Microclimatic Strategies for "Vila Residencial da UFRJ": Mitigating the Effects of High Temperatures

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Abstract. The urban morphology and both pavement and edifications materiality influence directly on the microclimate. Thus, urban form and microclimatic researches cooperate with the understanding of this interaction, besides they may evidence solutions to attenuate these negative effects in weather, such as the heat-island effect, which makes the environment comfort worse in cities of the tropical countries. In previous studies, a diagnostic of "Vila Residencial da UFRJ", situated on Rio de Janeiro, Brazil, has been done considering the variation of intra-urban temperature. The air temperature values have been measured and simulated in the interior of the Village as well as in its surroundings, in other to find the most intense heat areas. From the diagnostic about the region (urban morphology forwarding; climate variables and socioeconomic information), analysis and proposals of intervention strategies have been developed, tested with a broader series of computational simulations. Following the study, this article presents the developing process of an illustrated guide, in clear and accessible language, for the local people and leadership, exposing the relation between the factors that can increase temperature and the indicated means of mitigating them. The strategies were thought for the broader scenario of the Residential Village, fulfilling the needs of environmental comfort and the possibility of implementation according to local peculiarities, such as: the lack of space in some sidewalks and streets, making impracticable the planting of tree species; the need to work with low-cost materials and local labor, very often few specialized ones; absence of space between the buildings, among others.

1. Vila Residencial: urban configuration and public health

The Vila Residencial (VR) of the Universidade Federal do Rio de Janeiro (UFRJ) situated in Fundão Island, Rio de Janeiro city, was built in 1969 by the President Costa e Silva Bridge Construction and Exploring Company / Engineering and Constructions of Special Buildings Company - ECEX, as a place to host the workers that would build the Rio-Niterói Bridge. With the completion of the Bridge building in 1974, many of the workers and their families, not having another place to go, opted to stay in the Vila's accommodations. The initial urban configuration had the residences centered on their plots, with
front and side setbacks and backyards (Figure 1) that decreased the warm tropical weather of Fundão, bathed by the Guanabara Bay and a strait of the sea.

![Figure 1. Oswaldo's family House. Source: personal collection of Ary da Rocha Tristão, without date [1].](image)

Changes in VR urban morphology has altered its environmental comfort, such as horizontal and vertical expansions of the buildings that, besides eliminating the side setbacks to make attachments, have started to share the plot with brand new houses for the growing families. Those new buildings occupy the sidewalks in some cases, narrowing streets right-of-way and compromising the presence of trees (Figure 2). Furthermore, the wall built between the Vila and the bay, the change of the soil paving and the methodical option of removing trees during the densification process are, as well, relevant modifications in this place. The standard building typology of the VR creation lost space for the current plurality of both the constructions and the neighborhood profile, that has changed over time.

![Figure 2. Irregular sidewalk occupation in VR. Source: Google.](image)

The presence of the UFRJ and the consolidation of the UFRJ Science Park - an environment that intends to promote the interaction between the university and the companies - stimulated a real estate appreciation in the VR area and, consequently, a real estate speculation. The new local demand generated some changes in the way of living of the place, as well in its land use and occupancy. With the increasing density, rooms and collective residences have been built and rented, in many cases by UFRJ students and Science Park workers, which have their activities in the Vila surroundings.

The concept of a village evokes cooperation and enhances space unity - reinforced many times by associations, like the Vila Residencial Residents and Friends Association (AMAVILA), that may intend to help in the self-management of the local community health: physical, mental and social well-being [2]. It is known the microclimate interferes with the daily habits of the population, such as the use of
public spaces, and that its understanding is directly related to the decisions that impact the urban fabric. Since the city space is ever-changing, and not always for the sake of people’s wellness, elucidating to the local people ways of mitigating the heat sensation and the reason for their importance have both the same value. To understand those issues allows to intervene and improve the current moment and also may raise awareness to help future changes.

The effects of good urbanistic practices on health have been noticed. The forming process of the heat islands - which causes peaks of temperature and make it more variable during the daytime - affects the well-being, even though it does not become visible since the population habits many times contribute to health problems that can be worsened by the urban quality: “It is impressing how the heat peaks on the hotter days lead to an expressive increase of the mortality, which is not noticed, because it is hidden by the diseases it has exacerbated, like the myocardial infarctions and strokes” [3]. The heat, rain, pollution, and health are points to be handled with care in contemporary cities; Saldiva [3] says about the need of “antidotes that increase the urban resilience against climate-changing” in defense of the city’s and citizen’s health.

Both asphalt and concrete, which seal the soil and absorb heat, are replacing many unfilterable and vegetated areas on the urban surface. The presence of these materials contributes to forming heat islands, varying significantly the intraurban temperature. Even though many actions could be pointed out as capable to reduce the heating, VR has its dynamics, like the buildings’ expansion and the lack of permeable spaces to plant, making some solutions difficult to be adopted and others likely to be accepted and implemented. Therefore, it is very important for the residents and the local leaderships to understand the environmental problem of microclimate and all the issues that cause or contribute to it: this understanding may positively influence the developing of a healthier daily life.

Thus, the idea of an illustrated guide - Guide to a better climate: decreasing the heat sensation (Figure 3) - was developed, assembling selected strategies to mitigate the heat in different situations of VR. After conversations with Mr. Antonio José Avelino - Seu Toninho -, director of AMAVILA, it was understood that fitting the strategies into the local context would be strictly important for its acceptance and application. This context includes, for instance: narrow streets and sidewalks which would not be viable to plant trees; the need for working with low-cost materials and local labor, very often not specialized; the absence of space between the buildings; among others.

2. Urban changes and its climate effects

The population’s well-being and health are affected by urban planning, which deals with some correlated characteristics. Previous studies using the ENVI-met [4] software have exhibited the connection between urban morphology and heat levels in some areas of VR, indicating former’s impacts on people’s comfort sensation.

The VR previous houses contributed to a better quality of life for its residents. The implantation and the height of the buildings used to form a pattern in the landscape: single-story houses, that varied from
two to four bedrooms, with setbacks and backyard. Furthermore, according to "Seu Toninho" - who has lived in VR since its original configuration and owned the last house that remains the initial characteristics of implantation - besides the houses with setbacks and backyards, which could be wooded, the streets were greener than they currently are:

“My house was big, there were four bedrooms, it was very spacious. There was a large space in the back, vegetation, there were two ficus trees, huge ones, right in the front that provided a wonderful shade. In front of my house, there was a lot... All the houses had trees, mango trees [...] The Vila was very beautiful, a great place to live, despite not being urbanized, having neither asphalt nor sewage treatment. After that they paved everything, many people took the trees out of the sidewalks, they’ve cut them and extended their houses, taking out the garden and built more houses, you know.”

The wall (Figure 4) between the VR and the Guanabara Bay did not exist on the original plan. "Seu Toninho" recognizes that in the past the temperature in the Vila was cooler:

“We didn’t have walls around the Vila, all the streets ended at the sea, actually the Guanabara Bay. And today it’s what you’ve seen here, many walls, many tall houses, we don’t have that freshness anymore, the old days’ fresh, that breeze coming from the sea.”

Based on Avelino’s information (2019) it was possible to prepare a computational model circa of what VR was in its initial configuration. Due to the absence of plans or other documents that could indicate the right position and dimensions of the former houses, even in the University Technical Office (ETU), the only possible way to reconstruct the scenario was to base on his report.

Figure 4. Wall between the VR and the Guanabara Bay. Source: Google.

2.1. Computational Simulation

The city of Rio de Janeiro (22° 54' 10" S, 43° 12' 27" W) is classified as tropical wet and dry climate (Aw) according to Köppen-Geiger climate classification.

Computational simulations were processed with two software programs to analyze the VR urban morphology and climate: ENVI-met [4] allows the development of climate simulations in urban areas. The data raised were adapted into an input file to satisfy the program.

The initial conditions of simulation are in a file according to summer 2019 data: air temperature 309.85K; relative humidity 75.01%; wind speed of 3.0 m/s and direction 135° (southwest). These data were provided by Forte Copacabana station, Rio de Janeiro (INMET, without date). Specific humidity in 2500 m of 10.3 g of water per kg of air and roughness of 0.1 are considered [5].

The simulations were executed in summer 2019 (January, February and March averages), recording the data every 1 hour. Besides that, 3 scenarios were developed to compare variations in Vila urban landscape. Scenario I (Figure 5): VR currently. There is a high land occupation in the urban space and sparse vegetation, even in public areas, like the square.
Scenario II (Figure 6) shows a wooded VR. Public areas, as the square and streets, receive more vegetation. Scenario III (Figure 7) was developed according to photos and reports of "Seu Toninho", in a process of "landscape archeology". The current constructed area was replaced by the former, considering the house's setbacks and backyards. Both the vegetation and covering materials that were present in VR, like clay, sand, and grass, were added to compose this scenario.

According to Figures 5, 6 and 7, it is possible to notice the results of each scenario. In the first, the warm sensation is worse: there is less ventilation and high temperatures. The increasing of permeability in the urban mesh and the using of natural materials for paving could reduce the air temperature and improve the quality of life.

Not only the solutions to decrease the temperatures, but also the understanding of climate problems need to be recognized. Thus, the Guide must be attractive and understandable. Its colloquial language and the use of illustrations that dialogue, complement or exemplify the texts, makes it more dynamic. In this way, the cause and effect relation between urban transformations and heat temperatures, as well as between the proposals and the decreasing of air temperatures could be transmitted. With the dissemination of some practices, that were chosen according to the physical, economic and cultural local reality, the Guide understanding may also interfere in the future actions in the VR, aiming to stimulate new interventions that adapt to the weather and daily life. In this way, the Guide sought to introduce subjects such as heat islands, along with schematical drawings, before suggesting the measures to mitigate the heat.

3. Urban interventions: decreasing the heat sensation on the population dynamic

Great urban changes can be executed around a territorial enhancement, in some agent’s opinion. Some modifications in the city landscape are motivated by an understanding that they may
return whether in quality of life, convenience, income generation, etc. However, they could also have impacts and losses. This process is part of the urbanization context and densification of cities; without an appropriated planning to guide this growth, some faults could be consolidated, such as the vast replacement of green areas by constructed areas, which waterproof the soil. The absence of green spaces generates major problems and worsens situations that could be ameliorated with them. Moisture, heat, soil permeability and runoff, pollution, physical, mental and social health are some matters that green areas directly affect. The occupation and use of a place is an important thermometer to measure the environmental quality, which is linked to the comfort sensation of this space.

The modifications proposed in the Guide have as their main point the coherence with the VR dynamic. Thus, measures that could be effective and were verified in simulations, like green roofs, were considered incompatible with the residents' needs, since the verticalization of the buildings is a common practice, making them opt not to compromise their roofs with such intervention. The tree planting is an accessible solution not only economically, but also in terms of complexity, besides it supports in mitigating issues that go beyond the heat sensation.

Planting trees in public spaces could achieve both the heat decrease and thermal balance. Their presence in squares and streets encourages its use by residents and pedestrians, who could be protected from direct insolation. However, this measure must respect the pathways and not harm the population mobility. It is necessary to consider the size and root growth of the trees, besides their root crown space which, if correctly chosen, can help on the soil permeability. The roots should be deeper to not raise the pavement of sidewalks, since it could cause accidents to their users. The tree's size has to be verified because it influences the space it occupies and the shade it projects.

The urban heat island formation, which means regions with higher temperatures than in its natural surroundings [6], is related to a large percentage of non-reflective materials that retain the heat emitted during the day and are replacing green areas [7]. Due to that, investing in more reflective surfaces could be another alternative to mitigate high temperatures; it could be executed by painting pavements and roofs with light colors. In January 2019 the Brazilian city of Tietê, São Paulo, painted the asphalt of some streets with a light blue color, reducing the temperature of 54°C on the unpainted area to 47°C on the painted [8]. It is needed to be mindful of the degree of reflectance the color could cause; in that way, the white color on the floor, mainly on asphalt, could provoke visual discomfort and accidents, once it might reflect light enough to impair the vision of drivers and pedestrians. However, using white color on the roof would not negatively affect the population.

Although not much studied, cellular concrete is another low-cost alternative to mitigate the heat sensation inside the houses. The air incorporated in its structure gives it isolation proprieties and lightweight, allowing it to be used on roofs. A 2 cm layer of the material could be applied on roof tiles or slabs, as well on more insulated walls [9].

An intuitive solution was observed in the city of Santa Bárbara do Monte Verde (Minas Gerais, Brazil): a water hose with little holes connected to an outdoor tap and placed following the roof ridge. It is opened in intense heat moments and remains until the cooling of the roof tiles. The action may be repeated whenever it is necessary.

Green walls are important options for narrow streets, not affecting the sidewalk, street space and the residents’ dynamic of walking and automotive displacement. Currently in the VR there are some flowerpots on sidewalks in streets without planted trees (Figure 8); to maximize the contribution of this practice, a grid or pallet installation with climbing plants or flowerpots could be a simple and low cost option, improving both the indoor and outdoor thermal sensation, mitigating the local microclimate, where the heat sensation is severe.
A green wall is elaborated with climbing species that cover the wall, direct or indirectly. Depending on species characteristics it is necessary to use structuring elements as grids or cables to help plants to grow [10]. The green elements installation – both directly on walls or with auxiliary structures – should be thought according to the solar orientation, to protect the facades that receive more solar incidence.

According to Matheus et al. [11] studies, green walls help with the temperature regulation for better thermal comfort, not only with peaks in temperature but also in periods of thermal inertia. The study analyses the green walls’ and roofs’ performance in buildings in the southeastern region of Brazil: comparing neighboring buildings with and without green walls, a decrease of 2°C was noticed:

“In apartments with vines, the air temperature remained below 25 ºC, while the temperature registered in apartments without vines reached 27 ºC, mainly during the afternoon […]

During winter, the external temperature variated between 15 ºC and 32 ºC; the range was from 18 ºC to 27 ºC inside the apartment without the vine, and from 18 ºC to 25 ºC inside the one with the vine. It elucidates that the vine maintains the temperatures lower during the daytime, and, in the night, reduces the emission of infrared radiation due to its leaves.” [11].

Vegetating VR public spaces both with tree planting and green wall implementation (being aware of each space's characteristics and limitations) would promote a temperature decreasing, improving the local microclimate.

Figure 8. Flowerpots on VR’s sidewalks. Source: Authors.

Figure 9 and 10. Illustrations from the guide.

4. Final considerations

Vila Residencial is an urban space with its characteristics and dynamics, which have been changing with time. The greatest challenge is to succeed in urban changes that balance the residents’ needs with the quality of life. According to simulations, it is possible to compare some VR arrangements: houses centered on plots from the past; a larger land occupation in its present; and future possibilities of interventions, using primarily the vegetation in public areas and on walls.

Heat island and the vegetation's role on climate are topics explained in texts and illustrations of the guide. The using of materials as concrete and asphalt, which retain heat, is mentioned before explaining
some ways of mitigating these uncomfortable temperatures, like green walls. This article brings the creation process of the Guide: organizing information of urban changes and its climate effects in an accessible way to the population and local leadership, showing issues and manners that could positively improve their environment.

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