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MICHELE KOZOROSKI ALVES DE ALMEIDA TORRES

MULTICRITERIA ANALYSIS OF THE EFFICIENCY OF THE CARAGUATATUBA BICYCLE PATH SYSTEM

CARAGUATATUBA

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MICHELE KOZOROSKI ALVES DE ALMEIDA TORRES

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Orientadora: Profª. Drª. Vassiliki T. Galvão Boulomytis

Coorientador: Prof. Dr. Antônio Carlos Zuffo

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Ata de Defesa de Trabalho de Conclusão de Curso - Graduação

Na presente data realizou-se a sessão pública de defesa do Trabalho de Conclusão de Curso intitulado**ANÁLISE MULTICRITÉRIO DA EFICIÊNCIA DO SISTEMA CICLOVIÁRIO DE CARAGUATATUBA** apresentado(a) pelo(a) aluno(a) **Michele Kozoroski Alves de Almeida Torres (CG1701029)** do Curso **BACHARELADO EM ENGENHARIA CIVIL (Câmpus Caraguatatuba)**. Os trabalhos foram iniciados às 17h06min (dezessete horas e seis minutos) peb(a) Professor(a) presidente da banca examinadora, constituída pelos seguintes membros:

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Antonio Carlos Zuffo (Coorientador/ Examinador Externo)	UNICAMP	SIM	Aprovado
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Observações:

A banca examinadora, tendo terminado a apresentação do conteúdo da monografia, passou à arguição da candidata. Em seguida, os examinadores reuniram-se para avaliação e deram o parecer final sobre o trabalho apresentado pelo(a) aluno(a), tendo sido atribuído o seguinte resultado:

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Proclamados os resultados pelo presidente da banca examinadora, foram encerrados os trabalhos às 17h55min (dezessete horas e cinquenta e cinco minutos) e, para constar, eu lavrei a presente ata que assino juntamente com os demais membros da banca examinadora.

Caraguatatuba, 16 de dezembro de 2021

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Dedico esse trabalho à minha família.

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RESUMO

O município de Caraguatatuba concentra a maior população do litoral norte paulista. No entanto, o transporte público não é acessível em todos os bairros. Como a área urbana é plana, o uso da bicicleta como meio de transporte é intenso. O objetivo deste estudo foi avaliar o sistema cicloviário de Caraguatatuba, identificando suas fragilidades técnicas atuais. No início do estudo, foi realizada uma pesquisa com 70 usuários para avaliar os parâmetros técnicos relevantes: pavimentação, iluminação, segurança, sinalização, drenagem, manutenção, projeto, acessibilidade e integração com outros modais. Um mapa cognitivo foi construído para a seleção dos critérios, que em seguida foram avaliados por um grupo de especialistas. O método Delphi foi utilizado para a coleta e tratamento dos dados originais, e o Processo Analítico Hierárquico foi utilizado para a alocação dos valores de prioridade. Cada segmento de 100 m das rotas principais foi pontuado em um mapa usando. Por fim, foi construído um mapa em um Sistema de Informação Geográfica e encontrado o índice de eficiência da rede ciclável. Os índices entre 3,1 e 4 corresponderam ao maior percentual das ciclovias (em km), o que representa uma eficiência mediana (47 %), esses valores foram obtidos nos trechos da ciclovia localizada na avenida da praia. Nas ciclovias das rodovias sul, onde há menos turistas e maior vulnerabilidade social, as pontuações dos critérios individuais e índices locais de eficiência foram menores do que nas demais localidades, principalmente no que se refere à drenagem e manutenção. A metodologia deste estudo pode ser usada pelos gestores públicos para priorizar melhorias futuras para os locais mais críticos.

Palavras-chaves: Ciclovia, gestão urbana; análise multicritério; tomada de decisão; manutenção da infraestrutura urbana.

ABSTRACT

The municipality of Caraguatatuba has the largest population of the north coast of São Paulo. However, public transportation is not accessible in every neighborhood. As the urban area is flat, the use of bicycles as a means of transportation is intense. The purpose of this study was to evaluate the cycling system in Caraguatatuba, identifying its current technical fragilities. At the beginning of the study, a survey with 70 users was carried out to evaluate the technical relevant parameters: paving, lighting, safety, signaling, drainage, maintenance, design, accessibility and integration with other modes.A cognitive map was developed for the selection of criteria, which were then evaluated by a group of experts. The Deplhi method was used for the collection and treatment of the original data, and the Analytical Hierarchical Process was used for the allocation of priority values. Each segment of 100 m of the main routes was scored on a map using. Finally, a map was built on a Geographical Information System and the index of efficiency was found for the cycling network. The indexes between 3.1 and 4 corresponded to the highest percentage of the cycling paths (in km), which represents a median efficiency (47 %), these values were obtained in the stretches of the bike path located on the seaside avenue. In the southern highway cycling paths, where there are fewer tourists and more social vulnerability, the individual criteria scores and local indexes of efficiency were lower than at the other locations, particularly concerning the drainage and maintenance. The methodology of this study might be used by the public mangers to prioritize upcoming improvements for the most critical locations.

Keywords: Bikeway; urban management; multicriteria analysis; decision making; urban infrastructure maintenance.

1. INTRODUCTION

In urban areas, vehicle congestion is an everyday situation. In addition, this excess of automotive vehicles is increasing the concerns of the population and governments with the environment, health and safety of the population (ABADI; HURWITZ, 2018). Most of the world's population live in cities where urban transport is not fully developed. Moreover, to improve the economy and social development of these places, investments in transport infrastructure are essential (ROCKWOOD; GARMIRE, 2015).

The increase of sustainable mobility in cities is related to the use of bicycles. Another way to maximize the transport system is to create an integration between the mass transit system and non-motorized means of transport. Because of this integration, it is possible to improve the quality of urban life and offer more social equality to the local communities (MONTEIRO; CAMPOS, 2011).

Currently, 55 % of the world's population lives in urban areas and this proportion is expected to increase to 70 % by 2050 (UNITED NATIONS, 2020). One of the sustainable Development Goals (SDGs) is to promote more sustainability in cities, including the mobility process. The urban sustainable transportation policy is related to the citizens' rights and aims to respond to the needs of society at the economic, social and environmental levels. However, without interfering in a citizen's right which is mobility (CASTAÑON, 2011).

In Brazil, a few studies regarding the mobility by the use of bicycles revealed that the main initiatives have been in the City of Rio de Janeiro and Curitiba, State of Parana (MEDEIROS; DUARTE, 2014; PROCOPIUCK; SEGOVIA; PROCOPIUCK, 2021; TUCKER; MANAUGH, 2017). The lack of public policies causes a situation of semi-marginality for the users (GEOPOT, 2011). The National Urban Mobility Policy (BRAZIL, 2012) aims to integrate the different modes of transport and improve accessibility across the country. According to this law, it is foreseen that the municipalities must elaborate the local Urban Mobility Plan and include the bicycle infrastructure integrated with the other transportation modes (BRAZIL, 2012).

Bicycles are one of the most used individual vehicles in small urban centers. This is because in these places, the public transport is not accessible and one of the transportation alternatives for the population is the use of bicycles (GEOPOT, 2011).

Teschke et al. (2012) compared the types of routes and infrastructure resources for bicycles with the risks of injuries in Canada. The authors concluded that the route infrastructure, when properly designed, avoids the risk of accidents to users. Thus, the study demonstrates the importance of a good bicycle network.

Multicriteria methods combined with geographical information systems (GIS) have been widely used by urban planners for the decision-making processes (GUERREIRO et al., 2017; HRNCIR et al., 2017; MACIEL; FREITAS, 2016; ZUO; WEI, 2019) due to the possibility of processing a significant amount and variety of data.

The purpose of this study is toevaluate the efficiency of the bicycle network of the City of Caraguatatuba, State of São Paulo, Brazil, particularly the infrastructure conditions to users.

2. MATERIALS AND METHODS

2.1 Study area

The city of Caraguatatuba islocated on the northern coastline of the State of São Paulo. Ithas 119,625 inhabitants. In Figure 1, it is possible to observe that the altitude of the city of Caraguatatuba is low andvery close to the sea level. As the city is in a flat area, it facilitates the daily use of the bicycle as a means of transportation.

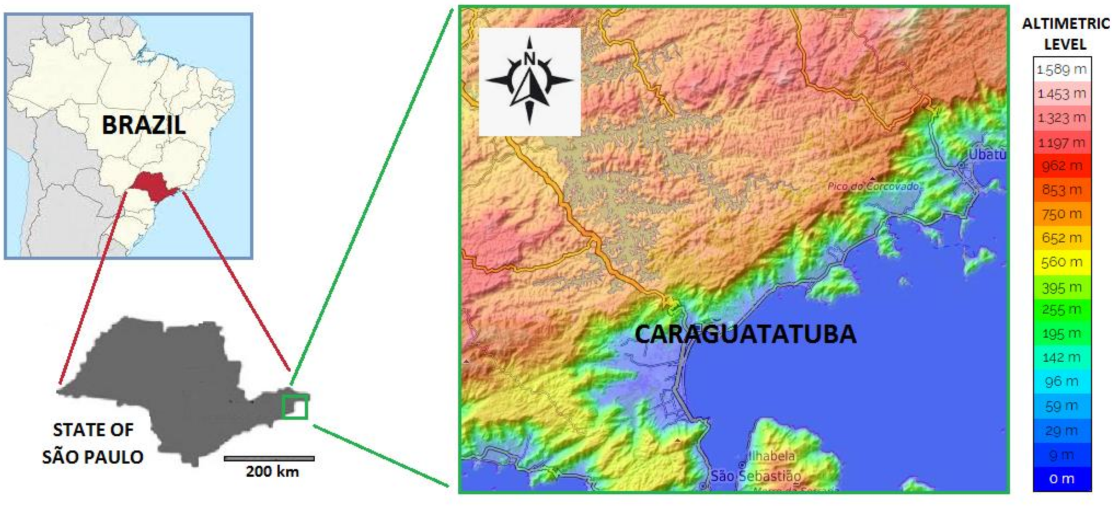


Figure 1. Municipality of Caraguatatuba. Source: Author.

Caraguatatuba is a tourist city and therefore, there is a large amount of floating population. The climate is tropical with significant rainfall throughout the year. The average annual temperature is 25 °C, and the average annual precipitation is 1,652.8 mm.

2.2 Methodology

2.2.1 Initial survey with users

The first part of this study was an online survey, using Google Form, with the users of the Caraguatatuba bicycle network. The form was answered anonymously and the target audience of the research was the IFSP students, between 16 and 52 years old, from professional to undergraduate courses. This target audience was chosen because they use the bike paths and lanes every day to move around the city. The survey was carried out for a month in 2018.

The purpose of the questionnaire was to determine the technical parameters that affect the quality of the bicycle network.

2.2.2 Definition of the analyzed criteria

After conducting the survey, all the data were analyzed. Based on the results, the factors assessed on the local bicycle network were determined. In the literature, several authors use different methods and criteria to analyze the specific bicycle network. Each of the criteria was chosen based on the characteristics of the places studied, according to Keeney (1992), where consistent criteria must be: essential, independent, controllable, operational, decomposable, non-redundant, complete, measurable, concise and understandable. A cognitive map was developed to subside this part of the study.

2.2.3 Conference with experts

In this stage, a conference was carried out with experts so that the parameters could be properly ranked. The interview took place in 2019.The first step was to select the appropriate experts to be part of the conference including professional and amateur cyclists, traffic agents, engineers and technicians (Figure 2).

Figure 2. Conference with the bicycle network experts. Source: Author.

At the beginning of the conference, it was explained what the purpose was and how the criteria would be ranked. Subsequently, experts assigned scores from 0 to 10 for the criteria, according to the degree of importance. The evaluation of each expert occurred independently; none of them encountered the others during the meeting. The selected and weighed criteria were: drainage, integration, light, maintenance, planning, safety, signaling, and paving. The Delphi expert-survey method was used for the data treatment (Figure 3).

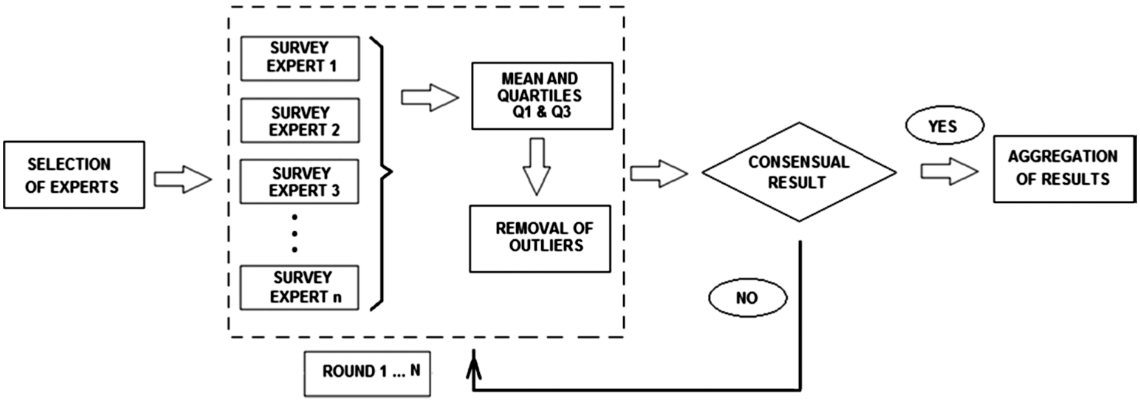


Figure 3. Conference with the bicycle network experts. Source: Boulomytis, Zuffo and Imteaz (2019).

2.2.4 Bicycle network assessment

Based on the criteria attribution, an on-site verification along the bicycle network was carried out to determinate the exact situation and numerically qualify all features. For the data analysis, the paths were divided into three parts (city center, along the highway and along the sea) and the respective subsections. The allocation of grades was based on literature review. The grade was given on a scale of 1 to 5, where 1 was considered “insignificant” and 5 was “very good”.

2.2.5 Method AHP

The Analytic Hierarchy Process (AHP) was used at the study to rank the criteria in a prioritisation mechanism of pairwise comparisons. The root square judgment scale was adopted according to Boulomytis, Zuffo and Imteaz (2019).One of the advantages of the AHP is the use of a consistency analysis to evaluate the results (BOULOMYTIS; ZUFFO; IMTEAZ, 2019).

The AHP assessment is performed with the comparison of the pairs of matrix A (n x n), given by Eq. 1:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} z_1/z_1 & \cdots & z_1/z_n \\ \vdots & \ddots & \vdots \\ z_n/z_1 & \cdots & z_n/z_n \end{bmatrix} \quad \text{(Eq. 1)}$$

The matrix highest eigenvalue (λmax) is calculated by Eq. 2:

$$\lambda_{max} = \sum_{i=1}^{n} (Av)_i/(nv_i) \quad \text{(Eq. 2)}$$

And the definition of the consistency index (CI), as expressed by Eq. 3:

$$CI = (\lambda_{max} - n)/(n - 1) \quad \text{(Eq. 3)}$$

To improve the evaluation of consistency errors, the measure of the consistency index (CR) is used, RI being the random index. The best solution would be to CI = 0. Thus, consistent values correspond to CR < 1, where:

$$CR = CI/RI \quad \text{(Eq. 4)}$$

2.2.6 Indicator of efficiency

The data was spatialized by the use of the ArcGis software version 10.3. Thematic maps were generated for each of the eight criteria used, based on the classification of the bicycle network subsections.The Indicator of Efficiency was derived for each segment of the bicycle network using the weighted average.This measure aimed to optimize the comparison among the sections of each individual criteria.

3. RESULTS AND DISCUSSION

3.1 Attribution of Criteria

The online questionnaire had 68 participants. They were students from the Federal Institute of Education, Science and Technology of São Paulo, Campus Caraguatatuba, from civil construction (professional) to civil engineering (undergraduate) courses.

Respondents informed that with better infrastructure conditions, they would use the bicycle more as a means of transport. About 67.1% suggested improvements in paving, drainage, maintenance, signaling and safety.

From the collected data, it was possible to verify that the bicycle network in Caraguatatuba is widely used, but it needs improvements in all parameters covered by the study. A cognitive map was drawn for the understanding of the connection among the proposed criteria and the problem statement (Figure 4) and the conditions of Kenney (1992), were properly analyzed. The final attributedcriteria were: drainage; integration; light; maintenance; pavement; planning; safety; signaling.

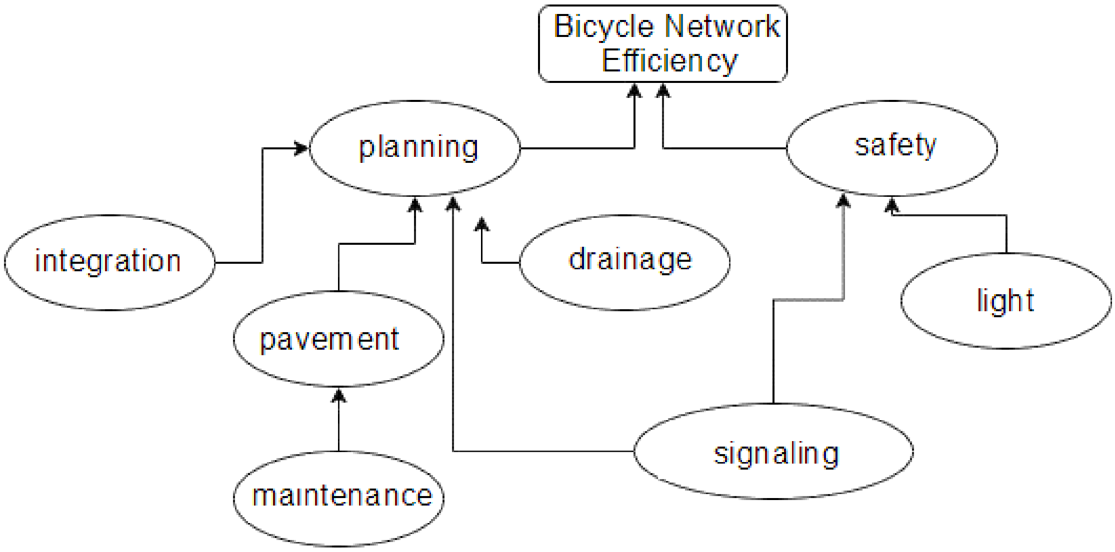


Figure 4. Cognitive map with the criteria proposed in the survey. Source: Author.

3.2 Attribution of values

The total number of experts who attended the decision-making conference was 12 (twelve), comprising professional and amateur cyclists, traffic agents, engineers and technicians. They assigned scores according to the degree of importance considered for each of the parameters. The scores were treated using the Delphi method. The Appendix (Table A2) presents the development of the Delphi method.

There were 4 rounds and the final score of the parameters, from the most important to least important, was: planning; safety; pavement; integration; maintenance; signaling; drainage; light (Table 1).

Table 1. Final criteria score and hierarchy.

Order of Importance	Score	Criteria
1	10,00	Planning
2	9,63	Safety
3	8,57	Pavement
4	8,50	Integration
5	8,38	Maintenance
6	8,00	Signalling
7	7,67	Drainage
8	7,57	Light

3.3 Literature review of the criteria qualitative features

Factors such as the location of bicycle paths and lanes, demand and safety are requirements that must be considered when planning a road. A bicycle path or lane planning enhances the areas in which the implementation of infrastructures for the circulation of cyclists must occur. These infrastructures are bicycle lanes, paths, racks, underground walkways, among others (MONTEIRO, 2011).

Paving can be described as one of the essential factors to ensure good conditions for the circulation of users. Factors such as cracks, patches and holes in the pavement to calculate the Road Condition Index based on the condition of the bicycle path pavement. This method evaluates each road segment with homogeneous geometry and traffic conditions (EPPERSON, 1994).

The basic requirements for paving a bicycle network are regular surface for the bearing, waterproof and non-slip. Preferably, the bike path and pedestrian walk should have visual differences, to avoid accidents. It is possible that the bicycle is used to integrate the different modes already present in cities, such as buses, trains and subways. In this way, it will be possible to improve the urban quality of life of all segments of society (MONTEIRO, 2011).

In the drainage criterion, drainage must be natural. Therefore, the lateral slope of the runway is 2 %, always to the side of the existing tracks. An important aspect is the position of the drops in the manhole, which should not be positioned along the road, but on the sides, so that accidents do not occur with cyclists (MONTEIRO,2011).

The safety of cyclists is one of the factors that must be taken into account when analyzing Brazilian bicycle paths. And the distance between cyclists, the flow of motor vehicles and the presence of entry for vehicles along the cycle path, are variables that should be used as determinants in this indicator (MONTEIRO; CAMPOS, 2011).

The maintenance of the roads is determined by the physical conditions of the road, noting abandonments or construction deficiencies. A scoring system was based established on variables according to the frequency of problems, namely: frequent; not too often; smoothly to classify this factor (DIXON, 1996).

Cycle paths must have vertical and horizontal signs. Vertical signage is represented by signs, which inform users about the particularities of the road. The horizontal signage is represented by paintings on the floor, through banners and drawings. The lighting of the lanes must guarantee the comfort and safety of cyclists. It ensures that motor vehicles are aware of the cyclist's presence and provides more safety to cyclists, preventing assaults and robberies (MONTEIRO, 2011).Table 2 presents different methods and analysis found in the literature regarding the analysis of bicycle network.

Table 2. Considerations found in literature about the bicycle network demands.

Literature	Considerations
Monteiro e Campos (2011)	Location Ease and comfort for the cyclist Accessibility and mobility Safety Security
Highway Capacity Manual (TRB, 2000)	Flow Speed Density of vehicle entrances
Dixon (1996)	Cyclist facilities Conflicts between cyclists and drivers Unobstructed visibility distance Improvements to intersections for cyclists Speed difference between vehicles and bicycles Motor vehicle volume Maintenance Programs for the improvement of bicycle transport
Botman (1995)	Traffic volume Overtaking frequency
Epperson(1994)	Road characteristics (paving, number of lanes, speed, width) traffic volume Location
Landis (1994)	Traffic volume Track characteristics (speed and width)

3.4 On-site assessment for the qualification of the criteria

For the analysis of drainage, paving, lighting, safety and signaling, the frequency of occurrence of anomalies during the subsections was taken into account. This analysis was done because these parameters are measurable. The analysis was carried out on the total of 31.76 km of the considered bicycle network. Table 3 presents the specifications used for these criteria in the validation of the subsections.

The analysis of qualitative parameters, planning, maintenance and integration was performed in a different way. They were classified as very bad, bad, average, good and very good, from 1 to 5, respectively. Some of the features assessed on-site are presented in the Appendix (Table A2).

Table 3. Quantitative features of the criteria assessed on-site.

Grade		Features
1	Pavement	Totally imperfect, holes larger than 60 cm in length, every 200 m.
2	Pavement	Numerous imperfections, holes between 45 cm and 60 cm in length, every 350 m.
3	Pavement	Few imperfections, holes between 30 cm and 45 cm in length, every 500 m.
4	Pavement	Spot imperfections, holes below 15 cm long, every 650 m.
5	Pavement	Track without imperfections, no holes.
1	Lighting	Absence of poles.
2	Lighting	Numerous imperfections, 10 poles running every 300 m.
3	Lighting	Few imperfections, 10 poles running every 250 m.
4	Lighting	Spot imperfections, 10 poles running every 200 m.
5	Lighting	No imperfections, 10 poles running every 150 m or less.
1	Safety	Unsafe track, with car entrance, lowered guide, without indentation with the track.
2	Safety	Track with low security, high contact with the street, less than 1 m of retreat from the track.
3	Safety	Track with medium security, medium contact with the track, between 1 m and 2 m of retreat from the track.
4	Safety	Track with high security, little contact with the track, between 2 m and 4 m of retreat from the track.
5	Safety	Totally safe track, without contact with the track, more than 4 m from the track.
1	Signaling	Runway without horizontal and vertical signage, no crosswalk, no painting.
2	Signaling	Track with low horizontal and vertical signs, pedestrian crossing and painting every 500 m or more.
3	Signaling	Lane with regular horizontal and vertical signage, pedestrian crossing and painting between 350 m and 500 m.
4	Signaling	Lane with medium horizontal and vertical signage, pedestrian lane and painting between 200 m and 350 m.
5	Signaling	Track with good horizontal and vertical signage, crosswalk and painting every 200 m or less.
1	Drainage	Abundant flooding points, absence of curb inlets or drainage system.
2	Drainage	High flooding points, at least 1 curb inlet every 600 m.
3	Drainage	Average flooding points, at least 1 curb inlet every 450 m.
4	Drainage	Low flooding points, at least 1 curb inlet every 300 m.
5	Drainage	No flooding points, at least 1 curb inlet or other drainage system every 150 m or less.

3.5 Criteria Individual Scores

The extended AHP approach was carried out, which generated the pairwise comparison matrix with the root square judgement scale (ZUFFO, 2011; BOULOMYTIS; ZUFFO; IMTEAZ, 2019), presented inthe Appendix (Table A3).The results are presented in Table 4. The other AHP steps were conducted to obtain the normalized weight vector. The consistency Index was 0.03 and the consistency ratio was 0.02. Thus, both presented consistent results as they were less than 0.1.

Table 4. Results of the pairwise comparison carried out in the study.

Criteria	Weight
Planning	10.00
Safety	8.24
Pavement	4.98
Integration	4.57
Maintenance	4.06
Signalling	3.34
Drainage	2.64
Light	2.15

3.6 Development of individual criteria maps

Based on the quantitative features of the criteria, the bicycle network was analyzed and classified. In the Appendix, Table A1 presents the result of this analysis and which situations were considered according to the featured conditions.

Each section of the cycle path received scores for all the criteria evaluated. With these data, individual maps were created by criteria to facilitate data analysis.

For the drainage criterion, 56 % of the cycle path scored 2 and these stretches are located on the city highway (Figure 5a).Regarding the integration, 57% of the bike path received an average grade (Figure 5b).

The light obtained 51 % of grade 4 and 49 % of grade 3, which represents a reasonable quality of this criterion in the city's cycle paths (Figure 6a). Maintenance results were not good. 62 % of the stretches scored 2, which means poor maintenance (Figure 6b).

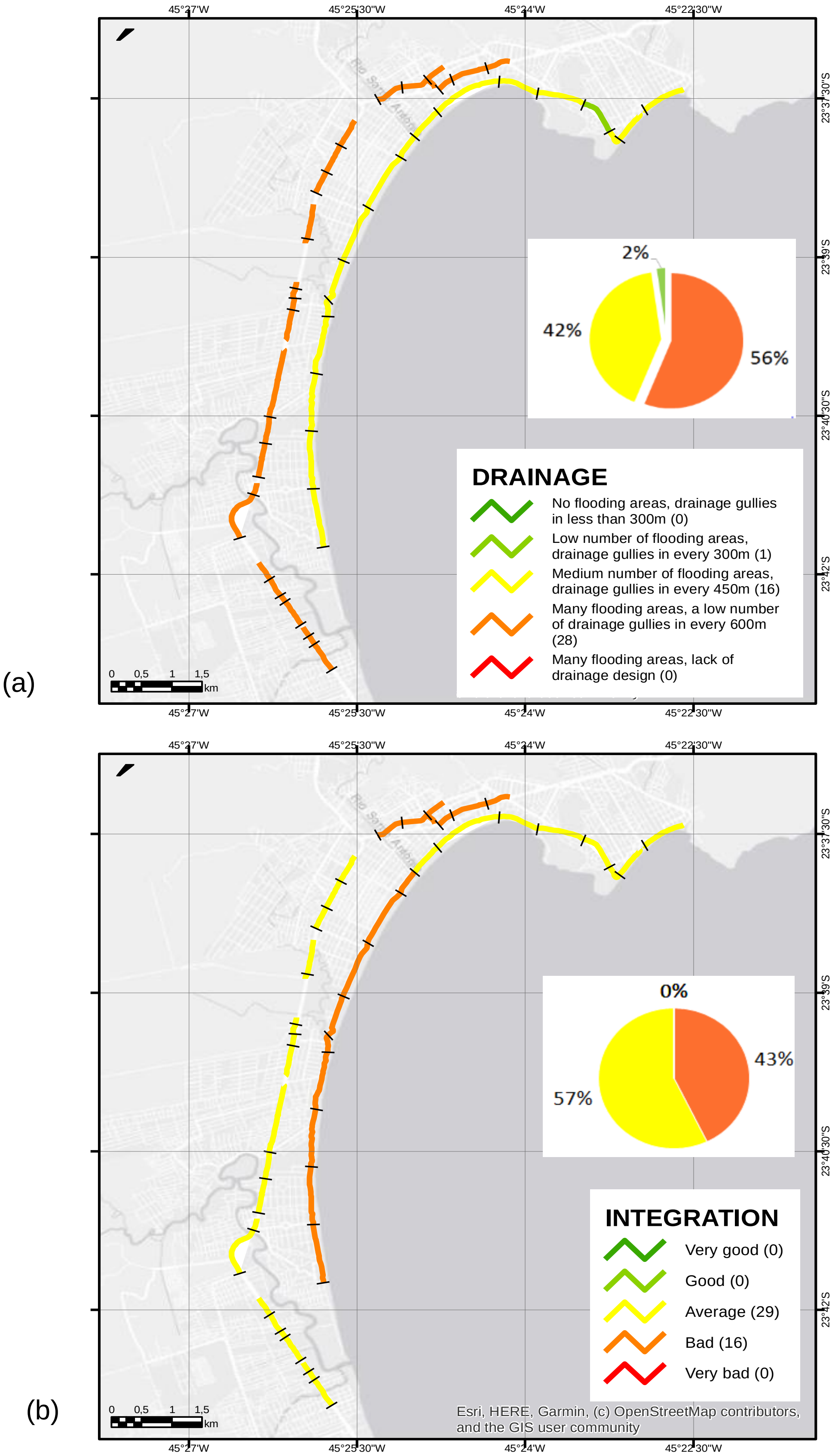
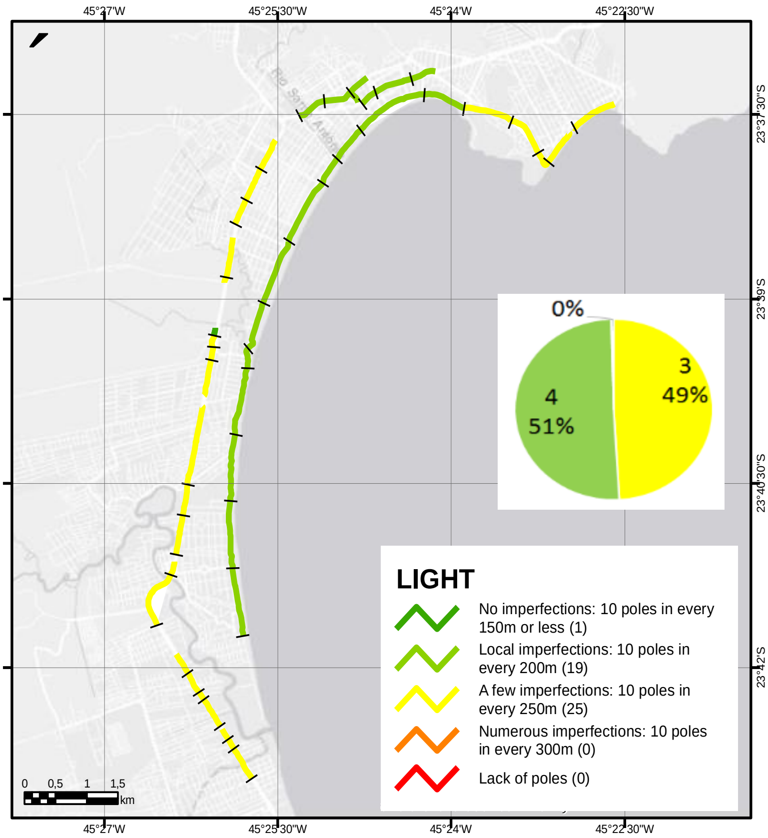


Figure 5. Individual indicator of efficiency: (a) drainage, (b) integration.

Source: Author.



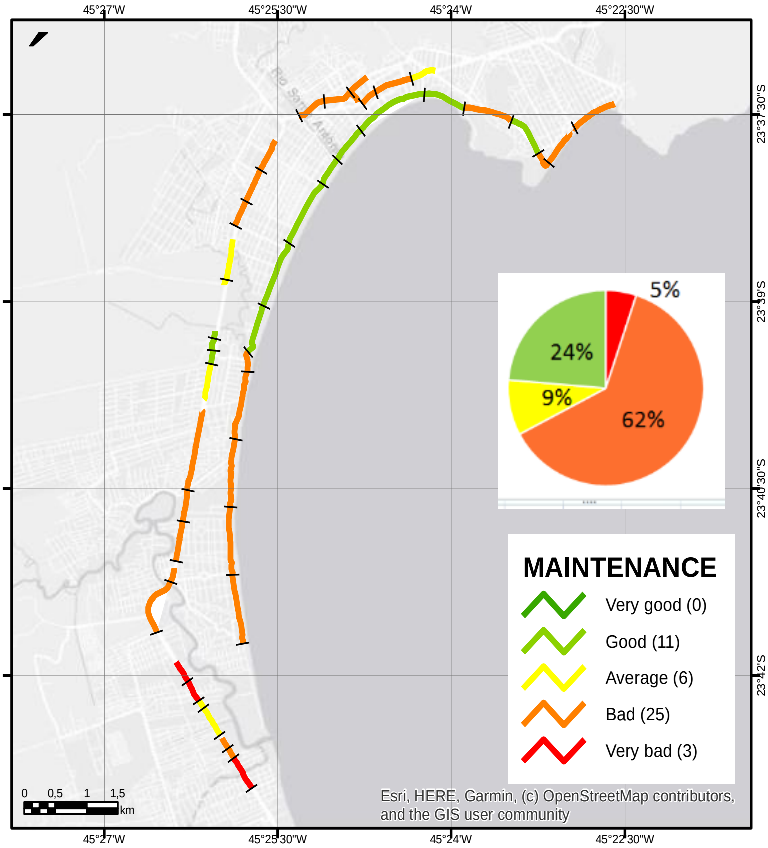
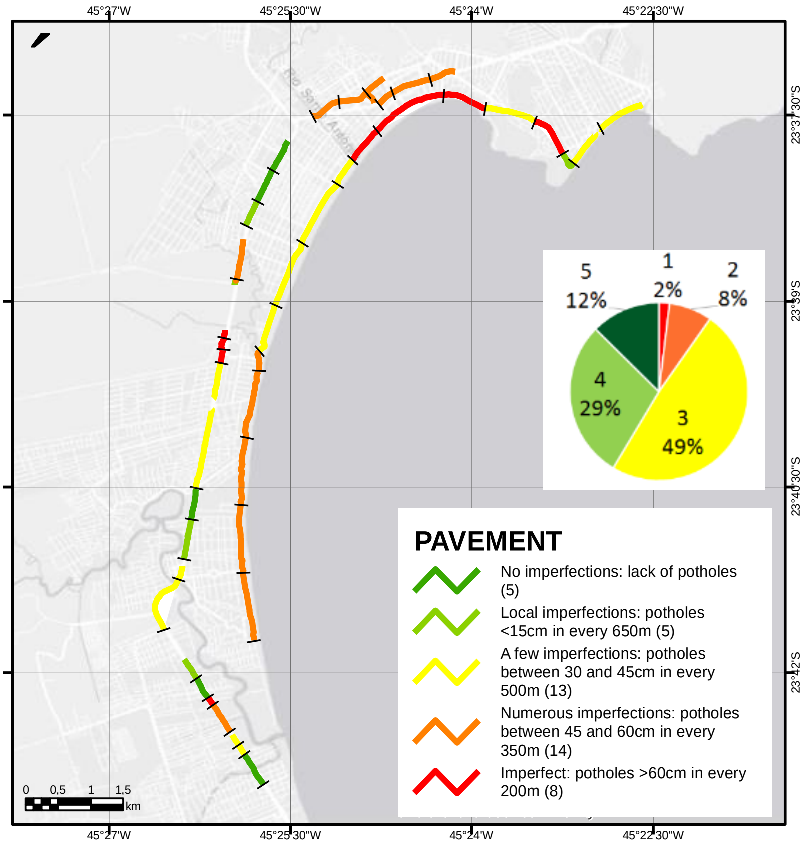


Figure 6. Individual indicator of efficiency: (a) light, (b) maintenance.

Source: Author.

In the pavement criterion, five categories were found, however 49 % of the sections were evaluated with grade 3 (Figure 7a). In the planning criterion, 54 % of the bike path was rated as bad and 35 % was rated as good (Figure 7b). For the safety criterion, 40 % obtained grade 1, which represents that a significant amount of the bicycle network is unsafe for its users (Figure 8a). In the signaling criterion, 55 % of the stretches obtained an evaluation score of 1 (Figure 8b), a result that indicates that most of the cycle path does not have adequate signage.



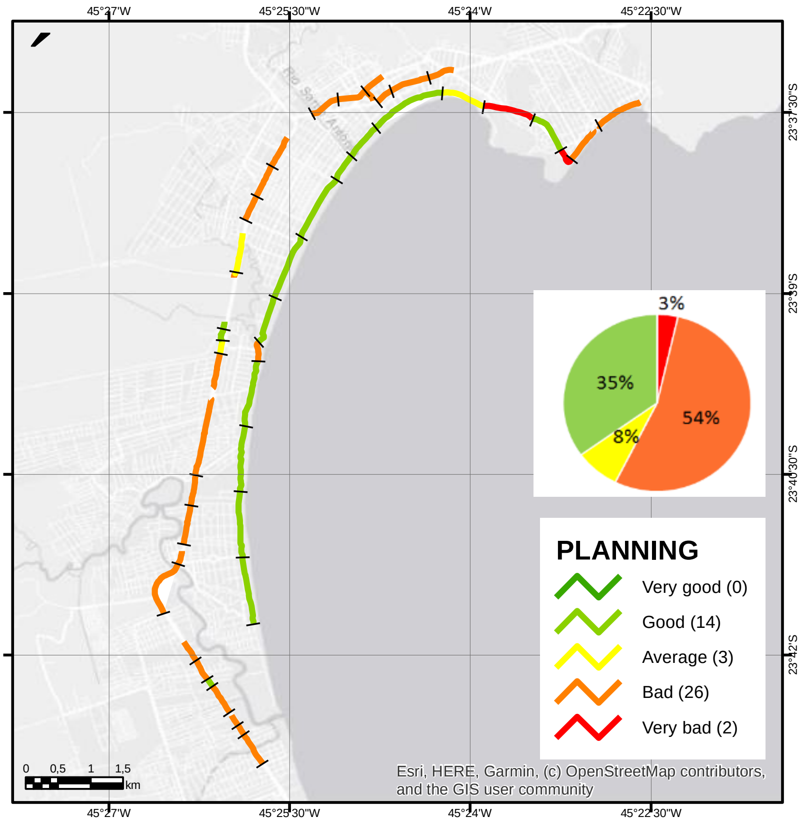
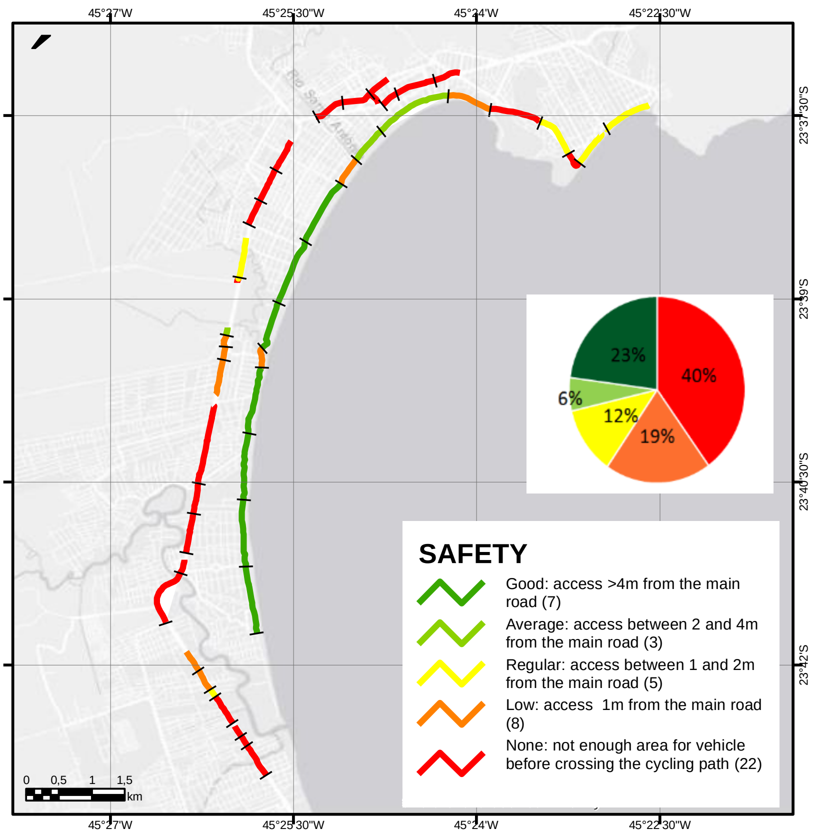


Figure 7. Individual indicator of efficiency: (a) pavement, (b) planning.

Source: Author.



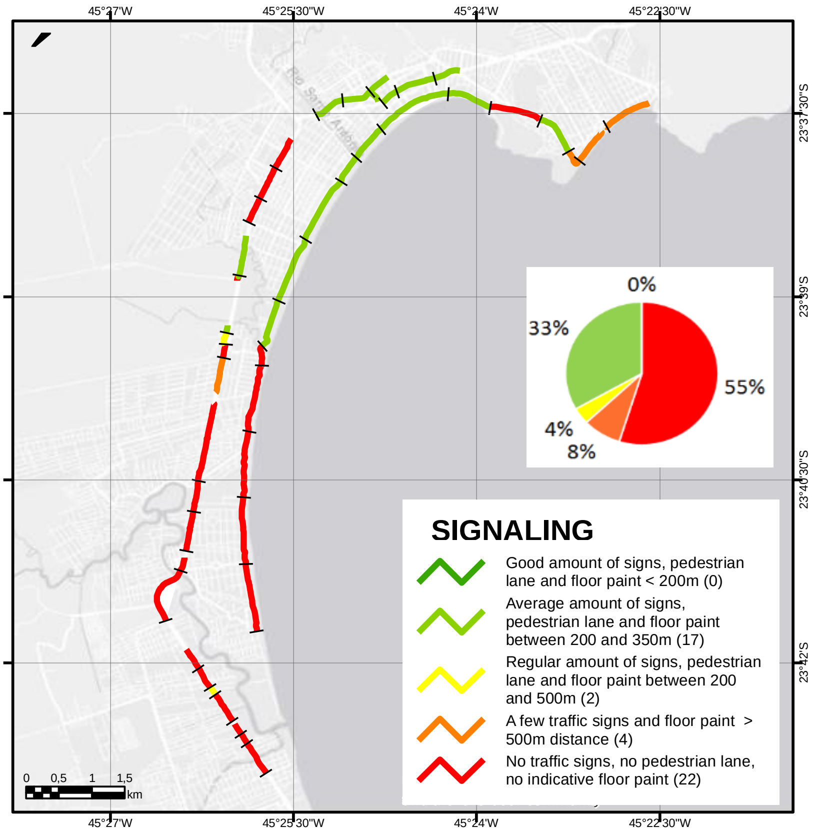


Figure 8. Individual indicator of efficiency: (a) safety, (b) signaling.

Source: Author.

3.7 Indicator of efficiency of the bicycle network

In Figure 9, the thematic map that was prepared with weighing each criterion, according to the score found by the use of the AHP method along the main bicycle network of Caraguatatuba municipality.

The study findings show that, no subsection from the bicycle network have the indicator of efficiency between the range of 4 and 5, and just 3 % of the network were classified between 0 and 1.

The indexes between 3 and 4 corresponded to the highest percentage of the bicycle network (in km), which represents average efficiency pattern (47 %).

In the southern bicycle network alongside the highway, where there are fewer tourists and more social vulnerability, the individual criteria scores and the local indicators of efficiency were lower than at the other locations, particularly concerning the drainage and maintenance (Table 5).

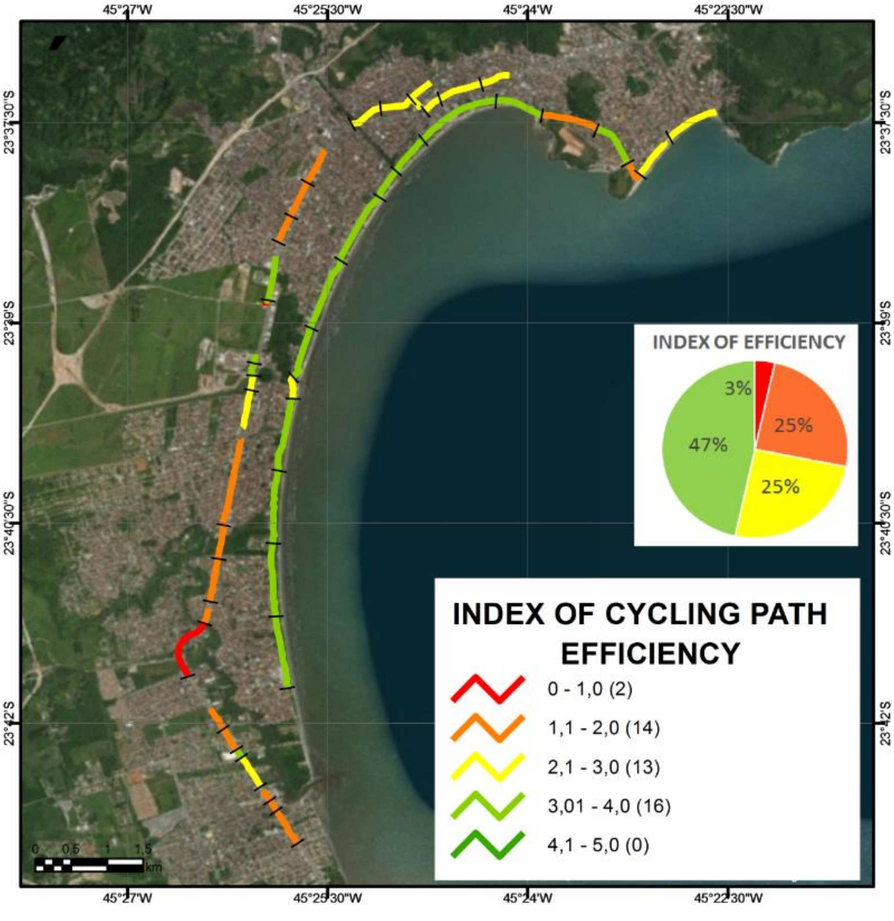


Figure 9. Bicycle network indicator of efficiency. Source: Author.

Table 5. Indicator of efficiency according to the bicycle network sections.

Section	Highest Indicator	Lowest Indicator	Average Indicator
Downtown	2.56	2.15	2.34
Along the highway	3.93	1.65	2.18
Along the coastline	3.04	1.82	3.20

4. CONCLUSION

The findings of this study developed a methodology to determine the indicator of efficiency of the bicycle network of Caraguatatuba municipality using the combination of the Delphi expert-survey method, the AHP and GIS spatial analysis. It was possible to characterize the bicycle network, based on qualitative and quantitative features assessed on-site.

During the course of the study, some areas ended up undergoing some type of change by the public authorities. Some of these changes were improvements to the current system, but other times they were only local maintenance services.

As shown in Table 5, the bike paths along the coastline have the best average of the indicator, but this location is not the most used by the population. The most used cycle lanes are located on the downtown and along the highway, and were the sections classified with the lowest scores.

We concluded that the bicycle network serves the majority of the population, but there are several types of specific and general problems. In the busiest times of the city, such as school and end-of-year holidays, which are the seasonal periods and long holidays, managers previously seek to maintain the bicycle network for the central and most used places of the city by tourists. However, in the suburbs, the network is often overlooked and suffers from deterioration.

The methodology of this study offers the public sectors the possibility of identifying the most critical locations to be prioritized for upcoming improvements.

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APPENDIX

Table A1. Delphi method.

1st round	1	2	3	4	5	6	7	8	9	10	11	12	Average	Q1	Q3
Pavement	7	9	7	8	10	9	8	9	10	9	10	8	8,67	8,00	9,25
Light	6	8	10	8	7	7	7	8	10	10	8	5	7,83	7,00	8,50
Safety	8	10	8	10	10	9	9	10	10	8	9	6	8,92	8,00	10,00
Signalling	6	8	9	8	8	8	8	10	9	8	10	7	8,25	8,00	9,00
Drainage	6	10	8	8	6	7	7	7	10	9	10	9	8,08	7,00	9,25
Maintenance	8	8	10	8	8	9	9	8	10	9	10	3	8,33	8,00	9,25
Planning	10	10	8	8	5	10	9	7	9	10	10	10	8,83	8,00	10,00
Integration	9	7	5	10	4	8	10	8	9	7	10	4	7,58	6,50	9,25

2nd round	1	2	3	4	5	6	7	8	9	10	11	12	Average	Q1	Q3
Pavement		9		8		9	8	9		9		8	8,57	8,00	9,00
Light		8		8	7	7	7	8			8		7,57	7,00	8,00
Safety	8	10	8	10	10	9	9	10	10	8	9		9,18	8,50	10,00
Signalling		8	9	8	8	8	8		9	8			8,25	8,00	8,25
Drainage			8	8		7	7	7		9		9	7,86	7,00	8,50
Maintenance	8	8		8	8	9	9	8		9			8,38	8,00	9,00
Planning	10	10	8	8		10	9		9	10	10	10	9,40	9,00	10,00
Integration	9	7				8		8	9	7	10		8,29	7,50	9,00

3rd round	1	2	3	4	5	6	7	8	9	10	11	12	Average	Q1	Q3
Pavement		9		8		9	8	9		9		8	8,57	8,00	9,00
Light		8		8	7	7	7	8			8		7,57	7,00	8,00
Safety		10		10	10	9	9	10	10		9		9,63	9,00	10,00
Signalling		8		8	8	8	8			8			8,00	8,00	8,00
Drainage			8	8		7	7	7				9	7,67	7,00	8,00
Maintenance	8	8		8	8	9	9	8		9			8,38	8,00	9,00
Planning	10	10				10	9		9	10	10	10	9,75	9,75	10,00
Integration	9					8		8	9				8,50	8,00	9,00

4th round	1	2	3	4	5	6	7	8	9	10	11	12	Average	Q1	Q3
Pavement		9		8		9	8	9		9		8	8,57	8,00	9,00
Light		8		8	7	7	7	8			8		7,57	7,00	8,00
Safety		10		10	10	9	9	10	10		9		9,63	9,00	10,00
Signalling		8		8	8	8	8			8			8,00	8,00	8,00
Drainage			8	8		7	7	7				9	7,67	7,00	8,00
Maintenance	8	8		8	8	9	9	8		9			8,38	8,00	9,00
Planning	10	10				10				10	10	10	10,00	10,00	10,00
Integration	9					8		8	9				8,50	8,00	9,00

Table A2. The bicycle network features on-site.

DRAINAGE




INTEGRATION


MAINTENANCE


PAVEMENT


SIGNALING

SAFETY


PLANNING


Table A3. The extended AHP approach

AHP extended approach of Zuffo (2011)	Planning	Safety	Pavement	Integration	maintenance	Signalling	Drainage	Light
	10,00	9,63	8,57	8,50	8,38	8,00	7,67	7,57
Planning	0,00	0,37	1,43	1,50	1,62	2,00	2,33	2,43
Safety		0,00	1,06	1,13	1,25	1,63	1,96	2,06
Pavement			0,00	0,07	0,19	0,57	0,90	1,00
Integration				0,00	0,12	0,50	0,83	0,93
Maintenance					0,00	0,38	0,71	0,81
Signalling						0,00	0,71	0,81
Drainage							0,00	0,81
Light								0,00

Pairwise Comparison Matrix	Planning	Safety	Pavement	Integration	maintenance	Signalling	Drainage	Light
Square root judgement scale	10,00	9,63	8,57	8,50	8,38	8,00	7,67	7,57
Planning	1,000	1,732	2,450	2,450	2,646	2,828	3,000	3,000
Safety	0,577	1,000	2,236	2,236	2,450	2,646	2,828	2,828
Pavement	0,408	0,447	1,000	1,414	1,414	1,732	2,000	2,236
Integration	0,408	0,447	0,707	1,000	1,414	1,732	2,000	2,236
Maintenance	0,378	0,408	0,707	0,707	1,000	1,732	2,000	2,000
Signalling	0,354	0,378	0,577	0,577	0,577	1,000	2,000	2,000
Drainage	0,333	0,354	0,500	0,500	0,500	0,500	1,000	2,000
Light	0,333	0,354	0,447	0,447	0,500	0,500	0,500	1,000

Normalized S'	3,79	5,12	8,62	9,33	10,50	12,67	15,33	17,30
Planning	0,264	0,338	0,284	0,262	0,252	0,223	0,196	0,173
Safety	0,152	0,195	0,259	0,240	0,233	0,209	0,185	0,163
Pavement	0,108	0,087	0,116	0,152	0,135	0,137	0,130	0,129
Integration	0,108	0,087	0,082	0,107	0,135	0,137	0,130	0,129
Maintenance	0,100	0,080	0,082	0,076	0,095	0,137	0,130	0,116
Signalling	0,093	0,074	0,067	0,062	0,055	0,079	0,130	0,116
Drainage	0,088	0,069	0,058	0,054	0,048	0,039	0,065	0,116
Light	0,088	0,069	0,052	0,048	0,048	0,039	0,033	0,058

Eigen Vector	x	w	Weight
Planning	0,249	2,06	10,00
Safety	0,205	1,698	8,24
Pavement	0,124	1,025	4,98
Integration	0,114	0,941	4,57
Maintenance	0,102	0,837	4,06
Signalling	0,084	0,689	3,34
Drainage	0,067	0,543	2,64
Light	0,054	0,443	2,15