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Multi-criteria assessment of cyclability of roads in Montes Claros, MG, Brazil

Rafael Aparecido Pereira Lopes
Master's student, UNIMONTES, Brazil
rafaaplopes@icloud.com

Narciso Ferreira dos Santos Neto
PhD, Professor, UNIMONTES, Brazil
narciso.ferreira@unimontes.br

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ABSTRACT
This study investigated the cycling infrastructure and cyclists' perceptions of sustainable urban mobility in Montes Claros, Minas Gerais, Brazil, based on bicycle use. The methodology involved an analysis of the road environment for cyclists and the application of questionnaires to experts and cyclists, using a multi-criteria approach. The results revealed limitations in the infrastructure, such as the lack of segregated bike lanes. Additionally, cyclists expressed concerns about safety, such as disrespect from drivers and insufficient lighting on roads. These findings highlight the need for investments in cycling infrastructure and public policies focused on safety and sustainable mobility. This study contributes to the knowledge of cyclability in Montes Claros by developing a procedure for cyclability analysis that can be used in other locations. Furthermore, it provides valuable information for urban planning and the promotion of bicycle use as a sustainable mode of transportation, with the potential to improve urban mobility and quality of life for the population.

KEYWORDS: Cyclability, Infrastructure, Urban mobility, Sustainable transport

1 INTRODUCTION

The increased use of non-motorized vehicles such as bicycles in urban transportation is widely advocated in the scientific literature to contribute to urban mobility, environmental causes, and public health. In urban mobility, the use of bicycles provides an effective solution to traffic congestion and parking shortages, which are recurring problems in medium and large cities. Bicycles require minimal space for circulation on roads and for parking. The environmental sustainability of bicycles is perhaps one of the main benefits promoted by their widespread use, as bicycles produce zero greenhouse gas emissions and require significantly less energy to be produced compared to motorized vehicles. Regarding public health, bicycles promote physical activity, a fundamental practice for people living in urban areas, where sedentary lifestyles prevail. Despite these benefits, the widespread adoption of bicycles as a mode of urban transportation is still hindered by several challenges, including infrastructure, safety, and social acceptance. For example, inadequate infrastructure for bicycles and the lack of safe bike lanes and parking discourage people from using bicycles. Additionally, the perception that bicycles are an unsafe mode of transportation, especially in busy urban areas, has further discouraged people from using this vehicle.

Therefore, in-depth studies are justified to promote the widespread adoption of bicycles in urban areas. There are various methods for implementing bicycle networks in different cities around the world, using a wide range of parameters for decision-making. In this sense, the objective of this study was to explore perspectives prior to the methods of developing cycling infrastructure by analyzing the cyclability, i.e., the level of ease of using a bicycle as a means of transportation in a determined location. The analysis consisted of developing a procedure based on multiple criteria established by different studies and used in questionnaires for cyclists, which include: criteria of topographic profile of roads established by AASHTO (American Association of State Highway Transportation Officials), FHWA (Federal Highway Administration), GEIPOT (Brazilian Transport Planning Company), and Austroads (Association of Australian and New Zealand Road Transport and Traffic Authorities), which are used to evaluate how much inclination a road can have for a given distance traveled by bicycle; criteria of stress level based on the Sorton and Walsh model and the Furth, Mekuria, and Nixon model, which

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consider stress factors for cyclists when using roads, including motorized vehicle speed, the number of vehicles, and road width; criteria for level of service, such as the Epperson-Davis pavement condition index, which establishes a mathematical equation that results in values from 0 to 3 (excellent), 3 to 4 (good), 4 and 5 (regular), and greater than 5 (poor conditions), based on specific roadway parameters, including average daily traffic volume, number of lanes, maximum speed limit, and outer lane width.

A multi-criteria evaluation was applied to determine finite criteria that support a cycling analysis procedure, using these methods and information on relevant factors collected from cyclists. Therefore, the Cyclability Index proposed here was developed for the city of Montes Claros, MG, Brazil, applying it to limited central areas and estimating cyclability to specify the ease of using a bicycle as a means of transportation in that locality.

2 MATERIAL AND METHODS

The methodology consisted of a descriptive study, addressing qualitative and quantitative aspects. The index was developed in two stages: the first consisted of conducting a literature review on cyclability, and the second consisted of a sequence of procedures adopted for developing the index.

2.1 Description of the study object

Montes Claros is the largest city in the northern region of the state of Minas Gerais, Brazil, with a population of 414,240 inhabitants (IBGE, 2022) and a road network oriented towards cars to the detriment of other modes of transportation. A Household Origin-Destination (O/D) survey[1] in Montes Claros revealed the following distribution of modes of transportation: Car: 23.1%; Public transportation: 29.2%; Chartered transportation: 1.8%; School: 1.9%; Own motorcycle and motorcycle taxi: 16.2%; Taxi: 0.3%; Bicycle: 3.9%; and Walking: 23.6%. In this scenario, the low use of bicycles compared to other alternatives, including walking, indicates relatively short trips that could be made by bicycle, but the lack of a more cycle-friendly environment forces many people to choose walking.

In recent years, Montes Claros government has encouraged the use of bicycles as a more sustainable transportation alternative, driven partly by the significant increase in cyclists that occurred during the COVID-19 pandemic in Brazil (CAU-RJ, 2022). This has been noticeable through the MOC + BIKE Program, which has resulted in an expansion of the city's cycling system. This system was previously composed of 9.15 kilometers of bike lanes and cycle paths, and the program increased it to 22.65 kilometers, approximately 148%.

[1] The Household Origin-Destination (O/D) survey was conducted in Montes Claros in 2018. The results were included in the document "Projeto Básico e Minuta do Edital de Concessão do Transporte Coletivo – Montes Claros/MG: Produto 4 – Prognóstico de Demanda", of the Cidade Viva Institute.

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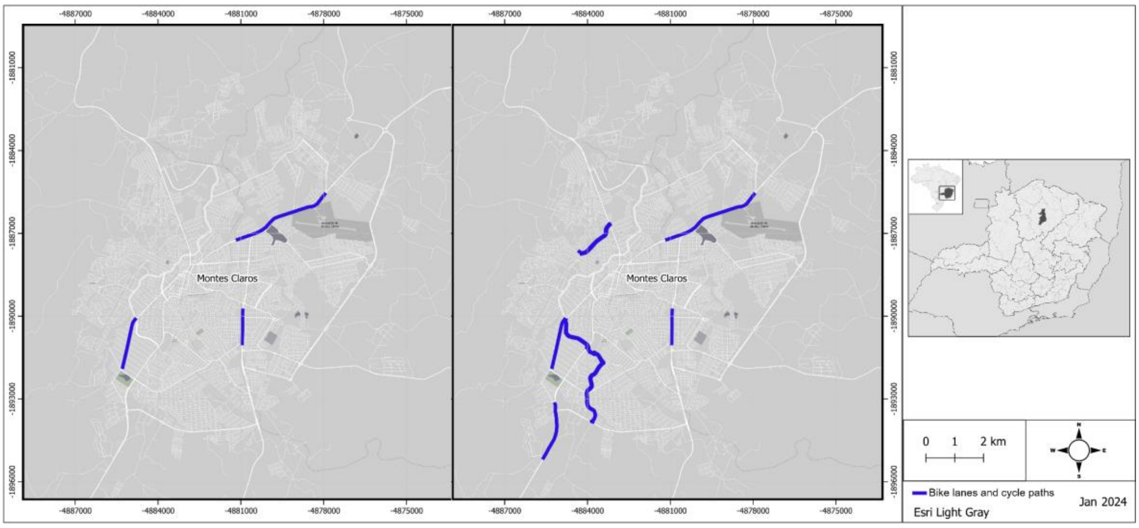
Figure 1 – Location of cycling areas before and after the MOC + BIKE Program in Montes Claros, MG, Brazil.



Source: Prepared by the author.

Although it is a positive advancement, this expansion is still small, considering the total extent of the city. Some neighborhoods and locations still lack cycling infrastructure, which can hinder broader adoption of the bicycle as a mode of transportation. A truly comprehensive cycling network should encompass the entire city, considering the mobility needs of all citizens. Although the MOC + BIKE Program has taken steps in the right direction, more efforts and investments are necessary to transform the bicycle into a viable transportation option for a larger portion of the population.

The spatial scope of the research involved four regions of Montes Claros: Centro, Independência, Major Prates, and Todos os Santos, as shown in Figure 2. These four regions were chosen from the planning regions introduced by Municipal Decree No. 3,393/2016, as shown in the Montes Claros Environmental Atlas, published in 2020.

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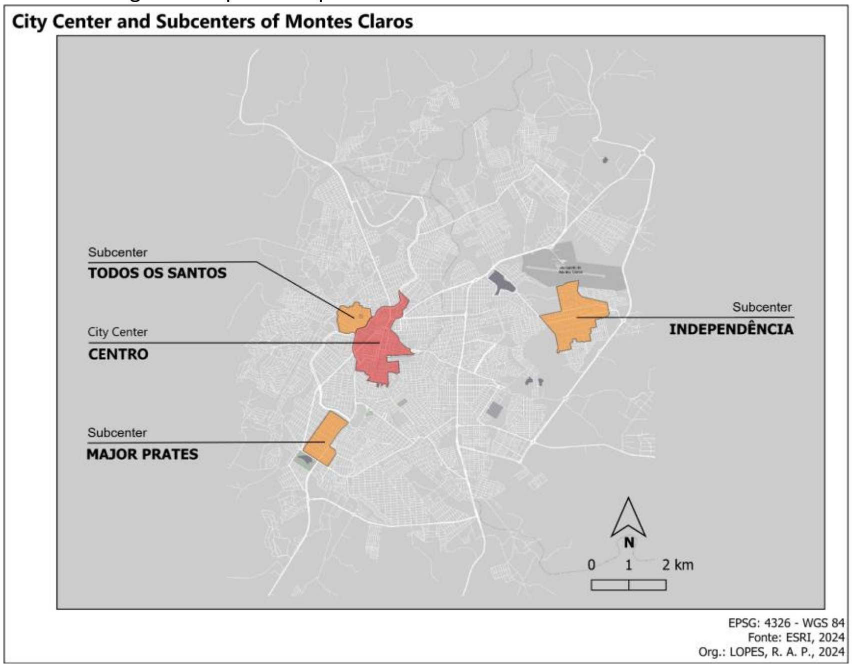
Figure 2 – Spatial scope of the research – Center and subcenters



Source: ESRI, 2024

The choice of the study regions (Centro, Independência, Major Prates, and Todos os Santos) is justified by their different socioeconomic profiles, which transform them into new central areas in the city. They are among the most populous regions of the city. Centro, as a central region of the city, concentrates both high-end and popular commerce and services, contributing to the urban dynamism. Todos os Santos is known for housing a traditional middle class, with valued properties and a good urban infrastructure, contributing to the establishment of a new urban center. Independência is marked by the presence of popular housing complexes and a humbler profile of its residents, making it an emerging center of great social relevance. Major Prates presents a mix of middle and lower-class residential neighborhoods, contributing to the diversification of urban centers in the city, reflecting the complexity of contemporary urban socioeconomic dynamics. These four regions not only reflect the city's socioeconomic heterogeneity but also contribute to the shape of new urban centers, promoting a dynamic and multifaceted urban landscape.

2.2 Stage 1: Theoretical and methodological foundation

In the first stage, the survey was conducted through research in electronic databases, such as Scopus, Capes/MEC Periodicals Portal, and Google Scholar, using keywords related to the study theme, such as cyclability, urban cycling, cycling infrastructure, among others. Studies published in English and Portuguese, focused on evaluating the quality of urban roads for cycling, were selected. The selected studies were analyzed and used to identify the main cyclability indicators that should be considered in the development of the proposed cyclability index. Furthermore, they were also used to identify the main methodologies used for evaluating the quality of urban roads for cycling.

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2.2.1 Cyclability

The cyclability of a location can be understood as the ability and convenience of reaching important destinations using a bicycle as a means of transportation (OSAMA AHMED & SAYED, 2016). Thus, factors such as comfort, travel time and distance, attractiveness, and safety have been widely used for in this evaluation (ARELLANA et al., 2020). Comfort and safety are closely linked to the level of stress caused by sharing the road with motorized vehicles in areas with few or no bike lanes (HEINEN; WEE; MAAT, 2010). Studies have suggested that cycling can easily cover distances of up to 5 km between origins and destinations (ODs) (IMT, 2013), and is still competitive in terms of travel times compared to other modes of transportation (KAPUKU et al., 2022). According to Krenn, Oja, and Titze (2015), the attractiveness for a cyclist is the presence of vegetation and water, contributing to sun protection, cooling and the aesthetics of the route. Exclusive cycle paths are fundamental for the migration of new people to the use of bicycle as a mode of transportation (ZUO; WEI, 2019). The cycle path and the cycle lane are examples of exclusive paths. The cycle path has physical protection for the cyclist, while the cycle lane only has pavement marking and signage. Public managers concerned with building cycle paths are seeing the growth of cycling and the reduction of accidents (NACTO, 2016).

2.2.2 Methods of analysis of cyclability of cycle networks

Various methods have been developed to estimate the cyclability of roads. The most recurrent approaches were reviewed and summarized in this section.

(1) Road gradient

The connectivity of the cycle network is important to encourage people to choose bicycles when planning a route (ZUO; WEI, 2019); however, the analysis of ramp length is fundamental when considering the design of connections between ODs in the city to eliminate roads and segments critical to the circulation of bicycles (ZUO; WEI, 2019). In this sense, four road gradient criteria from three different countries are highlighted: (AASHTO (1999); FHWA (1979); GEIPOT (2001); and Austroads (2011)). Table 1 summarizes these criteria, classifying them into three groups (desirable, acceptable, and unacceptable) according to the level of gradient as a function of the distance to be traveled (MAGALHÃES; CAMPOS; BANDEIRA, 2015).

Table 1 - Classification of road gradients according to cycle route design manuals

Criteria	Road gradient (declivity) as a function of distance		
	Desirable	**Acceptable**	**Unacceptable**
AASHTO	< 3.0%	3.0% to 5.0%	> 5.0% (15-240 m)
FHWA	< 7.0% (0-610 m)	2.0% to 11.0% (0-610 m)	3.0% to 11.0% (0-610 m)
GEIPOT	< 2.0%	> 2.0% (0-10 m)	> 2.0% (0-10 m)
Austroads	< 3.0%; or > 3.0% (7-200 m)	< 3.0%; or > 3.0% (7-200 m)	4.0% to 12.0% (7-200 m)

Source: AASHTO (1999); FHWA (1979); GEIPOT (2001); Austroads (2011) apud Magalhães, Campos e Bandeira (2015).

Despite the small variations in these criteria, they should be adopted as a first instance to eliminate roads that exceed the maximum acceptable from the cycle network or, at least, to

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adopt mitigation measures when it is not possible. Mitigation measures include rest areas, elevators, and adapted ramps to improve comfort during the travel.

(2) Sorton and Walsh (1994) and Mekuria, Furth, and Nixon (2012) models

The Sorton & Walsh model is an extrapolation of studies of motorized vehicles relating to stress levels for cyclists, following a logic that if there are problems for drivers of motorized vehicles, there will be more problems for cyclists. Three parameters were used to classify the roads from 1 (best) to 5 (worst): peak hour traffic volume, outer lane width, and motorized vehicle speed. Twenty-three different segments were filmed and a questionnaire was sent to 61 adult cyclists to extract indicators of cyclists' perception of traffic conditions to validate the stress levels of the roads.

The results showed different categories of cyclists based on different perceptions of the stress level for each proposed parameter, which can be divided into: experienced cyclists, when they ride on arterial roads and travel at least 30 kilometers per week; casual cyclists, when they do not ride on arterial roads, use the sidewalk, use the bicycle for recreation, and ride approximately 10 kilometers per week; and young cyclists, between 10 and 15 years old.

The Furth, Mekuria, and Nixon model was titled Level of Traffic Stress (LTS) and proposes a classification of roads from 1 (best) to 4 (worst) based on the Dutch Design Manual for Bicycle Traffic. Similar to the Sorton and Walsh model, stress levels differ for each cyclist group, but using the classification suggested by Geller (2007): the "strong and fearless", those willing to ride on any road; the "enthusiastic and confident", who do not show the same tolerance in mixing with fast and heavy traffic, but respond well to riding on bike paths along arterial roads and sharing local and collector roads with traffic; the "interested but concerned", those who avoid cycling in uncomfortable traffic, doing well only on autonomous paths and streets with small and slow traffic; and finally, the "no way", who have no interest in cycling. The authors considered several parameters for each type of road; for bike lanes, they considered the number of traffic lanes, curb reach, speed limit, and interruption of flow along bike lanes. They also analyzed shared roads and unsignalized intersections, establishing LTS from 1 to 4 for each proposed criterion.

(3) Epperson's pavement condition index (PCI) (1994)

It is a mathematical model proposed by Epperson (1994), which quantifies several qualitative variables of the road in an equation. PCI is calculated using the following equation:

$$PCI = \frac{ADTV}{f \times 3100} + \frac{V}{48} + \left(\frac{V}{48}\right) + [(4.25 - L) \times 1.635] + \sum FP + \sum FL$$

where: *ADTV* is the average daily traffic volume (vehicles h^{-1}); *f* is the number of traffic lanes; *V* is the allowed traffic speed (km h^{-1}); *L* is the outer lane width (m); and *FP* and *FL* are factors related to pavement and location with tabulated values, respectively.

The obtained PCI is utilized to classify the roads according to their level of service for cycling: 0 to 3 (excellent), 3 to 4 (good), 4 to 5 (regular), and greater than 5 (poor).

(4) Bicycle Level of Service by Landis, Vattikuti, and Brannick (1997)

This model is based on a survey of 150 cyclists about comfort and safety on 30 road segments in the city of Tampa, Florida (USA). The results were processed, a bicycle level of

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service was modeled, and the results were classified into levels of compatibility with bicycles ranging from A (extremely high) to F (extremely low). The proposed equation is as follows:

$$BLOS = 0.607 \times \ln\left(\frac{v_{ma}}{N_{th}}\right) + 0.901 \times \ln\left[S_{Ra} \times \left(1 + P_{HV_a}\right)\right] + 6.51 \times P_c - 0.005 \times w_e^2 - 1.883$$

where: *BLOS* is the bicycle level of service; V_{ma} is the directional traffic volume in 15 minutes; N_{th} is the number of traffic lanes; S_{Ra} is the allowed traffic speed (km h^{-1}); P_{HVa} is the pavement surface condition, evaluated on a scale of 1 to 5, according to the FHWA's Highway Performance Monitoring System (HPMS); P_c is the Percentage of heavy vehicles; and w_e is the outer lane width (m).

2.2.3 Multi-criteria analysis

Choosing a multi-criteria analysis method to solve a problem with several alternatives involving multiple objectives and criteria is challenging for the decision-maker, as there is no perfect method or one that can be applied to any problem (ISHIZAKA; NEMERY, 2013). Thus, the methods can be classified into the following approaches: (1) single synthesis criterion approaches; (2) interactive approaches; and (3) subordination approaches (Table 2).

Table 2 – Multi-criteria Analysis Methods

Approach	References
American school, characterized by aggregating several utility functions into a single function.	AHP (SAATY, 1980); Teoria da Escolha Social (ARROW, 1963); Teoria da Utilidade Multiatributo (Multi-Attribute Utility Theory, MAUT)
These are approaches where the decision-maker interacts with the model, seeking a single solution that is closest to the optimal point.	STEM (BENAYOUN et al., 1971); TRIMAP (CLíMACO; ANTUNES, 1987); ICW (STEUER, 1977) and (STEUER, 1986); PARETO RACE (KORHONEN; WALLENIUS, 1988).
French school, characterized by valuing a set of alternatives over families of criteria, building non-compensatory subordination relationships between alternatives.	ELECTRE (ROY, 1968); ELECTRE II (ROY; BERTIER, 1971); ELECTRE III (ROY, 1978); ELECTRE IV (ROY; HUGONNARD, 1981); ELECTRE IS (ROY; SKALKA, 1985); ELECTRE TRI (MOUSSEAU; SLOWINSKI; ZIELNIEWICZ, 1999); (YU, 1992).

Source: Treinta et al. (2014).

The Analytic Hierarchy Process (AHP) method was chosen for this study due to its a flexibility in involving experts and stakeholders, contributing to a more comprehensive and reliable approach. Additionally, the structure of the multi-criteria method was similar to that proposed by Veloso (2021).

2.3 Step 2: Development of a Cyclability Index for Montes Claros

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This phase consisted of developing a sequential methodology using three interconnected procedures: multi-criteria analysis using the Analytic Hierarchy Process (AHP), based on questionnaires applied to experts and cyclists; definition of criteria for evaluating indicators; and development of a mathematical model for the cyclability index.

The AHP multi-criteria analysis is a decision-making tool widely used in various fields, ranging from strategic business planning to the choice of public policies. This method allows decision-makers to weight and compare different criteria, enabling a more informed and accurate choice. According to Saaty (2008), the AHP enables decision-makers to express their judgments and estimates about the relative significance of factors or criteria that affect a decision. This makes it a valuable tool for analyzing and selecting complex alternatives involving multiple factors and variables.

Therefore, the AHP method was used based on the Saaty's Fundamental Scale, which consists of a series of values ranging from 1 to 9, each with a specific meaning regarding the relative importance of the criteria or alternatives considered in the analysis. A value of 1 represents equal importance, while a value of 9 represents a very strong difference in importance. This scale is essential for applying the application of the AHP method, as it allows decision-makers to compare and weigh different criteria and alternatives in a consistent and objective manner.

2.3.1 Questionnaire for Experts

The criteria established for analysis were extracted from the manuals of AASHTO (1999), FHWA (1979), GEIPOT (2001), and Austroads (2011), as well as from the studies of Sorton and Walsh (1994), Mekuria, Furth, and Nixon (2012), Epperson (1994), and Landis, Vattikuti, and Brannick (1997) (Table 3).

Table 3 - Structure of the questionnaire for experts

Category	Criteria
Topography (T)	Slope (T1)
Stress level (SL)	Traffic volume (SL1); Heavy traffic volume (SL2); Speed limit (SL3); Solar incidence (SL4).
Level of service (LOS)	Pavement surface condition (LOS1); Lane separation (LOS2); Bike lane (LOS3); Lane width (LOS4); Lighting (LOS5).

Source: Prepared by the author.

A semi-structured questionnaire was developed based on ten criteria grouped into three categories, with indicators represented by acronyms to facilitate analysis (Table 3), and sent to experts via Google Forms in March 2023.

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2.3.2 Questionnaire for Cyclists

A semi-structured questionnaire was created based on the six most relevant indicators identified through the survey of experts, targeting cyclists who travel in four regions of Montes Claros: Centro, Independência, Major Prates, and Todos os Santos. The purpose of this process was to assess cyclists' perceptions regarding the importance they attributed to the six most relevant indicators mentioned by experts. The six indicators selected from the survey of experts used in this questionnaire were: slope, heavy traffic volume, traffic volume, speed limit, bike lane, and lighting, and an additional question inviting cyclists to assign a degree of importance from 1 (least important) to 5 (most important).

The questionnaire for cyclists were applied through Google Forms between April 3rd and 15th. After data collection, only participants residing in the study regions were selected, resulting in a total of 43 cyclists with responses distributed as shown in Table 4. The use of an online tool for data collection proved efficient and practical, enabling greater reach and ease of access for participants.

Table 4 - Distribution of responses of cyclists by region

Region	Population	Response	Proportion
Centro	6,904	7	16.28%
Independência	15,071	11	25.58%
Major Prates	18,664	17	39.53%
Todos os Santos	10,532	8	18.60%
Total	51,171	43	100.00%

Source: Prepared by the author.

The data from this phase were subjected to a multi-criteria evaluation model that considers the relevance attributed by cyclists to the selected indicators. The application of the AHP method to these data allowed to define the priority order of indicators for each region (Table 5).

Table 5 – Weight of indicators by region.

Indicators	Centro	Independência	Major Prates	Todos os Santos
Traffic volume (SL1)	0.223	0.125	0.220	0.125
Heavy traffic volume (SL2)	0.223	0.125	0.220	0.051
Bike lane (LOS3)	0.202	0.233	0.220	0.233
Speed limit (SL3)	0.128	0.233	0.220	0.125
Slope (T1)	0.112	0.051	0.056	0.233
Lighting (LOS5)	0.112	0.233	0.056	0.233

Source: Prepared by the author.

The data analysis showed that cyclists' opinions varied according to the region investigated. However, the criterion "Bike lane" (LOS3) maintained relevant in all studied regions. This is significantly important for the research, as it establishes, comprehensively, the aspects that cyclists consider most relevant in their travels.

The criteria "Traffic volume" (SL1), "Heavy traffic volume" (SL2), "Speed limit" (SL3),

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and "Lighting" (LOS5) maintained a medium relevance, alternating among them in the four regions. The criterion "Slope" (T1) was identified as the least important indicator for cyclists. Additionally, there was a variation in weights attributed to these indicators, depending on the region, which can be attributed to the specific characteristics of each location, such as infrastructure, land use patterns, geographic location within the urban area, and the socioeconomic level of the population.

2.3.3 Field Research

This procedure was conducted with the objective of investigating, examining, and evaluating the studied spatial characteristics. Visual records, such as maps, photographs, and other relevant elements, were used to understand the built environment and evaluate the indicators.

Segments were selected based on parameters established within the four study regions (Centro, Independência, Major Prates, and Todos os Santos), requiring that the chosen segment had at least one arterial, collector, and local road, as well as the three uses defined by the Land Use and Occupation Law of Montes Claros. Thus, the study of the walkability index was based on the study conducted by Veloso (2021).

The predetermined indicators were subjected to a technical evaluation through observations and assignment of scores from 0 to 3, based on established criteria. Table 6 describes the six indicators evaluated in the field, with their respective evaluation criteria and scores.

Table 6 - Scoring criteria for the technical evaluation of indicators

Indicators	Optimal 3 points	Good 2 points	SUFFICIENT 1 point	INSUFFICIENT 0 points
Slope (T1) (FHWA)	≤ 3.0% (0-610m)	≤ 7.0% (0-610m)	≤ 7.0% a 11.0% (0-610m)	> 11.0% (0-610m)
Heavy traffic volume (SL2)	Low or absent	Moderate and fairly managed	Higher than ideal, with some comfort e safety	Excessively high
Traffic volume (SL1)	Usually fast in peak hours	Usually moderate in peak hours	Usually congested in peak hours	Usually slow in peak hours
Speed limit (SL3)	40 km h^{-1}	50 km h^{-1}	60 km h^{-1}	> 60 km h^{-1}
Bike lane (LOS3)	Existing along the entire road	Bike lane or cycle path along the entire road	Bike lane or cycle path along part of the road	No bike lane or cycle path
Lighting (LOS5)	Lighting points for cyclists	Lighting for roads (motorized vehicles)	-	Lighting obstructions by trees or broken lamps

Source: Prepared by the author.

The final step of the methodology for this work consisted of demonstrating the criteria used to evaluate the indicators in each study region. Thus, a mathematical model was developed

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to calculate the cyclability index. The objective was to test this model in the four central regions.

2.3.3 Development of the Cyclability Index Mathematical Model

The cyclability index developed in this study was determined first by establishing weights for the indicators, followed by recording the scores assigned to the seven selected indicators, using the technical analysis described in the previous section. The mathematical model used to calculate the cyclability index was based on the weighted sum of the scores of each indicator, considering their respective weights. Since the weights are normalized, i.e., their sum is equal to 1, this equation is a weighted average of the scores and weights. Therefore, the mathematical model selected to obtain the cyclability index was defined as follows:

$$CI = \sum (S_{ind} \times W_c)$$

where CI is the cyclability index; S_{ind} is the indicator score (0 to 3); W_c is the indicator weight (result of the AHP pairwise comparison matrices).

The formulation of this mathematical model incorporates specific characteristics and elements of the spatial context of this research, i.e., the city of Montes Claros. Additionally, the model more accurately considers the four central areas analyzed, thus reinforcing the studies on cycling assessment presented in this thesis.

3. RESULTS

The cyclability indices calculated for the 16 routes across the four study regions showed non-uniformity. This variation in cyclability index by segment was observed when relating the field-assigned score to the weight of each indicator, even when this variation occurs within the same classification after normalizing the results.

The results showed that all the evaluated routes exhibited cyclability indices below the threshold considered optimal or good, but only two were classified as insufficient. The absence of bike lanes in all the investigated routes was a determining factor for the low cyclability indices in the four study regions. The survey conducted with cyclists showed the presence of bike lanes as one of the most relevant indicators, with weights ranging from 20% to 23% for all the study regions.

Contrastingly, the slope index, which evaluates the degree of inclination of the roads, obtained satisfactory scores in all the investigated routes. However, its influence on the cyclability index calculation was limited, as the weight attributed to this indicator was less than 12% in all regions, except for Todos os Santos, where it resulted in a relevant weight of 23.30%. This difference in weight among indicators in the different locations can explain the data variance and the absence of scores classified as good or excellent.

Cyclists attributed greater importance to safety in the Centro area, which is characterized by a higher concentration of traffic and urban activities, considering the indices for traffic volume and heavy vehicle volume. This perception is related to the narrow geometry of

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the roads in this area, which can result in situations of greater stress and risk for cyclists. Major Prates also presents a high concentration of vehicles, but their roads are wider compared to the Centro. In this context, cyclists expressed a greater concern with the speed limit index, considering the capacity of these roads. Additionally, the lighting index received a significant weight in the Independência and Todos os Santos regions. In the case of Independência, this relevance can be attributed to its peripheral location, characterized by some vacant lands and an inadequate or absent lighting infrastructure. The lack of adequate lighting can represent an obstacle for cyclists, increasing the risk of accidents and reducing the feeling of safety during travels. Despite the good overall infrastructure in Todos os Santos, it is characterized by abundance of trees in various locations. This tree cover, although beneficial in many aspects, can result in difficulties related to lighting. Trees can block the light from lamps, creating shaded areas that can affect the visibility of cyclists, especially at night. Therefore, the importance attributed to lighting in this neighborhood is explained by the need for overcoming these specific tree cover-related challenges.

4 CONCLUSIONS

The obtained results revealed that the urban roads investigated in Montes Claros, MG, Brazil, presented cycling indices below the level considered good, indicating the need for improvements to promote the widespread adoption of bicycles as a mode of transportation in the city.

The lack of adequate infrastructure for bicycles was identified as one of the main challenges for the widespread adoption of bicycles. The absence of these elements discourages people from using bicycles as a mode of transportation and negatively affects the cycling of the analyzed roads.

The most relevant cycling indicators pointed out by cyclists were the presence of bike lanes and adequate lighting. These elements are essential for the safety and comfort of cyclists during their travels. Additionally, road geometry and the presence of heavy vehicles were also considered significant factors in cyclists' perception of safety.

Although all the investigated spatial areas achieved indices classified as sufficient, none of them reached an index considered good or excellent. These findings highlight the need for investments in infrastructure and public policies to improve urban road conditions and make them more suitable for cycling.

The results of this study provide important subsidies for public managers and urban planners, highlighting the importance of prioritizing the construction of bike lanes, improving lighting, and considering the safety of cyclists in urban mobility projects. The multi-criteria analysis approach adopted in this study, using the Analytic Hierarchy Process (AHP), can be applied in other localities to assess cycling and guide urban interventions focused on the use of bicycles.

Moreover, promoting the use of bicycles as a mode of transportation is not limited to improving infrastructure but also requires educational and awareness-raising actions to foster a culture of respect and sharing of roads between cyclists, pedestrians, and drivers.

Future research should expand the sample size, include different urban contexts,

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compare results with other methodologies, and explore the relationship between cyclability and other urban indicators, such as air quality and public health. Furthermore, monitoring changes in public policies related to sustainable mobility is important for assessing their impact on improving the cyclability in cities.

Despite these limitations, the present research significantly contributes to the knowledge about cyclability in Montes Claros. The suggestions for future research are focused on strengthening and expanding these findings, further improving the understanding of sustainable urban mobility and promoting the use of bicycles as a mode of transportation.

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