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## Geoprocessing and slope analysis of the cycling network of Londrina/PR

### Análisis de la pendiente de la red ciclista diseñada para Londrina / PR mediante técnicas de geoprocésamiento

### Análise da declividade da malha cicloviária projetada para Londrina/PR utilizando técnicas de geoprocessamento

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#### Abstract

The Bicycle Brazil Program, from the extinct Ministry of Cities - National Secretariat of Transport and Urban Mobility (BRAZIL, 2007) recommends that gradients higher than 5% should be avoided by cyclists in urban commuting since it is a transport powered by physical effort. Therefore, the objective of this research is to verify the slope conditions of the project of the cycle network by the city of Londrina (IPPUL, 2006; 2013; 2019; 2020) applying spatial analysis to a Digital Elevation Model (DEM) and the vector file of the project of the cycle network in a geoprocessing software. According to the obtained results, 40,6% of the proposed network is suitable for cycling infrastructure.

**Keywords:** Cycling infrastructure. Slope analysis. Londrina

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#### Resumen

El Programa Bicicleta Brasil, del extinto Ministerio de Ciudades - Secretaría Nacional de Transporte y Movilidad Urbana (BRASIL, 2007), recomienda que los ciclistas eviten inclinaciones superiores al 5% en los desplazamientos urbanos por tratarse de un transporte impulsado por el esfuerzo físico. Por tanto, el objetivo de esta investigación es verificar las condiciones de deterioro de la red ciclista proyectada por la ciudad de Londrina (IPPUL, 2006; 2013; 2019; 2020) utilizando

la estrategia de generación de un Modelo Digital de Elevación (DEM) y altimetría de operaciones. en software de geoprociamiento aplicado a la malla. De acuerdo con los resultados obtenidos, se concluyó que el 40,6% de la cuadrícula propuesta presenta una pendiente menor al 5%.

**Palabras clave:** Infraestrutura de bicicleta. Declínio. Londrina

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### Resumo

O Programa Bicicleta Brasil, do extinto Ministério das Cidades - Secretaria Nacional de Transporte e da Mobilidade Urbana (BRASIL, 2007) recomenda que inclinações superiores a 5% sejam evitadas pelos ciclistas no deslocamento urbano por se tratar de um transporte movido a esforço físico. Sendo assim, o objetivo desta pesquisa é verificar as condições de declividade da malha cicloviária projetada pelo município de Londrina (IPPUL, 2006; 2013; 2019; 2020) utilizando a estratégia de geração de um Modelo Digital de Elevação (MDE) e operações altimétricas em um *software* de geoprocessamento aplicados à malha. De acordo com os resultados obtidos, concluiu-se que 40,6% da malha proposta contempla uma inclinação abaixo de 5%.

**Palavras-chave:** Infraestrutura cicloviária. Declividade. Londrina.

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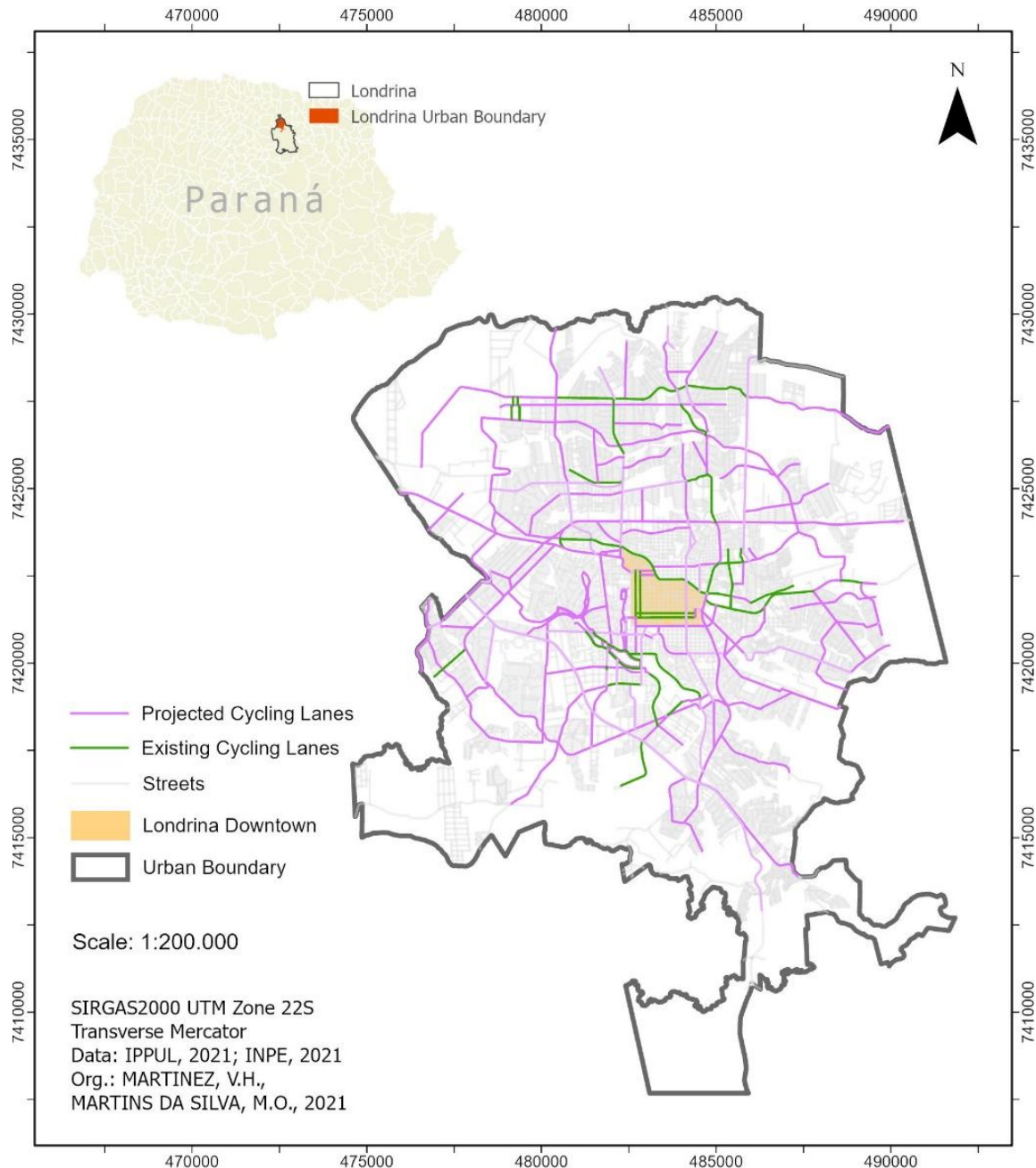
### Introdução

The precarious condition of urban mobility, along with more cars on the streets and, consequently, road traffic accidents increase, have become a challenge for urban planners. Since 2001, with the approval of the Statute of the City (Federal Law 10.257/2001), the elaboration of transport plans has been incorporated into the existence of Urban Mobility Plans as an instrument of urban development. After 11 years of the existence of the Statute of the City, the National Urban Mobility Policy is approved through the Federal Law 12.587/2012, which establishes deadlines for municipalities, as one of its guidelines establishing the “priority of non-motorized modes of transportation over the motorized ones” to offer the minimum of security in urban commuting (MARTINS DA SILVA; CUNHA, 2020, p. 253-254).

In 2004, the Brazilian Bicycle Mobility Program, also known as “Bicycle Brazil” was launched by the Federal Government, a program focused exclusively on commuting by bicycle. In 2007, as part of the program, the “Reference Notebook for the Elaboration Mobility Plan by Bicycle in Cities” was launched, providing subsidies for

municipalities in the implementation of a Bicycle Master Plan, being also an important instrument in the formulation of urban mobility policies, considering the active participation of the most diverse social groups, and mainly, the users of bicycles (BRAZIL, 2007).

**Map 1-** Proposed and existing cycle lanes in Londrina / PR



**Source:** MARTINEZ, V. H.; MARTINS DA SILVA, M. O., 2021

On October 4th, 2018, Federal Law 13.724 passed, instituting the Bicycle Brazil Program (PBB) to promote the use of bicycles, thus, improving urban mobility

conditions. One of the PPB objectives is “to increase the construction of cycle lanes and the marking of cycle lanes and shared (temporary) lanes on the road” (BRAZIL, 2018, p. 3, col. 2).

The spatial delimitation of the research (map 1) is the city of Londrina, in the north of the state of Paraná, with a territorial area of 1,652,569 km<sup>2</sup> and an estimated population of 575,377 inhabitants, with a demographic density of 306.52 inhabitants / km<sup>2</sup> (IBGE, 2021).

In 2006, the Londrina Urban Research and Planning Institute (IPPUL) planned 60 km of cycle lanes and tracks, but the initial project went through several changes. Until 2012, the city had only 12 km of lanes for cyclists. In 2013, research found that there was a predominance of transport by bicycle for work and study travels (59%) and with that, 328.7 km were planned, with the execution reaching only 38 km in 2017 and about 42 km in 2020 (MARTINS DA SILVA; CUNHA, 2020, p. 258).

In the most diverse cities, the cyclist's paths are directly affected by inclinations of the terrain, and culturally, steep gradient discourages the use of bicycles. However, the topographic configuration cannot determine the viability for cycling (BRAZIL, 2007, p. 62). Therefore, it is argued that good cycling planning based on the understanding of the conditions of the terrain should be a guide to adopt strategic actions to facilitate the commuting of cyclists, especially in the case of Londrina, where bicycles are predominantly used for work and study travels.

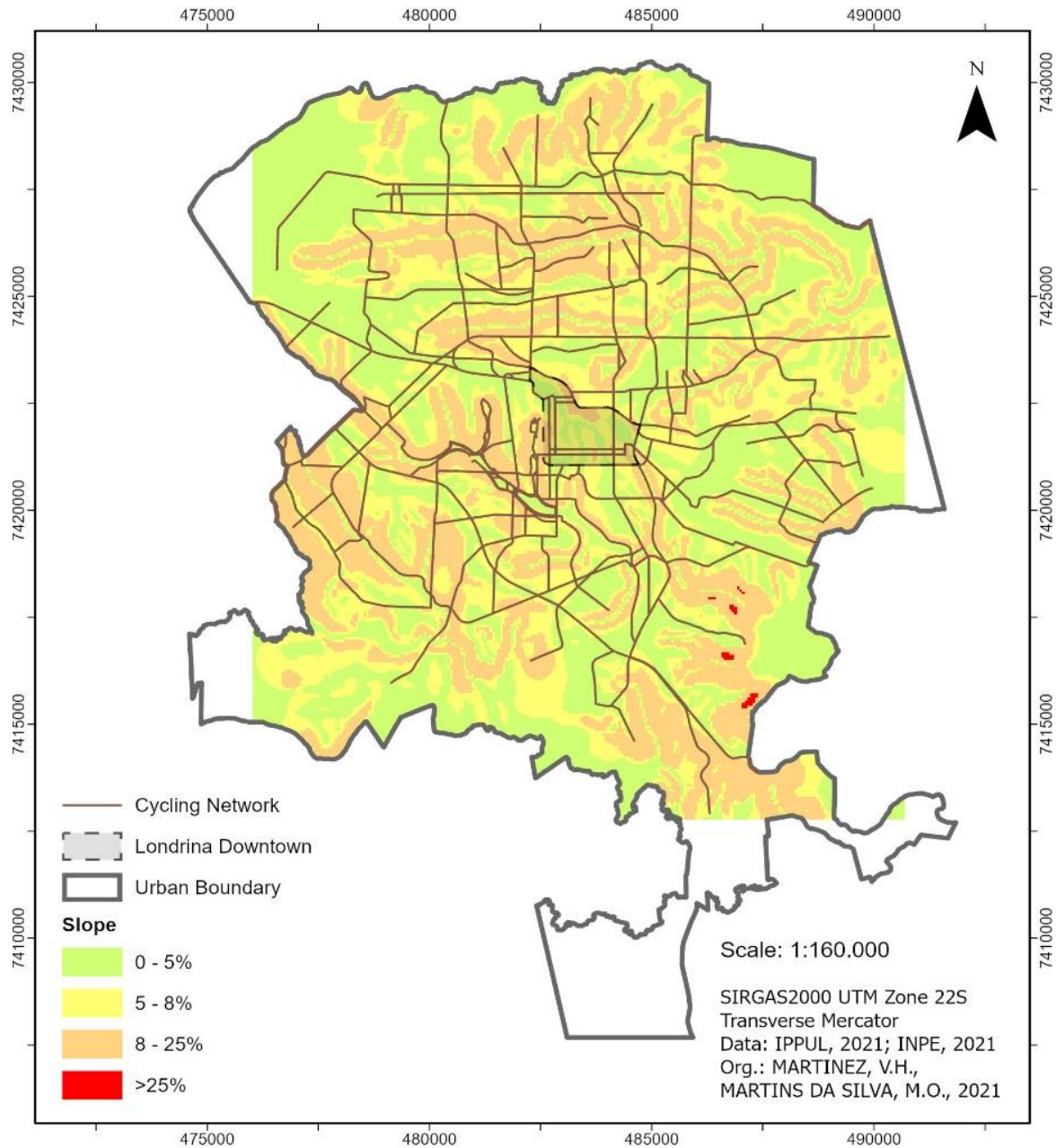
## Materials and methods

The acceptable gradient for cycling is variable. In the United States, the suggested grade reaches 8% for up to 90 m (the USA, 1999), in Scotland, values differ between 3 and 7% (SCOTLAND, 2011), and in Colombia, for up to 90 m a gradient of 10% is recommended (COLOMBIA, 2016).

The Bicycle Brazil Program indicates that the ideal gradient of the cycle network should be a maximum of 5% for up to 100 m since this type of displacement requires physical effort (BRAZIL, 2007 p. 62).

To determine the slope of the terrain and to define the portions indicated or not for the cycling practice, it was necessary to generate a Digital Elevation Model (DEM) that “represents the altitudes of the topographic surface aggregated to the geographic elements existing on it” (IBGE, 2020, p. 1).

**Map 2-** Slope and the cycle network in Londrina



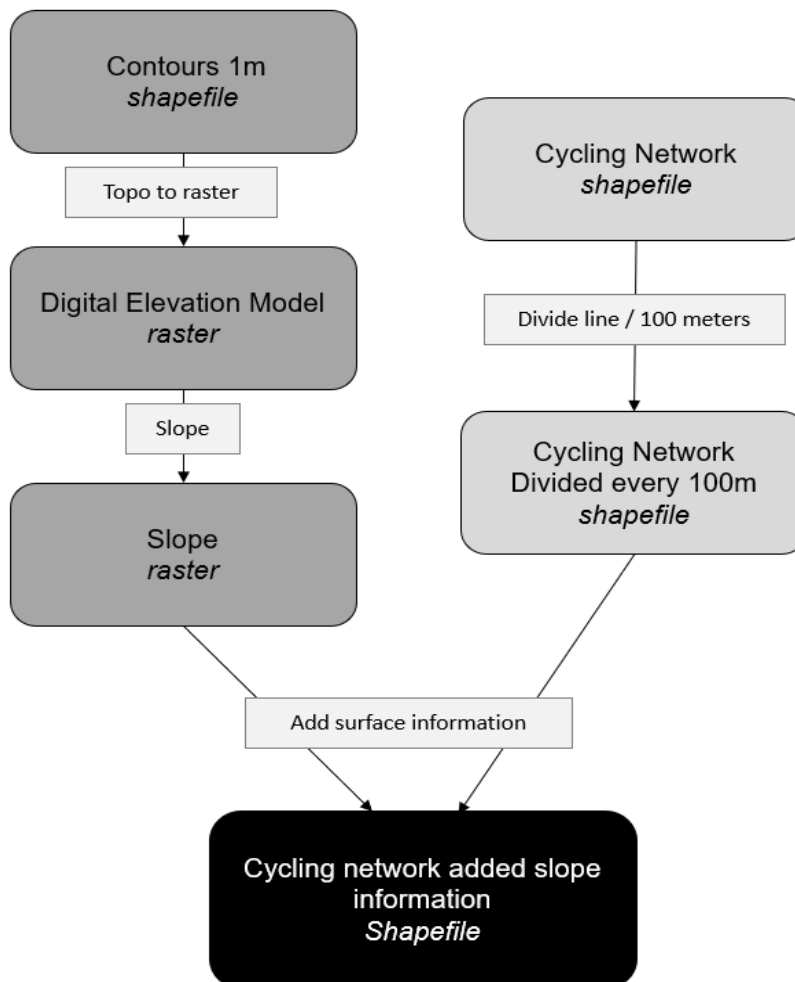
**Source:** MARTINEZ, V. H.; MARTINS DA SILVA, M. O., 2021

The DEM was generated from the georeferenced shapefile vector contour lines of 1 x 1 meter for the city of Londrina, available by IPPUL. This file was manipulated in a

GIS environment, and then, applying the “TopoToRaster” tool, the DEM was generated. In possession of the DEM, the “slope” tool was used to generate the slope of the study area, the same being categorized into four classes. All processing was performed using the ArcGIS Pro 2.7.0 software.

The file of the bicycle network of Londrina in shapefile vector format was also provided by IPPUL. This file contains information such as the length of each line, its location, and its condition (implanted or projected). Map 2 represents the cycle network of Londrina, overlaid on the slope raster.

**Flowchart 1-** Methodology applied on the research



**Source:** The authors, 2021

To add the slope value to each segment of the cycle network vector file, it was decided to fragment it every 100 m, according to the methodology adopted by Simeão; Manzato; Viviani (2018), which is based on the reflection of methodologies that follow

international standards. This measure is justified, therefore, for each segment of the cycle network, the average value of the slope pixels on which it overlays will be added. The longer the line, the higher the numbers of pixels and, consequently, the greater the slope value variable. With smaller segments, of 100m each, this value becomes more accurate, as each segment overlays to two or three pixels. Flowchart 1 represents the methodology used.

With the completion of operations, cycle path segments with a slope below 5% were considered "acceptable" and above 5% will serve as "warning points" for the implementation of infrastructure that helps cyclists in their travels.

## Results and discussions

With the processing of data, the cycle paths segments with a gradient between 0 and 5% reached 40.6% of the cycle network, which represents an average below the recommended by Brazil (2007), however, to understand this complexity, it was verified through the table of attributes that the values from 5 to 6% determine an extension of 13.5% of the network, that is, 54.1% of the network corresponds to a gradient slope of 0 to 6% (Table 1).

**Chart 1-** Classification of the cycle network according to 5% gradient slope

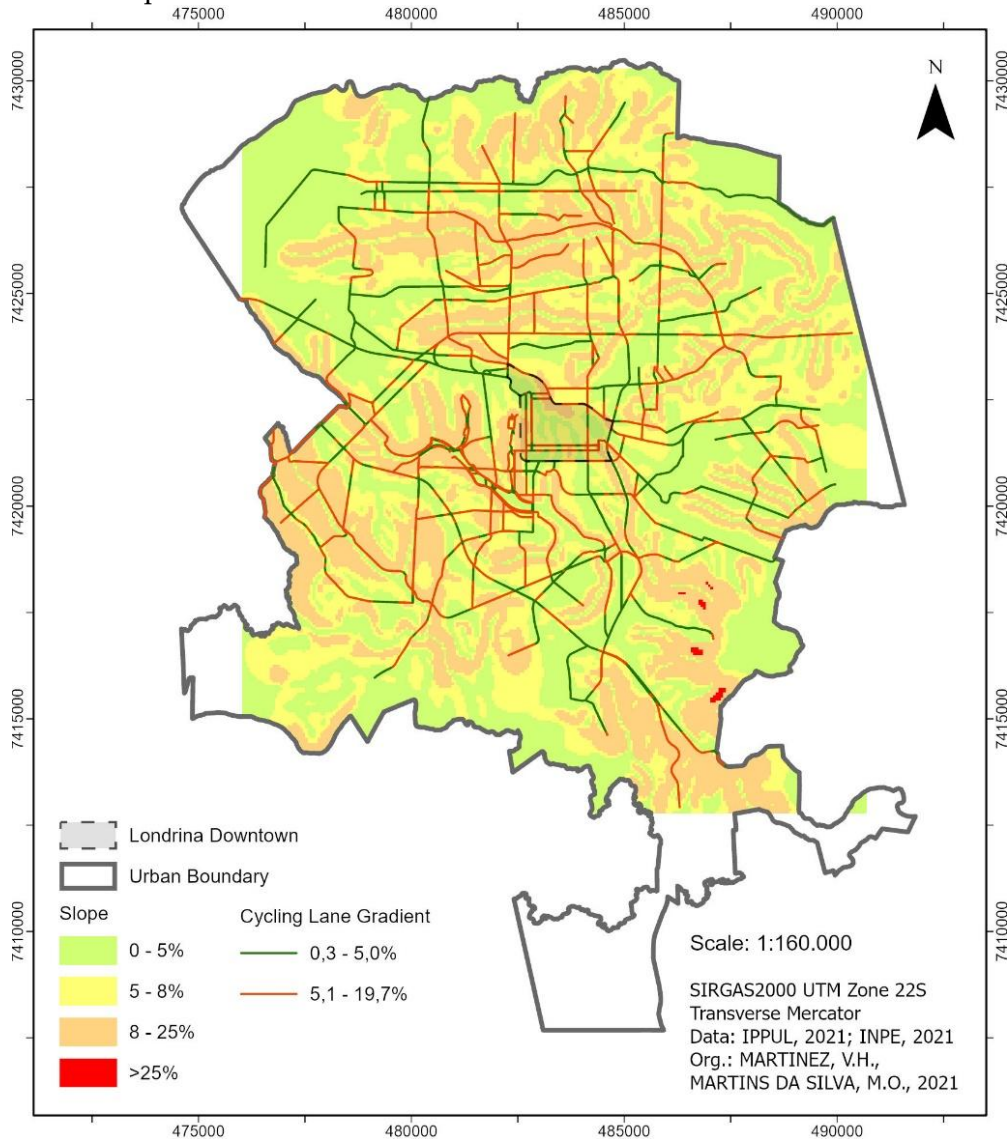
Slop class	Extension (km)	Extension (%)
0 - 5%	133,6	40,6
5 - 6%	44,4	13,5
6 - 8%	69,0	20,9
>8%	81,1	25

**Source:** The authors, 2021.

The understanding of the presented data occurs in the spatialization represented in map 3. As there are many cycle path segments of 100m each, the cartographic visualization of the slope value label of each segment is not possible, therefore, the map presents two classifications: segments from 0.3% to 5%, and 5.1% to 19.7%. The data for

each cycle segment is available in the attribute table, making it possible the use to subsidize future work and also the decision-making of city planners.

**Map 3** – Cycle path segments of the cycle network in Londrina classified with a gradient slope of 5%



Source: MARTINEZ, V. H.; MARTINS DA SILVA, M. O., 2021

Although 40.6% of the network includes a gradient slope of less than 5%, many of the cycle line segments range from 5.1 to 5.5%, which is still acceptable, as there may be minimal distortions in the processing results, there may be variations in the length of segments, and also other international references are also considered where the gradient slope of up to 8% (Chart 2) is acceptable depending on the terrain and conditions offered to the cyclist (the USA, 1999; COLOMBIA, 2016; SCOTLAND, 2011).



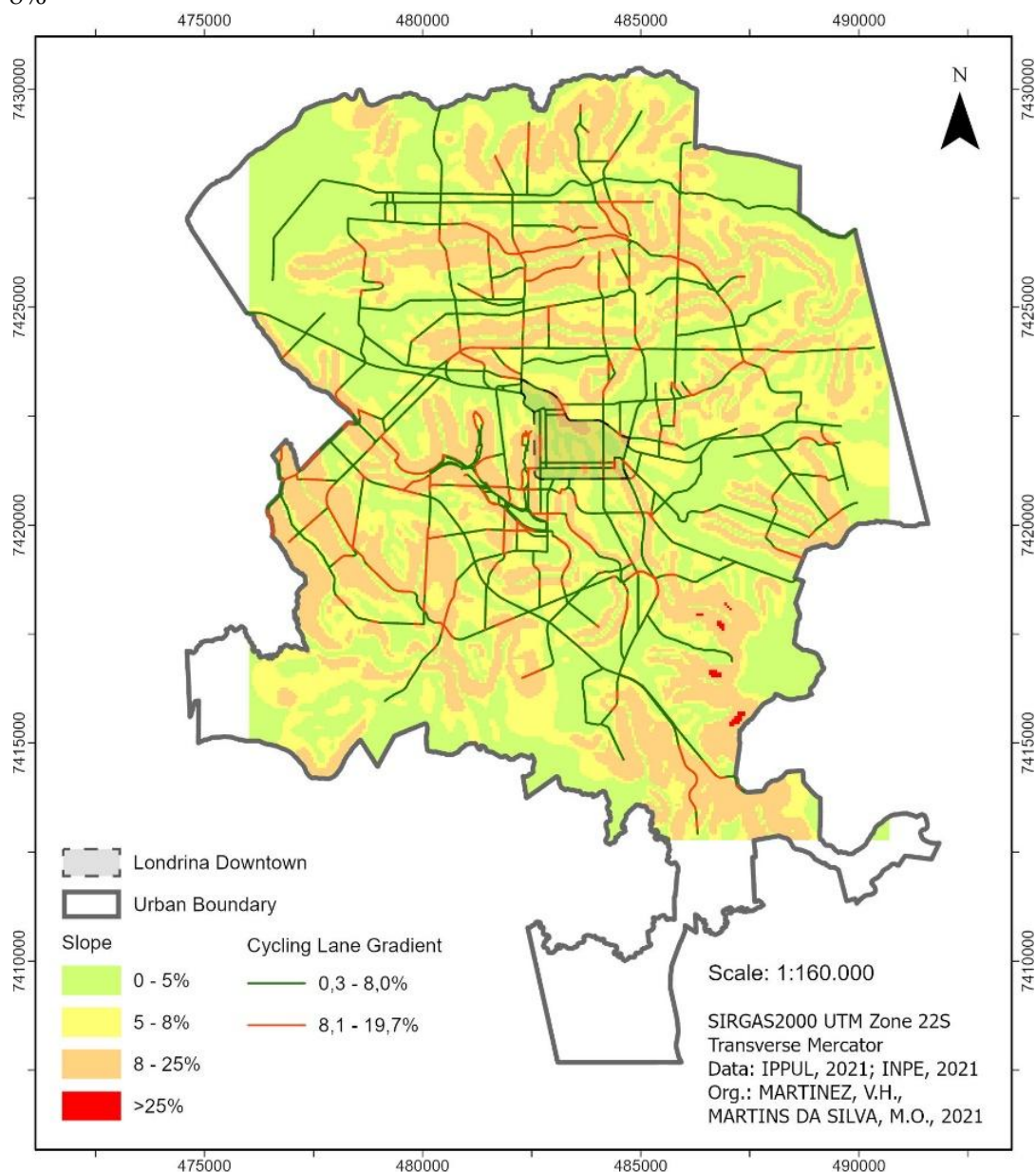
**Chart 2-** Classification of the cycle network according to 8% gradient slope

Slope class	Extension (km)	Extension (%)
0 - 5%	133.6	40.6
5 - 8%	113.5	34.4
>8%	81.1	25

Source: The authors, 2021

The understanding of the presented data occurs in the spatialization represented in map 4, with two classifications: from 0.3% to 8% and from 8.1% to 19.7%:

**Map 4.** Cycle path segments of the cycle network in Londrina classified with gradient slope of 8%



Source: MARTINEZ, V.H.; MARTINS DA SILVA, M.O., 2021

In this scenario, 75% of the network meets international standards. To meet the cyclist's demand in areas that require greater physical effort and are considered points of alert according to the methodology used, the PBB recommends:

Article 5 [...] I - stimulating the development of bicycle infrastructure projects; II - the implantation of bike lanes, bike tracks, shared lanes, properly signed; III - the construction of bicycle racks in terminals of public transport system; IV - the installation of bike racks along the circulation routes and specific parking lots in places with a high flow of people; V - the installation of support equipment for users, such as public restrooms and drinking fountains in strategic locations; VI - the implementation of a low-cost bicycle rental system in the terminals of the public collective transport system, in shopping centers and other places with a high flow of people; VII - the elaboration and dissemination of educational campaigns related to the safe use of bicycle and its benefits. (BRAZIL, 2018, p. 3, col. 2).

It is common to argue that the gradient slope is a determining factor for bicycle use as a means of transportation. It is understood that, even though the Londrina cycle network presents segments that can be physically demanding to cyclists, most of the proposal network contemplates the minimum requirements for the implementation of adequate infrastructure that provides support and security.

It is necessary to consider technological advancement and the improvement of bicycles through the gear system. Therefore, only the topographic configuration cannot determine the viability for cycling. It is necessary to follow the natural tendency of the road system in directions that smooth the gradient slope to make it possible to promote the use of bicycles as a means of transportation (BRAZIL, 2007, p. 62).

### **Final considerations**

The research objective was successfully achieved and serves as a subsidy for urban planners in decision making. The applied methodology also needs to dialogue with cyclists who face the challenges daily when cycling through the city, as the perception is variable and does not depend only on the mathematical models used.

The expansion of the cycle network is advocated as an element to promote active mobility and consequently its maintenance and offer of support services as demanded

by the PBB. The data show a low variation, which is very close to the 5% accepted by the Reference Notebook for the elaboration of the Bicycle Mobility Plan in the Cities, which defends the thesis that Londrina is a cycling city if it converges with the other technical recommendations.

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Authors' contribution:

Matheus Oliveira Martins da Silva: Preparation, Collection and interpretation of data, Mapping, discussion of results, bibliographical research

Victor Hugo Martinez: Data collection and interpretation, discussion of results, Mapping, bibliographic research

Marciel Lohmann: Data Interpretation; supervision and revision of the text.