Comparative Performance Analysis of Public Lighting Luminaires According to NBR 5101:2018 and 2024 Standards

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This study compares the performance of approximately 1,300 public lighting luminaires according to Brazilian standards NBR 5101:2018 and NBR 5101:2024. Using Dialux® software, over 37,500 simulations were conducted with IES photometric data from luminaires certified by INMETRO and listed by PROCEL. Five standard installation scenarios were modeled based on NBR 5101:2018 reference layouts. Results identify the most efficient luminaires for each case and outline the main changes in the 2024 standard, including correlated color temperature limits, stricter light pollution control, and reduced mounting angles. The findings indicate significant impacts on current projects and provide guidance for future public lighting implementations.

Keywords: Public Lighting. NBR 5101. Lighting Efficiency. Dialux Simulation.

Abbreviations: ABNT, Brazilian Association of Technical Standards. INMETRO, National Institute of Metrology. PROCEL, National Program for Electric Energy Conservation. IES, Illuminating Engineering Society. TCC, Correlated Color Temperature.

Public lighting is a key component of urban infrastructure, contributing to safety, quality of life, and the proper functioning of society, far beyond the basic function of illuminating streets [1]. Well-designed lighting systems reduce traffic accidents, discourage criminal activity, and encourage the use of public spaces during nighttime, fostering cultural and economic vitality in municipalities [2].

In Brazil, the Brazilian Association of Technical Standards (ABNT) defines technical requirements for public lighting through NBR 5101 – Public Lighting: Procedure [3]. This standard specifies the performance parameters for luminaires according to the classification of roads, including average luminance, global and longitudinal uniformity, threshold increment, and the luminance ratio of adjacent areas.

Other institutions also play important roles in public lighting regulation, like the National Institute of Metrology (INMETRO), through Ordinance No. 62 [4], certifies luminaires for public lighting to ensure compliance with efficiency and safety standards. Additionally, the National Program for Electric Energy Conservation (PROCEL) [5] promotes energy efficiency by encouraging the adoption of more efficient technologies and practices.

In addition to meeting efficiency and safety standards, the actual performance of luminaires in the field must be evaluated according to photometric criteria. IES (Illuminating Engineering Society) curves, which represent the spatial distribution of luminous intensity [6], are essential for determining light directionality and uniformity, enabling the selection of the most appropriate luminaires for each road type or application scenario [7].

Moreover, the recent update from NBR 5101:2018 to NBR 5101:2024 introduced significant changes, such as correlated color temperature limits, stricter light pollution control, and reduced installation angle allowances.

Understanding these changes and their implications for public lighting projects is essential for achieving efficiency, regulatory compliance, and sustainability in urban environments. This study addresses this gap by performing large-

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scale simulations to evaluate the impact of these regulatory updates.

Theoretical Background

Photometric Parameters

The design of public lighting systems is governed by photometric principles established in ABNT NBR 5461 [1] and operationalized in ABNT NBR 5101 [2], which define the parameters required to ensure visual comfort, safety, and energy efficiency in urban environments.

The primary photometric parameters are:

- Luminous flux (Φ) – the total quantity of light emitted by a source, measured in lumens (lm). It indicates the overall light output of a luminaire.
- Luminous intensity (I) – the amount of light emitted in a specific direction, expressed in candela (cd). It defines the directional distribution of the emitted light.
- Illuminance (E) – the amount of luminous flux incident per unit area, measured in lux (lx). It quantifies how much light reaches a surface.
- Luminance (L) – the measure of the perceived brightness of a surface, expressed in candela per square meter (cd/m^2), directly related to visual comfort and uniformity perception.
- Uniformity factors – overall uniformity (Uo), given by the ratio of minimum to average luminance or illuminance, and longitudinal uniformity (Ul), given by the ratio of minimum to maximum luminance along the driving axis. These factors ensure consistent light distribution and reduce visual fatigue.
- Threshold increment (TI) – a percentage value that quantifies the loss of visual performance due to disability glare, affecting the ability to detect objects on the road. Lower TI values indicate better glare control.
- Correlated color temperature (CCT) – expressed in kelvin (K), it describes the color appearance of the emitted light, influencing visual comfort, object recognition, and environmental perception.

Photometric data for luminaires is typically provided in IES files standardized by ANSI/IES LM-63 [3], which encode the spatial distribution of luminous intensity in polar coordinates. These files also contain essential technical specifications such as rated power, luminous efficacy, optical classification, and light distribution pattern.

Luminaire Mounting Data

The mounting configuration of luminaires plays a decisive role in the photometric performance of public lighting systems. For this study, the installation parameters were defined according to the standard road and pedestrian classes described in ABNT NBR 5101:2018, ensuring comparability across all scenarios.

For each class, the following variables were fixed:

- Mounting height (Hm) – vertical distance from the luminaire to the road surface, determined by road class.
- Overhang (O) – horizontal displacement between the pole and the road edge.
- Spacing (S) – center-to-center distance between poles along the road.
- Number of lanes (NL) – total traffic lanes considered in the design, influencing the required mounting height and luminaire distribution.
- Road width (R) – total pavement width, measured between curb edges, directly impacting pole spacing and light distribution requirements.
- Arrangement type – single-sided, opposite, or staggered configuration, depending on the road class.
- Mounting angle (Tilt) – angle between the luminaire optical axis and the horizontal plane, limited by standard requirements.

Road Classification

In NBR 5101:2018, road lighting classes are divided into V1–V5 for motorized traffic and

P1–P4 for pedestrian areas, each with specific photometric requirements [2]. The 2024 revision replaces these with Class C (conflict areas, C0–C5) and Class P (pedestrian areas, P1–P6), using parameters such as vehicle speed, traffic volume, and ambient luminance for classification [4].

Main Updates in NBR 5101:2024

The 2024 revision of NBR 5101 introduced significant changes in classification criteria, photometric performance thresholds, and environmental considerations, aiming to improve safety, efficiency, and sustainability in public lighting systems. While average luminance values remain unchanged, the new version establishes stricter requirements for global (Uo) and longitudinal uniformity (Ul), as well as lower permissible threshold increment (TI), enhancing visual comfort and glare control. A key modification is the adoption of a much warmer correlated color temperature (CCT) range of 1800–2200 K, replacing the typical LED values of 4000–5000 K used in the 2018 standard. This change is intended to reduce blue light emission and its associated impacts on human health, wildlife, and the night sky.

The 2024 update also strengthens light pollution control, introducing mandatory uplight emission limits in the 90–180° zone. Installation constraints have been tightened, with the maximum mounting tilt reduced from 15° to 5°, directly contributing to glare reduction and minimizing light trespass.

Overall, these updates reflect a shift towards more rigorous technical and environmental performance standards, requiring municipalities, designers, and manufacturers to adapt luminaire selection and installation practices to meet both regulatory compliance and sustainable urban lighting objectives.

Materials and Methods

This study followed a structured sequence of steps to evaluate the performance of public lighting luminaires under the criteria of both NBR 5101:2018 and NBR 5101:2024. The methodology comprised the following stages:

1. Acquisition of all IES photometric files available on the PROCEL website for luminaires certified by the National Institute of Metrology (INMETRO);
2. Organization and completion of photometric curve data provided by manufacturers;
3. Simulation of five standardized installation scenarios defined in NBR 5101:2018, due to the absence of reference scenarios in NBR 5101:2024, using all available luminaires and processed data in Dialux® software;
4. Analysis of the simulated performance results in compliance with NBR 5101:2024 requirements;
5. Comparison of luminous source performance with NBR 5101:2018 parameters to assess the impact of the latest standard update.
6. Identification and ranking of the best-performing suppliers based on their presence among the top 10 luminaires in each scenario, providing insights into portfolio versatility and market competitiveness.

Acquisition of Photometric Curves

INMETRO Ordinance No. 62 (INMETRO, 2023) defines the technical and safety requirements for road public lighting luminaires in Brazil, as established in the Technical Quality Regulation. One of the mandatory tests is the luminous distribution measurement, carried out by accredited laboratories. These laboratories generate the luminaire's photometric curve, which is converted into an IES file following ANSI/IES LM-63 standards and published both by manufacturers and PROCEL.

For this study, photometric curves were obtained from PROCEL Publication No. 22, which compiles LED luminaires for public lighting that meet INMETRO certification requirements. Approximately 1,300 IES files were collected for analysis.

The downloaded IES files contained inconsistent or incomplete information, such as missing luminaire model names, rated power, or correlated color temperature (CCT). To ensure compatibility with Dialux® simulation requirements, all IES files were manually reviewed and edited, standardizing metadata fields to enable automated processing and scenario generation.

Simulation Scenarios

Five installation scenarios were defined based on the standard mounting patterns in NBR 5101:2018 (Table 1). The 2018 configurations were adopted for both standards due to the absence of standardized mounting layouts in NBR 5101:2024. Each scenario corresponds to a specific roadway class for motorized traffic, paired with a pedestrian lighting class. The unilateral arrangement was used in all cases, with a maintenance factor of 0.8 to account for photometric performance degradation over time.

Table 1. Mounting configurations adopted in simulations.

Mounting Configurations Adopted in Simulations					
Class	**S (m)**	**Hm (m)**	**NLs**	**R (m)**	**O (m)**
V5	35.0	7.0	3	8.10	1.5
V4	35.0	8.0	3	9.0	1.5
V3	35.0	8.0	3	9.0	1.5
V2	35.0	9.0	4	10.8	2.5
V1	40.0	12.0	4	12.0	3.0

The simulations covered five combined scenarios of roadway and pedestrian lighting classes (Table 2). Pedestrian classes (P1–P4) were assigned according to NBR 5101:2018 requirements, without specific mounting standards, ensuring consistency between the two standards in the comparative analysis.

Table 2. Simulated scenarios.

Simulated Scenarios		
Scenario	**Roadway Class**	**Pedestrian Class**
1	V1/C1	P1
2	V2/C2	P2
3	V3/C3	P3
4	V4/C4	P4
5	V5/C5	P4

For NBR 5101:2024, the corresponding Conflict Area Classes (C1–C5) and Pedestrian Classes (P1–P5) were adopted for direct comparison, maintaining the same physical layouts from the 2018 scenarios.

Selection of Optimal Luminaires

For each scenario, the most efficient luminaire was selected from the set of models that fully met the requirements of both NBR 5101:2018 and NBR 5101:2024. Only the best-performing luminaire from each manufacturer was considered, ensuring that the analysis reflected optimal energy use.

Results

This section presents the outcomes of the simulations performed for the five scenarios defined by NBR 5101, applied to all luminaires certified by INMETRO. In total, approximately 37,500 simulations were conducted, allowing for a comprehensive evaluation of luminotechnical parameters under both the 2018 and 2024 versions of the standard.

The 2024 revision introduced stricter requirements, including a maximum tilt angle of 5° for luminaire mounting (compared to 15° in 2018) and more demanding pedestrian walkway lighting criteria, particularly the introduction of minimum horizontal illuminance instead of only uniformity factors. These changes significantly impacted approval rates, reducing the number of compliant luminaires in some scenarios but resulting in more realistic power ratings and energy consumption values.

Scenario Comparison

The Table 3 presents the number of approved luminaires for each scenario under both standards, along with the percentage relative to the total number tested in that scenario, and the power rating of the most energy-efficient approved luminaire.

The analysis reveals clear trends in how the 2024 update reshaped luminaire approval rates:

- Scenarios 1 to 3 (higher traffic and more demanding lighting classes) saw a substantial increase in approved luminaires, indicating that the revised criteria allowed more models to comply while still ensuring realistic power ratings. For example, in Scenario 2, approvals increased from 7 to 70 models, with a power reduction from 121 W to 100 W.
- Scenarios 4 and 5 (lower traffic or predominantly pedestrian areas) experienced a sharp drop in approved luminaires, from 800 to 90 in Scenario 4 and from 4,000 to 260 in Scenario 5. This is mainly due to the introduction of the minimum illuminance requirement for pedestrian walkways, which proved harder to meet than the previous uniformity-only criteria.
- In terms of power optimization, the 2024 standard maintained or reduced wattage in high-demand scenarios. However, in Scenario 4, the best- compliant luminaire under the new standard had a slightly higher wattage (48 W) than the most efficient 2018 model (33 W).
- The percentage of approved luminaires shows how the 2018 standard was more permissive in low- demand classes, potentially allowing oversized luminaires, whereas the 2024 revision imposes stricter alignment with actual operational needs.

Overall, the transition to NBR 5101:2024 resulted in more consistent and technically sound compliance, particularly for urban areas with complex lighting demands. However, the stricter pedestrian area criteria reduced the variety of compliant products, which could impact market options for low-intensity lighting applications.

Best Suppliers by Scenario Coverage

Beyond individual scenario results, the study consolidated performance to identify the suppliers with the broadest presence across scenarios, considering only their most energy- efficient approved luminaire per case.

Table 3. Approved luminaires and power comparison (NBR 2018 *vs*. NBR 2024).

Approved Luminaires and Power Comparison (NBR 5101:2018 *vs*. NBR 5101:2024)				
Scenario	**Quantity Approved Luminaires**		**Average Power (W)**	
	NBR 2018	**NBR 2024**	**NBR 2018**	**NBR 2024**
1	5 (0.05%)	40 (0.42%)	196	179
2	7 (0.08%)	70 (0.75%)	121	100
3	9 (0.09%)	90 (0.94%)	195	195
4	800 (8.60%)	90 (0.97%)	33	48
5	4,000 (43.0%)	260 (2.8%)	20	24

The Table 4 ranks suppliers by the number of different scenarios in which they appeared among the top 10 performers for that scenario, providing an indicator of portfolio versatility under the diverse requirements of NBR 5101.

Table 4. Top Suppliers by scenario.

Top Suppliers by Scenario		
Rank	**Manufacturer**	**Scenarios**
1	Philips	1, 3, 4, 5
2	Unilumen	3, 4, 5
3	Esb	2, 3, 4
4	Zagonel	1, 2
5	Sxlight	4, 5
6	Demape	4, 5
7	Tecnowatt	2, 4
8	Soneres	4, 5
9	Tradetek	1, 5
10	Lumer	3, 4

The supplier ranking analysis highlights notable differences in market presence and adaptability among manufacturers. Philips stands out as the most versatile supplier, achieving approvals in four different scenarios and demonstrating strong adaptability to varied urban lighting requirements. Unilumen and Esb follow, with approvals in three scenarios each, indicating a balanced ability to combine efficiency and compliance under both the 2018 and 2024 standards.

Manufacturers such as Zagonel, Sxlight, and Demape show solid competitiveness in specific applications, particularly in moderate-traffic and pedestrian-oriented lighting contexts, where technical performance requirements differ from those of high-traffic scenarios. Even suppliers that appear in only two scenarios, such as Tecnowatt and Soneres, present high- performance solutions within their targeted niches, suggesting specialization in certain roadway or pedestrian classes.

Overall, this supplier-based perspective complements the scenario-specific performance results by providing an additional layer of analysis for market evaluation. It also offers valuable insights for strategic procurement decisions in public lighting projects, enabling municipalities and designers to align supplier selection with regulatory compliance, energy efficiency, and application-specific performance goals.

Conclusion

This study evaluated INMETRO-certified luminaires under NBR 5101:2018 and 5101:2024 through 37,500 simulations in five roadway and pedestrian scenarios. The 2024 revision introduced stricter mounting tilt limits, higher uniformity, and minimum illuminance requirements for pedestrian areas, affecting both approval rates and optimal power ratings.

Approval counts increased in high-demand scenarios (1–3) but dropped sharply in low-demand/pedestrian scenarios (4–5). The power comparison revealed reductions in Scenario 1 (196 W to 179 W) and Scenario 2 (121 W to 100 W), stability in Scenario 3 (195 W to 195 W), and increases in Scenario 4 (33 W to 48 W) and Scenario 5 (20 W to 24 W). These changes show efficiency gains in demanding contexts, while stricter criteria for pedestrian lighting can raise power needs.

Supplier analysis identified Philips as the most versatile (approved in four scenarios), followed by Unilumen and Esb in three scenarios each.

The results indicate that NBR 5101:2024 promotes safer, more efficient, and environmentally responsible public lighting, but also narrows options for pedestrian-focused applications. Municipalities and designers must adapt luminaire selection to balance compliance, performance, and energy efficiency.

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