Environmental conditioning strategies and their influence on a multipurpose building in the commercial area of Gamarra, La Victoria

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Abstract

The objective of this research is to determine the effectiveness of environmental conditioning strategies applied in a multipurpose building in the commercial area of Gamarra, in the district of La Victoria. The commercial area of the Gamarra emporium is very frequented by workers, merchants, and consumers who daily tolerate the lack of comfort when circulating through the multipurpose buildings, which are not properly conditioned to receive a large number of people. The analysis developed in the project proposal is resolved through environmental parameters (bioclimatic strategies), which determine the adequate lighting, and thermal and acoustic comfort. The building understudy was subjected to virtual simulations of programs such as Design Builder and Sun Path, allowing to recognize the environmental conditioning problems generated in its interior, which affect the comfort of recurring users. Therefore, solutions were proposed to counteract the simulation results, leading to the restoration of the building to ensure the effective operation of the environmental conditioning..

Keywords: bioclimatic strategies, environmental conditioning, multi-purpose building, lighting comfort, thermal comfort, simulation

I. INTRODUCTION

Multipurpose buildings are a novel building typology that consists of the interconnection of several facilities in the same building, linking them in a way that satisfies the needs of their users. The most frequent facilities housed in this building typology are retail, housing, offices and public recreational spaces [1,2]; but they also incorporate transformable spaces, as this makes the building more flexible and multidisciplinary [3]. Therefore, with a large influx and variety of users circulating daily, it is essential that the building has active and passive environmental conditioning systems for a better experience [4,5].

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In Peru, this typology began to be used through constant renovations and adaptations of existing buildings [6], especially in sectors with a large influx of people. One of these sectors is the commercial [7] emporium of Gamarra, which functions as an urban center of commercial exchange, since it houses wholesalers and manufacturers that supply not only the capital but also other regions of Peru [8]-[10].

As a result, the demand for facilities is notable, the main one being commerce, followed by public recreation areas, offices, services, among others.

This research aims to demonstrate the design and construction pathologies on the environmental conditioning problems in a multipurpose building in the commercial area of Gamarra, La Victoria, based on the proposed architectural design strategies and the environmental parameters of the site. It is also intended to apply current technologies and solar simulation software [11] such as Sun Path and Design Builder.

The Design Builder software is specialized in the simulation of the environmental conditions to which a building is subjected based on the environmental parameters of its site and the environmental conditioning strategies adopted in its architectural design [12,13]. Its programming makes it possible to evaluate the level of comfort [14], energy consumption, and carbon emissions. In this way, the software ensures that the preliminary analysis of a building causes the least possible environmental impact during its construction and service life [15]. This is also attributed the evaluation of the constructed buildings, as it allows to identify if they are sick buildings, i.e. with low thermal [16], acoustic, or light comfort [17]. In this way, a solution can be given and the building can be restored [18].

The program is specially designed for architects and engineers, incorporating different functions according to the needs required by professionals. For architects, more emphasis is placed on advanced simulations of the environmental comfort of a building through an analysis of the energy and environmental efficiency of the three-dimensional volumetry. For engineers, it focuses on the evaluation of air conditioning systems, which includes the analysis of the renewable energies used and their energy consumption [19].

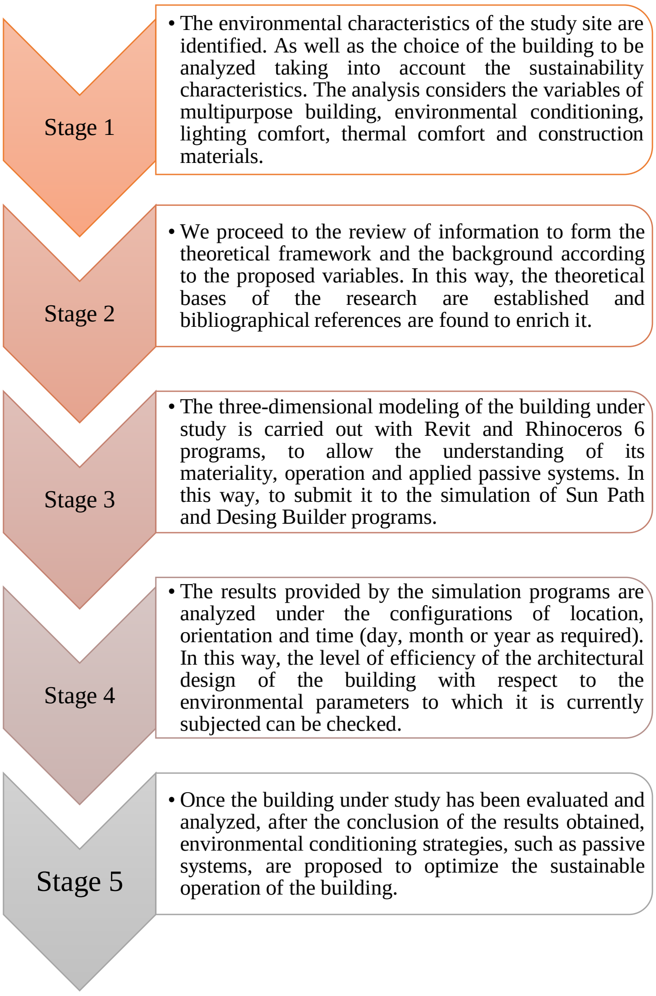
The study area is located in the commercial area of the Gamarra emporium, heavily frequented by workers, merchants, and consumers who daily transit tolerating the lack of comfort [20] when circulating through the multipurpose buildings [21], which are not properly conditioned to receive a large number of people.

Considering the current situation, it is necessary to have environments properly ventilated in a natural way [22] and manually controlled according to the needs of the users. Likewise, the aspect of lighting [23] and thermal [24] comfort is considered relevant in the architectural design proposed by bioclimatic architecture, which takes advantage of the type of climate and environment [25] for a greater comfort experience. Therefore, it is intended to determine the effectiveness of environmental conditioning strategies applied in a multipurpose building in the commercial area [26] of Gamarra, in the district La Victoria [27].

This research work has important the analysis of this building typology since it is common in the study area and houses a large influx of people daily [28]. Being of multifunctional and public use, important requirements must be taken into account for its optimal operation. The feasibility of this project is based on current technology that offers sophisticated software that allows the creation of solar and environmental conditioning simulations to for presentative volumes of the building to be analyzed.

II. METHODOLOGY

This research consists of 5 stages:



A. Study Area

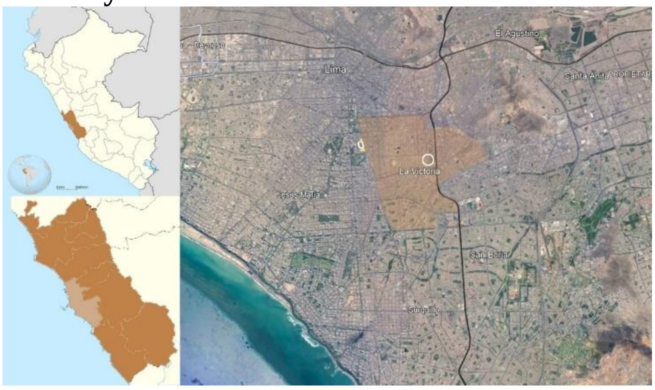


Figure 1. Map of the country, department and district of the study area.

The multipurpose architectural building of this study is located in the country of Peru, department of Lima, province of Lima, Lima Centro sector, district of La Victoria, as can be seen in Figure 3. In addition, the zoning of the study district, according to the District Municipality of La Victoria, also shows the high level of local, zonal and metropolitan commerce, whose concentration stands out in the Gamarra emporium highlighted with the yellow dotted lines. This emporium is recognized for being an area with the most important wholesalers at the national level and concentrates a large number of mixed-use buildings with facilities that meet the demands of users.

Figure 2. Delimitation of the study area: Emporio de Gamarra, La Victoria.

Figure 2 shows the district of La Victoria and its relationship with the other districts of Lima, such as Lince, Lima, San Luis, San Borja and San Isidro. It is also distinguished by its easy accessibility, as it is connected to two of Metropolitan Lima's main thorough-fares: the Vía Expresa and Av. Javier Prado Este.

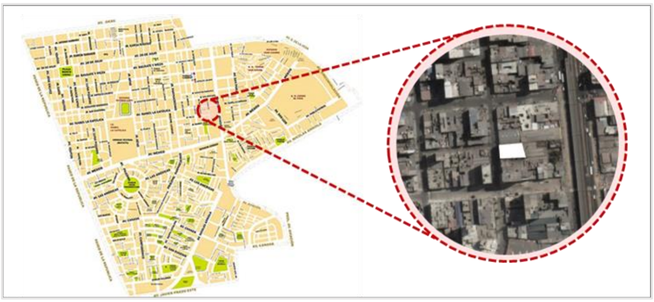


Figure 3. Unit of study: multi-purpose building Ya.

Figure 3 shows the urban morphology, streets and main avenues of the neighborhood where the study area is located, which is delimited by the red circular line that also shows the study unit, marked with a white rectangle, and its immediate surroundings.

The exact address of this building is: Jirón Prolongación Gamarra N°1043 Mz. "45" Lot N°3, which is easily accessible, since it is located near two main avenues: Av. Aviación and Av. México, in the Gamarra emporium.

B. Climatology

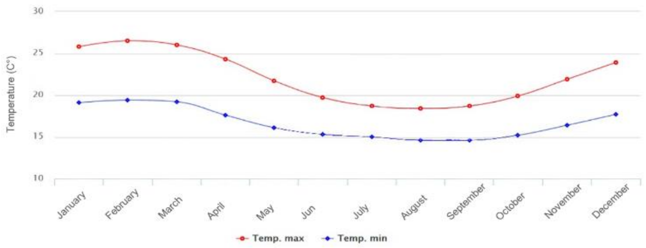


Figure 4. Temperatures for western Lima.

The highest temperatures are recorded in the months of January, February and March, the summer season in the southern hemisphere, with temperatures reaching 26.5°C, as shown in Figure 4. On the other hand, the lowest temperatures are found in the months of July, August and September, the winter season, dropping to 14.6°C.

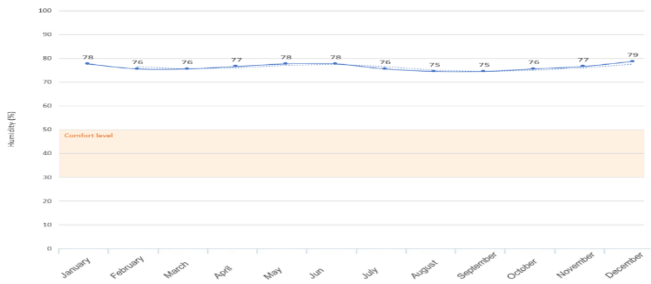


Figure 5. Table of humidity percentage indexes in Lima.

Humidity is generally very high in Lima throughout the year, as it exceeds the comfort limits, which are estimated to be between 30% and 50% to obtain the ideal humidity level. Figure 5 shows the statistics in percentage of humidity in the study site, where it is observed that in the months of December and January there is an increase in humidity com-pared to the months of August and September where humidity is perceived to a lesser degree

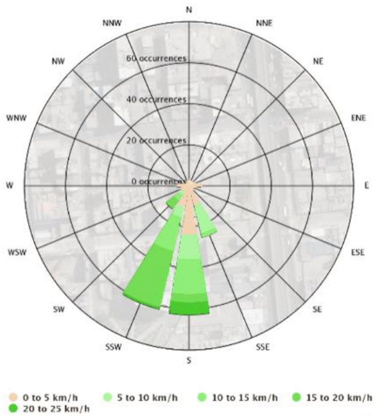


Figure 6. Wind rose of the city of Lima.

The wind direction is predominantly from the south and southwest, with a frequency of between 20 and 25 km/h from the south and between 15 and 20 km/h from the south-southwest, decreasing in speed as it approaches the center in both cases, as shown in Figure 6 of the Meteoblue wind rose. However, it should be noted that tall buildings and vegetation can redirect the winds. Therefore, it is imperative to evaluate these factors in the immediate surroundings of the building under study to optimally analyze how winds in-fluence it.

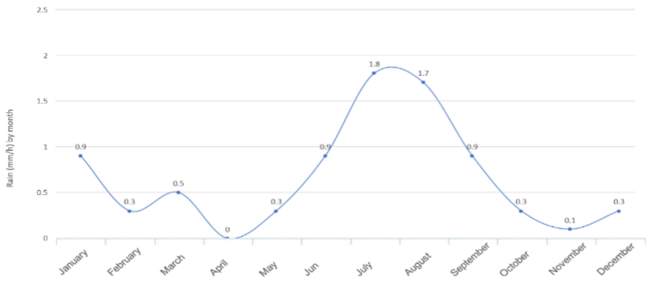


Figure 7. Precipitation in western Lima.

Rainfall is generally low throughout the year. According to SENAMHI statistics, shown in Figure 7, the highest rainfall intensity occurs in July, with 1.8 mm/h, and the lowest in April, with zero precipitation.

Table 1. Rainfall intensity

Precipitation intensity correspondence table		
Color	Intensity (mm/h)	Type of precipitation
	Greater tan 250	Large hail
	Greater tan 250	Torrential and hail
	100 to 250	Torrential and probably hail
	40 to 100	Very heavy to torrential rain
	16 to 40	Strong rain
	6’5 to 16	Moderate rain
	2’5 to 6’5	Light rain
	1 to 2’5	Weak rain
	0’4 to 1	Very light rain
	0’1 to 0’4	Trace precipitation

Table 1 shows the rainfall intensity correspondence table, where, according to the statistics in Figure 7, rainfall in Lima is classified as very light rain since it is between 0.4 and 1 mm/h on average.

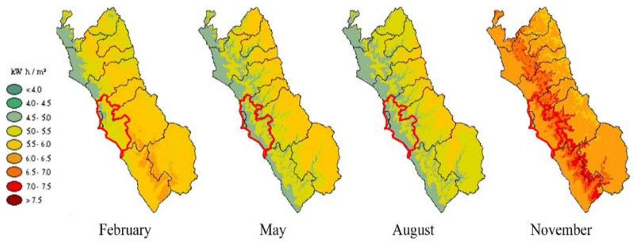


Figure 8. Solar irradiation map of Lima-Callao.

Figure 8 shows graphically the radiation levels in the department of Lima and its in-fluence on the territory every 3 months. The highest amount of solar radiation occurs in the month of November, which ranges between 5.5 - 7.5 Kw h/m3; and the lowest in the month of August, which ranges between 4.5 - 6 Kw h/m3. The province of Lima, delimited with a red line, is located in a medium radiation zone.

C. Topography

The study building is located in the Chala region, according to the investigations of geographer Javier Pulgar Vidal in 1938, with an altitude between 0 and 500 meters above sea level. The terrain is remarkably flat or nearly flat in its immediate surroundings.

Figure 9. Topographic map of Gamarra, La Victoria.

Figure 9 shows the relationship of the topographic slopes in the study sector and its surroundings by means of a sequence of colors, each one representing an altitude level, where the cold colors are the lowest levels, and the warm colors are the highest levels. On the right side, the color bar indicates the estimated altitude level in meters. This graph indicates that the study area delimited with a line is at a level between 169 and 177 meters above sea level.

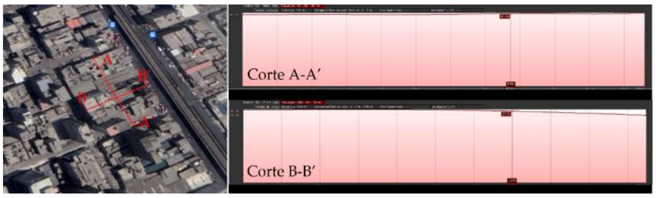


Figure 10. Topographic section of the study block.

Figure 10 shows the topographic section of the sector delimited by the continuous line in figure 9. This survey of the profile of the territory shows that the variation in level is not interrupted, i.e., the terrain is not rugged, it is almost flat in its entirety.

D. Unit of study

The multipurpose building analyzed in this research is the Ya building, which was built in November 2016. The professional responsible is the architect Oscar Joel Junco Guzmán.

Figure 11. Multi-purpose building Ya, warehouses, and internal offices.

This multipurpose building also has commercial facilities, offices, event areas and production workshops, as shown in Figures 11 B and 11 C. These functions complement each other, allowing the optimal functioning of the building in terms of functional architecture, thus fulfilling the purpose of a multipurpose building [29].

The materiality of the building consists of glass implement, metal rods, stainless steel lattice and black paint on the facade, as shown in Figure 11 A [30]-[32]. As construction materials, bricks, mortar, steel and concrete were used, in general, because the masonry construction system is used. Of which, we will proceed to perform the calculation of the thermal treatment to analyze its effectiveness with respect to the thermal balance of the building [33].

III. Results

A. Analysis of comfort in buildings

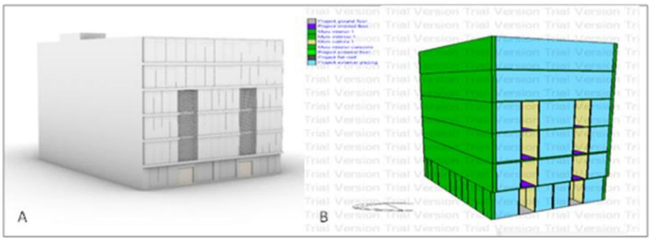


Figure 12. Three-dimensional study of building Ya.

The building is studied three-dimensionally using Revit BIM software and Rhinoceros 6 with detailed modeling, as shown in Figure 12A, to further investigate its functionality as an architectural element.

Figure 12 B shows the volumetric survey without visual detail of elements such as trusses, carpentry and metal works. It is modeled within the Design Builder program for the simulation of the environmental conditioning analysis of the building based on the environmental parameters of La Victoria [34,35]. In this way, it is observed how it responds to the climatic conditions of the site according to the data provided in the materiality configuration, which consists of the masonry system, concrete slabs and curtain walls.

Both three-dimensional studies were modeled based on the safety plans exhibited in the building for the general public.

B. Analysis of lighting comfort

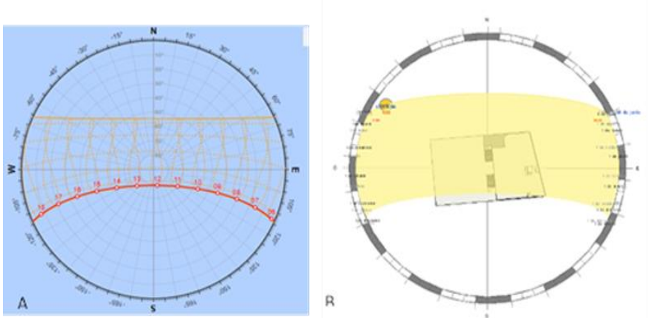


Figure 13. Solar trajectory of La Victoria.

The path of the sun in the La Victoria neighborhood leans toward the north, as shown in Figure 13 A; therefore, the south façade is the most naturally protected. Howev-er, the east and west facades are the most affected because they receive direct sun throughout the year, as does the north facade, but to a lesser extent. [36,37]

Figure 13 B shows that the main facade is located on the west side, an unfavorable position because it receives the sun during the peak hours of the building [38,39]. Even so, the proposal presents a facade of glass partitions and black paint, which causes internal overheating of the rooms and forces users to resort to alternative methods such as the use of air conditioning or fans. This causes an increase in electrical energy consumption in the building.

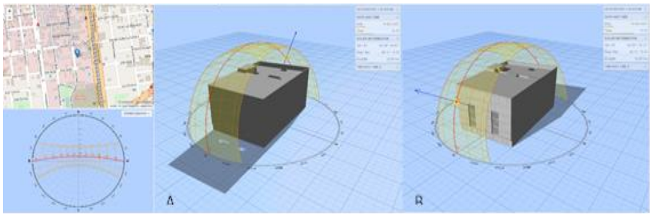


Figure 14. Autumnal equinox.

Figure 14 shows the volumetry in the simulation of the path of the sun, where the so-lar path throughout the year is graphically represented by a yellow curved surface and the path of the autumnal equinox (southern hemisphere) represented by a red curve that simulates the position of the sun throughout the day on March 19[40]. Figure 14 A shows the position of the sun at 9:00 a.m., located at the intersection of the red curve and the blue date coming from the center of the volumetry, where only the small skylights are illuminated. In Figure 14 B, the sun is on the west side at 16:00 h, where the entire main facade of the building, which has no solar protection, is illuminated.

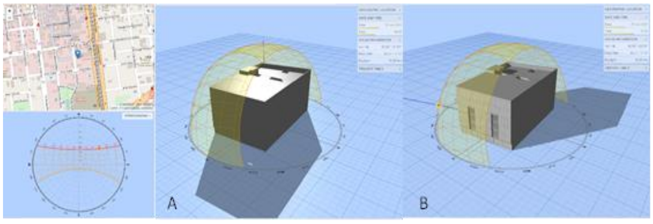


Figure 15. Winter solstice.

As the months pass, the sun's path changes position due to the Earth's translational motion. Figure 15 shows the path of the winter solstice, whose date is June 21, further north than the path in figure 14, so the shadow is longer. Figure 15 A shows that the sun illuminates the rear skylights at 9:00 am. Continuing the solar motion following the red curvature, at 16:00 h the sun illuminates the entire main facade of the building, as shown in figure 15 B.

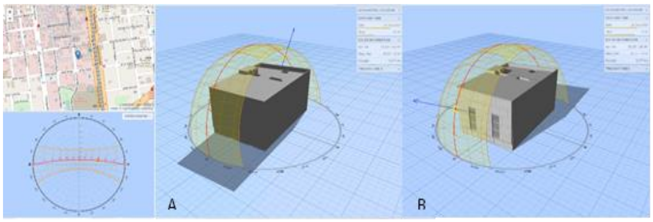


Figure 16. Spring Equinox.

Figure 16 shows the solar path at the vernal equinox, the date of which is September 23. In the stereographic solar projection plot below the map, it can be seen that the red curvature, which represents the solar motion during the specified day, returns to the mean as at the autumnal equinox. The sun at 9:00 h begins to illuminate the skylights as seen in Figure 16 A and at 16:00 h directly illuminates the main facade as seen in Figure 16 B. The main façade has the greatest impact of sunlight due to the location and orientation of the building; the entry of light is present throughout the year.

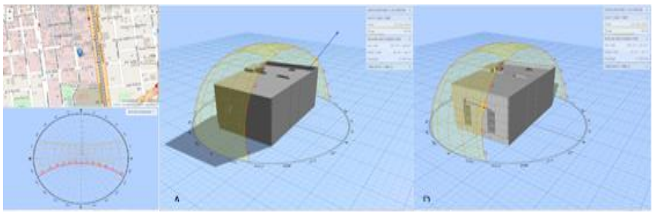


Figure 17. Summer solstice.

Figure 17 shows the simulation of the summer solstice on December 20. The path of the sun in the stereographic solar projection is shown to the south, starting the hottest days of the year. Figure 17 A shows the position of the sun in the east with little influence on the building, in contrast, in Figure 17 B the position of the sun is in the west, influencing in such a way that it illuminates the entire glass facade until sunset.

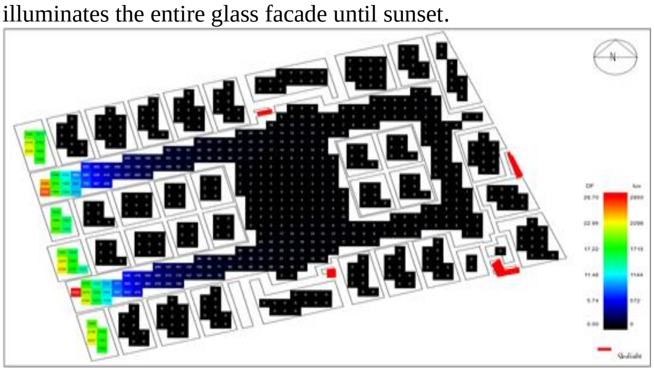


Figure 18. Lux per room on a typical floor of the Ya building.

Quantitatively, it is possible to check the level of influence that lighting has on the interior of the building. The volumetry submitted to the virtual simulation by the Design-Builder program shows the amount of lux that the interior of the building receives according to its internal distribution, represented graphically in Figure 18. The main façade presents a higher radiation and light entry, ranging from 1630 lux to 2860 lux, since it is covered with screens, but it does not have any type of solar protection system, which can cause glare and hot flashes. On the other hand, the skylights inside the proposal do not help the entry of natural light because the dimensions are not adequate with respect to the height of the building, so the simulation shows zero illumination inside the proposal. The amount of lighting recommended for the typology of commerce is between 300-500 lux, which the building does not meet, as we see that there are areas with very little or little natural light.

C. Thermal comfort analysis

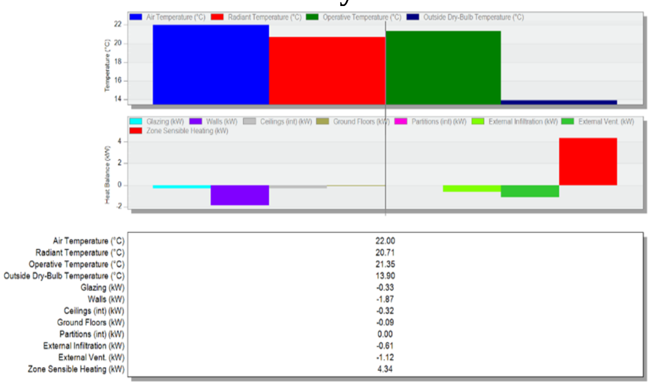


Figure 19. Temperature and Heat Loss.

The results of the Design Builder program show through simulation [41] that the average air temperature inside the building is 22°C, the average radiant temperature is 20.71°C, leading to an operating temperature of 21.35°C, as shown in Figure 19. These results show a slight excess of heat inside the building, which to some extent is detrimental to the comfort of the users, who resort to unsustainable and unhealthy options [42] for cooling, such as fans or air conditioning.

The proposed heat balance of the materials shows that the heat losses of the materials used in the project are low [43]. In the case of the glass partitions, it has a loss of -0.33 kW, the brick and mortar walls show a heat loss of -1.87 kW, the lightened slab roof shows a heat loss of -.32 kW. On the other hand, the most notable index is the heat gain of the sensible heating zone, which is 4.34 kW, this counter statistic shows that the building has a heat gain due to the enclosures and the small size of the skylights, which are not proportional to the height of the building.

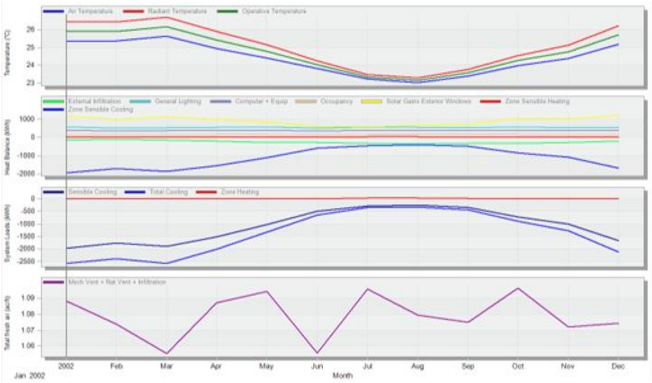


Figure 20. New Result Set-Block 1.

Figure 20 shows the results of the simulation in one year, i.e., by months, where there is a notable difference between the summer and winter months. The temperature ranges between 23.03°C and 26.69°C marked by the seasons of the year; however, these indices exceed the ideal temperature range for user comfort. On the other hand, the heat balance of the materials does not represent a notable variation, except in the sensible cooling zone, which increases between the winter months. The sensible cooling and total cooling indicators also increase in the winter months, but the thermal zone remains uniform and above. Finally, air renewals remain highly variable, between 1.06 ac/h and 1.10 ac/h every two months or so.

Table 2. Annual indexes of environmental parameters of the building

New Result Set - Block 1

EnergyPlus Output — 1 Jan - 31 Dec, Monthly — Evaluatic

Month												
Air Temperature (°C)	25.35	25.36	25.62	24.93	24.41	23.83	23.23	23.03	23.41	23.98	24.39	25.19
Radiant Temperature (°C)	26.46	26.42	26.69	25.91	25.15	24.25	23.47	23.28	23.76	24.54	25.13	26.21
Operative Temperature (°C)	25.90	25.89	26.15	25.42	24.78	24.04	23.35	23.15	23.58	24.26	24.76	25.70
External Infiltration (kWh)	-154.04	-109.23	-137.29	-212.68	-291.21	-287.37	-344.76	-358.76	-341.07	-343.62	-274.48	-205.56
General Lighting (kWh)	578.52	503.06	528.22	553.37	578.52	503.06	578.52	553.37	528.22	578.52	528.22	553.37
Computer + Equip (kWh)	398.44	348.14	368.10	381.67	398.44	351.33	398.44	383.27	366.50	398.44	366.50	383.27
Occupancy (kWh)	164.40	142.95	149.90	157.64	164.94	144.13	168.12	161.60	152.60	165.80	150.62	157.60
Solar Gains Exterior Windows (kWh)	1189.90	1012.95	1131.89	1001.76	849.51	596.97	595.35	661.91	724.67	1045.40	1038.06	1221.10
Zone Sensible Heating (kWh)	0.00	0.00	0.00	0.00	0.00	1.45	24.02	24.58	7.63	2.88	0.00	0.00
Zone Sensible Cooling (kWh)	-1963.83	-1721.22	-1870.51	-1548.44	-1123.99	-605.16	-453.22	-419.05	-499.56	-855.13	-1098.65	-1695.36
Sensible Cooling (kWh)	-1978.65	-1757.65	-1905.07	-1514.25	-1018.87	-490.59	-287.12	-253.59	-342.44	-715.55	-1008.55	-1678.85
Total Cooling (kWh)	-2572.53	-2398.57	-2570.06	-2012.84	-1333.14	-645.11	-350.92	-322.93	-437.86	-903.20	-1275.21	-2121.76
Zone Heating (kWh)	0.00	0.00	0.00	0.00	0.00	1.51	27.06	27.42	8.46	3.13	0.00	0.00
Mech Vent + Nat Vent + Infiltration (ac/h)	1.09	1.07	1.06	1.09	1.09	1.06	1.10	1.08	1.07	1.10	1.07	1.07

Table 2 shows more precisely the results shown in Figure 23, according to the overall average per month.

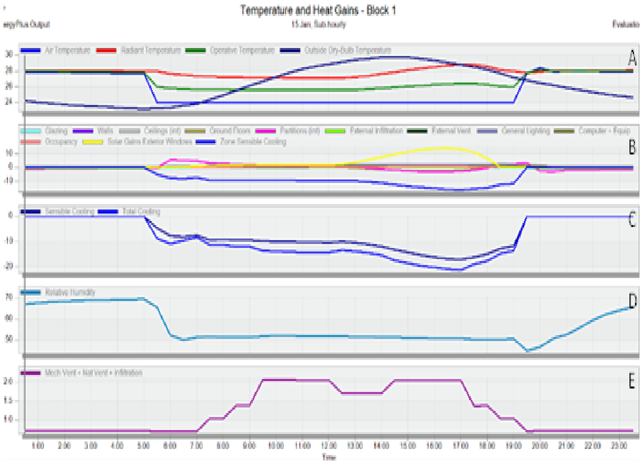


Figure 21. Summer heat gain simulation.

Table 3. Statistics of environmental parameters on January 15 (summer)

Temperature and Heat Gains - Block 1

EnergyPlus Output — 15 Jan, Sub-hourly — Evalua

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	27.85	27.76	24.00	24.00	24.00	24.00	24.00	24.00	24.00	28.45	28.00
Radiant Temperature (°C)	28.10	28.06	27.68	27.28	27.16	27.14	27.65	28.59	28.62	27.98	28.11
Operative Temperature (°C)	27.98	27.91	25.84	25.64	25.58	25.57	25.82	26.29	26.31	28.22	28.06
Outside Dry-Bulb Temperature (°C)	23.73	23.33	23.33	24.92	27.29	28.94	29.80	29.40	28.22	26.50	25.31
Glazing (kW)	-0.29	-0.28	-0.21	-0.05	0.07	0.12	0.61	0.79	0.18	-0.24	-0.27
Walls (kW)	0.45	0.16	0.82	0.28	0.44	1.11	1.50	1.55	2.03	1.21	1.09
Ceilings (int) (kW)	1.03	0.95	1.65	1.00	0.73	0.62	0.31	0.68	2.11	1.51	1.27
Ground Floors (kW)	-0.19	-0.18	0.52	0.11	0.05	0.03	-1.68	-2.45	0.04	-0.20	-0.17
Partitions (int) (kW)	-0.81	-0.43	5.73	2.89	1.79	1.18	-1.10	-3.20	-0.36	-2.80	-1.85
External Infiltration (kW)	-0.30	-0.32	-0.05	0.07	0.24	0.36	0.42	0.39	0.30	-0.14	-0.20
External Vent. (kW)	0.00	0.00	0.00	0.03	0.47	0.71	0.62	0.77	0.30	0.00	0.00
General Lighting (kW)	0.00	0.00	0.00	2.10	2.10	2.10	2.10	2.10	2.10	0.00	0.00
Computer + Equip (kW)	0.07	0.07	0.07	1.23	1.23	1.23	1.23	1.23	1.23	1.23	0.07
Occupancy (kW)	0.00	0.00	0.00	0.20	0.80	0.80	0.60	0.80	0.40	0.00	0.00
Solar Gains Exterior Windows (kW)	0.00	0.00	0.00	1.45	2.14	2.18	7.62	13.78	6.55	0.00	0.00
Zone Sensible Cooling (kW)	0.00	0.00	-7.67	-9.22	-9.51	-9.65	-11.34	-15.35	-14.68	0.00	0.00
Sensible Cooling (kW)	0.00	0.00	-7.67	-9.25	-10.00	-10.39	-11.98	-16.15	-14.99	0.00	0.00
Total Cooling (kW)	0.00	0.00	-10.86	-11.33	-13.96	-14.39	-15.41	-20.32	-17.68	0.00	0.00
Relative Humidity (%)	68.47	69.21	52.19	51.20	51.92	51.87	51.22	50.80	50.23	46.72	59.37
Mech Vent + Nat Vent + Infiltration (ac/h)	0.71	0.71	0.70	1.04	2.06	2.06	1.72	2.06	1.38	0.71	0.71

The following analysis includes a comparison between two days of the year belonging to the summer and winter seasons in the district of La Victoria. It is also observed that in both figures (21 and 22) the results of heat gains and losses produce peaks of noticeable variation between 14:00h and 18:00h. Figure 21 and Table 3 show the results of the simulation of the temperature and heat gains in the building on a day of the summer season, in this case January 15, so in the lower part the hours are shown and in the left vertical part, the indexes according to the requested calculation.

Figure 21 A shows the temperature variations, ranging from 24 to 28.62 °C, exceeding the ideal level for an active person (16 - 18 °C), causing overheating inside the building by exceeding the user's comfort range.

On the other hand, Figure 21 B shows the thermal balance of the materials, where for the most part it does not present a sharp variation; however, the solar gain of the exterior windows has the highest level with respect to the other materials with 13.78 KW. This is due to the fact that the main façade is oriented to the west and does not present any type of passive system solar protection in the architectural design.

Figure 21 C shows the cooling system indices where the most notable decrease is observed between 13:00 - 17:00 h, decreasing to -20.32KW at 16:00h.

Figure 21 D calculates the relative humidity which, due to the airtightness of the building, the indices vary between 46.72% and 69.21%, indicating that it is within the comfort range or with a small excess.

Finally, Figure 21 E shows the air renewals inside the building, being higher during 09:30 - 12:00 h and 14:30 - 17:00 h, with a maximum of 2.06 ac/h.

The precise indices of the results are shown in Table 3 in average for each two hours of the specified day.

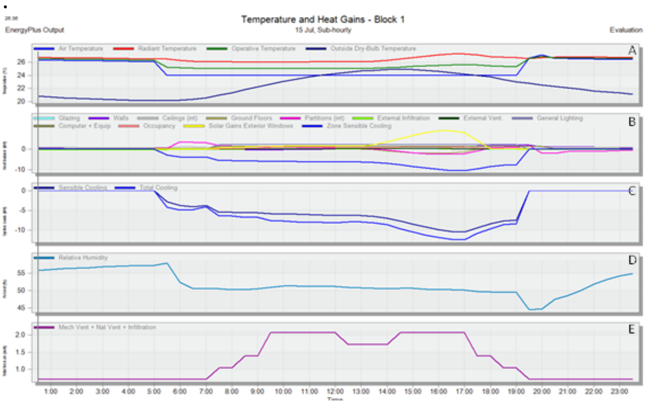


Figure 22. Winter heat gain simulation.

Table 4. Statistics of environmental parameters on July 15 (winter)

Temperature and Heat Gains - Block 1

EnergyPlus Output — 15 Jul, Sub-hourly — Evaluation

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	26.27	26.15	24.00	24.00	24.00	24.00	24.00	24.00	24.00	27.12	26.50
Radiant Temperature (°C)	26.67	26.58	26.31	26.08	26.05	26.09	26.34	27.13	26.89	26.73	26.77
Operative Temperature (°C)	26.47	26.36	25.16	25.04	25.02	25.05	25.17	25.56	25.45	26.92	26.64
Outside Dry-Bulb Temperature (°C)	20.48	20.20	20.20	21.35	23.08	24.28	24.90	24.61	23.75	22.50	21.64
Glazing (kW)	-0.30	-0.30	-0.26	-0.16	-0.08	-0.04	0.21	0.44	-0.26	-0.27	-0.29
Walls (kW)	0.24	-0.06	0.12	-0.34	-0.38	0.06	0.63	0.96	1.74	1.14	0.97
Ceilings (int) (kW)	0.71	0.66	1.00	0.55	0.39	0.32	0.19	0.28	1.48	0.85	0.80
Ground Floors (kW)	-0.18	-0.16	0.22	-0.05	-0.09	-0.12	-0.91	-2.01	0.87	-0.27	-0.21
Partitions (int) (kW)	-0.16	0.18	3.44	1.52	0.84	0.40	-0.54	-2.46	0.64	-1.97	-1.07
External Infiltration (kW)	-0.43	-0.44	-0.28	-0.20	-0.07	0.02	0.07	0.04	-0.02	-0.34	-0.36
External Vent. (kW)	0.00	0.00	0.00	0.00	0.00	0.04	0.10	0.09	0.00	0.00	0.00
General Lighting (kW)	0.00	0.00	0.00	2.10	2.10	2.10	2.10	2.10	2.10	0.00	0.00
Computer + Equip (kW)	0.07	0.07	0.07	1.23	1.23	1.23	1.23	1.23	1.23	1.23	0.07
Occupancy (kW)	0.00	0.00	0.00	0.20	0.80	0.80	0.60	0.80	0.40	0.00	0.00
Solar Gains Exterior Windows (kW)	0.00	0.00	0.00	0.80	1.38	1.58	3.45	8.69	0.00	0.00	0.00
Zone Sensible Cooling (kW)	0.00	0.00	-3.82	-5.61	-6.06	-6.29	-6.88	-9.84	-8.38	0.00	0.00
Sensible Cooling (kW)	0.00	0.00	-3.82	-5.51	-5.93	-6.34	-6.99	-9.93	-8.37	0.00	0.00
Total Cooling (kW)	0.00	0.00	-4.89	-6.46	-7.76	-8.22	-8.59	-11.95	-9.65	0.00	0.00
Relative Humidity (%)	56.49	57.07	52.45	50.25	51.29	51.18	50.59	50.34	49.67	44.81	51.82
Mech Vent + Nat Vent + Infiltration (ac/h)	0.71	0.71	0.71	1.05	2.07	2.07	1.73	2.07	1.39	0.71	0.71

In the case of Figure 22 and Table 4, the statistics correspond to July 15, winter in the southern hemisphere. Figure 22 A shows that the temperature variation ranges between 24 and 26°C, with an average of 25°C during peak hours. Despite being in winter, the building maintains the heat, overheating the rooms, although to a lesser extent than in the summer season, due to the greenhouse effect caused by having the glazed facade facing west.

As in Figure 21, although to a lesser extent, the heat balance of the materials is maintained as shown in Figure 22 B, except for the solar gain of the exterior windows with 8.69 KW, which contributes to the heat gain due to the greenhouse effect caused in the interior.

Figure 22 C shows the cooling system indices, which generally decrease between 5:00h and 19:30h, reducing to -11.95KW at 16:00h, lower compared to the summer season.

Likewise, in Figure 22 D the humidity indices vary between 44.81% and 56.49%, indicating that it remains in the ideal comfort range (30% - 50%).

Finally, Figure 22 E shows the air renewals inside the building, whose rates are similar to those in Figure 21, reaching the maximum of 2.07 ac/h during 10:00h, 12:00h, and 16:00h.

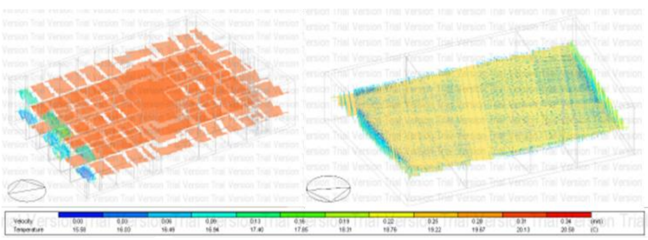


Figure 23. Volumetry subjected to temperature simulation, typical plants 1 and 2.

The volume has two typical floors from which the different functions within the multipurpose building derive. Figure 23 shows these two typical floors, where the second floor (23 A) has the most affluence since it is the commercial floor, which corresponds from the 1st floor to the 4th floor, where store stands are distributed. The typical second floor (23 B) includes offices, sewing shops, and multipurpose rooms, areas with less affluence and corresponds to the 5th and 6th floors. The colors are shown from cold to warm correspond to the apparent temperature level in the internal environments, taking into account the windows and partitions, where blue indicates the lowest temperature and red, the highest.

Figure 23 A shows that only the storage rooms at the front and part of the aisles have good lighting and ventilation is also feasible, but it only remains there since the lattice of the aisles limits the passage of wind. However, the thermal load is present due to the lack of good lighting in the back of the building, as everything is enclosed and has only small skylights that do not work in proportion to the building.

Figure 23 B shows the typical second floor, which has a glass facade and partitions so that natural lighting is not easily lost; however, the material also causes an increase in temperature at certain times of the day when the sun directly illuminates the facade and overheats the interior since it does not have any type of passive protection system. Ac-cording to the results of the Design-Builder program, the building in the Ya neighborhood has serious lighting and temperature problems. Despite the small skylights it has, it is not enough to supply natural light to the rooms and ventilate them, since the height of the building and the dimensions of the skylight are not proportional, so there is not enough light in the lower floors and the greenhouse effect is created. To achieve optimal thermal comfort [44] in a building, several aspects are involved, some of them very relevant, such as lighting, ventilation, and materiality. The balance between these three indicators is essential for the proper functioning of the building [45].

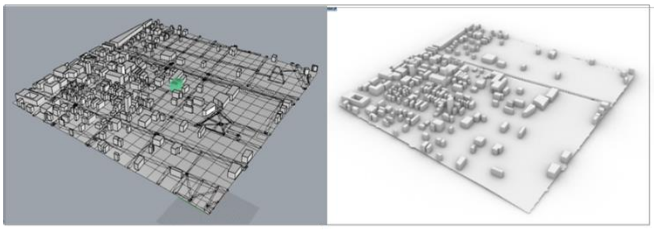


Figure 24. Relationship between the volumetry and its immediate surroundings.

The survey of the environment, with a radius of 0.3 km, was carried out with the CADMAPPER program, which downloads the volumes of the buildings in a given area from the internal data it has on the area. The importance of this survey, shown in Figure 24, is to submit it to the functions provided by the simulation and, in this way, to know to what extent the environmental parameters of the site influence the building in relation to its immediate surroundings.

Figure 25. Wind circulation towards the volumetry.

Winds in the district of La Victoria come mainly from the south and southwest, without much strength. In the area where the study building is located, the heights of the buildings are between 2 and 6 stories, with building Ya being 6 stories. Being one of the tallest buildings in the area, the winds are not deflected due to the fact that the buildings bordering the south and southwest of the building are lower in height, as shown graphically in Figure 25. Therefore, it is in a very good position to receive good ventilation which, in turn, must be controlled in winter. The building has a lattice of metal bars in a horizontal position in front of the main circulation corridors. However, while this could control the passage of the sun through the facade, it also greatly limits the passage of the wind, as it does not leave enough space for the wind to effectively ventilate the interior rooms [46].

D. Strategies applied in building

Figure 26. Modification of the facade of building Ya.

After analyzing the simulation results of the multipurpose building behavior against environmental parameters [47]. New environmental conditioning strategies that work effectively and can guarantee the comfort of the users are proposed [48]. Regarding the lighting problem, the excess heat on the main façade should be solved by controlling the entry of natural light, avoiding sunlight at peak hours and heat, and allowing the wind to pass through to improve interior ventilation and mitigate the accumulated heat. To this end, eaves are proposed on the sides of the building, taking into account the most optimal angle for effective control of light and shade, as shown in Figure 26. The extent of these eaves is represented by the orange dotted lines on the base plan of the building. It is also proposed to eliminate the two front central tents and relocate them to create an open circulation space, highlighted with a yellow shadow in Figure 26, allowing for better ventilation. In addition, this allows the interior tents to not overheat and have more natural lighting without shadows and without the need for overhangs in the center, as the same roof of the upper floor would function as a light regulator.

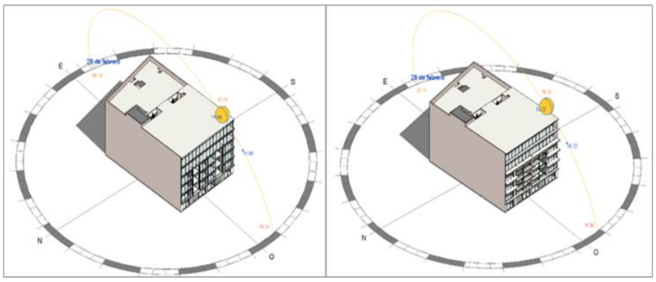


Figure 27. Comparison of the old and new facades of the Ya building.

Figure 27 shows the volumetry of the building before and after being rehabilitated with the new conditioning strategies applied to it, which is subjected to the simulation of the Sun Path of the Revit BIM program, where the position of the sun and the shadow it casts on the building are shown. The day chosen is February 28 at 15:00h, a summer day, since it is the period where the highest overheating occurs. From what can be seen in the figure, there is a greater presence of shadow on the building compared to the previous version.

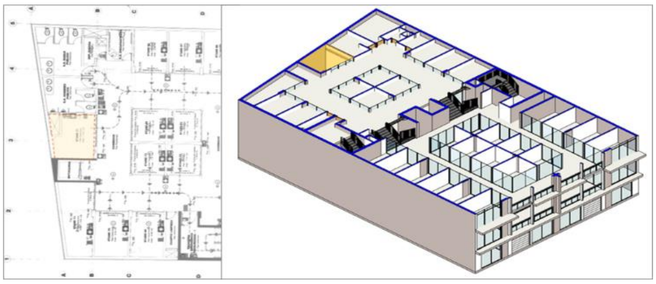


Figure 28. Rear skylight modification.

It is also intended to solve the shortage of natural light at the rear of the building, the east façade, so one of the skylights could be enlarged and leave the airflow free. In this way, cross ventilation could be generated between both east-west facades, tempering the internal environments and allowing the passage of light, for which we must take into ac-count the height of the building, which is approximately 15.60m, i.e., at least one-third of the height of the building is needed for the skylight to work in the best way. Therefore, the skylight should measure at least 3.2m on one of its sides, so taking into account the interior distribution and the structure, it was determined that the most advisable panel to open a skylight would be the one indicated in Figure 28 with a yellow tone, whose measurements are 4.30m long and 3.00m wide approximately. In this cloth, there is a skylight of smaller size and support, which must be discerned to achieve the objective. In addition, it is noted that it is placed next to the assessors' and toilets' plates, which further benefits the ventilation issue, as the toilet can have better ventilation by being next to this new skylight.

IV. DISCUSSION

The environmental conditioning strategies used in architectural design have a very relevant function since they guarantee the comfort of the users, one of the most important factors for a building to function, in addition to the spatiality and other elements that architectural design considers for the optimal functioning of the constructions. Therefore, these environmental conditioning strategies should become an indispensable requirement for the approval of projects to be executed; however, not only is it not considered a requirement, but many professionals do not take these criteria into account since it increases the complexity of a project, as well as the cost of the work, among other reasons, so they do not risk including them in the proposal.

In the heart of the commercial emporium of Gamarra, there are numerous old buildings that have been refurbished and modified according to their current use, so that over time they have become multipurpose buildings, giving priority to commercial facilities, offices, and workshops. In this research work, one of the recently constructed multipurpose buildings is studied in order to analyze the effectiveness of the rehabilitation strategies employed in it.

The results derived from the simulation of the building's volumetry in the Design-Builder and Sun Path programs show that the conditioning strategies used in the architectural design do not work effectively, as they concentrate heat on the main façade, which causes the greenhouse effect inside the building. In addition, without properly sized skylights, the heat in the air does not easily escape and does not allow for optimal ventilation of the area. This research recognizes the results of the environmental conditioning strategies of the building and proposes a solution in response to the problems generated according to the simulation to which the volumetry was subjected. In this way, generate that the building works at the level of environmental conditioning.

V. CONCLUSIONS

The building understudy, subjected to virtual simulations with programs such as Design Builder and Sun Path, made it possible to recognize the environmental condition-ing problems generated inside the building, which have an impact on the comfort of re-curring users. These problems compromise lighting and thermal comfort, the most im-portant being the exposure of the facade to the sun and the increase of the interior temper-ature due to lack of ventilation. Therefore, solutions were proposed to counteract the sim-ulation results, leading to the restoration of the building to ensure the effective operation of the environmental conditioning.

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