Bioclimatic performance in commercial spaces in Rio de Janeiro and Lisbon

1ª Quaresma, Ana Luisa de Carvalho

analuquaresma@gmail.com

2º Bastos, Jorge de Novais

Faculdade de Arquitetura, Universidade de Lisboa, Portugal

jnbastos@fa.ulisboa.pt

3rd Guedes, Manuel Correia

Instituto Superior Técnico, Lisbon, Portugal

mcguedes@civil.ist.utl.pt

Abstract

The retail sector significantly impacts urban economies, but often exhibits high energy consumption and resource usage, contributing to carbon emissions. These practices, aimed at enhancing sales through pre-established thermal and lighting patterns, contribute substantially to carbon emissions. This study investigates how architectural design can align with environmental and management goals in retail. By analyzing retail management dynamics and environmental issues, it evaluates sustainable energy solutions. These findings emphasize the need for more energy-efficient buildings with improved thermal and visual comfort and reduced reliance on mechanical systems. Advocating sustainable architectural practices in retail, this study underscores the importance of addressing environmental concerns and optimizing energy management for future growth and sustainability.

Keywords: *3 Retail architecture, Bioclimatic architecture, Energy consumption,*

1. Introduction

This study is part of doctoral research that proposes a simplified method for assessing the sustainability of commercial spaces, while also conducting a critical analysis of bioclimatic performance and its associated consumption. The primary objective of this method is to foster significant improvements in the physical environment of stores by adopting more efficient architectural solutions and construction practices.

A thorough observational analysis was conducted to examine the integration of form and function in commercial spaces as well as the construction techniques employed and relevant architectural details. The impact of construction efficiency was assessed through on-site conversations with employees and customers, with the aim of understanding comfort and discomfort indoors.

Predominant management patterns that compromise the bioclimatic performance of buildings and energy consumption in the study area were identified. To do so, it is necessary to examine the architectural typology used in stores located in regions with different climates, solar orientations, and cultures.

Throughout the research, similarities and differences in the construction of commercial spaces as well as the architectural typologies and strategies most commonly used to achieve a satisfactory level of comfort were identified.

2. Materials and Methods

This study, conducted until 2022 in the cities of Rio de Janeiro, Brazil and Lisbon, Portugal, aimed to identify pertinent and valuable information for the specific scope of analysis. This involved evaluating built spaces, identifying predominant typologies, and understanding the typical local architecture of commercial spaces in each region, thus contributing to knowledge organization.

Various aspects were addressed in this study, from the urban layout to the climatic context, and the thermal performance of commercial spaces. Our focus was to understand the existing architectural strategies aimed at achieving the necessary comfort and identifying possible improvements to optimize the performance of these typologies. We also explore the formats of retail spaces, the processes of buying and selling, and their influence on retail space.

To support this analysis, we consulted a variety of resources including scientific articles, manuals, textbooks, e-book chapters, and theses. All of these sources played a fundamental role in understanding the built environment in the areas under analysis, contributing to a comprehensive and well-founded approach.

Due to the scarcity of available data on commercial spaces in Brazil and Portugal, we adopted an unstructured observational research methodology. Our aim was to understand the dynamics of these spaces by investigating behavioral, social, and cultural phenomena in their natural context. The approach focused on the interior comfort of commercial spaces, promoting holistic interactions within built environments and enabling an iterative learning process.

The collected data were interpreted through a more subjective analysis, with the aim of identifying patterns, meanings, and emerging insights. Nevertheless, some aspects have been quantified in a structured manner to enrich our understanding.

3. Area of analysis

This analysis focused on two densely urban residential areas that evolved into commercial hubs since the 1950s: Avenida de Roma in Lisbon and Avenida Ataulfo de Paiva and Avenida Visconde de Pirajá in Rio de Janeiro. During this period, buildings were designed with little consideration for climate and energy efficiency despite advancements in technology. Various retail types were observed, with the predominant presence of gallery stores, which integrate public promenades into their interiors and rely on the building's infrastructure for water and energy supply.

Despite differences in territorial dimensions, both cities exhibit similar commercial urban areas characterized by significant trade growth, high purchasing power among residents, and dense populations (Rio de Janeiro: 5,556 inhabitants/km2; Lisbon: 5,455 inhabitants/km2). The energy consumption in both regions is noteworthy, with trade being the highest consumer, primarily reliant on electricity. In Portugal, the construction industry contributes significantly to energy consumption and greenhouse gas emissions, with buildings responsible for up to 30% of the emissions, mainly CO2 [1], (2), and (3).

4. Climatic context

The global energy crisis and climate change pose significant concerns, particularly in Lisbon and Rio de Janeiro, where extreme weather events, such as floods and fires, are increasingly frequent (4) and (5).

Lisbon has a Mediterranean climate with hot, dry summers, mild, humid winters, and a high thermal amplitude. Rio de Janeiro is hot and humid year-round, with temperatures varying by 6.8°C annually. Stores typically operate from 10 am to 10 pm, with Lisbon's milder temperatures interrupted by uncomfortable summers and winters exacerbated by humidity. Rio de Janeiro faces extreme summer heat but enjoys pleasant winters. Altitude influences these climate differences, with Lisbon being colder because of its higher elevation. Understanding these climates is crucial to ensure comfort and air quality during store operating hours (6), (7), (8), and (9).

5. Indoor Confort

A pleasant indoor environment is crucial for customer satisfaction and commercial success. Achieving thermal comfort is essential for operational success (10).

However, conventional standards such as ASHRAE or ISO may not suit diverse climates, leading to widespread air-conditioning use even in warmer countries. Evidence suggests that people in warmer climates prefer higher temperatures, which challenges conventional standards (11) page 71.

Conversations with employees and customers in Lisbon revealed the need for cooling on hot summer days and heating in winter. It is necessary to use constructive passive heating strategies to minimize cold temperatures and humidity, whereas in Rio de Janeiro, passive cooling strategies are essential year-round. Adaptations of the thermal comfort criteria are necessary to suit diverse climatic contexts.

6. Aspects of retail

Retail is an important field of study because of its impact on the economy, its functions in distribution, and its relationship with businesses that sell goods and services to retailers for their resale or use (12) Page 25. Retailers are the main contacts between manufacturers, wholesalers, and consumers, which is the last step in this process, making the exchange between them more efficient as well as being able to add value to them [18] pages 27 and 28.

According to Quartier, K. to [20], one of the primary objectives of retail is to achieve a store's financial viability and longevity. Implementing design solutions is essential for maximizing sales per square foot. Creating an atmosphere conducive to selling not only fosters experiences that increase the likelihood of making sales, but also exerts a strong influence on consumer buying behavior. In addition, prolonging the stay of shoppers in stores tends to stimulate impulse purchases, thus contributing to increased sales [20],

Therefore, the layout needs to be designed according to managers' requirements, and it is essential to design it strategically to maximize merchandise exposure, explore all internal walls, stimulate circulation and attract customers throughout the store, and promote safety for the operating store [20] page 56, [21],[23] page 431.

These attitudes are focused on better management of a retail business and leave aside any strategy related to green buildings certified as the most used in the world, such as the Green Building Council's LEED systems in the USA and United Kingdom, the BREEAM system, or bioclimatic architecture. adopted passive construction strategies [23].

6.1. Site analysis, store location and orientation

To meet the management criteria, the location of a store is one of the determining factors for its success and is one of the most expensive operations. In most cases, the best location is in urban centers (15).

Furthermore, to meet environmental criteria, it is vital to understand the solar orientation of the commercial space, that is, the way the sun falls, throughout the day and year, on building (11) page 22, as well as its wind regime. In hot climates, it is essential that the implementation of a store consider the wind regime for efficient ventilation and a consequent improvement in indoor comfort (16) page 32. These are the most important environmental factors for the design of high-performance commercial spaces.

By analyzing the solar orientation of Avenida de Roma, situated along the north-south axis, it was observed that all the buildings along this road were. However, there are no fixed construction elements intended to provide shading, which exposes them to morning solar influence on the east side and afternoon solar influence on the west side. During summer, shops situated on the west side of the avenue are particularly affected by intense heat, especially in August.

In the commercial area of Rio de Janeiro, the avenues are aligned in an east-west direction. Consequently, sun exposure is constant throughout the year during the hours when stores are open. In summer, the sun's incidence reaches its peak, affecting both sides of the road, whereas in winter, the southern portion of the road remains shaded.

Knowing the climate, location, and solar orientation of the analysis area and identifying the prevailing patterns to achieve good management will help identify the best solutions and minimize energy consumption.

7. Retail management patterns

7.1 The main retail paradigm

The main paradigm is the habit of keeping store doors open to communicate with customers that they are open to. They are designed to communicate free access, impress, attract people, and entice them to enter a store and walk around. The exterior of a store is designed to attract consumers, and the interior to impress them and keep them close to the products for as long as possible possible (17) pages 31 and (14) page 118.

Research shows that to attract customers and reduce the psychological barrier, retail stores and shopping malls often adopt this use, translating into large energy consumption, as the machines need to work at high power. Statistics prove that this expense can be four to eight times higher than that of an enclosed space [12].

It was observed that, in the two areas of analysis, there were already stores that made use of automatic doors. This system is highly effective because it preserves the cooled/heated air. In Lisbon, it is already used in food stores, in Rio de Janeiro in shopping malls, and punctually in small shopping centers. There are also stores that make use of wind curtains; this is an efficient system, but it is rarely used in smaller stores, which are the vast majority in the two areas of analysis.

7.2 The second retail paradigm

The retail paradigm of a single entrance streamlines management and enhances security, whereas multiple entrances can disrupt client flow and pose security risks (18) page 463., (19) page 64, (14) page 133.

However, this design hinders natural ventilation in larger spaces, necessitating reliance on mechanical systems for climate control (14) page 120. Unlike department stores, which often have multiple entrances but remain closed, smaller shops prioritize exclusivity, further limiting natural airflow [21].

Consequently, many stores suffer from stale air and humidity issues, particularly in regions like Lisbon and Rio de Janeiro with varying climatic challenges (20) page 48.

While one-sided ventilation may suffice for small shops, larger establishments benefit from cross-ventilation, achieving better air circulation and comfort (11) page 56.

ANSI/ASHRAE Standard 62.1-2010 outlines ventilation requirements, but existing HVAC systems in rented spaces often fall short, compromising comfort and energy efficiency [26], page 244 and [27].

Thus, it's imperative to rethink ventilation strategies to ensure optimal indoor air quality while minimizing energy expenditure, especially in spaces already equipped with HVAC

7.3 The third retail paradigm

The third paradigm is the creation of a pleasant thermal environment, recognized as one of the main human physiological demands as per (20) page 141.

Store interiors should be designed to provide an ideal environment in which customers can shop comfortably while promoting employee productivity and performance without interference from noise, humidity, or unwanted odors. Obtaining a pleasant shopping

environment emerges as a determining factor for the success of a commercial space; thus, ensuring thermal comfort in this context is essential for the success of operations according to (21) page 69.

Another important aspect of comfort concerns the degree of control that employees have over the environment, especially regarding air temperature. During visits to the stores surveyed, the author observed that in the vast majority of large stores, this control was inaccessible, resulting in discomfort and reduced worker productivity (20) page 50.

It is essential to comment on the lack of planning for these stores to adapt to the current refrigeration and heating systems, which causes visual pollution and acoustic discomfort.

There are also stores that do not have an HVAC system installed and make occasional use of portable air conditioning, especially in the summer, which has an energy expenditure almost double that of standard air conditioners.

7.4 The fourth retail paradigm

Finally, another essential paradigm is the need to make the store stand out among its peers using artificial lighting, which is highly valued because it promotes the prominence of merchandise and increases sales [21] and [24] page 458.

According to several studies, [27] page 222, (22) page 8. Studies have shown that store areas lit by natural lighting exhibit increased sales.

According to Mesher, L. [21], consumers found lighting to be brighter, more comfortable, and more pleasing to the eye, significantly increasing sales as well as the number of items sold, including daylight through skylights.

The perception of color is crucial for attracting buyer attention and influencing merchandise sales. Lighting plays a fundamental role; without it, there is no color. The quality of the color and how it is presented are essential for successful sales. Artificial lighting not only enhances colors, making them appealing, but also shapes a product's first impression and retailer identification. (24) page 33

Lighting is crucial for retail success, as it directly affects customer attraction and sales effectiveness. The proper use of general, accent, and ambient lighting is essential for creating a pleasant environment and promoting spontaneous and repeat purchases. Recommended lighting levels vary by store type and activity, with high-activity areas requiring a higher light intensity than low-activity areas. Establishing the right amount of light is crucial for accurately seeing product colors and positively influencing purchasing behavior. 367 and [22] page 105. This is the standard for most stores visited in Lisbon and Rio de Janeiro.

In large retail chains and shopping centers, there is little concern about expenses related to artificial lighting, and the occasional use of natural lighting is already in place, especially in large sales areas, circulation, and atriums. Regarding equipment, the majority already use energy-efficient bulbs such as LEDs. Despite exposure to abundant natural light during the day, many stores prefer powerful spotlights to highlight external displays, maintaining the same lighting during both the day and night, disregarding natural lighting. Resources, such as sensors and automation programs, could minimize energy costs, but the author noticed that these stores do not utilize such strategies.

It is worth noting that some newly established stores tend to be more flexible and consistent with their design components, aiming to minimize the costs of layout changes. They adopted

fixtures mounted on easily replaceable metal structures, eliminating the need for gypsum *plaster on the ceiling, thus reducing the waste resulting from layout changes or new renovations.*

7.5 The aspects of the storefront

Observing the aspects of a display case that directly influence both energy consumption and indoor comfort is essential. Solar orientation, shading, and use of special glazing are crucial considerations. (25) page 7, (11) page 30, and page 47.

The direct impact of the sun's rays on storefronts is evident through exterior cladding materials and colors, which affect the heating or cooling (11) page 42, (25) page 24.

Darker displays absorb more heat, keeping the store comfortable in winter, whereas lighter colors are preferable in warm climates (11) pages 45, 30, and 47.

Efficient strategies include glass facades with low heat absorption and shading [16].

Shading, through architectural details, vegetation, or internal curtains, reduces solar energy incidence, promoting comfort and protecting goods [16, 37].

Facade glass should control sunlight transmission, luminosity, and heat reflection; reduce air conditioning costs and noise levels; and provide UV protection [16, 37].

Glazed and shaded facades can be significantly cooler [37].

However, the analyzed showcases lacked sufficient opaque material to store and distribute energy efficiently, leading to undesired heat gains in summer [36].

8. Discussion

During this research, several difficulties were encountered such as the lack of information about this sector, both in public online statistical data for the two countries and in public online reports from large retailers. Finding concrete data on spending on energy, water and other aspects related to the topic was a very challenging task.

It is crucial to highlight that the retail sector, the object of study in this research, is characterized by high competitiveness, and does not disclose its operational cost metrics. Many of the public reports from major retail brands often do not reflect reality, and are often fragmented and inconsistent, or simply inaccessible.

Furthermore, data from public reports in Brazil and Portugal in the commerce sector are often grouped with other sectors in the Services Group, such as Hospitality and public services, which makes obtaining specific information even more difficult.

The information available exclusively to commerce does not distinguish the type of commerce and the type of construction, making its use for this study unfeasible.

This situation resulted in information gaps that, it is believed, would be extremely valuable for the depth and quality of the study. Therefore, the observational methodology was chosen due to the scarcity of data available to carry out a quantitative approach.

To give an example of the energy expenditure in this sector, here is the UK Climate Action Roadmap Report [34], which shows that there is a variation in the types of retail; for example, small stores have the highest energy expenditure, and in the Power-Friendly report for retail

buildings in the United States [35]. For example, the equipment consumes 84% of the energy spent on lighting and air conditioning.

9. Conclusion:

All of these standards are paramount to the success of the store space, but they are also the biggest contributors to the energy expenditure of this sector. Therefore, it is vital to understand these retail patterns. The predominant typology in the selected urban areas was individual stores within galleries designed to maximize land use and generate higher rents. However, most properties are rented to tenants who lack control over the building, thereby hindering investment in rehabilitation for better indoor comfort and lower energy consumption. Architectural patterns expose stores to weather, pollution, and noise, leading to significant energy losses. However, sustainable energy connections and architectural design relevance have been overlooked. Both Lisbon and Rio de Janeiro stores share glass-dominated facades that lack winter insulation and summer protection, resulting in similar energy losses. Poor internal conditions in sales areas contribute to discomfort and high energy consumption, mainly by relying on mechanical systems such as air conditioners. Optimizing energy consumption and indoor air quality is crucial for operational efficiency and customer satisfaction and poses a challenge in reconciling environmental and economic aspects within commercial spaces.

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