DL Abacus- A Simplified Simulation-Based Tool for Daylighting Performance Assessment in Brazilian Dwellings

Natalia Giraldo Vasquez1,2, Pedro O. Pizzetti Mariano1, Raphaela Walger da Fonseca1, Fernando O. Ruttkay Pereira1
1PósArq, Department of Architecture and Urbanism, Federal University of Santa Catarina, Florianópolis, Brazil
2 ICIEE, DTU Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

Abstract
The Brazilian National Standard for the assessment of residential buildings’ performance presents limitations regarding metrics and methods recommended for daylight assessments. This paper presents the proposed updates for the standard, along with the development of a simplified simulation-based tool – DL Abacus-. The spatial Daylight Autonomy of 36,000 parametric cases was obtained through CBDM simulations. The abacuses were developed based on the most restrictive cases meeting the proposed targets. We developed a set of 9 abacuses, separated by latitude and visible transmittance. The tool will be useful for the standard application, especially in low-budget projects and remote regions of the country.

Key Innovations
• The developed set of DL Abacus has been included in the Daylighting chapter of the Brazilian National Standard for the assessment of residential buildings’ performance (ABNT NBR 15.575).
• For the definition of the level of performance, our proposal uses a range of fraction target instead of different illuminance targets. Thus, the whole process of assessment (through the DL Abacus or simulation) would be optimized.

Practical Implications
The proposed DL-Abacus will reach a broader public, thanks to a simplified method that uses, as input, architectural variables to verify the daylight performance in dwellings. This tool will allow quick filtering of those spaces that do not meet the required criteria.

Introduction
With around 50% of the population living in a few big cities, urban centres in Latin America are characterized by high density (World Bank, 2017) and providing adequate indoor environmental quality could be challenging. The current worldwide health crisis due to Covid-19 has highlighted the importance of the dwellings’ indoor environment quality. This scenario has brought the daylight as an important matter for occupants’ health, as stated earlier (Andersen 2015; Velux 2019), and not only under an energy savings perspective. In Brazil, the National Standard for the assessment of residential buildings’ performance –ABNT/NBR15-575:2013- is mandatory (ABNT, 2013). The current version of the standard, introduced in 2013, has conceptual inconsistencies regarding the metrics and methods recommended for daylight assessments. For instance, the performance must be estimated through point-in-time assessments considering two different moments (hours) of the day in two dates, established in the standard, in a single point in the space.

Such a scenario, which has neglected recent scientific progress in the area, has motivated the update of the standard to a dynamic metric approach. Climate-based daylight metrics, evaluated across the space area, are more reliable in reporting building daylighting performance (Mardaljevic and Christoffersen, 2013) and have been used for evaluating daylighting performance (EN, 2018; IESNA, 2012). Several studies applied parametric climate-based daylight simulations for daylighting analysis (Dubois and Flodberg 2013; Cammarano et al. 2015; Saratsis et al. 2017; Lo Verso et al. 2017). Such analysis enables performance evaluation considering the climate variation along the year (Brembilla and Mardaljevic 2019).

The compulsory application of the standard, previous to the construction’s approval, might represent an increase in buildings’ costs since not all professionals (architects and engineers) have the knowledge to perform such evaluation. Aiming to ease the evaluation of daylighting performance, mostly in projects with low budgets, we introduced a graphic tool that enables any professional to verify the compulsory daylighting requirements. However, the proposal for the standard offers two methods to verify compliance with the criteria. This can be done through CBDM simulation or the proposed graphical tool – DL Abacus-. In this paper, we present both, the decision-making process involved in the targets proposed for updating the standard, along with the development of the simplified simulation-based tool to assess the performance of natural light in dwellings since the early design stages.

Methods
The database used for the abacuses’ development was generated through parametric simulations in Rhinoceros 3D-6 Software by using Grasshopper component, DIVA and Ladybug plug-ins. This set of digital tools has a high performance by using Radiance parameters for lighting simulations (Emami et al., 2014; Ward 1994). Hoopsnack plug-in was used for iterated actions. The programming structure used in this research is a theoretical structure
based on previous performance model studies (Oxman, 2006a; Oxman, 2006b; Oxman, et al., 2007). Such parametric model allows shape and information variations and is indicated when shape and data development are equally important. The developed programming employed a logical structure with variations in five stages: Environment, Choice, Organization, Simulation and Validation, in a cascade effect. The parametric process was consolidated in five steps: four regarding the programming operation and, one regarding the validation of its results. Details about the autonomous parametric process, developed for this study, can be found in (Mariano et al., 2020).

Table 1: Variables used for the sample generation

<table>
<thead>
<tr>
<th>Parametric variables</th>
<th>1.5m</th>
<th>2.25m</th>
<th>3.0m</th>
<th>3.75m</th>
<th>4.5m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room width (l)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room depth - Proportion based on the width</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>/ ε 1</td>
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<td>/ ε 1.5</td>
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<td>/ ε 2.5</td>
<td>/ ε 2.5</td>
<td>/ ε 2.5</td>
<td>/ ε 2.5</td>
<td>/ ε 2.5</td>
</tr>
<tr>
<td>Window sill</td>
<td>With</td>
<td>Without</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window position</td>
<td>Centred on the façade</td>
<td>In a corner of the façade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation</td>
<td>North, East, South, West</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tvis</td>
<td>40%; 60%; and 80%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balcony depth</td>
<td>0m; 1.5m; 3.0m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balcony handrail</td>
<td>With</td>
<td>Without</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhang depth</td>
<td>0m; 1.5m; 3.0m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstruction (°)</td>
<td>20°; 30°; 40°; 45°; 55°; 60°; 65°; 70°; 80°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latitudes/Cities</td>
<td>1°27′20″ S Belém</td>
<td>15°46′46″ S Brasilia</td>
<td>25°25′40″ S Curitiba</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceiling height</td>
<td>2.7m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lintel height</td>
<td>2.1m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glazing area</td>
<td>1/6 of the floor area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surfaces reflectance</td>
<td>Internal: 20% floor; 50% walls; 80% ceiling</td>
<td>External: 10% ground; 35% buildings.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parametric models

The variables presented in Table 1 were used as input to generate the database cases. These variables were based on geometrical patterns, commonly used in residential typologies widespread in the Brazilian construction industry (De Andrade and Cheng, 2006; Montes, 2016). The window area was defined as 1/6 of the floor area (Window-to-Floor Area Ratio) corresponding to the minimum opening criterion adopted by most Brazilian building codes (Pereira et al., 2015). The ceiling and window lintel heights were fixed since in the studied residential typologies such heights are commonly adopted. Regarding surfaces’ reflectance, we used reference values (IESNA, 2012). Since the use of different glazing in housing projects has increased in recent years, we studied three visual transmittances.

Figure 1: Obstruction angles (θ)

Obstructions from adjacent buildings were simplified. An urban grid composed of nine blocks with uniform height, separated by the urban infrastructure (street and sidewalks) was modelled. Each block is a unique volume, without gaps within buildings in the same block (Figure 1). Table 2 contains the radiance parameters adopted for the simulation performed by the visual parameterized algorithm.

Table 2: Radiance parameters

<table>
<thead>
<tr>
<th>Ab</th>
<th>Ad</th>
<th>Ap</th>
<th>Aa</th>
<th>Ar</th>
<th>Dt</th>
<th>Ds</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1024</td>
<td>256</td>
<td>0.1</td>
<td>256</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The visual algorithm runs Daylight Autonomy simulations (DA) on an analysis grid placed at 0.75m above the floor – the distance between nodes 0.3m-. Four orientations and three latitudes covering Brazilian territory were studied by using TMYx weather files (Crawley and Lawrie 2018). TMYx2004-2018 weather files were adopted, containing a series of recent data, corresponding to 14 years (Climate.OneBuilding.Org 2020). These files were chosen since they are part of a large database and due to the possibility of characterizing nowadays climate conditions. The simulations period considered ten hours per day, varying according to the latitude: between 8h to 18h (for Curitiba and Brasilia) and between 6h to 16h (in Belém). Thus, the assessments were performed during periods with high daylight availability, according to the latitude. As output, we obtained DA values for 50% of the occupancy period, for different illuminances. DA values were recorded in Excel spreadsheets for further analyses.

In Brazil, housing projects are delivered by construction companies without any type of shading device. Since the compliance must be made considering the features in which the projects are delivered, other metrics as Annual Solar Exposure were not considered in the assessment. It is worth pointing out that this standard is directed only for residential projects where users can control internal devices (e.g. curtains, black-outs, blinds) to minimize solar exposure and glare.

Criteria of assessment

In the standard update, we used the spatial Daylight Autonomy (sDA), introduced by IESNA (2012), as the metric to describe daylight sufficiency indoors. We used the fraction of the space (F) as a benchmark to classify the sDA. The Standard is mandatory for all residential buildings in which all rooms for a long-term stay (e.g. bedrooms, living rooms, dining rooms, kitchen, and home
office) must comply, simultaneously, with two criteria: minimum requirement and performance.

Table 3 presents the benchmarks examined to define the fraction of the space (F) and the illuminance (E) for each criterion. We were interested in identifying which benchmarks would allow complying with both criteria in a minimum of 50% of the cases with clear glazing. Therefore, the analyses looked for the balance between the targets (F_target and E_target) and the number of cases meeting the criteria simultaneously. From our understanding, the minimum requirement seeks an even daylight distribution (uniformity). Thus, we investigated two F and two E to define the benchmarks for this criterion. We proposed a range of fraction target instead of different E_target (as in the European Standard) to determine the level of performance. We tested two ranges of benchmarks for F (R1 and R2) and three benchmarks for E to select the targets to be used in the performance assessment. Non-parametric tests for independent samples were used to compare the differences in sDA values due to each F_target and E_target.

Table 3: Criteria and benchmarks investigated to define F_target and E_target.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>E_target</th>
<th>Range</th>
<th>F_target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Requirement</td>
<td>60lux, 100lux</td>
<td>-</td>
<td>90%</td>
</tr>
<tr>
<td>Level of Performance</td>
<td>200lux, 250lux, 300lux</td>
<td>R1 Sup. = 75%, Int. = 60%, Min. = 45%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R2 Sup. = 70%, Int. = 55%, Min. = 40%</td>
<td></td>
</tr>
</tbody>
</table>

In Brazil, integrating the balcony to the indoor area is a common modification in dwellings made mostly, by the occupants and allowed as well by local regulations. Such incorporation is made, mainly, by enclosing the balcony with glazing. Based on this, the new standard considers the balcony area as a part of the indoors. Non-parametric Mann-Whitney tests were used to compare differences between sDA values when the balcony area was included and when the balcony area was not included in the calculation. We also examined the number of cases meeting simultaneously both criteria due to balcony inclusion.

Differences due to visual transmittance

Aiming to identify whether separate abacuses must be produced according to Tvis, non-parametric Kruskal-Wallis tests were used to examine the differences in sDA according to the type of glazing. We studied such sDA differences for each criterion.

Developing a simplified simulation-based tool

The proposed tool—DL, Abacus—brings information about the provision of daylight, in an indoor space, according to the minimum requirement and the level of performance. We adopted the idea of a restrictive condition as a premise for the tool development. For instance, from the four orientations, the one with the lowest result was plotted in the abacuses. Thus, the assessment obtained through the abacuses could underestimate the daylighting assessment rather than overestimate it. Therefore, the abacuses could be used in cases that have not been simulated in our database and, with characteristics that would improve the provision of daylight (e.g. larger window areas or less deep spaces). The abacus structure is based on the geometric features of the room and, the obstructions from the adjacent buildings. As input, the user needs to verify the following features: i) existence or not of balcony/overhang; ii) room width; iii) room proportion and, iv) the obstruction angle. With this information, it will be verified whether a room met the criteria besides informing the performance level reached.

Three sets of abacuses were developed covering the Brazilian territory by a range of latitudes. The latitude ranges were defined based on a previous study (Fonseca, 2018) that evaluated the influence of climate on daylight availability, encompassing Brazilian latitudes between 2°N and 30°S and diverse façade orientations.

Results

We simulated 36000 cases in total. An initial descriptive analysis showed that, even with the lowest targets for the minimum requirement (sDA_60lux-75%) and the minimum level of performance (sDA_200lux-40%), those cases with rooms deeper than 7.5m and obstruction angle of 80° did not meet any of the criteria. For this reason, we excluded those 360 cases from our analyses and the abacuses.

Inclusion of balcony area in sDA calculation

Figure 2 presents the percentage of cases that meet the different benchmarks of F_target and E_target examined for each criterion, when the balcony area is added to and excluded from the sDA calculation. The analysis was performed only with clear glazing (Tvis 80%). Regarding performance level, F_target required to obtain the minimum level (45% in range R1 and 40% in R2, see Table 3) was considered as reference.

The incorporation of the balcony area into the sDA calculation increased the number of cases meeting the criterion, which was higher in the assessments of performance level. Despite the floor area and the room depth were increased when incorporating the balcony into sDA calculation, such increasing was at the front of the room, closer to the façade. Thus, the inclusion of an area with more daylight led to an increase in sDA. In each city (Figure 2a), the number of cases meeting at least the minimum performance level increased, especially when E_target= 300lux: an increase of 126.6% and 140.3% of cases meeting sDA_300lux-40% and sDA_300lux-45%, respectively (Figure 2b). We found that the number of cases meeting the performance level was significantly associated with the addition of the balcony area to the calculation (p < 0.05), since balconies have higher daylight availability.

With smaller differences, the number of cases meeting the minimum requirement also increased. Considering most of the area (F_target= 90%) with both E_target, the effect of including the balcony area in the sDA calculation was the lowest in terms of percentage of cases (Med= 3.4% more cases). A non-significant relationship between balcony area and cases meeting the minimum requirement (p >
Furthermore, for this criteria, the greater increase in number of cases was when \( E_{\text{target}} = 100\text{lux} \) and \( F_{\text{target}} = 75\% \); \( p < 0.05 \). Besides the fact of more cases had met the criterion when the balcony area is part of sDA calculation, this analysis pointed out that the minimum requirement was reached more easily than the minimum level of performance, even when the \( F_{\text{target}} \) was increased.

**Figure 2:** Relative difference in the percentage of cases meeting \( E_{\text{target}} \) and \( F_{\text{target}} \) when the balcony area is included vs. excluded from the sDA calculation.

Selecting \( F_{\text{target}} \) and \( E_{\text{target}} \)

Grouping by the different benchmarks of \( F_{\text{target}} \), we compared sDA values (Figure 3a) of those cases meeting each criterion, when the balcony area was incorporated into the calculation. Since the visible transmittance affects the illuminance levels, data used in this analysis considered only those cases with 80\% of visible transmittance (Figure 3b). Since sDA values presented non-normal distributions (\( p < 0.05 \)), we used non-parametric tests to examine the differences. Regarding the minimum requirement, Mann-Whitney tests reported significant differences in sDA values in both groups: \( F_{\text{target}} = 75\% \) (\( U = 7980806; p = 0.00; r = -0.16 \)) and \( F_{\text{target}} = 90\% \) (\( U = 4523731.5; p = 0.00; r = -0.10 \)), with higher sDA when \( E_{\text{target}} = 60\text{lux} \). For the performance, results from Kruskal-Wallis tests also indicated significant differences among the three \( E_{\text{target}} \) when \( F_{\text{target}} = 40\% \) (\( H(2) = 355.3; p < 0.05 \)) and \( F_{\text{target}} = 45\% \) (\( H(2) = 227.1; p < 0.05 \)). In both groups, when \( E_{\text{target}} = 200\text{lux} \) the sDA values were higher. Thus, we selected 60lux and 75\% of the area as sDA targets for the minimum requirement. Regarding the performance, \( E_{\text{target}} \) of 200lux was selected while further analysed for both ranges of \( F_{\text{target}} \) (R1 = 45%-60%-75% and R2 = 40%-55%-70%) were performed.

**Figure 3:** Data from cases (Tvis 80\%) meeting the criterion when the balcony area is added to sDA calculation.

**Figure 4:** Percentage of cases meeting simultaneously the Minimum requirement and Performance.

As next step, we quantified the number of cases meeting simultaneously both criterion: \( \text{sDA}_{60\text{lux}-75\%} + \text{sDA}_{200\text{lux}-45\%} \) and \( \text{sDA}_{60\text{lux}-75\%} + \text{sDA}_{200\text{lux}-40\%} \). With this analysis, we sought to guarantee that, at least 50\% of our sample met the criteria proposed for the new standard. Figure 4 presents the percentage of cases meeting both criteria simultaneously, separate by city and Tvis. A 5\% reduction in the benchmarks of \( F_{\text{target}} \) used to assess the performance level, allowed to increase the number of cases in compliance with the criteria. The three examined glazing showed an increase in the number of cases. When the Tvis was 80\%, the percentage of cases was higher than 50\% in the three cities (\( \text{Min} = 53.5\% \) in Curitiba and \( \text{Max} = 66.4\% \) in Brasilia).
Differences in sDA due to visible transmittance (Tvis)

Differences in sDA values were statistically significant between the three glazing types for both, minimum requirement criterion \([H(2) = 3950.4; p < 0.05]\) and level of performance criterion \([H(2) = 3139.1; p < 0.05]\). Therefore, we developed a set of three abacuses for each city: one per glazing visible transmittance.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>(F_{\text{target}})</th>
<th>(F_{\text{target}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Requirement</td>
<td>60lux</td>
<td>75%</td>
</tr>
<tr>
<td>Level of Performance</td>
<td>200lux</td>
<td>Sup. = 70%</td>
</tr>
</tbody>
</table>

Development of the DL Abacus

The set of abacuses will be a simplified simulation-based tool for daylighting performance assessment, included in the Standard as annexes. The range of latitudes of each set of abacuses was:

- Zone 1: Latitudes between 5°N and 9.9°S
- Zone 2: Latitudes between 10°S and 19.9°S
- Zone 3: Latitudes between 20°S and 34°S

We proposed that the abacuses based on Belém weather file (1°27′20″ S) can be used within Zone 1, abacuses based on Brasilia weather file (15°46′46″ S) can be used within Zone 2 and, abacuses based on Curitiba can be used within Zone 3. Each zone has a set of three abacuses, one for each glazing visible transmittance. Figure 6 presents the zones and the three abacuses developed for Zone 1. The core of the abacus is composed of cells. Each cell represents a small group of cases (four cases, one per orientation) for which, the lowest values of sDA60lux (minimum requirement) and sDA200lux (performance) have been plotted. The minimum requirement is represented by circles and the level of performance is plotted in yellow, as follows: ■ Superior level of performance when \(F_{\text{target}}\) ≥ 70%; ■ Intermediate level when \(F_{\text{target}}\) ≥ 55% and < 70%; ■ Minimum level of performance when \(F_{\text{target}}\) ≤ 55% and < 70%; ■ Cells in white are those cases in which the performance criterion was not met while, cells without the circle, are those cases in which the minimum requirement was not met either. Since both criteria must be met, cases complying with the standard will be those in yellow plus the circle.

Using the abacuses requires six steps:

1. Identifying the Zone according to the building’s location (latitude);
2. Selecting the abacus according to the glazing visible transmittance (Tvis);
3. Verifying, in the first column, whether the room has or not balcony/overhang;
4. Checking, in the second column, the line with the range within the room width is;
5. Selecting the line with the P index, which is the ratio between the width and depth of the room;
6. Verifying, within the obstruction angle columns, the range within such angle is. The intersection of the column and line will show the daylighting provision, as exemplified in Figure 6.
Figure 6: Abacuses according to the Tvis and for latitudes within Zone 1.
The abacuses were developed under the premise of enabling any building designer to assess the daylighting provision in their residential buildings projects. Nevertheless, this tool can be used since the early design stages, through a verification and improvement process of the daylighting provision of indoor spaces.

Checking differences with the current version of the standard

Even though there are conceptual differences between the current Standard and the one proposed, we compared the number of cases in compliance with the current Standard and the new proposal -which brings the addition of the balcony area to the sDA calculation and, the minimum requirement and performance level criteria-. In order to comply with the current version of the Standard, a room must meet the target illuminance (60 lux minimum) in the middle of the room over the four assessments (2 dates x 2 hours). The comparison was made only for those cases with visible transmittance of 80%. Through this comparison, we intended to demonstrate to the stakeholders that, even though the target illuminances were higher in our proposal, the climate-based assessment together with the spatial assessment and the addition of the balcony to the indoor area would improve both, the daylight quality and the methods used in the evaluation (Figure 7). Thus, the criteria proposed for updating the standard would not necessarily mean a higher level of difficulty to comply, one of the biggest concerns from the industry.

![Figure 7: Comparison between the current version of the standard and the proposal: cases meeting the criteria.](imageurl)

Discussion

The results presented in this paper summarized the premises we adopted for the revision and updating of the Brazilian National Standard for the assessment of residential buildings’ performance (ABNT/NBR15-775:2013), specifically for the Daylighting Performance Chapter. The current standard references the set of standards for the assessment of daylight, ABNT/NBR15-2125, introduced in 2005, with no updating until now. Therefore, the standards have not followed the last breakthroughs in the area, making them obsolete. Since 2013, this is the first update/upgrade of the standard, which is compulsory for dwellings. We approached this task as an opportunity to smooth the transition towards a future and more robust method. Thus, we focused this upgrade on one metric, the sDA, as the first step to approximate the industry to a better approach for daylighting performance assessment in residential buildings. Even though other parameters have an impact on the daylight quality (as outside view, glare and solar exposure), we understood that, in residential buildings, some of them could be easily controlled by users' actions (like operating blinds or curtains). On the other hand, the viability in the implementation of the proposal was another concern, which could be more difficult if additional parameters (as the ASE) were compulsory. The ASE, proposed in a non-residential context, should be carefully applied in dwellings (Heschong 2012). Certainly, by selecting lower targets the number of cases meeting the new criterion of the standard are higher. However, this is the initial step towards the improvement of the methods used for daylighting assessments in Brazilian buildings. We hope it will be followed by the revision -or even the replacement- of the set of standards for the assessment of natural lighting (NBR 15215:2005), as well as the future upgrading of the proposed targets. As stated by Houser, “standards and codes are products of consensus and compromise” which is, indeed, the case presented in this paper (Houser 2020).

We believe the inclusion of the DL Abacuses in the Standard will be useful for all practitioners. We are aware, nevertheless, of the tool’s limitations. For instance, the daylighting provision will be underrated in rooms wider than deeper or, when the window area is larger than 1/6 of the floor area. Also, the abacus can be used only in the assessment of rooms with rectangular geometry, due to the characteristics of our database. Finally, the compulsory nature of the Standard has an impact on the projects’ budget due to the costs that come from hiring an external consultancy to perform these assessments. In low-budget projects, usually social housing, the DL Abacus will enable all building designers to verify, improve and evaluate the daylighting provision in their projects.

Conclusion

In this paper, we presented the premises used for updating the ABNT/NBR1575:2013 - Daylighting Performance Chapter and the development of a simplified simulation-based tool for daylighting performance assessment.

From the decision-making process for selecting the targets, the addition of the balcony to the indoor area showed a significant effect on the reached performance level. Balconies improve the quality of indoor spaces, not only in terms of daylight. Since such addition has been a common practice in residential buildings, the assessment of the daylighting provision should take into consideration such benefits. Our analyses showed that variations of 50lux and 100lux in E\text{target} had a significant impact on the number of cases meeting the proposed criteria. Also, a reduction of 5% in the benchmarks of E\text{target} used for the definition of the level of performance, had a significant impact on this matter.

Since we adopted the idea of a restrictive condition for the development of the abacuses, the assessments made by it
can be conservative. It is, therefore, a reliable tool. However, the daylighting provision estimation can be lower compared to the results obtained through simulation. Finally, the tool can be replicated to any location with an available climate file.

Acknowledgement

This study was partially financed by CAPES- Brazil - Finance Code 001 and the National Council for Scientific and Technological Development CNPq–Brazil finance codes 151162/2019-0 and PQ 309394/2020-1.

References


