Environmental adequacy in modern South American collective housing: comparative analysis of daylight in six projects (1950 – 1954)

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Abstract

In the catalogue for the 1955 exhibition *Latin American Architecture Since 1945* (1956), the curators claimed that modern architecture in the region was characterized by environmental control strategies. Elements such as *brise-soleil* were seen by Hitchcock, Barr Jr., and Johnson as part of a broader regional effort to adapt modernist design to tropical climates. However, a review of existing literature reveals a lack of empirical studies assessing the validity of these claims. To address this gap, a pilot study was conducted using daylight analysis to evaluate six collective housing projects in the tropical cities of Rio de Janeiro and Caracas. The study employed computational simulations, incorporating certain modeling generalizations to allow for cross-case comparison. The main objective is to understand how general architectural design decisions—particularly in massing and facade articulation—influence daylight performance, thereby contributing to the ongoing debate on the environmental responsiveness of Latin American modernism.

Introduction

MoMA's exhibition *Latin American Architecture Since 1945* (1955) has propagated the idea that the region's modern architecture was characterized by a concern with environmental design. Horacio Torrent, professor at Pontificia Universidad Católica de Chile, summarizes these concerns as observed by the curators:

> "The restriction of materials and the modern transcendence of reinforced concrete; the attention to climatic variation, and the repeated use of control dispositive – brise soléil -, and a solidity in cultural traditions with 'very considerable' usage of color and ceramic tiles"[1]

Similar claim was made by Jeffrey Cook, a distinguished North American scholar on sustainable Architecture, by stating that "Hitchcock in 'Latin American Architecture Since 1945' published in 1955 illustrated how completely bioclimatic concepts had informed the new architecture of an entire continent."[2] This generalization is, in the original catalogue, unsubstantiated by data – either empirical or simulated – and, despite that, is often replicated in academic setting. If the environmental adequacy of these works is challenged

by computational simulations or in-site measurements, that means the canon of modern architecture – as stipulated by MoMA's curators in 1955 – needs to be revised; or its description can be fine-tuned to better represent the real condition of these structures. One possible issue is that while works of architecture selected for the exhibition might include environmental control devices, these might be misplaced or used in areas where users stay for only short periods of time.

Two steps are necessary to verify the claim of Latin American modern architecture's environmental adaptability: 1) a literature review on the topic, observing if there are previous publications that test the environmental adequacy of these projects and 2) In the case that there aren't any previous studies, the proposal of a methodology for comparative analysis. For the present research the general literature review was limited to Latin American context and in the second step, a pilot study, only daylight analysis was addressed. The decision to not include energy analysis resulted from technical considerations such as the computing capacity demanded for this kind of simulation on an entire floor plate of large-scale projects such as Eduardo Affonso Reidy's *Pedregulho* (1950).

Out of the 48 buildings included in *Latin American Architecture Since 1945* (1955), only six were selected for the daylight analysis based on two criteria: program and climate. All chosen works are collective housing designs located in tropical climates.

Work	Architect1	Architect2	City	Country	Climate	Year
Conjunto de Apartamentos	**Eduardo Affonso Reidy**		Rio de Janeiro	Brazil	Aw	1950
Unidade de Habitación	**Guido Bermudez**		Caracas	Venezuela	Aw	1954
Multicelulares, Cerro Piloto	**Guido Bermudez**	**Carlos Raúl Villanueva**	Caracas	Venezuela	Aw	1954
Edifício Antonio Ceppas	**Jorge Machado Moreira**		Rio de Janeiro	Brazil	Aw	1952
Edifícios Cintra, Bristol e Nova Caledônia	**Lúcio Costa**		Rio de Janeiro	Brazil	Aw	1953
Edifício Montserrat	**Moisés Benacerraf**	**Carlos Guinand**	Caracas	Venezuela	Aw	1950

Table 1 – Buildings from Latin American Architecture Since 1945 (1955) selected for analysis. Source: Author, 2025.

The research also postulates the relationship between daylight, depth of the building mass and orientation in relation to the sun. The relationship between these sets of data demonstrates design problems as well as similarities and differences between the approaches.

Methodology

The first step of the research is the literature review on the topic. Five reviews were undertaken by using the fixed search keywords "Latin American modern architecture" and adding: 1) daylight, 2) thermal, 3) cooling. The sample was limited to the first 50 results obtained through Google Scholar. Afterwards they were filtered again by having or not a relevant title, abstract, and, finally, the ones chosen for full review. The complete list of articles chosen for full review can be found in this article's Appendix. Another aspect also

taken into consideration was the area of the publications, showing to which discipline was this discussion most relevant.

Scholarly Search Table
keywords: latin american modern architecture +

Search term	daylight	thermal	cooling
Total itens returned	28400	26500	25800
Top 50	50	50	50
Articles with relevant titles	10	11	9
Articles with relevant abstracts	3	8	3
Number of articles selected for full review	2	6	2

Table 2 – Relevant publications according to title, abstract and those selected for full review. Source: Author, 2025.

For the comparative analysis between the set of chosen works, a computer simulation was performed using Climate Studio. Closed volumes and openings were modeled in Rhinoceros 8 and the following data was extracted from them: 1) mean lux, 2) median lux, 3) annual daylight availability (ASE), and 4) annual glare (DGP). These data are then related to two formal definitions: floorplan area and depth. The second one takes advantage of the fact that all projects analyzed are typologically linear bars, with a clearly recognizable depth direction. These relationships can then be better analyzed through scatter plots with a horizontal line marking the distance between the results and a desirable baseline.

As models were developed using plans taken from either the pdf of the catalog or more recently published articles on these buildings, some generalizations were considered to ensure the consistency of the set. The main objective of this exercise is to compare the macro formal decisions of designs for the tropical collective housing *Latin American Architecture Since 1945* (1955) in terms of daylight performance. In that sense minor specificities of each project that have a small impact were less relevant than choices that influenced the whole floorplate. Simulations were done in Solemma's ClimateStudio and all shading devices found (musharabya and brise-soleil) were modelled using the same grasshopper script which can be found on Appendix B. The modeling generalizations considered were:

1. Simple walls were modeled with a thickness of 18 centimeters and double or reinforced walls were modeled with 25 centimeters.
2. Windows were considered to have 120 centimeters of height and a sill height of 105 centimeters.
3. Slabs were considered 15 centimeters thick.
4. Glazing was modeled without thickness.
5. Brise-soleil were modeled using a grasshopper component (appendix A)
6. Musharabya were modeled using a grasshopper component (appendix B)
7. Simulations considered all doors open.
8. Simulations accounted for all floorplate area discounted walls.

The final part of the research compares daylight simulation results with the designs' orientation in relation to the North and building mass depth[3]. The research was also able to observe relationships between design choices and resultant environmental effects or tendencies.

Results – Literature Review

The literature review has shown that publications that treat the subject of daylight, thermal, and cooling analysis of Latin American modern architecture are divided in two categories: first, vague references to such strategies as a theme that permeates architectural historiography or, second, as an engineering-focused analysis on the performance of corporate structures for international hospitality companies (hotels or resorts). In that sense, the issue of environmental adaptability in Latin America's modern architecture heritage is either treated as cultural theme in historiography or as a performance-oriented problem related to the efficiency of more expensive items such as centralized air-conditioning systems or curtain walls.

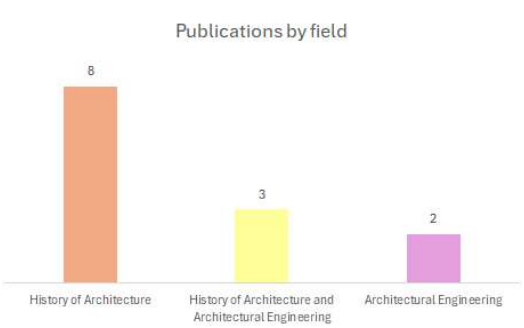

Chart 1 – Selected articles according to the type of publication. Source: author, 2025.
Chart 2 – Selected articles according to the field of the publication. Source: author, 2025.

Most of the publications are articles, with a master's dissertation focused on technical aspects of climatization in Latin American hotel offices and another, also highly technical, PhD dissertation on a generalist method for bioclimatic design. A book appeared consistently through variations of keywords: Daniel A. Barber's *Modern Architecture and Design: Before Air Conditioning* (2020) which blends architectural historiography and environmental strategies but does not establish a relationship between the two through data-driven analysis. While there are three publications that bend architectural historiography and architectural engineering, one is on post-occupancy assessment, another on urban design and the third is the already mentioned PhD dissertation.

What the literature review shows is a lack of analysis of architectural design itself and its consequences, what is particularly striking as design choices such as site design, landscaping, form, orientation, color, insulation, exterior shading, construction materials and tightness can amount to 60% of the building's heating, cooling and lightning necessities (Lechner, 2015). In that sense, there is a lack of literature that proposes a methodology for the intersection of architectural historiography (heritage), architectural design and environmental simulation. This crossing would allow for a discourse on architectural heritage based on environmental evidence which can impact the way these structures are understood as role models for design.

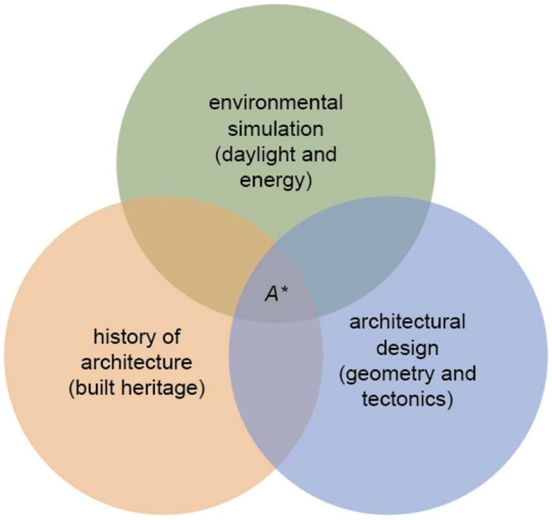

Figure 1 – Venn Diagram showcasing the crossing of different fields for a proposed methodology. A* = environmental and architectural analysis of built heritage. Source: author, 2025.

Results – daylight

Three distinct daylight 'behaviors' were observed in the collected data which were expressed in the graphs according to three color groups. Each series of data represent one floorplan – having buildings such as *Pedregulho*, *Multicelulares* and *Bristol* two or three different floor types.

Group Green: floor types characterized by adequate exposure and stable lightning.

Group Orange: floor types characterized by high exposure and stable lightning.

Group Blue: floor types characterized by high exposure and oscillating lightning.

By adequate this study understands as a illuminance around 500 lux for the median of the whole floorplate while for variation it is considered the amplitude of variation between mornings and afternoons.

In that sense projects such as Lúcio Costa's *Nova Cintra Bristol, e Caledônia*, Jorge Machado's *Antonio Ceppa*, and one of the floor types in Guido Bermudez's *Multicelulares* presented great performance in terms of daylight with good lightning conditions throughout the year. It is important to note that both Costa's and Machado's designs utilize the same strategy of brise-soleil and musharabya[4] which allows the entrance of indirect filtered light and have only around 25% of unprotected area in each module of the facade. *Multicelulares*, by comparison, do not possess any shading device but also present a great result. As it will be later shown, that might be attributed to orientation in relation to the sun and its compartmentalization.

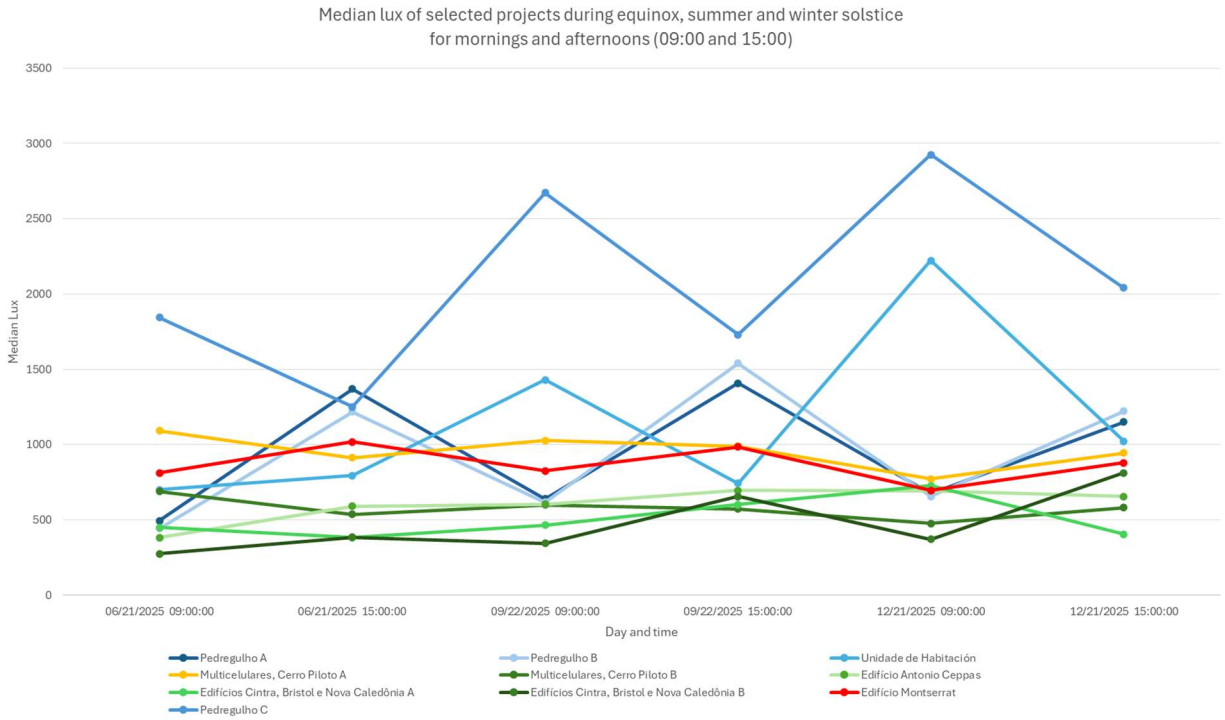

Chart 3 – Median illuminance (lux) for the whole floorplate in mornings (09:00 AM) and afternoons (15:00 PM) of each floor type. Source: author, 2025.

Projects in the orange group are also able to control the variation of temperature but have a much higher illuminance. This is the case with the other floor type for *Multicelulares*, with units less compartmentalized, and *Montserrat* which has a musharabya that covers only 50% of each façade module. In that sense it is perceived that while some projects like the last do include shading devices, it's reduced in size in relation to the façade module provides only a partial effect (stabilization) while not guaranteeing over exposure.

The blue group is composed of all floor plans for Reidy's *Pedregulho* and Guido Bermudez's *Unidad de Habitación*. These presented the worst performance of the set with

high exposure and oscillating lightning throughout the day. It also presented strong variance to seasons, with notable over exposition in the summer. While Unidad de Habitación does not have any shading device, Pedregulho has musharabya along its corridors. It that sense the shading device in Reidy's project is solely aesthetic, contributing to shading only in areas of low permanence while exterior facing residential units receive unprotected sunlight.

All analyzed projects presented satisfactory Spatial Daylight Autonomy and low Spatial Glare Probability, while many had a high level of Annual Sunlight Exposure. That means that a considerable portion of the floor slab is characterized by high levels of illuminance. While the median lux for the whole floor might not show rooms which might have adequate lightning throughout the year, the high levels of ASE reveal a design tendency of under protected sun entrance that created overly exposed areas along openings. Two projects that have good results on ASE are, once again, Costa's *Pedregulho* and Moreira's *Antonio Ceppa*, showing the success of their shading devices proportion and façade composition.

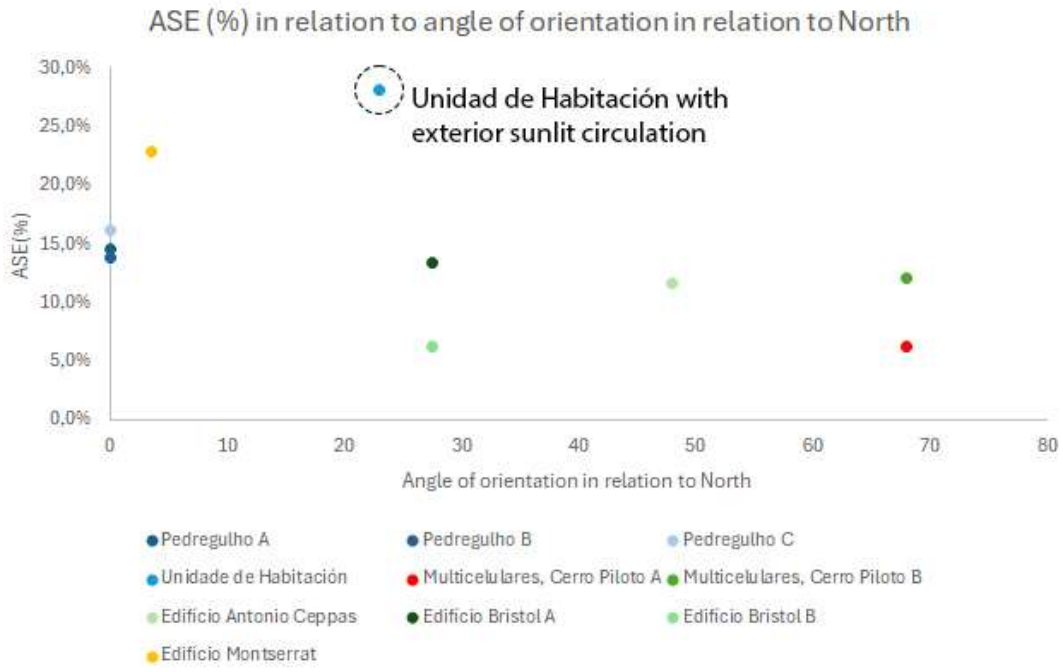

Chart 4 – Scatter plot showing the correlation between Annual Solar Exposure (ASE) and angle of orientation in relation to geographical North. Source: author, 2025.

A well-designed musharabya and brise-soleil has given good daylight performance for both projects, but which design choice has also allowed a good treatment of light in one of the floor plans of *Multicelulares* which does not have any shading device? This research has found that the good performance of *Multicelulares* has mostly to do with building orientation, which seems to be one of strongest factors of daylight intensity.

As can be seen in *Chart 4*, there is a tendency of lowering Annual Solar Exposure according to higher angle of orientation to the North, being zero an alignment with the geographical North. *Multicelulares*, which presented low daylight variation is approximately 68 degrees rotated while *Pedregulho*, which is aligned with the North, has one of the highest variations and worst performances. The position of *Unidad de Habitacion* in the graph is also skewed due to it being the only project with external corridors that receive direct sun radiation throughout the day. The shading elements of Costa's design are also remarkably successful when considering the huge difference between *Nova Cintra, Bristol and Caledônia's* Annual Solar Exposure in comparison to *Unidad de Habitación*.

If the floorplans are plotted according to Spatial Daylight Autonomy (sDA) and building depth, the traditional correlation between increasing building depth and lower sDA presents an exception: *Multicelulares*. Despite this being one of the thinnest structures in the set, approximately 9,30 meters deep, it has similar levels of Spatial Daylight Autonomy of Costa's designs, which are approximately 14,65 meters deep. This also presents us with two different inferences: the first reinforces the importance of building orientation in daylight access, with the high degree of rotation in *Multicelulares* frustrating the observed tendency; and the second being how the shading devices found in Costa's *Nova Cintra, Bristol and Caledônia* and Moreira's *Antonio Ceppa* filters the sun without compromising daylight autonomy; once again reinforcing the success of this particular case.

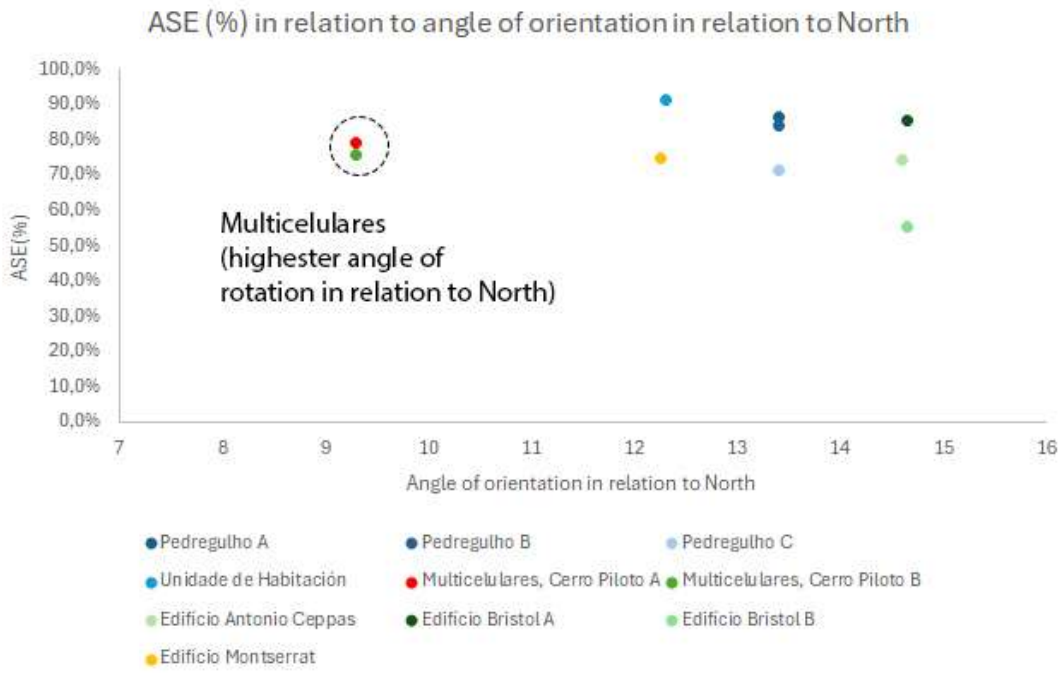

Chart 5 – Scatter plot showing the correlation between Annual Solar Exposure (ASE) and angle of orientation in relation to geographical North. Source: author, 2025.

Discussion

The literature review has revealed a methodological gap in understanding environmental characteristics of Latin American modern architectural heritage. By bridging architectural history, environmental simulation and architectural design it is possible to formulate a criticism of these works based on evidence. While this might seem as a pursuit unrelated to aesthetics, it is important to note how Lúcio Costa's *Nova Cintra, Bristol e Caledônia* as well as Jorge Machado's *Antonio Ceppa* are the most regionalist works of architecture – deviating from the strict sense of funtionalist modernism associated with the experiences in continental Europe. In that sense, the screens borrowed from intercultural exchange such as arab influences have allowed not only better environmental control but also a strong symbolic projection that is closely associated to a sensibility to the site and its cultural specificity. While the research has demonstrated a general inadaptability of *International Style* architecture to Rio de Janeiro and Caracas, there is great success in works of critical regionalism. These results suggest a more nuanced historical interpretation of the architectural developments in the regions – in terms of design and construction.

Two different proposed methods of analysis proved useful in identifying problems and successes with the adopted strategies. The first focused on the variations between mornings and afternoons on summer, winter solstice and Fall equinox revealed projects with ineffective shading strategies; and a second enabled associations between daylight performance and macro formal aspects of designs' building masses. The study has also shown that breaking up the data according to different room types may allow more sophisticated interpretations.

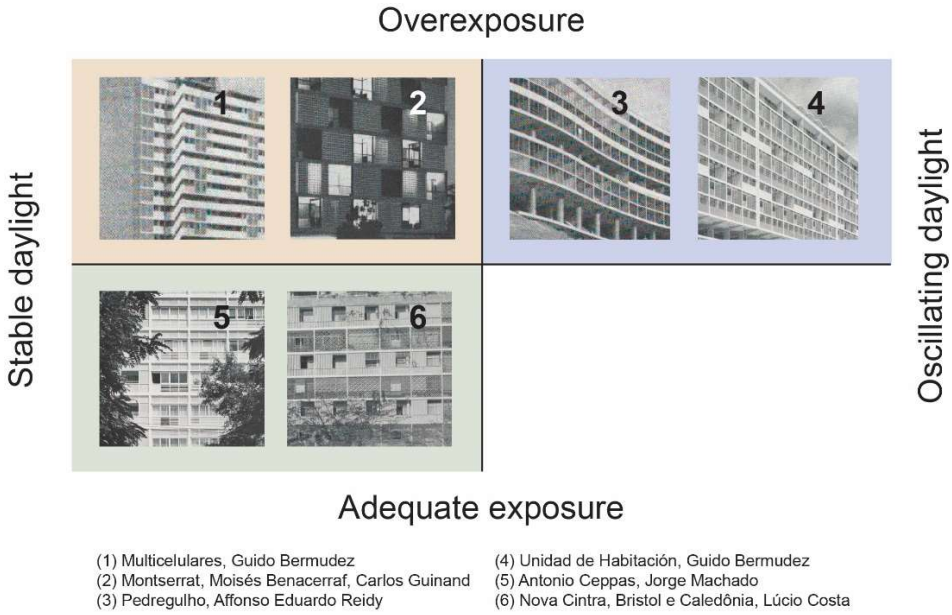

Figure 2 – Comparison in quadrants with the analyzed buildings. Source: author, 2025.

Appendix A – Literature review

REVELANT ABSTRACTS - DAYLIGHT
Keywords: latin american modern architecture daylight
Stop: 50 results

Publication title	Type of publication	Authors	Summary of text	Discipline	Method
Building the New World: Studies in the Modern Architecture of Latin America 1930-1960. Verso, 2000.	Book	Fraser, Valerie	Cites the role Carlos Raúl Villanueva in implementing passive design strategies for ventilation and daylight in Venezuela, . Also makes an interpretation on the role of daylight in defining exterior and interior spaces in the design for the Olympic Stadium in Mexico City (Augusto Pérez Palacios, Jorge Bravo and Raúl Salinas, 1952).	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
Daylight, Shape, and Cross-Cultural Influences Through the Routes of Discoveries: The Case of Baroque Temples. *Space and Culture*, *21*(4), 375-394.	Article	Cabeza-Lainez, J. M., & Almodovar-Melendo, J. M. (2018)	Studies the different treatment of light in different Baroque Cathedral designs in Latin America	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
Modern Architecture and Design Befor Air Conditioning	Book	Daniel A. Barber	Book that presents panoramic view on modern architectural design and its relations to environmental performance	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)

Table 3 – Publications with relevant abstracts for the search "Latin american modern architecture daylight". Source: author, 2025.

REVELANT ABSTRACTS - cooling
Keywords: latin american modern architecture cooling
Stop: 50 results

Publication title	Type of publication	Authors	Summary of text	Discipline	Method
Modern Architecture and Design Befor Air Conditioning	Book	Daniel A. Barber	Book that presents panoramic view on modern architectural design and its relations to environmental performance	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
A Decade of Passive Cooling: A Perspective From the USA	Article	Jeffrey Cook	Mentions how "For instance Hitchcock in Latin American Architecture since 1945, published in 1955 illustrated how completely bioclimatic concepts had informed the new architecture of an entire continent."	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
Richard Neutra's Search for the Southland: California, Latin America and Spain	Article	Brett Tipey	Presents design strategies used by Richard Neutra for the design of houses on hot climates, such as those in the Caribbean or Southern United States.	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
Le Corbusier, the Brise-Soleil, and the Socio-Climatic Project of Modern Architecture, 1929-1963	Article	Daniel A. Barber	Research on the influence of Le Corbusier's designs on Latin American architecture and its vernacular climate-oriented adaptations.	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
THE COMFORT TRIANGLES: A NEW TOOL FOR BIOCLIMATIC DESIGN	PhD Dissertation	John Martin Evans	"Presents the development, application and testing of a new graphic analysis tool to identify, select and verify different bioclimatic strategies according to climate conditions and requirements for comfort. The Comfort Triangles tool relates outdoor daily temperature variations with the modification of thermal performance achieved indoors, using two key variables, average daily temperatures and temperature swings." Also presents a history of biofilic design in Latin American context.	History of Architecture and Architectural Engineering	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies).

Table 4 – Publications with relevant abstracts for the search "Latin american modern architecture cooling". Source: author, 2025.

REVELANT ABSTRACTS - THERMAL
Keywords: latin american modern architecture thermal
Stop: 50 results

Publication title	Type of publication	Authors	Summary of text	Discipline	Method
Modern Architecture and Design Befor Air Conditioning	Book	Daniel A. Barber	Book that presents panoramic view on modern architectural design and its relations to environmental performance	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
An environmental and social approach in the modern architecture of Brazil: The work of Lina Bo Bardi	Article	Steffan Lehman	The article showcases sustainability concerns that can be found in the work of Italian-Brazilian architect Lina Bo Bardi	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies)
Integration of building archetypes and typological urban forms to assess energy performance and thermal comfort: Proposal of suitable parameters for Latin America	Article	Vanessa Guillén-Mena, Koldobika Martin-Escudero, and Olatz Irulegi	Breakdown of built environment (small urban scale) through elements and anaysis of their environmental interrelationship	Architectural Engineering	Morphological and typological analysis associated to environmental parameters
Modernist housing estate "revival": a paradigm to upgrade Latin America's slums?	Article	J R Núñez Collado, and R Potangaroa	Post-occupancy assessment of modernist low-income estates in Santo Domingos. Studies both spatial as well as environmental characteristics.	History of Architecture and Architectural Engineering	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies). Opinion polling regarding characteristics of modernist housing estate in Santo Domingo
Modern Again: Tradition and Modernity in the Pedregulho Housing Complex in Rio de Janeiro	Article	Flávia Brito do Nascimento	Historiographical account of the relevance of this design according to the canon. Post-occupancy assessment of modernist Pedregulho Housing Complex. Studies both spatial as well as environmental and constructive characteristics.	History of Architecture	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies).
Santiago de Chile: The Standardization of Indoor–Outdoor Transitions, On the Dynamics between Public Spaces and Climate Control	Book chapter	Lionel Epiney	Chapter of a publication by Birkhauer (Switzerland). Studies the regulatory, constructive and formal elements that influence the climate control in buildings located in Santiago de Chile.	History of Architecture and Architectural Engineering	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies).
THE COMFORT TRIANGLES: A NEW TOOL FOR BIOCLIMATIC DESIGN	PhD Dissertation	John Martin Evans	"Presents the development, application and testing of a new graphic analysis tool to identify, select and verify different bioclimatic strategies according to climate conditions and requirements for comfort. The Comfort Triangles tool relates outdoor daily temperature variations with the modification of thermal performance achieved indoors, using two key variables, average daily temperatures and temperature swings." Also presents a history of biofilic design in Latin American context.	History of Architecture and Architectural Engineering	Historiographical (primary sources), architectural criticism (relating form to environmental conditions and design strategies).
Achieving energy efficiency in a hotel office building under tropical Latin American climatic conditions	Master's Thesis	Luis Arias	Breakdown of elements of hotel design and construction and anaysis of their environmental interrelationship and performance (energy and climate control)	Architectural Engineering	Morphological and typological analysis associated to environmental parameters

Table 5 – Publications with relevant abstracts for the search "Latin american modern architecture thermal". Source: author, 2025.

Appendix B – Grasshopper scripts

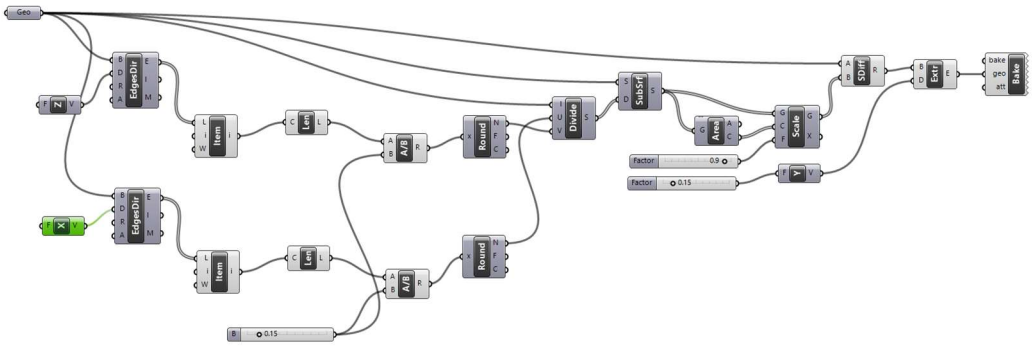

Figure 3 – Musharabya generator script. Source: author, 2025.

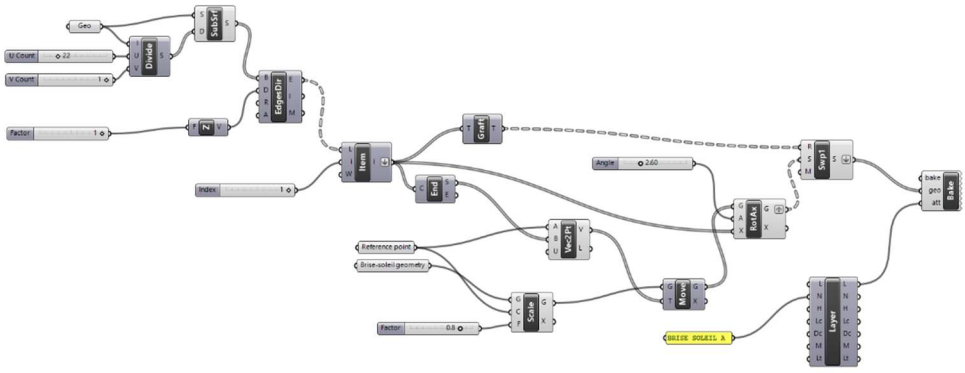

Figure 4 – Brise-soleil generator script. Source: author, 2025.

Appendix C – Collected daylight data

Work	Floor type	Circulation	Median Lux						sDA	ASE	sDG
			06/21/2025 09:00:00	06/21/2025 15:00:00	09/22/2025 09:00:00	09/22/2025 15:00:00	12/21/2025 09:00:00	12/21/2025 15:00:00			
Pedregulho	**A**	Point access	495	1370	641	1408	677	1150	86,5%	14,6%	26,2%
	B	Single loaded corridor	443	1218	617	1539	656	1223	84,0%	13,9%	26,3%
	C	Single loaded corridor	1844	1252	2673	1729	2925	2042	71,4%	16,1%	22,5%
Unidade de Habitación	**A**	Single loaded corridor	701	794	1429	744	2223	1023	91,1%	28,1%	30,3%
Multicelulares, Cerro Piloto	**A**	Single loaded corridor	1092	913	1027	989	773	944	79,1%	6,2%	30,2%
	B	Single loaded corridor	689	538	600	574	477	581	75,9%	12,1%	21,2%
Edifício Antonio Ceppas	**A**	Point access	382	591	605	695	693	655	74,4%	11,7%	16,1%
Edifício Bristol	**A**	Point access	451	382	466	603	728	405	85,3%	13,4%	27,0%
	B	Point access	275	384	344	656	371	813	55,4%	6,2%	18,6%
Edifício Montserrat	**A**	Double loaded corridor	813	1018	825	985	697	879	74,7%	22,9%	31,4%

Table 6 – Median illuminance (lux) for the whole floorplate in mornings (09:00 AM) and afternoons (15:00 PM) of each floor type. Spatial Daylight Autonomy, Annual Sunlight Exposure and Spatial Glare Probability for each project. Source: author, 2025.

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Notes

[1]See: Torrent, Horacio. Latinoamérica, las arquitecturas, las exposiciones, las revistas y las ideas: moma 1955. In: Las exposiciones de arquitectura y la arquitectura de las exposiciones. Las arquitectura española y las exposiciones internacionales (1929-1975): actas preliminares. Pamplona 8-9 mayo 2014, Escuela Técnica Superior de Arquitectura, Universidad de Navarra / coord. Por José Manuel Pozo Municio, Héctor García-Diego Villarías, Beatriz Caballero Zubía, 2014, ISBN 978-84-92409-61-7, págs. 81-92

[2]See: Cook, Jeffrey. A decade of passive cooling: A Perspective from the USA. Passive and Low Energy Ecotechniques. Proceedings of the Third International PLEA Conference, Mexico City, Mexico, 6–11 (August 1984) 1985, Pages 73-87.

[3] The building depth considered for Montserrat was half of the total due to it being the only double loaded corridor project in the set.

[4]Arab architectural element for sun protection. It was interpreted and used in Latin America as a wooden or ceramic screen that also allows for internal privacy in the interface with the street.