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University Campus Architectural and Urban Quality: Research Projects at CEFET-MG - Brazil

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Abstract

In Brazil, between 2002 and 2014, there was an increase in the number of undergraduate and graduate students of over 100%. Although higher-education institutions have experienced significant growth, the lack of technical standards is noticeable for the planning, management and evaluation of its campus spaces. Technical diagnoses of university spaces and the identification of urban and architectural influence on the quality of life of the academic community may support master-plan guidelines for the sustainable development of university campuses. One research project employing post-occupancy evaluation tools collected data on the users' and experts' perspective. Other projects employed thermographic validation to point out possible causes related to the urban heat-island phenomenon by following mitigated systemized strategies. Data images were generated using a TD FLIR T300 camera. Another proposed a method of analyzing the wind behavior in a micro urban environment on the basis of geometric models and computational numerical simulations. It took into consideration that a numerical simulation technique applied to the study of natural ventilation effects provides ways to quantify and qualify the air flow around the buildings. These research projects developed by a research group at CEFET-MG are expected to generate evidence that may guide future expansions and renovations at universities campuses.

Keywords: Computational Fluid Dynamics, Heat island, Post-occupancy evaluation, Thermal images, University Campus quality of life.

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Introduction

Over the past few years, studies about the quality of life have increasingly been focusing on urban reality, as the majority of the world's population lives in urban places. This can be pointed as a reason for the appearance of a new line of research on the quality of urban life (Santos and Martins, 2007). Around the world, it has also recognized that the health and quality of life are top priority areas of the Sixth Environment Action Programme (European Commission, 2006).

On the other hand, Universities have been recognized as an active agent in the society development and evolution. It is sustained that their role is to promote cultural, scientific and technical development of new generations, but also of the whole society (The Magna Charta Observatory, 1988).

In Brazil, between 2002 and 2014, there was an increase in the number of undergraduate and graduate students of over 100%. Although higher-education institutions have experienced significant growth, the lack of technical standards is noticeable for planning, management and evaluation of its campus spaces.

In this context, university campuses can be considered as micro cities as well as urban spaces. They are composed with services, infrastructures, multiplicity, functional and social hierarchy. It also can be noticed when analyzing its characteristics, form, dimension and organization, also considering their location, usually in urban areas or even merged in the city.

In spite of the known difficulties to find a universal definition of quality of life in urban spaces, there is some consensus concerning the approach conducting to its conceptualization.

Quality of life can be determined by a number of factors which together make the life lighter, easier and pleasant. The relevance that each factor has on different people can vary but generally are similar. Among the factors that influence the quality of life, a few can be mentioned, such as the security sense, time spent in traffic, public transport quality, the presence of green and recreational areas in the cities, financial and professional accomplishment, the comfort feeling, and so on. Quality of life is widely related to love, health, and education. Having access to cultural events, a decent home, a nice healthy meal and to feel good – all of which compromise and solidify the overall sense of having quality of life "[...] which is one of the goals to be achieved in the present stage of mankind's development" (Nobre, 1995).

In a university, the quality of life envelop, in addition to the points listed before, are relevant the issues related to urban planning, distances, traffic flows and urban mobility, obstacles and permeability, leisure, meeting and contemplation, light and shadow, thermal and acoustic comfort, construction procedures and materials, external access, parking areas, service structures and urban equipments, design quality and the final product quality (Rodrigues et al., 2009; Carvalho, 2013).

Technical diagnoses of university spaces and identification of urban and architectural influence on the quality of life of the academic community, being through data collection, thermal measurements or computational simulation, may support master-plan guidelines for the sustainable development of university campuses.

A Case Study: CEFET-MG, Belo Horizonte – Brazil

The diagnosis has been performed at the Federal Center for Technological Education of Minas Gerais (CEFET-MG) in order to consolidate the understanding of the campus spaces. This paper discusses and presents results from three research projects developed at CEFET-MG by postgraduate students at Civil Engineering Post Graduation Course involved in ARCOS Research Group:

1. Post-Occupancy Evaluation of Urban Spaces in Universities;
2. Infrared Thermograph Application in Urban Surfaces;
3. Numerical Simulation of Wind Behavior in Micro Urban Environment.

CEFET-MG is a Federal Institution that offers, since 1909, public, high quality and out of charge education starting from technological high school, undergraduate and graduate education in more than 10 knowledge areas. Nowadays CEFET-MG has about 15.000 students in its 10 campuses in Minas Gerais State in Brazil.

The Campus II is located in an urban area of the city of Belo Horizonte, and occupies an area of twelve hectares. The community of the Campus has about 5.000 users, being 4.600 students, 200 professors and lecturers (teachers) and 200 staff employees. The buildings to support academic activities congregate schools and institutes, and several buildings for services such as the library and the restaurant, the computational centre, the academic services outside activities among others.

The methodology presented in the next section was implemented and tested as case studies in the Campus II.

Methodology

The first step of the methodology approach is the identification of a set of quality of life dimensions, which is related to aspects of the campuses livability (Rodrigues et al., 2005; 2009). As in a small city, the livability in a university campus is conditioned by many factors, such as the environmental conditions, mobility, accessibility to services and work places, and social conditions as mentioned before.

To develop such standards a technical diagnosis of micro urban spaces is required as well as identifying the urban and architectural influence on the quality of life of the academic community.

Post-occupancy Evaluation of Urban Spaces in Universities

This research was conducted by collecting data which took into consideration the perspectives of users and experts, employing post-occupancy evaluation tools, using a previously defined list and gathering the opinion of a set of users.

Created by Kevin Lynch in the 60s, walkthrough is a powerful POE tool that consists in an analysis method that combines both observation and interview, enabling, thus, the description of negative and positive aspects of the analyzed environment. In its application, photographs, sketches, maps, plans, checklists, audio and video, drawings, bookmarks and sheets could be used. Because it is a flexible instrument, the walkthrough allows several methods and approach uses, molding itself to every situation, making each job unique. Its application allows identifying which environment aspects or uses deserve to be evaluated and which techniques should be employed to obtain the data. Because of this, it has been constantly used in the built environment performance evaluation (Rheingantz et al., 2009).

To apply the research was necessary to divide the territory into five smaller areas to facilitate data interpretation from Sectors 1 to 5. Figure 1 shows the CEFET-MG - Unit II plant with the demarcation of the studied areas. The numbers from 1 to 21 are the buildings and important urban places. In Figure 2 some images taken from important views are shown.

Figure 1. *CEFET-MG - Unit II Plant*

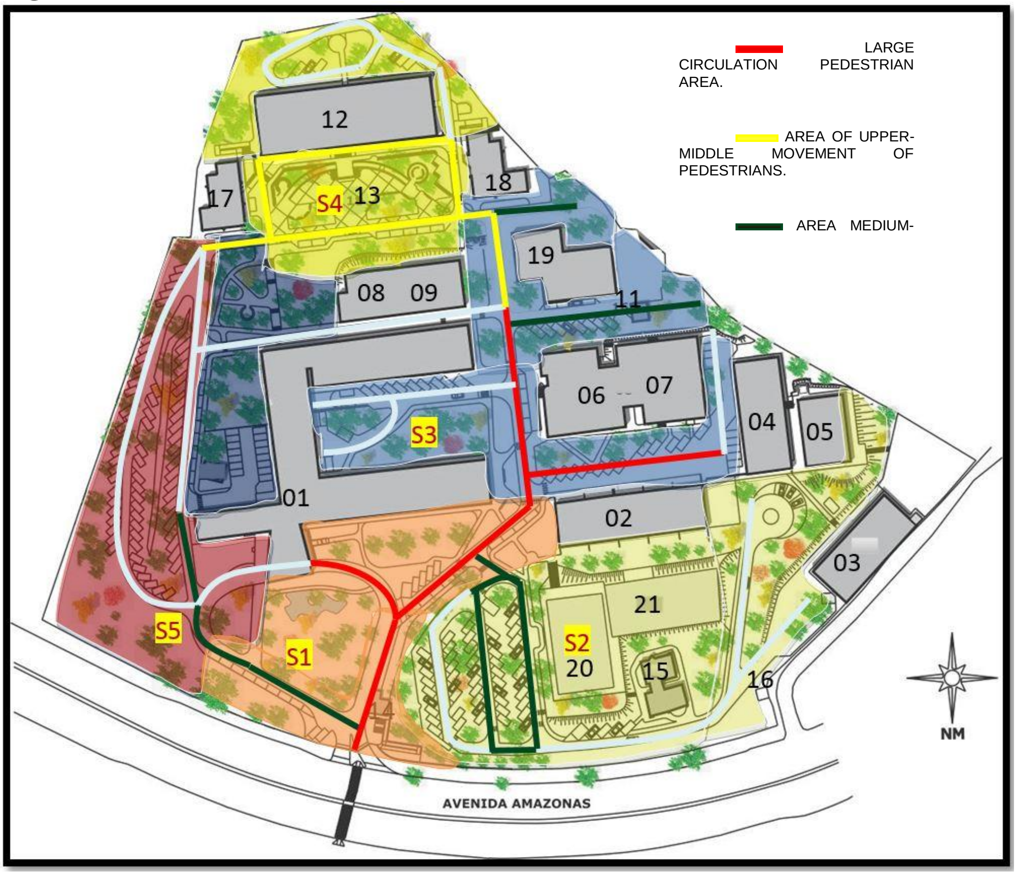


Figure 2. *CEFET-MG – Areas View at Campus II*

(a): Main Entrance's View

(b): Main School Building's View

(c): Library Building

(d): Main Street

(e): Main Square

(f): Street Circulation and Parking Lot

For the work development, the spaces were classified according to their use and characteristics as described below:

Use: passing, leisure, study, rest, exercise, work, meal, maintenance.
Spatial characteristics: confinement, privacy, reduced privacy, reduced interaction, interaction, high interaction.
Environmental comfort: acoustic comfort, natural and artificial lighting, thermal comfort, solar radiation, shading, natural ventilation.
Physical characteristics: floor type, slope, materials, infrastructure for people with special needs, signposts.

The parameters for urban space interpretation and readout, encompassed by the research are described below:

The area in the city: location, coordination with the city, environment, mobility and security.

The urban landscape: place, tracing (blocks, roads, lots), land occupation (density, time of construction, state of repair), land use, recreation areas, green areas.
The urban environment: modes of appropriation of public space and its relationship to urban form, circulation (flows and pathways), location of the main buildings, the main references for users (markings and meeting places), the places and their identities.
Technical analysis of spaces: accessibility, entrances, streets, parking lots, living areas, suitability of projects for people with special needs, amount of open and closed spaces, meeting and bustling areas, building materials quality, and internal urban equipment.

To treat the research information acquired and turn data into numbers, statistical methods were used. First, to validate the methods used, also considering cost and time, the research was made with a representative sample, since a study with the entire population, due to the university size, would be a complex task. Hence, statistical inference was used to make possible generalizing the sample to the population. To deal with the parameters of the samples and therefore the population from which the samples were extracted, it was considered the data of this population behave in accordance with a Normal Distribution (Devore, 2011).

Infrared Thermographic Application in Urban Surfaces

Infrared thermographic is a qualified tool commonly used in structural and pathologic analysis, even though, not many application cases in urban areas are registered. A thermographic validation of urban spaces inside a microclimate including technical mensuration can represent the causes related with urban heat island phenomenon, which can turn into mitigated systemized strategies of master's plans.

This study at CEFET-MG, Brazil has the purpose to identify and to create a methodology in order to recognize the thermal behavior in different urban surfaces inside the campus, and its influences of the heat island generation.

The methodology is based on previous literature reviews about the urban surfaces thermal performance and its measurement strategies. A data collection was developed, in a 24 hours period, through thermographic images generated using a thermal-digital FLIR T300 camera.

The admeasurements of the weather station data was realized through the simultaneous data collection from AT (air temperature) and RH (relative humidity), using both data from the campus weather station and the WBIGT portable thermometer (wet bulbe index – globe thermometer) during a one hour period.

The methodology, using the Urban Canopy Layer (UCL) concepts, can be described such as:

i. Identify the specific areas to be researched using building and tree shadow studies;

ii. Characterize the materials and qualify the areas as paved or permeable surfaces;
iii. Identify the height reference for weather data measurement to include de warm zones (UCL);
iv. Define monitoring reference points for the urban areas using the thermal imager;
v. Identify the ideal weather conditions for taking the measurements;
vi. Define the appropriate equipment;
vii. Design the monitoring routines of surface temperature, weather conditions, data collection and statistical treatment,
viii. Develop the monitoring strategy to result admeasurements using an infrared thermometer;
ix. Perform the data treatment;
x. Discuss the results comparing to the post occupation evaluation of anterior researches;
xi. Identify the results impact in the sustainable development of the campuses.

The images were guided by a surface mapping of the construction and vegetation shadow geometry considering the use, the materials and the thermal performance as Figures 3 to 6.

Figure 3. *Campus II Research Areas and Reference Points – Areas 1 to 3*

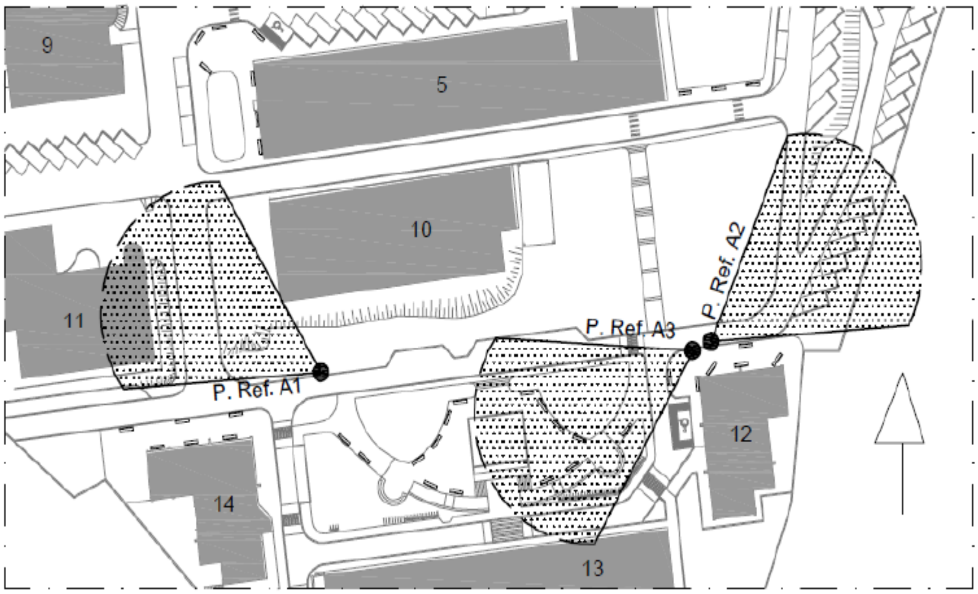


Figure 4. *Area 1 (A1) – Reference Measurement Point - Thermal Image and Local Picture*

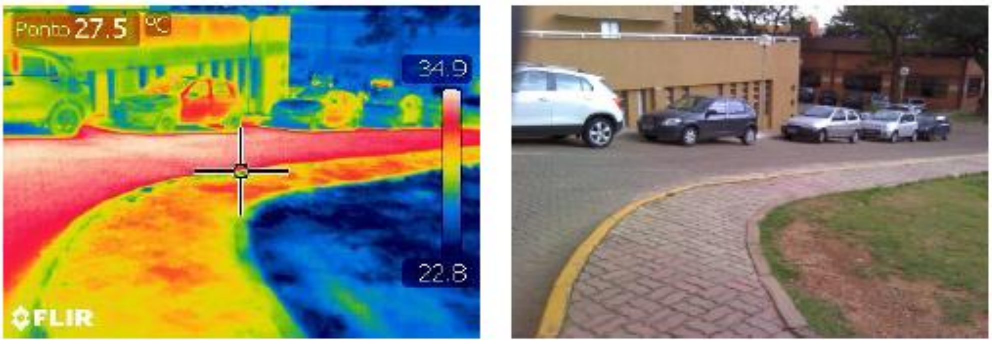


Figure 5. *Area 2 (A2) – Reference Measurement Point - Thermal Image and Local Picture*

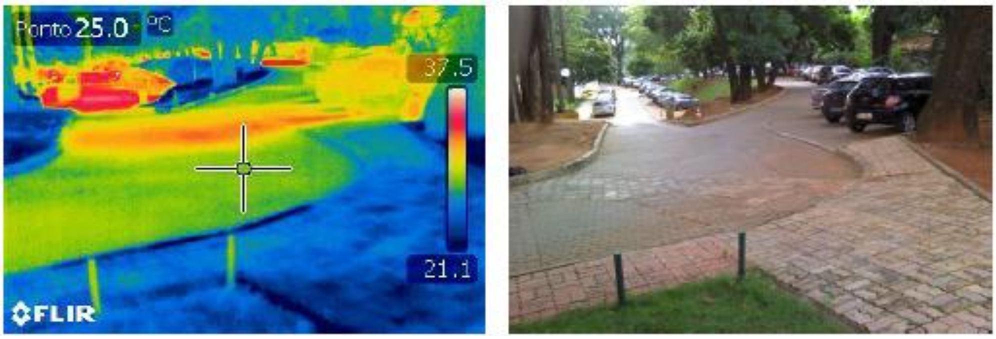
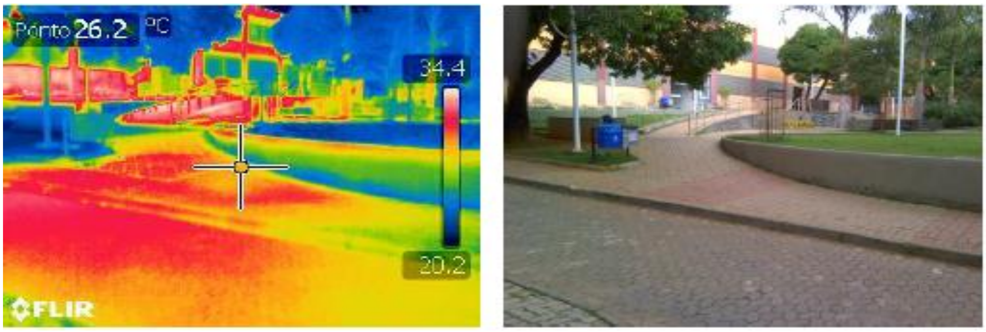


Figure 6. *Area 3 (A3) – Reference Measurement Point - Thermal Image and Local Picture*

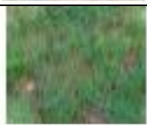


For the materials monitoring, 32 samples of surface materials were selected and followed the methodology described:

i. Registration of sample groups using thermal imager. The parameters were the same for the Area A1, mostly sunny;
ii. Registration of three sequential values of surface temperature in every sample and black globe, taking notes about the existence of shadows in the samples;
iii. Registration of sky condition from no cloudy, semi cloudy or cloudy.

The selected materials used in the surface campus are shown in Table 1.

Table 1. *Surface Materials – CEFET-MG, Campus II*

Function	Material	Colour	Area (m²)	Picture
street	Concrete Block	gray	A1= 3370.3 A2= 1819.7 A3=1159.9	
sidewalk	ConcreteBlock	light gray and light red	A1=1670.9 A2= 95.3 A3=869.8	 
permeable surface	Grass Natural Field	grass and natural field	A1= 4956.5 A2= 2238.9 A3=2239.7	 

The results were processed, classified and discussed facing to post-occupancy evaluation previously done at this campus.

Numerical Simulation of Wind Behavior in Micro Urban Environments

The building wind follows variables that change depending on the country, region, state and the constructive typologies. The air movement is one of the least understood behaviors although it represents major challenges in fluid dynamics, especially when buildings act as a barrier to the external environment. The numerical simulation technique applied to study natural ventilation effects provides ways to quantify and qualify the air flow around the buildings, in addition to presenting detailed information about the air disposal (Smagorinsky, 1963).

This research proposes a wind behavior analysis method evaluated in a micro urban environment, through geometric models and computational numerical simulations (Rodi et al., 1997; White, 2015).

The main scientific question that motivated the research was: how the architectural concept is able to influence the movement of the wind within the built environment?

To achieve the research goals a methodology divided into: Characterization of the object of study and data collection; Geometry Generation (Figure 7); Mesh generation (Figure 8); Boundary conditions (Figure 9) and Equations for Computational Fluid Dynamics models generating images was created. Examples from these images generated in four difference levels, considering distance from the floor, are shown in Figure 10.

Figure 7. *Geometry Generation*

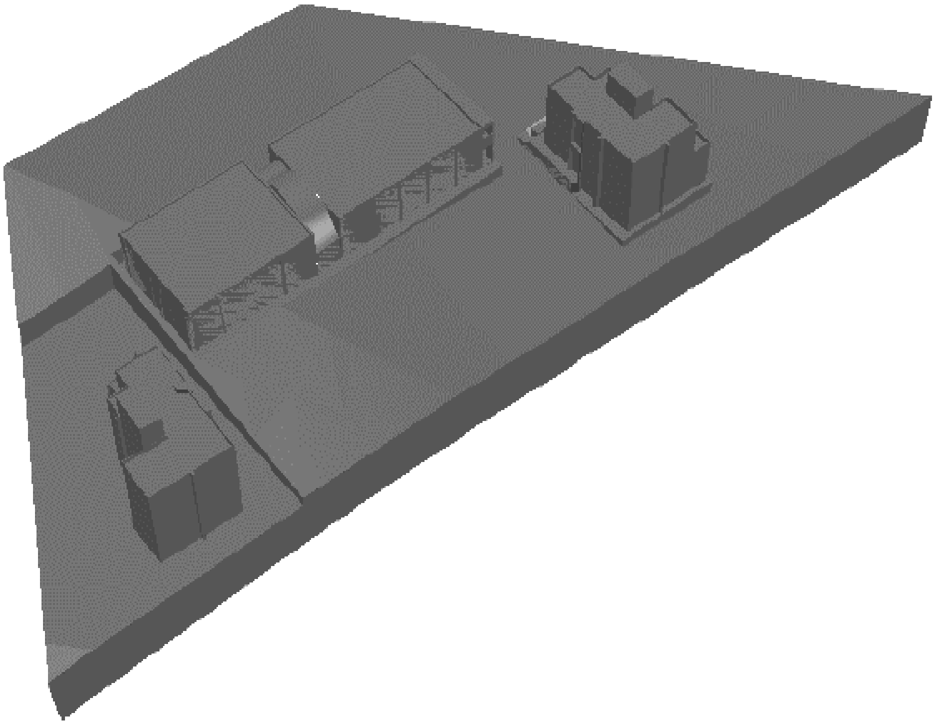
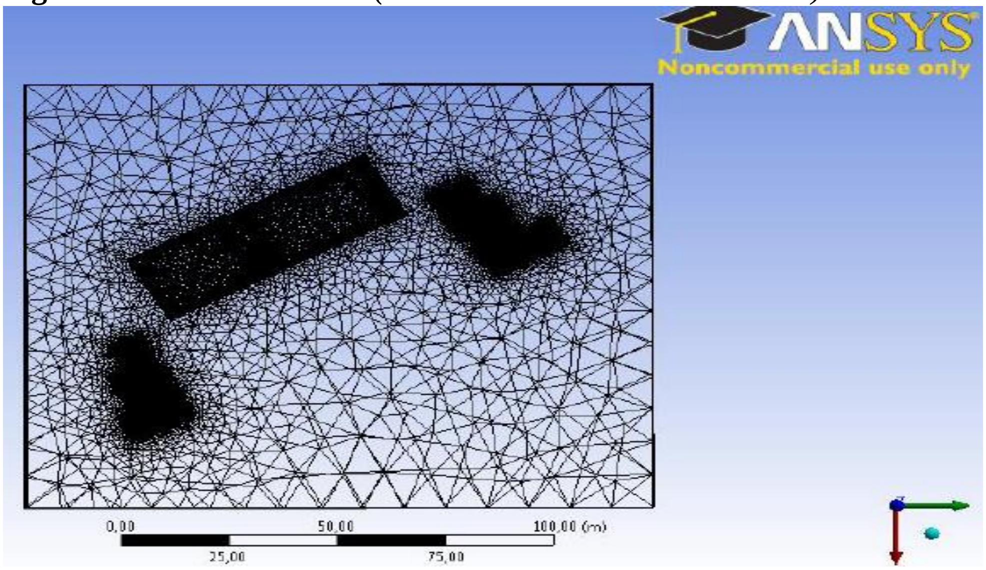


Figure 8. *Mesh Generation (Solid and Tridimensional Views)*



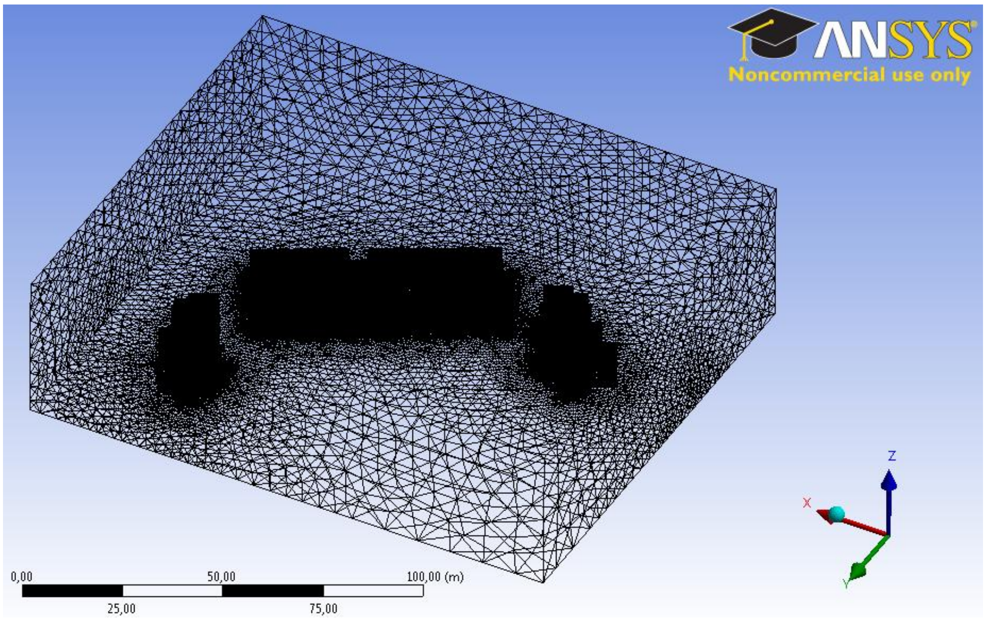


Figure 9. *Boundary Conditions*

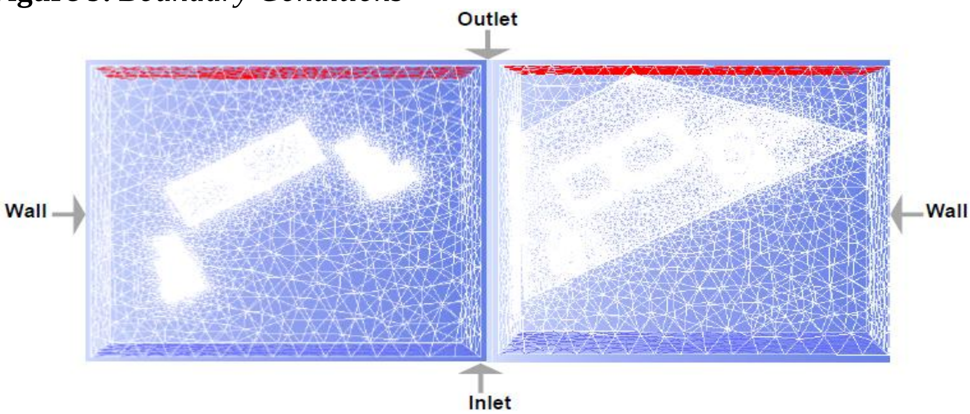
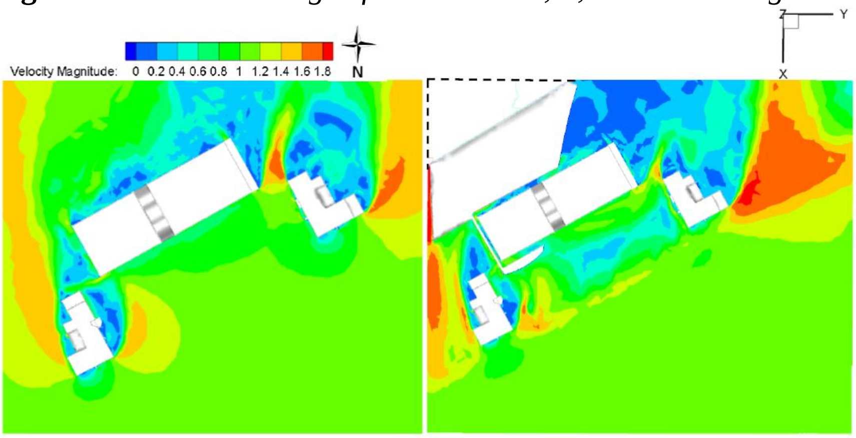
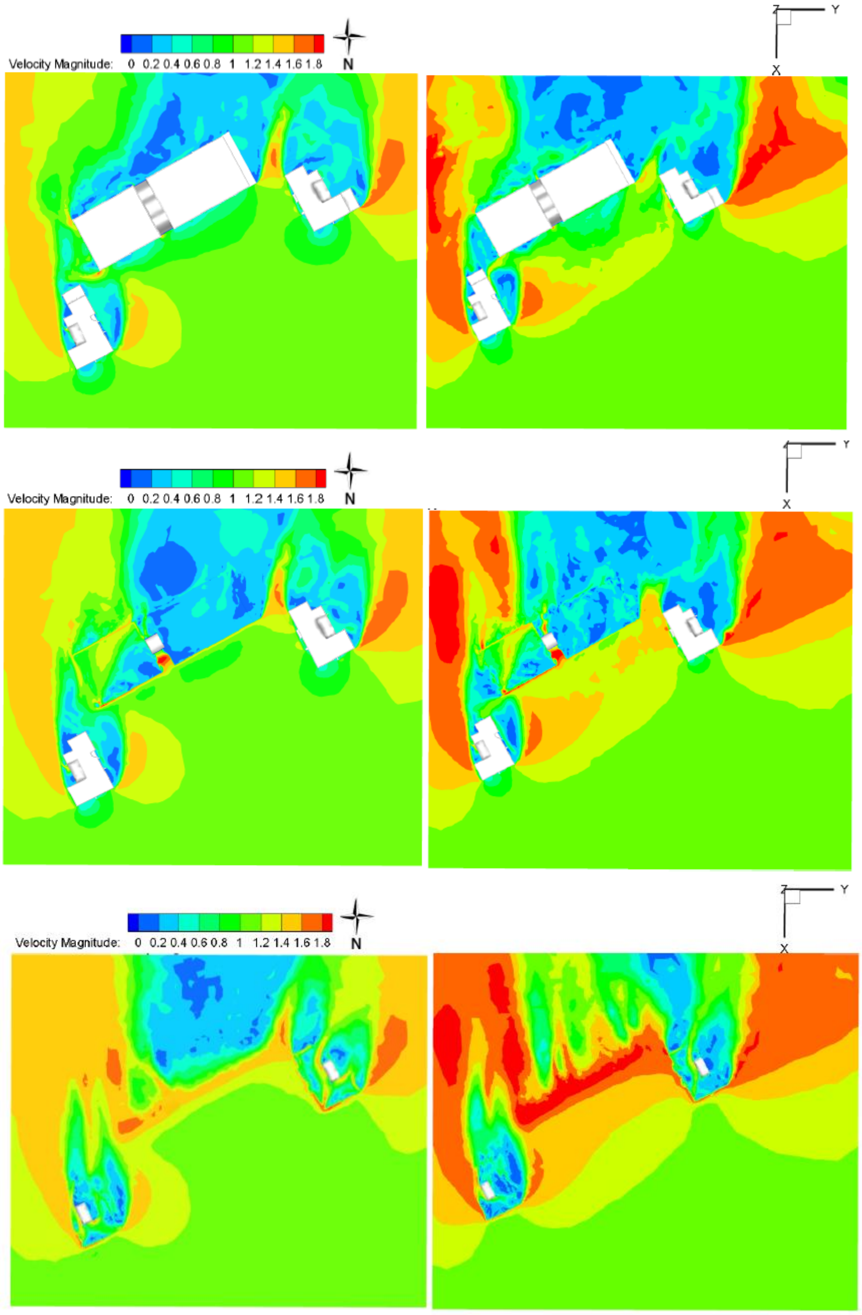


Figure 10. *Sector 4 Images from Levels 2, 6, 10 and 14 High Meters*





Results

The principal results are pointed as follow.

1. The objective or intent of this research is not to suggest solutions, but rather to identify the existing problems in CEFET-MG Campus II. It should be noted that the implementation of APO in urban areas of higher education institutions, due to the scale, is complex and time consuming and must be evaluated and adapted to each space considering the different situations technical, social and policies involved.

In the first Case Study the results revealed that the Institution's campus has security issues, as well as drawbacks regarding artificial lighting and environments. However, among the aspects, factors such as natural lighting and ventilation, acoustic comfort and parking spaces give a positive evaluation.

It is necessary to point out that the territory that makes up the Unit II became part of the CEFET-MG at the end of the 70s and its spaces, in addition to being under construction, are going through an institutional expansion, with the creation of new courses. This expansion is possible because the space has flexibility because of its urban fabric, density, spatial and physical characteristics.

Thus, the APO application is advisable to assist intervention projects on infrastructure in urban furniture and equipment already in place for the formation of a pleasant, safe and can meet the functions expected of an educational institution.

2. In the Infrared thermographic application in urban surfaces Case Study the results obtained in the study's first phase indicate the tree shading efficacy for the urban temperature decrease if compared with the materials type and hue. In this study, the surface temperature on shaded environments was 20 °C lower than surfaces on sunny environments. According the literature (EPA, 2014), the use of the infrared imager allowed to observe the sun incidence angle influence on surface temperature, which highlights the importance of the pavement's orientation and topography.

   The second stage of this research showed results related to the influence of the shade on the surface's temperature. The highest temperature difference between similar materials with different shades was approximately 10 °C in a sunny environment, as the cementitious material samples showed. Similar results were observed in Chudnovsky et al. (2004) and Doulos et al. (2004) researches, where also was noticed that, the darker material hue the hotter the surface during temperature peak hours.

   Monitoring urban paved surface temperatures with an infrared thermometer (TI) may lead to significant errors. Factors such as the type of shading, wind, material characteristics and its application in the urban environment, may influence in how uniform the temperature on surface area is. Erroneous measurements happen because the thermal-imager covers smaller surface areas on each measurement.
3. For the Wind simulations the LES model with Smagorinsky subgrade was adopted. The air velocity distribution and the pressure coefficient go into the same direction as the experimental data. The results confirm other wind comportment methods studied in the literature review. The natural wind behaviour changes the direction as well the wind velocity can increase or decrease depending on the building interaction. In high speed conditions, the air flow around the buildings presents bigger energy quantity generating large eddies. In the urban ventilation analysis these wind large eddies are more important to be considerate than the small ones.

Conclusions

The research projects main purpose is to provide a conceptual basis for the implementation of a decision support system. The diagnoses integrate the users' perception, measurements and simulations to provide data to analyze the impact of future interventions on the campuses quality of life.

1. In the pursuit of building the technical diagnostics of urban spaces that make up the territory of the CEFET-MG Campus II was made possible through the methods used to identify the desires and needs of the academic community, as well as factors that interfere with their quality of life.
   It is noteworthy that the POE implementation in urban areas of the university, due to its scale, is complex and requires a great amount of time, besides the great determination of the executors and participants. Their replication is possible, but it must be evaluated and adapted to each space, considering different technical and political configurations involved.
2. The thermal-imager was the most reliable alternative to on-site surface temperature monitoring comparing to the common infrared thermometer. The thermal images captured by the equipment allow the areas temperature identification, and the temperature distribution and type of shading visualizations along the surfaces. Another important advantage of the thermal-imager is the possibility of the instantaneous covering of large areas temperature, eliminating the necessity of large amount of measuring points.
3. In the Numerical Simulation of wind behaviour in Micro Urban Environments Case Study preliminary results obtained reflect the wind behaviour of a sector within CEFET-MG - Campus II, attesting to the numerical simulation accuracy for the experimental data collected. These results serve as a basis for the complete simulation, expecting a systematization of an air drainage method for architectural analysis.

Thinking about a space focused on the academic community, it is necessary to develop projects based on the principles of sustainability, accessibility, energy efficiency, environmental preservation, flexibility, social and cultural integration, safety and comfort that stimulate the users' minds of providing quality of life. The space should be supportive, pluralistic, and should also embrace the community.

The methods employed and the research results obtained may help to build a master plan in guiding future expansions and renovations for the Institution and contributing to post-occupancy evaluation of other campuses of education.

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