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Optimising urban routes as a factor to favour sustainable school transport

Gaspar Mora-Navarro[a,*], Carmen Femenia-Ribera[a], Jose Martinez-Llario[a], Enrique Antequera-Terroso[b]

[a] Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Camino de Vera, s/n, Valencia 46022, Spain
[b] Department of Urban Planning, Universitat Politècnica de València, Camino de Vera, s/n, Valencia 46022, Spain

1. Introduction

As the population grows the current trend is for people to concentrate in cities, while rural areas become less populated. The urban area is estimated to multiply by 3 in 2030 (Seto et al., 2011). Most citizens need to move around the city on a daily basis, and many choose a private car as their means of transport. This causes air pollution problems and greenhouse gas emissions in cities.

Authorities are increasingly taking measures to accomplish healthier cities by encouraging people to active transportation; that is, to travel by bicycle or on foot. As the authorities are extending bike lane networks, this means that using bicycle-sharing systems is increasingly extending, just as many studies about fuel savings, pollution, effects on health and the risks of moving around the city on a bicycle have shown (de Hartog et al., 2010; Faghih-Imania and Elurub, 2015; Frade and Ribeiro, 2015; García-Palomares et al., 2012). Together bicycle-sharing systems, cycling web route planners (Su et al., 2010) and studies that analysed the factors that influence choice of route (Broach et al., 2012; Ehrgott et al., 2012; Rybarczyk and Wu, 2010) have started to appear.

An important parameter to take in account in this issue is walkability. Walkability is the degree to which the built environment supports the possibility of individuals engaging in active transportation in one area of a city (e.g. walking, biking) (Howell et al., 2017). There are several city walkability indices, all of which correlate with active transportation behaviours (Walkability Index, Walk Score®, Walkability Scale, etc.). The Walkability Index, henceforth referred to as walkability, is the most popular (Lefebvre-Ropars et al., 2017). To obtain an area's walkability, the following parameters are considered: land use mix, street connectivity, residential density and retail intensity (Poulsen et al., 2018).

The online Walk Score® Calculator (Walk Score®, n.d) is being used to plan research and in applications to measure the walkability of an address (Aston et al., 2016; Hall and Ram, 2018). This index assesses the walking potential of a place by combining three elements: the shortest distance to a group of preselected destinations, block length, and the intersection density around the origin. Higher Walk Scores indicate that neighbourhoods are more walkable, and residents are closer to transit and activity opportunities (e.g. commercial, recreational, etc.) (Akbari et al., 2018).

A relevant factor that can tip the balance when it comes to choosing motorised transport or travelling by bicycle or on foot is the number of trees along the route because this increases pedestrian comfort (Takebayashi et al., 2017). Apart from purifying air, trees improve the city's aesthetics (Lothian, 1999) and, conversely to popular belief, trees even lower the incidence of asthma in children (Dales et al., 2008). Trees in natural spaces in cities, like parks and greenbelt areas, benefit human health (Frumkin, 2001), and may even benefit children's social, emotional and behavioural development (Richardson et al., 2017). Citizen accessibility to green spaces is the object of many studies (Fan et al., 2017; Žlender and Ward Thompson, 2017). Quantifying the number of trees, and their vigorousness, is important. The number of trees is a factor that the present work takes into account. Many types of telematic techniques are available to count the number of trees, such as orthophotographs, remote sensing, LIDAR, and even imagery and computer vision (Recio et al., 2013; Seiferling et al., 2017).

Accessibility is a crucial factor that comes into play when choosing a means of transport or travelling on foot or by bicycle around a city; e.g., the ease with which we can move around a city. Accessibility is determined by the elements that we come across on our way (built environment), such as footpaths, zebra crossings, pedestrian zones, traffic lights, bicycle lanes, parks, greenbelt areas, squares, etc. Previous studies have attempted to correlate the built environment with walking or biking as a means of transport in the city (Panter et al., 2008; Wong et al., 2011; Etman et al., 2014; Cerin et al., 2017). These studies conclude that citizens positively evaluate their moving around the city being easy and offering connectivity, short routes and safety. Two highlighted factors are the availability of zebra crossings and parallel parking. The more zebra crossings and the less parallel parking, the more likely people will decide to walk or ride a bicycle (de Vries et al., 2010). Reduced parking availability creates a disincentive for using automobiles. A policy implication derived from this is that authorities should not prioritise expanding parking facilities if their main objective is to improve walk access for residents to schools, rail stations, bus stations, etc. (Akbari et al., 2018).

* Corresponding author.
E-mail address: joamona@cgf.upv.es (G. Mora-Navarro).

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A very important accessibility factor is slopes because they are very limiting for people with reduced mobility, or who use wheelchairs or push prams. Steep slopes make upward pedestrian movements difficult, and downward movements can be hazardous. A slope is a highly relevant factor even for calculating routes for vehicles because they significantly increase the amount of fuel employed (Lorente-Sánchez et al., 2016).

Another important element that affects our choice of means of transport is traffic on streets. Studies suggest that children avoid walking or cycling along busy roads on their way to school (Krenn et al., 2014).

Conversely, however, other studies have not been able to relate characteristics on school routes (built environment) with the routes chosen to go to school, and have found that the only factor that correlates with not using a car is a short route (Wong et al., 2011).

Finding an optimum root on foot or by bicycle between two points in a city is no simple task. For each person, the optimum route may differ depending on the time, their physical condition or preferences. Nowadays with vast amounts of readily available geographic data, it is possible to calculate huge quantities of types of routes that differ from the shortest one; for instance, the most accessible route may be where a slope or the minimum footpath width is limited. A more comfortable route can also be obtained according to each user's preferences at a given time, who might wish to avoid areas in the city with higher pollen density, noisier places, or wish to seek shade because it is very hot. Some pedestrians may prefer streets with either more trees or monuments. Obtaining routes becomes less evident as the city grows in size because the variables to bear in mind also grow.

According to the literature, the pedestrians who wish to walk prefer routes that include pedestrian zones and good facilities for crossing streets, such as traffic lights or zebra crossings, junctions (Anciaes and Jones, 2018; de Vries et al., 2010), tree-lined streets (Takebayashi et al., 2017), which are not very noisy and are free of heavy traffic (Ehrgott et al., 2012; Krenn et al., 2014), as well as short routes (Wong et al., 2011). Therefore, we conducted a survey with the parents of primary schoolchildren that asked them about their preferences for walking to school. The thesis of this research is: if users can calculate more pleasurable routes around the city, they will be encouraged to travel more on foot, which will help improve users' health status and the city itself. This work shows a geoportal in which more comfortable routes are calculated according to pedestrian preferences.

2. General process to calculate optimum routes

Calculating routes involves a significant cartographic work component. First of all, it is necessary to obtain network stretches and ensure that the network topology is correct. Network stretches define the lines where access is available. Topology is defined as the spatial relation of some objects with others: connected, indoors, outdoors, overlapping, etc. For networks, a correct topology means that stretches are properlly connected to one another, and stretches must divide on crossings with two stretches or more. The stretches that must be passed via tunnels or bridges can cross other stretches without being divided. The end points of stretches are known as nodes (Fig. 1).

With networks for pedestrians, users can move around by walking in both directions in all stretches. However, some networks include stretches that can be walked around in only one direction; i.e., moving in one direction is not the same as moving in another direction. In such cases, it is necessary to bear in mind the direction that each stretch is drawn or digitalised in (Fig. 2).

Once the network is topographically correct, the next step is associate a cost, also called an impedance cost, to each stretch (Fig. 2). In some cases, moving over a stretch in one direction can incur a different cost than it would in the opposite direction; e.g., if there is a downward slope because, depending on the application, the cost can be much less than moving through the stretch in an upward direction. So such

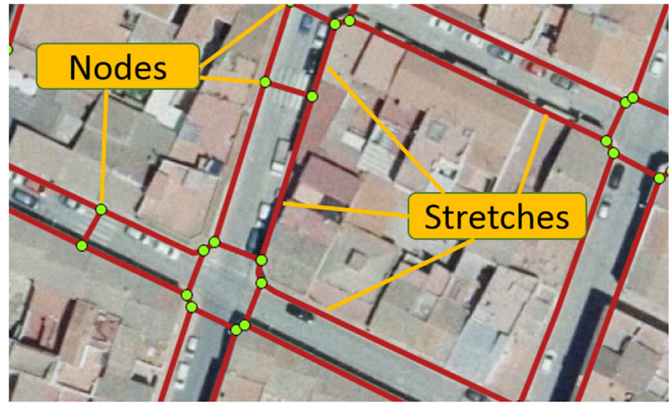

Fig. 1. Stretches network and nodes.

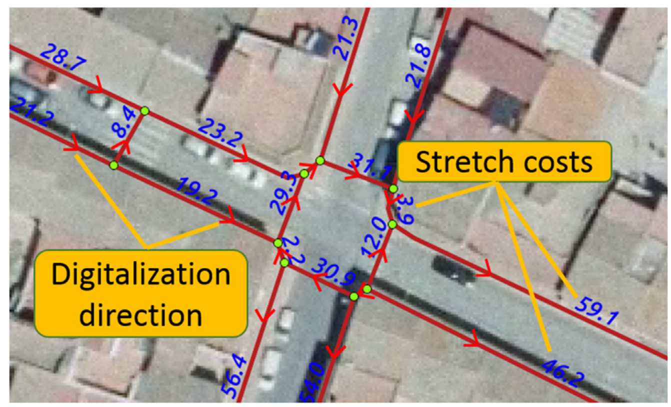

Fig. 2. Stretch costs.

applications include two costs per stretch, one in each digitalisation direction.

Once we have the network and know the costs of each stretch, an algorithm capable of locating the series of connected stretches that leads from one network point to another is needed, and in such a way that the sum of the total costs of all stretches is minimum. This is a so-called optimum route. Several algorithms exist to calculate optimum routes: Floyd-Warshall's, Johnson, A-star or Dijkstra. A-star algorithm performs well in networks with many edges. It is widely used to calculate optimised routes (Wei and Xiaoguang, 2013).

The main difficulty lies in calculating the costs of each stretch. The first step consists in deciding which variables are to be considered, a decision that depends on the application. The most important factor to calculate routes for private cars is the time taken to travel each stretch, where time represents the cost field in this case. The cost will, therefore, depend on the maximum speed of each stretch, traffic, the number of junctions, etc. When attempting to calculate the optimum route for pedestrians who wish to walk, the factors that need to be considered to calculate the costs of each stretch completely differ.

Calculating the cost of all the directions of each stretch is the most important task. This cost considers the variables needed for each route type, and each variable is also weighted so that it has a stronger or weaker influence on the final cost. Normally, the cost of stretches depends on stretch length. What the variables do is to amend stretch length in such a way that, if the value of the variable is positive for the pursued purpose, length will be artificially subtracted from the stretch, and vice versa if the variable takes a negative value. The calculation system seeks a combination of stretches with a minimum total cost sum. Thus the cheapest stretches are those with the most favourable conditions for route type, which are more frequently selected. For example, if the intention is to seek the most comfortable routes for pedestrians, the