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Location–allocation models applied to urban public services. Spatial analysis of Primary Health Care Centers in the city of Luján, Argentina

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Abstract

The actual digital technologies and particularly the association between the Geographical Information Systems (GIS) and the assistance to the Spatial Decision Support System (SDSS) have generated important possibilities for the treatment of spatial information. As regards the use of location-allocation models, this presentation assesses the possibilities of using such models in the field of the geography of services. In this paper theoretical aspects of the analyzed problems are presented, as well as methodological standardized questions for their solution through the use of GIS+SDSS. An applied case study related to the spatial analysis of Primary Health Care Centers (PHCC) in the city of Lujan, Argentina is also presented.

Keywords: Spatial analysis, location-allocation models, primary health care centres, GIS, SDSS.

Introduction

The application of geographical analysis procedures, oriented towards service planning, is actually presented as a very dynamic field of investigation starting from the use of Geographical Information Systems (GIS) as well as the Spatial Decision Support Systems (SDSS).

The models of higher application were defined from a conceptual and practical view some four decades ago (Revelle, Ch. and Swain, R. 1970; Austin, C. 1974; McAllister, D. 1976) and during the decade of 1990 this information slowly spread throughout the digitalization field, through software intended to support decision-making.

Digital standardization of procedures has evolved along with socio-economic aspects in population´s basic services diversification as in the ap-

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pearance of a post-fordist model in which small and medium enterprises (SMEs) supplying services to the industry and other enterprises have an important role.

In view of the above, the spatial location of services appeared to be of a great importance in many aspects, particularly in the field of public services, and in attempts to improve the levels of spatial equity for the population to be served.

Along these lines, the present work may be considered as a later stage for spatial data exploration and has as a principal objective to set forth a standardization of the theoretical methodological aspects of spatial localization in order to prioritize, from a geographical perspective, the process of decision making at the moment of installing, relocating or increasing a given number of installations of public urban services.

The application implemented here will be centered on the spatial localization of the PHCCs in the city of Luján, Argentina (34°34´13´´S and 59°06´18´´ W), with a population of 78,500 in 2012 (Municipalidad de Luján, 2012). Efficient and equitable access to public services must be guaranteed.

Theoretical background

Location-allocation models

Geographical studies have a broad tradition in the generation of theories and general models for the analysis of human activities. Particularly, as regards the tertiary activities, it is possible to consider the *theory of central places* proposed by Walter Christaller in 1933 as a model of optimum spatial localization of urban centres at a regional level. In its formulation, the concepts of *threshold and reach* are presented as a deductive basis from which we can explain certain empiric regularities that were presented in the systematization carried out by Beavon, K. (1980).

From a model-based view, the localizations (potential supply and demand points), the distances (ideal or real) and the costs of displacements (spatial friction) are presented as the principal factors that produce different territorial configurations in the system. A series of studies focuses on the tertiary activity and as regards evolution, goes forward in a change of scale from the analysis of urban centres (regional) towards the inside centres of the city (local). This materializes in the *geography of marketing*, a concept presented by Berry, B. (1971) having been widely analyzed in its current capacities by a series of authors (Moreno-Jiménez, A. 1995, 2004; Bosque-Sendra, J. 2004; Bosque-Sendra, J. and Moreno-Jiménez, A. 2004; Salado-García, M. 2004; Moreno-Jiménez, A. and Buzai, G. eds. 2008).

From this point of view, the theory of localization takes into consideration problems in the installation of services and generates a double objective: on the one hand to find the optimum localizations, and on the other to determine the allocation of demand for such centres. To resolve this double objective models of *allocation-localization* have been developed.

According to Ramírez, L. and Bosque-Sendra, J. (2001), the location-allocation models meet the following characteristics: a) they are mathematical models since this language is considered appropriate to capture reality; b) they are spatial models at intermediate scale because the aspects to be solved are already delimited in a territory; and c) they are normative models because it is necessary to look for the best solution to a given problem.

In synthesis those models attempt to assess the actual locations of service centres on a demand distribution basis, and to generate alternatives to achieve a more efficient and/or equitable spatial distribution. Those models are designed to find the optimum localizations and determine the best links of the demand (allocation).

In recent years the application of location-allocation models, even those operationalized based on a Geographical Information Systems basis, have been framed in a specific system called Spatial Decision Support System (SDSS).[2] According to Bosque-Sendra, J. *et al*. (2000), the SDSS's principal objective is to supply a necessary environment in hardware and software to facilitate users in spatial decision-making matters. In this sense, the study of *exploration* problems, the *generation* of various solutions and the *evaluation* of different alternatives need to be assessed. .

Densham, P. (1991) presents two well differentiated levels as regards the application of SDSS, one in which the user takes decisions through generating, evaluating and choosing solution alternatives, and the system interface achieving a multidirectional interaction between the data base and its possibilities for making numerical and graphical reports.

Finally, it must be noted that location-allocation models are very useful methodologies to support decision-making for health care in developing countries (Rahman, S. and Smith, D. 2000).

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[2] Decision Support Systems (DSS) were initially developed in the economic and management sciences during the 1950s and 1960s and were widely diffused during the next two decades. Likewise, the concept of Spatial Decision Support Systems (SDSS) was developed at the same time, being the Geodata Analysis and Display Systems (GADS) developed by IBM (*International Business Machines*) during the 1970s. Since the second half of the 1980s, DSS have begun to be adopted as tools for the enlargement of the technology capacity GIS. Some aspects of this process were developed by Malczewski, J. (1998).

Orientation of the location-allocation

From a general point of view, the orientation supplied for the model of location-allocation, will be influenced by the nature of the service. If the service is private, it will basically focus on improving *spatial efficiency,* on the other hand, if it is public, it will try to improve *spatial equity*. Both refer to the enhancement of global parameters for the access to the service: the sum of the total displacements, accessibility values or differences among extreme values.

Similarly, a notorious difference is shown if the equipment to be installed is *desired* (beneficial) or *not desired* (prejudicial). While the first ones basically generate positive externalities (hospitals, schools, cultural centres etc.) the second ones generate negative externalities (cemeteries, jails, rubbish dumps, etc.).

Therefore, taking in to account the previous considerations, the SDSS will contemplate different possibilities of methodological application according to the objective in charge of finding the localization of the service centres.

Methodology

Searching for candidate sites and their combinations

The application of location-allocation models implies having an offer, distributed in a point manner, and a demand which, for reasons of simplification, may be assigned to a centroid of each area and a transport network linking them. However, the application of methods attempt to find new supply locations must first consider the determination of possible *candidate sites*, that is to say a quantity of selected points with the purpose of selecting the best one(s) according to the applied model objective.

There are two basic possibilities for the consideration of candidate sites: a) obtain them through procedures of thematic superposition and multi-criteria evaluation (MCE) techniques, and b) consider each centroid of demand as a possible site for the installation. The MCE techniques were extensively developed in Buzai, G. and Baxendale, C. (2011) and the use of the centroids of areas as candidate sites was studied methodologically by Fotheringham, A. *et al*. (1995). The second technique appears to be linked with the modifiable area unit problem (MAUP) at the moment in which a variation in the number of spatial units will allow possible modification of the results obtained.

Therefore, avoiding the necessity of assessing the infinite localizations, the models work with the combinations of p centres in n candidates points, being $p<n$; where p will be the best sites obtained (Church, R. and Sorensen, P. 1994; Lea, A. and Simmons, J. 1995).

Even when the above-mentioned simplifications are carried out, the calculations are extensive, and thus heuristic mechanisms (for iterative procedures of proof and error in a continuous approximation to the best solution) are being sought to obtain results (Densham, P. and Rushton, G. 1992). One such method is presented in this work.

The identification of possible solutions based upon the application of combinatorial supplies extremely high values when changing the elements *n* and *x* applying:

$$\frac{n!}{x!(n-x)!} \tag{1}$$

For example, in a simple case of locating 2 entities among 10 candidate sites, the result is 45 possibilities. If we raise the number of entities to 4, the result will be. To obtain the best 12 sites within the 70 candidate sites (centroids) in Luján, we need to use heuristic methods as there are 10,638,894,058,520 election possibilities.

Facing the overwhelming amount of calculations, the heuristic strategy of approximation to the best solution is theoretically quite acceptable; another proposal also points to the consideration of a multiple interchange of two or three candidates simultaneously, however, for the substantial improvement in the time calculations, the advance in the computational capacities of *hardware* continues being fundamental.

Models for desirable equipments

p-median model

The *p-median model* is an initial and simpler form of the location-allocation modelling procedures. Its objective is to *minimize* the sum of the total of the products of the population displacements from the points of demand (centroids that group the dispersed demand) to the supply points. The function objective is:

where a_i is the weight associated to each demand point d_{ij} is the distance be-

$$\text{Minimize } \{F = \sum_{i=1}^{n} \sum_{j=1}^{m} a_i d_{ij} x_{ik}\} \tag{2}$$

tween potential demand *i* and supply *j* points, x_{ij} is the allocation factor which is equal to 1, if the center of offer *j* is the closest to the point of demand *i* and 0 to the contrary; *n* is the total amount of demand points and *m* the potential supply points (considering the existing ones).

The model is called *p-median* because it is considered that *p* is the number of installations to be located. The objective of this model is to find the minimum value of the function objective *F* and with this the greater spatial efficiency in respect to the total number of displacements from demand centres towards the *p* supply points.

The *p-median* model can be enlarged by incorporating a restriction of distance. It has a similar objective as the previous one, but in this case considering none of the (d_{ij}) surpass a determinate reach value (S).

$$\text{If } d_{ij} \leq S \Rightarrow x_{ij} = 1 \tag{3}$$

$$\text{If } d_{ij} > S \Rightarrow x_{ij} = 0 \tag{4}$$

even though d_{ij} is the lowest value for both points.

This way, on one side it is intended to act on the global cost of displacements (efficiency) and on the other, it is intended to minimize the maximum distances of transfer (equity).

Applying this restriction, it is possible that the solution does not appear from the quantity of the requested points, in this sense it is possible that the necessity of extending them emerges.

Maximum coverage model

The *maximum coverage model* has the objective to *maximize* the total of demand values within a coverage ratio (R) prefixed for the supply points. Within these surfaces the largest amount of demand must remain assigned.

$$\text{Maximize } \{F = \sum_{i \in I} a_i x_i\} \tag{5}$$

where I is the group of demand points (indexed by i) a_i is the population in the demand node i and x_i are 1 if the center of demand i is located inside the area of coverage ($x_i \leq R$) and 0 in a contrary case.

Maximum coverage model with distance constraint

The maximum coverage model can be enlarged by incorporating a restriction of distance, whose object is to maximize the total demand values within a ratio of coverage prefixed for the supply points, considering that all the demand exists within a radio S, greater than the reach of the goods or services.

The formulas which are present in Buzai, G. and Baxendale, C. (2011) are used to find optimum locations, for non-desirable equipment will not be developed here. Conceptually, those seek for the inverse effect to those presented here.

Modelling for distances calculations

When applying location-allocation models, the development of distance calculation from the demand and supply points (d_{ij}), that is, from the centroids of areas with grouped demand towards the existing installations, or towards the candidate points, is an important procedure.

From the coordinates of each location in an absolute space different measures of distance, named metrics, can be calculated.[3]

The straight line distance or Euclidean distance which appears due to the consideration of an ideal space where there are no limitations to transit in any sense is obtained through the application of the following formula:

The *Manhattan* distance or *city block* which assumes a displacement through a regular grid is given by:

In both cases, the results are obtained considering absolute coordinates over the geographical space and while in the first case is used the Pythagorean solution for calculating the hypotenuse of the triangle, in the second case is used the sum of the measure units for both hicks.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{6}$$

$$d_{ij} = \left|x_i - x_j\right| + \left|y_i - y_j\right| \tag{7}$$

With the aim of generating possibilities of more flexible calculations which tend to surpass the *Manhattan* metric considering the sub-estimation problems caused by localizations among blocks or the appearance of barriers, or overestimation from the appearance of streets in different direction of the basic circulation grid (Hodgson, M. *et al.* 1995), the *Lp* metric has been proposed.

$$d_{ij}^{\beta} = \left(\left|x_i - x_j\right|^p + \left|y_i - y_j\right|^p\right)^{\frac{\beta}{p}} \tag{8}$$

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[3] A metric that permit the calculation of distance between points, as has been expressed in Bosque-Sendra, J. (1992), must meet certain conditions: Positivity ($d_{ij} \geq 0$), Identity, if $d_{ij} = 0$, Simmetry ($d_{ij} = d_{ji}$) and Triangular Inequality ($d_{ij} \leq d_k + d_{kj}$).

Here appears a β parameter which indicates a modification of the costs of displacements with the distance, and note that when β=1 we have the *Manhattan* distance with p =1 and *Euclidean* with p = 2. The *Lp* metric was proposed by Love, R. and Morris, J. (1972) and turns out to be an excellent application alternative when it is not possible to calculate over the street network, yet knowing the urban road structure.

However, when the distance calculus is carried out on a geometrical basis from a structure of a *raster* layers, it is also possible to initially establish a correspondence with the analyzed metrics.

A step forward from *absolute space* to *relative space* happens when the distances between two locations are calculated in other units of measurement (time or any other types of cost), which are based on a *map of friction* which incorporates for each pixel a relative value to the effort which must be expended in order to traverse it. In this way, from each point entity we can generate a *cost surface* which corresponds to the cost (effort) which accumulates in each pixel of the study area in order to reach the said entity.

The present application incorporates the thematic layer of the road network of the study area. The distance calculations were made up on such a basis.

Application: location-allocation model applied to Primary Health Care Centers (PHCC) in the City of Luján, Argentina [4]

The application carried out is based in the theoretical and methodological aspects carried out and it presents an analysis based on vector spatial structure made up by points, arcs (lines) and polygons (areas). The application focusing on the analysis of the spatial justice of the health services, considered as a fundamental issue of the development procedure with GIS in the framework of geography of health studies (Buzai, G. 2009; Fuenzalida, M. 2010).

In this configuration, the points correspond to the existing PHCC and centroids of census radii which work as demand points (upon assigning the population values of potential demands) and at the same time as candidate sites for new center localization; the lines correspond to the streets through which the demand and supply points will be spatially linked and the polygons are areas with diverse population values of potential utility.

Figure 1 demonstrates the study area. *Figure 2* presents some of the mentioned components on the studied area: street net, localization and census

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[4] The thematic layers used in the application, correspond to (1) 70 census radii of Luján city, 2010 (2) centroids of census radii as points of demand and candidate sites for localization of the service offer (3) 12 PHCC as offer points, and (4) vial net as friction map. The numerical data taken in to account are: (5) Population of 6 to 14 years per census radii with potential offer value. Software: Flower Map © Ultrecht University, Holland.

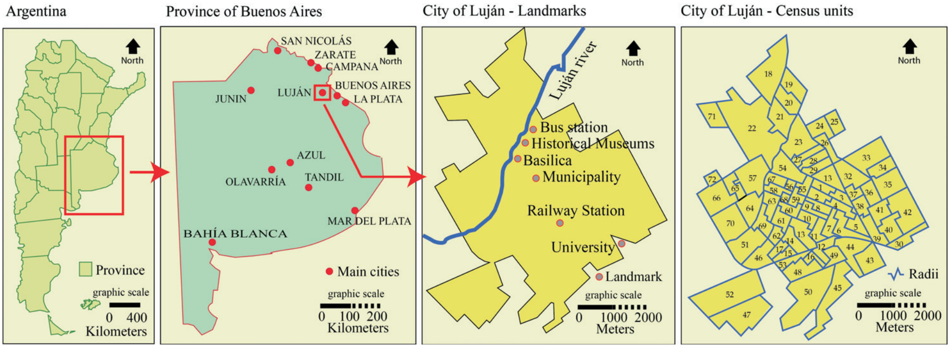

Fig. 1. Location of sutdy area of Luján. *Source:* Edited by the author

radii limits and localization of the 12 existing PHCC which, for the purpose of modelling, were assigned to the centroid of the corresponding census radii.

The first calculus carried out successfully determines the best placement for a total of 12 PHCC considering that each one of the 70 census radii, through its centroid, is presented as a candidate site for the localization. The result presents the spatial configuration of 12 selected points from a total of 70 that is a unique solution of the immense number of possible combinations.

To obtain this, we have used a model of maximum coverage of demand, one of the practical orientations of great possibilities in the environment of Geographical Information Systems (Spaulding, B. and Cromley, R. 2007). In this model, candidate sites which may capture all the population demand were selected considering that no inhabitant of the study area is located more than 1,500 meters from the nearest PHCC, since through a previous exploratory analysis, it was possible to determine that with this distance restriction one can obtain, the same quantity of existing PHCC, which would permit its perfect comparison.

Figure 3 presents the map with the 12 optimum centres obtained; and *Figure 4* is the spider map (also called *desire map*), made up from the centres and the demand allocation from the census radii which are included within each influence area, is presented in the following figures.

The alphanumerical data correspond to this spatial configuration can be seen clearly in *Table 1* from which the following information is presented:

Column 1 – Label: Number of census radii/centroid.
Column 2 – CAPS 1: Existing PHCC.
Column 3 – CAPS 2: Optimal PHCC.
Column 4 – Demand (around a distance of 1,500 meters): Population UBN of potential demand to each optimum center.

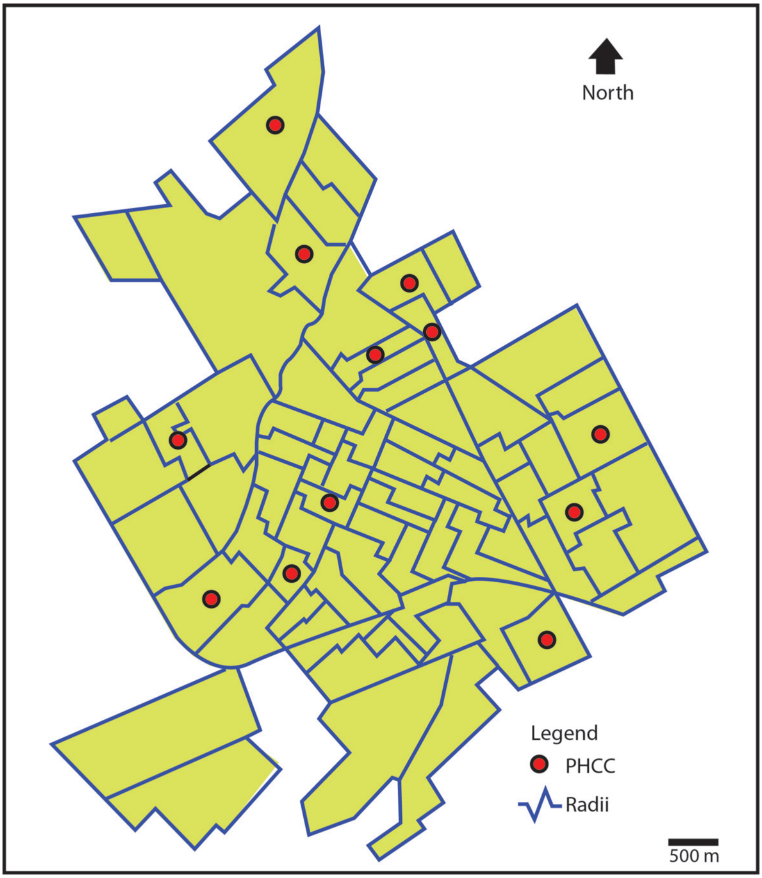

Fig. 2. City of Luján. Census radii, streets and twelve Primary Health Care Centers (PHCC).
Source: Edited by the author (performed with Flow Map)

Column 5 – Center (around a distance of 1,500 meters): Centroid to which the data of the census radii are assigned.

Column 6 – Distance (around a distance of 1,500 meters): Distance between centroids.

Column 7 – UBN: Population of Unsatisfied Basics Needs in each census radii (Original variable from the Argentine national census: NBI *Necesidades Básicas Insatisfechas*, *Synthesis of poverty*).

The 12 existing PHCC are in the centroids of the census radii 18, 21, 24, 26, 27, 35, 41, 43, 51, 60, 62 and 65, while the optimum localization PHCC with a maximum coverage of 1,500 meters, would be located in 20, 21, 26, 36, 42, 48, 49, 51, 52, 59, 65 and 71. Upon being coincident the census radii centroids

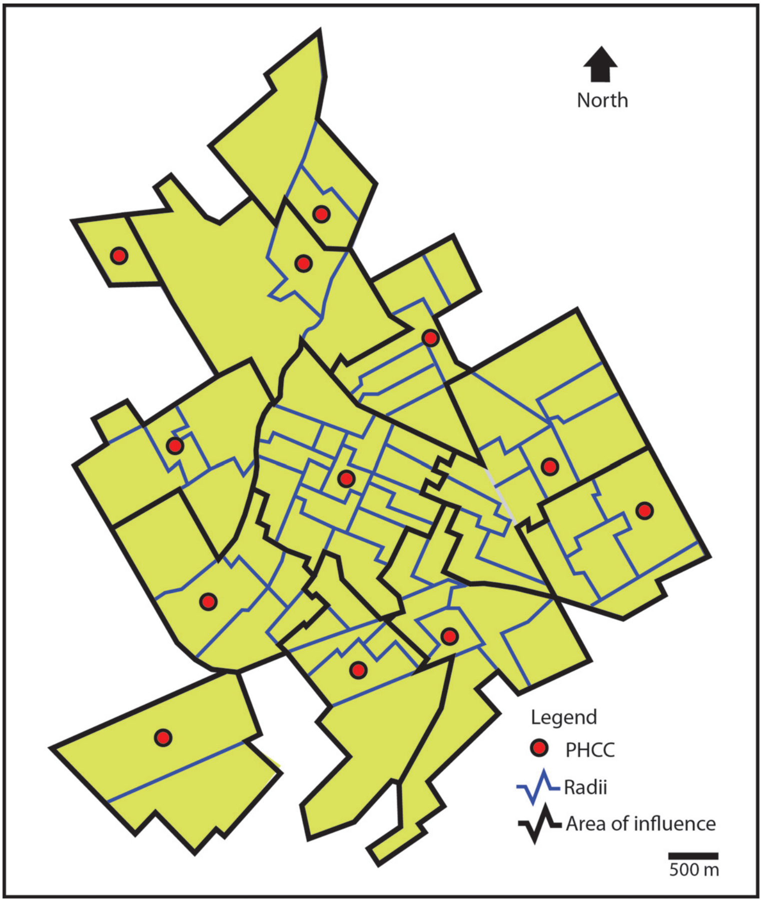

Fig. 3. 12 PHCC optimum location identified and influence areas obtained as model of coverage with a solution of 1,500 meters. *Source:* see *Fig. 2.*

of 21, 26, 51, and 65, there is a 33% of spatial correspondence between the real and the optimum spatial configuration.

The data about the population of *potential demand* was adjusted to the inhabitants with UBN. The localization 36 has the highest value of potential demand with UBN, with 1,552 inhabitants and localization 52 has the smallest value with 72 inhabitants, in their respective influence areas. The entire values are useful in order to figure out the calculations of distance and the population assignation to the localization of the 12 optimum PHCC. The calculations made on the total values give out the following results *(Table 2).*

Figure 5 shows the accumulative values of population with UBN as regards of distance to the optimum centres as a group, and *Figure 6* presents the

Table 1. Results of the allocation solution

Label	PHCC-1	PHCC-2	Demand	Center	Distance	UBN
1	–	–	0	59	1,156.43	1
2	–	–	0	59	858.08	16
3	–	–	0	36	1,000.76	28
4	–	–	0	36	1,178.04	54
5	–	–	0	36	1,342.81	15
6	–	–	0	36	1,409.72	32
7	–	–	0	49	1,449.77	36
8	–	–	0	59	776.50	10
9	–	–	0	59	808.25	4
10	–	–	0	59	1,030.10	12
11	–	–	0	49	1,275.07	7
12	–	–	0	49	442.75	44
13	–	–	0	59	1,355.58	25
14	–	–	0	48	1,241.13	98
15	–	–	0	48	1,161.43	133
16	–	–	0	48	719.14	26
17	–	–	0	51	1,288.40	54
18	x	–	0	20	1,123.14	366
19	–	–	0	20	725.80	427
20	–	x	1,320	20	0.00	527
21	x	x	467	21	0.00	253
22	–	–	0	21	1,340.49	139
23	–	–	0	21	1,095.67	75
24	x	–	0	26	662.02	174
25	–	–	0	26	1,031.66	91
26	x	x	568	26	0.00	106
27	x	–	0	26	702.79	10
28	–	–	0	26	656.45	60
29	–	–	0	26	869.44	43
30	–	–	0	42	1,094.01	57
31	–	–	0	26	1,184.07	84
32	–	–	0	36	1,037.71	36
33	–	–	0	36	1,411.08	209
34	–	–	0	36	1,071.01	419
35	x	–	0	36	724.51	332
36	–	x	1,552	36	0.00	164
37	–	–	0	36	724.31	42
38	–	–	0	36	603.73	47
39	–	–	0	42	1,280.13	59
40	–	–	0	42	853.03	138
41	x	–	0	36	991.11	174
42	–	x	535	42	0.00	281
43	x	–	0	49	1387.81	68
44	–	–	0	49	706.16	109
45	–	–	0	49	1,490.86	164

Table 1. (Continued)

Label	PHCC-1	PHCC-2	Demand	Center	Distance	UBN
46	–	–	0	51	914.01	224
47	–	–	0	52	936.32	23
48	–	x	664	48	0.00	63
49	–	x	506	49	0.00	78
50	–	–	0	48	1,286.38	213
51	x	x	951	51	0.00	264
52	–	x	72	52	0.00	49
53	–	–	0	48	458.37	131
54	–	–	0	59	1,286.35	32
55	–	–	0	59	653.28	14
56	–	–	0	59	613.87	2
57	–	–	0	65	902.74	124
58	–	–	0	59	685.21	7
59	–	x	319	59	0.00	5
60	x	–	0	59	466.56	33
61	–	–	0	59	958.29	66
62	x	–	0	51	1,296.78	64
63	–	–	0	59	1,136.41	62
64	–	–	0	65	898.86	121
65	x	x	773	65	0.00	124
66	–	–	0	65	925.70	167
67	–	–	0	59	1,043.33	28
68	–	–	0	59	485.96	2
69	–	–	0	51	962.81	136
70	–	–	0	51	1,398.99	209
71	–	x	84	71	0.00	84
72	–	–	0	65	1,282.49	237

Source: Calculation by the author

expansion of the calculus considering the 12 existing PHCC and it calculates the localization of 5 PHCC in potential optimal locations.[5]

In effect, the five selected sites correspond to peripherals census radii: three sites in the South, one site in the North, and one site in the Eastern sector. The allocation of potential demand (*Figure 7*) generates minor displacements.

The alphanumerical data corresponding to this spatial configuration can be seen in *Table 3* composed by the following information:

Column 1 – Label: Number of census radii (centroid).

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[5] The *social map* of the city of Luján shows a typical configuration of the Latin American city (Buzai, G. 2003; Buzai, G. and Marcos, M. 2012), where the favored areas have central location and the non favored areas are located in the periphery. In 2010 Luján presents 20 peripherals census radii, therefore it was considered the possibility of including 1/4 of the spatial unities with vacancy of PHCC.

Table 2. Calculations on the basis of total values of Table 1

Calculations	Meters
Distances to centroids	59,853
Distances to population	5,961,586
Averages of distances to centroids	831
Averages of distances to population	83,949
Minimum distance	0
Maximum distance	1,490
Standard deviation to distances to centroids	453
Standard deviation to distances to population	104,409

Source: Calculation by the author

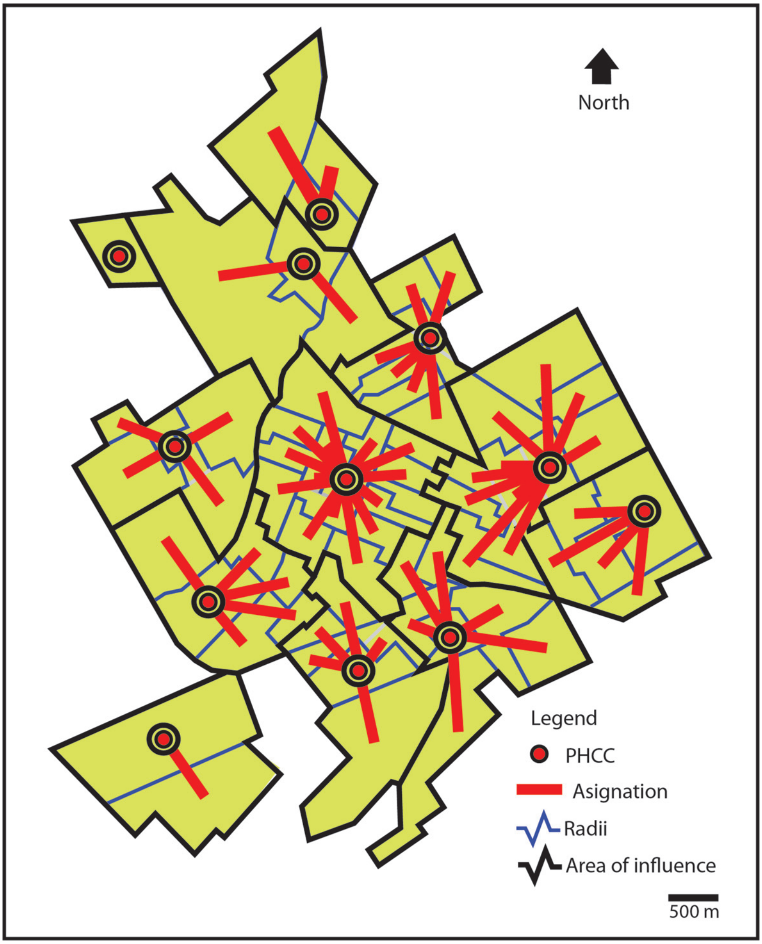

Fig. 4. 12 optimum locations and allocations of potential demand. *Source:* see *Fig. 2.*

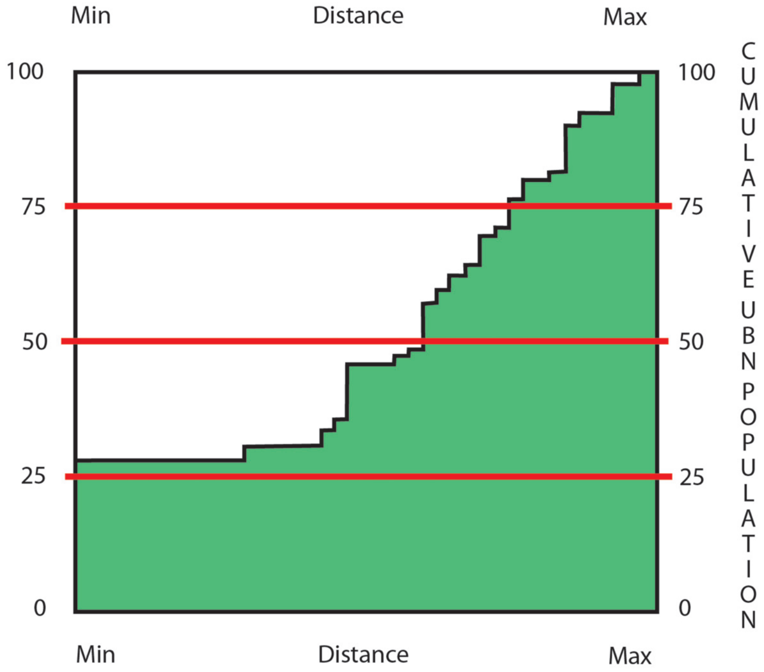

Fig. 5. Graphic of accumulated frequencies covering the potential demand.
Source: see *Fig. 2.*

Column 2 – CAPS 1: Existing PHCC.

Column 3 –CAPS 3: Optimal PHCC (result obtained considering PHCC-1).

Column 4 – Demand (within 1,500 meters of distance): Population UBN of potential demand to each optimum center.

Column 5 – Center (within 1,500 meters of distance): Centroids to which the data of the census radii are assigned.

Column 6 – Distance (within 1,500 meters): Distance between centroids.

Column 7 – UBN: Population with Unsatisfied Basics Needs in each census radii.

The 12 PHCC of Luján are selected in *Table 3* (PHCC-1). To those were added the localizations 39, 48, 49, 52, and 71 (PHCC-2). The configuration expands to 20 PHCC. The values of assigned potential demand decrease remarkably. In general, although localization 35 maintains a high value of 1,166 inhabitants, being that localization 43 has the lowest value with 68 inhabitants with UBN in its influential area. All the values are useful for calculating the distance and the assignation of population for the location of the 20 optimum

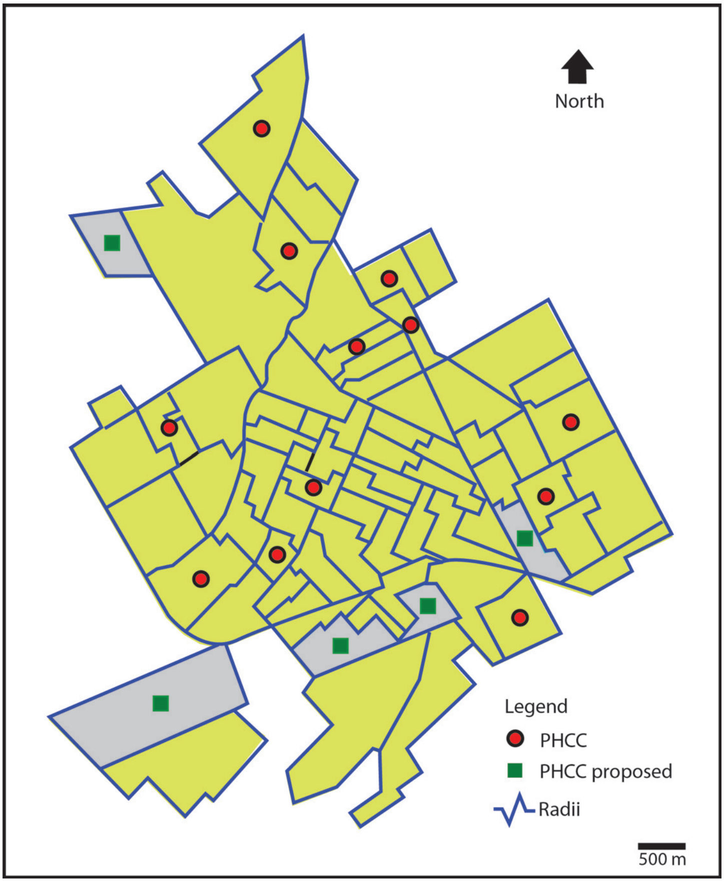

Fig. 6. 12 PHCC+5 proposal. Calculations made with Flow Map software.
Source: see *Fig. 2.*

PHCC. The calculations figured out upon the total values give the following results *(Table 4).*

Figure 8 graphics the accumulative values of population with UBN as regards the distance to the optimum centres.

Comparing the data given by the statistics presented in *Table 2* and *Table 4*, we can see that there exists a decrease in the following values: *Distances to the population of* 59,611,586 to 5,091,082; *Distances covered departure and return* of 11,923,172 to 10,182,164 and *Standard deviation* from distances to population from 104,409 to 101,211. This indicates that with the second solution the parameters of spatial efficiency (distances) and spatial equity (standard deviation) have improved.

Table 3. Allocation solution results

Label	PHCC-1	PHCC-3	Demand	Center	Distance	UBN
1	–	–	0	27	1,368.54	1
2	–	–	0	60	1,247.07	16
3	–	–	0	39	1,449.72	28
4	–	–	0	39	1,395.17	54
5	–	–	0	39	733.11	15
6	–	–	0	39	1,099.96	32
7	–	–	0	60	1,363.27	36
8	–	–	0	60	1,165.49	10
9	–	–	0	60	899.70	4
10	–	–	0	60	636.11	12
11	–	–	0	60	1,256.18	7
12	–	–	0	49	442.75	44
13	–	–	0	60	959.74	25
14	–	–	0	62	734.39	98
15	–	–	0	62	813.39	133
16	–	–	0	48	719.14	26
17	–	–	0	62	603.54	54
18	x	x	793	18	0.00	366
19	–	–	0	18	994.75	427
20	–	–	0	21	757.82	527
21	x	x	919	21	0.00	253
22	–	–	0	21	1,340.49	139
23	–	–	0	27	626.24	75
24	x	x	265	24	0.00	174
25	–	–	0	24	527.85	91
26	x	x	226	26	0.00	106
27	x	x	221	27	0.00	10
28	–	–	0	27	322.62	60
29	–	–	0	27	579.61	43
30	–	–	0	39	1,434.59	57
31	–	–	0	26	1,184.07	84
32	–	–	0	26	1,374.13	36
33	–	–	0	35	1,178.16	209
34	–	–	0	35	521.75	419
35	x	x	1,166	35	0.00	332
36	–	–	0	35	724.51	164
37	–	–	0	35	1,291.02	42
38	–	–	0	41	852.10	47
39	–	x	383	39	0.00	59
40	–	–	0	39	618.73	138
41	x	x	502	41	0.00	174
42	–	–	0	41	1,013.56	281
43	x	x	68	43	0.00	68
44	–	–	0	49	706.16	109
45	–	–	0	49	1,490.86	164

Table 3. (Continued)

Label	PHCC-1	PHCC-3	Demand	Center	Distance	UBN
46	–	–	0	51	914.01	224
47	–	–	0	52	936.32	23
48	–	x	433	48	0.00	63
49	–	x	395	49	0.00	78
50	–	–	0	48	1,286.38	213
51	x	x	697	51	0.00	264
52	–	x	72	52	0.00	49
53	–	–	0	48	458.37	131
54	–	–	0	27	889.29	32
55	–	–	0	60	991.48	14
56	–	–	0	60	927.30	2
57	–	–	0	65	902.74	124
58	–	–	0	60	990.64	7
59	–	–	0	60	466.56	5
60	x	x	329	60	0.00	33
61	–	–	0	60	502.41	66
62	x	x	485	62	0.00	64
63	–	–	0	60	684.59	62
64	–	–	0	65	898.86	121
65	x	x	773	65	0.00	124
66	–	–	0	65	925.70	167
67	–	–	0	60	1,348.76	28
68	–	–	0	60	523.24	2
69	–	–	0	62	750.62	136
70	–	–	0	51	1,398.99	209
71	–	x	84	71	0.00	84
72	–	–	0	65	1,282.49	237

Source: Calculation by the author

Table 4. Calculations on the basis of total values of Table 3

Calculations	Meters
Distances to centroids	51,505
Distances to population	5,091,082
Averages of distances to centroids	715
Averages of distances to population	71,686
Minimum distance	0
Maximum distance	1,490
Standard deviation to distances to centroids	485
Standard deviation to distances to population	101,211

Source: Calculation by the author

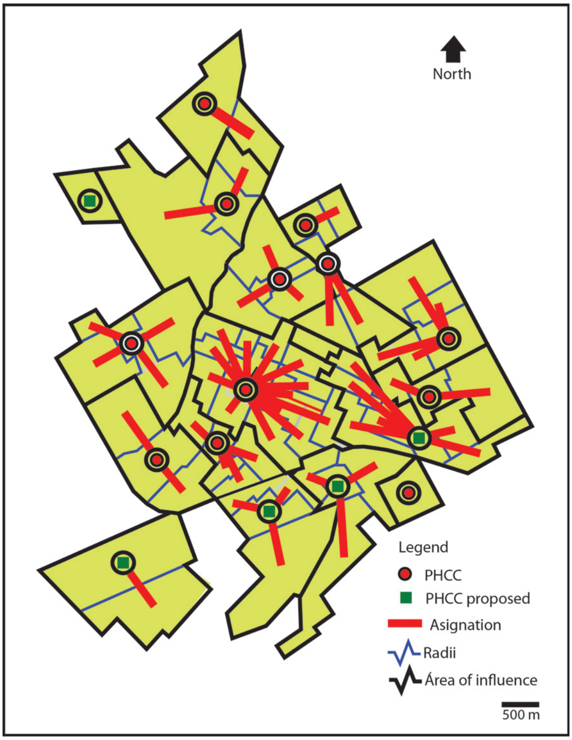

Fig. 7. Allocation of potential demand to solution of 17 PHCC. *Source:* see *Fig. 2*.

Fig. 8. Graphic of the accumulated frequencies coverage of potential demand. *Source:* see *Fig. 2*.

Conclusions

In this work the aptitude of the location-allocation models was exemplified based on the calculus of coverage, mainly applied in the search of efficiency and spatial equity of the Primary Health Care Centers (PHCC) in the city of Luján. Also, the obtaining of solutions that start going into the process of verticalisation (Eastman, J. 2007) through the Geographical Information Systems (GIS) and of the Spatial Decision Support System (SDSS) supply important possibilities for the right support on decision making in spatial issues.

The questions answered in this work are the following: which is the rate of correspondence between the real localization of the supply points and the ideal localization based on the spatial distribution of the demand population? In which way the spatial efficiency and the spatial equity is modified in accordance to the reallocation of these points and finally where should new installations be settled in order to satisfy the distributed demand? The application carried out for the city of Luján has clearly answered these aspects by presenting key elements for the urban planning of the studied area.

By generating concrete results which allow us to answer these questions, one may note that the theoretical–methodological guidelines currently developed in the interior of the technologies GIS+SDSS allow a valid approximation to the solution of complex localization.

We consider that automated spatial analysis contributes to support the theoretical–methodological geographical basis, in decision-making processes in urban planning issues, thus allowing one to confront actions oriented to reducing aspects of socio-spatial inequalities of the population.

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