Simulating the effects of population evolution on public services location in a region

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ABSTRACT

Public services location in Extremadura (a sparsely populated region in Spain) was analysed in 1996. In that study, the best network was determined according to minimise the distance or time everyone had to take to access to public services as education, health or Civil Service Information. Now, by using the age structure as well as fertility and death rates, we are going to simulate the evolution of population in Extremadura and so, to test the effects of this change on the quality of public services network. We think it is very important for public deciders to know where and which investments are going to be necessaries.

1. Introduction

Migration from rural areas to cities has been a constant flow all over the world along this century. This flow threatens to change the territorial structure in our countries.

The reasons of this process are to search better opportunities of work and to satisfy some necessities as education or health.

The latter is the problem that is tried to be solved in this study. Migration could be restrained if a *pyramidal development* was set up. This way of development should bring nearer social services to the population of underdeveloped areas and it would be based on a set of duty points, each one with an influence zone.

This analysis has been applied on Extremadura. With a mainly agrarian economy and a great proportion of occupied people in this economic sector, an intra-regional migration is caused by the high level of unemployment and the search of a better offer of public social services.

In the study done in 1996, the best network was determined according to minimise the distance or time everyone had to take to access to public services as education, health or Civil Service Information. Now, by using the age structure as well as fertility and death rates, we are going to simulate the evolution of population in Extremadura and so, to test the effects of this change on the quality of public services network. We think it is very important for public deciders to know where and which investments are going to be necessaries.

The outcomes of that paper could drive the deciders to done a public investment to reduce cost of travel. However, it analysed a static problem, not a dynamic one, as so, it did not take into account the population growth and the improvement of infrastructures (mainly, roads). Both factors reduce the target population as well as time of travel.

The former is the only studied in this paper because the other depends on politic decisions.

2. Methodology

We have used two approaches: the first, a normative one and the second, a positive one. The former was also used in the paper of 1996.

2.1 Weighted average distance method

Firstly, we are going to introduce the normative approach. In few words, everybody without the service must go to the nearest town with it.

The distribution of a set of public social services, the flows of population caused by this distribution and the flows - attracting centres have been studied here. The latter are the main objective: to find them is to build a territorial structure that bring nearer public social services to potential users and they can be a focal point of development.

Influence areas have been delimited for each set of services, that is, which influence area is for a specific set of services.

Since population and distance are the two main variables of the problem, the most important concepts and hypothesis are related to them: *minimum distance criteria, population basic level, potential population, displaced population flow and weighted average distance (wad).*

The hypothesis of minimum distance criteria has been used to set up the influence areas. It is defined as:

Assumed two towns, A and B, A is assigned to B _ distance (A, B) = min distance (A, X), B∈ X, being X the set of towns where the combination of services that the population of town A has not got and needs is present.

The values of distances in the hypothesis above are measured in kilometres since road distances are taken into account. Perhaps it could have measured in terms of accessibility and spent time and so the quality of roads would be taken into account. However, this estimation of accessibility and time has not been possible to be done.

An important concept is potential population. Demand of each service was unknown, but to estimate it was necessary. Consequently, the whole population that can need the service has been taken into account; that is, a massive access to the service is thought.

From the former, two additional concepts are derived: population basic level and displaced population flow. Whereas population basic level is the minimum population that has a given set of services, displaced population flow is thought as the amount of people that must go to another town to have a given set of services.

It is important to make clear that population basic level is not related to a specific town, but a zone. The amount of people does not need to belong to an only town. In fact, it musts be located in an area.

Two types of duty points or centres appear: those ones that serve mainly the town where they are and the others whose mission is to serve the area where they are. If the population basic level were determinated according to the population of the place where the duty point is present, many localities without duty point would be over this minimum level. That is why to take into account the zone population is necessary.

Finally, weighted average distance (*wad*) is a very important definition in this study. It is defined as the average distance that an inhabitant of an area must go to have a given set of services. From this, it is inferred that if the population of the head town is a high proportion of the total population, the value of *wad* will be lower than the other corresponding to the opposite case.

If there are n towns in a given area, *wad* is defined as:

$$wad = \frac{\sum_{i=1}^{i=N} pop_i \, C(d_i)}{\sum_{i=1}^{i=N} pop_i}, \quad (1)$$

where pop_i is the population of the locality i, C (d_i) the function of transport cost, d_i the distance between the town i and the head town and i =1,..., n.

This tool is useful to determinate the goodness of the structure since its diminution implies an upgrade of the access to social services. It can be understood as a lessening of transport per capita if a cost per km. and person equal a C is assumed.

The services that have been taken into account have been: **education** (school, high school and centre of university level), **health** (Centro de Salud and hospital), **Law administration** (first instance court, provincial high court and regional high court) and **regional Civil Service** (public information office).

The different levels of set of social services according to each combination of services appear in Figure 1. This study is going to be focused on level 5, 4 y 3. Higher levels are excluded because the 1.99% of places in Extremadura have a set of services with level up to 5 and, due to hierarchical structuring of levels, all the cities with level higher than 5 have level 5 too. Levels 0, 1 and 2 are not taken into account due to its low presence of social services.

Three steps have been followed: first, to delimit influence areas for each set, then to study the values of potential proportion and displaced population flow and, finally, to analyse the values of *wad* for each area.

Figure 1

Combinations of services that cause each level

	S	HS	CS	PIO	C	H	U	PHC	RHC
0	No service is required								
1	This								
2	This	1 of these three							
3	**This**	**2 of these three**							
4	**This**	**This**	**This**	**This**					
5	**This**	**This**	**This**	**This**	**This**				
6	This	This	This	This	This	1 of these two			
7	This	This	This	This	This	This	This		
8	This	This	This	This	This	This	This	This	

9	This	This	This	This	This	This	This	This	This

Key: S (school), HS (high school), CS (Centro de Salud), PIO (public information office), C (court), H (hospital), U (centre of university level), PHC (provincial high court) and RHC (regional high court).

That paper concluded that level-4 areas had the best *wad*, that is, people had not to travel a lot to get a service.

The same method is going to be used to study the situation in 2001, 2006, 2011 and 2016 and, after that, we are going to compare the figures with those in 1996. Thus, it would be possible to know if zones with high *wad* in 1996 keep these values.

Besides, we show the population of each zone to test if high *wad* values correspond to high quantity of users.

2.2 Potential customers approach (Huff's model)

The location of public services can be also studied in a positive way and so, it is possible to find the towns with more potential users. We have used a model borrowed from models representing consumer spatial behaviour in order to delineate retail-trading areas and to define tier potential customers. We have found that the model presented by Huff (Huff, 1964) could be very useful. Unlike the models of other market analysts, Huff's theoretical models for defining trading areas and estimating the expected number of customers for a particular shopping area focused on the consumer rather than the firm as the primary agent. In addition to the parameters used in the traditional gravity models in this field of research, population masses of areas and the distance between these areas, Huff introduced the element of possible competition between neighbouring areas by introducing the customer ability to choose between alternatives.

The theoretical model used was based on the following assumptions:

- Larger settlements offer more public facilities and will attract customers from little settlements.
- People will make use of public facilities less if the distance to be covered to these facilities increases. Over a certain distance, nobody will make use of the facilities anymore: the distance may be prohibitive or the customers will use facilities, which are located nearer to their homes.
- As providers of public facilities settlements will compete with each other in a spatial system of settlements of various size and geographical position. Therefore, the level of public facilities present in a settlement depends not only on the number of its inhabitants, but also on the presence or absence of possible alternatives in its surroundings.

The starting point in the theoretical attraction model can be formulated as follows: the attraction public facilities in settlement j exert on the population of settlement i (A_{ij}) varies with some function f of the population of settlement j (M_j) and inversely with some function g of the distance between settlement j and settlement i (D_{ij}).

$$A_{ij} = \frac{f(M_j)}{g(d_{ij})} \text{ (2).}$$

However, various settlements *j* exert an attraction on the population of settlement *i*. From the viewpoint of settlement *i*, A_{ij} can be expressed as a proportion of the total attraction (A_i) added for all settlements *n* ($A_i = \sum_n A_{in}$)

$$P_{ij} = \frac{A_{ij}}{A_i} = \frac{f(M_j) / g(d_{ij})}{\sum_n f(M_n) / g(d_{in})} \text{ (3)}$$

The proportion (P_{ij}) in formula (3) indicates the probability that an inhabitant of settlement *i* uses the public facilities of settlement *j*. Multiplying P_{ij} by the number of inhabitants of settlement *i* (M_i) yields the estimation of the number of inhabitants living in settlement *i* regularly using the public facilities of settlement *j* (C_{ij}).

$$C_{ij} = P_{ij} * M_i \text{ (4)}$$

Adding the values of C_{ij} for all settlements *i* yields the total number of potential customers of the public facilities in settlement *j* coming from all settlements *i* (including those of settlement *j*)

$$C_j = \sum_i C_{ij} = \sum_i (P_{ij} * M_i) \text{ (5)}$$

Finally, it is interesting to note that adding the values of C_{ij} in formula (4) for all settlements *j* yields the number of inhabitants of settlement *i*, since the sum of P_{ij} over *j* equals 1. The model yields, therefore, a redistribution of the total population of the settlements: from inhabitants if settlements to potential customers of public facilities in those settlements.

As the range of the public facilities is 60 km., we have taken into account it as the maximum. Besides, we present a simple specification: the function f (M_i) in formula (2) is defined as $\boldsymbol{f(M_j) = M_j}$ and the function g (d_{ij}) in this formula as $\boldsymbol{g(d_{ij}) = d_{ij}}$. There are as many models as functions f (M_i) and g (d_{ij}).

Thus, the probability that an inhabitant of settlement *i* uses the public facilities of settlement *j* (P_{ij}) is computed by the following formula:

$$\boldsymbol{P_{ij}} = \frac{\boldsymbol{M_j} / \boldsymbol{d_{ij}}}{\sum_{n: d_{in} \leq 60} \boldsymbol{M_n} / \boldsymbol{d_{in}}} \text{ (6), if } \boldsymbol{d_{ij}} \leq 60 \text{ km and } P_{ij} = 0 \text{ if } d_{ij} > 60 \text{ km}$$

where:

- M_j= the number of inhabitants of settlement *j*.
- d_{ij}= the distance between the settlements *i* and *j*.

- the sum in the denominator sees to it that the total potential of local customers from settlement *i* equals the number of inhabitants of this settlement.

The estimation of the number of inhabitants living in settlement *i* regularly using the public facilities of settlement *i* (C_{ij}) is calculated from P_{ij} and M_i by formula (4) above. The total potential of customers of settlement *j* (C_j) is subsequently obtained by adding the values of C_{ij} for all settlements at a distance of 60 km. or less using formula (5) above.

2.3. Simulation of the evolution of population

It was necessary to simulate the population of each town for those years. The crude birth and death rates of each town in 1996 were used to do it. Besides, we have assumed several hypotheses:

- Rates are assumed constant along the period.
- Sex and age structure of the population are not considered (we have not these data).
- Migration is not taken into account because there are no data on local level migration.

Besides, we have presumed that the main features of migration in Extremadura are:

- A return of migrants, who are aged people, to the region.
- An inner migration towards the biggest towns in the region.

These hypothesis defined, the model used to predict the evolution of the population is:

$$P_t = P_0 \left[1 + (n - m)\right]^t$$

where, P_t is the population in year t, P_0 the population in year 0 (1996), n the crude birth rate, m the death rate and t the year.

The data sources have been the Spanish Census of Population (1996) of Instituto Nacional de Estadística and some publications of the Statistical Office of the Regional Government.

3. Results

The aim of this paper is to study the influence of the evolution of population in the quality of service areas made in 1996.

We can analyse the changes of each *wad* shown in Appendix 1. The main feature is that the *wad's* keep or reduce their values, that is, in average, customers are nearer. Therefore, the effect of an investment made according to ’96 outcomes would be constant.

The reasons of this apparently permanent structure are the higher population growth of head-towns and the fact that farther settlements usually are isolated and sparsely populated. Besides, the latter present lesser growth rates and so, the impact of their evolution will be gradually lesser.

Therefore, demographic evolution will not change the measure of quality of public service structure.

The *wad*s keep their values because the relationship between moving population and staying population does not vary. In consequence, an investment decided, according to ’96 results, in order to reduce the *wad* will keep be valid.

However, some additional facts have to be considered:

- Age structure of the population: the analysis of the population pyramids from Regional Health Service shows that less populated areas have higher degrees of ageing. Therefore, we can expect that the **actual** evolution will be less that the predicted.

- Inner migrations: a previous study, made by the authors in 1997, proved that this process is happening in Extremadura towards the most populated towns in the region.

If the latter facts are taken into account, we see that the rates have not to be stable. That is, whereas a young population will be progressively growing its birth rate, an aged one will grow its death rate and reduce the birth one.

Therefore, we think that the most populated towns will and have to be the aim of the public investment in order to build a public information structure.

The other approach shows the same results (see Appendix 2): the values of attraction of public facilities, probability of using and potential consumers do not change. We have an “apparently stable” structure again, where an investment, decided according to ’96 results, is expected to have the same effects along the time.

If different functional forms of f (M_j) and g (d_{ij}) were taken into account, the results would be very similar because the less populated settlements are usually located very sparsely. Consequently, there would not be many differences if the decider paid more attention to population or distance.

We think that the results by using these simple functional forms are very useful and have enough power to explain the reality.

Finally, if the hypotheses are broken, we come to the same conclusion as before: the most populated settlements are expected to grow more and so, they must be the main and first targets for investments in public information facilities.

The goal of public deciders must be different: improving this structure. We think that this paper shows that it is better to improve an existing facility than to build a new one. Thus, settlements without enough population to hold a new facility can receive some investments. Only unserved population was taken into account in this new analysis and both methods would yield the preferences or necessities of public facilities.

4. Conclusions

In this paper, the impact of the demographic changes on the structure of public information facilities in Extremadura.

Since it is a sparsely populated region, the study is important because the services must be located near the customers. By using two different approaches, the problem has been analysed. Both models have yielded similar results: stable situation along the time and so, all the settlements would have to be considered for investing.

Nevertheless, if the assumed hypotheses were broken (and we expect them to do it), the most populated settlements are the preferred objectives.

Otherwise, we think that the study must be aimed to improve the existing structure, not to build more facilities due to the low population of Extremadura.

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APPENDIX 1

Weighted average distances 1996-2016

	1996	2001	2006	2011	2016
Alcántara	16,90	13,86	13,99	14,11	14,23
Alburquerque	6,18	6,30	6,34	6,37	6,41
Alconchel	14,19	14,08	14,01	13,94	13,86
Almendralejo	5,27	5,18	5,13	5,08	5,02
Arroyo de la Luz	11,30	11,29	11,27	11,25	11,24
Azuaga	10,40	10,48	10,49	10,50	10,51
Badajoz	0,95	0,94	0,94	0,94	0,93
Barcarrota	15,73	15,97	16,07	16,18	16,28
Castuera	9,49	9,48	9,51	9,53	9,56
Cabeza del Buey	6,04	5,80	5,73	5,67	5,60
Cáceres	3,52	3,40	3,37	3,35	3,32
Coria	6,35	6,14	6,06	5,98	5,90
Don Benito	2,86	2,86	2,85	2,83	2,81
Fregenal de la Sierra	7,68	7,64	7,61	7,57	7,54
Guareña	7,78	7,56	7,44	7,31	7,18
Herrera del Duque	13,72	13,50	13,36	13,21	13,07
Hervás	16,52	16,60	16,64	16,69	16,74
Hoyos	14,72	14,70	14,67	14,63	14,60
Jerez de los Caballeros	9,79	9,69	9,68	9,68	9,68
Jaraíz de la Vera	16,49	16,38	16,37	16,36	16,34
Llerena	10,95	11,01	11,10	11,19	11,28
Logrosán	19,26	19,15	19,08	19,01	18,94
Mérida	3,70	3,68	3,69	3,69	3,70
Montehermoso	20,95	20,82	20,67	20,52	20,37
Miajadas	16,94	16,71	16,59	16,46	16,34
Monesterio	9,41	9,40	9,41	9,42	9,44
Montijo	7,54	7,35	7,27	7,19	7,12
Moraleja	0,13	0,12	0,11	0,11	0,10
Navalmoral de la Mata	12,10	11,71	11,53	11,36	11,19
Olivenza	3,13	3,04	3,00	2,95	2,91
Plasencia	6,14	6,00	5,94	5,88	5,82
Talarrubias	14,92	14,94	14,91	14,89	14,86
Trujillo	14,21	14,22	14,16	14,11	14,06
Valencia de Alcántara	15,23	15,25	15,28	15,31	15,34
Villafranca de los Barros	8,16	8,11	8,07	8,03	8,00
Villanueva de la Serena	6,56	6,50	6,46	6,42	6,38
Zafra	8,97	8,85	8,79	8,74	8,68

APPENDIX 2

Potential customers 1996-2016

	1996	2001	2006	2011	2016
Alcántara	10126,33	9930,80	10369,02	10829,17	11312,46
Alburquerque	13688,19	13620,00	14285,85	14985,85	15721,82
Alconchel	9907,82	9826,67	10338,24	10878,23	11448,29
Almendralejo	45503,50	46146,96	48888,30	51797,76	54885,87
Arroyo de la Luz	17056,65	16921,41	17770,02	18665,21	19609,74
Azuaga	18502,20	17999,26	18704,84	19440,03	20206,15
Badajoz	129446,15	132470,99	140429,72	148868,74	157817,08
Barcarrota	16490,94	16359,29	17195,62	18077,60	19007,83
Castuera	22236,08	22000,91	22984,76	24015,86	25096,64
Cabeza del Buey	13409,15	13148,11	13752,80	14386,84	15051,71
Cáceres	91027,08	92721,67	97828,24	103223,48	108923,93
Coria	24743,56	24788,22	26028,63	27338,09	28720,64
Don Benito	45869,08	46254,09	48806,27	51505,42	54360,27
Fregenal de la Sierra	16963,12	16782,41	17624,40	18510,27	19442,36
Guareña	19791,35	19979,92	21139,85	22372,42	23682,42
Herrera del Duque	12253,43	12015,93	12526,80	13061,54	13621,33
Hervás	16545,37	16273,94	16855,90	17462,54	18095,06
Hoyos	12300,48	12161,91	12745,72	13362,21	14013,45
Jerez de los Caballeros	22416,64	22431,82	23611,87	24856,86	26170,47
Jaraíz de la Vera	30390,50	30246,10	31542,61	32902,32	34328,54
Llerena	17087,31	16765,26	17374,83	18012,12	18678,59
Logrosán	16812,04	16409,42	16928,95	17468,15	18027,87
Mérida	68672,79	70552,88	75095,45	79938,46	85102,12
Montehermoso	21736,52	21645,40	22619,93	23648,18	24733,48
Miajadas	31625,11	31624,95	33187,14	34835,42	36574,80
Monesterio	8378,53	8327,36	8734,80	9163,44	9614,43
Montijo	30960,98	31441,79	33284,57	35240,13	37315,56
Moraleja	19602,97	19695,51	20686,43	21732,34	22836,46
Navalmoral de la Mata	36676,35	36834,11	38601,70	40466,42	42433,87
Olivenza	17228,53	17422,25	18495,46	19637,70	20853,51
Plasencia	54503,22	54952,39	57716,37	60626,83	63691,84
Talarrubias	13660,40	13396,64	14009,12	14651,33	15324,78
Trujillo	23879,23	23343,57	24282,50	25265,13	26293,72
Valencia de Alcántara	12367,98	12214,27	12758,31	13327,89	13924,26
Villafranca de los Barros	31252,88	31495,55	33248,46	35103,64	37067,27
Villanueva de la Serena	38754,67	38833,40	40913,45	43110,55	45431,54
Zafra	33921,88	34121,73	36044,69	38080,95	40237,37