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Accessibility to Nodes of Interest: Demographic Weighting the Logistic Model

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This research fits into the genre of spatial analysis, aimed at better understanding of population dynamics in relation to the presence and distribution of infrastructure and related services. Specifically, the analysis uses a model of the gravitational type, based on the assumption of the impedance (attractiveness) territorial, based on a curve of type logistics to determine the accessibility of the same, to which to add a system of weights. In this sense, the model was weighted according to the population, to determine the level of "population served" in terms of infrastructure and related services included in the model.

Keywords: *accessibility, regional development, impedance curves, territorial statistics, infrastructures, logistic form, weighted indices.*

JEL Classification: *O18*

1. Introduction

Over the past few decades, from the end of the 50s of XX century, the attention to a greater knowledge of the territories, the relative accessibility, attractiveness and consequent control of the same has affected more and more governmental authorities of the countries.

It has gone from a simple "personalist conception" of the territorial governance to approaches more and more technical - scientific, based on the possibility of obtaining information as capillaries in the area, as well as the application of real equations can explain the distribution of resources in the same territory, in order to better government.

A pioneer in this kind of approaches was Hansen (1959), who first applied a mathematical model called "gravity" to the territory.

The excellent results obtained by this author have prompted other researchers, subsequently, to continue on the path taken, as well as to test new approaches (Andy and Niemeier, 1997).

That is how the measures defined as "cumulative opportunities" and "the utilitarian choice", due to the collaboration of multiple authors.

However, the approach of "gravity", to date, has provided the highest and best contribution to the knowledge of the territory, also because it is the most objective among those produced so far.

The writer has had occasion to apply the gravity model, suitably elaborated, three Italian regions: Tuscany, Trentino - Alto - Adige and Friuli - Venezia – Giulia (de Candia and Chiocchini, 2014).

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For Tuscany was produced a real benchmarking, whereas three distinct functions of impedance (exponential, logistic and linear) summarizing the results both by arithmetic average, either by MPI (Mazziotta and Pareto, 2007).

For Trentino - Alto - Adige and Friuli - Venezia - Giulia was produced map accessibility and consequent attractiveness at the municipal level, whereas function of impedance is the logistic curve and synthesis by arithmetic mean, which has been shown to be the best approach to territorial representation.

This paper aims to provide a further contribution to the field, building a system of weights based on the resident population, in order to pinpoint what is the degree of distribution of the services offered to the population, in terms of infrastructure in the area.

2. Materials and Methods

The research focuses on the areas of Tuscany, which are analyzed for the presence of the following infrastructure: hospitals with emergency room, upper secondary grade schools, railway stations and airports.

Following the approach of gravity, we arrive at the following synthetic formulation:

$$A_i = \sum_{j \in D} W_j^{\beta} \; f(c_{i,j}, \alpha)$$

Where A_i is the accessibility of a resident of the area i with respect to the node j in the region D, W_j^{β} is a measure of the activities or services (mass of opportunity) located in zone j, β is a calibration parameter (used to account for the effects agglomeration) and $f(c_{i,j})$ is a function of impedance generally decreasing with the cost (or with the distance or travel time).

Using the impedance in the form of logistics, we arrive at the following equation:

$$f(c_{i,j}) = \left(\frac{1}{1 + \exp - k(c_{i,j} - c_0)} \right)$$

with

$$c_0 = \frac{1}{2}(c_{min} + c_{max})$$

where

c_{min} is the minimum cost
c_{max} the maximum cost observed and
$k = 2 \ln(\frac{1}{\gamma} - 1)/(c_{max} - c_{min})$
$\gamma > 0$

To get good results, γ must be greater than zero, but not too big. Following previous approaches, which have proved more encouraging that, there is γ equal to 0.05.

The summary of the results is achieved by weighted arithmetic mean, using the resident population as calculated from the XV Census of the Italian population and housing.

Were produced two different approaches, one called "weighted average", the other "index weighted average" according to the following formulations:

$$\begin{matrix} \mu_i = \sum_{ij}(x_{ij}/p_i) * 100 \\ \mu = \sum_{ij} \mu_i / n \end{matrix} \qquad \text{(Weighted average)}$$

$$\begin{matrix} \mu_i = \sum_{ij}(x_{ij} p_i)/p_i \\ \mu = \sum_{ij} \mu_i / n \end{matrix} \qquad \text{(Index weighted average)}$$

where

x_{ij} is the impedance function developed for the common i and for infrastructure j,
p_i is the population of the municipality,
μ_i is the weighted arithmetic mean for each municipality i.

3. GIS Analysis to Calculate Impedance Distances

The impedance distance (travel time) were calculated through the GIS software ArcGIS Network Analyst module. For the calculation is used the road graph Multinet of Tom Tom where the data on road conditions are updated at the end of 2013. The starting points used as source data are the centroids of the municipalities of Tuscany (ISTAT 2012) and centroid of the sub-municipal areas (ISTAT 2010) only for the city of Florence. The destination points used are all the considered infrastructures (hospitals, railway stations, secondary schools and airports). The infrastructure used are derived from georeferencing public administrative archives and these are integrated with the Point of Interest that are included in the graph road datasets. The facilities used, are:

- Railway stations (platinum, gold e silver) year 2012 RFI (Railway Italian Infrastructures) source;
- Airport year 2010 ENAC (Italian Civil Aviation Authority) source;
- Public and private hospital with first aid year 2007 Health and Care Ministry source;
- Secondary school year 2011 Ministry of Education source.

The output OD cost matrix, that is the result of GIS processes, consists of all drivetime and kilometric distances from origins to destinations. The calculations are performed in ideal conditions and in the absence of traffic and using a traveling speed that is set on the road graph. The traveling speed used, is referred to the highway code speed and to road signs contained in the updated road graph. The tool used is ArcGIS "find closest facilities" contained in the Network Analyst package; this tool allows you to calculate all the driving distance starting from closest to farthest.

4. Results and Discussion

The Tuscan territory is divided administratively into ten provinces: Arezzo, Florence, Grosseto, Livorno, Lucca, Massa - Carrara, Pisa, Pistoia, Prato, and Siena. There are in total 287 municipalities and 3,672,202 inhabitants, according to the latest Census of Population and Housing (ISTAT, 2011).

In developing the model, as explained above, we proceeded to isolate the metropolitan area of Florence, for which data on districts were available.

Also, have been eliminated island communities (as "isolated" by definition) resulting in a matrix of impedance functions for the remaining 276 municipalities.

The results of the weighted models are summarized in the pie charts below:

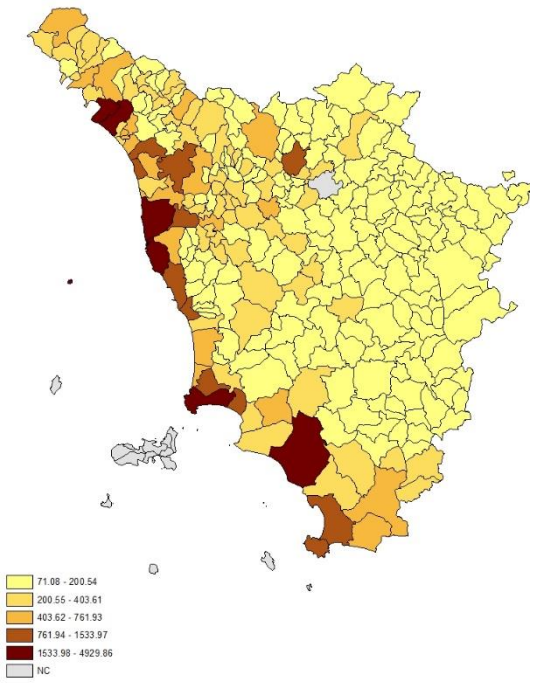

Figure 1. *Synthesis of the model by index weighted average*

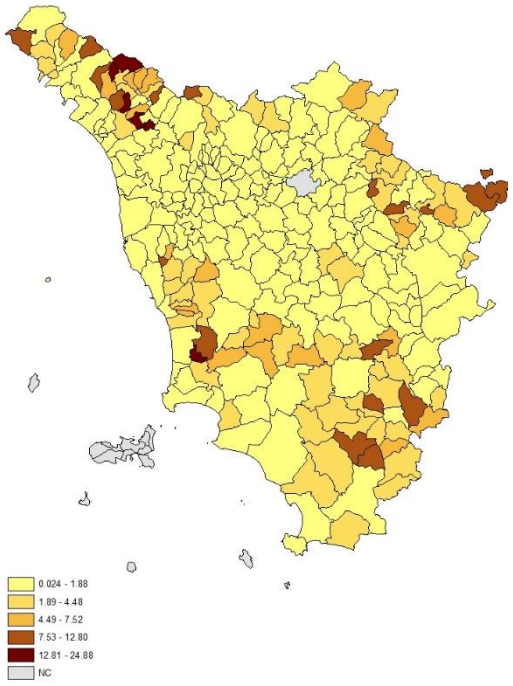

Figure 2. *Synthesis of the model by average weighted*

The pie charts show the results are quite dissimilar between the two models. In particular, the weighting obtained with "weighted average index" shows a situation "in leopard spots", where the municipalities are served less than riparian, with the area between Florence - Pisa - Livorno, which records accessibility of medium - low, depending on the population served by infrastructure.

Conversely, municipalities pertaining to the part of the Apennine region are those that are best served.

This weighting system shows its limits, as the common Apennines are among the least accessible (and therefore attractive) in terms of infrastructure in the area. The work already published by the authors (de Candia and Chiocchini, 2014), therefore, lead to reject this weighting system.

With regard to the synthesis achieved by "weighted average", the results presented in Figure 2 show a more homogeneous. In general, the Tuscan towns showed a good accessibility on the population served. The common "least served" are those of the Apennines bordering Umbria and partly those bordering Lazio. A similar situation for ordinary Apennines bordering Liguria.

In addition, the area between Florence - Pisa - Livorno with the best infrastructure, the best is the one with the population served.

In fact, the system "weighted average" works like this: low accessibility and low population pays a low rate for the population served; high accessibility and high population corresponds to a high rate for the population served.

In between, common from time to time show medium - low to medium - high rates for the population served.

4.1. Florence

The metropolitan area of Florence is divided into five districts: Centro storico, Campo di Marte, Gavinana - Galluzzo, Isolotto - Legnaia e Rifredi.

With a population of 358,079 inhabitants, is the most populous region.

For the city of Florence was made to develop the model of synthesis only according to the "weighted average" (not very useful given the results obtained with the synthetic "index weighted average" using only hospitals equipped with first aid (distributed by area) in analyzed as other infrastructure (airports, railway stations) are present in only "exemplary" (respectively "Leonardo da Vinci" and "Santa Maria Novella"). As for the upper secondary school level, data there is no comprehensive mapping and ultimately for the same constituency.

***Table 1**. Summary by "weighted average" for districts*

Districts	Population 2011	Weighted average
Isolotto - Legnaia	66,430	0.00063
Centro Storico	62,516	0.00068
Rifredi	102,834	0.00042
Gavinana - Galluzzo	39,663	0.00109
Campo di Marte	86,636	0.00052

Table 1 summarizes the data on population for districts of the city of Florence (ISTAT, 2011) and summarizes the impedance function in the form of logistics according to the "weighted average".

The results show a great addition plexus hospital for each district, as well as a strong homogeneity between the districts themselves.

If you want to try the classic "nit-picking" the district Galluzzo - Certosa shows the index lower, further proof that good accessibility but low population corresponds to a lower index of population served. It is, however, of infinitesimal.

5. Conclusions

Research has further helped to define and improve the map of the accessibility in relation to the territorial breakdown at local authority in which the authors have been discussing extensively in the past.

The addition of a weighting system that takes into account the "population served" not only contributes to the improvement of the primitive model, but adds a new connotation and new information available to policy makers and governance of the territory.

In addition, the report also has carried a real benchmarking between the approach called "index weighted average" and the approach "weighted average", preferring the latter.

Further progress in the application of such a model of accessibility weighted territory can be applied and extented in other regions (as in the authors'), but also in new infrastructures, economic data and environmental data, according to the availability of data and the degree of capillarity of information of local authority.

6. Acknowledgements

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