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The Computational Simulation of Iconic Hotel Designs: the Natural Lighting in the Maksoud Hotel

Felipe Corres Melachos[1], Samuel Bertrand Melo Nazareth[2], Marina Sugai Brant de Carvalho[3]
[1]*Faculty of Civil Engineering, Architecture and Urban Design – Campinas State University, Campinas, BRAZIL.*
[2]*Faculty of Architecture and Urban Design – University of São Paulo, São Paulo, BRAZIL.*
[3]*School of Professional and Executive Talent – Universitat Politècnica de Catalunya, Barcelona, SPAIN.*
Corresponding Author: Felipe Corres Melachos

ABSTRACT
Computational simulations tools have transformed the shape-finding and form-finding processes of architectural and engineering endeavors from the last decades of the 20th century up to our present date, mostly in structural analysis and in rather urgent environmental comfort related analysis. It is known that the (Architecture, Engineering, and Construction) AEC industry is one of the most pollutant economic sectors of the globe, and that the financial and carbon of the lighting cost of its interior spatial outputs throughout their life cycles is substantial. Thus, this research presents itself as an experimental computational simulation in the realm of natural lighting of architectural design, with the objective to measure the illuminance levels pertaining to natural lighting in hotel apartment rooms and its typical floors. The selected object of study for the given simulation was an iconic hotel in São Paulo, Brazil – the Maksoud Plaza, one of the city´s landmarks when it comes to its skyline and hotel industry in the later decades of the twentieth century. The computational simulation methodology undertaken was the parametric and geometric modeling, opting for open-source plug-ins in low-cost base modeling software. It is hoped that this research contributes to the dissemination of algorithmic definitions in the academic community, in their conceptual and mechanical workflow, as well as in their respective updating when it comes to the latest version of its most utilized plug-ins.
Keywords: *computational simulation; parametric modeling; natural lighting; illuminance; Maksoud Plaza.*

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I. INTRODUCTION

The array of computational simulation techniques has transformed the manner of architectural design process in the latter decades of the 20th century and early 21st century, yielding an ever-growing number of protocols [1] pertaining to daylight analysis [2–4]. Such analyses are important in the sense of the pollutant impact of the Architecture, Engineering and Construction (AEC) Industry [5], whereas the glazing and window-to-wall ratios (WWRs) came forth as important energy saving tools [6–8].

Hence, this research presents as its main scope the development of an experimental computational simulation procedure in the realm of natural lighting of architectural design, aiming to assess natural light dependency through illuminance indexes – the density of incident luminous flux incident on a point of a surface [9]. Illuminance indexes were chosen, amongst the existing indexes for natural lighting, for their standardization in Brazil, the location of study and research of the authors. The ABNT NBR 15575-1 [10] (establishes minimal illuminance indexes for residential units in *lux* by means of algorithms further explored in ABNT NBR 15215-3 [11].

Hotels per se, although not residential in use, do not have a proper illumination standardization in Brazil. However, hotel buildings conform a significant portion of the country's greatest city's skyline and economic activity [12,13], and thus, a considerable portion of São Paulo's AEC's pollutant output. Amongst São Paulo's most iconic hotel buildings is Maksoud Plaza Hotel [12,14] (Fig. 1), inaugurated in 1979 [15] in the Paulista avenue, designed and built by Henry Maksoud's own engineering branch, Hidroservice S. A. [14]. Towering at with 21 floors, the hotel stood tall in the São Paulo skyline, and despite absorbing much of the city's brutalist heritage, the Maksoud Plaza could be considered a step towards pos-modernist ideals [15]. This particular hotel was built to be the best in the world and became the most notorious in São Paulo during the 80s and 90s [12,14].

Despite possessing a highly self-sufficient back of the house (BOH) programme which included a full industrial kitchen and even a well, the hotel lacked periodical updating to retain competitive [16], and closed in

2021 during the COVID pandemic [17]. Today the brand Maksoud Plaza is still active [18], but the building remains closed to the public and its furniture and art objects are being auctioned in order to clear the company's debts [19].

A B

Figure 1: The Maksoud Plaza atrium (A) and the rooftop view from the Paulista Avenue surroundings of the Bela Vista District (B).

The chosen methodological procedure for the computational simulation of illuminance from natural daylight was parametric modeling due to its dissemination in recent research [20–22], availability of open-source and/or low-cost plugins and software as well as a wide network of assistance for users [23,24], rapid visualization of results [25,26]. Also, there is a known unavailability of dissemination of protocols in academia [2,3,26], whereas the authors of the paper either work or have worked and research in endeavors pertaining to state-of-the-art computational simulations involving parametric modeling. Hence, it is hoped that this research operates in the sense to disseminate updated protocols of algorithmic definitions with low-cost and/or open-source plug-ins aligned with the state-of-the-art of the industry, aiming to optimize daylight entrance in economically relevant architectures such as large upscale hotel complexes.

II. MATERIAL AND METHODS

The scheme below is a synthesis of the methodological procedures to be adopted in this paper, to be divided into three four major sections: 1-data input; 2-information processing; 3-data analysis & modeling; 4 results & discussion (Fig. 2). The "data input" phase of the research consisted of the gathering of bibliographical references on books, theses, papers, and on the web pertaining to two main research themes – hotel design and natural lighting computational simulation methods. The research has shown that the Maksoud Plaza is one of the most iconic and self-sufficient hotel designs ever made in Brazil [14], leading to its *in-situ* visitation and detailed photographical registry of its front of house (FOH) and back of house (BOH) areas (Fig. 3). Such visitations were also important for they rendered the obtention of the technical drawings of the architectural design of the Maksoud Plaza Hotel, in a complete collection of pdf files. Such collection is not to be shown in its full to assert the security of the hotel grounds. However, excerpts of its material in reduced scale such as in Fig. 2 shall be presented when necessary to convey the research's methodology.

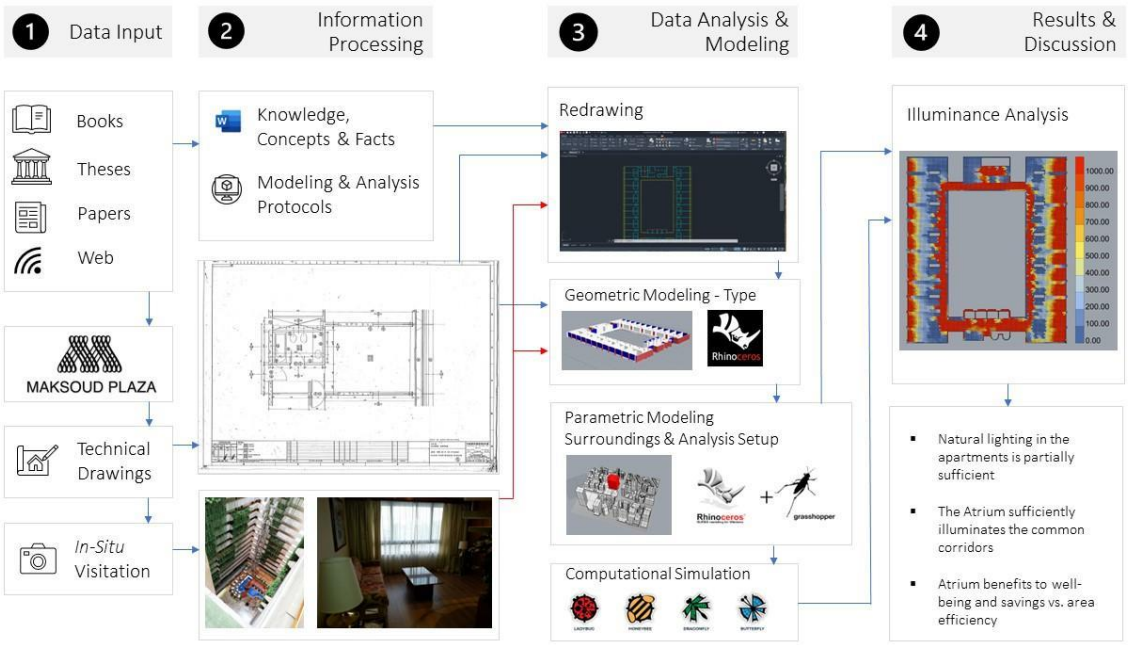


Figure 2: The flow of the methodology

Figure 3: The lobby (A), towered by the atrium (B) and looked upon the typical floors' hallways (C). In the underground levels, accessed by escalators (D), are expansible auditoriums and smaller conference rooms (E). From the third floor up are the typical floors, with two single beds or king-size beds (F), date media and office spaces (G), and Italian marble on the bathroom (H).

In step 2 "Information Processing", the second scope of literature review, geared towards natural lighting analysis, came to prominence in the sense of rendering of the establishment of the simulation protocols to be conducted in the step 3 'Data Analysis & Modeling". Such protocols were greatly assisted by the professional

involvement, current and previous, of the authors with parametric modeling practices in architectural consulting firms both nationally and overseas. The literature review of this research revealed that there is not a technical normative pertaining the natural lighting indexes and its computational simulation in Brazilian territory, being the ABNT NBR 15575-1 [10] the most appropriated standard available for such measurements despite its gearing towards residential units. ABNT NBR 15575-1 [10] establishes minimal general illuminance values in *lux* units for several common and service residential environments and delineates that simulation methods in Brazil are to be withheld as according to the algorithm presented in ABNT NBR 15215-3 [11].

Also, it is important to mention that this "Information Processing" step was greatly enhanced by the analysis of the *in-situ* visitations photographical registry (Fig. 3), as well as the body of technical drawings obtained by means of the contacts with the technical division of the hotel. Such analysis was complemented and marked by a deepening of understanding of the Maksoud Plaza Hotel constructive and architectural features. Such in-depth comprehension also paved the way for the methodological procedures to be undertaken in the research's Step 3.

Step 3 "Data Analysis & Modeling" commenced with the redrawing of the Maksoud Plaza Hotel original construction drawing floorplans with AutoCAD® from its original pieces via X-Ref mapping (Fig. 4). Such process was important to foster the constructive and architectural comprehension of the object of study already undertaken in Step 2 and allowed for the geometric modeling of the hotel aiming for its natural daylight computational simulation. It is important to distinguish geometric modeling from parametric modeling in the sense that the former does not use parametric algorithms [27], allowing the rapid modeling of well-defined geometries by means of the software's own editing tools [28].

Such .dwg outputs for the hotel typical floors were then used to extrude their respective geometries in Rhino 3D®. Professional experience from the authors regarding computational simulation has shown that layering the modeled geometries renders most accurate and faster simulation results (Fig. 5). The layers for the typical floor geometric wall were represented by colors and discretized as glass, roof, ground, internal walls, external walls, and floor. Such discretization is also a result of professional practice experience.

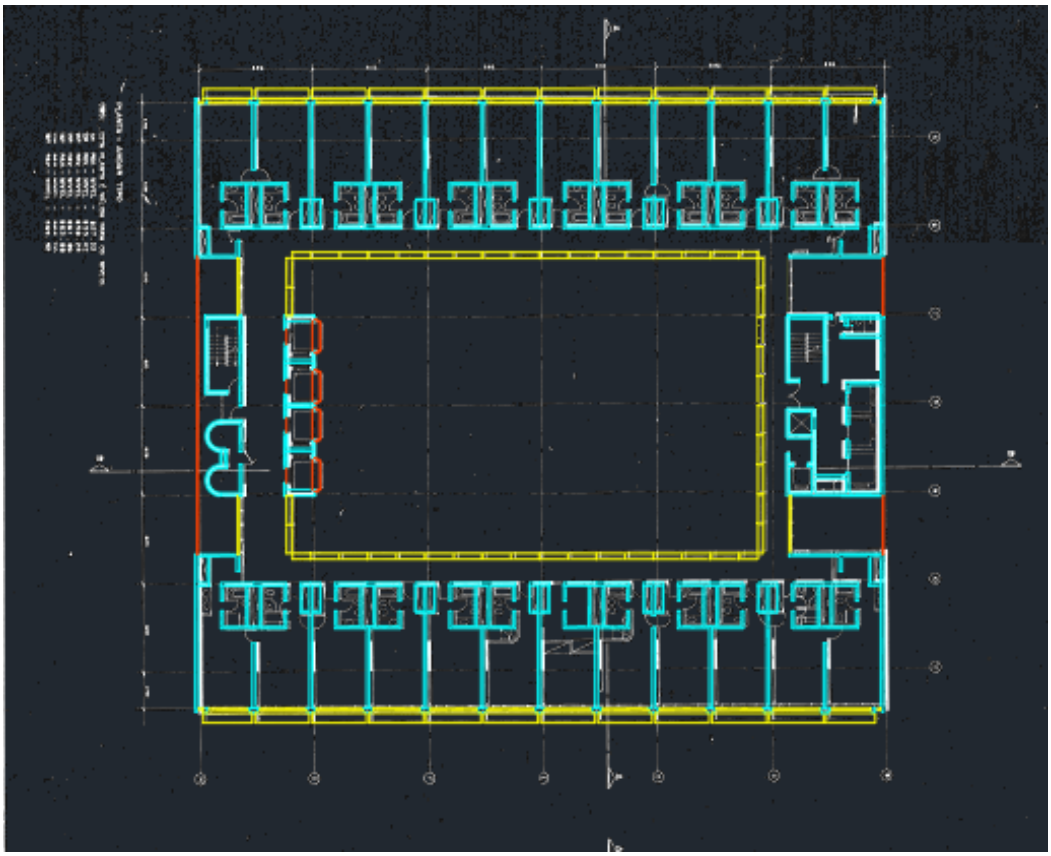


Figure 4: Typical floor redrawing via X-Ref mapping in AutoCAD®.

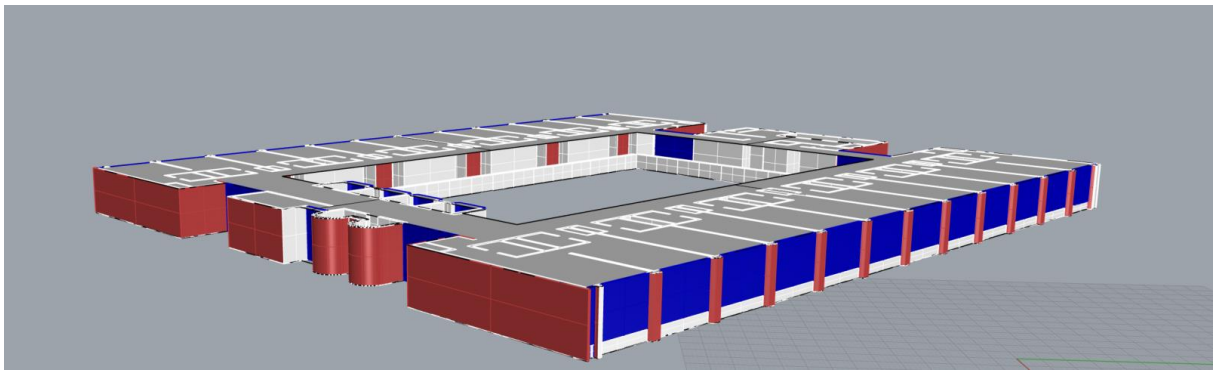
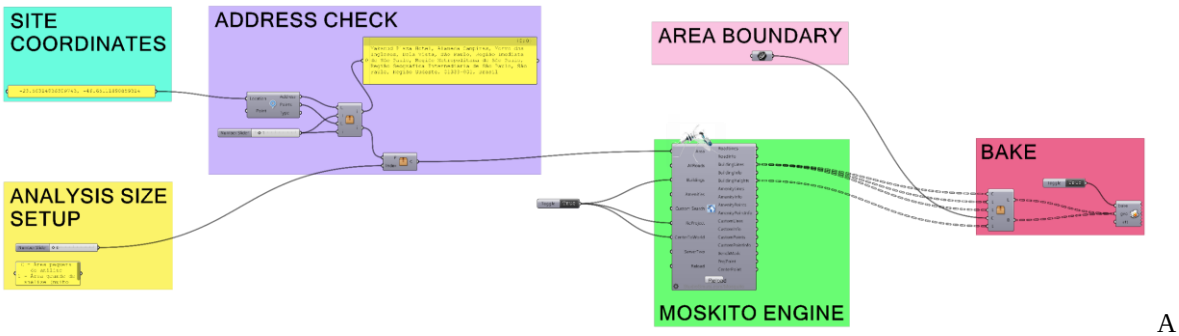
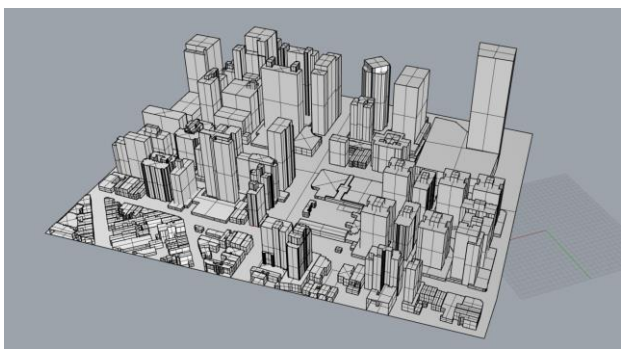


Figure 5: Typical floor geometric modeling in Rhino 3D®, with layers separated by color.

The proper computational simulation of the illuminance can only be computed if the surroundings are properly modeled [10,11]. Hence, a definition was conceived using Parametric Modeling associating the object of study's site coordinates to its existing urban and architectural features (Fig. 6A). Such definition aggregated Grasshopper 3D® and its plugin Mosquito 0.5®, which absorbs data from Google [29] and yields the desired simulation surroundings (Fig. 6B). Such surroundings can then be added to the geometric modeling of the redrawn object of study (Fig. 6C), where each typical floor, roof floor and base floor were separated into different layers of color red. For visualization and simulation purposes, the translucid central atrium covering was kept in a separate layer (blue in Fig. 6C).



A



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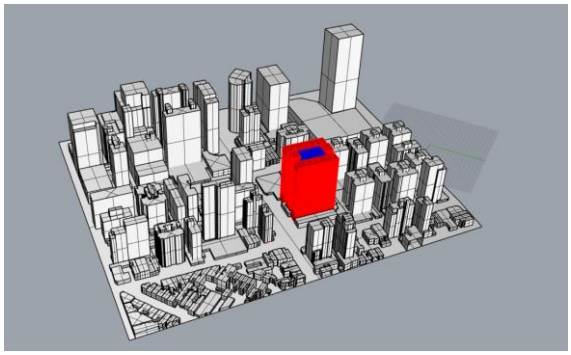


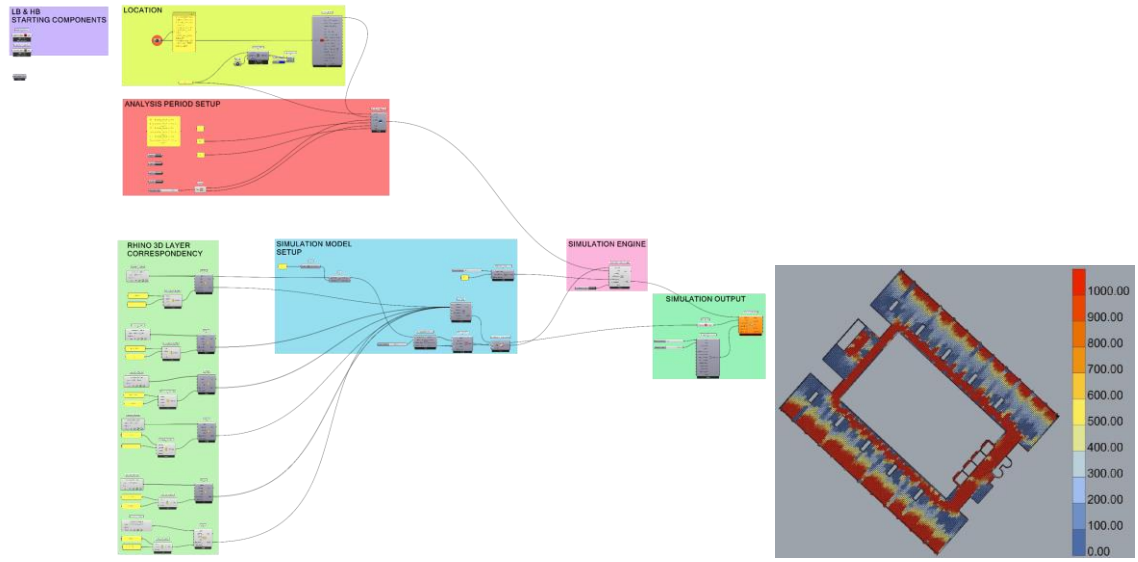
C

Figure 6: Definition yielding the urban surroundings of the object of study (A), its output in the Rhino3D interface (B) and insertion of the object of study's geometrical model (C).

Step 4 "Results & Discussion" was possible through the development of another definition, this time using Grasshopper 3D alongside its plugins from Ladybug Tools - Ladybug and Honeybee (Fig. 7A). The publication of this definition is important for further reference in correlated literature for it encompasses different versions of Ladybug Tools plug-ins, including its latest version 1.6.0. The proper dissemination of updated algorithmic definitions is a constant challenge in academic publications given conflicting ratio of highly reputed journals' processing period and the industry's rapid evolving rhythm [22,26]. The Analysis periods were set up for the April 23th @9h30 AM and October 23th @3h30 M as according to ABNT NBR 15575-1 [10] and ABNT NBR 15215-3 [11] in horizontal planes elevated 75 cm from the soil. Such analyses were conducted from the first

typical floor (3rd hotel floor), the 14th hotel floor (middle typical floor), and the last typical floor (21st hotel floor) to assure a simulation covering the whole of the hotel's architecture and urban context. Illuminance results were made visible with heatmaps available in Ladybug such as the sample for Dec. 21st at 15h30 (Fig. 7B).

Posteriorly, such computational simulation outputs were confronted to the existing daylight regulations in Brazil [10,11], in a cross-reference to the scarce state-of-the-art regarding hotel design architecture, especially for Cfa climates [30]. Such discussion aimed to verify the quality of the resulting architectural space in terms of architectural lighting geared towards hospitality design despite its mounting real-state pressures to make the most of every square meter [13].



A B

Figure 7: Definition of the Computational Simulation (A) and its output (B) for daylight analysis in the hotel typical floor for 23.10 @ 15h30.

III. RESULTS

The results of the computational simulation conceived in step 3 (Fig. 4) as according to Brazilian national standards ABNT NBR 15575-1 [10] and ABNT NBR 15215-3 [11] can be appreciated in the table 1 below. Such results are better interpreted alongside Fig. 8, where a zoning of the average apartment of the Maksoud Plaza Hotel, with either two double beds or a large king-size bed is displayed. Fig. 8 reveals, based upon the construction drawings' analysis and the buildings visitations, that there is a customary layout disposition of the suites, notwithstanding particular interior design choices for certain events and room variations. In results shown in table 1 the geographical north is always upwards.

Before analyzing the simulation results it is important to state that ABNT NBR 15575-1 [10] establishes that living areas, resting areas, kitchen, and service areas need to have a minimal illuminance index of 60 lux to be cleared for use. Nonetheless, the same regulations state that bathrooms, internal hallways and/or stairways, common hallways, common stairways, garages, and other spaces do not have minimal illuminance indexes.

The initial simulations, pertaining to the dates of 23.04 and 23.10, were taken in São Paulo's autumn and spring respectively. São Paulo is situated in the southern hemisphere, in a latitude virtually aligned with the Tropic of Capricorn. At the 23.04 simulations, all floors yielded outputs where the northeastern façade of the hotel presented illuminance indexes higher than 800 lux for their suites' social and working areas. Such façades had their resting areas range higher than 500 lux. Bathrooms and internal corridors remained dark, nearing the minimal 0 lux scale. Hence, the 23.04 simulations for the northwestern façade for the 3rd, 14th, and 21st floor follow ABNT NBR 15575-1 [10].

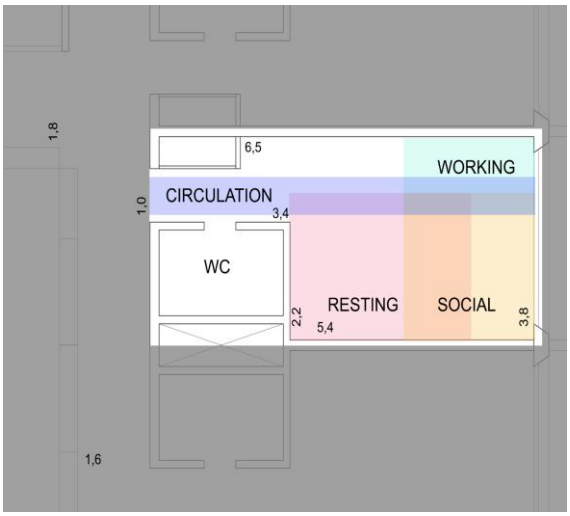


Figure 8: Maksoud Plaza Apartment Zoning.

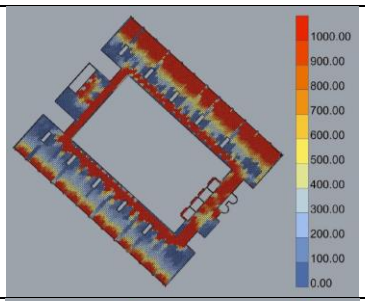
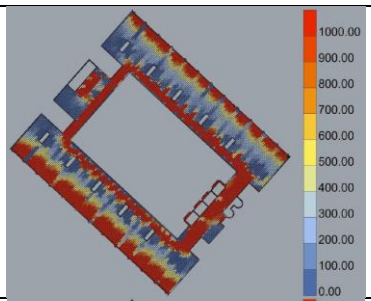
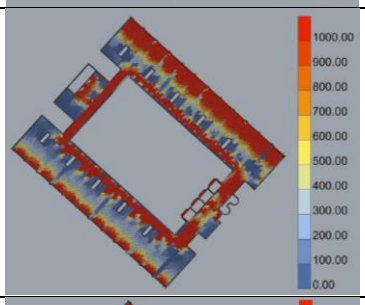
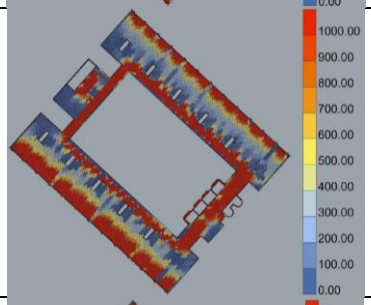
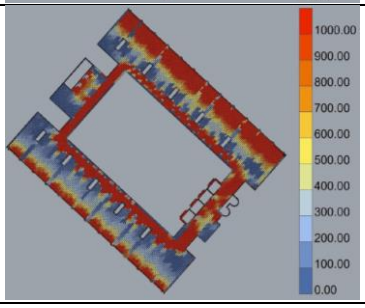
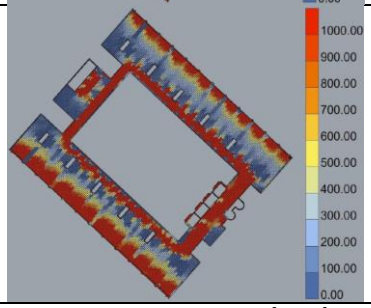
DAY – 23/04		**DAY – 23/10**
FLOOR	**TIME OF THE DAY**	
	09H30	**15H30**
3 TH		
14TH		
21ST		

Table 1: Illuminance Simulation Results for 23.04 and 23.10, at 09h30 and 15h30, for the 3rd, 14th, and 21st floor respectively. Results are indicated chromatically in lux.

However, the southwestern façade of the hotel has a little more trouble assuring proper illuminance indexes to its resting areas. The very tip of social and working areas have maximized lux indexes for all three

floor samples, whereas the resting area assures an illuminance index in the range of the 100-200 lux. It still complies with the standing regulation.

Upon analyzing the 23.10 simulations, the illuminance indexes seem to reverse themselves amongst the analyzed façades. In all sampled levels, the southwestern facades' social and working zones present illuminance indexes higher than 800 lux, with their resting zones well above 500 lux as well. However, the northeastern facade's resting areas retain 100-200 lux illuminance indexes.

IV. DISCUSSION & CONCLUSION

The results of this research have shown that the Maksoud Plaza Hotel illuminance indexes comply with the ABNT NBR 15575-1 [10] and ABNT NBR 15215-3 [11] when it comes to natural daylight alone. Such conformity could be associated with its architectural implantation, even though it is situated in a verticalized neighborhood. The construction drawings indicate that the roof level of the building reaches 890,21 meters at its uttermost point and considering that its volume is concentrated in the middle of the lot, there is not much interference when it comes to sun glazing in its facades for the adjacent, also tall buildings, are also centered in their lots.

The atrium of the building, a feature that the Maksoud Plaza inherited from the American Hyatt Hotels in the 70s (12,14), despite rendering less space available for commercial use, provides scenic views and more natural light entrances. The maxed illuminance indexes (Table 1) in the common corridors have shown the lighting saving potential of the atrium in the typical floors' hallways and provide ground for future discussion regarding established typical floor area x room area ratios (12,14,16,31). There is also room for further debate regarding the glare coming from such uncontrolled daylight illuminance in Cfa climates [30], where upscale hotels might aspire to recreate international ambiences [32].

The dissemination of updated parametric modeling protocols associated to computational simulation techniques, associated to industry-operating practices, is important for possible upcoming standardization trends in Cfa climates [30], regarding in energy efficiency labeling of buildings (33). Such protocols are to be determinant in the establishment of efficient design protocols of net-zero buildings, especially when it comes to developing countries with hot-humid climates.

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