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Studies by associating the urban morphology and the ventilation: Residential Village of UFRJ

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1. Introduction

Urban areas influence and are influenced by local climate, whose behaviour interferes with quality of people´s lives, and can result in an energy consumption increase in the case of intra-urban temperature rise. In Brazil, there seems to be a shortage of microclimatology studies that are directly useable in urban planning and design. The understanding of relations between ventilation dynamics and urban morphology helps us to find configurations of the urban mesh and allows us the ability to mitigate, at least in part, impacts generated by changes in local climate.

The effects of urban heating are present in all climates and can be observed in the formation of urban heat islands (UHI) and the variation in intra-urban temperatures. The heat island is a thermal anomaly where the average temperature of the atmosphere for a certain urban area becomes higher than that of the surrounding regions not urbanized; heating takes place in the air layer nearest to the ground. The temperature variations may be several degrees centigrade, and basically occur due to infrared radiation emission differences between the built-up regions and those not constructed (Corbella and Yannas, 2003).

On the other hand, the variations IN intra-urban temperature are related to differences in air temperature especially in urban areas. These processes may or may not be significantly altered by climatic conditions. Several causes can contribute to changes in microclimatic processes, such as: conversion of solar energy into heat, resulting from urban morphology and nature of the various surfaces and materials; reduction of green areas and soil sealing; the presence of anthropogenic sources of heat and moisture, such as the use of air conditioners, refrigerators and burning fuel for automobiles and industries.

The urban barriers formed by the intense presence of buildings, although channelling the winds in streets and avenues, produce a limitation of ventilation in certain isolated areas and surrounded by buildings. Both climate changes as those produced by human presence and activities affect the quality of life of the inhabitants and promote increased energy consumption as a result of heating in urban areas.

Materials such as asphalt, concrete, glass, tiles, among others, help with heat absorption and promote A temperature rise in urban areas. In the humid tropics, from a bioclimatic point of view, compact clusters promote the heating of air in urban areas, resulting in increased use of air conditioning equipment. The generation of pollution is another important consequence of intense occupation associated with blockage of ventilation in certain confined areas bringing serious problems to the health of the inhabitants.

Starting from the assumption that climate characteristics are determining factors, which set urban morphology, the location of the metropolis, and the urban context must be considered before carrying out urban project propositions, densification, or sprawl. The recognition that the introduction or modification of elements on the urban fabric is able to interfere in the dynamics of heat exchange and ventilation, marking the importance of the specifics of place in shaping microclimate and environmental comfort (Drach and Corbella, 2010; Drach et al., 2013).

The research object of this study is the Residential Village on the campus of the University City (Federal University of Rio de Janeiro) on Fundão Island, Rio de Janeiro, Brazil. Since its initial occupation the region has experienced an intense process of consolidation and the original lots have been subdivided resulting in an inappropriate occupation to the humid tropical climate, with the following characteristics: blocking ventilation, lack of vegetation and use of heat absorbing materials.

The understanding of relations between ventilation dynamics and urban morphology helps us to find configurations of the urban mesh able to mitigate, at least in part, impacts generated by changes in the local climate. The Federal University of Rio de Janeiro's - UFRJ - campus, on Fundão Island, is going through a phase of constant changes and there are plans for new construction and intervention, according to UFRJ's Master Plan 2020 (2009), already sketched out. The employment of microclimatology studies in UFRJ's campus area, more specifically in the Residential Village - RV - would represent a unique opportunity to develop a study of the ventilation dynamics for that region before large modifications occur.

The use of alternative strategies such as passive ventilation in that region could represent a major contribution to increase environmental comfort of users. In addition, it would allow for the development of a region with high quality of life and reduced environmental and financial costs.

2. Brief history of the deployment of Residential Village

The Island of Fundão, where the University City and the Residential Village are located, was formed from the connection of nine islands located in Inhaúma Cove, one of them already called Island of Fundão. The islands were interconnected using the hydraulic landfill - landfill constructed of material transported by a stream of water - and earthwork, spanning from 1949 to 1952. As shown in Figure 1a, the depiction of the beginning of hydraulic landfill works, as can be seen in the background, three of the islands still separated by the sea. Source: Historical Archives of the Technical Office of the University of Brazil – ETUB, 1952. In Figure 1b, the complex for the University City location can be observed, with its connected islands. Source: ETUB (1954).

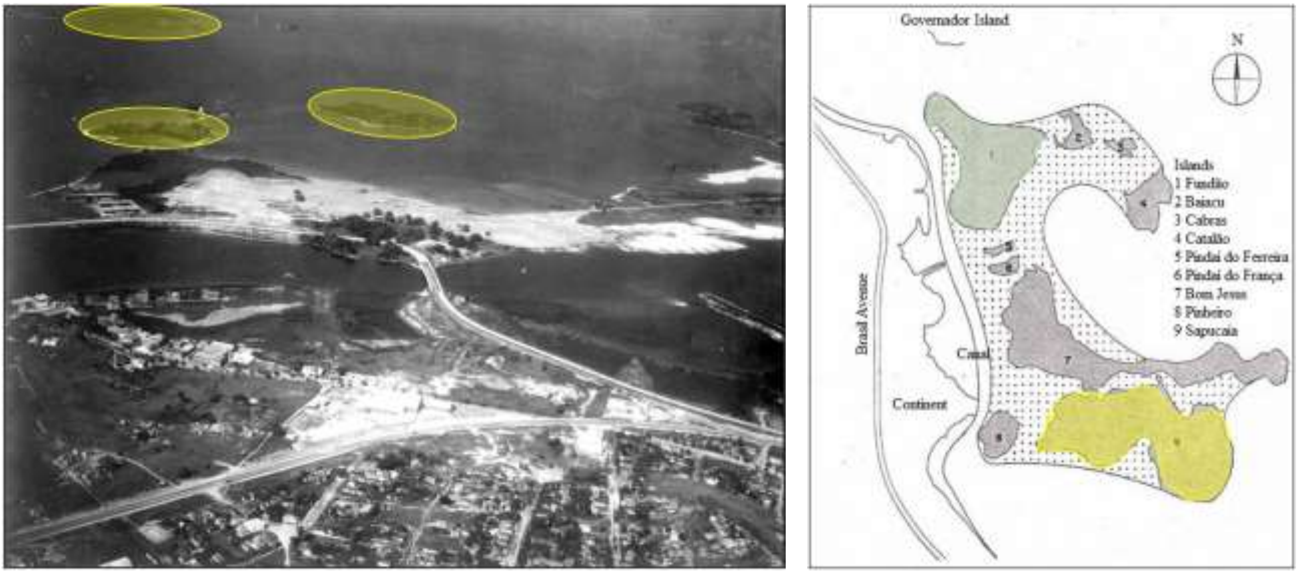


Fig. 1 Interconnection of the nine islands: a) Hydraulic fill and b) complex of the island of Fundão. Source: ETUB (1952 and 1954).

In January 1969 at the start of construction of the Rio-Niterói Bridge connecting the cities of Rio de Janeiro and Niteroi, six construction sites were installed at strategic points in the area: Fundão Island, Caju Island, Conceição Island, Canteiro do Mar, Niterói access, and Rio de Janeiro access. The site of the works on Fundão Island was set up at the southern end of the University City on a plot of 300.000m², on the grounds of the former Island of Sapucaia (Figure 2), with UFRJ permission. This construction site was comprised of 180 residential units and support service facilities to assist workers and their family members, and after the end of construction, many families chose to remain in the region as illegal occupants.

Fig. 2. Village for workers at the time of construction of the Rio-Niterói Bridge. Source: apud Freire, 2010

The Rio-Niterói Bridge with a total length of 13,29km, and 8,83km reaching over the Bay of Guanabara, was inaugurated on March 4, 1974. After finishing the work, the construction workers' housing villages went through a natural process of deactivation. Although the UFRJ demanded that the area became unoccupied, it did not occur since "a significant portion of its former workers were reluctant to vacate the barracks, claiming that they had nowhere else to go" (Freire, 2010). The recovery of the area by the UFRJ did not occur. What in fact happened was the consolidation of the region driven by the addition of more inhabitants. Consequently, there was the need to create more space to live through the construction of illegal extensions to the original houses, the so called "puxadinhos", a common practice in Brazil. In Figure 3, a "puxadinho" built on the sidewalk can be seen.

Fig. 3 "Puxadinho" built on a sidewalk. Source: Patricia Drach.

Nowadays the Residential Village finds itself on the University Campus and occupies an area of 20 thousand square meters, holding nearly two thousand people in about 350 homes. It is worth mentioning that the inhabitants were granted legal possession of the land, but that they continue to struggle for public service and quality of life improvements in the region. The RV is now included in the "University's Residence Politics" – CIDUNI – of the "University's City prefecture".

The RV densification process resulted in an urban setting unfavourable to wind penetration, despite its location close to an arm of the sea. It is important to mention that the whole RV is surrounded by concrete walls, which might aggravate the situation, New constructions near the village, especially the Technology Park of the University, tend to promote an even greater blockage of ventilation. The study of alternatives for dealing with the lack of ventilation is part of the research in the microclimate changes in this residential village. The Wind Tunnel based in the Faculty of Architecture and Urbanism - FAU / UFRJ is being used to carry out these studies.

The knowledge of land use is fundamental for the development of urban climate studies (Brandão, 1996; Lombardo, 1985). The land use map for the Fundão Island (Source: Update Figueiredo et al, 2007) is shown in Figure 4a, and the Residential Village can be observed in yellow. On its side, the Technological Park (TP) can be seen. Figure 4b shows the predominance of the Southeast wind, followed by the South and East (Sol-Air, 2013) winds.

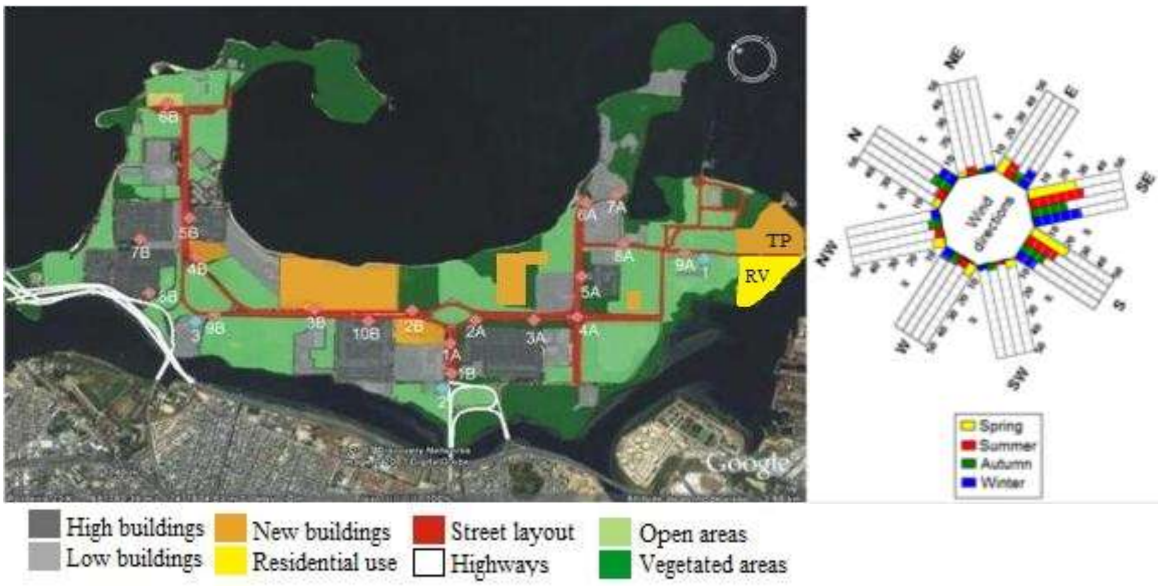


Fig. 4 Fundão Island: a) Landuse map – Ago./2014. Source: Figueiredo et al., 2007; b) Wind directions. Source: Sol-Ar, 2013

3. Purpose

The intention of this research is to develop a study on the ventilation and air temperature in Fundão residential village, as it is facing constant changes and an intense densification process. As this is an ongoing study of a dynamic scenario, it is expected that the evaluation of strategies can be used to point out the best design alternatives for the region.

4. Methods

The identification and data collection campaigns of each measurement point occurred following Romero's view (2001) under which the space is analysed considering its features, thus taking into account not only environmental and climatic elements, but also cultural, historical and technological aspects. Charts with bioclimatic analysis (Romero, 2001) of each measurement point were filled to complement the information and get a closer picture of each scenario, as can be observed in chart model Figure 5. These charts have information (temperature, solar radiation, humidity, colour, light, sounds, urban furniture and covertures, vegetation etc) and images related to the area of each point.

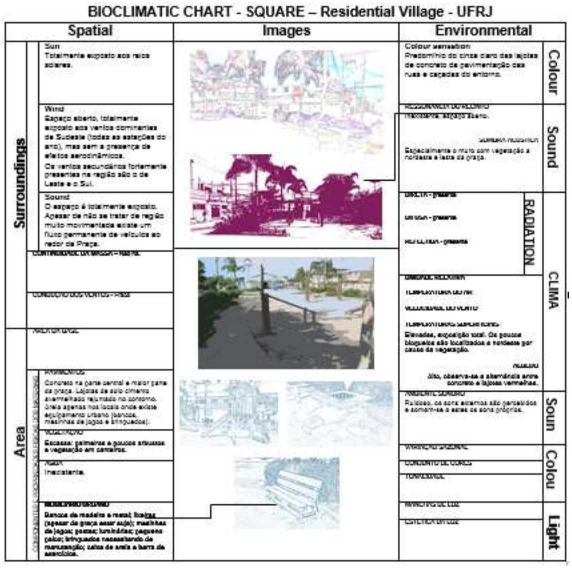
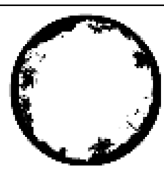
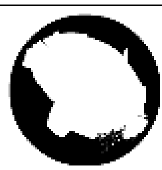
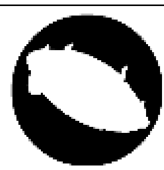


Fig. 5 Charts with bioclimatic analysis example

Each point was georeferenced and documented with images obtained through a fish eye lens. From the images, black and white masks were generated and the sky view factor was calculated (Table 1).

Table 1. Documentation for each point

Points	1 RV - Vitória Régia Street	2 RV - Violetas Street	3 RV - Square	4 RV - Margaridas Street	5 RV - Cravos Street
Coordinates	22.869871° S 43.217603° W	22.869705° S 43.217092° W	22.868691° S 43.217165° W	22.868968° S 43.218822° W	22.868789° S 43.219070° W
Image					
Black and White Mask					
SVF	0.256	0.249	0.660	0.481	0.345

4.1 Eolic erosion or sand-drag technique

For ventilation studies, the eolic erosion method (or "sand dragging") was adopted. That can be of great help in understanding the paths the wind takes in the urban environment, as well as their entries and possible barriers (Drach et al., 2010). With this technique, vented or sealed areas can be observed from the pedestrian's level, depending on the winds prevailing directions and velocities.

The study of the areas where the sand accumulates combined with the study of solar radiation, allows for the identification of the possibility of heat island development, as well as areas where pollutants are concentrated. The eolic erosion consists of applying selected sand on all exposed surfaces of the model and, after that, turning on the wind tunnel. When the tunnel is turned off, it is possible to identify the areas with low or no ventilation by observing where the sand remained intact.

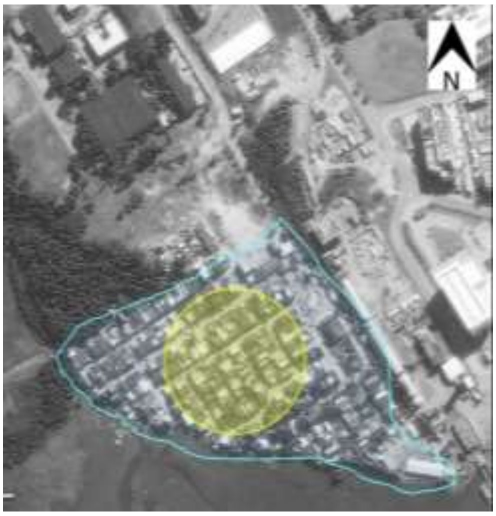
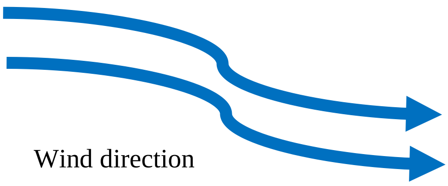
4.2 Air temperature - transect method

The air temperature was measured using the transect method, carried in a short time space and under intense insolation. Five stop points were selected, within the RV and this selection sought to represent the diversity of morphology within the RV, e.g., tree-lined street, narrow street, broad street, open place (square), proximity to the sea. The region map was taken as a basis for building the 3D model tested in the wind tunnel, but the heights and new buildings were observed in situ.

5. Results

The experiments carried out in the wind tunnel with the RV model allowed to observe the wind paths and may suggest, wherever possible, alternatives to deal with the lack of ventilation or intense ventilation, which does not seem to be the case in the RV. The wind directions were tested (Sol-Air, 2013) by prioritizing the more intense winds in the region: Southeast, South and East (Table 2).

Table 2. Predominant wind directions

 	Step	Southeast 	South 	East 
	Initial Stage			
				
	Final Result			

It is possible to notice from the images in Table 2 – Final results - that the ventilation inside the area is not well distributed and urban configuration seems not be helpful to promote the wind penetration inside the urban area. In addition to that, the intense sunlight in the region with virtually no shadows, results in environmental discomfort.

The air temperature was measured in each one of the 5 points (Figures 6 and 7) and the initial results obtained indicate, as expected, that vegetation affects temperature, minimizing the heat observed in the region (Points 1 and 2).

Fig. 6 Air temperature was measured in each one of the 5 points

Fig. 7 Air temperature was measured in each one of the 5 points – local results

Unfortunately, only a small stretch of the RV has some of vegetation in the streets. In RV's Square, although the vegetation does not provide a great amount of shade to protect the residents from the intense sunrays, it does help to decrease temperature. Apart from that, the presence of more ventilation in the open area of the square may also contribute to the comfort in that specific Point.

6. Discussion and conclusions

The initial studies of the air temperature behaviour are being developed by using the transect method, and the initial results point to expected results, i.e., the importance of vegetation for both shading and lowering the temperatures observed in the region..

The results from the experiment using the wind tunnel are helpful to the understanding of how the wind blows in the RV. A poor ventilation inside the RV was observed, as a result of a more compact and populated urban area. The urban mesh presents low porosity and brings about barriers for air penetration.

Although this research is at an early stage and these are preliminary results, the findings seem to be relevant to define the next steps. More investigation is needed and computer simulations will be provided, as well as field measurements.

As the project progresses, the aim is to outline strategies for climate sensitive design. Thus, the interference in the urban morphology of the RV would take into account not only the position of streets in relation to the prevailing and secondary winds, but also the barriers in the environment. The close link between urban geometry and outdoor comfort could contribute to planners and designers' ability to create urban spaces of quality.

Acknowledgment

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