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BUILDING A BICYCLE SUITABILITY MAP FOR COIMBRA

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Abstract *The adoption of faster modes of transportation (mainly the private car) has changed profoundly the spatial organisation of cities. The increase in distance covered due to increased speed of travel and to urban sprawl leads to an increase in energy consumption, being the transportation sector a huge consumer responsible for 61.5% of total world oil consumption and a global final energy consumption of 31.6% in EU-27 (2007). Due to unsustainable transportation conditions, many cities suffer from congestion and various other traffic problems. Such situations get worse with solutions mostly seen in the development of new infrastructure for motorized modes of transportation, and construction of car parking structures. The bicycle, considered the most efficient among all modes of transportation including walking, is a travel mode that can be adopted in most cities contributing for urban sustainability given the associated environmental, economic and social advantages. In many nations a large number of policy initiatives have focused on discouraging the use of private cars, encouraging the use of sustainable modes of transportation, like public transportation and other forms such as bicycling. Given the importance of developing initiatives that favour the use of bicycle as an urban transportation mode, an analysis of city suitability, including distances and slopes of street network, is crucial in order to help decision-makers to plan the city for bicycle. In this research Geographical Information Systems (GIS) technology was used for this purpose and some results are presented concerning the city of Coimbra.*

1. INTRODUCTION: THE ROLE OF BICYCLE IN URBAN SUSTAINABILITY

The automobile city emerged after the Second World War in developed countries when motorisation became widespread. As transportation systems became faster and cheaper, city dwellers used them to travel more and to cover a greater distance, resulting in urban sprawl and reduced density. The increase in distance covered due to increased speed of travel and sprawl leads to an increase in energy consumption, as demonstrated by [1]; public transportation being incompatible with low density. As recognized by [2], urban form and infrastructure is the key to transportation sustainability, higher-density land-use being inherently more energy-efficient because distances are shorter, which may encourage a shift in the mode of transportation, and improve the safety and attractiveness of cities.

The bicycle mode of transportation is a travel mode that can be adopted in most cities contributing for urban sustainability given the associated environmental, economic, social (including public health) advantages. In many nations a large number of policy initiatives have focused on discouraging the use of private cars, encouraging the use of sustainable modes of transportation, like public and other forms such as bicycling [3]. Dedicated bicycle lanes and the implementation of priority rules for cyclists are examples of actions taken in many cities.

The topography, along with the size and density of a city, are very important basic factors for bicycling suitability. The best-known example is Amsterdam, which is compact, with topography adequate for cycling (and the same in Copenhagen). A smaller city is more navigable by bicycle just because shorter trips are more likely. 85% of journeys by bicycle in Amsterdam are shorter than 5 km, a fact inevitably owing to the compact size of the city. A series of political choices further restricted and discouraged private car use within the city and protected riders from the presence of cars (e.g. strict speed limits of 30 km/h on lanes shared with bicycles, automatic legal liability of car drivers in case of accident).

Cycling (and walking) positively affects almost all aspects of mobility, health, accessibility of places of interest, city structure, pollution, climate change etc. and increases the liveability of our cities.

Concerning energy in particular, the transportation sector is a huge consumer, responsible for 61.5% of total world oil consumption [4]. Reducing the fuel used in this sector is one of the highest priorities for all countries. The conventional car is an exceptionally inefficient form of urban transportation, typically consuming about 3 MJ of fuel per person-km if the driver is the sole occupant. Cyclists, by contrast, consume around a raw 80 kJ [5] per person-km of food (17-25 kJ/km at the wheel after metabolic and mechanical losses), less than 1/30th of the primary 'fuel' requirements of cars.

Concerning the relationship with public transportation, as a feeder mode, the bicycle is substantially faster than walking and, according to [6], the combined use of the bicycle and public for one trip, has seen a substantial increase over the past decade in many industrialized countries as part of the search for more sustainable solutions.

Given the importance of developing initiatives that favour the use of bicycle as an urban mode, an analysis of city suitability, including distances and slopes of street network, is

crucial in order to help decision-makers to plan the city for bicycle. In this research Geographical Information Systems (GIS) technology was used for this purpose and some results are presented concerning the city of Coimbra.

2. ASSESSING THE SUITABILITY OF COIMBRA STREET NETWORK FOR RIDING BICYCLES

When riding a bicycle, slope, or grade, is very important. Grades greater than 5% are undesirable because the ascents are difficult for many path users, and the descents cause some users to exceed the speeds at which they are competent or comfortable not being able to stop to avoid hazards. Steep uphill grades in relatively long distances may force users to walk their bike or take a long detour. Both Austroads and the *American Association of State Highway and Transportation Officials* (AASHTO) have proposed desirable grades of paths for ease of cycling. The AASHTO [7] gives the following guidance on grades of paths:

Slope	**Acceptable Length**
5-6%	240 m
7%	120 m
8%	90 m
9%	60 m
10%	30 m
11+%	15 m

Table 1. Desirable uphill gradients for ease of cycling [7].

Several factors are important for implementing an urban bicycle network. Sometimes, the drawback of hilly cities, can be mitigated with mechanical devices (e.g. Trondheim in Norway, http://www.trampe.no/english/). Coimbra is an old city that spread from the historical center (its hilly part) into new urban areas. However, city dimension (in what concerns its urban area) may be a favourable factor. Another positive factor may be the relatively high number of students living in the city (secondary schools, higher education institutions, etc.) and the likely acceptance of youth concerning active modes of transport. Therefore, the analysis of suitability of the existing transportation network for riding bicycle in Coimbra should address two important aspects: (i) identifying street stretches suitable for cycling given the respective grade; (ii) identifying places for implementing mechanical devices that add connectivity among cyclable sub-networks.

In such a context, the major component of this study has been the development of a map that portrays the suitability of the existing transportation network for riding bicycle in Coimbra. Given the constraints related to street grades and the hilly nature of important areas of Coimbra, an analysis of the suitability of street network of the city for bicycling was developed using GIS technology, in particular the ESRI *Network Analyst* (NA) extension. The streets of the urban area of Coimbra were analysed in order to obtain a

city-inclusive suitability map of the bicycle transportation system. A digital surface model was used in order to assign slopes to each network arc, taking into consideration the arc direction (e.g., a given arc can have an uphill and a downhill part). GIS was programmed via VBA scripts allowing to configure the NA network according to a convenient set of parameters. Among those parameter configurations the following can be highlighted: the maximum cyclable uphill slope, the maximum cyclable downhill slope, and the minimum slope for which mechanical assistance is required; inappropriate and prohibited roads for cycling could also automatically not be considered using the parameterization. In the analysis, the arcs were classified according to their uphill and downhill slopes: the higher of them was considered, according to Table 1, since riders can go both ways (Fig. 1 - left-hand side).

A set of points considered representative, w.r.t. plateau zones and population, was defined. Using the NA parameterized s.t. there are no slopes higher than 5% (in both directions), maximum 2000 m ride length service areas for those points were generated, without mechanical assistance (shown in pink color) – Fig. 1, center map. In this map arcs with slopes between 5% and 6% (both ways) are also shown since it might be possible to make some of those arcs cyclable with some intervention (e.g. improving the existing infrastructure in key connections - e.g. those highlighted with red circles). Moreover, three disconnect zones can be identified and the map strongly suggests places for mechanical devices.

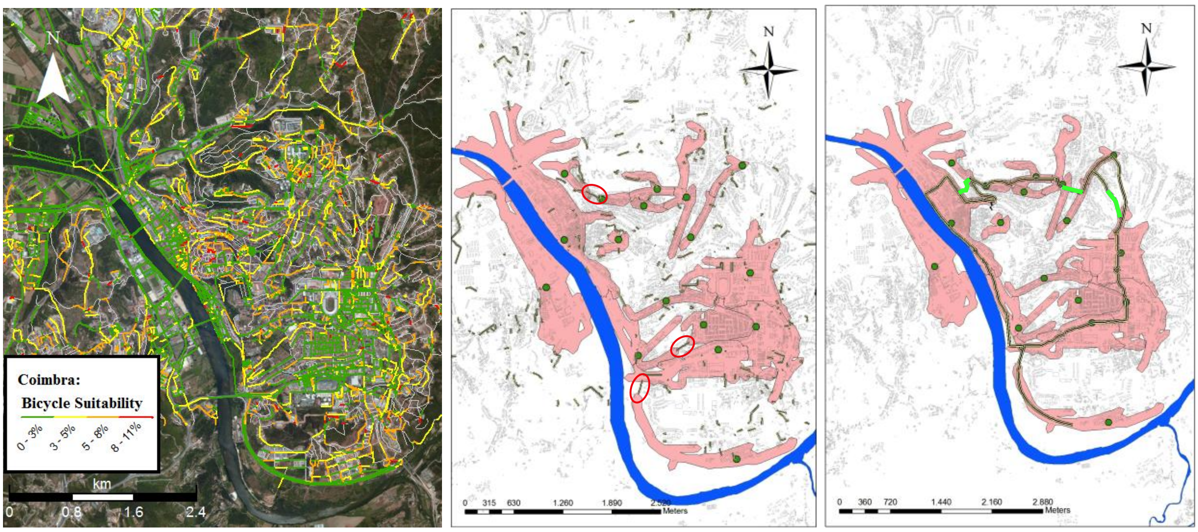

Figure 1. Coimbra - Cyclable street stretches, cyclable areas and possible bicycle path circuit.

The right-hand-side map features the same service areas, now with a possible location for mechanical devices (light-green color), as well as a possible bicycle path circuit, with which the vast majority of the city east of the river, including its eastern bank, becomes cyclable.

3. CONCLUSIONS & FUTURE WORK

This paper shows how current GIS technology can be used to analyse the suitability of a city for cycling and identify stretches where an intervention (e.g., road design) or assistance (e.g., addition of mechanical devices) may improve overall cyclability.

As future developments, several can be enumerated, such as analysing: alternative locations for mechanical devices; possible bike-sharing solutions, namely in what concerns location of parking places and integration with the urban public transportation system; opportunities for bike-path improvements, so as to make the traffic network more cycling-friendly; energy assessment of traditional and electric-assisted bicycles; economic costs of all of the above.

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