Evaluation of cycle network potential for daily utility journeys in Lisbon

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Abstract

The commitment in promoting bicycle use is currently of high priority worldwide, according to a wealth of national and international strategic documents. In fact, this option enhances urban life through the quality of urban space and social dynamics, and contributes to the reduction of pollutant emissions and the improvement of individual health.

In this context, bicycle use may be considered in our daily choices regarding mobility and put into action for utility trips and not only in leisure times, related to green spaces.

This work identifies as of outmost importance the design of cycle networks that respond to citizens' needs regarding daily trips and discusses the criteria involved. The type of network infrastructure considered depends on the road network hierarchy, being the supply of dedicated cycle lanes in distribution channels together with appropriate traffic calming measures in the local access network.

The results obtained show a cycle network that complies with the criteria of available width within the existing carriageway to introduce a cycle lane adjacent to car lanes. Depending on the minimum permissible width standards and the consideration of the possibility of parking places reduction, results obtained differ namely in terms of network connectivity, redundancy or directness, influencing the effectiveness in meeting the needs of utility cyclists in their daily journeys.

Also, the network can be put into effect without a very significant investment. Such a view is, therefore tenable both in terms of infrastructure adaptation and the respective constraints and costs involved.

Introduction

Cycling is increasing in popularity as both a means of transport and recreation. However, private car is by far the most used mode, even though its negative impacts and undesirable aspects in relation to traffic congestion, safety and pollution. Cycling, in turn, is a clean and efficient mode and it is particularly well suited to many of the trips in inner urban areas, mostly made by cars nowadays (Pucher & Buehler, 2007). Many utilitarian daily trips, such as travelling to work or to school, are less than 5 kilometers, which is a distance that can be covered more rapidly on a bicycle than in a car (European Commission, 2000). Also, cycling can play a crucial role in offsetting the issues caused by motorized transport. In fact, besides being more economical and contributing potentially to the reduction of road congestion, cycling offers relevant environmental and health benefits for the community (Department for Transport, 2008). Therefore, it should be envisaged in all urban planning activities irrespective of the involved scale.

Acknowledgement of cyclists ensures that current planning decisions meet future needs in terms of providing appropriate facilities, in order not to jeopardize the future of this mode (Dufour, 2010).

Methodology and Methods

The methodological approach of this work is based on the integration of spatial information of the streets of Lisbon previously processed through the use of a geographic information system (GIS). After the diagnosis of the case study current situation in terms of existing cycle network, the potential of this work is discussed as it may answer to the need to improve not only the network itself but the overall bicycle utilization. The approach relies on data exhaustively collected in Google Earth regarding the number and corresponding width of lanes of every second and third level segment of the network hierarchy. This data allows evaluating the possibility of introducing a cycle lane in each road segment of the city's network (second and third road hierarchy levels). Possible measurement errors are considered and included in the analysis.

The principles and criteria that should be taken into consideration in the analysis of the spatial information were chosen. Accordingly, selected indicators are used to assess the final cycle network performance both in terms of connectivity and attractiveness.

Case Study

Diagnosis of the current situation

Lisbon, capital of Portugal and the urban centre of the Lisbon Metropolitan Area, has roughly 550.000 inhabitants.

In Lisbon, the predominance of private car use and the need to promote a more effective cycle mobility, require balance and prioritization of different types of networks, as planning processes are dealing with competing ambitions from different users. The fact is that both traffic from the outskirts to the centre and within the city contribute to the high volumes observed in Lisbon.

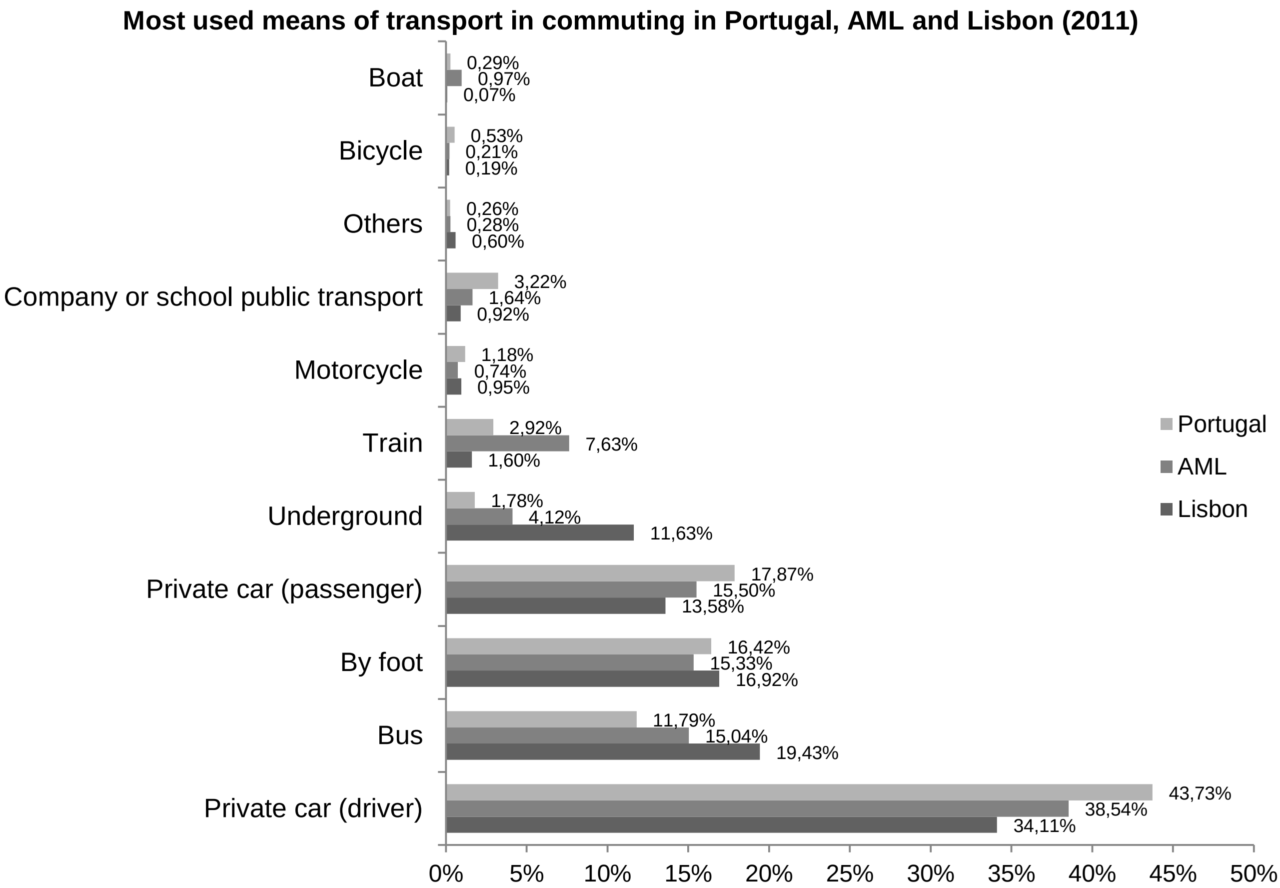

Figure 1 – Comparative analysis of most used modes of transport in commuting in Portugal, AML (Lisbon Metropolitan Area) and Lisbon (Source: INE, 2011)

Figure 1 illustrates the unbalanced modal split in Portugal and that the percentage of bicycle use is rather small. The same observation is valid regarding both the Lisbon metropolitan area and the municipality of Lisbon. The proportion of public transport use is higher inside Lisbon than at the national level, as expected, due to better urban infrastructure and facilities. Conversely, bicycle share is lower in Lisbon than the national average, as Lisbon has less cycle infrastructures than elsewhere (in relative terms). In fact, the purpose of a cycle network is to provide cyclists with safer and more convenient cycling mobility (Austroads, 2011).

The existing cycle network was designed mainly with the purpose of linking the green spaces and ecological assets in the city through the so-called green corridors, Figure 2. In the municipality of Lisbon, there are already 78 km of cycle lanes and a clear trend and willingness to increase the length and the use of the network.

The fact is that, in some cases, it might not address a significant number of cyclists' aspirations, namely those that use or are likely to be using the bicycle as a means of transport on a daily basis. In addition to this, it is difficult to collect information about cyclists' trips, as they are not intrinsically limited to the road infrastructure. The study of these movements is complex and specific attention should be paid to the methods used in selecting the relevant data to consider in design.

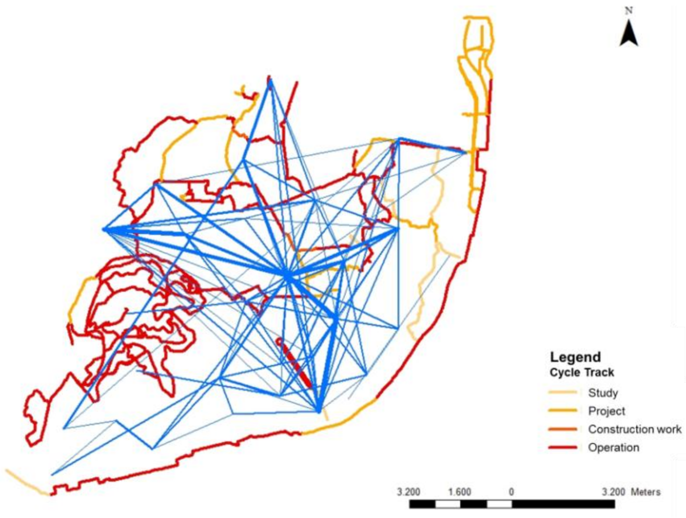

Figure 2 – Cycle network in Lisbon and main desirable lines

The desire lines represented in Figure 2 result from the analysis of the origin-destination matrix from a survey conducted in Lisbon in 2004 (CML, 2005). As reliable information has not been collected regarding cycle trips in Lisbon, the values considered are related to the total amount of trips for all motorized modes which enables the analysis of not only existing bike trips but also potential of bike trips.

As in the case of the other modes, there is no effective cycling network unless it meets the main desired lines. The fact is that if these are not met, cyclists will choose other routes even though a dedicated cycle network exists. The information presented in Figure 2 reinforces the idea that the existing cycling network does not address an important part of trips, strongly oriented to the city centre where the economic activity is mainly located. Thus, the design of cycle networks that respond to citizens' needs regarding daily trips gains particular relevance.

Regarding the existing road network in Lisbon, it is divided into five hierarchical levels according to Lisbon's master plan. The first level corresponds to the structural network, the second to the main distribution network, the third to the secondary distribution network and the two remaining to proximity and local access, respectively. Regulatory provisions in the Lisbon master plan state that it is not possible to have a cycle lane in a first level road due to speed conditions and safety concerns. Actually, where the speed and volume of traffic is high, the options may be to consider an off-carriageway option for cyclists or wider cycle lanes that allow for increased separation between cyclists and other vehicles, which are both not feasible in Lisbon in most cases due to its density levels.

Moreover, fourth and fifth levels of the network are considered to be intrinsically part of the network. Regulation indicates that traffic calming measures should be put into practice from the outset in fourth and fifth level roads. Consequently, it is therefore considered that these segments are implicitly a part of a cycle network as the road environment and speed conditions are suitable to the coexistence of all modes including active modes. In these cases, in low speed environment the coexistence is acceptable and even advantageous. However, the possible existence of crossing flows through the neighbourhoods should be analyzed on a case by case basis in order to evaluate if the adequate conditions to coexistence are met. If not, additional traffic calming measures should be taken.

On the other hand, roads belonging to the second and third levels are suitable to be used by cyclists although it might occur in a segregated lane, depending on the on-site specific speed and traffic conditions.

Assumptions for the network definition

Prior to the network definition, it is crucial to identify the profile of the users that it will serve. In this context, based on the mismatch between existent cycling network offer and the main desirable lines of trips, daily users aspirations might not be met. Therefore, it is necessary to complement the network in terms of promoting a better response to the needs of utilitarian cyclists.

The type of infrastructure considered is the cycle lane. This option relies on the assumption that the network obtained should be extent and redundant, providing the required connectivity.

A good cycle network has the following features: safety, coherence, directness, attractiveness and comfort (Austroads, 2011).

Results and Discussion

It should be noted that only the second and third levels of the road network hierarchy were considered in the final proposal of this work. Lane and carriageway widths $(Larg_i^j)$ were carefully and exhaustively measured and number of lanes was determined in order to implement for each link a condition for the acceptance of the introduction of a cycle lane.

$$Larg_i^j \geq N_i \times LA_{min}^j + LC_{min}^j$$

Where: i, segment of the road environment;

j, minimum permissible width criterion

N_i, number of lanes of segment i;

LA_{min}^j, car lane minimum width considered in criterion j;

LC_{min}^j, cycle lane minimum width considered in criterion j.

Table 1 – Minimum widths considered in each criterion

	LA_{min}	LC_{min}
Criterion 1	2,7 m	1,2 m
Criterion 2	3 m	1,2 m
Criterion 3	2,7 m	1,5 m
Criterion 4	3 m	1,5 m

It is important to make the analysis on the possibility of introducing a cycle lane in each second or third level segment based on the four criteria presented in Table 1. It is intended to assess the impact of the consideration of minimum absolute widths and minimum recommended widths in extension and configuration.

In addition, there is the intention to evaluate to what extent the removal of parking places might play a role in the verification of the width condition and therefore influence the final configuration of the network.

The results of the application of the width criteria are presented in Figures 3 to 14 as well as the current existent and projected cycle tracks in order to have the perception of the complementarity of the cycle network as a whole.

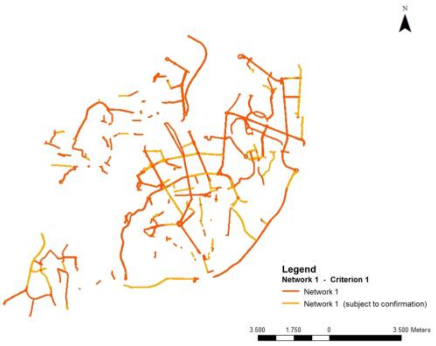

Figure 3 – Road network that allows the insertion of a cycle lane according to criterion 1

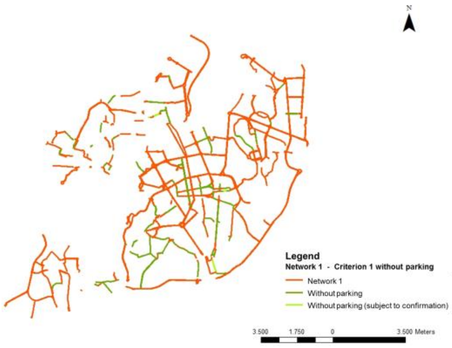

Figure 4 – Road network that allows the insertion of a cycle lane considering removal of parking places if necessary, according to criterion 1

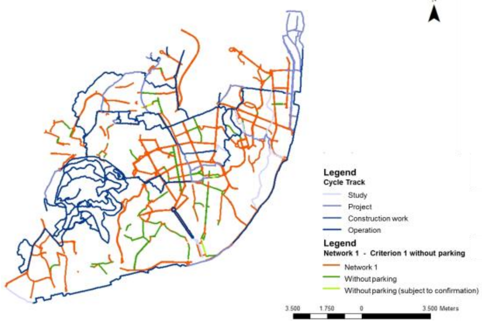

Figure 5 – Road network according to criterion 1 (with or without parking removal) complemented with existent or projected cycle tracks

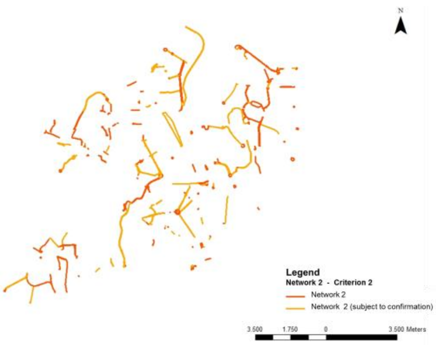

Figure 6 – Road network that allows the insertion of a cycle lane according to criterion 2

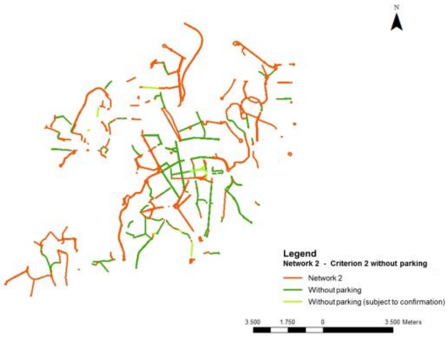

Figure 7 – Road network that allows the insertion of a cycle lane considering removal of parking places if necessary, according to criterion 2

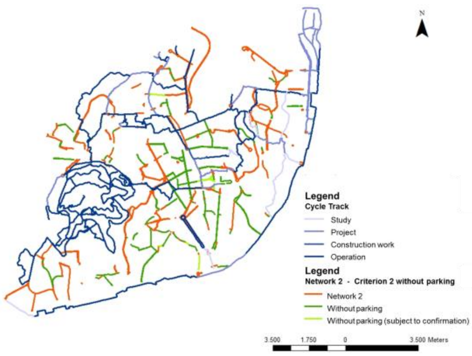

Figure 8 – Road network according to criterion 2 (with or without parking removal) complemented with existent or projected cycle tracks

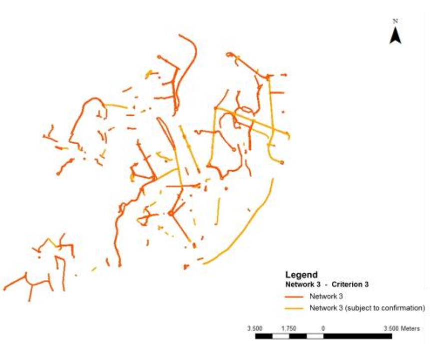

Figure 9 – Road network that allows the insertion of a cycle lane according to criterion 3

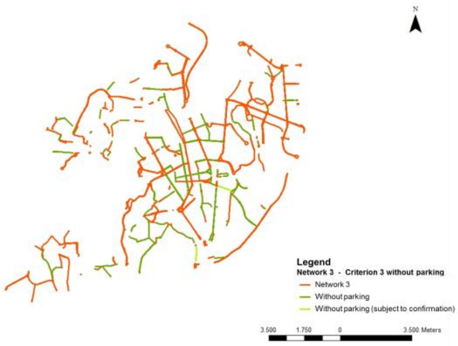

Figure 10 – Road network that allows the insertion of a cycle lane considering removal of parking places if necessary, according to criterion 3

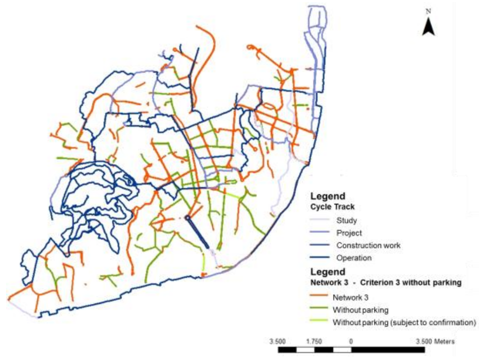

Figure 11 – Road network according to criterion 3 (with or without parking removal) complemented with existent or projected cycle tracks

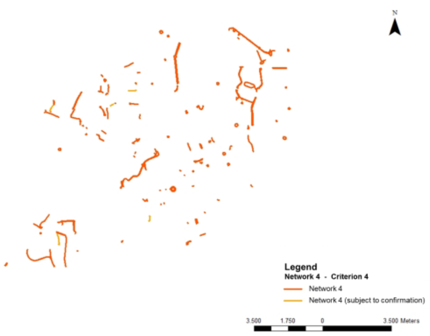

Figure 12 – Road network that allows the insertion of a cycle lane according to criterion 4

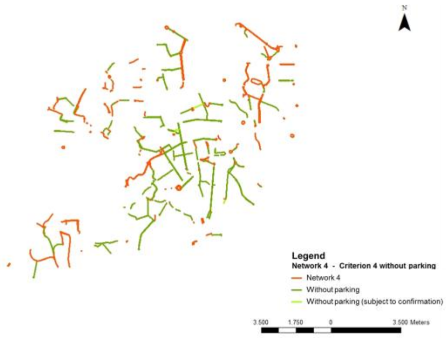

Figure 13 – Road network that allows the insertion of a cycle lane considering removal of parking places if necessary, according to criterion 4

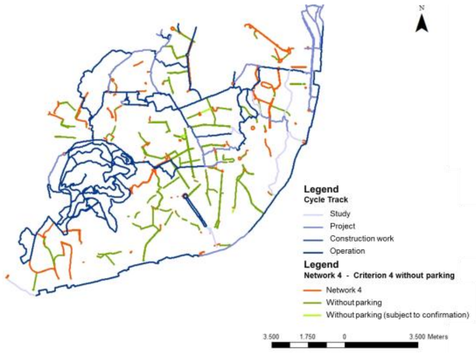

Figure 14 – Road network according to criterion 4 (with or without parking removal) complemented with existent or projected cycle tracks

As expected, criterion 1 has better overall results in terms of coverage and connectivity of the network. In fact, the consideration of less stringent criteria leads to more encouraging results for the cycle potential in Lisbon. Similarly, the application of criterion 4 result in a dispersed and fragmented network, as this is the most demanding criterion among those taken into consideration. It should be noted that the scattered points on the maps mainly visible in the map of criterion 4 may result from a simplification regarding the minimum admissible width in roundabouts and curves.

Connectivity, as an essential attribute of a transport network, must be assessed in this case. In this context, redundancy and sinuosity are considered a contribution to assess the connectivity of a network.

Redundancy was evaluated in this case as the ratio between the extension of the network obtained and the existing road network in each zone for each criteria and considering both the total network (second to fifth levels) and only the explicit (second and third levels). The values obtained vary from approximately 0.1 and 0.6 for the second and third levels and from 0,6 to 0,9 when considering also fourth and fifth levels.

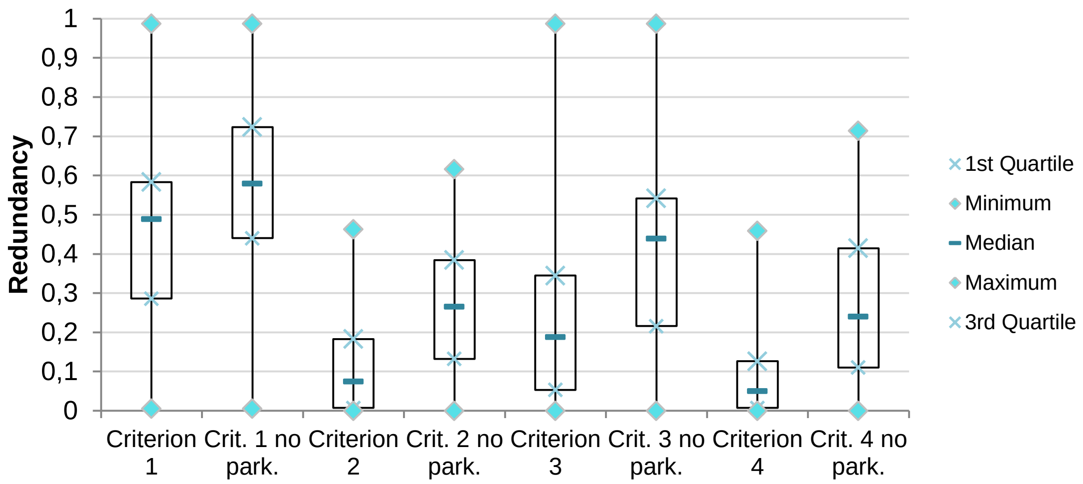

Figure 15 – Dispersion of redundancy values considering only 2nd and 3rd level roads

Table 2 – Sinuosity of the connections between the centroids of the 40 zones considered

		Criterion 1	Crit. 1 no park.	Criterion 2	Crit. 2 no park.	Criterion 3	Crit. 3 no park.	Criterion 4	Crit. 4 no park.
Sinuosity of the connections between centroids	Average	1.50	1.45	1.62	1.57	1.65	1.47	1.69	1.78
	Standard deviation	0.37	0.38	0.54	0.51	0.58	0.39	0.68	0.84
	Proportion of stablished connections between centroids	**0.60**	**0.81**	**0.39**	**0.76**	**0.57**	**0.76**	**0.39**	**0.72**

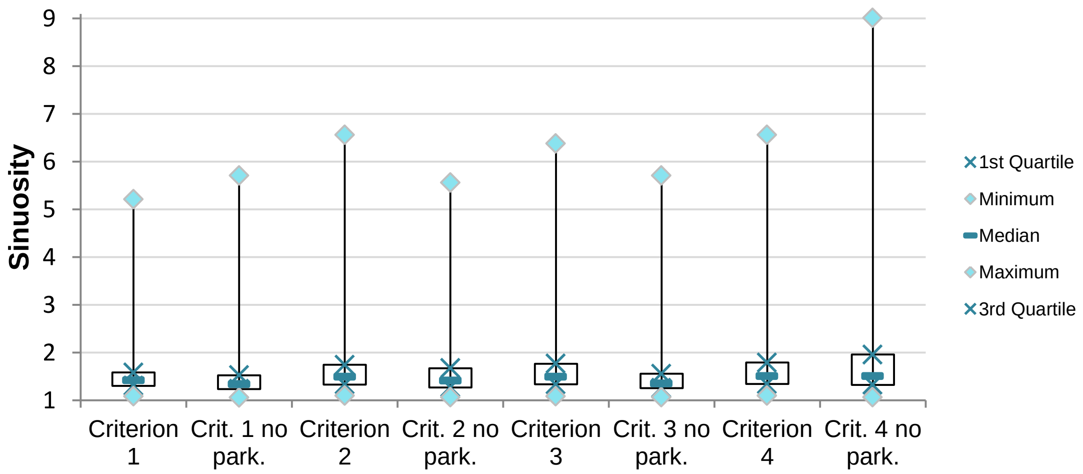

Figure 16 – Dispersion of sinuosity values

Average results of sinuosity are satisfactory as they are mainly below 2, which indicates an adequate directness in general, although the punctual maximum values that occur in a specific pair O/D and probably result from their centroids' locations.

Attractiveness of the network from the perspective of its users is a relevant aspect to assess as well. The network obtained based on width criteria is assessed based on the adaptation of an algorithm developed by (Félix, 2012). For each arc, its impedance or travel cost is given by:

$$imp = \sum_{i} w_i \times \alpha_i \times c$$

where,

i - Relevant criteria for route choice (fastness, slope and safety);

w_i - Weight of criteria for each profile (*commuters*) (Félix 2012);

a_i - Cost factor;

c - Reference cost which depends on the length and average speed, in time units.

Only the three main variables influencing the route choice by commuting cyclists were considered in the model, as they explain almost 70 % of the route choice process: fastness, slope and safety. The weights were changed so that their sum is equal to 1. Also, only the commuter profile was taken into account due to the purpose of this work.

The results that reveal the perception of current commuting cyclists regarding the city of Lisbon is presented in Figure 18 and Figure 17.

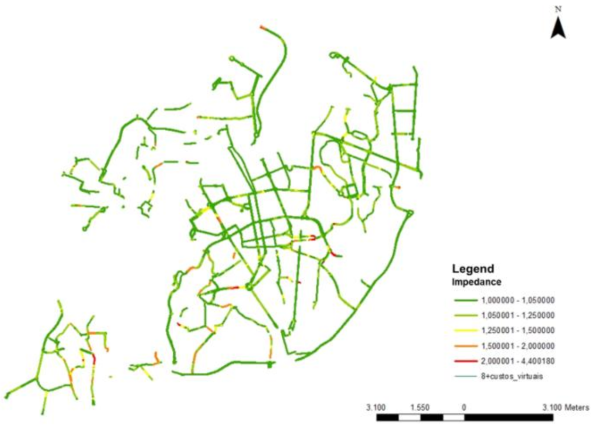

Figure 17 – Impedance map based on the second and third level eligible arch

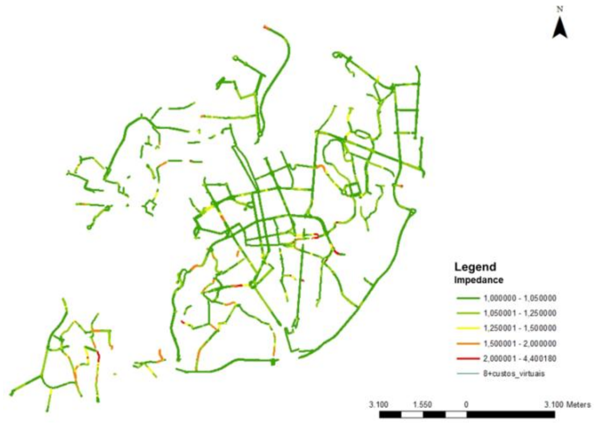

Figure 18 – Impedance map based on the network resulting from criterion 1, considering removing parking places

Conclusions and Future Work

The case study enabled reaching encouraging results towards the implementation and usage of Lisbon cycle lanes policies. In fact, the configuration and extension of the cycling network which results from the introduction of cycle lanes in the current primary e secondary distribution networks, only by reducing the cycle lanes' width in each fragment considered, keeping the road capacity in terms of motored traffic concomitantly almost unchanged, shows the feasibility of the established goals, with acceptable costs when referring to the expected advantages.

However, concerning different requirements levels in what relates the minimum accepted width to each type of lane, the network that results from the fragments that validate the demand of one cycle lane introduction per way is significantly different. It should be noted that the lower limit establishment to the lanes minimum width must be taken into account, also taking into account that it may derail the implementation of a cycling network composed by cycle lanes. Safety aspects should indeed be considered in a first step at all instances so that it should not be in question when, for example, trying to reach better cycling network connectivity characteristics. Not less important are the expected impacts that the introduction of cycle lanes in the road network may have in their capacity, by means of speed reduction. These aspects should be taken into account when actually implementing the cycling network.

The best network obtained in terms of territorial distribution and connectivity is, as expected, the one that results from the analysis of the minimum width values.

In what concerns the fulfillment of the main desirable lines, it shows that the most minimum width permissive criteria allows answering the needs of daily trips of current and potential users, once all trips were considered in the origin/destiny table. The mean values reached in terms of sinuosity between centroids show that the network obtained allows the connection, almost in a direct way, of the main trip generators. So, it can be stated that the network will answer the daily trips inherent needs and not only the leisure trips. It is noticed that the parking removal analysis along the roads, enables reaching much different results when compared to the initial ones. It also presents significant advantages in terms of fragmentation comprehensiveness and reduction.

Cost evaluation made for different network feasible configuration points out both at total and unit length values which are considered acceptable, mainly when referring to the advantage obtained in terms of increasing traffic safety of current cyclist and of the introduction of new cycling users.

This dissertation suggests primary investigation on the criteria associated with the design of utility cycle networks aiming at promoting an effective modal transfer to cycling. Much more work with different criteria and different restrictions of the road network is, however, necessary to ensure adequacy of the methodology. In the future, a similar approach can be used in other cities.

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