

# Environment and Urbanization: Microclimatic Variations in a Brownfield Site in Sao Paulo, Brazil

Denise Duarte and Joana Gonçalves

Laboratório de Conforto Ambiental e Eficiência Energética (LABAUT), Departamento de Tecnologia  
Faculdade de Arquitetura e Urbanismo da Universidade de São Paulo (FAUUSP)  
Rua do Lago, 876, Cidade Universitária, 05508-060, São Paulo, Brasil  
E-mail: dhduarte@terra.com.br, jocarch@usp.br

**ABSTRACT:** This paper addresses urban microclimates as a function of urban design in central Sao Paulo, Brazil. Sao Paulo is now the second largest city in the world with a population of nearly 19 million in its metropolitan area. It has a tropical, albeit polluted climate and is subject to a wide range of urban micro climates, due to its occupation patterns and topography. The city is located 60Km from the sea at latitude 23°24´S, with altitudes varying between 720m and 850m above sea level. In this urban context, this paper focuses on the urban microclimates at Barra Funda site, in central Sao Paulo, ranging from an mild and humid to arid in close proximity. To evaluate the current urban microclimates and comfort conditions in outdoor spaces, on-site measurements of air temperature, humidity, noise, sky view factor, wind speed and direction were carried out over a day in summer (November 2005) in six different locations within short walking distances to each other. Significant differences were found, mapped and analysed. The results can lead to the proposals for improving the public realm aimed, identifying the most appropriate design solutions for the area.

**Keywords:** microclimate, outdoor space, measurements, urban design

## 1. INTRODUCTION

Sao Paulo is now the second largest city in the world with a population of nearly 19 million. Sprawling high-rise and high-density development is interspersed with *favelas* and low dense neighbourhoods and dry outdoor environments. Urban infrastructure is poor, air and water pollution is high and green space is at a premium.

The site of interest for these studies is located in an area of the city classified by the local government in the last decade as one of the areas for *Operações Urbanas* [1] – a process whereby parts of the city are selected to for substantial interventions and changes of its urban configuration as well as addressing economic and social characteristics, through public and private partnerships. This same area was chosen for a national design competition, held in 2004, promoted by the Municipal Administration of Sao Paulo and IAB - Brazilian Institute of Architects/Department of Sao Paulo - to create the Bairro Novo (New Neighbourhood). The competition aimed to create a new urban fabric with more public amenities and facilities, including an improved landscape. This brownfield site was chosen as an area of intervention for a pilot project that brought together British and Brazilian expertise in the field of sustainable urban design to explore environmental approaches supporting urban renaissance in Sao Paulo, resulting in socio-economic benefits.

The neighbourhood is a hostile environment for pedestrians, who experience lack of sidewalks, air pollution, lack of vegetation and permeable surfaces,

lack of shading, poor design of services facilities and resting points in the public spaces - all problems generated by the inadequate urbanization process.

On the other hand the climatic analysis of São Paulo shows the possibilities to achieve thermal comfort almost all year round. With regards to the hot and humid summer days, simple strategies such as shading and enhancement of air flow, if incorporated into urban design, can bring thermal conditions back towards the comfort zone.

Results could support proposals for the improvement of the public realm targeted by the public sector, identifying the most appropriate design solutions for the area. This work sits within a broader research context considering urban environmental design. In that sense, the studies began in 2004 with the submission for the national competition Bairro Novo, in which first ideas about new urban spaces were explored considering environmental issues [2]. More recently, the brownfield site in Barra Funda is one of the case studies of the research project entitled Sustainable Urban Spaces – a collaboration between FAUUSP, Brazil; UEL, London; and The Martin Centre, from the Cambridge University - UK, (2005 and 2006). In a further development, the work executed in the last year will continue for a further year, undertaking in-depth analyses to inform a framework for future design proposals.

## 2. SÃO PAULO URBAN ENVIRONMENT

### 2.1. Environment and Green Spaces

Environmental issues are of major concern in São Paulo. Besides air pollution and the heat island effect certain areas suffer from other environmental problems such as regular floods (more than 400 sites are likely to be flooded during the rainy season in summer). Furthermore, the city of São Paulo at the turn of the 21<sup>st</sup> century had 1,9 million people living in around 1.850 *favelas*, distributed across the city, of which 65% of the occupied land was originally designated as green public spaces. It is worth noting that only 16,4% of the city is currently covered by green areas, whereas the majority of the city surface is impervious (fig.1) [3].



**Figure 1:** Paraisópolis' *Favela* and Ibirapuera Park with buildings designed by Oscar Niemeyer.

Environmental and socio-economic indicators are used by public organizations to assess urban quality in São Paulo. From 1991 to 2000 the city lost 5.345ha of green coverage due to urban occupation; 56% is concentrated in only 10 districts from the periphery, where there is a high population increase. All these factors, with vegetation suppression, topographical alterations and informal settlements have been continuously lowering the urban environmental quality [3]. On this basis, in 2004 out of the 96 districts in which the city is divided, only 4 were well classified (Socorro, Morumbi, Alto de Pinheiros, Marsilac) – among the greenest neighbourhoods. In parallel, 18 districts were scored from “bad” to “extremely bad”.

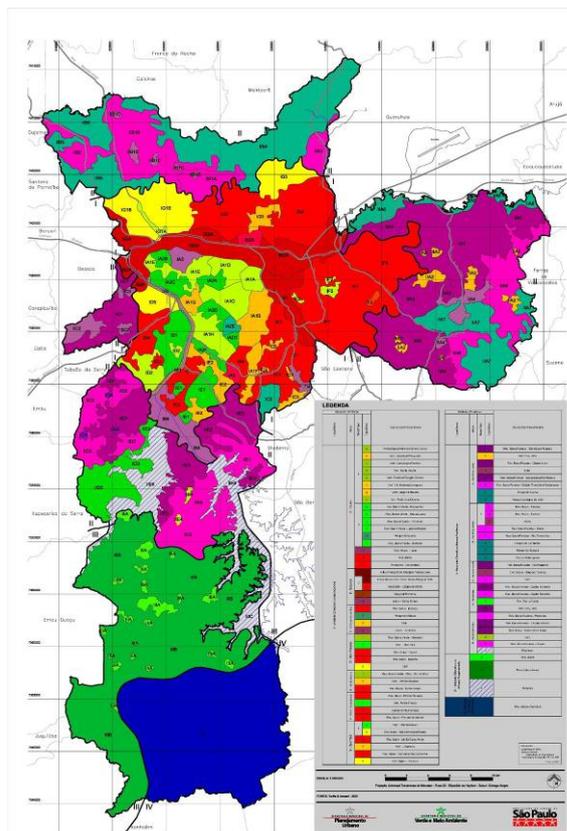
Today, 67 significant locations in the city, of different sizes, present some kind of green cover in which vegetation is identified mainly in three different conditions: fragments of natural vegetation, planted areas (parks, green squares and street trees) and small clusters with individual trees isolated in private sites. Nevertheless, currently the restoration of good quality public spaces and vegetation in the city is a major challenge for urban planning and design. In the consolidated areas of downtown and its surroundings there are no public sites available for parks and green spaces.

### 2.2. Environment and Climate

São Paulo metropolitan area has almost 19 million inhabitants. The city is located at latitude 23°24'S, with a modified tropical climate due to altitude (between 720 and 850m above sea level). Previous geographical studies identified the great variety and complexity of its urban climate [4].

The metropolitan region is surrounded by forests, dams, mountains, and presents heat islands associated to its urban configuration, with differences as far as 10°C during calm wind conditions [5]. In the city, the evapotranspiration ratio, typically lower, accentuates the temperature differences with its surroundings. Drainage rapidly removes most of the rain water and for this reason, only a small amount of absorbed radiation is used for evaporation [6]. Geographers [4] distinguish climatic particularities of São Paulo, such as the riverside freeways, the Paulista Avenue Canyon [7] and the occupation patterns in the shanty-towns with their impact on the local microclimate.

Some research demonstrated [8] that the climatic metropolitan phenomenon has extended beyond the city limits, adversely affecting the natural climate up to the basin of the Tietê river. Moreover, the climatic phenomena must be also measured against the social and spatial practices, as they represent the urban reality. The urban climate map is a lot more fragmented than the natural climate (fig.2).

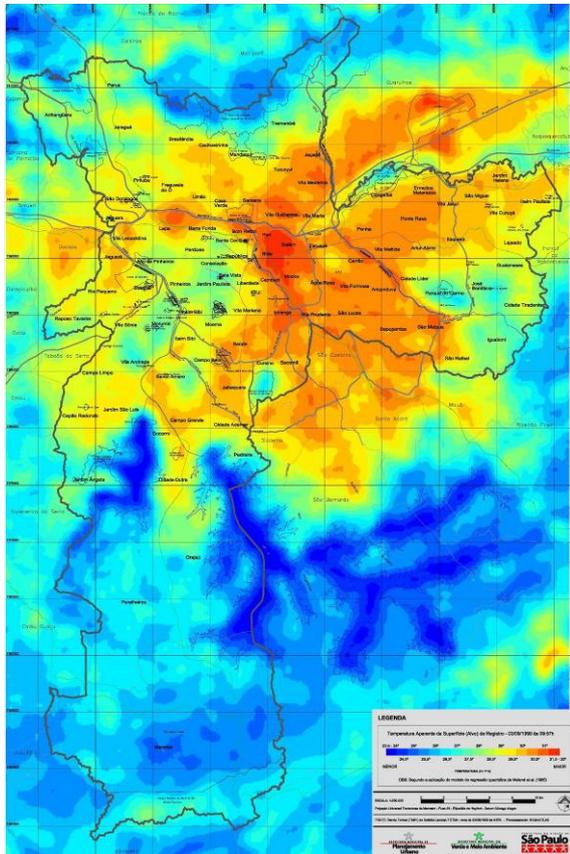


**Figure 2:** Map of the urban climate in the São Paulo. (<http://atlasambiental.prefeitura.sp.gov.br>)

This demonstrates that the use, vehicles and human fluxes, residential typologies and the industrial production, commerce and services create cells, neighbourhoods and places with particular environmental conditions. Understanding the urban climate of the riverside freeways, for example, presupposes an understanding of the fluxes, and the physical, biological, social and human interactions.

The satellite image (fig.3) shows that in the centre of the metropolis there are major transformations of energy and pollution, derived from urbanization.

Environmentally speaking, Barra Funda is mentioned as one of the more inhospitable central areas, because of the lack of public amenities and facilities, added to climatic and air quality problems.



**Figure 3:** Thermal satellite image of São Paulo. (<http://atlasambiental.prefeitura.sp.gov.br>)

### 3. AREA OF INTERVENTION

#### 3.1. Barra Funda: Urbanization and Environment

The area of Barra Funda is located within the Água Branca district in the west zone of São Paulo, 5km from downtown, crossed by a main railway line and stretches to the edge of Tietê River, encompassing 107ha. Considering the urban infrastructure, Barra Funda Station is the second largest transport station in the city and is located in the heart of this site. Therefore, public access from other locations of the city as well as from the metropolitan area, is well facilitated by different means of transportation. Places and buildings assigned to culture and leisure activities are major points of interest: SESC Pompéia; Casa das Caldeiras; Memorial da América Latina and Água Funda Park. In 1991 the population of Barra Funda was around 16.000 people but falling to a figure close to 12.100 by 2004, resulting in an annual growth rate of -2,1% and density of 112 p/ha. The extremely low

density for such an urban site is explained by the historical processes that have affected the area since the 1960s.

The urbanisation process of the northwest region began with the introduction of the railway together with the development of industrial activities. The immediate consequence upon the urban configuration was the formation of relatively large sites to accommodate industrial buildings and warehouses. In the 1960s, the national economic “boom” had a big impact on the demise of the area. The demand for bigger industrial sites led the factory buildings to the outskirts of the city, which was supported by the shift in the key transportation network from railways to roads. Today, following the displacement of these industries, many of the old warehouses and industrial buildings have been demolished; others were simply deserted, turning the area into a brownfield, where pedestrians’ mobility and comfort are compromised. However, 34% of the local income is still associated with the industrial sector, 64% in commerce and services and 2% in the construction industry.

A range of different urban occupation patterns (fig.4 and 5), crossed by major busy roads, configure the urban environment: blocks of old warehouses; isolated tall buildings; a central three storey transport interchange station the size of a city block; clusters of low dense residential blocks; big parking lots; open spaces alongside the railway lines, hard landscaped public spaces and the Água Funda Park (the only significant green area in the neighbourhood). Consequently, the site opens up possibilities for environmental regeneration, as a case study of typical brownfield sites in the city.

The Latin America Square, designed by Niemeyer in 1990’s, is the second biggest public space in Barra Funda site, after the Água Branca Park, close to the station, in the centre of the area of interest, characterized by lack of greenery and shading, hard-surface pavement and inhibiting physical barriers all around. However, acknowledging the relationship between the use of public realm and environmental conditions, the use of the Latin American Square is compromised by its harsh environment.



**Figure 4:** Aerial view of Barra Funda brownfield site.

#### 3.2. Public Interest

The Água Branca district is one of the areas designated by Local Authorities as appropriate for redevelopment - called *Operações Urbanas*, which are urban regeneration projects carried out in the last decade in parts of the city considered strategic in urban and economic terms. Considering the principles of the *Operações Urbanas*, urban and economic

development could be achieved by exceeding locally prescribed building heights and plot ratios. As a trade off, private initiative should invest in public spaces and amenity necessary for that region. The public sector would be responsible for improvements in the infrastructure, including accessibility, public lighting and sanitation. However, such initiatives were not successful in Água Branca, when applied in 1996. Ultimately, some construction was carried out, but remained isolated, without the expected catalyst effect upon a broader urban regeneration, thus maintaining the local unattractive and problematic urban environment.

In 2004, the Municipal Agency for Urbanization, EMURB, together with the Institute of Brazilian Architects, promoted a national design competition entitled Bairro Novo (107ha). In a city with major infrastructure deficiencies, primarily regarding mobility, drainage and lack of inviting open spaces, the competition aimed to promote ideas for a new neighbourhood in Barra Funda, which were applicable to the revitalization of urban brownfield sites in the central São Paulo.

#### **4. ENVIRONMENTAL MEASUREMENTS**

##### **4.1. Synoptic Conditions and Method**

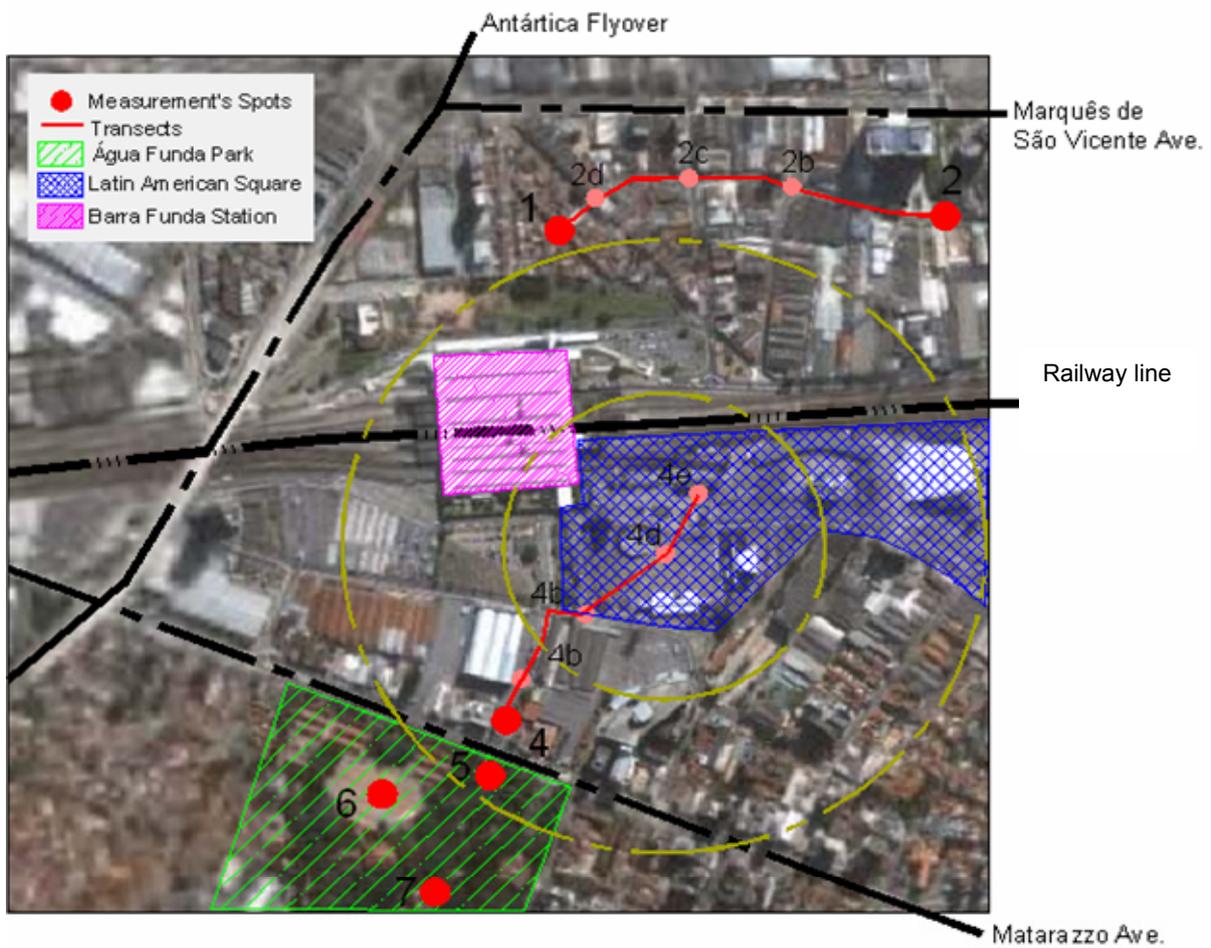
The area of interest for the on-site urban studies is located inside the area designated for the national competition Bairro Novo, with the main railway station at its centre and bounded by the green park and

major avenues, encompassing 73ha, within a circle of approximately 300m radius. The contrasting environmental conditions are noticeable within walking distances, which was the main criterion for selecting the site.

Meteorological data collected at the official station of INMET – National Institute of Meteorology in November 17<sup>th</sup> and 18<sup>th</sup> showed a cold mass in the Atlantic Ocean, close to the coast of Southeast Brazil, associated with instability areas over the continent. This cold mass arrived in the metropolitan region and, in the afternoon 18<sup>th</sup>, the city was under a post frontal condition; at the site, however the cold mass did not have a significant influence in the temperatures. Due to the rapid pre-heating effects during this time of the year and the presence of high humidity in the atmosphere, instability areas were formed in the late afternoon, culminating in rainfall by the end of the day.

To evaluate the current environmental conditions in outdoor spaces in the area of interest, on-site measurements of air temperature, humidity, noise, sky view factor, illuminance, wind speed and direction were carried out in November 18<sup>th</sup> 2005, during summertime, in seven different sites located within short walking distances.

Significant differences were found, mapped and analysed in sites spaced within a 250m radius (fig.5 and 6). The measured data was qualitatively correlated to the urban morphology of the site, i.e.: built density, type of pavement, presence of vegetation and water, noise sources, and the geometric configuration of open spaces.



**Figure 5:** Aerial view of the case study area showing main urban spaces and location of measurement's sites.

The seven sites corresponded to the following:

1. Two-storey housing street with trees
2. Public Building Plaza (Fórum Trabalhista)
3. Latin American Square
4. Francisco Matarazzo Av.(towards Latin American Square)
5. Francisco Matarazzo Avenue (Park Entrance)
6. Horse's Arena at Água Funda Park
7. Dense vegetation and trees at Água Funda Park



**Figure 6:** Measurement sites and transects surroundings and instruments' exposure conditions.

Temperature, humidity and wind readings were taken from 7h to 8h, from 10h to 11h, from 13h to 14h and from 16h to 17h, all of them at 15 minutes intervals. The last reading, from 19h to 20h was discarded because of a summer storm in the late afternoon. The measuring equipment were located at 1m above ground. In addition to the seven fixed sites, two transects were carried out, from P1 to P2 and from P4 to P3. For the measurements, 16 people from LABAUT – Laboratory of Environment and Energy/FAUUSP took part in the field work, operating the various instruments.

Fisheye photographs were taken in each location (fig.7) showing the various degrees of exposure to solar radiation, which is predominantly high in most of the cases as a result of urban form with significant amount of open spaces, resulting in poorer environmental quality spaces.

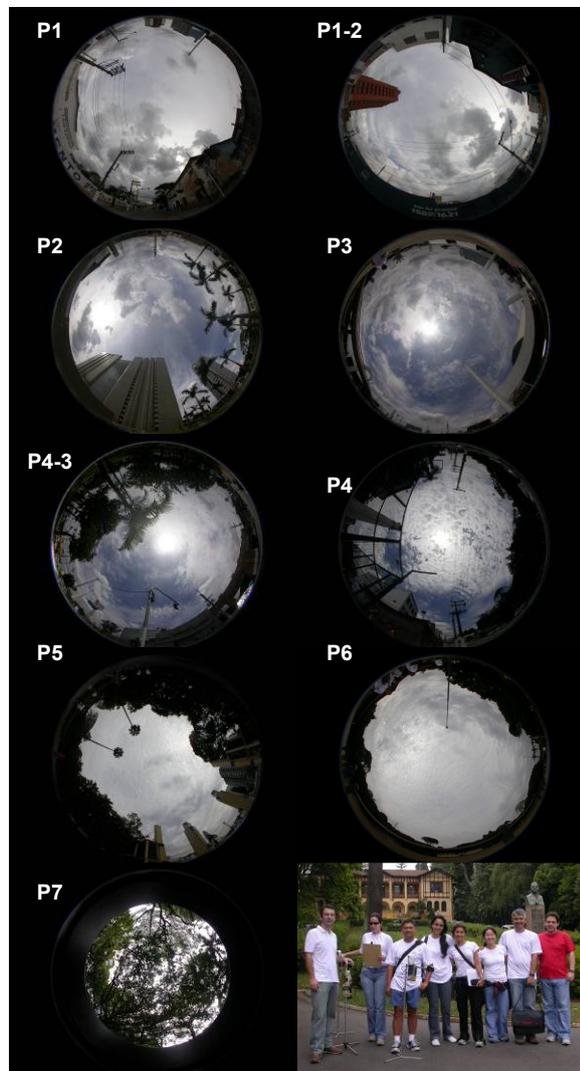


Figure 7: Fisheye pictures and part of the team.

Acoustic measurements were carried out hourly intervals during a week day, from 7h to 17h, aiming to register the impact of traffic on urban noise, highlighting the peak hours.

Table 1: Noise results.

Express Way	Matarazzo Av.	L <sub>Aeq</sub> _dB(A)
		76
Secondary Roads	Latin American Square	68
	R.Bento T.Ferraz	73
	Fórum	62
	Rua Quirino dos Santos	61
	R.Bosque / R.Tomas Edson	62
Local Streets	R. do Bosque / R.Fairbanks	52

Complementary measurements, in local streets were also taken to characterize the acoustic environment in the area. Apart from the local streets, all the other measurements surpassed the World Health Organization (WHO) recommendations for acceptable urban noise levels.

#### 4.2. Results and Assessments

The microclimatic variations found in the macroscale in a previous study [9] were also found at pedestrian level – refer to figs.8 and 9. Such differences are also evident in the photos representing the surroundings of each measurement site. As expected, temperatures inside the park were much lower than in the other more urbanized sites. Furthermore the differences between the other six locations were around 2 or 3°C, which is significant in terms of thermal comfort sensation.

During the morning measurements the Latin American Square showed a rapid increase in air temperature, related to its design characteristics (concrete impervious surface, excessive exposure to solar radiation, lack of shading, vegetation and water). In the afternoon, besides the sites inside the park, all of the others followed the same range of variation of around 2°C, under a partially cloudy sky and wind speeds of 2m/s.

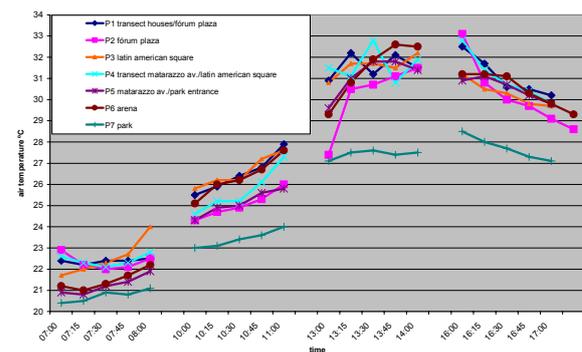


Figure 8: Air temperature from P1 to P7.

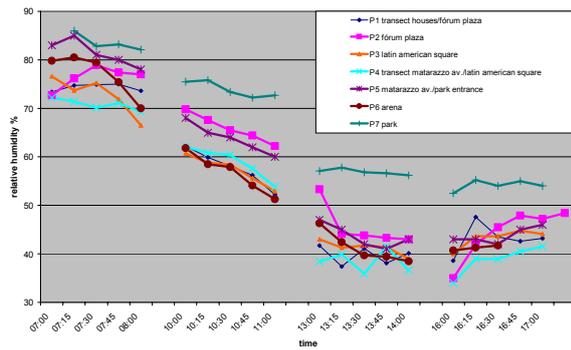


Figure 9: Relative humidity from P1 to P7.

## 5. FINAL CONSIDERATIONS AND FUTURE STEPS

Besides the measured parameters, it is also acknowledged that several other variables influence local microclimates. Measurements at pedestrian level are influenced by all forms of human activity. The thermal loads, humidity and pollution generated by traffic, the suddenly changes in wind speed created by vehicle movement, the heat generated by equipment, such as air conditioning plant in buildings, they all influence the results, stretching beyond the effects of the local built environment itself.

The environmental assessments of collected data will continue. Data of other fixed meteorological stations in the city will be added to this environmental assessment. The initial qualitative analysis will be expanded to quantitative correlations between the environmental variables previously measured and sky view factor, physical characteristics of hard and soft landscapes and built density. Following that, outdoor thermal comfort indices will be applied, together with computer simulations (currently in progress) to support further assessments and design guidelines.

## 6. ACKNOWLEDGEMENT

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