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## Accessibility and GIS

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# ACCESSIBILITY AND GIS

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## ABSTRACT

Today it is widely understood that one cannot promote development regardless of different territorial specifications that make the nation mosaic. We cannot promote the development of the whole without the knowledge of each small territory and the relationship between them.

This is why recent territorial planning is facing these principles. Planning policies are concerned with equity and a better distribution of people and activities in the territory, which is why accessibility, regardless if it is measured in time, cost, distance, or population, are the most important variables that one must consider in the early stages of planning.

In what concerns population studies there are several different methodologies for its analysis and understanding, considering spatial interaction. Unfortunately, accessibility is widely evaluated by methodologies that do not consider a real spatial model.

The traditional methods for accessibility evaluation do not consider the whole territory; they are mainly based in matrix methods and in node/arc logic. By using this type of method, one cannot get information to the whole territory. It was usual to get an accessibility index for a specific node of the network, but not for any point.

Today accessibility measurement, regardless if its unit is time, cost, or distance, must be evaluated for the whole territory and not only on the network.

The usual methods for accessibility evaluation, based in graph theory, are quite easy to essay in a vector format GIS analysis, but if one wants to create a continuous model, we must work in a raster environment. This, of course, will reduce the geometrical accuracy of the information; however, it opens a wide range of new analysis capabilities.

This is why although the original information was in vector format, the analysis was made mainly using raster data.

The general structure of the accessibility evaluation methodology has 3 phases:

- Data Acquisition and Integration
- Cost Surface Modeling
- Accessibility Analysis

This paper describes the development and application of a GIS-based methodology for accessibility evaluation, and its different potential applications in planning studies using the Lisbon and Tagus Valley Region as a case study area.

## INTRODUCTION

Today accessibility is considered, by planners and other technicians, as a key variable for territorial development and planning. This is happening because development and planning policies are concerned with equity and a better distribution of people and activities in the territory and also because nowadays it is widely understood that one can not promote development regardless of different territorial specifications that make the nation mosaic. We can not promote the development of the whole without the knowledge of each small territory and the relationship between them.

Traditional accessibility methods do not take under consideration a real territorial model; they are mainly based in matrix methods and in node/arc logic, that are not suitable for the needs of a real territorial analysis. So, accessibility measurement, regardless if its expressed in time, cost or distance, must be evaluated for the whole territory, as a continuous surface, and not only on the infrastructure network.

## METHODOLOGY AND RESULTS

The usual methods for accessibility evaluation, based in graph theory, are quite easy to implement using a vector format GIS analysis. But to create a continuous model, it must be done in a raster environment. Of course, it will reduce the geometrical accuracy of the information, but it opens a wide range of new analysis capabilities. Here we will present the methodological basis and some potential results.

The proposed methodology has 3 main phases:

- Data Acquisition and Integration
- Cost Surface Modeling
- Accessibility Analysis

### Data Acquisition and Integration

The first phase is dedicated to the data acquisition and integration in what concerns the preparation of the geographical information. The most important information is the one that describes the road network.

In this case, as in many others, the original information was structured according to a classification that was not suitable for the project needs. More, the geometrical detail was also excessive for the purpose of this study. So, the two first steps were the line weeding of the road network and its reclassification.

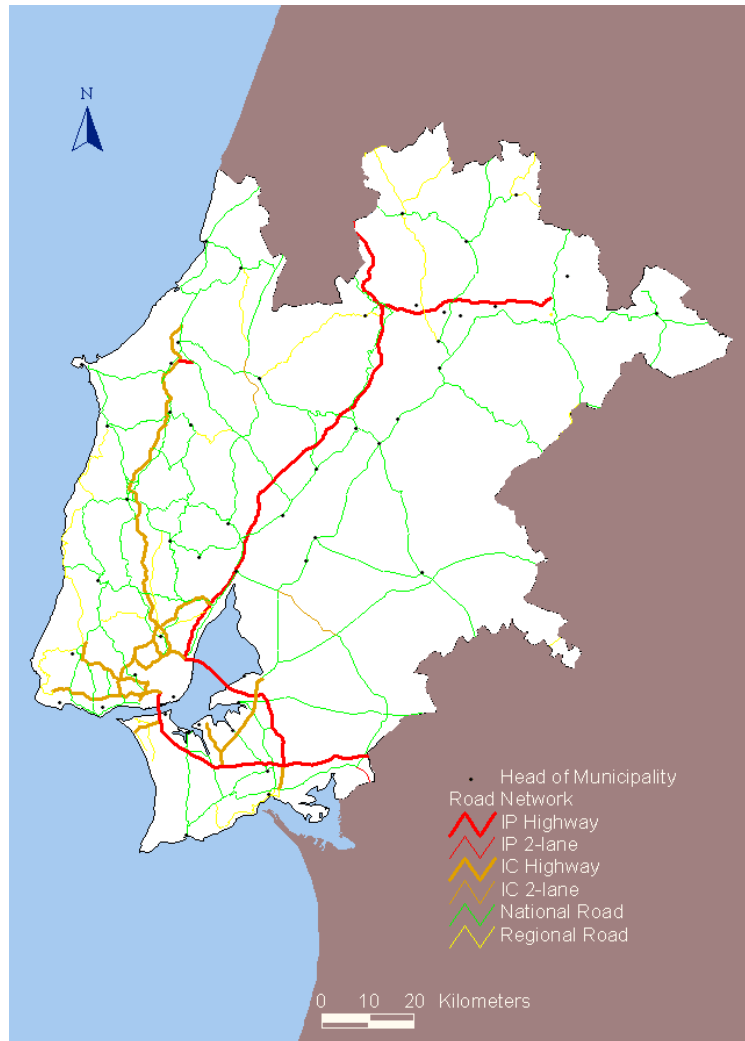
The final road network was classified according to the following structure:

Road Category	Level
IP highway	41
IP 2 lane	21
IC highway	42
IC 2 lane	22
National Road	23
Regional Road	24
Municipal Road (former national)	25
Municipal Road	26

IP and IC are the two main route categories in Portugal: IP (Main route) is the first level and IC (Complementary route) is the second level.

Each road category, as you can see, has a specific level to make it easier for the integration process.

**Figure 1 – IP, IC, National and Regional Road Network**



In this early phase of the project we have also created a file with every highway node and another one with the centroid of every municipality town (the city hall's town), both identified by a specific code.

Another decision of this early phase was that for accomplishing the purpose of modeling the whole territory, as a continuous surface, it was necessary to work with raster format. Because we were working at regional level it was enough for our accuracy purposes, a grid with a pixel dimension of 100 m. Using this pixel dimension it is necessary a matrix of 1580 rows by 1519 columns to cover the whole region, which means a total of 2.400.020 cells.

## Cost Surface Modeling

The key issue in accessibility measurement is the definition of the cost surface. This surface can be created reporting to many different cost units (distance, time, currency, or any other unit) and by many different methods and it establishes the impedance for crossing each individual cell.

In this case we have used travel time measured in minutes as unit and road category as main classifier without any territorial barrier.

The first step is to establish the average speed according to the road category and then to calculate the cell crossing time by using the following equation:

$$CCT = \frac{P \times 60}{TS \times 1000}$$

where:

CCT – Cell Crossing Time (minutes)  
 P – Pixel Size  
 TS – Travelling Speed (Km/h)

For example if one are travelling in a 2 lane IP the result is the following:

$$CCT = \frac{P \times 60}{TS \times 1000} = \frac{100 \times 60}{80 \times 1000} = \frac{6}{80} = 0.0750$$

The overall results of this equation for the project are presented in the next table.

Road Category	Average Speed	Cell Crossing Time (minutes)
IP highway	110	0.0545
IP 2 lane	80	0.0750
IC highway	110	0.0545
IC 2 lane	70	0.0857
National Road	60	0.1000
Regional Road	55	0.1091
Municipal Road (former national)	50	0.1200
Municipal Road	50	0.1200

To fill the gap between road infrastructures and consider the whole territory it was established the average walking speed for every cell outside the network: 6 Km/h (1 minute of cell crossing time).

It was necessary to create two different cost surfaces. One with the whole road network and another one without the highways. This was done because if one can consider that it is easy to get in an out of a road at any point, in an highway it is only possible to do that at specific points. This means that modeling accessibility with highways makes it necessary to do some specific methodological.

The next subsection presents the core methodology for accessibility analysis and some examples to illustrate the potential results.

## Accessibility Analysis

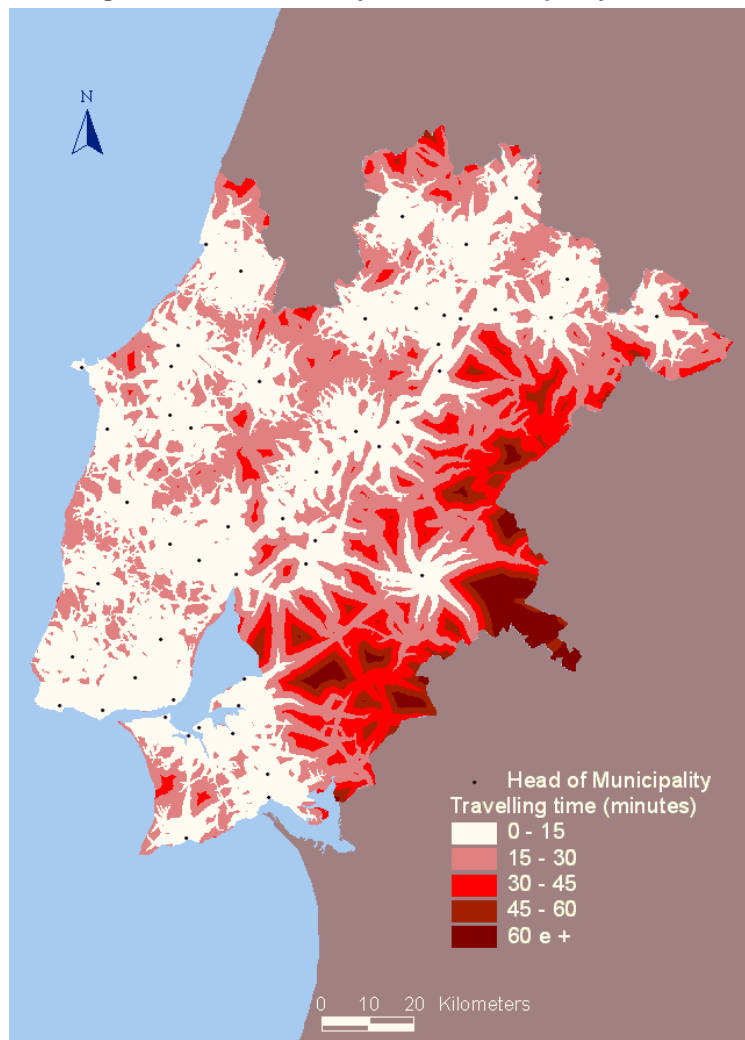
After building the cost surface it should be easy to make the accessibility evaluation. It is only necessary to have an origin and then to apply a costdistance function using that specific cost surface. And this is true if one consider that people can get in and out of the road network everywhere, ignoring highways.

The costdistance function calculates the less cumulative cost starting from one or several origins and travelling through a cost surface.

It was with this easy calculation that we have made the first analysis.

**Accessibility to the Municipality Town.** The idea is to find the accessibility to the nearest municipality town considering travel time starting from the city centroid.

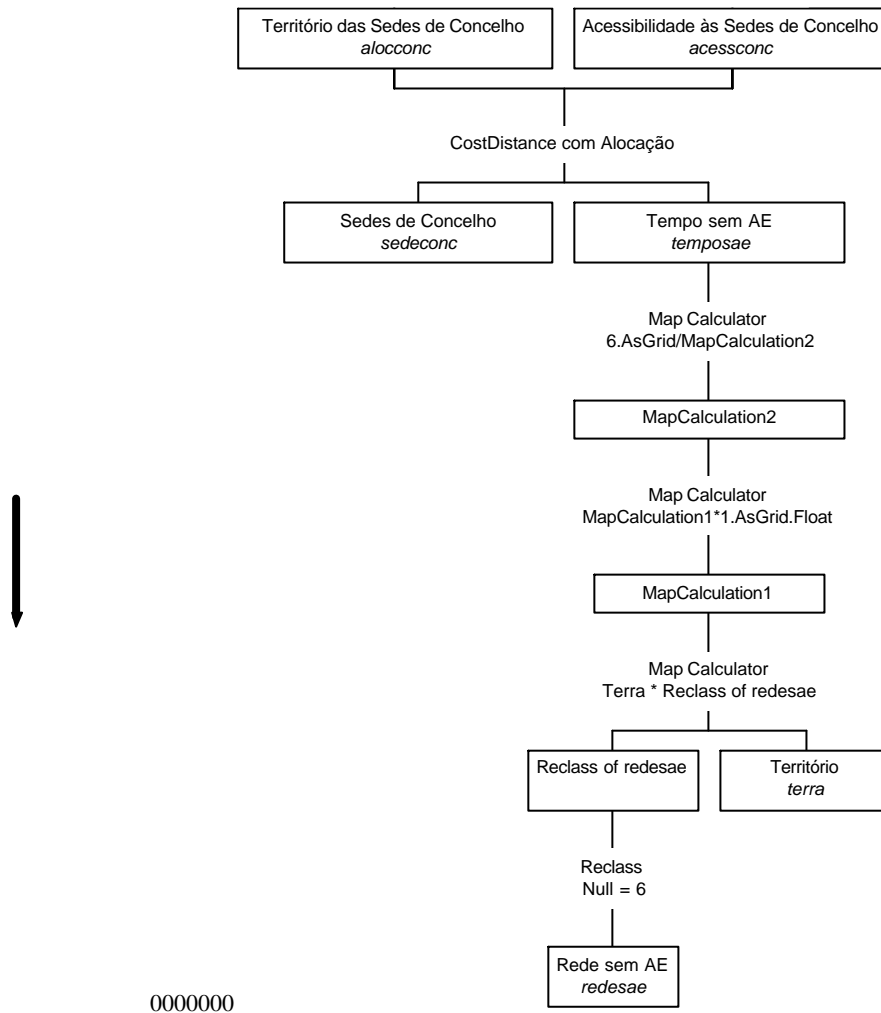
**Figure 2 – Accessibility to the Municipality Town**



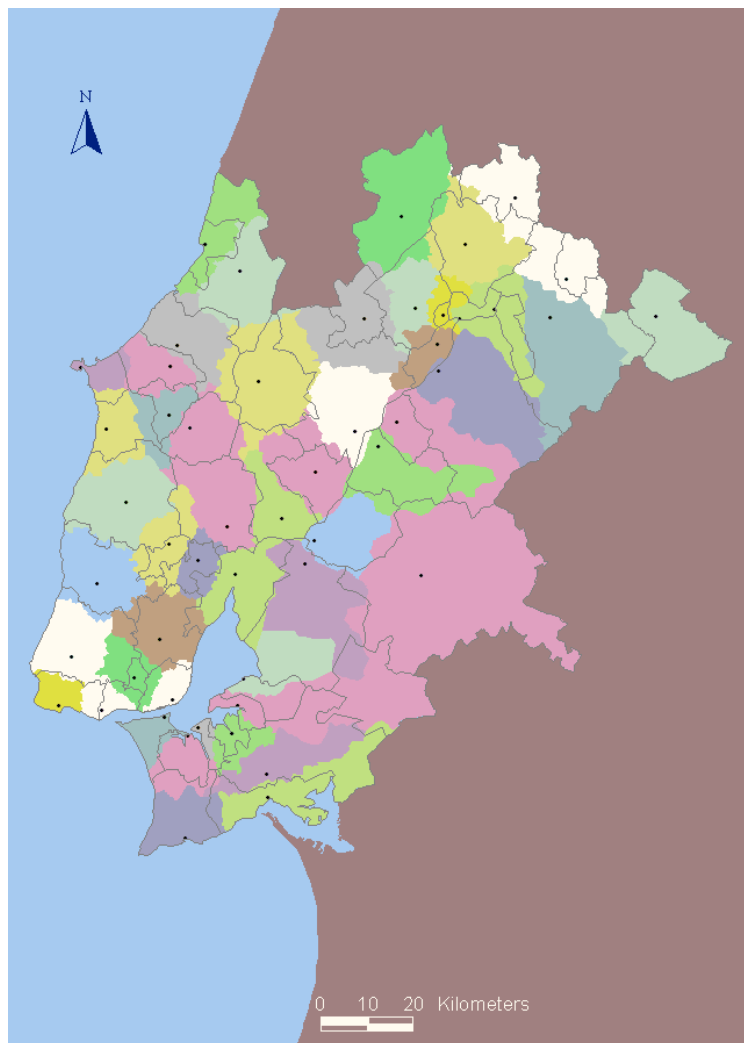
In this case we have considered all roads except highways. So the calculation was quite easy.

The following schema describes the data workflow that was used to obtain the map shown above.

**Figure 3 – Accessibility to the Municipality Town: Data Workflow**



The other result of this analysis is the definition of the municipal territory according to accessibility. This territorial allocation can be very useful for planners, especially for the definition of equipment networks and site selection studies.

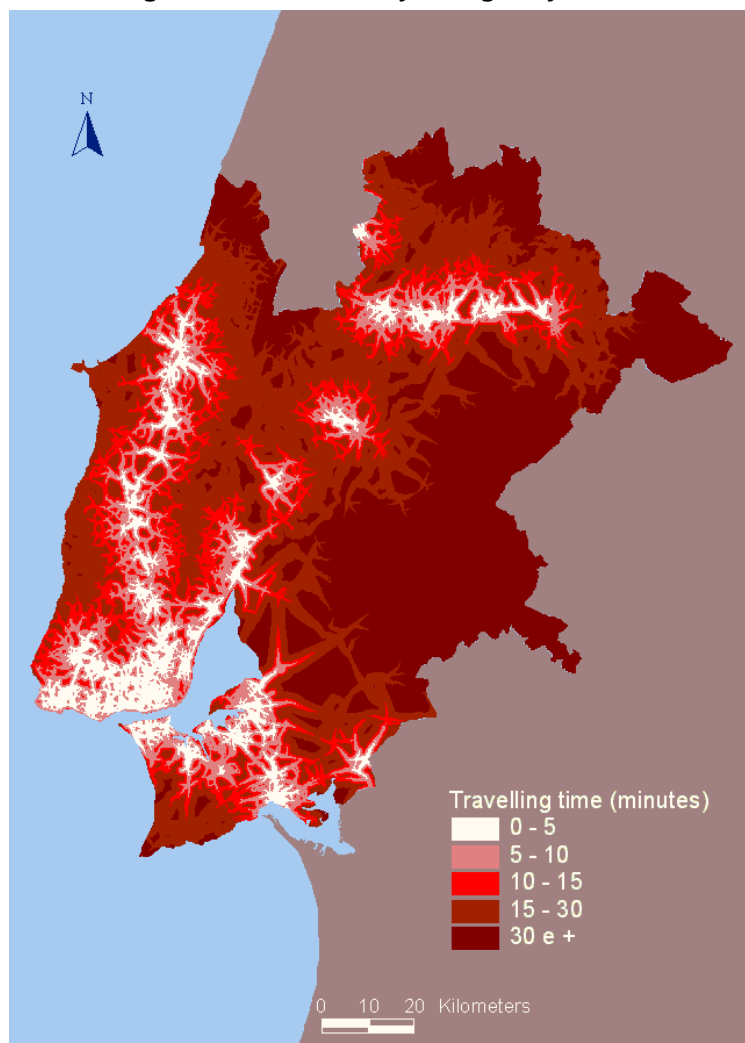
**Figure 4 – Territorial Allocation to the Municipality Town**

Another useful result can be obtained by quantifying the amount of territory within travel time buffers from the municipality town. This idea enables us to find out if there is a strong territorial connectivity between the municipality town and its hinterland. If the values are high it means that we can talk about equity because population is near to its major center.

For example in the region of Lisbon and Tagus Valley the results are quite good.

Considering the same methodology it is possible to measure the accessibility to the nearest highway node. This is one of the most important variables in entrepreneurial site location studies.



**Figure 6 – Accessibility to Highway Nodes**

**Accessibility to Lisbon.** The idea is to find the accessibility to Lisbon considering travel time starting from the city centroid and the whole road network, including highways. This is a more complex process due to specific behavior of highways and the river crossing.

In what concerns the road network we must consider two different situations:

- travelling by highway
- travelling by regular roads

Then we must compare the accessibility values between them and pick the best travelling time, which is of course the lowest one, as the final accessibility value.

To get the travelling time from Lisbon by highway it is necessary to make a 3-step calculation:

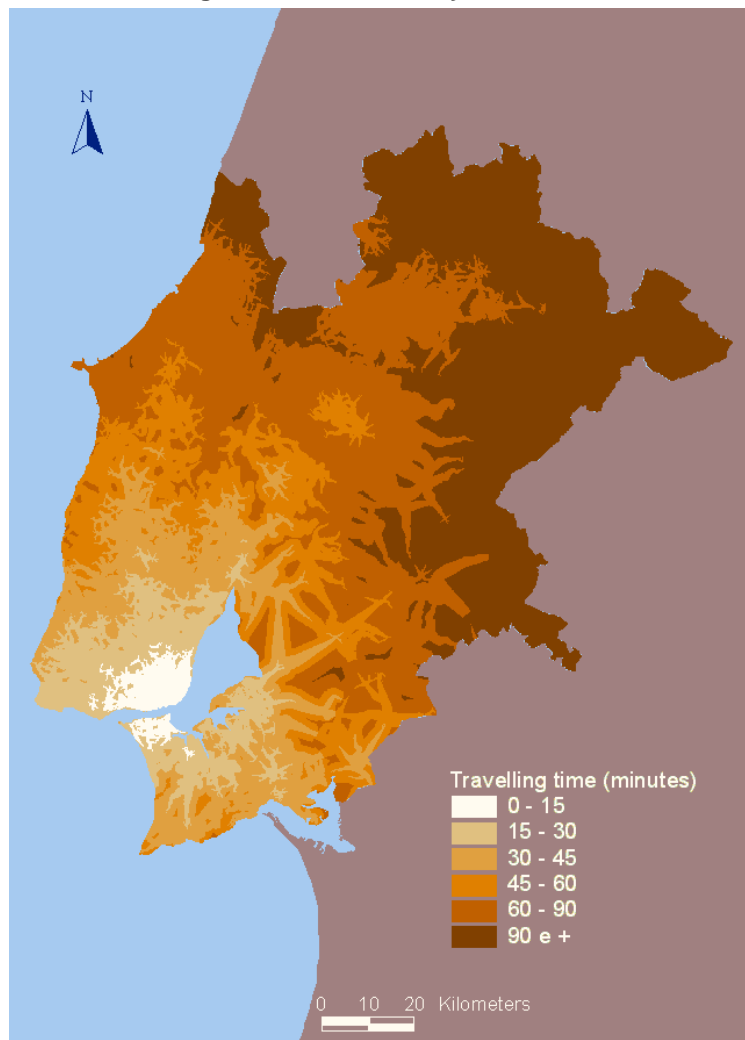
- Estimate the travelling time to each highway node. This is done by only using the cells that there are in the road network.
- Estimate the traveling time and territorial allocation for each highway node. This is done by using all road network (except highways) and also the cells outside the network.

- Add the travelling time from Lisbon to the node to its hinterland travelling time to the node. This is done by a simple overlay of two grids: the hinterland grid, in which each hinterland has the value of the travelling time from Lisbon to its node, and the grid of accessibility to the highway nodes (see figure 6).

Then we must compare if it is quickest to travel by highway or by another road using the minimum value of the two grids.

Because there are restrictions for crossing the river in Lisbon (there is only highway crossing of the river), we have considered the possibility of using the ferryboat that connects Lisbon to Almada. So the travelling time grid that considers only the regular roads is the result of the minimum value of travelling from Lisbon or from Almada (south side of the river) increased by 35 minutes (crossing time).

**Figure 7 – Accessibility to Lisbon**

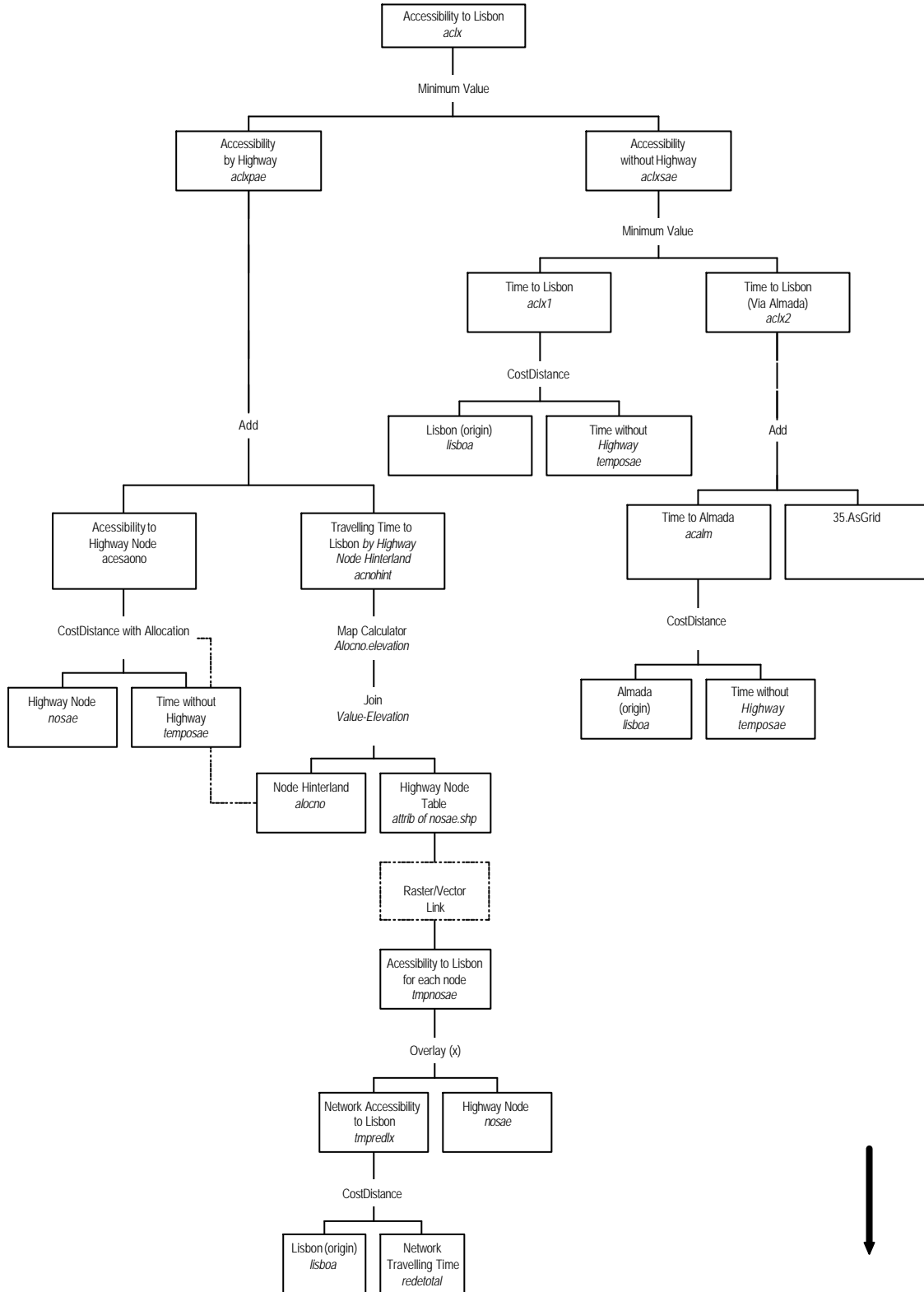


The map presented above clearly shows the highway effect in accessibility. That is why there are some islands of higher accessibility in the inner areas of the region. Those islands correspond to the surroundings of the highway nodes.

The next schema resumes the data workflow for the accessibility to Lisbon measurement.

**Figure 8 – Accessibility to Lisbon: Data Workflow**

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## CONCLUSIONS

After working about this subject there are two main remarks that one must consider:

- The methodology here proposed can be essential for a complete integration of accessibility in many different studies
- The examples here presented, clearly shows that accessibility can and must be analyzed in a GIS environment in order to obtain a dynamic and full territorial coverage

The model here presented can receive several further developments. This model can be improved by moving towards some major domains, yet neglected, such as:

**Traffic data.** Instead of building a simple cost surface based on a fixed travel time cost, it is possible to integrate traffic data in order to get a more accurate travel time. Traffic flows by day time schedules and traffic restrictions by road segment gives us a more detailed information about the accessibility behavior.

**Barriers.** Physical barriers and other information regarding land surface are important to get a better view of territorial accessibility, especially that considering off-road travelling.

**Vehicle data.** More complex accessibility models can take under consideration vehicle data as one factor shaping the cost surface.

**Urban network data.** Not every towns as the same importance. It is possible to cross urban network data, such as population, services or equipment, to express accessibility of population to goods and basic services.

Nevertheless, although we did not present more examples, it is quite an easy exercise to think about the different applications of the accessibility maps here presented.

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