Application of GIS in Public Transportation

Case-study: Almada, Portugal

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Introduction

Spatial Planning is always connected with a country' development process. It aids to provide a good quality of life to the citizens, creating strategies to achieve more balanced and competitive territories. The mobility and accessibility are the main factors of cohesion, social integration and promotion of competitiveness and economic development. This paper intends to illustrate Geographic Information System transportation tools (GIS-T) in the planning of public transportation and create a model that analyzes the demand and supply in order to optimize its utilization rates. This article introduces a case-study: Almada, a Portuguese city peripheral to Lisbon, the country's capital. The main goal of this paper is to demonstrate the importance of Geographic Information System (GIS) as a support tool in developing policies for the organization, management and promotion of transport efficiency.

Objects

The objectives of this study are:

- Demonstrate the importance of GIS in the analysis of the transport network;
- Refer examples of Models that are applicable in transport networks management;
- Refer different types of analysis tools;
- Build a model that permits automatically find new bus stops and thus define new lines.

GIS definition

GIS is a system that allows the collection, maintenance, storage and analysis of spatial information. It boosts processes as identifying and solving environmental

problems, social, economic and political transparency, not only know regarding to where they occur but also to who is affected the most (BOLSTAD, 2008). GIS is a compound of hardware, software, data, and technical analysts, all constantly evolving. Today with the technological progress it is possible to buy faster computers with higher quality and larger storage space for information. These computers have to support an increasing number of programs for data collection, integration, editing, analysis and outputs either in digital or in paper. Two major groups of software coexist: the more complete and expensive programs, with licenses restrictions (Arcgis, Geomedia, Mapinfo, Idrisi), and the ones that are easily downloaded on internet, more commonly known as free open source (Grass, Spring).

GIS -T definition

As mentioned before, GIS is an important tool in designing policies to support the organization, management and promotion processes of transport efficiency. In the mobility and transportation subjects GIS is essential in the treatment and analysis of all the basic information (statistical or cartographic) related to travel movements. It's essential to test different models, explore multiple scenarios and compare other distance analyses, in order to obtain the correct results. Along with the expansion of GIS market, and the consequent development of new transportation analysis applications, appears the concept of GIS-T (Geographical Information Systems in Transportation). As it can be seen in the Figure 1, GIS-T is a structure that connects several applications of Transportation Information Systems (TIS) with the GIS applications (VONDEROHE et al., 1993). Therfore GIS-T applications are targeted to the analysis of transport networks, which are used for management and public transport planning and for business logistics.

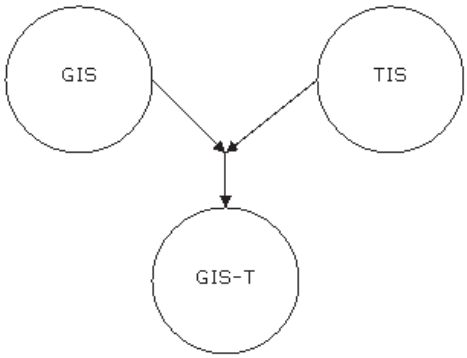

Figure 2 – GIS-T (VONDERHORE et al., 1993)

GIS/GIS-T Applications

GIS-T applications are divided in two major groups. The first one comprises the generic applications, commonly found in GIS products, concerning editing, display and spatial conditional search functions (WATERS, et al., 1999). The edition tools

have the ability to modify the attributes of a link or easily add a new link to the network. In order to get a better perception of the road location it's possible to display under the raster image theme. The spatial conditional search function has the ability to locate several attributes from a feature, e.g. which roads contains 2 lanes or if that roads are paved or unpaved. Another common tool is the buffer, which has the ability to create areas with a distance where one can find specific attributes, e.g. a specific bus stop serves how many people or schools. The second major group regards to the applications that are specifically developed for GIS-T and are only found in this segment products, e.g. infrastructure planning and management, transportation safety analysis, travel demand analysis, traffic monitoring and control, public transit, planning and operations, environmental impacts assessment, intelligent transportation system (ITS), routing and scheduling.
Recently new technologies have emerged and GIS-T applications have been growing and becoming more powerful, e.g. Global Positioning System (GPS) can offer traffic information in real time and provide helpful location-based services (LBS), as finding the closest petrol station (SHAW et al., 2006).

Models GIS-T

GIS-T Enterprise Data Model (DUEKER et al., 1997) applies to all types of transportation (bus, train, boat, airplanes), in different scales and containing different softwares. This model is based on the analysis and cartographic representation of various topics related to the transport network. Include jurisdiction of the various transport entities and the location of an event in the transport network. Enterprise Data Model developed the linear referencing system (LRS). This improvement on the basic model of links and nodes allows adding more information on links, e.g. quality of the pavement and development of a network hierarchy to improve the routes calculation.
Another important model is Arcgis Transport Data Model (BUTLER, 2008). This model intends to apply a set of data and applications for transportation organization that use Arcgis. It also includes an amount of information regarding the topology of the network, rail road and systems of linear referencing.
Currently there are several companies focused on developing specialized transportations commercial packages with GIS-T capabilities. Two of the most known commercial GIS –T applications are TransCAD of Caliper Corporation and PTV Vision VISUM of PTV AG Company. These products include several transportation analysis operations, like shortest path analysis, problems with vehicle routing and cost reduction through geographic accessibility measuring, taking into account complex roads attributes such as different direction of travel or condition access restrictions for several types of vehicles. At the present these applications are very important in transportation planning to avoid mobility's problems and to minimize cost and time.

Components GIS-T

The four major components of a GIS-T are encoding, management, analysis and reporting (RODRIGUE, 2006). Encoding represents the network in links and intersects them with nodes. It is not only possible to encode the information in quantitative terms, assigning an ID number, but also to characterize it in a qualitative manner, e.g. assign the name of the link, the direction, the number of lanes, the state of the pavement, the restrictions traffic, speed category. Thereafter, the encoded information must be included in a database that can spatially divide it, grouping it by country, state, place and in different types of networks, e.g. highways, railways. This analysis is based on the database and provides the application with tools that create conditions to query, e.g. traffic volume per hour. The obtained information will be reported and actions will be taken, e.g. if it'll be necessary to increase the number of bus routes and what will be the days and hours.

Model

This work will focus on the municipality of Almada, a small but densely populated city with 70.2 km² and 166,103 inhabitants. The choice of this municipality is related to its location, in the periphery of the capital of Portugal, Lisbon.

Figure 3 - Municipality of Almada

Over the years Almada assumed a role of dormitory town, because of the proximity of Lisbon and the high quality of life combined with a moderate housing cost compare to the national capital. To ensure quality of life, it is important to take account the public service of transportation. Almada's municipality provides several types of connections to Lisbon: train, boat and bus. These services have a key role in the identity of the city, since they assure the mobility of thousands of people on a daily basis. Additionally in the last years Almada has strongly invested in tourism, services and culture in order to become more and more as autonomous and not just a dormitory town of Lisbon. For this it was essential the development of Almada's

subway which together with existing road services, has contributed significantly to the increased of the inhabitant's mobility.

The future model will be based in the analysis of all the types of transport that Almada provides and the population that is served. It is important to observe the offer and the demand of the municipality before building a specific model. This tool is directed to the analysis of the bus transportation, in order to find its weaknesses and to refer potential improvements. The main goal of this model is to locate automatically new stops and increase the population that is served. It will be build in *Arcgis* using the tool *model builder* that permits to automatically run the future model for the location of the new bus stops and consequently the calculation of the new routes. It will be necessary to use some specific extension in *Arcgis* like network analyst and spatial analyst. The model is divided in 4 parts: calculation of the population that is served by each stop (Figure 3); definition of the location of the new stops (Figure 4); calculation of the population covered by these new points; recalculation of the bus routes (Figure 5).

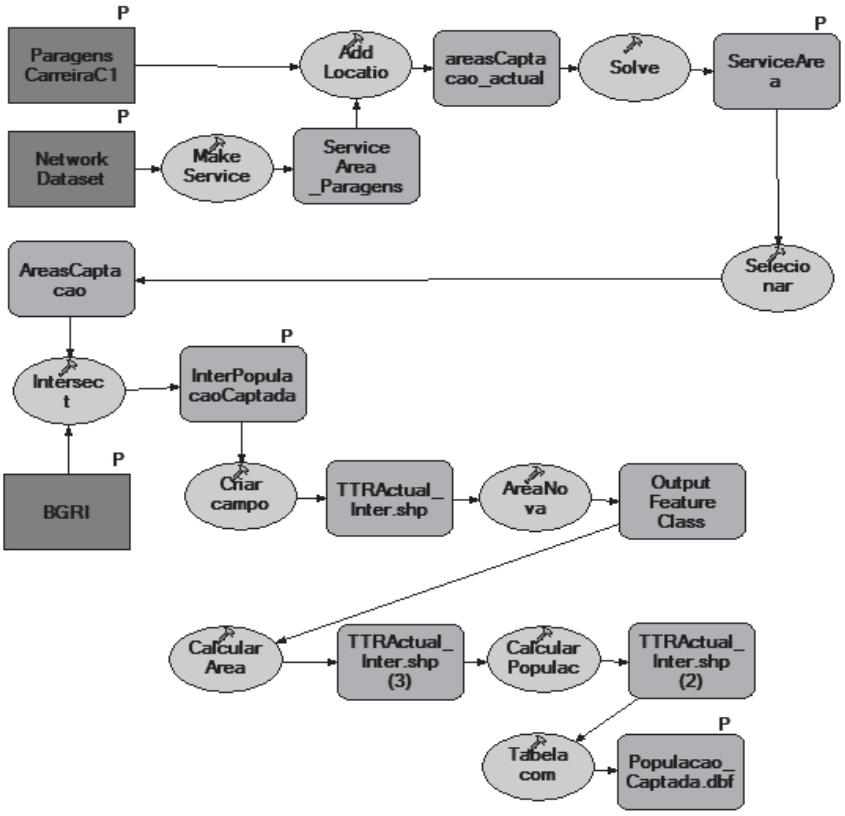

Figure 4 – Example in model builder of a previews work of the calculation of the population that is served by each stop

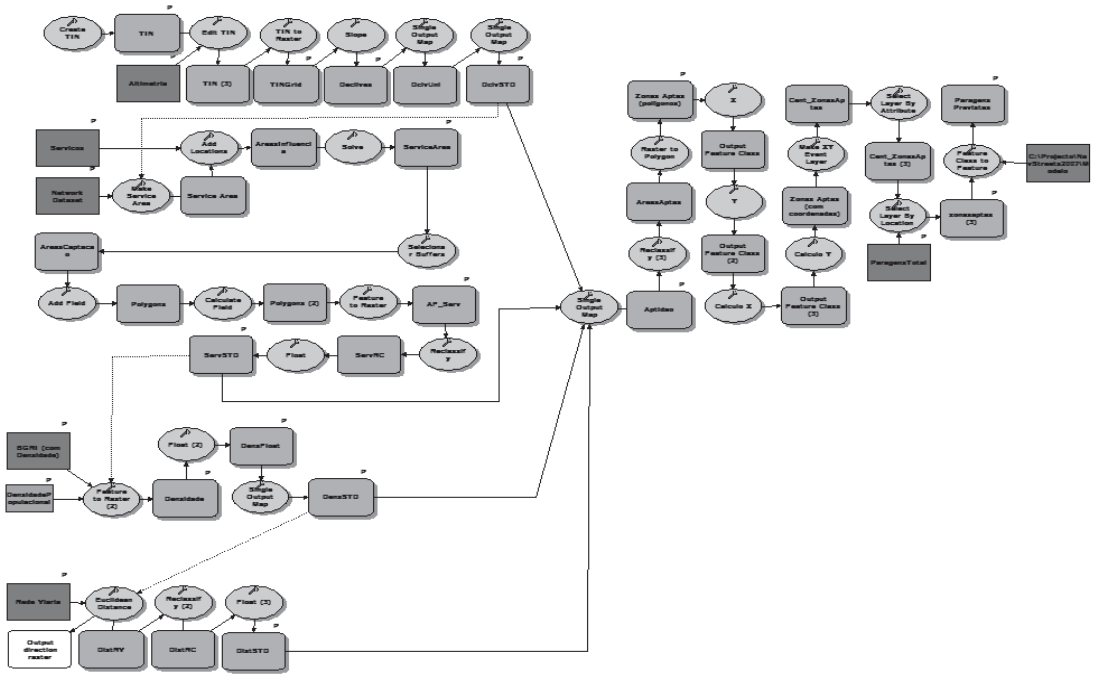

Figure 5 - Example in model builder of a previews work of the definition of the location of the new stops

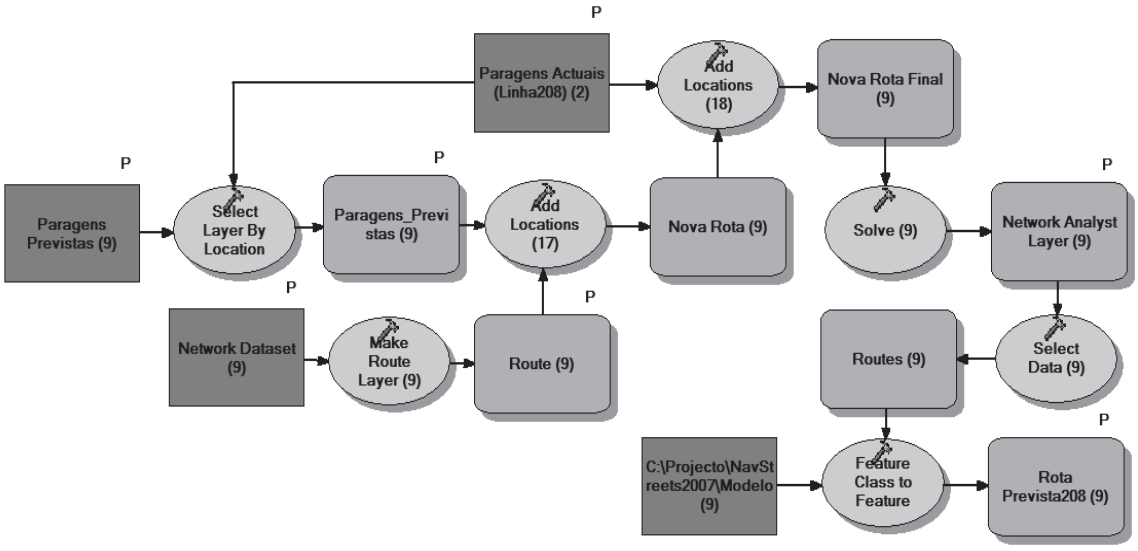

Figure 6 - Example in model builder of a previews work of the recalculation of the bus routes

The first part is based on the creation of areas of influence around each stop (Figure 6). It is taken into account the maximum distance that a person would be willing to go, therefore a buffer of 150m is defined. Through the intersection of this areas of influence with BGRI database, which already includes the 2001 Census, it is calculated the total population residing within the several areas.

Figure 7 - Example of Services Areas of a previews work

Concerning the location of the new stops it is necessary to evaluate some variables like: slopes (S), services location (SE), population density (PD) and Network (NT). Each variable has a specific weight, as it represents different geographical realities and consequently affects the location of the new stops in a different way (S=0.1, SE= 0.25, PD=0.25, NT=0.40). The sum of these variables returns the areas that are more suitable for the location of the new stops (Figure 7).

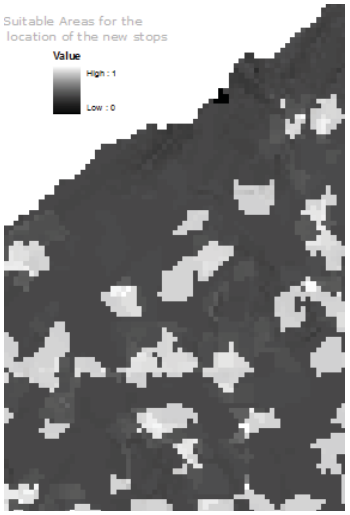

Figure 8 - Areas with good location for the new bus stops of a previews work

It is then calculated the center of the obtained areas and selected the points at a distance of 200 meters of the existing stops, as this is considered the ideal distance between the new and the existing stops. This last operation gives the exact of new stops. Finally it is calculated the total population covered by the new stops and the corresponding new routes, in addition to the update of the lines that already exist (Figure 8).

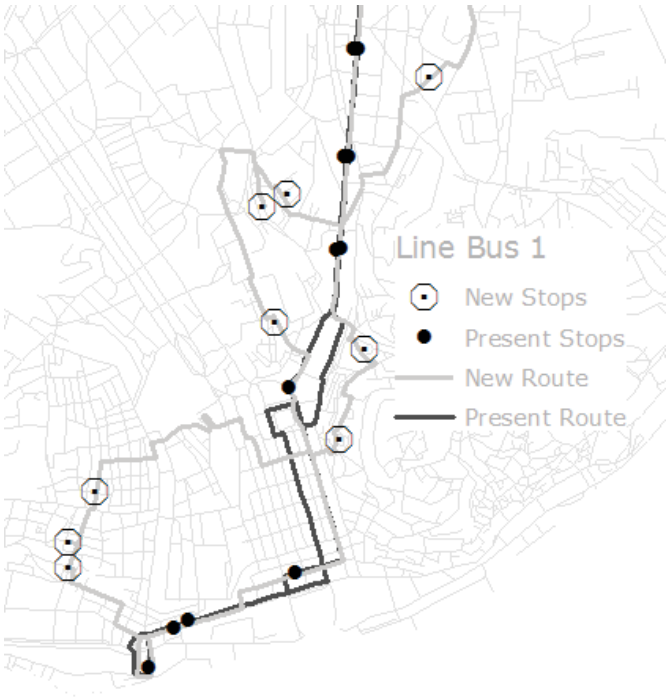

Figure 9 - Recalculation of the routes of a previews work

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