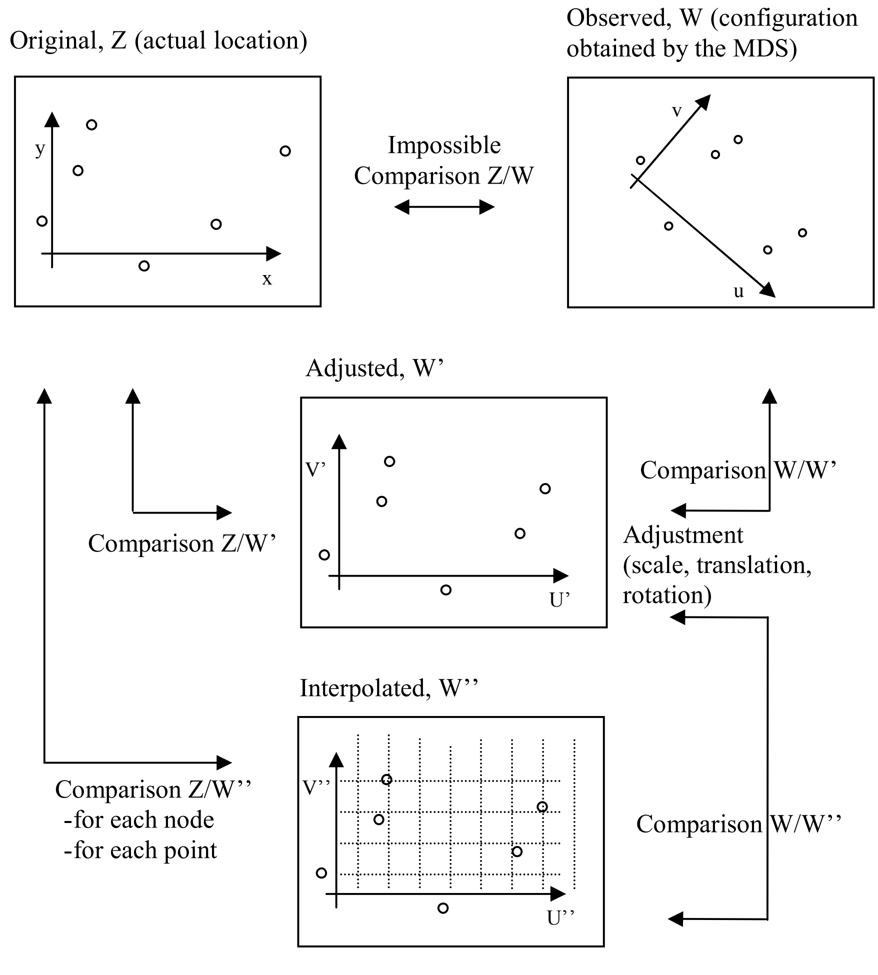

Figure 2. Main phases in bi-dimensional regression (after Cauvin, 1984a)

The application of this technique to the configuration obtained by the MDS for the estimations of distances in Alcalá de Henares produced a number of cartographic outputs from which the final distorted configuration, which summarises for the whole area the deformations associated with the estimations of distances, has been selected (Figure 3). The software adopted in this phase is named DARCY. It was developed by Waldo Tobler in the 1970s and readapted at the University Louis Pasteur in Strasbourg by Serradj and Hirsch (Cauvin, ND). The improved version allows the production of intermediate cartographic representations between the original and the final images. Animations based on the successive display of these intermediate maps facilitate an understanding on how deformations are produced.

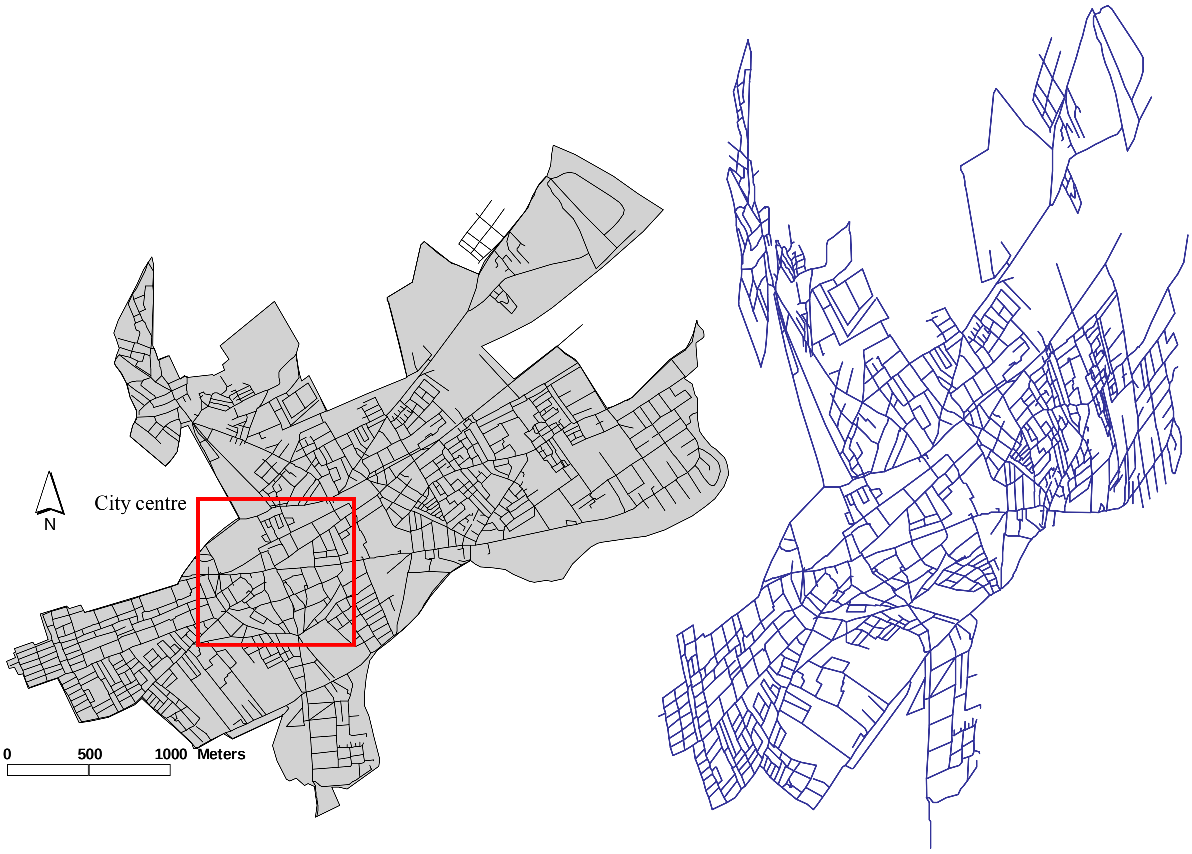

Figure 3. Current street network and distorted image result of the bi-dimensional regression.

In general terms, distances East-West have been shortened and distances North-South enlarged while the city centre has been expanded in the distorted image. The reasons behind these deformations are due to different personal factors, including age, sex, socio-economic status, ethnic group, religion, amongst others (Nerlove and Munroe, 1971; Gilmartin and Patton, 1984; Escobar, 1991) but also due to factors related to the environment (Lynch, 1960; De Jonge, 1962). Since our analysis only considers average estimated distances, the personal factors are disregarded and only factors related to the environment considered. Amongst the last group of factors, the current configuration of the street network in Alcalá de Henares, with well-defined circulation axes East-West makes displacements in this direction easy while an intricate maze of streets result of a Medieval Age urbanism, makes displacements North-South difficult. This would explain the different distortion found in each direction.

Inclusion of the cognitive configuration in the GIS

The cartographic configurations presented in figure 3 present an identical number of street segments and the same identifier for each of them. This made it easy the integration of both, through a simple relational union operation, in a GIS environment.

The result of such union was the obtention of a single street network which arcs were defined by a unique identifier and by a set of two different values of length; one corresponding to the current location of the original 17 points and another corresponding to the distorted image resulted from the estimated distances between the same points.

Within the same system, location of services and users' addresses were integrated.

A number of GIS allocation analyses that combined both types of distances, locations of services and users' addresses demonstrated how users choose the closest services in terms of cognitive distances instead of actual distances.

ACCESSIBILITY AND TIME GEOGRAPHY

Time Geography focuses on the objective barriers that individuals' spatiotemporal budgets impose in the potential use of public services (Hagerstrand, 1970; 1989). In the example presented in Figure 4, a prism of potential accessibility is determined by speed in displacements and bonded activities of an individual making A and C the only accessible services but not B.

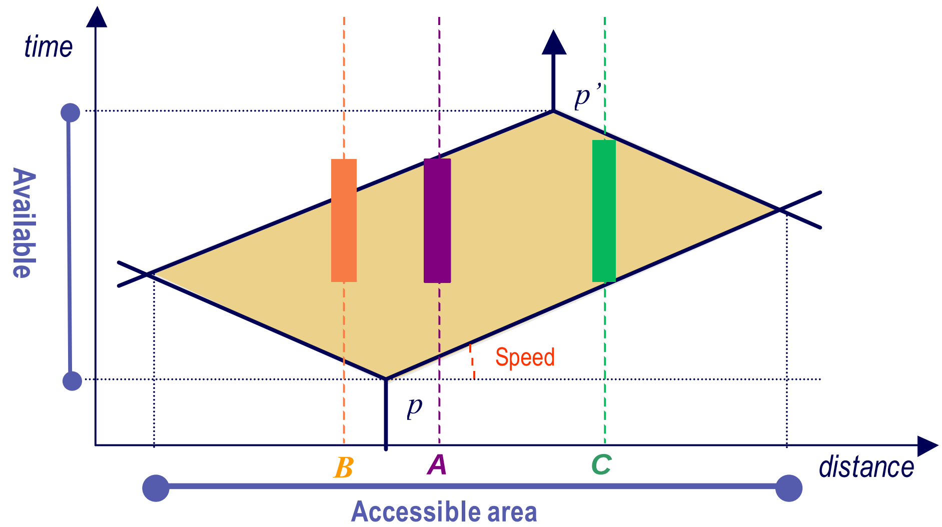

Figure 4. Individual space-time prism. Despite the proximity of B to the starting point p, this individual can only use facilities located at A and C from p but not B.

There have been several attempts to computerise this kind of prism being the program PESASP (Program for Evaluating Alternative Sample Paths) the pioneer (Lenntorp, 1977; 1981; 1982). In some instances a set of new modules has been programmed over existing software while in others, brand new software has been developed. The outcomes range from potential path area computation on individual prisms (Miller, 1991) to the measurement of potential stay time in each point within the studied area (O'Sullivan et al, 2000) or the modelling of possible interactions between individuals possessing predetermined spatiotemporal constraints (Huisman, Forer and Albrecht, 1997; Huisman and Forer, 1998).

Objectives

The main objective of this part of the project consisted on assessing the possibilities of a commercial GIS package (ARC/INFO) in integrating and managing spatiotemporal budgets that would allow a Time Geography-based analysis of the spatiotemporal accessibility to public services. Crèches and kindergartens in the city of Alcalá de Henares were the object of the study.

Activity Diaries in GIS

The spatiotemporal budgets were obtained through the compilation of individual activity diaries amongst public services users. The process followed for the integration of these diaries with the information related to the location and characteristics (namely business hours) of services and the street network is summarised in figure 5.

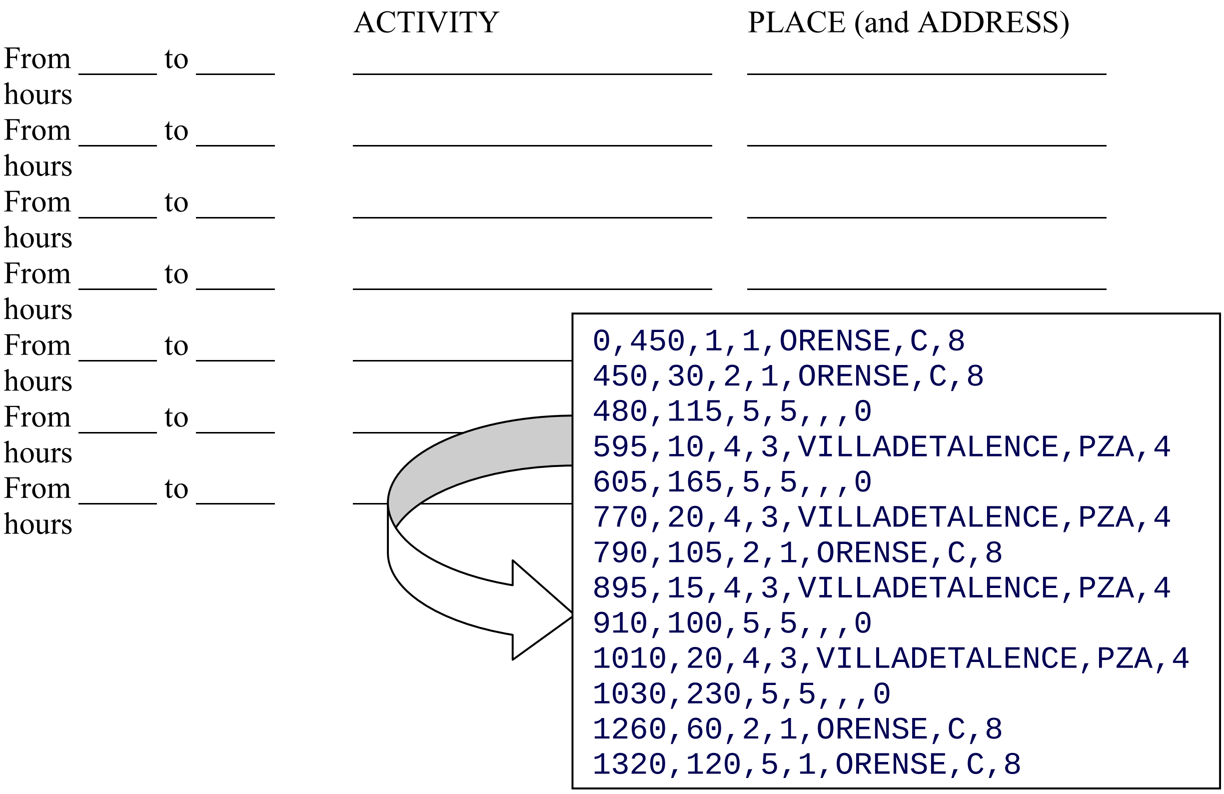

Figure 5. From activity diary questionnaire to *ascii* file

For each of the individual activity diary an independent file named with the identifier of the point representing the address was created. The number of records in these files was dependent on the number of bonded activities included in the diary and on the number of times the subject had free time between activities.

Temporal information related to the starting time for each of the activities was registered through the number of cumulated minutes from 0.00am and the duration, also in minutes, of each of these activities. This choice facilitated later on the computation of total and average duration of bonded activities and free time.

The spatial information included in the diaries (addresses for bonded activities) was registered within the street network through address geocoding. This allowed the calculation of distances between residential address, work place and services.

The resulting system included four main layers of information: street network, work addresses, services addresses and residential addresses.

Analysis of the Spatiotemporal Constraints

The ARC/INFO *near* [assigns Id. check help] command was used to establish a relationship between each of the points included in the addresses layers and the street network nodes. Later, the command *nodedistance* check help calculated the minimum impedance origin-destination matrix for each of the network node with three different transportation modes (walk, car and bus).

An AML module was then developed to facilitate (a) queries on total and average number of invested hours in bonded and free activities, total and average number of hours in each of the five types of activity (basic necessities, home work, work, use of public services or shopping, and leisure/others), and (b) temporal distribution diagrams of each activity and Time Geography functional places diagrams.

The individual diaries were classified in six different groups based on the combination of the degree of commitment to bonded activities (high, medium and low) and the duration of available time.

Evaluation of the Individual Variability in the Possibilities for Centre Choice

The information considered in the evaluation of the individual variability in the possibilities for centre choice included spatiotemporal budgets expressed in the diaries, localisation and business hours of service centres and individual displacement speed. Four different indicators reflected this variability: (a) number of accessible positions at the centres, (b) total number of open hours accessible within the individual accessibility prisms, (c) number of consecutive accessible hours[1], and (d) displacement time to access the service.

The approach adopted to obtain these indicators is summarised as follows:

1. Establishment of links between attributes included the residential addresses layer, the origin-destination matrix (based on the transportation mode most frequently used by the individual), and the attributes included in the services layer.
2. The first relation between tables allows knowing the impedances in minutes between any residential address and all nodes within the street network. The second relation allows knowing whether the queried node is associated with any accessible service centre at that moment. If the response is positive, then the cumulated impedance to the destination node (or accessible service), number of available positions at the service etc.
3. The obtained results (number of available positions, cumulated impedances, hours accessible, etc) for each node are then added up and registered in the attribute table of the residential address layer. It is after this moment that spatiotemporal accessibility analyses can be undertaken.

[1] Business hours are often divided by a long break in the early afternoon. In these instances, only the longest opened period was considered.

Figure 6 demonstrates the fact that individuals living close to each other have access to a significant different number of kindergarten positions. As it was expected, individuals not having great spatiotemporal constraints have the choice to register their kids in almost any of the existing centres.

Spatiotemporal accessibility to kindergartens for each of the individuals

Figure 6. Distribution of residential addresses and spatiotemporal accessibility to kindergarten positions.

CONCLUSION

The studies presented in this paper demonstrate that Personal Geographies can managed by GIS. The possibilities brought by the integration of Cognitive and Time Geographies and GIS to accessibility analysis open new doors to the task of services planning.

As it has been demonstrated, people's services choice is highly based on distances but being these distances more related to the cognitive space than to its physical characteristics, it is imperative their consideration in accessibility analysis.

In the other hand, potential access to services is a function of time budgets rather than distances alone. Through the spatiotemporal GIS model presented, consideration to time can be given in GIS accessibility analyses.

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