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Assessment of the discrepancy between daylight factor and using illuminance data methods by climate zones under EN:17037

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Abstract:
Conducting a rigorous evaluation of the daylight performance of buildings is essential for human health and energy efficiency. Today, there are two main methods used for analysis: the daylight factor, which has been used since the early 1900s, and the newer approach known as climate-based modelling. Both methods are employed in the EN 17037 Daylight in Buildings' standard. Utilizing different calculation methods causes discrepancies in daylight provision performance analyses of a room. However, there is no definition or limitation for this subject in the standard. As a result, researchers prefer different calculation methods for the same location in daylighting analyses without a clear justification. Additionally, there is a lack of parametric methods that follow the guidelines of the standard. This study aims to analyse the impact of calculation methods on daylighting analyses according to different regions and generate parametric methods in compliance with the standard. In this respect, comparison calculations are conducted for a theoretical room situated in all 81 provinces of Turkey, where variant climate types occur over a year. Furthermore, parametric workflows are generated using Rhinoceros/Grasshopper following the directives of the standard. The findings indicate that the method choice affects the illumination levels in all zones, ranging from 15 to 114 %.

Keywords:
daylighting; daylight provision; Grasshopper; daylight factor; using climate data

1 Introduction

Numerous studies have demonstrated that the dynamic characteristics of daylight, which result in varying illuminance levels and light colours throughout the day, are in sync with the human circadian rhythm [1-5]. Architects prioritise improving the daylight performance of buildings in which occupants spend a long time. This focus aims to benefit from the physiological and psychological effects of daylight and conserve dwindling energy resources. Today, it is becoming increasingly common to analyse daylighting performance using simulation tools during the design phase of a project [6-11]. The analysis may be conducted through the daylight factor method or using the annual climate data method.

Daylighting studies were put into a mathematical formula in the early 1900s during the reconstruction of postwar Europe [12]. The pioneer of these studies, Waldraw, stated that daylight analyses cannot be conducted by considering the dynamic form of daylight that differs during the day and year; instead, a uniformly distributed sky model should be used [13]. Therefore, the daylight factor (DF), signifying the ratio of the 'internal horizontal diffuse illuminance' to the 'external diffuse horizontal illuminance' on the work plane of a room under overcast sky conditions, has been used since the beginning of the 20th century [14-16]. In the overcast sky model, which was standardised by CIE in 1942, the light distribution is diffused and direct illuminance is neglected [17]. Due to the fact that in many locations variable sky conditions occur over a year, researchers have investigated the accuracy of calculations using the daylight factor method. Tregenza [18] measured external and internal horizontal illuminance levels at the University of Nottingham between May 1978 and July 1979. Significant differences were observed between the estimated and measured values. These findings have motivated studies to generate new formulas and models, including direct sunlight. In order to achieve realistic sky conditions, the daylight coefficients approach was developed. This method divides the sky into patches and generates sky matrices to determine both the direct and diffused illumination levels [19]. Researchers have attempted to determine the total illuminance by incorporating global solar radiation, sun altitude, azimuth angle, and cloudiness parameters [20, 21]. New sky models were created such as 'clear sky', 'intermediate sky', and so forth [22]. To evaluate the long-term daylight performance of a building accurately, it is necessary to consider a wide range of sky conditions. However, calculating the sky matrix for each condition individually was particularly challenging. Mardeljevic, the founder of climate-based daylight modelling, pointed out that with advances in computer technology, sky matrices can be estimated for the entire year using the finite element method. Additionally, Mardeljevic stated that hourly or sub-hourly meteorological climate data can be employed for this purpose [23]. Today, long-term climate data for many locations worldwide are available, and outcome metrics such as useful daylight illuminance (UDI), daylight autonomy (DA), and spatial daylight autonomy (sDA) have been developed for climate-based modelling [23-25]. The timeline of the development process for both methods is shown in Figure 1.

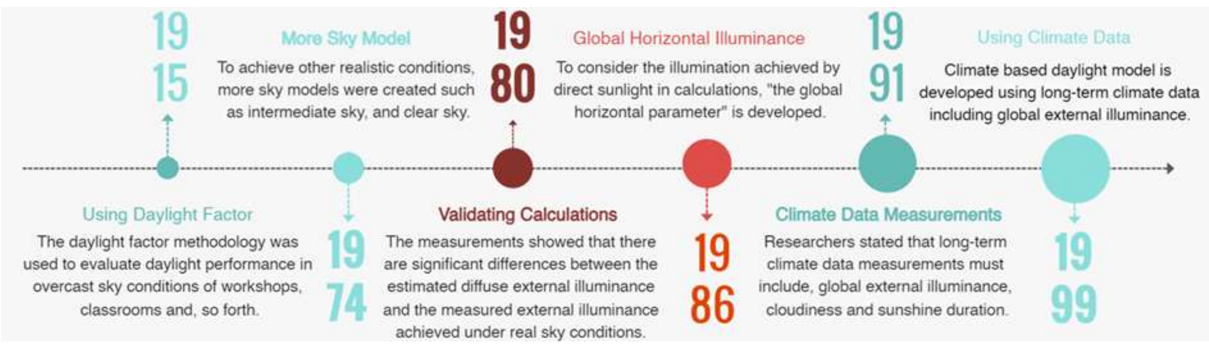

Figure 1. The timeline of the two methods' development

Based on these studies, the calculation method 'using illuminance level' is considered in the EN 17037 Daylight in Buildings' standard, published in 2018. The EN 17037 Daylight in Buildings' standard was published by the European Committee for Standardization (CEN) and is used in daylighting studies, especially in European countries [26-29]. One of the four criteria specified in the standard for evaluating the daylighting performance of rooms is 'daylight provision', which has been an integral part of daylighting analyses for many years [30]. The daylight provision performance of a room was evaluated using two criteria: target illuminance level (ET) and minimum target illuminance level (ETM). ET is the value that should be achieved at 50 % of the reference plane and ETM is the value that should be acquired at 95% of the reference plane. Both ET and ETM should be provided at least half of the daylight hours. Two methods are recommended in the standard for calculating 'daylight provision': The first method is the 'using daylight factor' which is based on the CIE overcast sky model, whereas the second is the 'using illuminance levels' relying on climate data.

Solar radiation that forms horizontal illumination on the Earth's surface has two components: direct visible irradiance from the solar disk and diffuse visible irradiance of the sky scattered by particles in the atmosphere [31]. In daylight theory, this issue is considered with two notions: 'diffuse horizontal illumination ($E_{v,d}$) ', which is generated by only skylight and 'global horizontal illumination ($E_{v,g}$)' which is composed of both direct sunlight and diffused skylight [32]. As mentioned earlier, $E_{v,d}$ is employed in the first method, and direct sunlight is neglected, whereas $E_{v,g}$ is employed in the second method, and both components of daylight are considered in the calculations using the sky matrix. This difference in input parameters causes noteworthy disparities in sunny regions [33].

The standard recommends choosing the 'appropriate sky type' in the calculations and states that the DF method can lead to a reduction in sunny climates. However, there is no definition for 'sunny climate' or directive for the selection of the 'appropriate sky type' for different climate zones. In temperate climate zones, variant sky types occur throughout the year, including both overcast sky and clear sky. Therefore, it is not easy to make a decision on the appropriate calculation method worthfully. Consequently, in discrete research, different calculation methods are preferred for the same location such as Istanbul [27, 34]. Due to its recent publication, the number of studies referring to the EN 17037 standard is limited, and these studies did not use a parametric workflow following the EN 17037 directives as they evaluated only one or a few cases and were conducted in a specific location [25, 27, 28]. Instead, the daylight autonomy (DA), spatial daylight autonomy (sDA) or useful daylight illuminance (UDI) parameters, which are utilized in the climate-based daylight modelling, are preferred due to the similarity to the second method recommended in the standard [8, 28, 35]. These parameters result in a percentage ratio rather than an illuminance level. Nevertheless, the method recommended in the standard determines the performance of a room according to the illuminance levels. Therefore, there is a need for a comparative study of zones with variant sky types and to establish a parametric methodology in accordance with the standard.

The daylighting performance of a room is influenced by several factors, including its location, orientation, size, form, placement, and transparency of openings, as well as the depth of the room and reflectance of surfaces [36]. Since the amount of direct sunlight varies primarily depending on the geographical conditions, location parameters come to the fore when discussing the effect of method choice. In this study, calculations were performed using both methods through a theoretical room with fixed parameters located in all 81 provinces of Turkey, where variant climate types can be observed over a year. This study provides an assessment of the discrepancy between the two methods recommended by the standard by comparing their results across different climate zones. Furthermore, it contributes to reducing time losses in daylighting studies, owing to the parametric workflows generated in accordance with the standard to obtain illuminance levels at a specific ratio of the reference plane.

2 The study area

Turkey has a wide geographic area, lying from Asia to Europe, and its coasts extend from the Mediterranean Sea to the Black Sea. It has a large scale of “global horizontal radiation” in the range of 1,145-1,875 kWh/m², and “annual average sunlight exposure durations” between 4,22-8,50 hour/day (Figure 2, Figure 3). Therefore, various types of climate can be observed across the country. Turkey was selected as the study area due to its climatic diversity, which has the potential to provide comparisons for many other zones with similar climatic parameters. Four main zones can be observed according to meteorological maps of Turkey:

- The first zone, located on the southern and western coasts of Turkey, is characterised by a Mediterranean climate zone with clear-sky type most of the year, high global radiation (1,714-1,875 kWh/m²), and long sunlight durations (7,50-8,50 hours/day).
- The second zone is found in the north of the Mediterranean zone where a temperate climate is observed with high global radiation (1,552-1,713 kWh/m²) and sunlight durations in the range of 6,50-7,49 hours/day. This zone extends further to the northern regions of the west, due to the climate effects of the Mediterranean Sea.
- The third zone lying in the central Anatolia region, has intermediate global radiation in the range of 1,390-1,551 kWh/m² and intermediate sunlight durations in the range of 5,50-6,49 hours/day.
- The fourth zone, located in the Northern Black Sea region, is characterised by a temperate climate type with low global radiation (1,145-1,389 kWh/m²) and low sunlight durations (4,22-5,49 hours/day), where the sky is covered with clouds most of the year.

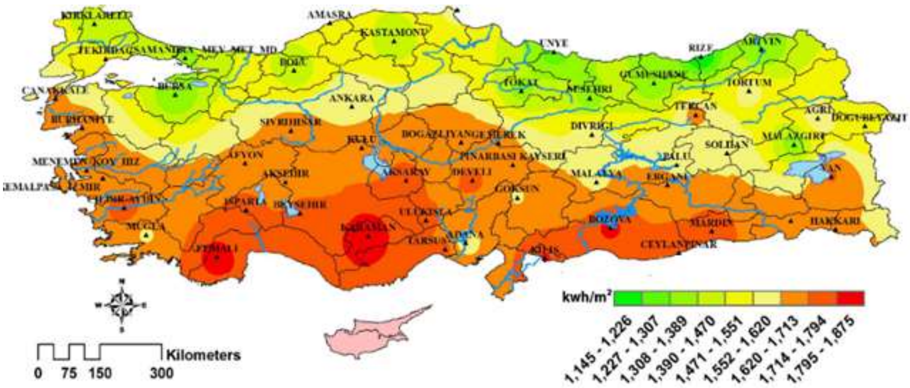

Figure 2. The distribution of average annual total global solar radiation in Turkey [37]

Figure 3. Average exposure to sunlight durations per day in Turkey [38]

Provinces with comparable climate data were categorised based on meteorological maps to facilitate the analysis of the method selection effects by zone. As a consequence, Zone-1 held 11 provinces, Zone-2; 27 provinces, Zone-3; 34 provinces, and Zone-4; 9 provinces, respectively (Figure 4).

Figure 4. Zones generated in the study based on the meteorological data

3 Research methodology

The research methodology was based on modelling a simple room located in all 81 provinces of Turkey, where different climate zones can be observed. The primary objective of this study was to assess the discrepancy between the two methods across various climate zones and develop parametric workflows in alignment with the EN 17037 standard. The parametric design is compatible with the theoretical approach of this study, as it enables the calculation of many alternatives in a short time [39, 40]. The calculation tool should enable Daylight Factor and climate-based daylight calculations. Furthermore, it should allow the selection of multiple locations, convert the output data to illuminance levels, and be appropriate for evaluating the results automatically, thus avoiding manual or one-by-one assessments. The integrated software and plug-in package Rhinoceros/Grasshopper / Ladybug & Honeybee met the requirements of the study by providing modelling capabilities, developing a parametric interface, conducting daylight analysis, and following design revisions simultaneously [41-44]. In this respect, this package is a common solution preferred in daylighting studies [45-47]. To organise the research flow according to the EN 17037 standard, a parametric methodology was generated for the calculations using Rhino/Grasshopper and Ladybug/Honeybee. The results were exported to Excel, where web-based cartogram map graphics were prepared for visualisation. The research methodology was composed of three phases: modelling, creating workflows in Grasshopper, and data analysis.

3.1 Modelling the room

In the first phase, a theoretical room was created based on the typical dimensions and opening sizes commonly used in Turkey. To focus on the main subject of the study, the limitations of the model room were established with dimensions of 4 m width, 5 m depth, and 3,5 a height. The room was oriented to the south, featuring an opening 2 m in width and 2,2 m in height, and a parapet height of 0,85 m. This configuration results in a window-to-wall ratio of 0,3. The reflectance of the interior surfaces is specified in accordance with the EN 17037 standard, ceiling: 0,80, wall: 0,60, floor: 0,40 and the transmittance of the window glass is accepted as

0.85, which refers to a basic double glass' value. Following the recommendations of the standard, the reference plane was settled 0,85 m above the floor and 0,50 m away from the walls. Using the equation stated in the standard, grid intervals were calculated as a maximum of 0,62 m. For more precision, 48 calculation points with 0,50 m intervals were generated in the study (Figure 7, Phase 1).

3.2 Parametric workflows created in Grasshopper

As illustrated in Figure 5 and Figure 6, this paper presents two algorithmic workflows generated in Grasshopper. The first workflow is for determining illuminance levels "using daylight factor (method 1)" and the second one is for calculating illuminance levels "using illuminance data (method 2)".

The first step before creating the workflows was to select the appropriate climate data. Daylighting analyses in Grasshopper/Ladybug primarily depend on climate data downloaded from a website [48]. The website data source provides three types of climate files for Turkey, which are obtained using different calculation methods with extensions of IWEC (The International Weather for Energy Calculation), TurTMY (Turkey Typical Meteorological Year), TurTMYx (Turkey Typical Meteorological Year Expanded). The IWEC climate data were obtained as part of the ASHRAE 1015 research project and span from 1982 and 1999. The data were specific to only Istanbul, Izmir, and Ankara provinces [49]. TurTMY climate data, covering the period of 1989-2006, were generated by Pusat et al. [50] utilising the widely applied 'typical weather year approach' with the Finkelstein-Schafer statistical method. This method is based on creating a typical year via the selected months of the mean, maximum, and minimum values of the climate parameters. After an initial investigation of only eight provinces of Turkey (İstanbul, Ankara, Trabzon, Van, Diyarbakır, Adana, Sivas, and Denizli), the enquiry was enlarged to encompass all the provinces of the country in 2022 [51, 52]. 'TurTMYx' files are created by the authors of the website for the range of 2007-2021 [52]. This study aims to perform calculations for all provinces in Turkey. Therefore, the first approach in selecting climate data was using the files with the 'TurTMYx' extension, since they are the most recent ones. However, these files do not originate from academic or government sources. Therefore, their reliability could not be validated. As illustrated in Phase 2 of Figure 7, climate data with the TurTMY extensions were selected since they are based on peer-reviewed academic research, are more up-to-date than the IWEC data, and are available for all provinces in Turkey.

After selecting the climate data and importing weather files, workflows were generated to determine the illuminance levels in accordance with the standard (Phase 2 of Figure 7).

Workflow of the first calculation method (Daylight factor model - Figure 5):

- The $E_{v,d,med}$ values were calculated according to the directives of the standards for all the provinces.
- To obtain precise results 'HB Daylight factor' is used with the 'HB Radiance Parameter' and the 'detail level' is set to '2'.
- The results of the 48 calculation points are ordered from smallest to largest with the 'Sort' tool.
- 'List Length' and 'Round' features are used to determine the area corresponding to the 50 % and 5 % of the reference plane that target illuminations do not need to provide. The 'Ceiling' option of the 'Round' is employed to round the rational numbers to natural numbers.
- The list is separated by rounded numbers via the 'Split'. The 'B' set, which has high performed values, is selected.
- The lowest elements of the set 'B' are filtered with 'List Item'. Thus, DF values provided at least 50 % and 95 % of the reference plane were obtained.
- The obtained values are multiplied by '100' and divided by the 'median external diffuse illuminance levels'.

- Consequently, illumination levels provided at 50 % and 95 % of the reference plane at least half of the daylight hours were achieved.

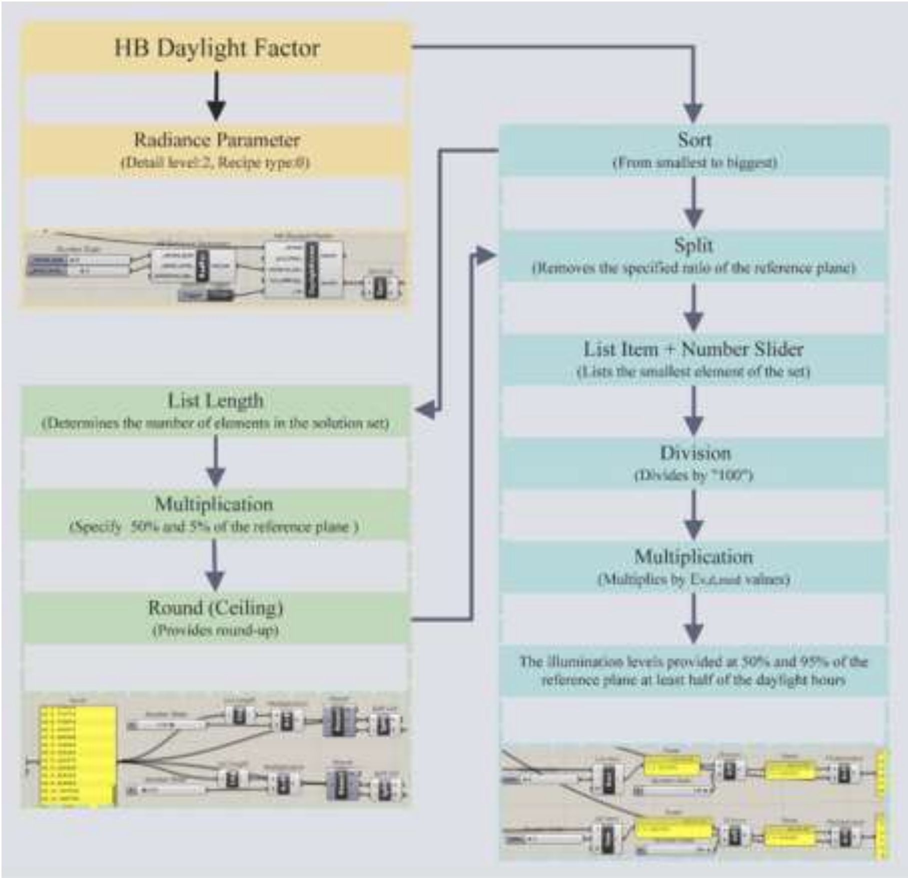

Figure 5. Workflow of the first calculation method

Workflow of the second calculation method (Using illuminance levels - Figure 6):

- The workflow for the second method begins by listing the links for the climate data of 81 provinces in Turkey.
- The list is connected to the “list item” and "number slider", which has a range of 0-80, to perform a multi-calculating process.
- The “Download EPW” was utilized to access the links.
- The ‘epw’ data is converted to ‘wea’ format via ‘HB Wea From EPW’.
- For hourly calculations over a year ‘HB Annual Daylight’ is utilized.
- To achieve precise results the ‘HB Radiance Parameter’ is used and ‘Detail Level’ is set to ‘2’.
- Calculation results are converted to hourly data with ‘Annual to Data’.
- Using "LB Deconstruct Data", 48 data set is created. Each set contained 8760 elements (365 d × 24 h).
- Since the standard evaluations are carried out according to half of the daylight hours, the results are flipped with the ‘Flip Matrix’ command. Thus, the 48-calculation point’s 8760-hour data is converted to 8760 datasets with 48 elements.
- For each hour set:
  - The data of 48 calculation points ordered from smallest to biggest.
  - ‘List Length’ and ‘Round’ tools are used to determine the area corresponding to the 50 % and 5 % of the reference plane that target illuminations do not need to provide. The ‘Ceiling’ option of ‘Round’ is used to round the rational numbers to natural numbers.

- Using the ‘Split’ command the list is separated by rounded numbers. Since the list is ordered from smallest to largest, the ‘B’ set, which has high performed values, is selected.

- The lowest elements of the high-performing sets ‘B’ are filtered with ‘list item’ and ‘8760 items’ are converted to ‘a list’ using the ‘flatten’ property of the list item command. Consequently, illuminance levels achieved at least 50 % and at least 95 % of the reference plane were obtained over half of the year.
- To range these values from biggest to smallest, ‘Sort’ is used with the ‘reverse’ property.
- The value obtained at least 2190 hours, is determined with the ‘list item’ command.
- Consequently, illumination levels provided at 50 % and 95 % of the reference plane at least half of the daylight hours were achieved.
- As this process will be repeated 81 times, the ‘data recorder’ command is used to list the results automatically.

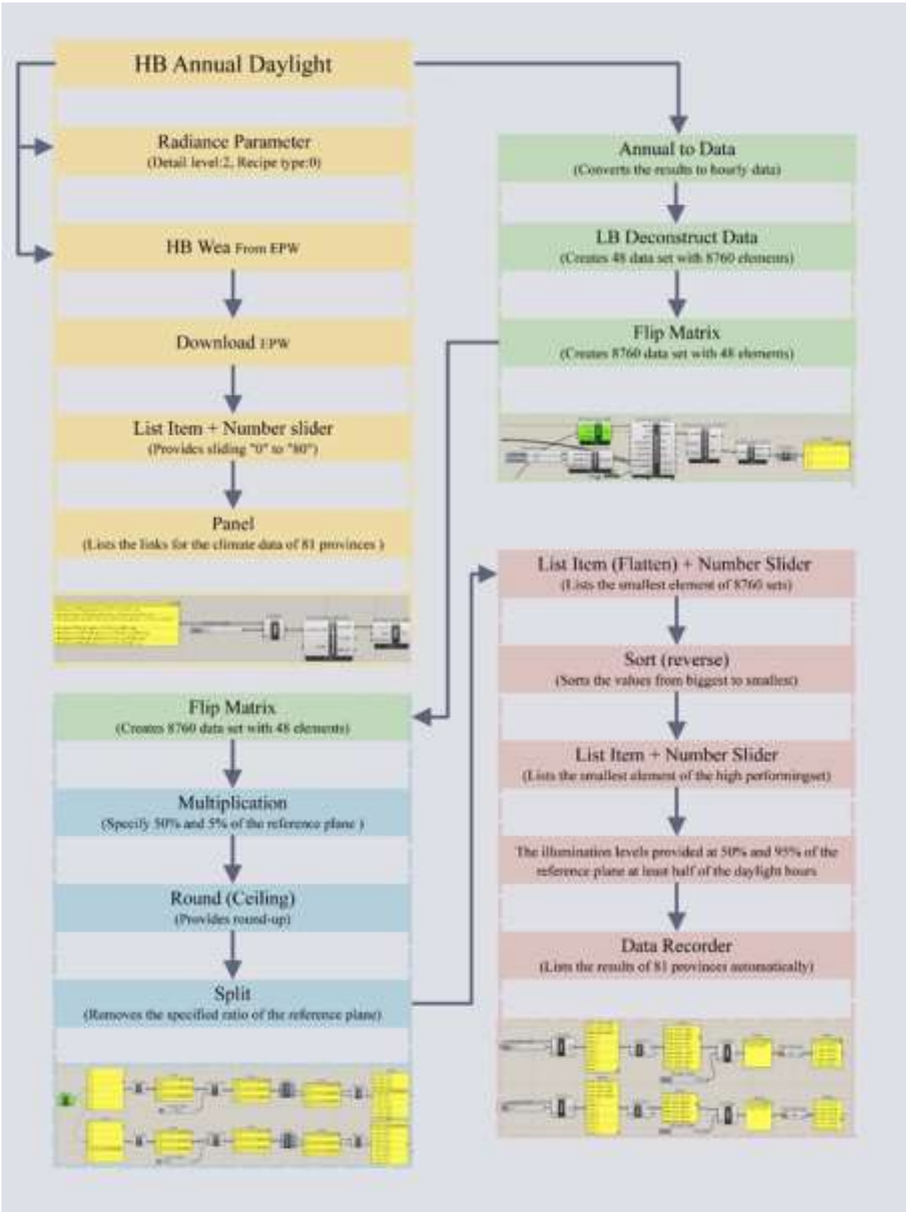

Figure 6. Workflow of the second calculation method

3.3 Analysing data

Phase 3 illustrated in Figure 7 demonstrates the data analysis methodology used to achieve the main goal of the study. The provinces were grouped according to the meteorological maps shown in Figure 2 and Figure 3. The calculation data were transferred to Excel for comparison. The illuminance ranges and impact of the method choice according to the variant climate regions were explored. Moreover, the compatibility of the distribution of the calculated results with Turkey's meteorological maps was also evaluated. After the calculations, visual expressions were prepared using web-based cartogram maps in Microsoft Excel.

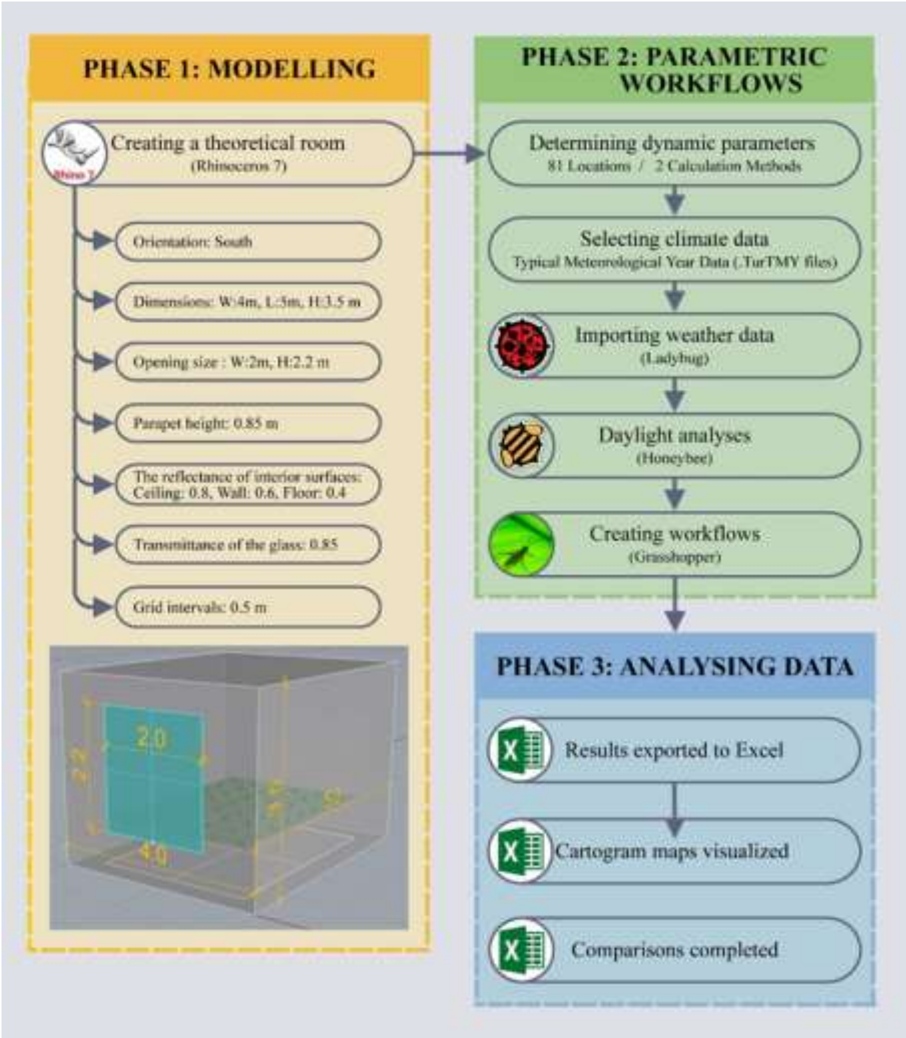

Figure 7. Organization of research methodology

4 Results and discussion

A total of 162 calculations were performed in this study. To explore the accuracy of the methods, the distribution of the calculation results was compared with meteorological maps of Turkey, as shown in Figure 2 and Figure 3.

Due to the adaptive mechanism of eye optics, the impact on visual comfort can vary immensely between high and low illuminance levels, even though the difference in lux values are the same. For instance, a difference of 200 lm/m² between 1200-1400 lm/m² and 100-300 lm/m² affects the daylight provision performance of the room at low levels. Conversely, it had an insignificant impact at high levels. Therefore, the discrepancies by zone were explored through a ratio. For example, while the illuminance level obtained using the 1st method for Hatay

Province was 722 lm/m^2, it was 1146 lm/m^2 using the 2nd method. The difference was found as 424 lm/m^2 and divided by 722 lm/m^2; the difference ratio was determined to be 59 %.
The results were evaluated not only through a ratio but also by using the recommended limit values in the EN 17037 standard for target illuminance levels (ET) and minimum target illuminance levels (ETM). Three target levels, 'minimum', 'medium', and 'high', are established for this parameter in the standard. Analyses conducted by a daylighting consultant were instrumental in providing designers with guidance for the effective utilisation of daylight. Thus, the impact of the method choice on daylight provision performance was assessed, and the degree of divergence was evaluated. The results were classified based on the recommended limit value levels for the ET performance and ETM performance in the standard. To analyse the variation between the two methods, a score was given for the values, '0' if inadequate range, '1' for minimum range, '2' for medium range, and '3' for high range values (Table 1). The performance level provided for both ET and ETM was considered in the concurrent evaluation of ET and ETM. For instance, in Hatay Province, a score of '2' was given for ET performance, whereas a score of '1' was given for ETM performance. In such instances, the common value of both parameters is '1', so the daylight provision performance for Hatay province is designated as '1'.

Table 1. Target illuminance levels for rooms with vertical and inclined openings (adapted from EN 17037 [30])

Parameter	**Inadequate** (lm/m²)	**Minimum** (lm/m²)	**Medium** (lm/m²)	**High** (lm/m²)
Target illuminance level at 50 % of reference plane (E_T) / Score assigned for assessments	< 300 / 0	300 / 1	500 / 2	750 / 3
Min. target illuminance level at 95 % of reference plane (E_{TM}) / Score assigned for assessments	< 100 / 0	100 / 1	300 / 2	500 / 3

4.1 The distribution of illuminance levels

The main difference between the two approaches lies in the way, how the illuminance is distributed in the skydome. The amount of solar radiation reaching the atmosphere depends on the location, day of the year, and time of day. The luminance caused by extra-terrestrial solar radiation is a function of the clearness index of the atmosphere and air mass, which is composed of air temperature, humidity, and dust [53]. In the overcast sky model, the light distribution was established uniformly from the zenith to the horizon in a 3:1 gradient. As a result, the illuminance of a sky element depends on the zenith luminance, the elevation angle of the sky element above the horizon, and the angular distance between the sky element and zenith [54]. In the second method, the sun disk is not neglected and the skydome is subdivided into parts to generate a skymesh [19, 55, 56]. The illuminance distribution was determined by considering the angular distance of the sky element from the sun disk and the zenith distance of the sun. The luminance is highest around the position of the sun and decreases as moving towards the sky perpendicular to it. Hence, each patch was calculated individually and there wasan integrated attenuation of extra-terrestrial solar radiation instead of a gradient distribution [57].
There were significant differences in the distribution of the illuminance levels between the two methods. Since the first method maintains a uniform distribution of the zenith brightness, the external luminance values are influenced by air mass components, specifically air temperature and humidity. However, these components were not related to the amount of daylight. The distribution of air temperature and humidity in Turkey proceeds from west to east [58]. Thus, the distribution in the first method followed this direction and did not align with those shown in Figure 2 and Figure 3. In Method 2, the illuminance levels achieved in the southern provinces were higher than those obtained in the northern provinces and the distribution of the values conformed to the meteorological maps of Turkey (Figure 8).

The inclusion of direct sunlight illuminance in the second method resulted in higher values of both $E_{ref,50}$ and $E_{ref,95}$ throughout the country. The $E_{ref,95}$ parameter considers low illuminance and a large percentage of the reference plane, including areas that are disadvantageous for daylighting. Hence, the difference ratio between the two methods increased in the calculation results of these areas (Table 2).

Table 2. Illuminance ranges achieved according to two methods

	Zone-1	Zone-2	Zone-3	Zone-4	All
$E_{ref,50}$ Method 1 (lx)	705-893	601-837	610-837	425-816	425-893
$E_{ref,50}$ Method 2 (lx)	1162-1285	1002-1236	852-1183	555-1027	555-1285
$E_{ref,95}$ Method 1 (lx)	336-426	287-399	291-399	203 -389	203-426
$E_{ref,95}$ Method 2 (lx)	667-716	565-703	494-663	325-558	325-716

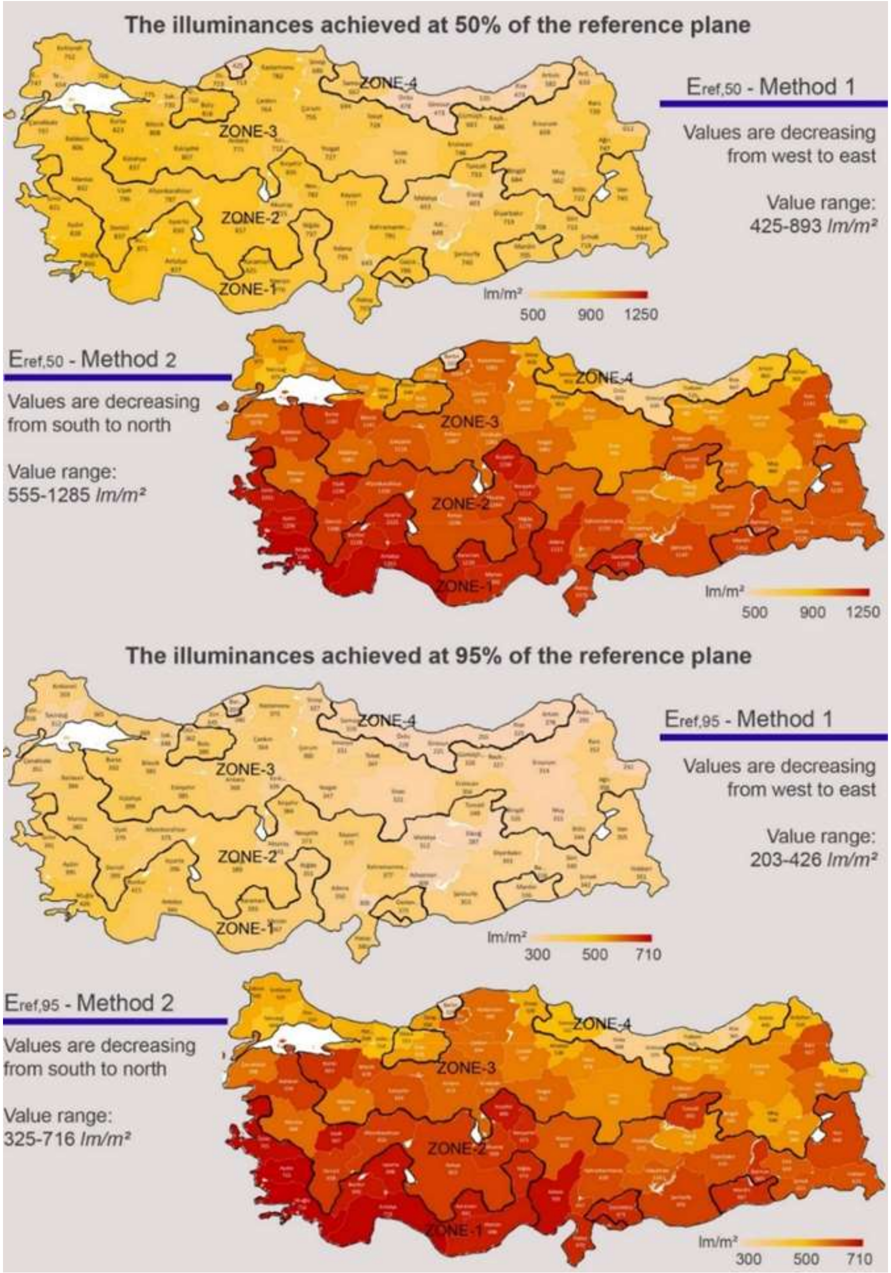

Figure 8. The illuminance levels achieved according to two methods

4.2 The difference ratio by zones

The difference ratio between the two methods ranged from 15 to 73 % for $E_{ref,50}$ and from 41 to 114 % for $E_{ref,95}$. Because the distribution in the first method was from west to east and from south to north in the second method, the values in the difference map increased from northwest to southeast. The largest difference occurred in the second zone, which included southeastern provinces. As the global radiation decreases, the impact of direct sunlight decreases, resulting in a decrease in the difference ratio between the two methods. In Zones 1 and 2, with high global radiation, this ratio was very close, whereas in Zones 3 and 4, the decrease was noticeable. The variations in Eref,95 were as high as 80 % in Zones 1 and 2, indicating an almost twofold difference in the results between the two methods. Due to the low global radiation and sunshine duration, the lowest average difference ratio was achieved in Zone 4. Therefore, in each zone, the average difference ratio is over 50 %. Even in the northern provinces with low annual sunshine duration and annual global solar radiation, the average difference ratio was 30 % for $E_{ref,50}$ and 59 % for $E_{ref,95}$ (Table 3 and Figure 9).

Table 3. Difference ratio by zones

	Zone-1	Zone-2	Zone-3	Zone-4	All
$E_{ref,50}$ Difference (%)	40-65	35-73	15-57	24-48	15-73
Average Difference ($E_{ref,50}$) (%)	52	54	41	34	46
$E_{ref,95}$ Difference (%)	66-99	59-114	41-83	42-79	41-114
Average Difference ($E_{ref,95}$) (%)	80	83	66	59	73

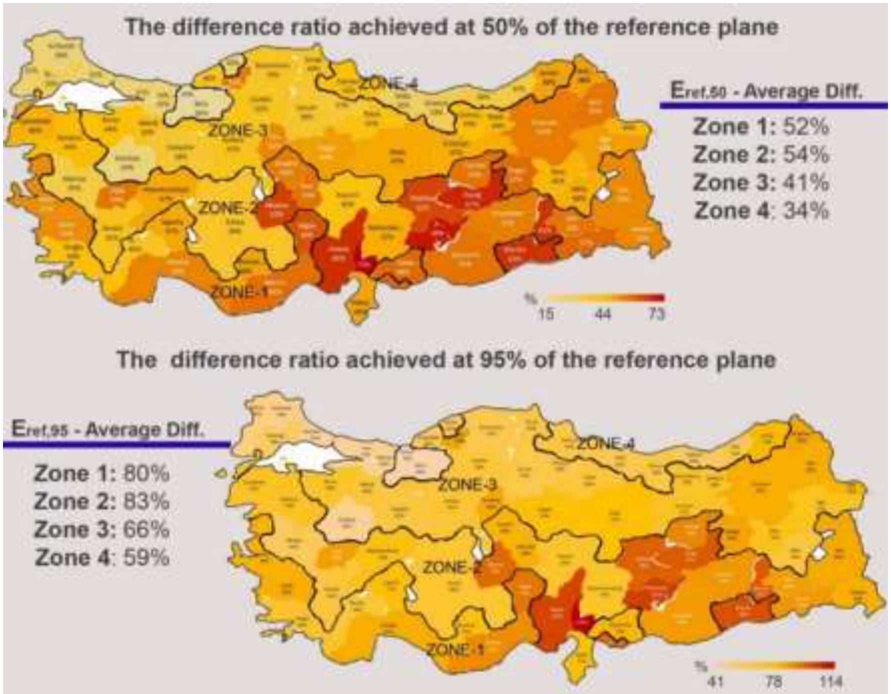

Figure 9. Average difference ratio by zones

4.3 The effect of method choice on daylight provision performance

Significant difference ratios ranging from 59-80 % were obtained in 95 % of the reference plane, as explained in Section 4.3 and shown in Figure 3. This has led to considerable discrepancies in the ETM performance of the room. During the concurrent evaluation of the ET and ETM together, these inconsistencies impacted the daylighting performance of the room. In the first method, the provinces in Zones 1, 2, and 3 showed medium performance, whereas in the second method, their performance was high. Similarly, provinces situated in Zone 4 demonstrated minimum performance using the first method and medium performance using the second method. Across the country, except in a few provinces, the daylight provision performance of the room was affected at least one level by method choice (Figure 10).

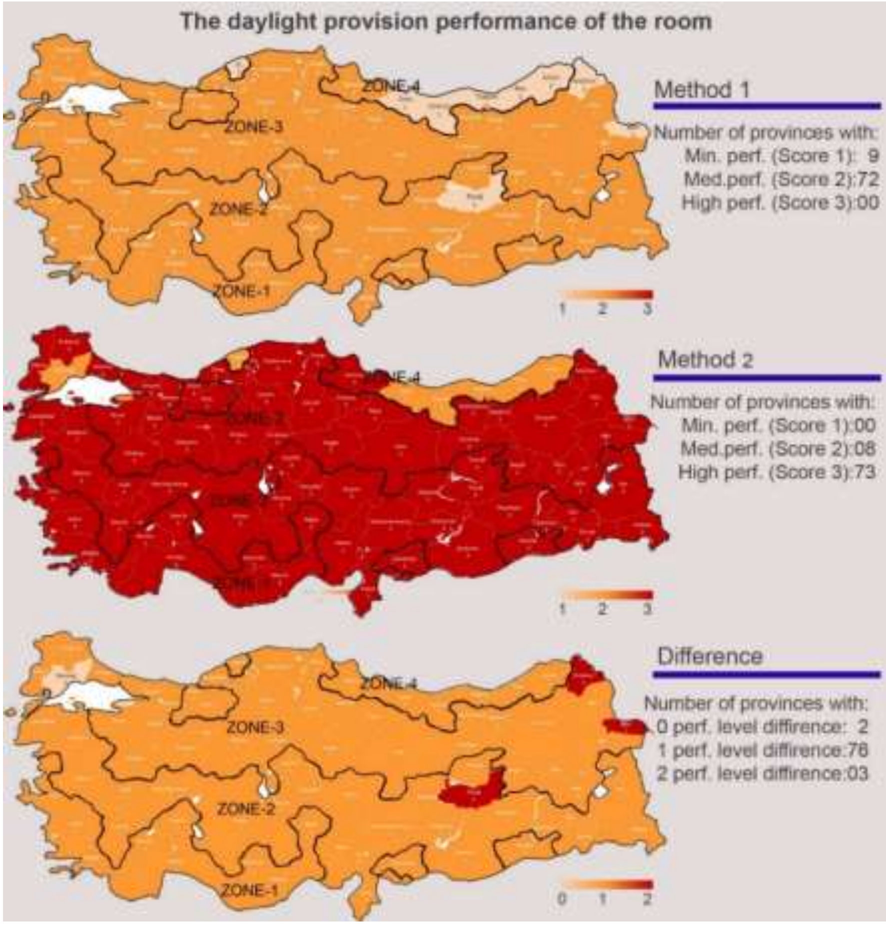

Figure 10. Degrees of daylight provision performance difference

Considering the distribution of values, the difference ratio between the two methods, and the impact of method choice on daylight provision performance, it becomes evident that the choice of method can influence the calculation results across all regions. This has the potential to create misconceptions in daylight provision analysis. The lighting consultant's recommendations to the designer could result in misguided decisions, such as enlarging the opening size and reducing the depth of the room to improve daylighting performance, although this is unnecessary.

5 Conclusions

This study focused on investigating the impact of calculation methods across various zones and the step-by-step presentation of parametric workflows in accordance with the guidelines of the standard. All 81 provinces of Turkey with variant climate zones were selected as study areas, and calculations were performed using a theoretical room with fixed parameters. The distribution of the values, the difference ratio between the results of the two methods according to zone, and the effect of utilising different calculation methods on the daylight provision performance of the room were scrutinised. The calculations demonstrated that the choice of the method affects the results significantly.

In Turkey, global solar radiation values are distributed from south to north, with the highest values in the south and the lowest values in the north. The annual average sunlight duration hours also followed a similar distribution. The illumination level achieved in the first method was distributed from east to west, whereas it was distributed from south to north in the second method. The first method does not take into account the position of the solar disk, and the illumination is distributed to the skydome with a 3:1 gradient ratio from the zenith to the horizon. Therefore, the results are affected only by zenith brightness which is determined by the extraterrestrial solar global radiation that reaches the atmosphere from the sun, and the air mass components, such as air temperature and humidity, which do not directly affect the amount of daylight. The variation in air mass components ranges from west to east in Turkey. Thus, the distribution of values in the first method follows this west-to-east direction, which contrasts with the patterns shown in the 'solar global radiation' and 'annual sunshine duration' maps. Conversely, the distribution of values from higher to lower levels in the second method corresponds with the patterns seen in 'solar global radiation' and 'annual sunshine duration' maps.

The illumination caused by direct sunlight was neglected in the first method; therefore, major differences occurred in the illuminance levels. The highest difference ratio was observed in Zones 1 and 2, where the global solar radiation was high and the annual sunshine duration was long. There was an average difference of 34-83 % between the two methods. In particular, in the $E_{ref,95}$ values, which include low illuminance levels, the disparity ratio reached 83 %.

The significant difference in the ratios between the ETM results of the two methods caused notable differences in the daylight provision performance of the room during the simultaneous evaluation of ET and ETM together. The performance of the room varied by at least one performance level across the country, with the exception of two provinces. It is important to note that the daylight provision performance was assessed according to the limit values. Thus, even minor variations of 1-2 lm/m² can influence the performance. Therefore, using ratios for comparison provides more information on the discrepancies between the two methods.

Analyses conducted by a daylighting consultant are crucial for providing designers with the necessary guidance for the efficient use of daylight. It was concluded that the use of the second method for daylight analysis across all zones of the country is advisable. This recommendation is supported by the similarity of the illuminance distribution with the meteorological data, the substantial illuminance differences observed between the two methods, and the potential misleading impact of the first method on daylight analysis.

This study makes contributions to method selection in daylighting studies and would reduce the time losses with 'workflows' developed in Grasshopper. This study may be expanded with other parametric case studies and locations within sunny climate zones to classify the effect of method choice on daylight provision.

Abbreviations

CEN – European Committee for Standardization
DF – Daylight factor (%)
DA – Daylight autonomy (%)
$E_{ref,50}$ – The illuminance levels achieved at 50 % of the reference plane (lm/m²)
$E_{ref,95}$ – The illuminance levels achieved at 95 % of the reference plane (lm/m²)
E_T – Target illuminance (lm/m²)
E_{TM} – Target minimum illuminance (lm/m²)
$E_{v,d}$ – Diffuse horizontal illuminance(lm/m²)
$E_{v,g,}$– Global horizontal illuminance (lm/m²)
$E_{v,d, med}$ – Median external diffuse horizontal illuminance (lm/m²)
$E_{v,g, med}$ – Median external global horizontal illuminance (lm/m²)
sDA – Spatial daylight autonomy (%)
UDI – Useful daylight illuminance (%)

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