GeoJournal of Tourism and Geosites
ISSN 2065-1198, E-ISSN 2065-0817

Year XVII, vol. 52, no. 1, 2024, p.125-132
DOI 10.30892/gtg.52112-1189

# GENERAL CONDITION ASSESSMENT METHOD FOR SIGNALIZED INTERSECTIONS: THE CASE OF IBAGUE, COLOMBIA

**Juan GOMEZ**
Universidad de Ibagué, Programa de Ingeniería Civil, Facultad de Ingeniería,
Ibagué, Colombia, e-mail: 2520191009@estudiantesunibague.edu.co

**Karen TRIANA***
Universidad de Ibagué, Programa de Ingeniería Civil, Facultad de Ingeniería,
Ibagué, Colombia, e-mail: 2520191037@estudiantesunibague.edu.co

**Mario VARGAS**
Universidad de Ibagué, Programa de Ingeniería Civil, Facultad de Ingeniería,
Ibagué, Colombia, e-mail: 2520191038@estudiantesunibague.edu.co

**Diego ESCOBAR**
Universidad Nacional de Colombia sede Manizales, Departamento de Ingeniería Civil,
Grupo de Investigación en Movilidad Sostenible, Manizales, Colombia, e-mail: daescobarga@unal.edu.co

**Juan ZULUAGA-VILLERMO**
Universidad de Ibagué, Programa de Ingeniería civil, Grupo de Investigación MYSCO, Ibagué, Colombia, e-mail: juan.zuluaga@unibague.edu.co

**Citation:** Gomez, J., Triana, K., Vargas, M., Escobar, D. & Zuluaga-Villermo, J. (2024). GENERAL CONDITION ASSESSMENT METHOD FOR SIGNALIZED INTERSECTIONS: THE CASE OF IBAGUE, COLOMBIA. *GeoJournal of Tourism and Geosites*, 52(1), 125–132. https://doi.org/10.30892/gtg.52112-1189

**Abstract:** This study proposes a new method created to perform a universal assessment on the status of signalized intersections implemented in the city of Ibague, Colombia. The condition of each signalized intersection is classified according to parameters established to improve vehicular and pedestrian traffic, as well as the long-term development of the city. To achieve the research objective, the aspects to be evaluated are divided in two categories: Functionality and Utility, as well as specific criteria for each of them. Therefore, field data is collected using a geospatial tool and assigning levels of importance associated with a numerical scale that is plotted on maps of influence. We can therefore conclude that the proposed assessment method is not only necessary, but suitable for the evaluation of signalized intersections, which effectively assess the pertinent aspects, granting a rating supported by their respective analysis, and making the comparison of their specific conditions over time possible. For example, in the case study of Ibague 2023, according to the evaluation method, 59% of the intersections were ranked in the lowest states of the scale, also showing that between 2018 and 2023 there was an overall decay, as most of the intersections (85%) lowered their ratings and degraded to a greater extent compared to those with improvements.

**Key words:** Signalized intersections, Ibague, development, traffic signal network, criteria, evaluation, comparison

* * * * * *

## INTRODUCTION

The method proposed in this article was applied to the signalized intersections in the city of Ibague, Colombia. Ibague is a city located in the central zone of the country as shown in Figure 1, it has easy access from various surrounding regions, a pleasant climate, and a low cost of living compared to other capital cities, which makes it a very attractive place to live. The city went from having 529,635 inhabitants in 2018 to 542,046 in 2023, a fact that reflects the uniform growth of the city in every aspect (Reyes et al., 2021), in addition, after the most critical stage of the pandemic, the automobile market increased by 32.8% in Colombia (Cuellar, 2021). The traffic light network of the city is based on traffic lights with fixed times.

According to the municipal mayor's office in 2019, there were 92 traffic-light intersections that included 567 vehicular traffic lights, 233 pedestrian traffic lights and 75 traffic light controllers (Secretariat of Mobility, 2019). Fabian Tinoco, operating director of this entity, mentioned that along with the "Strategic Public Transportation System" (SETP for its acronym in Spanish), they are working to replace the current controllers that regulate traffic, which are more than 15 years old (Secretariat of Mobility, 2022). Despite the different plans proposed such as the one from 2019 in which the secretariat of mobility allocated 145 million Colombian pesos for preventive and corrective maintenance, and another 6.000 million Colombian pesos for the modernization of the traffic lights in the city center, there is no evidence of a change on a daily basis (Secretariat of Mobility, 2019). This problem affects the population and is reflected in crashes caused by synchronization errors (El Olfato, 2020), this situation is aggravated by insecurity, since the wiring is occasionally stolen (Alerta Tolima, 2021) being a complex problem with no definitive solution so far (El Nuevo Día, 2022).

* Corresponding author

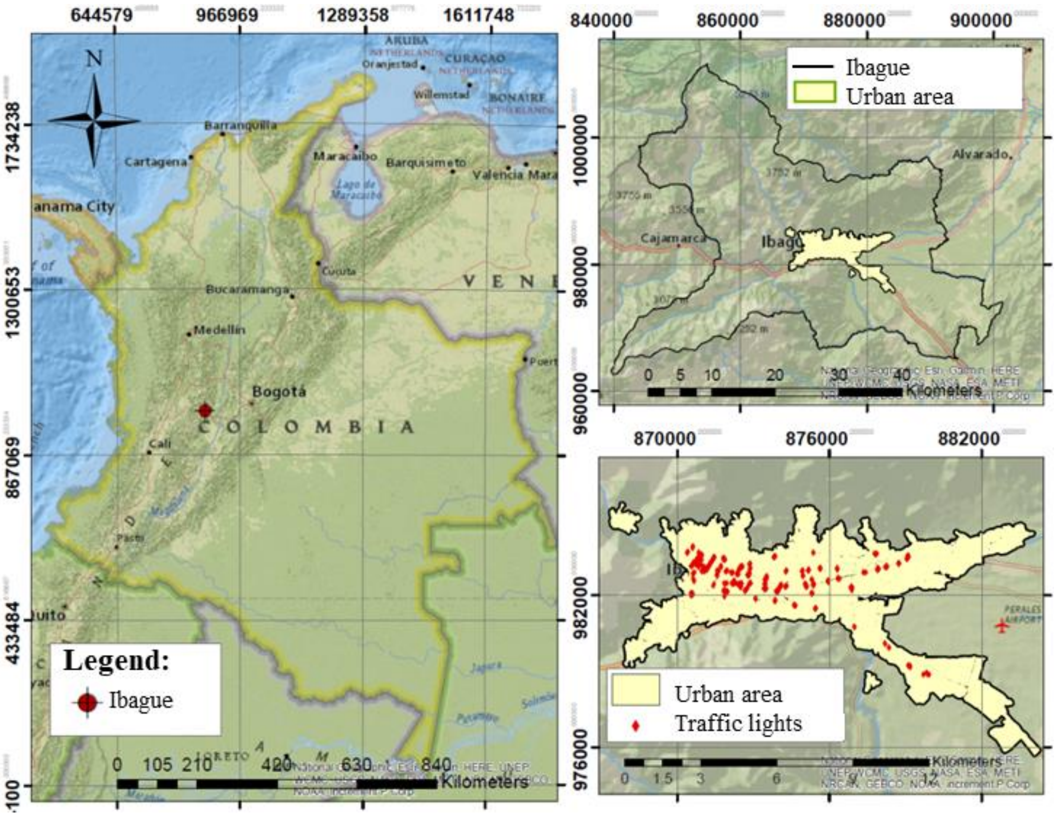


Figure 1. Location map (Source: Authors)

Generally speaking, by having traffic signalized intersections as the object of research, it is essential to consider that the concentration of vehicles at an intersection can eventually overwhelm the capacity of an entire system. Thus, vehicle and pedestrian traffic lights are key to guarantee safety and optimal traffic flow (O'Flaherty, 2018). At the same time, the essential element of traffic signalized intersections are traffic lights, which are useful devices not only to alternate the traffic of a vehicular or pedestrian flow, but also to regulate speeds. They control the circulation by lanes and minimize the number and the severity of potential collisions, providing order and safety. For this reason, the implementation of a method to evaluate and classify the condition of a signalized intersection is of the utmost importance to ensure that these are properly maintained and supervised for optimal functionality within the city, aiming to promote its organization and development. In this context, a research was carried out in the same city (Ibague), which highlights the importance of studying its urban change and provides criteria for analysis (Francel, 2017).

Multiple sources have addressed the issue of analyzing and evaluating urban intersections as an alternative towards the improvement of their condition, highlighting the importance of carrying out this assessment to benefit transportation and the proper functioning of the entire road network, as stated in a study on the importance of intersections for urban mobility, if an intersection does not meet its functionality, the entire road network is affected (Garcia et al., 2015); similarly, proposals aiming to address this issue are based on the use of traffic signals, reduction of delays and the elimination of conflict points, such a situation is evaluated in a study of the most important signalized intersections in Managua, Nicaragua, which brought up the need for the traffic light network to provide a better service, especially considering the growth of the vehicle fleet and the high accident rate at such critical traffic points, therefore, structural elements such as the type and condition of metal brackets, traffic lights, faces and traffic light controllers should be considered (Vega and Guevara, 2012). Likewise, a work of approximation to road safety models in traffic signalized intersections in Medellin, together with the geographic location, geometric conditions, and their composition, also considers other aspects of the road environment such as lighting and the presence of bus stops (Betancur, 2018). On the other hand, a study from New York University highlights the importance of models and simulations to evaluate the safety of signalized intersections, where data is a solid basis for decision making through the implementation of geospatial tools (Yang et al., 2021). In addition, aspects such as the study of demarcation influence on driver behavior were considered, concluding that the information that drivers receive visually is decisive for road safety, being presented in a clear and coherent way (Fiolić et al., 2023), as well as recognizing the pedestrian as a fundamental individual in urban dynamics not only improves safety at intersections, but also contributes to the creation of more inclusive and sustainable urban environments (Belge and Ercan, 2022).

Other important issues in the development of this work, such as criteria to be evaluated and their respective levels of importance were previously studied by taking into account categories such as functionality, utility, congestion, and pedestrian phase. The functionality category according to the authors is composed of criteria such as signaling (25%), painting (15%), phases (17%), position (13%), brightness (18%), and visibility (12%). On the other hand, the utility category is divided into the following criteria with their respective levels of importance: necessity and appropriateness (40%), pedestrian friendliness (30%), and disability (30%) (Gonzalez and Lopez, 2018).

The method faces considerable challenges, being especially vulnerable to changes in intersection infrastructure, which raises concerns about the stability and consistency of the assessments over time in a dynamic environment. Despite the use of georeferencing tools, the complexity in data collection requires considerable refinement and simulation, introducing the possibility of errors and inaccuracies that affect the integrity of the results and the reliability of the assessments. The reliance on data assimilation also raises doubts about objectivity, as interpretation by the analyst can significantly influence the final ratings. As in the research carried out in Doha, Qatar when proposing a method for evaluating sidewalks, concluding that it could allow policymakers, practitioners, consultants, and others to make fast and accurate decisions regarding required improvements. In this sense, this research is timely, since promoting walkability has become a challenge which applies especially to developing countries (Shaaban, 2019).

Therefore, it is possible to reach an ideal such as the one presented in the city of Osaka, Japan, where the transition to safer streets is proposed through an integrated and inclusive design (Doi et al., 2016). Based on the application of the method in the city of Ibague Colombia, improvements can be sought in the traffic signal network and infrastructure at signalized intersections. Examples in other Latin American countries, such as Ecuador, show research on adaptive traffic signal systems that regulate traffic according to demand, increasing safety and flow efficiency. In Ecuador, this approach has been applied in cities such as Cuenca and Guayaquil, using computerized intersections that monitor traffic volumes in real time using video detection cameras (Lojano, 2013). Likewise, Hertogenbosch, The Netherlands, is an example of traffic light modernization, where automation allows green signals when users are approaching, traffic permitting. When there is only one user waiting, the green light lasts 4 seconds; if there are several, the last one with a yellow signal is given way. This strategy demonstrates that proper automation can provide safe and efficient circulation for all road users (Equipo Digital, 2019).

## MATERIALS AND METHODS

The methodology of this research is described in six stages explained below and shown in Figure 2.

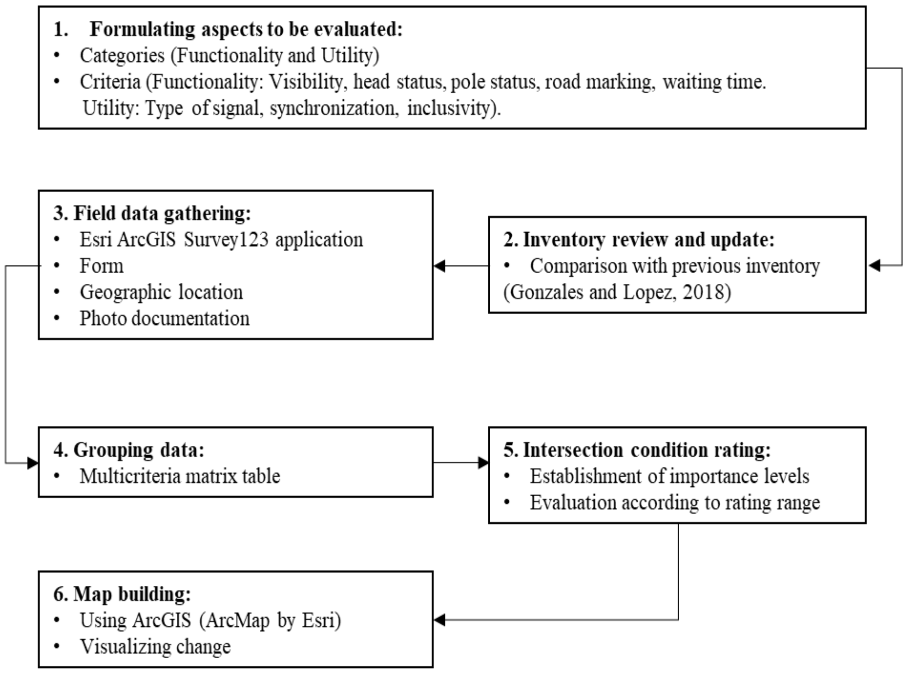


Figure 2. Research methodology

1. Formulating aspects to be evaluated. At this stage, the evaluating elements to be considered for the assessment of the signalized intersections are detailed. They were divided into two main categories, each with their respective criteria, explained below.

A. Functionality: This category refers to the status of the infrastructure of the traffic signalized intersection and the different elements that have an influence on its proper functioning and fulfillment of its purpose.

1. Visibility: Everything related to being able to see the signals and the traffic light modules without difficulty was considered. This variable was evaluated through two dichotomous questions consisting of the presence of obstacles and upper and/or lower head.

2. Head status: It is important to assess the quality of the traffic lights, as this is crucial to ensure that the intended signal or warning reaches the users correctly. In this criterion, the type of light, the condition of the luminous module, the brightness and the presence of a visor were considered.

3. Pole status: This aspect is considered relevant because the poles not only serve as a support but also to warn about the presence of a traffic light. This criterion considers the existence of the reflective coating, its condition, and the type of material the pole is made of.

4. Road marking: The existence and condition of road marking is of great importance as they inform and warn to drive with caution and comply with the provisions of these signs. It was reviewed for this study whether the intersections had the

necessary markings for a signalized intersection, which should include a continuous stop line, crosswalk, blocking restriction, direction indicator arrow and lane line (Road Signage Manual, 2015).

5. Waiting time: This was evaluated by verifying the correct functioning of the traffic lights at the signalized intersection by being able to measure all waiting times.

B. Utility: This category is designed to check the accessibility and inclusion of traffic signalized intersections, i.e., whether they guarantee ease of flow for people regardless of their mobility condition. The criteria considered are the type of indication, synchronization and inclusivity.

1. Type of signal: This category is proposed with the objective of checking that intersections provide pertinent signal indications not only to drivers but also to pedestrians. This includes vehicular, vehicular with direction, pedestrian, and pedestrian with countdown.

2. Synchronization: This assessment checks whether vehicular and pedestrian circulation alternate correctly, otherwise accidents could occur.

3. Inclusivity: It is evaluated due to the importance of equal conditions for all people to be able to move around without major problems. Thus, the criterion takes into account the existence of ramps and tactile signage.

2. Inventory review and update: Based on the inventory proposed as part of the undergraduate Project entitled Development of inventory of traffic signalized intersections in the city of Ibague (Gonzalez and Lopez, 2018), and to verify such inventory, an inspection was carried out throughout the city. It was concluded that the inventory of signalized intersections remains the same, with only one update in the entire city, this being the intersection at 14 Av. and 110th St. (Surti Plaza Ambala).

3. Field data gathering: Once the list of intersections to be analyzed has been defined, the field work is carried out by filling in a form previously prepared for each signalized intersection, using the Esri ArcGIS Survey123 application. This is a form-based solution that allows collecting the most significant data on the actual state of each object of study, which also records the geographic location and produces photographic evidence.

4. Grouping data: The data obtained previously was tabulated with the purpose of consolidating the information and being able to make it easier for visualizing the analysis in a much clearer manner. The format is shown in Table 1 specifying each percentage.

Table 1. Multicriteria matrix

| # | Intersection | Category | Criteria | % | Score | Rating | | | Condition |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Partial** | **Total** | **Intersection total** | |
| Intersection number | Intersection address with entry | Functionality | Visibility | 19% | | | 100% | | |
| | | | Head status | 26% | | | | | |
| | | | Pole status | 22% | | | | | |
| | | | Road marking | 33% | | | | | |
| | | | Waiting time | -- | | | | | |
| | | Utility | Type of signal | 30% | | | | | |
| | | | Synchronization | 40% | | | | | |
| | | | Inclusivity | 30% | | | | | |
| | Intersection address with entry | Functionality | Visibility | 19% | | | 100% | | |
| | | | Head status | 26% | | | | | |
| | | | Pole status | 22% | | | | | |
| | | | Road marking | 33% | | | | | |
| | | | Waiting time | -- | | | | | |
| | | Utility | Type of signal | 30% | | | | | |
| | | | Synchronization | 40% | | | | | |
| | | | Inclusivity | 30% | | | | | |

5. Intersection condition rating: With the information already analyzed, percentages are assigned to each of the criteria according to their level of importance, which was defined according to a similar study conducted by Gonzalez and Lopez in 2018 and following the hierarchy of importance and proportionality stated therein and in accordance with the 2022 Road Signage Manual. It is worth clarifying that the two main categories equally affect the final rating. Thus, the levels of importance affect to a greater or lesser extent the total rating of each criterion. The following section shows some of the aspects considered to define the levels of importance according to the Road Signage Manual.

A. Functionality:

1. Visibility: It is essential to consider the location of poles at an intersection as this has a direct impact on the safety and visibility of traffic signals. In addition, it is important that traffic elements are visible at all times, regardless of weather conditions or time of day (Road Signage Manual, 2022).

2. Head status: The head condition of traffic light modules is essential for road safety as it ensures the correct display of signals to drivers. It includes key components such as the face, light module, lenses, visor, contrast plate and controller. These requirements are fundamental for the reliable operation of traffic signals and the prevention of road accidents (Road Signage Manual, 2022).

3. Pole status: Road safety depends to a large extent on the condition of the poles supporting the traffic lights. These poles must follow NTC 47393 standards, with the appropriate materials to guarantee their retro-reflectivity and specific colors. The poles may be traffic yellow or white and must have four black stripes 25 cm wide each, separated by 25 cm. These standards ensure the visibility of traffic lights and ultimately contribute to road safety (Road Signage Manual, 2022).

4. Road marking: Demarcation at intersections regulated by traffic lights is essential for road safety. It includes a continuous stop line and crosswalk lines that should allow drivers to identify the traffic light signals. These markings must be slip-resistant to avoid incidents and be retro-reflective to improve visibility. In addition, it is mandatory for roads to have a definitive and well-maintained demarcation. These regulations are crucial for safe and efficient traffic at intersections with traffic lights (Road Signage Manual, 2022).

5. Waiting time: Defining waiting times in a combined phase for pedestrians and vehicles is essential for road safety. It is recommended to consider the number of possible conflicts. The operation of a waiting system must be consistent and adapted to traffic needs, which requires the confrontation of updated traffic count information to regulate changes in traffic volumes efficiently. These practices are fundamental to traffic management and safety at intersections (Road Signage Manual, 2022).

B. Utility:

1. Type of signal: The indication provided by traffic signals intended to control pedestrians, cyclists and other users is vital for road safety. These devices are installed for the exclusive purpose of providing safety and regulating traffic for this group of users. Traffic signals are recommended in areas with a high volume of pedestrians and at intersections that relate to infrastructure for these users. In addition, it is suggested that they are located close to school areas or institutions. These measures significantly improve the safety of pedestrians and cyclists on the roads (Road Signage Manual, 2022).

2. Synchronization: Traffic signal synchronization allows for a continuous flow of vehicles at intersections. During normal operation, no one should regulate traffic against the traffic light signals. Cycles of 60 to 120 seconds are used, with possible exceptions in special cases, but cycles longer than 150 seconds are not recommended. These practices are essential to manage traffic efficiently and ensure safety at intersections (Road Signage Manual, 2022).

3. Inclusivity: Floor markings with tactile surfaces are essential in pedestrian zones and areas surrounding road infrastructure. These surfaces should be slip-resistant and preferably have contrasting color. Their purpose is to safely guide pedestrians, especially those with visual impairment or low vision, by providing information, warnings and signage of possible obstacles or hazards in pedestrian areas and at intersections. This is vital to ensure the safety and accessibility of all people in urban environments (Road Signage Manual, 2022).

Once the scores for each criteria are tabulated in the evaluation rubric (table 1), the values are analyzed mathematically. First, by using the weighted average formula, called partial rating by criteria (Pr) in this specific study as shown in equation 1, in which, each value is taken according to each criteria score (cr) and then multiplied by its percentage (cp), then every result is added, obtaining the partial qualification for a single category.Partial rating by criteria (Pr):

$$P_r = \sum(cp * cr) \qquad (1)$$ (Source: developed by authors)

With the above and knowing that the two categories have the same value in the final consideration, both, partial functionality rating ($P_{fr}$) and partial utility rating ($P_{ur}$), are arithmetically averaged to obtain the score of only one entry or traffic light ($T_{er}$). Total entry rating (Ter):

$$T_{er} = \frac{P_{fr} + P_{ur}}{2} \qquad (2)$$ (Source: developed by authors)

Depending on the number of traffic lights or entries (N = as they are called in this case), the scores of the entries ($T_{er}$) should be averaged to calculate the total rating of the intersection (Tir). Scores and other ratings are represented in proposed dimensionless units from 0 to 5. Total intersection rating (Tir):

$$T_{ir} = \frac{\sum_{i=1}^{N} T_{er}}{N} \qquad (3)$$ (Source: developed by authors)

A graphic example of the characteristics that would merit each of the qualifications of the established scale is presented in Figure 3.

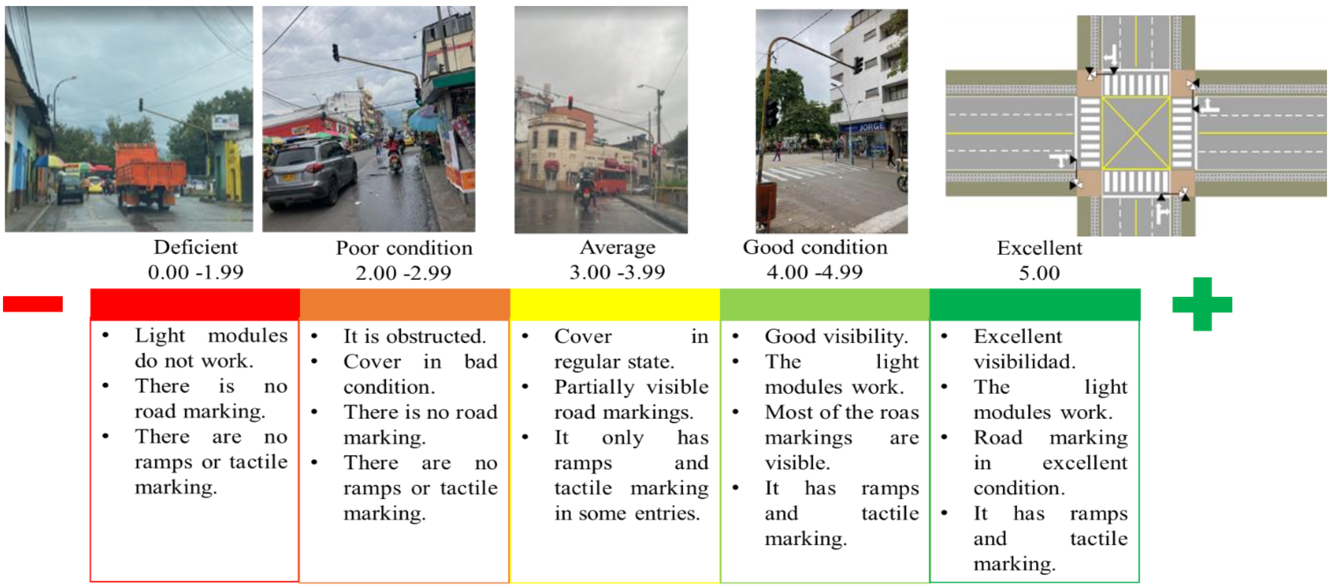


Figure 3. Examples of qualification scales (Source: Authors)

Map building: Having all the necessary data and qualifications, we proceed to make different maps to show location of the analyzed points and the status of the signalized intersections for the year 2018 and 2023, and finally a comparison to be able to visualize their improvement or degradation. This is carried out using the Esri's ArcGIS software and its ArcMap program as a geo-referencing and mapping tool in order to finally reach an adequate analysis of the results by using a geostatistical interpolation method (Kriging) with a linear regression analysis. This procedure generates an estimated surface from a scattered set of points based on the value of each of the ratings and matching them to the color scale. For example, if there are nearby points with high ratings, they will be visualized with a color closer to green, which symbolizes a good condition of the zone. On the other hand, if there are points with lower ratings, they are related to a color closer to red indicating poor condition. In this order of ideas, the Kriging geostatistical analysis uses the probabilistic concept of variance (equation 4), combining it with the input data such as the scores of the intersections (Tir) and the distances (h) between them. By fitting a linear function to the map expressing in which points the value of the dependent variable (Tir) has the greatest impact.

$$v = c_0 + c * h \quad (4) \qquad c_0 + c: \textit{Asymptotic variance, values of Tir} \quad h: \textit{Distance between points.}$$ (Source: Krige, 1951)

## RESULTS AND DISCUSSION

Initially, the intersections in the area were rated using a multi-criteria matrix and assigning ratings to each criterion. This allows the calculation of partial ratings per category, then a rating per traffic light, and finally a total rating for the intersection condition. Table 2 describes process for the first intersection analyzed shown in Figure 4, 1st Av. and 10th ST.

Figure 4. Signalized Intersection No. 1 - 1st. Av. and 10th St. (Source: Authors, 2022)

Table 2. Evaluation of Signalized Intersection No.1 - 1st Av. and 10th St.

| # | Intersection | Category | Criteria | % | Score | Rating | | | Condition |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Partial | Total | Intersection total | |
| 1 | 1st Av. -1st St. (West entry) | Functionality | Visibility | 19% | 4.30 | 4.34 | 4.19 | 3.81 | Average |
| | | | Head status | 26% | 4.70 | | | | |
| | | | Pole status | 22% | 4.60 | | | | |
| | | | Road marking | 33% | 3.90 | | | | |
| | | | Waiting time | -- | Complete | | | | |
| | | Utility | Type of signal | 30% | 3.00 | 4.05 | | | |
| | | | Synchronization | 40% | 4.50 | | | | |
| | | | Inclusivity | 30% | 4.50 | | | | |
| | 1st Av. -1st St. (East entry) | Functionality | Visibility | 19% | 4.20 | 3.25 | 3.42 | | |
| | | | Head status | 26% | 4.60 | | | | |
| | | | Pole status | 22% | 4.20 | | | | |
| | | | Road marking | 33% | 1.00 | | | | |
| | | | Waiting time | -- | Complete | | | | |
| | | Utility | Type of signal | 30% | 3.00 | 3.60 | | | |
| | | | Synchronization | 40% | 4.50 | | | | |
| | | | Inclusivity | 30% | 3.00 | | | | |

Subsequently, with the help of the ArcGIS tool, a set of software products in the field of Geographic Information Systems and the Kriging geostatistical method, the results were captured graphically as an influence map, initially forming the representation of the status of each traffic-light intersection in the city of Ibague corresponding only to the year 2023, as shown in Figure 5, in which red means deficient condition, orange means poor, yellow means average, light green means good condition and dark green means excellent. As illustrated in Figure 6 according to the context of the city. It is essential to visualize the changes on the physical and technological conditions of the signalized intersections in the city of Ibague between 2018 and 2023. Improvements are shown in intense green, decay in intense red and milder degradations in yellow and orange. In the map in Figure 6, the main avenues of the city are highlighted as reference points. It should be noted that the Kriging analysis is limited to the relevant data of the study, which explains the blank areas, where there are no traffic lights nearby. Finally, to conceptualize what was found, a graphical representation was prepared through a circular diagram in Figure 7 relating the amount of data and the percentage of intersections corresponding to the different type of status for the year 2023.

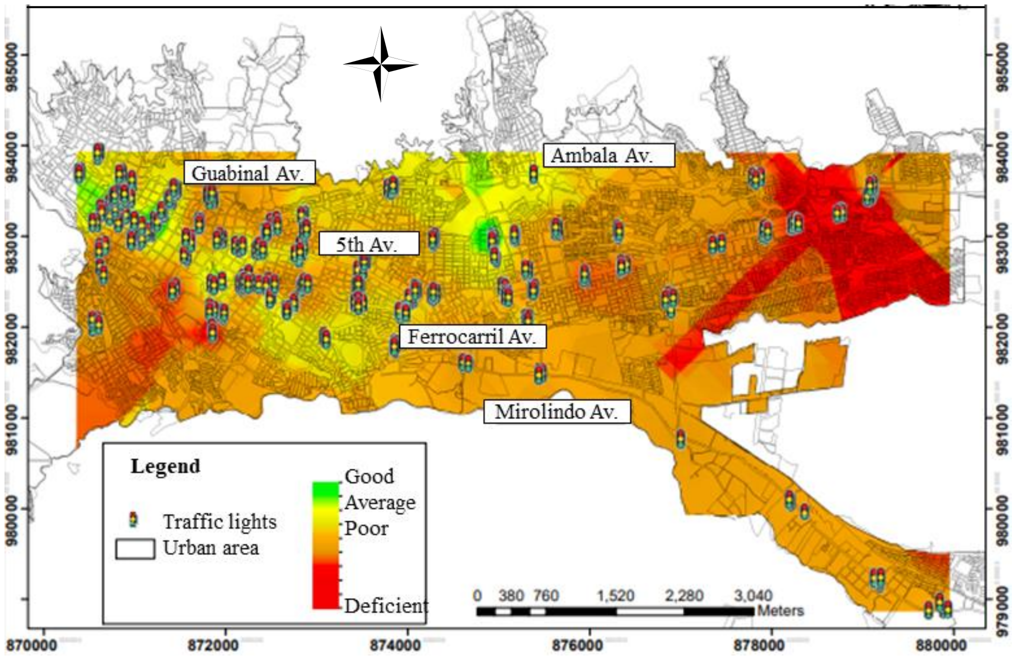


Figure 5. Map of traffic signalized intersection status 2023 (Source: Authors)

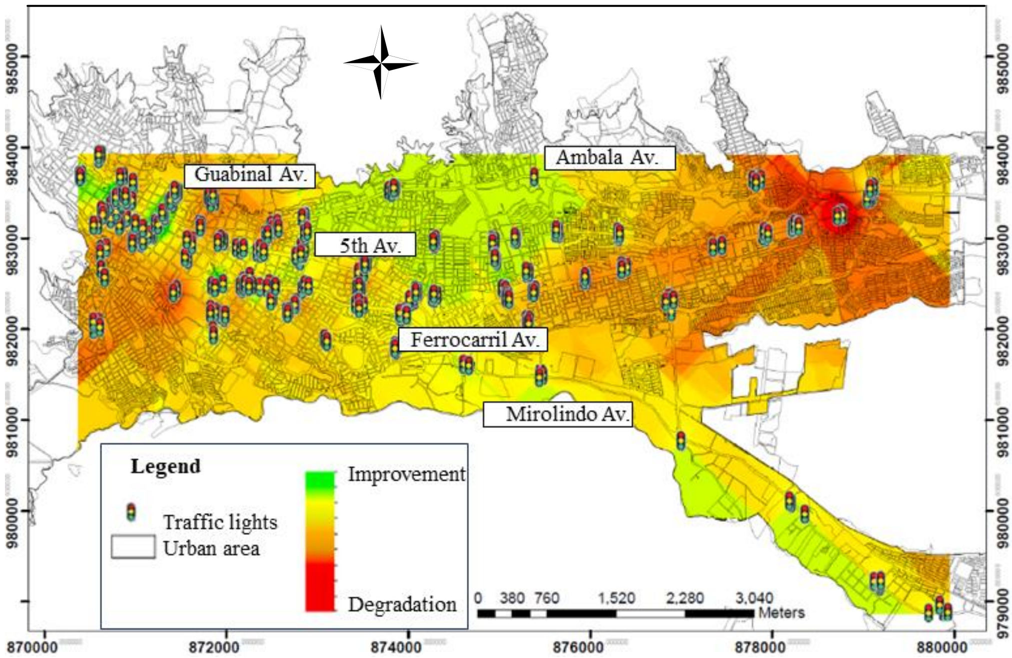


Figure 6. Comparison map of Signalized intersections year 2018 vs 2023 (Source: Authors)

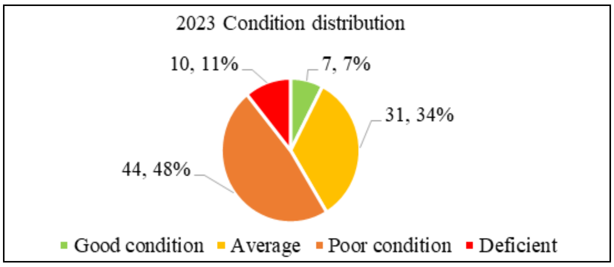


Figure 7. Status of signalized intersections 2023

## CONCLUSION

This research reaches the following main conclusions: 1) The method is suitable for evaluating intersections and can be used to specify their characterization, as well as to provide a rating that allows for analysis and monitoring over time. 2) The application of this assessment method is important for planning the maintenance of these road infrastructure elements, which in fact, must be done by the competent entities. 3) The limitations of this method consist of susceptibility to changes in the infrastructure, extensive data cleaning, and subjective interpretation by the analyst. 4) By implementing this method in the case study of Ibague, Colombia, it can be concluded that between 2018 and 2023 most of the total number of intersections (85%) lowered their rating and in turn deteriorated to a greater extent compared to those that presented improvements. Additionally, a significant deterioration is observed since in the first year of study a minimum percentage of intersections were in the lowest states of deterioration, the majority in regular condition and a higher percentage in good condition with respect to the assessment results of 2023. Therefore, lack of maintenance and lack of adaptation to mobility needs are the main causes of degradation.

**Author Contributions:** Conceptualization, D.E. and J.Z.; methodology, J.Z.; software, J.G. and K.D. and M.V.; validation, D.E.; formal analysis, J.G. and K.D. and M.V.; investigation, J.G. and K.D. and M.V.; data curation, J.G. and K.D. and M.V.; writing - original draft preparation, J.G. and K.D. and M.V.; writing - review and editing, J.G. and K.D. and M.V. and D.E. and J.Z.; visualization, J.G. and K.D. and M.V.; supervision, D.E. and J.Z.; project administration, D.E. and J.Z. . All authors have read and agreed to the published version of the manuscript.

**Funding:** Not applicable.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study may be obtained on request from the corresponding author.

**Acknowledgments:** The research undertaken was made possible by the equal scientific involvement of all the authors concerned.

**Conflicts of Interest:** The authors declare no conflict of interest.

## REFERENCES


Alerta, T. (2021). *No paran los robos de semáforos en Ibagué, sin luz quedó el de la calle 25 con carrera Quinta. [The theft of traffic lights in Ibague does not stop, the one on 25th Street and 5th Avenue was left without lights].* Alerta Tolima. Ibague (in Spanish).

Belge, Z.S., & Ercan, M.A. (2022). Mobility and the Role of Pedestrian in the Making of Public Space: The Case Study of Mersin. *Elsevier,* 60, 386-393. https://doi.org/10.1016/j.trpro.2021.12.050

Betancur, B.R. (2018). *Aproximación a modelos de seguridad vial en intersecciones semaforizadas de Medellín. [Approximation to road safety models at traffic signalized intersections in Medellín],* Master's Dissertation, National University of Colombia, Medellin, Colombia.

Cuellar, J. (2022). *Mercado automotor en el Tolima aumentó un 35,44% durante 202.1 [Automotive market in Tolima increased 35.44% in 2021].* El Nuevo Dia Newspaper. Ibague (in Spanish).

Doi, K., Sunagawa, T., Inoi, H., & Yoh, K. (2016). Transitioning to safer streets through an integrated and inclusive design. *IATSS,* 39, 87-94. http://dx.doi.org/10.1016/j.iatssr.2016.03.001

El Nuevo, D. (2022). *Semáforos de Ibagué, sin solución a corto plazo. [Traffic lights in Ibagué, no solution in the short term].* El Nuevo Dia Newspaper. Ibague (in Spanish).

El Olfato. (2020). *Aparatoso accidente de tránsito en el centro de Ibagué por fallas en los semáforos. [Traffic accident in downtown Ibague due to traffic light problems].* El Olfato, Ibague (in Spanish). https://www.elolfato.com/

Equipo Digital. (2019). *Esto sí es el futuro! Así funcionan los semáforos más "inteligentes" del mundo. [This is the future! This is how the "smartest" traffic lights in the world work].* Canal Uno, Bogota (in Spanish).

Fiolić, M., Babić, D., Babić, D., & Tomasović, S. (2023). Effect of road markings and road signs quality on driving behaviour, driver's gaze patterns and driver's cognitive load at night-time. *Elsevier,* 99, 306-318. https://doi.org/10.3390/safety6020024.

Francel, A. (2017). *La superposición de cartografía histórica como método de análisis morfológico y toma de decisiones urbanísticas. [The superimposition of historical cartography as a method of morphological analysis and urban planning decision making].* Urbe Revista Brasileira de Gestão Urbana, 9(2), 293–313 (in Spanish).

Garcia, E., Vidaña, J., & Rodriguez, A. (2015). *Análisis y Evaluación de Intersecciones Urbanas. [Analysis and assessment of urban intersections].* Culcyt//Vialidad (in Spanish ).

Gonzalez, P., & Lopez, D. (2018). *Desarrollo de inventario de intersecciones semaforizadas de la ciudad de Ibagué. [Development of an inventory of traffic signalized intersections in the city of Ibague],* Undergraduate Dissertation, University of Ibague, Ibague, Colombia.

INVIAS. (2023). Manual de señalización vial [Road signage manual]. Ministry of transportation, Colombia.

Lojano, J.P.G. (2013). *Propuesta para la implementación de un modelo semafórico adaptativo a sistemas integrados de transporte. [Proposal for the implementation of an adaptive traffic light model for integrated transportation systems],* Master's Dissertation, Pontifical Catholic University of Ecuador, Quito, Ecuador.

O'Flaherty, C.A. (2018). *Transport Planning and Traffic Engineering*, Elsevier, The Netherlands.

Reyes, A., Bulla, B., & Quijano, A. (2021). *Informe de calidad de vida Ibagué 2021 [Ibague 2021 quality of life report].* DANE (in Spanish).

Secretariat of mobility. (2022). *Entérese de las causas de algunos daños en la red semafórica en Ibagué. [Find out the causes of some damages in the traffic light network of Ibague],* Ibague Mayor's office, Ibague, Colombia.

Secretariat of mobility. (2019). *Inició etapa precontractual para modernizar red semafórica de Ibagué. [Pre-contractual stage for the modernization of Ibague's traffic light network has begun],* Ibague Mayor's office, Ibague, Colombia.

Shaaban, K. (2019). Assessing Sidewalk and Corridor Walkability in Developing Countries. *MDPI,* 11, 3865. https://doi.org/10.3390/su11143865

Vega, F., & Guevara, A. (2012). *Estudio de las principales intersecciones semaforizadas: En distrito uno y cinco. [Study of the main traffic signalized intersections: In districts one and five],* Undergraduate Dissertation, National University of Engineering, Managua, Nicaragua.

Yang, D., Ozbay, K., Xie, K., Yang, H., & Zuo, F. (2021). A functional approach for characterizing safety risk of signalized intersections at the movement level: An exploratory análisis. *Elsevier,* 163, 10-12. https://doi.org/10.1016/j.aap.2021.106446


Article history: Received: 21.10.2023 Revised: 27.12.2023 Accepted: 25.01.2024 Available online: 20.02.2024