STREETS BUILINGS OPEN SPACES

A SOCIAL AND ENVIRONMENTAL COMFORT ANALYSIS

AUTHORS
RACHEL ISLAND AND MIROSLAV KIS

ADVISOR
EUGENIO MORELLO

POLITECNICO DI MILANO

Faculty of Architecture and Society

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STREETS, BUILDINGS, OPEN SPACES:

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Authors:
Rachel Island
Miroslav Kis

Advisor:
Eugenio Morello

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Abstract

This work combines research on environmental comfort and social comfort, attempting to find correlations between the two. More specifically, environmental comfort is studied in terms of urban ventilation and shadows, and parameters for studying social comfort are defined. Urban morphology is used as a structure for the work; six diverse urban patterns are identified and used as variables to determine how social and environmental comfort change in relation to urban form, and in relation to each other. The aim of the study is to determine which urban morphological factors perform well on both the social and environmental comfort scales.

The methodology for defining and analyzing social comofort is based on a literature review of relevent authors. Specific factors for measuring social comfort are defined as a result of the literature review process, in which seven different conceptions of how to make better public spaces are discussed. The factors considered in the social analysis include visual permeability, physical permeability, traffic flow, walkability, active building fronts, building diversity, building density, size and number of open spaces, access, and comfort.

In this study, environmental comfort is based on a wind and shadow analysis; other environmental factors are not considered. The methodology for defining and analyzing environmental comfort is based on a combination of local and general studies, in which each case study is analyzed first in its natural environment and then all the case studies are analyzed under the same generic conditions in order to remove variables related to location. The factors considered in the environmental analysis are wind speeds and shadows in streets and open spaces, calculated as a result of changing wind direction, time of year, geographical location, and urban morphology.

The case studies that performed the best in terms of both social and environmental comfort were Novi Sad and New York. Other case studies perfomed well in one area but not in others: For instance, the Moscow sample scored well in many areas of envionmental comfort, but the social scores were very low. Outcomes suggest that there may be some conflicts between social and environmental comfort. However, even within the area of environmental comfort there are many conflicting factors, and the same is true for social comfort. In each case, it is necessary to balance the trade-offs in order to maximize positive results. Overall, the two goals are not incompatible, but more research into the relationships between social and environmetal comfort could produce more well-balanced results.

Introduction

The aim of this work is to conduct an interdisciplinary study, combining both an environmental and social analysis of urban form. Many studies have been done on the correlations between urban morphology and environmental comfort, as well as on the correlations between morphology and the social environment. However, little work has been conducted comparing the effects of morphology on both environmental comfort and social comfort. Therefore, this work aims to identify which urban morphological factors contribute to improved social comfort, which contribute to improved environmental comfort, and whether there is significant overlap between them. In other words, do the morphological factors that produce better social environments also produce better environmental conditions? The importance of this work stems from the need to develop more sustainable cities, and the fact that sustainability is not solely an environmental issue; sustainability must consider social factors as well.

Part one includes background research and methodology. The first three chapters consist of a literature review on the topics of urban morphology, social comfort, and environmental comfort. The first chapter, discusses urban morphology from the theoretical point of view and offers a deep insight into the analysis of urban types, blocks, urban spaces etc., referencing authors such as Bill Erickson, David Seex, Leon Krier, Schwalbach, and Peterek. Each of them gave a significant contribution to the field of urban morphology and their opinions and findings are presented and discussed. As such, this section is divided into two subsections: theoretical findings, and a literature review of the authors mentioned.

The second chapter first defines the connection between morphology and social comfort and then discusses what morphological factors makes better public spaces for people, attempting to find criteria for judging social comfort by reviewing the work of prominent authors such as Kevin Lynch, Donald Appleyard, Matthew Carmona, Jane Jacobs, Jan Gehl and Douglas Farr. The final section is divided into three parts: streets, buildings and open spaces, and specific physical requirements are identified for improving social comfort in these areas based on the work of the authors discussed.

The third chapter offers a broad discussion in the area of environmental comfort. It is divided into four sections. The first one talks about city and city forms in general and it is an introductory part. It discusses the urban microclimate, thermal and wind comfort and human perception and reaction to the comfort. The second part offers a discussion of the previous study cases performed on urban comfort. The third part discusses wind and offers a deep analysis of the role that wind has in the city involving wind speed, wind loads, wind tunnel tests and more. Lastly, the fourth part discusses the role of shadows in urban planning and comfort.

The fourth chapter describes the methodology for defining and analyzing environmental and social comfort. The methodology section includes a description of pattern selection criteria, the computer programs used, and the parameters selected for the social and environmental analysis. Pattern selection is divided into three sections: criteria, sample size, and location. The programs used, including Google Earth, Sketchup, Photoshop and Autodesk Vasari are briefly described, as well as the tools and methodology used to carry out the social analysis. A detailed description of the tools and methodology used in the wind and solar studies is provided in the environmental analysis section.

Part two includes a description and analysis of each of the six case studies: New York, Chicago, Barcelona, Hanover, Moscow, and Novi Sad. Each case study has two elements, the social comfort analysis and the environmental comfort analysis. The social comfort analysis is divided into three sections: streets, buildings and open spaces. In the streets section, the topics of visual permeability, connectivity, traffic flow, and walkability are analyzed. In the buildings sections, the topics of active fronts, building variety, mixed use and building density are analyzed. The section on open spaces analyzes the topics of size and number, access, and comfort.

The environmental comfort analysis is divided into two parts, a localized analysis, and a generalized analysis. In the localized analysis, each model is analyzed in its own context, for instance, the New York model is analyzed using the wind and solar parameters for New York. This demonstrates how well the model performs in its natural context. The localized wind and solar studies are conducted during both summer and winter conditions. In the second part, the New York model is analyzed under general conditions, which are kept the same for all six case studies. The wind study is conducted using four wind directions: North, Northwest, West, and Southwest. The solar study is conducted using Boston as a common location for all the case studies. The objective of the generalized wind and solar analysis is to compare the performance of each of the case studies under common conditions. The same analyses are carried out in all six case studies.

Part three includes results and conclusions. In the results section, social and environmental comfort are first discussed separately and then a comparison of the social and environmental results is carried out.

The results suggest that in some cases, social and environmental comfort are in conflict with each other, but overall they are not incompatible. It is worth noting that the case studies with the best results in terms of both social and environmental comfort, Novi Sad and New York, have more differences than similarities in terms of their urban morphology. The Novi Sad and New York samples both come from central areas, with relatively high ground coverage and a diversity of uses, which resulted in higher social scores. But in terms of building heights, building types, street layout, etc., Novi Sad and New York are very different.

This suggests that there is not one solution to improving social and environmental comfort in cities; there are many. The most obvious conflict between social and environmental comfort appears to be density. Higher density improves walkability and other important social factors, but it also increases shadow coverage, which is a negative in winter months. However Novi Sad was able to balance this conflict by combinging high ground coverage with low building heights, which increases the walkability of the streets without blocking too much sunlight in winter.

Further reseach in this area could focus on developing more comprehensive tools for studying social and environmental comfort together. There will always be trade-offs, but a better understanding of the relationship between social and environmental comfort will help designers and policy mankers balance gains and losses in each area, which will lead to a more wholistic view or urban design.

PART I

URBAN MORPHOLOGY

I. CITY AND URBAN FORMS

A CITY

To understand the city and its structure it can be made a comparison between a city and a tree or a leaf.
Certain cities look like trees, the other ones remind us of the leaves. The structural difference between a tree and a leaf is still significant. While the tree is open, the leaf has a closed shape. Trees are completely disconnected on a given scale: even of two twigs are spatially close. If they do not belong to the same branch, to go from one to the other means moving down to the beginning and then up all the hierarchy of branches. Leaves, on the opposite side, are completely connected on intermediary scales. The veins of a leaf are disconnected on the two larger scales but entirely connected on the two or three following intermediary scales before presenting tiny-tree like structures on the finest capillary scales.

Even the ancient historical cities had a structure in the shape of leaves, deltas, lungs, brains and even as the vein systems. Many of them very connected in many ways and were complex at many levels.

The history of urban planning has evolved from leaf-like to tree-like planning and creation of networks, with a consequent loss of efficiency and resilience. The historical evolution of urban systems, reminds on the evolution of all living organisms. The evolution only allows systems to survive to those ones that can resist the inevitable catastrophes of history, and rebuild and reinforce themselves every times their fabric is damaged.

Like all living organisms, and especially leaves with their capacity to photosynthesize solar energy, cities are open systems constantly exchanging energy and matter with the outside in order to maintain their structures. Flows run through them constantly, people and goods, all forms of energy, water, wind and sun.

Cities are not like stones or tables; they are not closed systems that can maintain their structure without exchanges of matter and energy with the outside. “They are like candles whose flame burns steadily as a result of the disequilibrium in the energy flow that sustains it. We have to move beyond the very notion of closed/open systems or of equilibrium/disequilibrium.” Therefore, a system has to close itself off from the outside world to maintain its structures and its internal environment. If it did not, it would disintegrate. This closure is allowed by the fact that the system is open. “(Serge Salat, 2011).

FORM OF A CITY AND COMPLEXITY OF FORMS

Defining the form of a city is like asking what you have to know about a city to understand it. Understand it or experience it, see it, love it, leave it-it is a certain feeling that exists between a personification of the city and its treatment as a pure spatial object remains an essential feature of our attitude to the city, whether we like it or not.

The term form can have many possible meanings: shape, configuration, structure, pattern, organization and system of relationships. The form of a city is constituted by the spatial and social patterns that compose it and that allow us to describe its networks, its built spaces, and its empty spaces in geometric, topological and hierarchical terms in two, three and even four dimensions, where it is always incorporated the temporal depth that every city consists of.

Form is a result of many forces. The visible external form of the city is nothing but a manifestation of the invisible structural laws of the urban system. The structure of systems is defined by the elements that compose them and by the relationships that define their interaction. The hierarchies of built forms which involves urban blocks, neighborhoods, districts, cities; the network of communication and the urban services that connect these units on every scale and such human activities as living, working, commerce, education, and leisure form so many super imposed hierarchies.

The city is a cultural fact; therefore, urban morphology cannot be separated from social morphology. It is hard to draw a line between physical and social characteristics of the city. They are together incorporated.

The city is a construction of a signification. Many cities and towns were carefully studied and planned for several centuries. For example, the small towns in Tuscany demonstrate a perfect integration of the geometric order of monuments and plazas following the gradual form of the streets. Another example is Piazza del Campo in Siena as another Italian city, where the square was carefully studied and planned many time before it was finally built.

Therefore, urban form is not a material object. *“It is the urban landscape that would not exist without the human interaction”. (*Serge Salat, 2011).

THE URBAN SYSTEM

Urban forms are the physical substrate of the global urban system. The urban system is social to begin with at the first place. As mentioned before, it is impossible to differentiate physical part of the city from the social because the city is at once a social and a spatial entity.

COMPONENTS OF URBAN MORPHOLOGY: LEVELS OF INTERACTION

The breakdown of the morphological system into six levels that will be proposed is established simply for purposes of analysis. The levels interact with one another and with the global urban system.

According to the Serge Salat's book "Cities and Forms", urban morphology can be sorted into six different levels that include all the components of a city.

1. The first level involves people and activities. Social interactions govern the organization of a city, just as the urban composition impacts its interactions. By definition, cities are the places of exchanges and activities.
2. The second level corresponds to the network of streets and the road grid of the city. The arrangements of roads, whether it came spontaneously or was planned by decision makers, plays a primal role in transportation and in modes of travel and thus in the city's social activity, on the one hand, and its footprint, on the other.
3. The third level is the study of plot subdivisions. Their organization plays a decisive role in the form of the built environment. For example, the smaller the subdivisions, the harder it is to build giant towers because there is not enough room between towers to create a nice environment (in terms of space and light).
4. The fourth level talks about the topography and relief of the site. Topography affects street patterns. The compact street grid of medieval Zurich remained as it was, confined to the banks of the lake and the river until technological advances made it possible for the city to conquer the surrounding hills. The street pattern winds in curves hugging the topography of hills and rivers, in examples of Rome and Tokyo.
5. The fifth level corresponds to land use and activity distribution. These are decisive factors that influence the flows of people, the consumption of transit-related energy, and the organization of different built elements, and that have social, economic, and environmental consequences.
6. The sixth level sees the city in three dimensions. The wind and the sun are factored in as are the evacuation of pollutants and the temperature of the city. Integrating the study of climatic factors into the morphological study of the built environment makes it possible for us, for example, to develop a method of evaluation heating energy needs in countries with cold or temperature climates.

Built environment, land, plot subdivision, and traffic grid, cannot be randomly combined. Some combinations are allowed, other ones are not. Cities that are discontinued, made of separated objects, fragmented by highways will never have the same environmental characteristics as continuous cities formed around streets and a plaza. Street patterns, plot subdivisions and the built environment are arranged according to a syntax. Modernism largely destroyed the syntax of a city. However, a new stronger and more structured syntax was introduced.

URBAN FABRIC

A metaphor that refers to weaving (textiles) or biology (plant or bone tissues), the term "*tissue urbain"*-urban tissue or fabric-has a dual meaning. It represents a local view that shortly 'forgets' the organization of the whole, the framework, the skeleton, to focus on the filling and the substance. It also denotes an organization informed by both a strong solidarity between elements and a capacity to adapt and be modified and transformed. Applied to the city, the term speaks of continuity and renewal, performance and variation. (Serge Salat, 2011)

Urban fabric is the physical aspect of urbanism, emphasizing building types, thoroughfares, open space, frontages, and streetscapes but excluding environmental, functional, economic and sociocultural aspects. (Steven Marshall, 2013)

The importance of the urban fabric cannot be diminished. It presents the intermediary scale between the architecture of buildings and the overarching lines of urbanism, and therefore the framework of everyday life.

URBAN SYNTAX

Urban fabrics sometimes can be the expression of a single system. Looking at the historical city, it was formed from a series of successive systems, layered and sedimented into a dense network of significations.

Nowadays, the stratification with its complex values and meanings vanished from the modern cities, which was divided into zones and fragmented into single, separate functions. A layered dense place was supplanted by an undifferentiated space that did not have a meaning.

The current speeded up urbanization has destroyed the urban syntax. The elements of the urban fabric: route networks, plot subdivisions, built structures, empty spaces constituted a language with a syntax. However, this syntax has vanished with the modern urbanism. (Laura Vaughan, 2007)

Referring to Salat (2011) theoretical approach, the components of the urban syntax are:

- Public Space;
- Buildings-Constructed Space;
- Plots; and
- Roads.

7. PUBLIC SPACE. Plots within the blocks and the rooms in the buildings are subdivisions. Like in a puzzle, they cover the whole area, edge to edge, leaving no empty space. Plots are all connected by edges to the public street space. This space, in which all of the blocks are submerged and the plots connected, is the city's most basic component. Traditional urban syntax is therefore articulated firstly inside a continuous public space. All is accessible to all because the public space connects urban blocks like in the same way as the sea connects the islands. Modern urban syntax, on the contrary, fragments the public space by dividing it with highway and roads for motorists, which are impassable barriers for pedestrians. Concluding,

without a continuous public space, a city is not a city.

8. BUILDING is a permanent or temporary structure enclosed within exterior walls and a roof, and it includes all attached apparatus, equipment, and fixtures.

9. In the traditional cities, the buildings have a façade that faces the street and they were oriented towards urban space by necessity. In the modern cities, buildings are orientated towards undifferentiated green space and many urban functions have moved indoors, and shops, institutions and organisations have grown larger.

10. PLOT scale is another component of urban syntax. Whereas the plot divisions in most European cities were historically determined, rooted as they are in a territory, soil, topography and climate, based on rural subdivisions, the modern city wiped the historical slate clean, along with its subdivisions, to create a world of huge towers, a monotonous cities that compromise a variety of buildings that give rhythm to urban space. Thus the modernist break is the first one and much more serious than a mere break in architectural form.

11. ROAD. The fourth component is a road. The roads themselves have a hierarchical structure. Top tiers routes, as boulevards in Paris, for example, are interconnected; intermediary roads are connected to at least one other intermediary road or to a higher level route. Local routes are connected to intermediary roads. Following the rule, the sub-networks become fragmented.

12. In the modern cities the grid is designed for cars, and instead of boulevards, the upper level roads are urban highways that create breaks in the city. Boulevards have a role to delimit the urban fabric by structuring it on a bigger scale. On the opposite side, the highways break up the urban fabric by fragmenting and disjoining it. Whereas boulevards integrate the urban structure into a higher-level order, urban highways disintegrate the city's structure. Beside the fact, the roads represent barriers; the main difference of the function is that road in the modern conceptualization is a functional space, purely for traffic distribution, for connecting points. However, in the traditional city, the road has multiple purposes and therefore it is a social space.

According to Stephen Marshall (2009), street syntax follows four basic rules:

1. *“The street system forms a single contiguous network. Inside this system, top tier streets are all connected.*

2. *All plots can be accessed connected to the exterior network.*

3. *All buildings are directly connected to the exterior space.*

4. *All buildings are joined to one or more plots. “*

Streets are the basic components of the urban syntax. All buildings and plots are connected to streets. Literally, the street system contains the whole of the city. If we would remove a street from the urban fabric we would effectively remove a series of plots and buildings along with it. The streets can serve as the basis of a complete, exhaustive system of addresses. To be sure, streets are a composite unit but, because of their connectivity and continuity, they lend themselves to creating organized structures. As basic components, the number of streets can be increased to create entire cities. In such way, the street syntax becomes the urban syntax.

URBAN TEXTURES, URBAN MORPHOLOGY, SHAPE FACTORS AND CLIMATE

Ventilation and radiative exchanges in urban spaces are strongly influenced by urban morphology. They create an urban microclimate that determines thermal comfort, air quality and energy consumption.

These environmental effects show a good correlation with a small number of morphological parameters, as studies have demonstrated. For instance, the solar absorption is correlated with the volume-to-surface ratio, and the ventilation potential is correlated with permeability.

Solar absorption is defined as a process in which solar radiation is retained by a substance and converted into heat energy. The creation of heat energy also causes the substance to emit its own radiation. While air permeability is the ability of a fabric to allow air to pass through it.

To describe urban morphology and model its interaction with the climate and energy, shape factors can be used. For example, pollution migration can be described with the following function:

$$M=f\,(v, d, A\ B, C)$$

where:

V=wind speed;

D=wind direction;

A, B, C=urban shape factors.

Carlo Ratti, Nick Baker and Koen Steemers conducted an energy analysis of the three urban texture of the cities of London, Berlin and Toulouse (2004). The analysis that was performed showed the impact of the different shape factors.

While performing a study of the effects urban morphology has on the urban climate, there are certain factors to be analyzed. The main shape factors are the following:

Volume to surface ratio- V/S ratio

For a given building, the volume to surface ratio reflects the mean distance of an inhabitant from the envelope. Its dimension is in meters. This parameter provides information on the ventilation and natural envelope is well insulated. It is the opposite from the surface to volume ratio. Studies have been performed in London, Berlin and Toulouse on samples of urban fabric, 400 x 400 meters. The measurements showed that the volume to surface ratio is about 6 meters in Berlin, 4.62 meters in London, and 4 meters in Toulouse. The buildings in Berlin, which are more compact and bigger, have less passive potential than the medieval morphologies like the old center of Toulouse.

Surface to Volume ratio- S/V

The surface area to volume (S/V) ratio is an important factor determining heat loss and gain. The greater the surface area the more the heat gain/loss through it. It means as small S/V ratios, that implies minimum heat gain and minimum heat loss.

To minimize the losses and gains through the fabric of a building, a compact shape is desirable. The most compact orthogonal building would be a cube. This configuration, however, may place a large portion of the floor area far from perimeter daylighting. Contrary to this, a building massing that optimizes daylighting and ventilation would be elongated so that more of the building area is closer to the perimeter. While this may appear to compromise the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed daylighting system will more than compensate for the increased fabric losses.

In hot dry climates S/V ratio should be as low as possible as this would minimize heat gain. In cold-dry climates, also S/V ratios should be as low as possible to minimize heat losses. In warm-humid climates, the prime concern is creating airy spaces. This might not necessarily minimize the S/V ratio. Further, the materials of construction should be such that they do not store heat.

On the following graph, it is possible to observe bad and good example of S/V ratio.

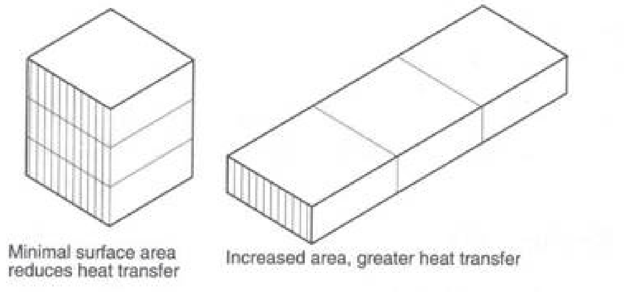


Figure 1 Good and bad example of S/V ratio

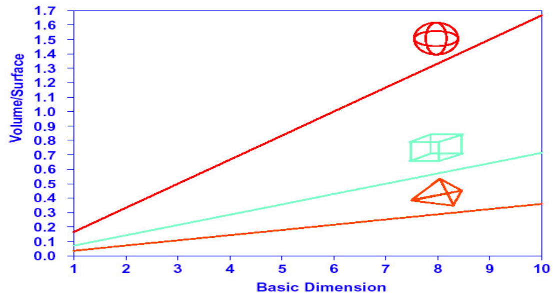


Figure 2 Volume to surface ratio

The factors of the external environment that influence heat transfer through the building envelope are:

- Temperature of ground, air or snow with which the building envelope is in contact.
- The direction and speed of winds blowing at the building.
- Solar radiation incident on the building.

In principle, to minimize heat transfer through the building envelope the building shape should be as compact as possible, tending toward a cube. However, to optimize the building shape while considering the three factors above is a more complex matter. (Basam Behsh, 2002)

Passive volume

The passive volume occupies the area distant less than 6 meters from the envelope, that benefits from natural ventilation and light. This is the key parameter in characterizing the building's potential for passive systems use. Referring to the above mentioned case study performed, the passive volume ration is 61% in Berlin, 77% in London, and 84% in Toulouse. The complex, medieval morphology of the old Toulouse center displays a significantly higher rate of passive volume than the massive, regular morphology of modern Berlin. Buildings in Berlin are characterized than around 40% of them that are centrally located in the city do not have an access to natural light and ventilation. Moreover, in certain areas of Shanghai, the buildings can exceed 50% and that as a consequence increases city's needs for energy.

The variation in the height of the surfaces and of the perimeters of horizontal sections

The variation of the height of the buildings describes the openness of the city to the sky and its degree of obstruction. This shape factor provides information on daily radiant energy gains and on the radiant energy losses of high wavelengths to the night sky. It is also useful for describing the dispersion of pollutants by the wind.

The surface/height parameter also measures a percentage of obstruction and allows us to evaluate the urban ventilation potential.

Vertical sections and directionality

The main climate factors are solar radiation and wind direction. These two factors interact with street width and orientation. The obstruction of buildings in a specific known direction can be evaluated with a vertical section or a mean height. An isotropic urban fabric will have a little variation in its profiles while an urban fabric with known directional elements, like wide boulevards, will have profiles with greater variations.

In addition, there are another shape factors not analyzed in the experiment but they can have important role while performing the urban analysis:

- **Sky view factor-** (ψ_s), is a measure of the degree to which the sky is obscured by the surroundings for a given point. Watson and Johnson (1987) express it as the ratio of solar radiation received by a planar surface compared with that received from the entire hemispheric radiating environment.
- **Skyline – rugosity of the skyline.** Rugosity, fr, is a measure of small-scale variations or amplitude in the height of a surface,

  $$\mathbf{f_r = A_r/A_g}$$

  Where: Ar is the real (true, actual) surface area and Ag is the geometric surface area.
- **Shadow density**. Shadow density is calculated by observing shadows on a given area of the ground at regular intervals. It is the highest in streets with courtyards textures.

Consequently, daylight availability in streets with this urban type is lower. High shadow density gives many benefits in hot climates because it protects pedestrians and the horizontal street surfaces from solar radiation. Shadow density is high in narrow streets. On the other side, daylight availability in courtyards is two times higher than in the streets. This observation corresponds to the nature of these textures, which are generally turned toward the interior and the microclimate of the courtyards and away from exterior area via the street façades.

In conclusion, an analysis of urban forms must specify climate conditions, since shape factors have different impacts in different climates. Courtyard urban textures are not advisable in hot humid climates or in tropical climates where the thermal mass effect has no impact because of the slight variation between day and night temperatures. However, not all continuous courtyard form ensure better environmental performances than free standing pavilions. Changes in proportions can cause radical variations. For example, big buildings with large courtyards like in Moscow, are efficient in very cold climates, because under certain geometric conditions, they concentrate solar radiations and protect against cold winds. In temperature and cold climates, these urban forms make the best use of land.

II. Review of relevant authors

"LEXICON: ORGANIZATION OF THE BUILDINGS" NICOLIN PIERLUIGI

Pierluigi Nicolin (2006) in his article introduces several categories of how a building can be studied and analyzed. Those categories are the following ones:

1. Layout
2. Layer
3. Pattern
4. Pattern language
5. Grid
6. Network
7. Mat building
8. Cluster
9. Genetic code.

LAYOUT

The fulfilment of a separation between the supporting structure of the building shell and the additional elements that make possible the use of a particular space drove architecture to resort to concepts like performance and scale, and above all layout.

Even Le Corbusier (2007) in his book *"Toward an Architecture",* after stressing the indispensable role of the pan as the fundamental concept of architecture (without which "*there can be no grandeur of aim or expression, nor rhythm, not mass, nor coherence"),* ended up theorizing about its "*liberation*" and demanding for it "*the most active imagination."*

It was at the end of the fifties when

the concept of layout, as the process of organization of a space inside a container that is assumed to exist, began to be used not just for the arrangement of machinery in a 'neutral industrial setting in order to optimize the productivity of a manufacturing plant, but also for the planimetric organization of the containers of commercial spaces. As a method of organizing the activities and functions of a particular space, the techniques of the layout have been refined both through the development of genuine principles of planning and as a framework for the design of mobile and flexible systems and equipment. From the workspaces of the office to libraries, gyms, shopping malls and now even dwellings, treated as flexible and adaptable spaces.

LAYER

Tschumi and Koolhaas introduced new term-a layer (1982). Layers prefigure levels that are independent of one another and once when they become superimposed, they produce unexpected configurations. For instance, in the project for the Parque de la Villete, Tschumi identified- in a style of Kandinsky-three layers: the level of points, lines and surfaces. Park de la Villete is the third-largest park in Paris, occupying 35.5 hectares in area, located at the northeastern edge of the 19th arrondissement.

The points were named the *folies,* constructions that formed a grid with a module of 120 meters. These were structures organized in a cubic lattice of 10x10x10 and each with a distinctive form of its own, determined by the chance of permutations of its basic elements.

The lines were the paths-one made up of two axes at right angles to each other and one taking a winding course-and the walls.

The surfaces were the spaces where activities were carried out and had various shapes, some of them elementary-triangular, circular, and rectangular-and others more complicated.

Again, in the La Vilette case, Koolhaas identified five levels:

1-Bands-thin rectangular strips each characterized by a function.

2-Confetti-dots like activities (kiosks, picnic areas or children's playgrounds) distributed at random

3-Axes of access and circulation, including the main boulevard

4-Outstanding features, including the museums, the preexisting buildings and two artificial hillocks;

5-The connections with the surrounding part of the city.

PATTERN

A pattern, as a term describes a discernible regularity in the world or in a manmade design. As such, the elements of a pattern repeat in a predictable manner.

The pattern of the city can be seen as the distribution and mixture of the settlement's different functions and formal components. The pattern of a city is good when similar formal components or functions are distributed over an area that is not too large. On the other hand, it is poor if there is a segregation of individual elements and functions in large mono-functional zones separated from each other by vast areas containing other things. (Kevin Lynch, 1981)

In *Matter and Memory* (1896), Hendri Bergson asserted that: "*the objects which surround my body reflects its possible action upon them.*" A building can convey the history of the body's encounter with the outside world through their materiality, the articulation of their joints, their different kinds of facades has turned image into fetish, and reconsideration of the physical and material qualities of architecture has nonetheless gained a new prominence in the contemporary tectonic tradition. The intention is to suggest that combination of visual and tactile experience evoked by Berguson, and then by Walter Benjamin when he discerned in vision the contrast between an optical and a tactile perception. Especially since images have become tangible, this contrast can be found an architecture, as well.

This means that the understanding of a pattern involves the traces of the construction process, the criteria adopted in the juxtaposition of panels and the signs left by inhabitants.

PATTERN LANGUAGE

A pattern language is a method of describing good design practices within a field of expertise.

Christopher Alexander (1979) while proposing his opinion about the best models, has stated that "patterns" could become a linguistic system in the formulation, which afterwards he named "pattern language". He argued that "pattern language" is a system that permits users to generate an infinite variety of three-dimensional combinations such as buildings, gardens and cities, obtaining results comparable to those of the good old days. Searching for examples of his pattern language, Alexander has explored cultures belonging to different places and times, eventually identifying a total of 253 patterns. "*From the regional scale and the distribution of urban settlements to ornament and the objects of your life*".

GRID

"Laying down a grid should be a mapping of the possible, not restraining order. A grid is a necklace, folded in a certain way, which at any instant can be pulled apart and shifted dramatically-a movable feast, not necessarily serious, fixed one moment, vanishing and refigured in the other. Each point on grid is allowed a charmed life." (Cecil Balmond, *Informal,* Prestel, London, 2002, p. 372.)

While the grid is traditionally seen as a more or less regular Cartesian structure of repetition that generates static and rational forms, for some contemporary approaches to design it is a means of coming up with unpredictable and mutable forms and spaces. Brought to life and rendered malleable through the use of increasingly advanced computer programs, such meshes are deformed and moved around to materialize complex relationships and connections between the different variables of the architecture and the environment taken into consideration by designers.

Eisenman, for example, in modeling the spatial and formal relations of his designs, transforms his initially Cartesian grids into evolutionary and flexible working matrices that assist the generative process of diagrams through an operation called “morphing”. This technique is adopted by the cinema and used to obtained a fusion of different figures into a single image so that no one of them dominates over another. (Peter Eisenman, 1999)

NETWORK

Between the middle of the fifties and the middle of the sixties of the last century, one of the most stimulating and ambiguous paradigms of the twentieth century was established: the idea of network and global communication. It is interesting to note that this paradigm took shape through the interaction between architecture, city planning and the then newborn art of communication.

In 1963, the Greek architect and city planner Constantinos Doxiadis and a number of researchers in a wide range of disciplines, including the young Marshall McLuhan and the elderly Buckminster Fuller, had met to discuss how the phenomenon of the visible and invisible networks through which communication took place into a sort of global village.

The meeting, recorder in the pages of Doxiadis’s journals Ekistics, has had an echo that continues to the present day in all the talk about the digital and constituted from the doubts and critics that surround the very concept of globalization today.

“Those years also saw the theoretical contribution of the members of Team 10, who had identified the network as the key structure in the evolution of the city…” (Pier Vittorio Aureli, 2003)

This is how the network as a concept was born.

MAT BUILDING

Today mats are all over the place. Sometimes they are called fields, patterns, carpets of matrices, and are presented as an alternative to object-oriented and sculptural architecture or to mega-buildings that cover areas of the ground. No type of building, it can be said, without fear of exaggeration, reflects more precisely the logic and imagination of contemporary architecture. The mat responds to the recurrent demands for a certain indeterminateness of scale and figure, for flexibility of use and for a mixture of functions. It is a response to the increasingly invasive character of architecture with regards to the city and the landscape, and sets out to intervene in the dynamics between structure and infrastructure produced by this aggressiveness.

CLUSTER

Alison and Peter Smithson, founders of Team 10 and the authors of the *“The Charged Void: Urbanism”* (2005) and “*Cluster City*” (1957-1959), were among the most influential architects of the second half of the twentieth century. Their reassessment of modernism shifted the focus of architecture and city planning onto the details and uniqueness of human associations and urban models and specific features of the climate. Many of their ideas, whether social (cluster, social groups) or architectural (Brutalism, nature of materials) were developed through a process where from their strong commitment to social ideals came to a more general consideration of the problems of the natural environment and the habitat.

The Smithsons came to the conclusion that the city was multilayered, a heterogeneous, discontinuous space governed by nonlinear relationships. Their reflections on this space, and the space of the people, who actually live in it, were the key to a line of research that has had a decisive influence on developments in contemporary architecture. In essence, the aspects of territoriality, the landscape, mobility and infrastructure played an important role in their work on planning and design, making their redefinition necessary.

Therefore, Smithsons introduced a new term-"Cluster". Cluster is used to avoid association with the concept of the 'street'; a place that the Smithson's felt was outdated, since the use of cars prevents the street from being a place for a resident to identify with their environment.

GENETIC CODE

One of the aspects that are emerging in the experimentation with generative art is the possibility of applying the same principles to city planning and architecture. Designing in a generative way means treating the city as a living being. The "Genetic Code", or with other words, the DNA of the city is studied, its history is investigated, its evolution in relation to the number of its inhabitants and its economic development. Working on the DNA of a city means taking account of the profound genetic diversity or urban fabrics. Each city is unique and unrepeatable. Reconstructing the generic code of a city is a generative project. Once it is identified, we can increase the complexity, the quality and the capacity of the city in order to respond to our needs.

URBAN TYPES: APPENDIX 2: BILL ERICKSON AND DAVID SEEX

Bill Erickson and David Seex (2001) divided the urban block types and urban grid types in the following way:

Urban block types:

a) Blocks with private outdoor spaces
b) Blocks with public outdoor spaces
c) Thick building with courtyard
d) Detached dwelling
e) Large block with a large internal space
f) Thin block with rear access
g) Single-use block
h) Blocks with detached dwellings

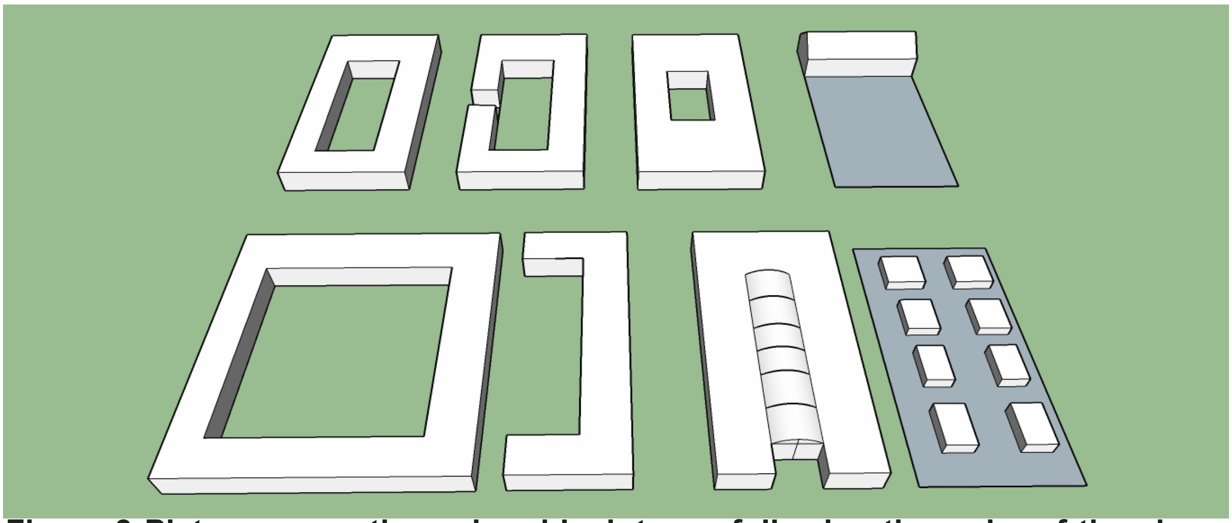


Figure 3 Picture presenting urban block types following the order of the above outlined types (a starts up on the left)

Urban grid types:

a) Regular grid

b) Organic grid

c) Distorted grid

d) Informal or highly distorted grid

e) Grid types and natural movement

Urban grids have two consistent elements:

- A lattice of streets; and
- A series of blocks formed by buildings.

URBAN BLOCKS

The Size of Blocks

Block size will be determined by the building types that occupy it. Where the buildings are detached, the size of the building in conjunction with any desired set-back will give a minimum plot size, and the block can then be subdivided accordingly. Some building types such as flats or offices may be well suited to square blocks, while others such as terraced or row houses are better suited thin blocks.

The open space inside a block may be associated with particular buildings within the block, for example in the form of a garden, or it may be shared between all the buildings in the block, as a car park. These outdoor spaces are essential to the functions of the buildings as they provide light as well as usable space. The size of the block is a simple addition of the typical depth of the buildings plus the minimum size of the desired open space.

URBAN BLOCK TYPES

1-Blocks with private outdoor space

Gardens may belong to particular dwellings or be shared by a group of dwellings, but in any case, in addition to outdoor living space, they provide a physical separation between buildings which gives privacy. A minimum distance between buildings would be about 20 m, so if the buildings were two-floors houses each garden may be 8-10 m deep which would give a total block width of 40 m.

2-Blocks with public outdoor spaces

If the central space is to be used for servicing or parking the space needs to be large enough to allow access. This will vary with circumstances but 20 m is a practical minimum.

3-Thicker buildings

Where building types suggest a thicker section, such as an office building, the internal space will shrink if the block size remains the same. In this case the space shrinks to a courtyard and while this may still provide light and air it will no longer provide privacy between neighbors. With uses such as offices this is not likely to be a problem.

4-Large blocks

If blocks are very large then the internal spaces will also be large and while this may provide a high level of amenity it will reduce the overall density. Over time this development pressure can lead to extended buildings into the internal space, which may be inappropriate. On the other hand, some building, such as schools, require large areas of open space.

5-Thin blocks

If the block layout is too thin it will provide room for buildings along one frontage only. This may not be ideal for uses such as housing where the privacy at the rear may be compromised. However, in other cases a thin block can be used to provide service access to the rear of buildings. This is particularly useful for rows of shops, for example.

9-Single-use blocks

Many modern buildings occupy entire blocks. They may include internal spaces that act like outdoor spaces, such as atrium or a gallery. They can be sized in a similar manner by assessing the typical depth of the building and the size of the internal space. Single-use buildings are more adaptable and can fit into odd-shaped blocks.

10-Blocks with detached buildings

Many building types are associated with a good deal of outdoor space.

URBAN GRID TYPES

1-Regular grid is the most obvious grid where the blocks are regular and rectangular. The streets form a tight network but while the grid may be regular, the buildings and plots may differ to a degree within the rigid layout.

2-Organic grid

Settlements that are less rigorously planned, such as traditional villages, have more irregular and arbitrary grid. The example of a Greek island village illustrates this type. Here the layout is irregular and has evolved over many years, but the streets do join up to a form a network and there are very few dead end streets. Both streets and blocks are of differing sizes and meet at odd angles; however, on observation is evident that there is a degree of uniformity in the nature of the buildings.

3-Distorted grid

While regular grids are sometimes felt

to be boring, organic grids are difficult to plan. A compromise is frequently arrived at by using a distorted grid; which creates more interesting streets but mostly in regular blocks. In this example the streets curve and are of different lengths; however, the blocks have a marked similarity, as do the buildings and plots.

4-Informal or highly distorted grid

This type of a grid is composed by the streets that are of various sizes and they make curves and form organic shapes. Therefore, it can be called, informal pattern. The streets no longer form a network, and many of the streets do not join up at all. This forces people to make long journeys. However, on close examination it is evident that the roads have been placed in such a way that the building plots are all of a similar size and the buildings are more or less placed at a uniform distance. In some ways this can be thought of as a highly distorted grid.

Typical Buildings and Their Requirements

Summarizing the space requirements of the principle building types and some of the standards applied to them by British and other European planning authorities, there can be emphasized several building types:

- residential buildings
- office buildings
- shops and stores
- small industrial units.

URBAN BUILDING BLOCKS: THORSTEN BÜRKLIN AND MICHAEL PETEREK

From Individual Building to Building Block of the City

The city is more than just a summary of its individual buildings. In its neighborhoods and quarters-the arenas of our day-to-day lives-it is made up of built structural elements that mediate between the scale of the individual architectural objects and that of larger units such as neighborhoods or even entire urban districts. (Thorsten Bürklin and Michael Peterek, 2007)

These structural elements can also be named “building blocks of the city”. They can appear as different forms and geometries in the urban layout: rows, blocks, courtyards, arcades, ribbons, solitaires, groups and “sheds”.

By virtue of their special form and unique combinations, they influence the way we live together by promoting certain functions and lifestyle and hindering others.

Knowledge of these building blocks is therefore an essential aspect of the craft of urban design. Urban planners and architects must handle with them in order to evaluate the effects that their designs will have. It is only by understanding these urban elements-which differ greatly in terms of form, function, size and significance-that they can responsibly design cities.

The following section present these building blocks from different perspectives, focusing on their spatial structure and design, functional objectives, integration into the urban environment, the associated differentiation of private and public areas, and the conditions under which they emerge.

Each building block is discussed in relation to the following four points:

- Form and spatial structure (physical description of the urban element)
- Formation of urban space (the impact of the "building block" and the significance it has for its surroundings and for urban space)
- Functions, orientation and access
- Historical examples.

The distinction between these buildings are not always clear in architectural and urban reality.

1. THE ROW

The row is one of the oldest and most important structural elements in cities and settlements. It joins individual plots of land and buildings along a straight, angular or curved line, formed and accessed the street. It creates a broader urban planning context that extends beyond the individual building. The basic spatial structure of large areas of our cities and villages consists of rows.

Form and Spatial Structure

Constitutive of the row is that the buildings' entrances and access paths are oriented toward the street, which defines the row spatially and functionally.

Additionally to the form, rows can have entirely different development forms. They can be open or closed and have one or two sides.

In open rows of single-family or semi-detached homes, there is open space surrounding the buildings. Whereas single-family homes have open space on all four sides, each semi-detached house is joined to its twin on one side. In terraces, there are no gaps between the buildings, which form a continuous visible spatial edge.

In one sided row, only one side of the street is developed; a two-sided row has buildings on both sides. The buildings on opposite sides of a two-sided row need not necessarily to be identical. The two sides of the row are formally independent of each other. The row, particularly in its open form, can be excellently adapted to dynamic site topographies.

The row is a highly flexible urban building block and allows for diverse formal principles. The appearance, three-dimensional form (width, depth, height) and functions of the individual buildings in a row can be similar or even absolutely identical. They can also differ significantly in appearance. This means that each building can have a distinct appearance and identity.

Economic efficiently is another reason why one-sided rows are usually an exception in urban planning.

Formation of Urban Space

Through their direct link to the street, rows form clear and distinguishable urban spaces. At the same time, they are integrated into the infrastructure

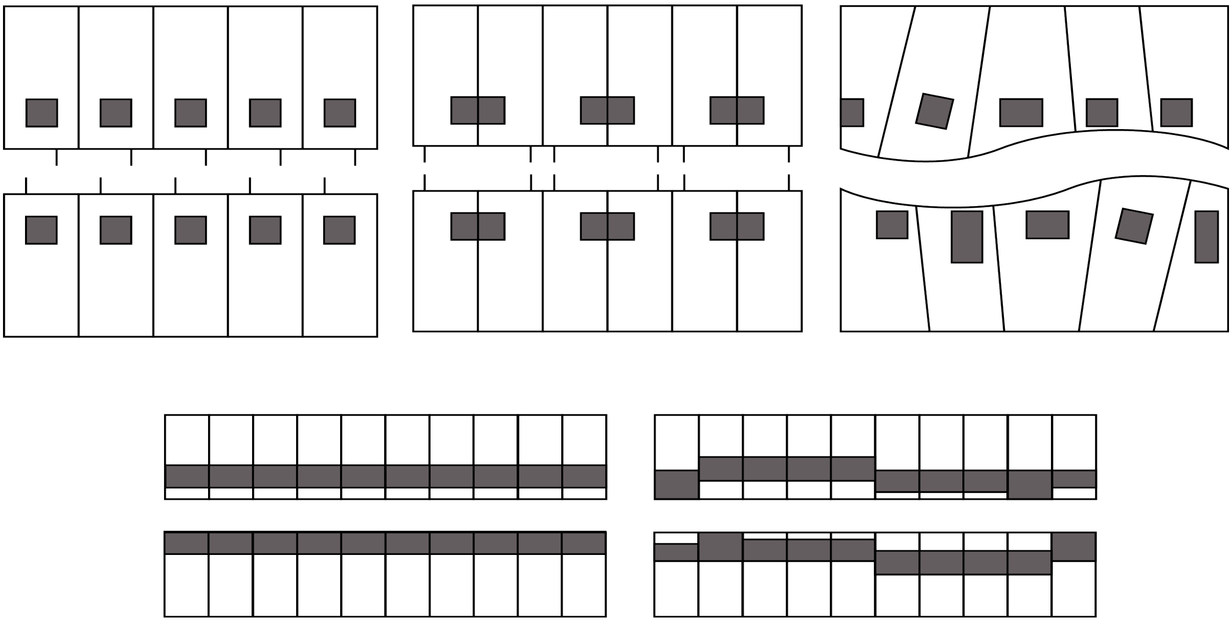


Figure 4 Different forms of open and closed rows

network of the entire city. Rows can be easily connected to other urban elements such as city blocks, ribbons or solitaires.

Due to their orientation toward the street, rows are characterized by a clear spatial demarcation between front and rear.

Historical Examples

The cities of the middle Ages were also based on rows of plots and buildings. Although these buildings were identical in terms of typology, their architectural details were often quite different.

2. THE CITY BLOCK

The city block, as a row, is one of the oldest and most important elements of urban design. Starting from the Antiquity, the experts stated that it had a major influence on the structure of European cities. Nevertheless, at the beginning of the 20th century urban planes argued that it created inequitable living conditions in the cities, and it was not until the end of the century that its positive qualities as an urban element were rediscovered.

Form and Spatial Structure

The block consists of a group of plots-a single property-and it is surrounded and accessed by streets on all sides. The front facades of the buildings forming the block are oriented toward the street, creating a clear distinction between the block's interior and exterior space and a strong architectural orientation toward a front public area and a rear private realm.

Block geometries

Blocks can have a wide range of geometries. They can be triangular, rectangular, square, polygonal, oval, semicircular or even circular. The decisive factor is that, on all sides, they are accessed by and oriented toward the outside area.

Blocks of buildings can be closed on all sides, or the edges can be interrupted and contain gaps. An open city block consists of short rows of terraced, semi-detached or single-family homes, but they must be situated so close to each other that they do not mar the impression of a block and appear to be solitaires.

Formation of Urban Space

The city block facilitates close integration into the surrounding urban structure. It is linked to the network of city streets and building lines, which define it spatially and geometrically. The city block is a continuous closed urban space, accessible from all sides, that ensures the continuity of surrounding structures and exterior urban areas.

3. THE COURTYARD (INVERSE BLOCK)

In terms of urban organization, the courtyard can be seen as the inversion of the city block. The formal arrangement of buildings can be identical for the block and the courtyard, but while buildings on the block are accessed from the outside, the buildings of a courtyard are accessed from the inside.

As used in urban planning terminology, the term 'courtyard' derives from typological models such as the enclosed farmyard or monastery complexes in which the buildings are grouped in cloisters around a courtyard. The term therefore refers to an ensemble of buildings with an open area that is central to its formal and functional organization. As a whole, these architectural ensembles have a self-contained, introverted character.

Form and Spatial Structure

Courtyards are usually designed as a complete unit. Their layout is largely based on the principle of neighborly and collective existence.

Edges of the courtyard are largely closed off spatially.

Like the city block, the courtyard can have entirely different geometric forms. As a forecourt or entrance court, for instance, it can also function as a sub-element in a block structure.

4. THE ARCADE

The arcade has generally evolved as a roofed-over street, lined with shops and businesses, which leads between lines of buildings from one place to the next. The arcade is structurally related to the courtyard and it is accessed from the inside.

Form and Spatial Structure

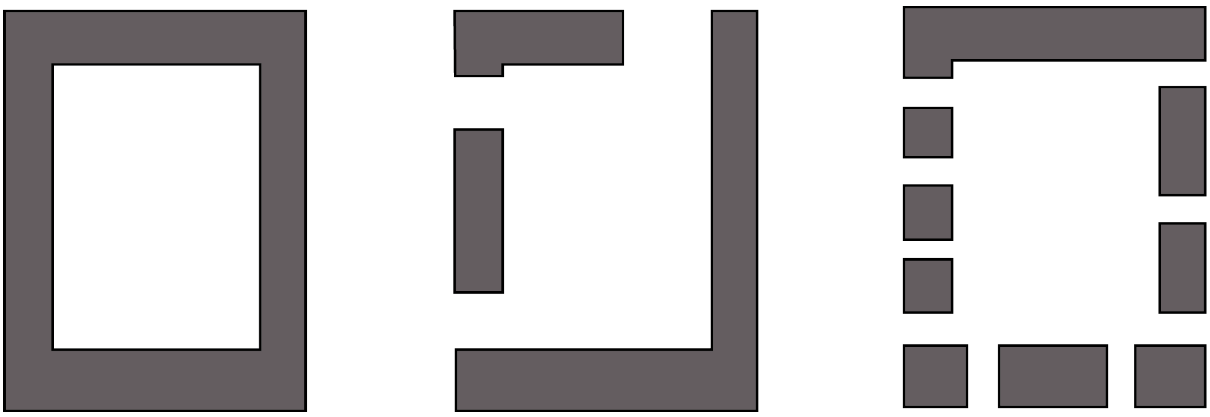


Figure 5 Different forms of the city block

In most cases, the arcade is a shopping and commercial street covered by a glass roof. As a public path, it is usually accessible only to pedestrians. It is enclosed on both sides by the facades of the adjoining buildings, which are usually carefully designed to create a prestigious impression. Merchandise displayed in the shops on the street is visible to al from large windows.

Arcades can be straight, angular or curved. They can take almost any possible linear from or branch off in different directions. The broader spaces at these intersection points can create small squares where people can spend free time.

Arcades may run between two different buildings. They may also take the form of public paths run through compact block structures. Where this is the case, a great idea of attention is usually paid to the design of the inside facades. In such cases, the interior facades are usually carefully designed to reflect the formal characteristics of the exterior.

Formation of Urban Space

The arcade connects paths in the city. This is especially true of the well-known 19^{th} century arcades in Paris, Brussels, London, Naples and Milan. For instance, the famous galleria Vittorio Emanuele II in Milan is the shortest route between two important city sites-the cathedral and La Scala opera house. Sometimes arcades can create shortcuts that optimize the access network of the city, at least for pedestrians. The glass-roofed arcades in Hamburg, which offer protection from the weather, still provide an important secondary access system to the center of town.

As a result of the arcade's roof, a climate buffer emerges inside that considerably enhances the arcade's appeal as a place to stay, especially during the cold seasons of the year. Nowadays, a large number of arcades are heated in winter and air-conditioned in summer-but this requires clear spatial separations.

Historical Examples

Arcades became fashionable in European cities such as Paris, Milan and Vienna in the 19^{th} century. They provided the affluent middle classes with a place to stroll that was protected from the weather-and a space that was

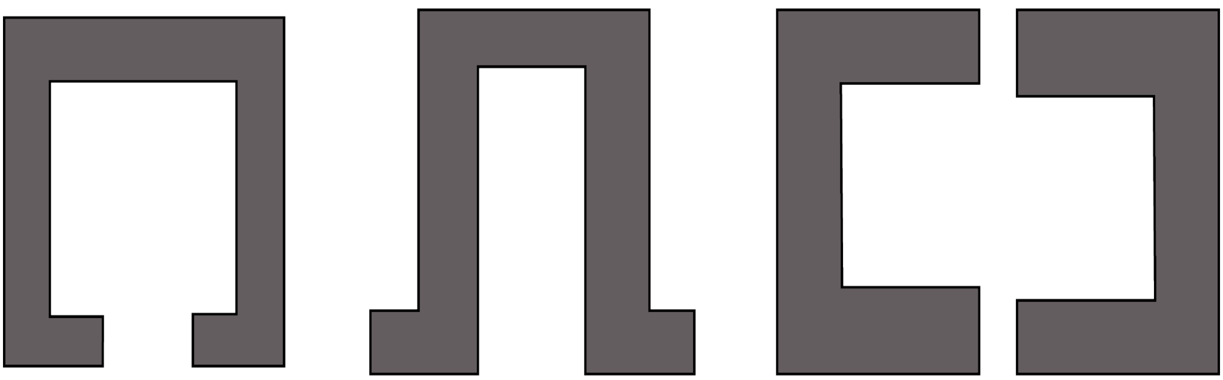


Figure 6 Different courtyards forms

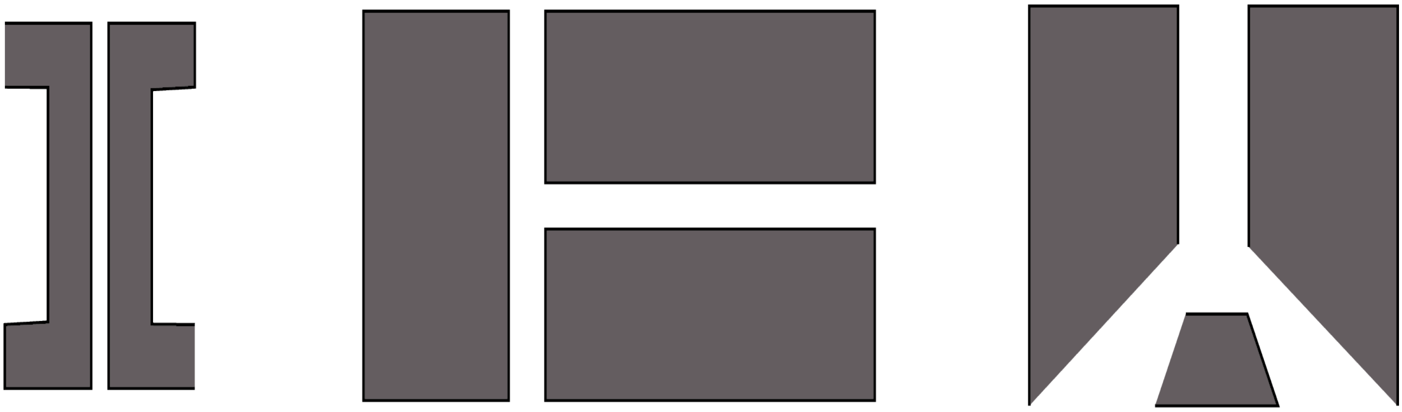


Figure 7 Different arcade forms

removed from the noise and dirt of the street.

5-THE RIBBON

Ribbons are linear, freestanding urban elements that are deliberately oriented away from the street space to achieve "hygienic" advantages such as the best possible exposure to light and ventilation. They were developed in the 1920s as a reaction to the overcrowded urban space created by the block structures and corridor streets of the traditional city. They can thus be understood as a critique living conditions in the tenements constructed in the late 19th century.

Form and Spatial Structure

The ribbon can be seen as a further development of the row. However, in contrast, it is not designed to form a bordered street space. In most cases inly its "head", or short side, is oriented toward the access street. This independence from the street vector allows the ribbon to be oriented to achieve maximum exposure to sunlight.

Ribbons are thus not parallel but perpendicular to the street and are accessed via a secondary footpath. Access to ribbon developments is usually from the side less favored by the sun, such as east or north side.

There are additive ribbon development and couples ribbons.

The additive of this pattern in ribbon development creates an extensive urban structure in which the front side of each ribbon faces the back of the adjacent one. This direct juxtaposition of rear spaces can result in a lack of spatial clarity.

Another possibility consists in a mirrored rather than an additive arrangement or ribbons and their access paths. The result is a series of "coupled" ribbons with the open spaces between the ribbons containing either adjacent front areas or adjacent rear in an alternating pattern.

Ribbons can be composed of single-family houses joined in a line or joined multiple-family dwelling.

The ribbon can be understood as typical of the age of mass production. Its linearity and the repetition of individual units make it highly amenable to the use of industrially prefabricated elements.

Historical Examples

The ribbon is a comparatively new urban building block. Examples can be seen at the case of Adelphi development in London or in the case of the blocks with outdoor-corridor access that were built in northern Italy in the late 19th century.

The most prominent example is the Dammerstock residential estate, which was constructed in Karlsruhe in the period of 1927-1928, as an exhibition project.

6-THE SOLITAIRE

A solitaire refers to a building that either stands alone or is clearly distinguishable from its urban surroundings. Freestanding buildings as granges, farmhouses, castles and monasteries have been part of the cultural landscape since time immemorial.

Solitaires normally were public buildings (temples, churches, town halls) or the building of the ruling classes (castles, fortresses). They were later built as residences for the rich (villas, palaces) or like schools, theatres, opera houses, museums, hospitals, parliament buildings, universities.

Today, the solitaires found in large cities include residential and office towers as well as freestanding, single-family homes that use up an increasing amount of land.

Form and Spatial Structure

Solitaires are quite distinctive from the surrounding buildings in terms of their size, importance geometry, architectural design and construction materials.

Where a solitaire is not connected with any other building, its design can be relatively independent from the urban-planning context in terms of form and proportions.

URBAN ANALYSIS: GERRIT SCHWALBACH (2009)

Preparation for Analysis and Planning Phases.

Planning phases:

- Defining the subject matter;
- Scale and spatial demarcation;
- Continuation and monitoring;
- Working with other specialist planners.

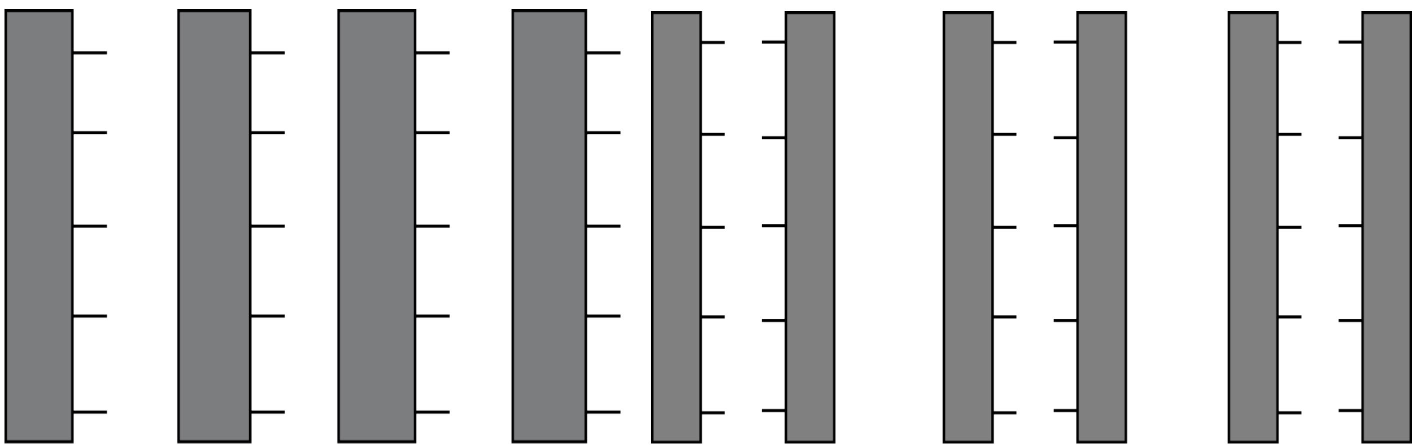


Figure 8 Additive ribbon forms (left) & Coupled ribbon forms (right)

In theory, an observed area contains endless amount of information, which allows a corresponding amount of analysis to be performed.

1. Defining the subject matter. There are two reasons for conducting an urban analysis.

- To reveal the overall picture. This means using urban analysis to obtain an overall picture of the area of investigation or of a whole urban area. This may involve mass vacancy, orientation of the building, building maintenance etc. The aim of the urban analysis is to replace suspicion with a definite diagnosis.
- To provide an answer to a specific issue. This means analyzing specific features: the condition of existing residential buildings, the population's social situation, or the urban compatibility of a prospective building project.

2. Scale and spatial demarcation

Any information gained from an analysis is subject to scale. For example, information relating to individual building could be relevant to a single building unit, but useless for analyzing the whole city. It is important to provide information that can be seen in wider context. If exaggerated, too much large area-information can mislead findings on the area's relationship with the wider context. Therefore, it is crucial to compress the data obtained.

3. Continuation and monitoring

Continuing the analysis involves building ion the investigation at particular intervals. Continues may involve the same methods of analysis, or expand them or modify it. Monitoring in an urban analysis context means long-term observation of the area under investigation, usually by surveying a constant set of values at regular intervals, comparing the results, and comparing with other areas of investigation with regard to certain values. Typical surveyed values include the number of inhabitants and the demographic and social population characteristics.

4. Working with other specialist planners

It is impossible for a signal specialist planner to conduct an urban analysis, as many require specialized knowledge. This means that, when preparing

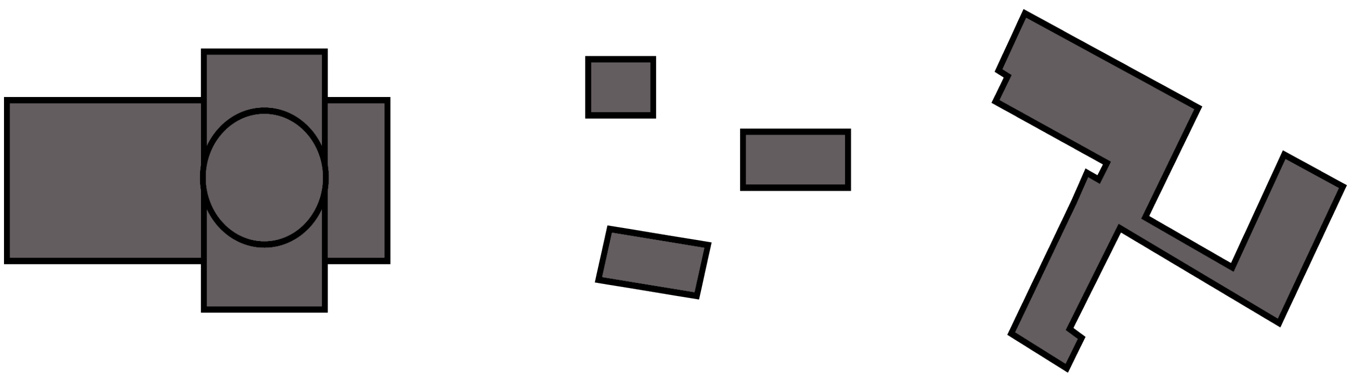


Figure 9 Different forms of the solitaire

and setting an agenda for an urban analysis, the factors analyzed and the expertise needed must be clearly decided. Urban planners and architects usually supervise the main stages of urban analysis, investigating land use, transport construction structures.

Performing a general analysis of the area of interest an attention needs to be paid on the following sections and they help us to understand and become familiar with the area in detail.

- Strengths;
- Weaknesses;
- Opportunities; and
- Dangers.

Criteria can be diverse:

Strength: good access, plenty of green space, cultural diversity.

Weakness: gaps in local services, noise pressures, vacancies.

Opportunities: a place for young families to live, Conversation of empty buildings.

Dangers: increase in vacancies, damage to local image.

URBAN COMPONENTS: from HOUSES, PALACES, CITIES; LEON KRIER (1984)

Leon Krier in his book *“Houses, Palaces, Cities”* gave his approach towards urban design and its way of understanding urban space. He tackled the topics of urban orientation, building block size of it and form of a street etc. Urban design he defines as: *“Urban block should be as small in length and width as is typologically viable; they should form as may well defined streets and squares as possible in the form of a multi-directional horizontal pattern of urban spaces.“*

Referring to a building block, it can be identified as the most important typological element in the composition of urban spaces. As a typological element it can generate urban space but it can also remain unidentified and merely result from the order of an urban pattern.

The building block is either the instrument to form streets and squares or it results from a pattern of streets and squares.

The block is primarily defined as a plot of land surrounded by a multitude of planned and unplanned paths, roads and streets. While the rural blocks do not have to be of any specific size, the urban ones, have to have well defined characteristics such as size, volume, orientation, typology, order and complexity in order to become urban.

Urban blocks create urban space compounded of streets and squares and blocks.

There are three types of urban space:

a) The urban blocks are the result of a pattern of streets and squares. The pattern is typologically classifiable.

b) The pattern of streets and squares is the result of the position of the blocks. The blocks are typologically classifiable.

c) The streets and squares are precise formal types. These public rooms are typologically classifiable.

INTERPRETATION OF THE LITERATURE REVIEW

As Serge Salat stated, the city is a complex creation, and we agree on that. Whether it is smaller or bigger, it anyways involves complexity on many levels. City is not just a physical formation but it is a whole story involving space, streets, buildings and final-the people living in that giant space. We must not neither forget the atmosphere influences in terms of weather conditions. It could not be ever the same whether one city is located in hot or warm climate. Its constitution, form and shape play role of the urban thermal comfort and overall people's perception and satisfaction with life in a specific city, which is extremely important. More in depth on this cause will be discussed in the sections to come.

Planning a city is a challenging task and for that matter, it is strongly recommended to plan wisely and perform the right analysis before. As mentioned above urban structure is complex and it consist of many elements. All these elements are the compounds of the broadly called term-urban morphology.

One of the most important element of the urban morphology is a building. It has a particular role in our thesis. Building is defined as a usually roofed and walled structure built for permanent use (as for a dwelling). Building can have a variety of shapes. The shape is the one that directly affects the air/wind flow afterwards analyzed.

Another element of great importance is a street. Street can have many shapes too and can stretch in many directions. It is defined as a public road in a city, town, or village, typically with houses and buildings on one or both sides. Street is a flat long space convenient for wind flow, which can pass without being disturbed. It gets disturbed when it hits the building and therefore provokes side effects.

Many authors have talked about cities, urban forms and urban morphology. We introduced the approaches of four of them and of the ones that we believe

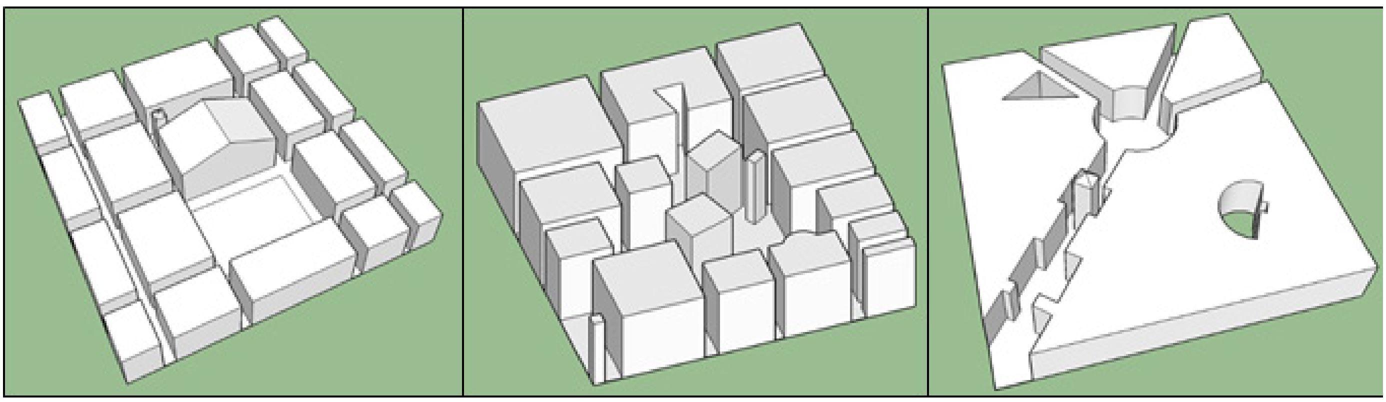


Figure 10 Example of three types of urban blocks

gave us inspiration and a good basis for our thesis work. It was a relevant introduction using their approaches and opinions towards the urban forms, blocks and building types. They outlined many types of the urban block and urban grid types and they introduced the different patterns of the urban forms, and we recognized the importance of them. They gave us the inspirations and an idea in which way to focus our thesis work and what kind of experiments to perform.

We took a few examples of theirs and implemented them in our work. We have conducted an analysis on the six cities and each of them in terms of urban morphology, has a particular shape.

The following two sections will introduce social and environmental analysis performed involving buildings and the streets as the main elements.

Social comfort

“Is the city one thing or two? On the face of it, the city is two things: a large collection of buildings linked by space, and a complex system of human activity linked by interaction. We can call these the physical city and the social city. Urban practice and theory must connect one to the other” (Hillier and Vaughan 2007).

From this perspective, the city can be seen as one thing only to the extent that its two parts, the physical city and the social city, are able to work together. The author continues by proposing that the social city exists on either side of the physical city, in the sense that the social city, as a complex system of human activity, brings the physical city into existence, but later the social city becomes in some ways a product of what has been created.

A similar concept is described by Knox and Pinch (2010), who state that urban spaces are created by people, and these spaces develop their form and character as a result of the people who use them. The users of space inevitably impose their character on it, modifying their environment to fit their needs and values. But at the same time, the users themselves are influenced by the physical environment they inhabit and by the people around them. “Therefore there is a continuous two-way process, a sociospatial dialectic (Soja 1980), in which people create and modify urban spaces, while at the same time being conditioned by the spaces in which they live and work.”

Architect Jan Gehl states that urban structures and planning have a clear influence on human behavior. He claims that if better city space is provided, use will increase, independent of culture, climate and social situations. In general, attracting people to use urban spaces is a matter of “issuing a tempting invitation.”

But considering the connection between morphology and society, which specific morphological factors contribute to better spaces for people?

The issue of what is a “better” space is highly controversial in itself, since what is better for one person, or group of people, may not be better for others. Patsy Healy notes that “collective place-making efforts that aim to expand the opportunities for human flourishing in the places of daily life need to proceed with great sensitivity to who lives where, what they do (…) how they relate to each other, what they care about and feel they need.”

In an attempt to define a variety of conceptions of how to create better social spaces, this chapter will highlight a selection of prominent authors and their views on public spaces. The work of Matthew Carmona, Kevin Lynch, Allan Jacobs and Donald Appleyard, Jane Jacobs, Jan Gehl and Douglas Farr are referenced.

With these references, it may not be possible to concretely define what a "good" social space would be, but it may be possible to identify some positive characteristics of public space. For instance, improving the safety of streets, attracting more people to the streets, improving social mix and interaction between diverse groups, etc.

The aim of this chapter is to identify and discuss the morphological factors that contribute to improving the social environment in cities, which we will refer to as "social comfort." The chapter is divided into two parts: Conceptions of a "Good Space," where the work of the selected authors is discussed, and Morphological Factors, where the physical elements affecting social comfort are discussed separately. The morphological factors are divided into three subsections: streets, buildings, and open spaces; in each subsection, the most relevant factors affecting social comfort, as identified by the previously named authors, are discussed.

Conceptions of Better Public Space

Matthew Carmona

Carmona analyzes different aspects of the morphological dimension, discussing lot pattern and building orientation, active fronts, street grain, grid type, and visual and physical permeability. In each case, certain consequences of urban morphology are discussed, including the effect of different urban forms on social and physical functions.

Carmona discusses urban morphology in connection to its historical development, primarily analyzing the differences between traditional and modernist urban space. He sites Parma, Italy as an example of traditional space, in which the buildings make up a generalized and highly concentrated mass. The urban blocks define the streets and squares of the city, which form a finely-meshed grid of streets with a small-scale block pattern. The buildings are generally shorter in height, while a few landmark buildings, such as churches, have a taller height.

The plan of Saint Die represents a modernist example. The buildings are separate pavilions freestanding in a more generalized type of urban space. Instead of a finely-meshed street grid with small blocks, the modernist example is characterized by a coarsely meshed road grid, and buildings are set within a superblock system made up of relatively large urban blocks. The super blocks are surrounded by major roads carrying all non-local traffic.

From these examples it is possible to define some categories for urban space. The traditional category consists of an urban space in which the buildings define the open spaces, and the blocks are small in scale. The modernist category consists of buildings as separate objects in space, and the blocks are large in scale. However, mixed categories are also possible, for instance, large blocks with buildings defining space, or small blocks with buildings in space.

Lot Pattern

Urban blocks are typically subdivided into individual building lots. The lots may be oriented back to back, with the building fronts facing the street and a shared boundary in the back. The lots may also face main streets on the front and face service alleys in the back. Less commonly, there are through lots, where both the front and rear of the buildings face main streets. In modernist examples, a different situation exists. As freestanding shapes in space, modernist buildings ignore the socially constructed distinction between front and back. The buildings are not oriented to the street; often the buildings face inward with their backs to the streets. This has consequences for the neighborhood social life, since neighborhoods generally benefit from having building fronts that face onto public space, for access to social and public activities, and backs that face quieter areas for more private activities.

Active Fronts

A distinction can also be made between active and passive fronts. In traditional urban spaces, buildings line the streets and open spaces giving them form. There is a strong connection between the buildings and the streets and squares; frequent entrances and windows connect the buildings to the public realm. Modern architecture creates a different situation. Because freestanding buildings are surrounded by public space, at least some of this space must be faced by backs. Therefore, in a modern urban environment, the relationship between buildings and the public spaces adjoining them increasingly shifts from socially active to socially passive.

Street Grain

Street grain refers to the size of the urban blocks and street network. Street patterns composed of many small-scale street blocks have a fine grain, while patterns with fewer, larger blocks have a coarser grain. An area with smaller blocks offers a greater choice of routs and generally a higher permeability than an area with larger blocks. Permeability refers to the extent to which an environment allows for a choice of routs through and within it; it is a measure of the opportunity for movement. Visual permeability refers to the ability to see the routs through an environment, while physical permeability refers to the ability to move through the environment. In addition to physical permeability, smaller blocks also increase visual permeability, therefore increasing a person's awareness of the environment and the opportunities available.

Grid Type

A distinction can be made between regular, or ideal grids, and deformed or organic grids. Regular grids are characterized by straight and regular street patterns, and are usually planned, showing a degree of geometric discipline. Due to the ease of laying out straight streets, regular grids are sometimes overlaid on top of more organic patterns; they are also a typical feature of new world settlements, such as many cities in the United States. Irregular or organic grids are characterized by apparent irregularity and are more typical in regions with a long history of incremental development. The grids in traditional city centers are often described as organic, referring to the fact that the streets appear to have developed naturally rather than having been consciously planned. The streets were generally developed as a result of pedestrian movement and evolved and developed with use over long periods of time. The grid type is not important in terms of physical permeability, which is affected more by the size of the grain than the grid type. But grid type does affect visual permeability. Visual permeability is higher in regular grids and more limited in deformed grid types. However, deformed grids may also affect potential movement in a second-hand way because of the reduced visual permeability.

KEVIN LYNCH

Lynch suggests a limited set of performance dimensions for the spatial form of cities. The dimensions are tied to urban morphology and can be analyzed in connection with changes in the physical environment. Each of the dimensions refers to a cluster of qualities, which all have a common basis and can be measured in a common way. The five performance dimensions are vitality, sense, fit, access, and control.

Vitality is a measure of the degree to which the environment supports the vital functions of human beings; how it protects the survival of the species. It is an anthropocentric criteria, focused specifically on human survival, however, it could be enlarged to also consider the survival of other species that do not contribute to our own survival. An urban environment with high vitality should sustain humans in terms of food production, healthy environmental conditions, safety, etc.

Sense is the degree to which the space can be clearly perceived and differentiated in time and space, and the degree to which that mental structure correlates with the values and concepts of its residents. In other words, the match between our environment, our sensory and mental capabilities, and our cultural constructs.

Fit is the degree to which the form and capacity of spaces and equipment matches the patterns of interaction that users typically engage in, or would like to engage in, including the adaptability of the setting to future actions.

Access refers to the ability of everyone in the network to reach other persons, activities, resources, services, information, or places. It also refers to the number and diversity of accessible elements within the network.

Control is the degree to which the use and access to spaces and activities is controlled by the people who use, work or reside in them, including the ability of those users to create, repair, modify and manage the spaces they use.

These five performance dimensions can be measured in connection to morphological changes in the environment. For instance, density, street grain, mix of uses, and temporal mix are four morphological variables, which can be used to enhance or weaken the five performance dimensions.

Density

Residential and urban density is clearly related to the issue of access. The number and variety of services available within walking distance is lower in areas of low density like suburbs. This has consequences for members of the population without cars, such as the elderly, teenagers, people with disabilities, or those who cannot afford a car. Density is not only important for access to services, jobs, etc.; it is also important in improving the sense of a place and facilitating social interaction. Therefore, a minimum urban density is important for improving access and sense of a place.

Grain

Coarse grain decreases access to other kinds of people and other ways of life, therefore increasing social segregation. Inequities in terms of access to resources and facilities are also likely to increase as a result of the increased social segregation. Violence and tension may also increase, however, if the grain is sufficiently coarse, opportunities for intergroup violence may decline and instead turn inward. Regional coordination and control are more difficult in coarse grained settlements, while local control may be enhanced. A fine-grained place, on the other hand, is made up of small buildings, small open spaces, and small enterprises. These smaller parts can be more easily adapted and fitted to the various needs and activities of the occupants. The smaller parts are more completely under the control of the users, and can be sensed as more connected to individual values and experiences. Therefore, a smaller grain enhances the access, sense and control of a place.

Mix of Uses

The mix of uses has an important effect on the availability of services and opportunities in an area and therefore improves access. The issue of scale is also important here; an area with mixed uses generally has smaller shops and enterprises where customers may feel more valued and more in control.

Temporal Mix

Temporal mix, or "grain of timing," refers to the number of services and users that are present at different times of the day. An area should not only have a mix of uses, but a mix of uses that are open at different times. This ensures that the activity level of a place will be maintained throughout the day and evening hours. Temporal mix is related to mix of uses in that a higher mix has substantial advantages in terms of access, diversity and interest. But the level of mix must be within the limitations of good fit; in other words, the mix must fit with the needs and values of the users.

JACOBS AND APPLEYARD

Jacobs and Appleyard form a critique against modernist architecture and identify some of the problems that have arisen from it. They name eight problems of modern urban design. Poor living environments: housing conditions have generally improved but the surrounding environments are still dangerous, polluted and noisy, with longer and more stressful commutes. Giantism and loss of control: buildings and transportation systems have grown drastically in size, with vast isolated districts. Large-scale privatization and loss of public life: the quality of public spaces has declined, and with it the number of places where people of different social groups can meet. Centrifugal fragmentation: communities have become increasingly homogeneous and the city itself has spread out to form extensive monocultures and specialized destinations. Destruction of valued places: relentless exploitation has led to the destruction of historic places and natural amenities that no longer turn a profit. Placelessness: cities have become meaningless places, we no longer know where materials and products come from and who is behind what. Injustice, cities are symbols of inequality and the difference between the environments of the rich and poor is striking. Rootless professionalism: design professionals today are part of the problem; there is too little inquiry; quick surveys are made and instant solutions devised.

Starting from this basis, they propose a number of goals for the future of good urban design: livability; identity and control; access to opportunity, imagination, and joy; authenticity and meaning; open communities and public life; self-reliance; justice. The seven goals are defined below.

SEVEN GOALS

Livability

A city should be a place where everyone can live in relative comfort. People need an living environment where they can relax and restore themselves. This means a well-managed environment relatively free of noise, overcrowding, danger, excessive pollution, garbage and other nuisances.

Identity and control

People should feel that some part of the environment belongs to them, individually and collectively. People should be encouraged to participate in the creation and maintenance of their environment. Urban spaces should be designed for those who use and are affected by them, not those who own them. People must be encouraged to care for the existing environment, both the natural one and the urban environment. Conservation encourages identify and control, and a stronger sense of community.

Access to opportunity, imagination, and joy: People should find the city a place where they can extend their experiences and meet new people. In a functional sense, people should have access to alternative housing and job choices. They should also find the city an enlightening cultural experience. The urban environment is often taken too seriously, but cities should be a place of excitement, allowing for fantasy and imagination. Fantasy is usually something attempted by commercial facilities, with low levels of inspiration. But cities should be a place for experimentation, allowing people to expand their experiences.

Authenticity and meaning

People should be able to understand the city, it's basic layout, public functions, and institutions, and they should be aware of the opportunities it offers. An authentic city is a city where the origins of things and places are clear. The city should not be dominated by one type of group. "A city should present itself as a readable story, in an engaging and, if necessary, provocative way." When it is too obvious, people are indifferent, when it is too complex they are overwhelmed. This can affect the forms of the city in terms of morphology, signage, public information and education.

Community and public life

Cities should encourage their citizen to participate in public life. As a result of giantism and fragmentation, public life and public places are diminishing. A city should be more than a collection of separate interest groups, classes, and neighborhoods; it should encourage a commitment to a larger goal, supporting tolerance, justice, law, and democracy. Public life should be encouraged in cities, not only through institutions, but also with the urban structure and public spaces.

Urban self-reliance

Cities must become more self-sustaining in their use of energy and other non-renewable resources. Self-reliance will reduce dependence and exploitation across regions and countries, and it will also establish a stronger sense of local identity. Safe and healthy environments should be accessible to everyone. Society should be more pluralistic, with a more even distribution of power, and where the values and cultures of diverse groups are validated and negotiated in a just way. When the good of the individual and the good of the public are at odds, a just society must find a way to balance these diverse goals, allowing for identity while maintaining public concern.

THE URBAN FABRIC

Jacobs and Appleyard identify five physical characterizes for achieving the goals mentioned above. In order to function, all five must be present, not just one or two. The five characteristics are livability, density, mixed use, buildings defining space, and diversity.

Livability

As defined above, livability refers to the quality of the urban environment. The streets and neighborhoods of the city must be livable in the sense that there must be an absence of noise, pollution, danger, etc. People should feel comfortable and safe using the streets, parks, and other urban spaces.

Density

There must be some minimum density of residential development as well as intensity of land use. Developments must be sufficiently dense in order to allow for interaction between groups, connection to resources and opportunities, etc.

Mixed Use

There must be an integration of urban activities, including living, working, shopping etc, and these activities must be in some reasonable proximity to each other.

Buildings Defining Space: The manmade environment, particularly buildings, must define public space, as opposed to the typical modernist buildings, which for the most part act as objects in space.

Diversity

There must be many separate, distinct buildings, instead of a few large buildings. The arrangements should be complex and diverse, to allow for more interest and excitement in the urban environment.

JANE JACOBS

Jane Jacobs emphasizes the need for diversity in maintaining the vitality and safety of urban spaces. In order to adequate diversity, she identifies four contributing factors: mixed primary uses, small blocks, aged buildings, and density.

THE NEED FOR DIVERSITY

Diversity is important because it enhances the vitality of streets, neighborhoods and parks. For instance, the vitality of the street depends on the mix of uses that border it--the buildings, the open spaces--and the mix of users on the street. If the streets look interesting, the city looks interesting; if the streets look dull, the city looks dull: if the streets appear safe the city appears safe. The safety of streets should not and cannot be maintained primary by police. Instead, the solution Jane Jacobs proposes is "an intricate, almost unconscious, network of voluntary controls and standards among the people themselves, and enforced by the people themselves."

To produce this "network of voluntary controls" there must be a clear distinction between public space and private space, and in-between areas without clear boundaries should be avoided; the area under public surveillance must be clear to everyone. Second there must be eyes on the street, from the windows of residences and from the shops. Therefore, the buildings must be facing the street, not turning their backs to it. Attempts to create interior courtyards as places of safety, rather than focusing on the safety of the street is futile. The streets are the most effective method for handling strangers and there is no replacement for safe streets. Without safe streets the only solutions are to let danger hold sway, retreat to cars and avoid the streets, or divide the district into turfs, a method gangs use for defending their territory. Finally, the streets must have a fairly continuous stream of users to increase the number of eyes on the street and attract attention from people in the buildings. No one looks out on an empty street.

It is clear that lively streets make safe streets, but you cannot make people use streets they have no reason to use. Lively streets need many attractions, such as stores and other public places, including those used by night. They give people a reason to use the streets, and draw people past areas where attractions are absent. Additionally, there must be a diversity of enterprises to attract different groups of users and give those users reasons for crossing paths. Furthermore, shopkeepers are useful in themselves; they are natural guardians of the street because they hate broken windows and crime. Fourth, the people using the street are in themselves an attraction to other people. People attract people.

GENERATORS OF DIVERSITY

According to Jane Jacobs, the most important factors for producing higher diversity are mixed primary uses, small blocks, aged buildings, and density.

Mixed Primary Uses

The important role that shops and other businesses play in maintaining an active sidewalk life and safe streets has already been discussed. Therefore business functions are a vital characteristic in every part of the city, including residential areas. The practice of separating business areas from residential areas has dangerous consequences in terms of maintaining street safety because purely residential areas lack the requirements for voluntary control. The need for mixed land uses is promoted for other reasons as well. Mixed use planning reduces the need for vehicular transportation and increases neighborhood diversity.

Additionally, Jane Jacobs emphasizes that city districts must have more than one primary use in order to support the economic vitality of the local businesses. Each district or neighborhood should have more than one primary function, and preferably more than two. The availability of more functions in the neighborhood ensures the presence of people who are on different schedules and use places for different purposes, but who are able to use many facilities in common. Jane Jacobs discusses the example of the lower tip of Manhattan, in which the financial district is put at risk because the users present in this area are mainly businessmen. Shops and restaurants are not able to maintain steady business because their only customers come in hoards during the lunch hour and are largely absent the rest of the day. Plans were developed to increase the number of housing projects in this area to create a residential population, but the numbers would not be substantial enough to balance to large working population. However, developing tourist attractions in the area would bring people in during leisure hours, when the working population is not present. A large tourist population would attract more shops and restaurants and give them more steady business. Therefore, ensuring an area has more than one primary function is a fundamental requirement for securing the economic and social vitality of the area.

Small Blocks

Short blocks are preferable to long blocks because short blocks increase the number of streets and intersections and therefore the number of opportunities to turn corners. Short blocks allow for more choices of paths to take to reach a particular destination, which in turn increases the chances for people from diverse groups to meet and interact. On the other hand, long blocks create and island effect. The number of paths that a person can take to reach his or her destination are limited, so users tend to frequently use the same streets. This discourages people from traveling down neighboring streets and isolates side blocks. The distribution of shops and businesses is also affected by block size. Businesses develop on well-traveled paths, and long blocks channel users down certain streets, making those streets overcrowded and leaving others empty and un-surveillanced.

Aged Buildings

Each neighborhood district should mix buildings of varying age and condition, including a significant proportion of old buildings. This mix of buildings should also be fairly close grained. Promoting building variety is a matter of economic concern since new and old construction types have different rental values. Even in areas predominated by older construction, it is necessary have buildings in different states of renovation. Renovating all the buildings will lead to a similar situation as building all new construction. In order to produce a variety of shops and services in the district, it is necessary to have a variety of buildings at different value marks to attract users of different economic means. Places dominated by new construction become areas for high-end services and chain stores. Hole-in-the-wall businesses are found in areas of older construction. However a similar problem develops in areas where all the buildings are old and unmaintained. Investors with choice choose not to situate their businesses in these areas because of the reduced economic opportunity and the neighborhood suffers as a result.

Density

The neighborhood must have a sufficiently dense concentration of people who are present in the area for different reasons, including residential populations. The issue of density is a common topic in urban planning; high-density mixed-use arrangements are the preferred environmental standard because of the reduced need for motorized transportation. But Jane Jacobs discusses the need for density in cities in relation to human interaction and the need to deal with strangers. Low densities, of the kind that are found in suburbs, can function on the edges of cities where the social climate is more cohesive, but low densities within the city are less functional. In-between densities in cities are the most problematic since residents are constantly faced with strangers but lack the higher density sidewalk life and voluntary control mechanisms that would help them deal with strangers. Jacobs suggests densities of more than 100 residences per acre. The difficulty lies in maintaining other types of diversity while maximizing density, because there should be a mix of building types, not only high-rise buildings. The desire for mixed land use and some lively green areas also reduces the overall residential density. Therefore the density should only increase to the point that diversity of building types and uses must be sacrificed in order to continue. In order to maintain an average of more than one hundred residences per acre, while maintaining the desired level of diversity, it is necessary to increase ground coverage (to about 70%) and reduce open spaces. This is a controversial issue since many contemporary urban designs favor lower ground coverage and more open space. However, Jacobs is willing to sacrifice more open space in exchange for higher density and diversity.

JAN GEHL

Jan Gehl identifies four interconnected goals for creating better urban environments. He proposes that good urban spaces should be lively, safe, sustainable, and healthy. In each section, the physical requirements for reaching the goal are described.

LIVELY

Inviting, lively cities are attractive in themselves, but they are also the starting point for a safe, sustainable and healthy cities. In lively cities, the presence of other people in itself signals which places are worth while; lack of people in the city signals that something is wrong.

Quality vs. Quantity

A varied and complex life where recreational and social activities are mixed is a prerequisite for lively cities. However, high numbers do not equal liveliness and crowds do not create good public life. Quality is more important and underscores the need for a multifaceted environment.

Life in the city is a self-reinforcing process, people come where people are. Good space and critical mass are how small events grow. The opposite is also true, when there is not enough critical mass, the lack of activity prevents future activities from developing. The concentration of people in a space is important. With a larger scale city, there are fewer people and activities to populate a space.

Compact, direct and logical routs are another necessity, along with modest dimensions, and a clear space hierarchy, where decisions have been made about which spaces are the most important. This contrasts with contemporary urban practices, where there is too much common space and the spaces are too large: “parks and recreational areas are generously strewn over plans with little thought given to natural sequences, which spaces are important, or the extent to which it is even meaningful to build them.”

Density

Higher density does not produce liveliness; reasonable density and good quality space are almost always preferable to higher densities. The densities should not be so high that the ground level environment is negatively impacted, which means that the sun must reach the streets. Additionally, people on the top floors of high-rise buildings venture into the streets less often and have less visual contact with the street. Lively cities need a compact structure, reasonable population density, acceptable walking and biking distances, and good quality public spaces.

Slow Traffic

Liveliness is not just a matter of how many people there are but also how long they stay. Instead of attracting more people sometimes it is better to encourage the same number of people to stay longer. There is more life is places where people move slower, therefore slower traffic like walking and biking is preferable to fast automobile traffic, which increases numbers, but not staying-time

Soft Edges

The edges of the city provide limits to the visual field and define individual spaces. Edges along the ground floor should have doors and exchange points between inside and outside. More entrances and windows provide more opportunities for life in and around the buildings to interact with life in the city. The edges are also a potential staying zone, when opportunities for sitting or standing are provided.

The optimal situation is narrow units and many doors. Thriving commercial streets often have a facade length of five or six meters, at an ordinary walking speed, this means that there are new activities and things to see about every five seconds.

As a summary, Gehl identifies several physical design elements that improve the liveliness of cities. These elements are: scale and rhythm, transparency, appeal to many senses, texture and details, mixed functions, and vertical facades.

SAFE

Feeling safe in the city is a vital characteristic, however, safety depends on liveliness, and vice versa. It is difficult to have one without the other.

Liveliness

Life in streets improves safety, the presence of others signals that the place is acceptably good, and both the real and perceived safety in increased. Life in the buildings also improves the safety of streets; areas with mixed functions provide more activities in and near the buildings at different times of the day, and lights from active buildings send comforting signals. Ground floor design is the most important; soft edges make the city more welcoming, while shops with closed shutters create a sense of rejection and insecurity.

Traffic

Accidents are another safety hazard, but policies have focused on reducing accidents by making even more room for cars, which only attracts more cars. Meanwhile walking and biking space has deteriorated. What is needed is shared streets giving priority to pedestrians. New studies have indicated that the risk of accidents can be reduced by physically mixing traffic types. But this policy can have consequences for pedestrian quality since they must be constantly vigilant. Shared streets are recommended where pedestrians are given priority of movement. In some cases care free zones may be preferable.

Layout

Good city layout improves security because it is easier to find our way around. Streets can be winding and varied, but many connections and links are important, along with signs, directions, and a clear hierarchy.

Soft Edges

Soft transitions between public and private improve safety, especially in residential areas. Soft edges in the form of porches or front yards provide more opportunity for residents to interact with the street. These transitional zones must be clearly articulated to distinguish between public and private space.

SUSTAINABLE

Walking and Biking

Promoting walking and biking would be an important step toward sustainability. Walking and biking uses fewer resources and does not affect the environment in negative ways. Pedestrian and bicycle traffic does not crowd city streets because their space requirements are relatively small compared with cars; a bike path can transport 5 times as many people as a car lane and the parking space is ten times smaller.

Public Transit: Quality public transport and quality public space go together because the quality of the journeys to and from transit stops has a large impact on the effectiveness of the transport system. A compact city structure with short walking distances is a prerequisite for public transit. Social sustainability is also enhanced when people without cars are able to access more opportunities. Public spaces should be equally accessible to different social groups, and the city should allow people to encounter social diversity by sharing the same spaces.

HEALTHY

Exercise

Numerous changes in modern society have led to new health challenges. For instance, the sedentary work life, the use of cars as the dominant mode of transportation, and passive recreational activities such as watching tv have all contributed to rising rates of obesity in developed countries, especially in the United States. The costs are high in terms of a loss of quality of life, health effects, and a shorter life span.

Exercise is no longer a integrated part of daily life, instead, exercise has become a voluntary activity, however, voluntary exercise requires time commitments, determination and willpower, and organized options also cost money.

Creating more opportunities for walking and biking in the city brings back exercise as a part of daily life. Cities like Copenhagen, Melbourne, New York, Sydney and Mexico City have prioritized walking and biking, upgrading pedestrian networks with broader sidewalks and shade trees, removing interruptions, and improving street crossings. To produce a successful walking and biking culture, it should be simple, uncomplicated, and safe to walk at all times of the day or night, with good furniture, details, and lighting. Convincing people to walk and bike will require changes in planning, however, walking and biking connections should be addressed first, before other transport needs.

DUANY, SPECK AND LYDON

In *The Smart Growth Manual*, Duany, Speck and Lyndon outline specific requirements for regional and neighborhood planning, as well as the design of streets and buildings.

THE REGION

At the regional level, Duany et al. discuss the regional principles, the regional plan, and regional trasportation. The ideology is that growth is inevitable, however, it should be managed in the most intelligent way possible through the use of smart regional plans. Regional plans should should emphasize the use of existing infrastructure, and affordable housing. Undesirable land uses must be distributed equitably, and farmland and natural assets must be protected. Building efforts should be organized around the concepts of smart growth, and cities without adaquate water resources should not continue to grow.

Additionally, smart growth recognizes the need to make transportation and land-use decisions together. Transportation plans should be balanced, mixing walking, biking and other modes of transportation, while at the same time reducing the need for transportation by designing self-sufficient neighborhoods. These neighborhoods, must reduce high-speed traffic in order to remain walkable.

THE NEIGHBORHOOD

At the neighborhood level, Duany et al. discuss the natural context, neighborhood components, and neighborhood structure. Smart growth communities must preserve their natural amenities, including woodlands, natural topography, wetlands, etc. Smart growth communities maintian large open spaces and link them into green corridors for the benefit of humans and wildlife.

In terms of neighborhood components, each neighborhood should contain a mix of uses, including large and small dwellings, retail spaces, workplaces, and civic buildings. Ideally, they should also provide walking access to schools, recreational centers, and open spaces. Higher densities should be encouraged because they improve the functioning of non-residential activities and public transit.

The neighborhood structure should be scaled to fit the pedestrian. The neighborhood should have a dense center with the main public space and smaller parks scattered throughout. Zoning should not separate uses; instead it should put compatible uses together. The neighborhood should be designed for efficient public transit, and allow for small-scale food sourcing.

THE STREET

At the street level, Duany discusses thoroughfare network, thoroufare design, public streetscape, private streetscape, and parking.

The thoroughfare network should consist of relatively small blocks continually lined by buildings, with streets that connect wherever feasible.

Thoroughfare design should be equitable for the pedestrian, bicycle and automobile. This is accomplished by calming traffic with a combination of design speeds, complex intersections, tight corners and on-street parking. According to the urban context, a variety of thoroughfare design types should be planned, including avenues, boulevards, streets, roads, alleys, lanes, passages and paths.

In addition to moving cars, streets must be designed as public spaces. They must include sidewalks, trees, curbs, lighting etc. However, errors to be avoided include excessive lighting, unnecessarily fancy materials, and sidewalk obstructions.

In order to create an inviting public space, private buildings should be designed to enclose the street space, with closely-aligned building fronts. Semi-public elements such as porches, terraces, and balconies increase activity in the street. Building heights should correspond to the size of the public space, however, skyscrapers are questionable in all but the densest urban areas because too much development potential is used on one site. All buildings should have doors and windows facing the street for natural surveillance.

Pedestrian friendly streets cannot be flanked by parking lots or garage doors. Parking lots should be placed in-between blocks, out of sight of pedestrians. Additionally, planning mixed-use neighborhoods reduces the need for parking spaces because theyre is less car dependency.

THE BUILDINGS

At the level of buildings, Duany et al. discuss building types, green construction, and architectural design. In terms of building types, smart growth codes prescribe a mix including midrise, highrise, commercial lofts, apartment houses, live/work buildings, rowhouses, cottages, and large houses.

In terms of green construction, buildings should be designed to optimize solar access and provide operable windows. They should minimize the heat island effect by using light-colored materials and landscaping. They should conserve energy, use sustainable materials, limit construction waste, and insure healthy indoor air quality.

DOUGLAS FARR

In the LEED neighborhood design standards, Farr defines prerequisites for building more sustainable neighborhoods. These prerequisites include walkable streets, compact developments, connected and open communities, access to recreational activities, and mixed-use neighborhoods.

WALKABLE STREETS

In order to achieve walkable streets, three different criteria need to be considered: facades and entries, ground level uses, and design speeds. The requirements for achieving each criteria are described below.

Façades and Entries

A number of criteria must be met in order to fulfill the facades and entries requirements:

The building facades facing the street should not be more than 7.5 meters from the property line.

Functional entries to buildings should occur at an average of 9 meters or less along non-residential or mixed-use blocks.

All ground-level retail, service and trade uses that face a public space should have clear glass on at least 60% of their facades.

For facades facing sidewalks, no more than 40% of the facade should be without doors or windows.

Ground Level Uses

The criteria for ground-level uses are as follows:

-Any ground-level retail, service or trade windows facing streets should be kept visible (unshuttered) at night.

On street parking should be provided on at least 70% of both sides of the block, with the exception of alleyways.

Sidewalks should be provided on both sides of the street. New sidewalks should be at least 3 meters wide on retail or mixed-use blocks and 1.5 meters wide on all other blocks.

50% of office buildings should include ground floor retail; 100% of mixed-use buildings should include ground floor retail, live-work spaces, or ground-floor dwelling units.

All ground-floor services should be directly accessible from the sidewalk or other public space.

Buildings should have a minimum building-height to street-width ratio of 1:1.5, in other words, at least 1 meter of building height for every 1.5 meters of street width, counted from the center of the street to the building facade.

Speed

The speed requirements are as follows:

Residential streets should be designed for a target speed of no more than 30 km/h.

Non-residential streets should be designed for a target speed of no more than 40 km/h.

Compact Development

Development density is measuring in dwelling units per hectare. At least 25 dwelling units per hectare are required to receive 1 point, and maximum points are given for developments with more than 156 dwelling units per hectare.

Connected and Open Community

Neighborhood blocks should be designed on a small scale so that there are at least 116 street intersections per square kilometer. Maximum points are given to neighborhoods with more than 154 intersections per square kilometer.

Access to Recreational Facilities

Neighborhoods should be designed so that an outdoor recreation facility lies within 800 meters of dwellings and non-residential uses. The recreational facilities should be publicly accessible and at least 0.4 hectares in area.

Mixed Uses

At least 50% of dwelling units in a neighborhood should be within 400 meters of a mixture of uses. Maximum points are given to neighborhoods with more than 20 diverse uses within 400 meters.

Housing Types

Five main categories of housing types are provided: detached residential, duplex or townhouse, apartment building with less than 4 floors, apartment building with 5 to 8 floors, apartment building with 9 or more floors. Maximum points are given to developments with a higher diversity of dwelling types.

Morphological factors

The objective of this section is to compare the work of the different authors and define specific morphological factors for improving the social comfort of urban spaces. Some additional authors are also cited. The morphological factors are divided into three sections: streets, buildings and open spaces.

STREETS

Visual Permeability

Visual permeability and grid type are discussed by Carmona and Gehl. Carmona identifies three primary street structures, regular, distorted, and organic. In the case of deformed or organic grid types, irregularities in the grid may affect visual permeability, making navigation more difficult. It may also affect the legibility of the space, making it easier to get lost.

Jan Gehl emphasizes the importance of a street hierarchy and good layout.

He states that streets can be winding and varied, but many connections and links are important, along with signs, directions, and a clear hierarchy.

Physical Permeability

The connection between physical permeability, block size, and street grain are discussed by Carmona, Jane Jacobs, Lynch, Duany and Farr.

According to Jane Jacobs, physical permeability is enhanced by short blocks, Short blocks increase the number of streets and intersections and therefore the choice of paths that people can take to reach their destination. Long blocks create an island effect.

Carmona also supports smaller blocks because finely meshed grids offer moe ways to get from place to another. Girds with bigger blocks offer fewer options. If connections are severed, creating dead ends, the grid becomes disconnected and permeability is reduced, which can have serious impacts, especially in coarsely meshed grids.

Lynch states that coarse grain and large blocks decrease access to other kinds of people and other ways of life, therefore increasing social segregation. Inequities in terms of access to resources and facilities are also likely to increase.

Farr calls for small scale blocks with 116 to 154 intersections per square kilometer.

Traffic Flow

Traffic flow is discussed by Gehl and Appleyard. Gehl highlights the importance of slower traffic and less room for cars. He suggest sharing street space between cars, bikes, and pedestrians, but emphasizes that pedestrians should have priority.

Appleyard and Lintel (1972), compared three San Francisco streets with different traffic volumes. On the streets with less traffic, there was a more active sidewalk life, people used the sidewalks and corner stores as places to meet people and interact. On the streets with more traffic, people only used the sidewalk as a pathway to reach their destination. On the streets with less traffic, the sidewalk life was supported by the ability for people to cross the street at many intervals, whereas heavier traffic disconnected one side of the street from the other.

Walkability

Walkability is discussed by Gehl and Farr. Gehl supports walkable streets because they increase the liveliness, safety, and sustainability of streets. Additionally, creating more opportunities for walking and biking in the city brings back exercise as a part of daily life, improving the health of the urban population.

For Farr, achieving walkable streets depends on many factors including: improved facades and entries, more ground level uses, wider sidewalks, and lower traffic speeds.

BUILDINGS

Active Fronts

The need for active fronts is discussed by Carmona, Jane Jacobs, Jan Gehl and Duany et al.

Carmona discusses active fronts in connection to traditional and modern architecture. In traditional urban spaces, there is a strong connection between the buildings and the streets; frequent entrances and windows connect the buildings to the public realm. In the case of modern architecture, buildings often turn their backs to the streets. Therefore, in the transition from traditional to modern spaces, the relationship between buildings and the public realm shifts from socially active to socially passive.

For Jane Jacobs, the need for active fronts is connected to security. More connections to the street and more activity increase the "eyes on the street." Therefore, lively streets increase opportunities for neighborhood surveillance.

Gehl highlights the need for "soft edges." He states that edges along the ground floor should have doors and exchange points between inside and outside. More entrances and windows provide more opportunities interaction. The edges are also a potential staying zone, when opportunities for sitting or standing are provided.

Building Diversity

The need for building diversity is mentioned by Jane Jacobs, Gehl, Appleyard and Farr. Allan Jacobs and Donald Appleyard state that there must be many separate, distinct buildings, instead of a few large buildings, and there arrangements should be complex and diverse.

Jane Jacobs supports several kinds of building diversity including: height, age, and condition. A variety of building heights supports the diversity of the neighborhood in terms of living arrangements, proximity to the street, etc. Age and condition affect the economic and social diversity of the neighborhood by providing different rent levels for residences and businesses.

Farr identifies categories of housing types including: detached, townhouse, low-rise, midrise, and high-rise apartments. Maximum points to developments with a higher diversity of housing types.

Mixed Use

Mixed Use is discussed by Jane Jacobs,

Lynch, Appleyard, Duany and Farr. Appleyard states that there must be an integration of urban activities, including living, working, shopping etc, and these activities should be in some reasonable proximity to each other.

Lynch highlights that the mix of uses has an important effect on the availability of services and opportunities in an area and therefore improves access. The temporal mix of activities is also important. Neighborhoods should have activities that are open at different times of the day.

For Jane Jacobs, a mix of primary uses is a vital characteristic. The mix should include uses that attract a variety of social groups who will use the area during different hours but whose needs are compatible with each other. A mix of uses is essential for sustaining economic and social vitality, and also improves the security of streets and open spaces.

According to Farr, at least 50% of dwelling units in a neighborhood should be within 400 meters of a mixture of uses. Maximum points are given to neighborhoods with more than 20 diverse uses within 400 meters.

Building Density

Density is discussed by Lynch, Appleyard, Jane Jacobs, Gehl and Farr. For Appleyard, there must be some minimum density of residential development as well as intensity of land use. Developments must be sufficiently dense in order to allow for interaction between groups, connection to resources and opportunities, etc.

Lynch comments that residential and urban density is clearly related to the issue of access. The number and variety of services available within walking distance is lower in areas of low density. This has consequences for members of the population without cars. Density is not only important for access to services, jobs, etc.; it is also important in improving the sense of a place and facilitating social interaction.

Jane Jacobs supports higher density as long as it doesn't reduce the building diversity. For instance, maximum densities are achieved with high-rise buildings, but in order to maintain building diversity, lower densities are acceptable.

Gehl supports reasonable density and good quality space over higher densities. He states that the densities should be high enough to concentrate people and activities, but not be so high that the ground level environment is negatively impacted, such as when the buildings block sunlight from reaching the streets.

Farr also supports compact developments. Development density is measured in dwelling units per hectare; at least 25 dwelling units per hectare are required, and maximum points are given for developments with more than 156 dwelling units per hectare.

OPEN SPACES

Size and Number

The size and number of open spaces is discussed by Jane Jacobs and Gehl. Jane Jacobs supports a few well-positioned and active spaces. More green spaces are not always beneficial; unsurveilanced green spaces can increase crime and degenerate a neighborhood.

Gehl advocates for many small open spaces rather than a few large ones. There should also be a space heirarchy in which the more important spaces are highlighted.

Access

Access in general is discussed by all the authors. In particular, access is one of the performance dimensions defined by Lynch. For Lynch, access refers to the ability of everyone in the network to reach other persons, activities, resources, services, information, or places. It also refers to the number and diversity of accessible elements within the network.

Additionally, Appleyard states that public life should be encouraged in cities, not only through institutions, but also with the urban structure and public spaces. Public spaces should be a place where people from separate groups meet and interact, which means access must be open to all groups.

According to Farr, neighorhoods should be designed so that an outdoor recreation facility lies within 800 meters of dwellings and non-residential uses. The recreational facilities should be publicly accessible and at least 0.4 hectares in area.

Comfort

Comfort in open spaces is discussed primarily by Gehl, who discusses the need for protection, comfort and beauty in public spaces. Parks and squares should have a comfortable enviornmental condition, with sufficient protection from the elements and unpleasant conditions. Comfortable seating and high aesthetic quality encourage people to stay longer. Aesthetic quality can be enhanced with natural elements, quality materials, and fine details.

Environmental Comfort

I. Urban microclimate

A microclimate is a local atmospheric zone where the climate differs from the surrounding area. Microclimates exist, near bodies of water which may cool the local atmosphere, or in heavily urban areas where brick, concrete, and asphalt absorb the sun's energy, heat up, and reradiate that heat to the ambient air. The resulting urban heat island that is created presents the area of a microclimate.

Urban microclimate consists of local variations as a result of many factors: wind, humidity, solar radiation and temperature.

In some cases, the urban heat island effect causes a difference in temperature of up to 10°C between the city and the surrounding green belt, while it often leads to reduced precipitation, increased pollution and a number of other potentially undesirable effects.

Urban areas are heat traps that absorb a great deal of solar radiation and serve to warm the air within them. This is caused by the physical and thermal properties of the materials used in construction, as well as topographical factors that serve to trap warmth and reduce winds. (Lutz Katzschener, Sofia Thorsson, 2009)

URBAN MICROCLIMATE CAUSE

There are many causes for the phenomenon of the urban microclimate. Some of them have been mentioned in the previous section but outlining them at one place, they are:

1. **Anthropogenic Heat Production**

Heat production is a result of most human activity inside and outside buildings. For the urban microclimate, buildings are permanent heating appliances discharging heat around the clock, all year round. Space heating and cooling, artificial lighting, and the use of domestic and office appliances are among the main sources of such heat, which is transferred outdoors by transmission through building elements and by air exchange. The rate of heat transmission is higher the less well insulated buildings are, and the higher the built density. Built form and building construction are thus critical considerations.

2. **Airflow Patterns and Humidity**

Wind velocity in a city is generally lower than in the open country area. This is due to the sheltering effect of buildings, and results in a lower rate of heat dissipation by convection. On the other hand, tall buildings and the channeling effects of street canyons lead to complex air flow patterns and produce turbulence. Built form and density are again important considerations. The cooling effect of vegetation has been reported by many researchers comparing air temperatures in urban parks to those in street canyons (Arthur Rosenfeld, 1997). Generally, however, most cities lack substantial green areas and bodies of water, and thus obtain little benefit from evapotranspiration and evaporative cooling. Consequently, humidity tends to be lower in the city than in rural areas.

3. **Effect of Air Pollution**

The two main families of pollutants have opposite effects on the urban climate. Greenhouse gases such as CO_2 and CH_4 absorb the long-wave radiation emitted by terrestrial surfaces. This reduces the rate of cooling of these surfaces, thus causing higher temperatures at ground level. Aerosols, on the other hand, reduce the transmission of solar radiation through the urban atmosphere. This results in a smaller amount of solar radiation reaching the ground and leads to lower temperatures at ground level. Thus, greenhouse gases contribute to the heat island effect, whilst particulates have cooling effect. Neither of these effects can be judged with any precision from the weather data available to designers. Generally, guessing would tend to underestimate temperatures and overestimate solar radiation.

4. **Built Form**

Built density and built form are composite variables combining parameters such as the area of exposed external surfaces, the thermal capacities and surface reflectance of built elements, and the view of sun and sky by surfaces. Individually or in combination, these parameters have multiple effects on the urban microclimate. They influence the magnitude of incident solar radiation, the air movement inside and outside buildings, and the mean and peak temperatures of external surfaces and air. Compared to flat, open ground, a built site has a larger external surface area on which to receive solar radiation. In the urban environment, however, view of the sun is commonly partly obstructed by neighboring buildings, an effect which increases with latitude and reaches its peak on high density sites in midwinter. A surface's view of the sun at any given time is largely determined by the built form and by street widths and orientations.

Summarizing, to reduce the heat island effect, the designers should consider:

- built form and density;
- street canyon geometry;
- building design and materials;
- urban materials and surface
- water and vegetation;
- traffic reduction;
- use of renewable energy

II. Urban Outdoor Comfort- The Human Perception and Reaction

Thermal comfort of persons staying outdoors is one of the factors that has a direct influence on the outdoor activities in streets, squares, playgrounds, urban parks and any other outdoor locations suitable for quality time spending.

The amount and intensity of these

activities is affected by the level of the comfort citizens' experience when they are exposed to the climatic conditions in the mentioned outdoor spaces.

For example, on a hot summer day the thermal discomfort of people staying outdoors and being exposed to the sun may discourage them from occupying available city parks. The thermal discomfort they feel may be a combination of the air temperature, the surface temperature of the ground, the wind speed and the humidity level. The availability of shaded outdoor areas may result in greater usage of the open space by the public. (Tania Sharmin, 2012)

On a contrary, in a cold region, a combination of the wind speed and air temperature, or the obstruction of the sun in shaded areas may as a result discourage people from staying outdoors while the provision of sunny areas from the prevailing winds may encourage public activities in that outdoor space.

Concluding, minimizing outdoor discomfort may enhance the vitality of the location during periods of extreme temperatures-low in winter and high in summer.

The existing levels of the air temperature, solar radiation and wind, in a particular location, can be modified by the design details of the outdoor spaces. Such details might refer to provision of shading elements, materials and colors of the surrounding hard surfaces. Moreover, details of surrounding surfaces, wind "breaks" or 'openness" to wind, matters in this case.

Therefore, depending on the choice of different design details, the exposure or protection from solar radiation, the temperatures of the surrounding surfaces and the local wind speed, can be modified largely. Furthermore, also the outdoor space design details can have an effect on the local air temperature. (Saimum Kabir and Md.Mizanur Rahaman, 2012)

URBAN COMFORT AND THE PEOPLE

Research on outdoor comfort involves different conditions and issues, not encountered in studies on indoor comfort.

When staying outdoors, people expect variability in the exposure conditions: variation of sun and shade, changes in wind speed, and similar. Pedestrians may be exposed to intense solar radiation and to the winds, which are factors that vary greatly due the temperature and humidity conditions.

Furthermore, people staying outdoors usually wear different clothing in different seasons, clothing that are suitable to the dominant climate. Therefore if a certain experiment is planned to be performed, fixed standard clothing is not applicable in outdoor research. In each particular season, the subjects should wear clothes that are commonly used in that particular location and season. Thus, in an outdoor comfort study conducted in Japan, the subjects wore, in each season, clothes commonly worn by local persons when staying outdoors.

By comparing outdoor comfort studies

conducted in different seasons, and/or in regions with different climates, it would be possible to evaluate the effect of changes in the prevailing climatic conditions on the temperature range within which people feel comfortable outdoors, when the subjects are wearing clothing common for outdoor exposure in the given location and season.

The effect of direct exposure to solar radiation is not limited to the thermal sensation. In winter, it may produce specific pleasure. On a hot summer day, it may produce specific discomfort, beyond the heat sensation. In un-shaded areas, pedestrians may also be exposed to surface temperatures much higher in summer and lower in winter than the ambient air temperature.

Outdoors, wind speeds are much higher than the air speeds common indoor. Wind in summer, up to a certain speed, may be specifically pleasant, while in winter it may be specifically annoying. These factors have to be included in evaluating the overall subjective responses to the outdoor environment.

IMPORTANT FUNCTIONALITY OF THE OUTDOOR SPACES

Microclimatic characteristics in the outdoor urban spaces have an influence on the people of using them. The microclimate influence people's behavior and therefore it is important to make it function in a proper way.

Improved microclimatic conditions have in turn major implications for the development of cities. Having a control of the discomfort, successful areas are able to attract large number of people, which in turn attract businesses, workers, residents and in a turn area becomes economically profitable. The energy use of the surrounding buildings can also be affected. Concluding, successful outdoor spaces can benefit the image of the city. (Marialena Nikolopoulou, 2001)

The important of the final look of the city has been recognized in a case of San Francisco. In the city, by the law it is arranged that new buildings have to be sited so that winds at ground level are limited to 5 m/s in areas where people sit for 90% of daylight hours. As well, new constructions cannot cast a shadow on a park between one hour after sunrise and one hour before sunset, throughout the year. (Bosselmann, 1988)

URBAN DESIGN AND OUTDOOR SPACES

There is adequate understanding of the influence of climate on urban settlements. For instance, the way self-shading streets protect the buildings and the surrounding spaces from the hot sun, in hot arid climates, or dispersed buildings to allow for easy flow of wing through the spaces in hot humid climates.

In cases where the urban fabric is already existing and cannot be modified, alterations are possible down to the scale of the urban block in order to improve the overall microclimate in surroundings. In a conclusion, urban microclimate control is possible. Shading whole streets is feasible whether in the form of trees, with the advantage of cooling via evapotranspiration through the leaves, or man-made canopies with the available materials, solutions are found worldwide and they are not stick to the specific cultures.

THERMAL COMFORT

Classical comfort theory is defined by the model where they production of heat is equal to the heat losses to the environment, where the goal is to keep constant the temperature of the 37 ^{o}C. Environmental conditions that provide thermal satisfaction depend only on the activity of the subjects and their clothing level and they fall within a narrow band.

People tend to improve their comfort conditions by changing their clothing and metabolic rate or by interacting with the building. (Baruch Givoni, 2003)

HISTORY OF ANALYZING OUTDOOR URBAN COMFORT

According the A.J. McMichael (2003), outdoor environment is quite complex in terms of variability, temporally and spatially and in terms of the people who are engaged in variety of activities available at that environment. Despite the complexity of the system, there have been only a few tries to understand the outdoor comfort.

- The first people who mentioned the issues of urban outdoor complex were Gold in 1930s and Siple and Passel in the Antartic in the 1940s, who were creators of the wind-chill index.
- In 1973 Penwarden attempted a more systematic approach for thermal conditions outdoors, by adding a term for the solar radiation to the steady state model.
- In 1980s a team of researchers at Barkeley worked on thermal comfort outdoors, specifically focusing on implications of design solutions for the microclimate of San Francisco, which led to the legislation for solar access and wind protection. Moreover, mathematical model of the thermoregulatory system was employed for calculating the comfort conditions.

III. WIND, WIND SPEED AND WIND COMFORT IN PLANNING

WIND-DEFINITION

Wind is defined as the flow of gases on a large scale. Wind is moving air and is caused by differences in air pressure within our atmosphere. Air under high pressure moves toward areas of low pressure. The greater the difference in pressure, the faster the air flows. [1]

Wind is composed of a many eddies of different sizes and rotational characteristics carried along in a stream of air which flows and moves horizontally regarding the earth's surface. Wind eddies are small vortices that spin in circles in the atmosphere. These eddies give wind stormy or powerful character. The wind strength in the lowers levels of the atmosphere mainly arises from interaction with surface features. The average wind speed over a time period of the order of ten minutes or more, tends to increase with height, while the strength decreases with height.

A size of the eddies influences the

turbulence effects on the buildings. Large eddies, whose dimensions are comparable with the structure, give rise to the pressure as they surround the building. On the other hand, small eddies create a pressure on a various spots of the structure that become practically uncorrelated with distance of separation. (P. Mendis, T. Ngo, N. Haritos, A. Hira, 2007)

Eddies that are generated around a typical structure are shown in the following figure:

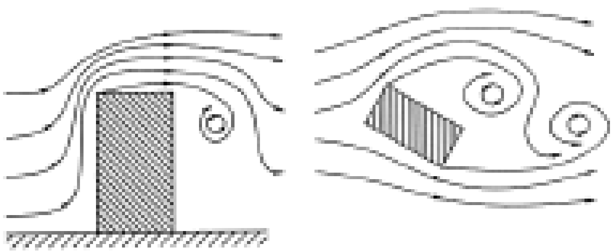


Figure 11 Figure: Generation of eddies; A. Elevation, B. Plan

In the history there were example when the structure collapsed due to the effects of wind, as a consequence of bad wind loading pre-building treatments. The best known structural collapse was the Tacoma Narrows Bridge which happened in 1940 at a wind speed of only 19 m/s. It crashed after it had developed a series of torsional and flexural mode of oscillation.

Regarding the reaction of the structures being hit by a strong wind, there are several phenomenon:

- Buffeting;
- Vortex shedding
- Galloping
- Flutter.

Slender structures are likely to be sensitive to the turbulence buffeting. Transverse or cross-wind response is more likely to arise from vortex shedding or galloping but may also result from excitation by turbulence buffeting. Flutter is a series of motions, which usually appears in a combination of bending and torsion and can result in instability.

However, wind flutter and galloping are generally not an issue for the buildings and cannot cause severe problems nor damage the structures.

More crucial and interesting to know is the connection between human response to vibration and perception of motion. Generally, humans are surprisingly sensitive to vibration to the extent that movements may feel uncomfortable even if they correspond to relatively low levels of stress and strain.

WIND SPEED

Understanding wind speed is just as important as understanding where the wind is coming from. Wind can gently rustle leaves on a tree, or it can cause severe structural damage to buildings. It all depends on how fast it is moving.

Wind speed is commonly measured in knots, miles per hour, meters per second, or feet per second. There are a host of conversion tools available online (example: NOAA Wind Conversion Tool).

The table below translates wind velocity to visual movement on land. It has been adapted from the Beaufort Wind Scale, a common scale for comparing wind speed that is used in many countries.

Table 1 Beaufort Wind Scale

WIND SPEED	DESCRIPTION	LAND CONDITIONS
<0.3 m/s	Calm	Smoke rises vertically
0.3 – 1.5 m/s	Light air	Smoke drift indicates direction; leaves are still
1.6 – 3.4 m/s	Light breeze	Leaves rustle; wind felt on skin
3.5 – 5.4 m/s	Gentle breeze	Leaves and small twigs moving; light flags extended
5.5 – 7.9 m/s	Moderate breeze	Small branches move; dust and loose paper rises
8 – 10.7 m/s	Fresh breeze	Moderate sized branches move; small trees sway
10.8–13.8 m/s	Strong breeze	Large branches move; umbrella hard to use
13.9 – 17.1 m/s	High wind	Whole tree moves; hard to walk against the wind
17.2–20.7 m/s	Gale	Twigs break from tree; extremely difficult to walk in wind
20.8–24.4 m/s	Strong gale	Branches break from tree; small trees blow over
24.5–28.4 m/s	Storm	Trees broken or uprooted; structural damage imminent
28.5–32.6 m/s	Violent storm	Widespread vegetation and structural damage
≥ 32.7 m/s	Hurricane force	Severe widespread vegetation and structural damage

At high points above the surface of the earth, where frictional effects are insignificant, air movements depend on the pressure gradients in the atmosphere, which arise as a thermodynamic consequence of variable solar heating of the earth. This wind speed at the upper level of the atmosphere is defined as the *gradient wind velocity.*

Different earth terrains can be categorized according to their associated roughness length. The following table explains it in depth.

Going closer to the surface the wind speed is affected by the frictional drag of the air stream over the terrain. Knowing the roughness length, a wind profile for different terrains can be made.

On the following picture it is possible, as well, to observe the windprofile applied to different terrain characteristics.

WIND COMFORT IN URBAN PLANNING

There is raising awareness about the quality of urban places and it has been

Table 2 Different earth terrains

Terrain category	Roughness length, (m)
Exposed open terrain with few or no obstructions and water surfaces at service-ability wind speeds	0.002 0.002
Water surfaces, open terrain, grassland with few, well scattered obstructions having heights generally from 1.5-10 m.	0.02
Terrain with numerous closely spaced obstructions 3 to 5 m high such as areas of suburban housing.	0.2
Terrain with numerous large, high (10 m to 30 m) and closely spaced obstructions such as large city centers and well developed industrial complexes.	2

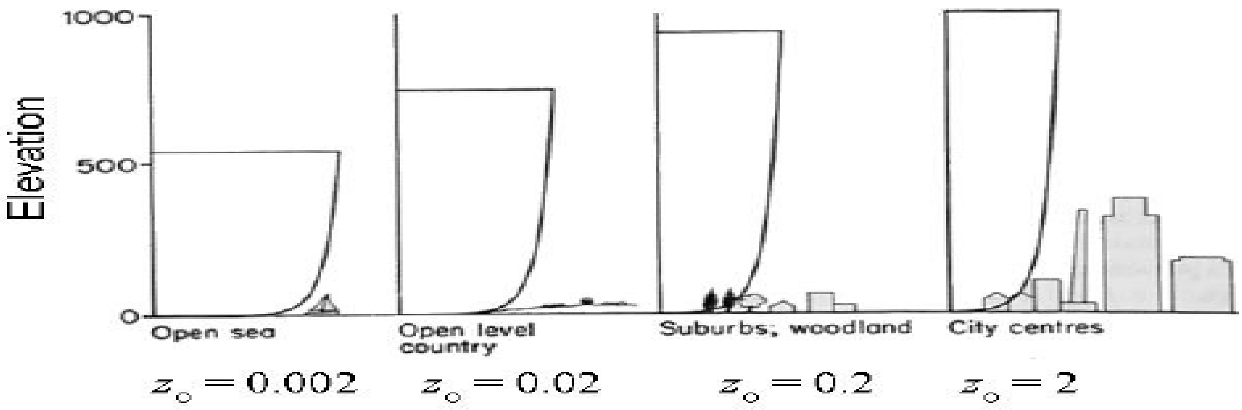


Figure 12 Mean wind profiles for different terrains

a constant topic of discussions. Wind is an important environmental factor that has an effect on the comfort and safety of the pedestrians.

Nowadays, in the modern cities there are more and more built high constructions and complex forms. It is paid more attention on the design and buildings to be attractive and appealing. However, a little attention is paid on the significant problems that appear after as a consequence of this sort of constructions. As a consequence there is a significant problem regarding wind discomfort around these buildings.

Therefore, architects and town planners need guidelines and simple design tools to take account of wind in their projects. In order to assess wind comfort in urban planning, there were done computational fluid dynamics simulations. (CFD) There was done a research using Fluent software for wind studies in urban environments and results were compared with wind tunnel tests. The research showed that the wind mean velocity around buildings can be simulated numerically with a very high degree of accuracy. Based on the results that came out of the usage of the Fluent software, there were identified different wind types and wind speeds around buildings. (P. Mendis, T. Ngo, N. Haritos, A. Hira, 2007)

ROLE AND LOSS OF URBAN SPACES

Throughout the history, urban public space has always played a central role in the life of cities. Nevertheless, modern cities have been significantly influenced by economical and technological demands. As a result, this has affected the public spaces and caused their loss. (Madanipour, 1999) and a loss of climate responsive design (Eliasson, 2000; Ryser and Halseth, 2008). In nowadays world of increasing urbanization, if society wants to focus and improve sustainable development, the urban quality is a first thing on the list of accomplishments to fulfill.

Pedestrians' outdoor comfort in urban spaces is a key factor for their usage by local population. (Sigrid Reiter, 2001)

Local wind speeds and solar radiation

are the only microclimatic parameters that depend widely on urban planning, particularly on the site location, building forms, geometry and orientation of open spaces. Therefore, urban designers can play on the interaction between these climatic parameters and the urban morphology to promote pedestrians' comfort in public spaces. Despite the fact that *"wind speed at pedestrian level is one of the most important environmental parameter determining user satisfaction in urban open spaces"* (Stathopoulos, 2006; Tacken, 1989; Walton, 2007) it was often denied by the urban planners.

CFD-COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics, usually abbreviated as CFD, and as mentioned above, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows.

CFD modelling is a more cost-effective and time-saving design tool for wind engineering studies. Moreover, CFD simulations give a quantitative wind flow representation of the whole volume simulated and not only in a few specific points related to the presence of measure instruments.

Good knowledge in fluid mechanics are required to use CFD simulations correctly. That involves choosing simulation volume dimensions, boundary conditions, grid resolution, turbulence model etc.

According to the study done by Dutch specialists, regarding the wind, 15 m/s of the speed presents a danger for pedestrians.

In the following table, it is possible to observe the division of the wind comfort by the wind values.

For comfort:

- P stands for probability, (U>5 m/s);
- U for average hourly wind speed at 1.5 m above the ground. Pmax is given in the table down.
  For safety: U>15 m/s and attached table above.

Tools that have been developed to detect various wind effects and they can be separated in three groups:

1. For a simple isolated building or an urban building located next to a large open space: the corner effect, the passage effect, the front vortex, the wake effect and the bar effect.
2. For wind flows around little groups of buildings that are isolated or located next to a large open space: the double corner effect, the Venturi

Table 3 Values acceptable for wind comfort (Willemsen and Wisse, 2007)

In % hours per year	Grade	Activity-Traversing	Activity-Strolling	Activity-Sitting
<2.5	A	Good	Good	Good
2.5-5	B	Good	Good	Moderate
5-10	C	Good	Moderate	Poor
10-20	D	Moderate	Poor	Poor
>20	E	Poor	Poor	Poor

Table 4 Values of P acceptable for wind safety (Willemsen and Wisse, 2007)

Table: Values of P acceptable for wind safety (Willemsen and Wisse, 2007)	
Value of P in % hours per year	Danger for all activities
<= 0.3	Limited risk
> 0.3	Dangerous

effect and the mesh effect.

3. For wind flows in dense urban areas: the urban mask effect and the high-rise building effect in a dense urban environment.

WIND EFFECT ACCESS

In order to access different wind effects, there are certain tools:

- the corner effect around an unsheltered building
- the front vortex around an unsheltered building
- the double corner effect between two buildings
- the mesh effect
- the corner effect around a high-rise building located in a dense urban zone.

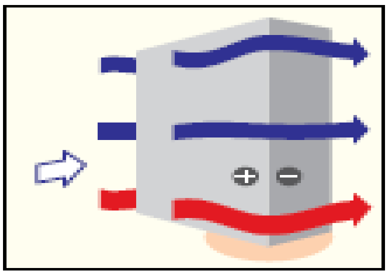


Figure 13 The Corner Effect

1. **The Corner effect** is the acceleration of the wind at the corners of the building façade exposed to the wind.

The building height is the key parameter influencing the corner effect around a single building. More the building is high, more critical are the wind discomfort zones. In order to limit the corner effect, it is advisable to reduce the height of the building zones along the public spaces, especially around corners.

2. **The front vortex around an unsheltered building**

The wind effect is uncomfortable for buildings whose height is greater than 60 m. However, for buildings whose height is less than 50 m, there is a protection zone upwind of the building. For building height going above 100 m, the front vortex seems completely separated.

Fig.6 : The front vortex.

3. **The double corner effect between two unsheltered buildings**

This type of the effect does not exist if the width between buildings is less than 6 m.

Porous elements such as trees, permeable screens, placed in a passage between buildings can reduce the discomfort risk. A building located in front of the entrance of this passage between buildings can also prevent the double corner effect.

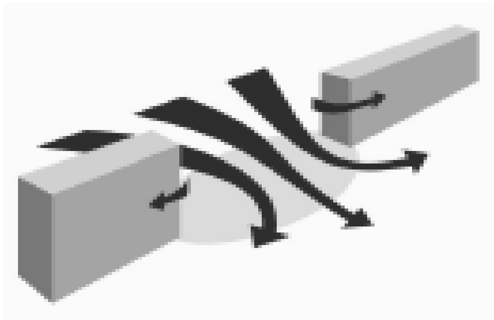


Figure 15 The Double corner effect

4. **The mesh effect** is the effect that appears in many European cities. It is typical to appear in closed urban blocks where the wind strikes the building and since it cannot pass through it or cannot find any other hole in the building, it goes up and continues moving above the mentioned urban block.

Despite the height of the buildings and direction of the wind, the interior of the buildings offers wind protection.

Additionally, if the whole surrounding city blocks are of the same height, that can create even better and more efficient wind protective effect.

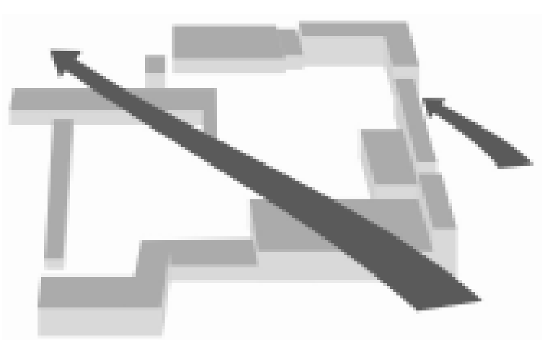


Figure 16 The mesh effect

5. **The corner effect around a high-rise building located in a dense urban zone**

Tall buildings are building whose height is at least double the average height of the surrounding buildings. Concluded out of research, the presence of a high building changed entirely the flow of the air in the nearby streets. The critical zone covers a circle whose radius is the height of the tall building.

Concluding, for the tall buildings the best solution in terms of wind protection is always decreasing the height. It is hard to achieve a harmony between high-rise buildings and pedestrians' comfort. It is crucial to avoid a development of high-rise buildings close to relaxation places, squares, playgrounds. No matter that certain wind protection can be created in terms of windbreaks, at many times they cannot be reliable and they might create wind flows in unwanted directions.

TYPICAL LOCATIONS OF STRONG WIND IN BUILT UP AREAS

When a gust of wind hits a tall building's surface, it tends to reflect towards the ground causing high-speed winds on the windward side, as well as near

Figure 17 The Corner Effect

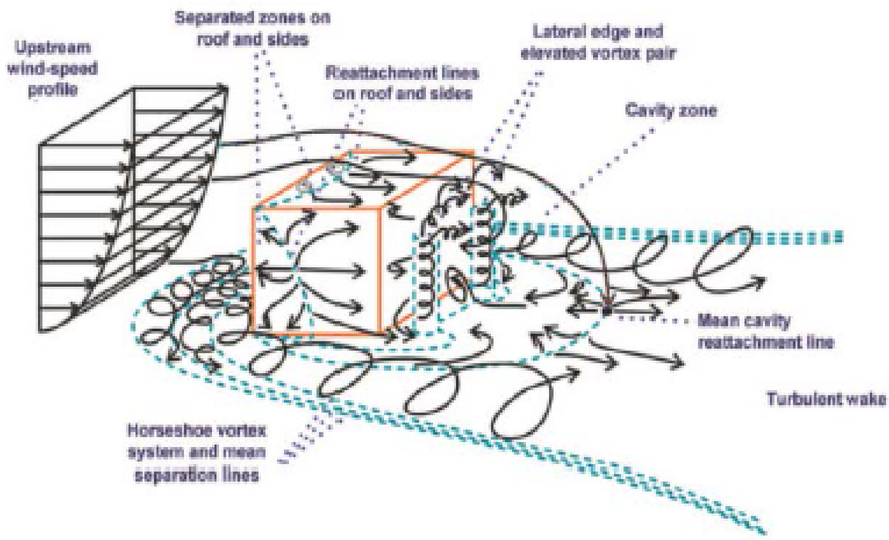


Figure 18 Regions of high surface wind speeds around a tall building

corners of the buildings at street/ pedestrian level. In case of a strong wind, occurrences at pedestrian areas often occur at the three regions and are associated with the three types of flow, as shown on the graph.

Three types of flow:

FIRST TYPE. Vortex flow between buildings, near ground level,

SECOND TYPE. Descending air flows passing around building corners,

THIRD TYPE. Air flows passing through passages at ground level connecting the windward and leeward sides of building. (M. Fadl and J. Karadelis, 2013)

PEDESTRIAN COMFORT

Pedestrian comfort criteria are based on mechanical wind effects without consideration of other meteorological conditions (temperature, relative humidity). These criteria provide an assessment of comfort if assuming that pedestrians are appropriately dressed for a specified outdoor activity during any given season. There are five types of pedestrian comfort classes defined. (ted Stathopoulos, 2006)

IV. WIND DESIGN ON TALL BUILDINGS

When designing a simple low rise and medium-rise building applying simple techniques for wind loading treatment is acceptable. However, when building constructions that go high in the sky, or with other words-high-rise buildings or even skyscrapers, simple methods are not good enough. Such a simple treatments can lead to unwanted results and can cause under-estimations. What is the most crucial, applying just superficial techniques for wind loading, neglect many factors which are of great important when constructing high buildings. These factors are: dynamic response (effects of resonance, acceleration, damping, and structural

Table 5 Comfort Classes

Comfort Classes	Description	Location types (Examples)
Sitting	Occurrence: >70% of the time. Acceptable for sedentary activities, including sitting	Outdoor cafes, patios, terraces, benches, Gardens, Fountains, Monuments.
Standing	Occurrence: >80% of the time. Acceptable for standing, strolling, etc.	Building Entrances, Exits. Children's Play Areas
Walking	Occurrence: > 80% of the time. Acceptable for walking, or rigorous activities	Public/Private Sidewalks Pathways. Public/Private Vehicular Drop-Off Zones
Uncomfortable	Occurrence: >20% of the time. Unacceptable for walking	
Dangereous	Occurrence: > 0.01 % of the time. Dangerous to walk	

stiffness), interference from other structures, wind directionality and cross wind response.

WIND LOADS

Wind load is defined as the horizontal load used in the design of a structure to account for the effects of wind.[2] The characteristics of wind pressure on a structure are a function of the characteristics of the approaching wind, the geometry of the structure that is considered, and the geometry and proximity of the structures upwind. The pressure hitting the building is not constant, but it varies, partly as a result of the strength of the wind, partly a result of local vortex shedding at the edges of the structures themselves. The pressure that fluctuates can create fatigue damage to the structures. Also it must be known that pressure are not uniformly distributed all over the surface of the structure analyzed. It depends on the position of the building. (Bijan Samali, 2007)

Regarding the design documents and applying standards when constructing, it should be kept in mind that the standards do not apply to buildings or structures that have uncommon shape or location.

There can be differentiated two types of wind loads and they will be discussed in the following sections.

ALONG AND CROSS-WIND LOADING

When wind approaches and hits the building, a complex air stream is created. This complex air stream rises as a result of the distortion of the mean flow, flow separation, the formation of vortices and development of the wake. As a consequence of these effects, large wind pressure fluctuations can occur on the surface of a building. As a result, an intense localized fluctuating forces carry on the façade of these structures. Under these fluctuating forces, a buildings tends to vibrate in rectilinear and torsional movements, as shown on the picture. The amplitude of the oscillations depends on the nature of the forces and the dynamic characteristics of the building observed.

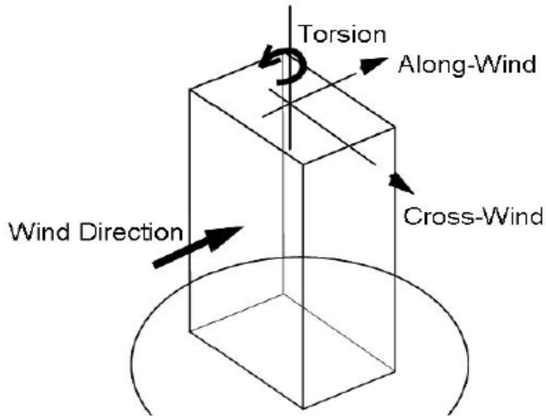


Figure 19 Wind response direction

1.1. ALONG-WIND LOADING

Along-wind is the term which refers to drag forces. Pressure fluctuations on windward face (building's frontal face that wind hits) and leeward face (back face of the building) as well as wind load interaction with buildings causes along-wind load (Ilgin and Günel, 2007; Dagnew, 2009). Some techniques, such as the "gust loading factor" approach, are developed to predict forces and response in the along-wind direction (Li et al., 2004). The gust factor approach is used in international standards and codes to evaluate the dynamic along-wind forces and their effects on tall buildings (Zhou, 2002).

1.2. ACROSS-WIND LOADING

Across-wind response is a perpendicular fluctuation response of wind excitation (Ilgin and Günel, 2007). In tall buildings, across-wind excitation is divided into three mechanisms: vortex shedding, incident turbulence, higher derivatives of a cross-wind displacement (galloping, flutter and lock-in) (Mendis, 2007). In recent years, there have been vast theoretical and experimental investigations about the across-wind effects on tall buildings (Liang, 2004).

a) **Vortex shedding**. Tall buildings are bluff bodies that cause the flow to separate from the surface of the structure, rather than follow the body contour.
b) **The incident turbulence.** This mechanism refers to the situation where the turbulence characteristics of the natural wind give rise to changing wind speeds and directions that directly make varying lift and drag forces and pitching moments on a structure.
c) **Higher derivatives of crosswind displacement.** There exist three commonly known displacement dependent excitations: galloping, flutter and lock-in.

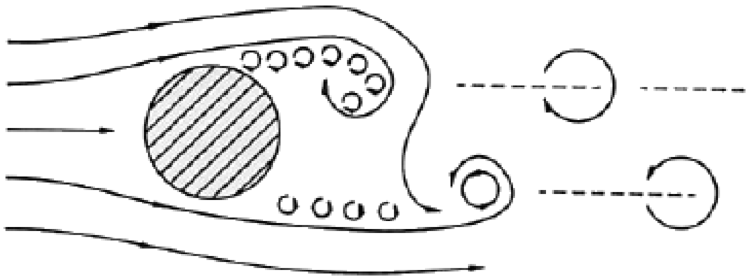


Figure 20 Vortex formation in the wake of a bluff object

COMPARISON OF EVALUATION OF THE ACROSS-WIND AND ALONG-WIND RESPONSE

Tall buildings are very sensitive to cross-wind motion. This sensitivity becomes obvious as wind speed rises. In the design of tall buildings, the cross-wind response usually controls over the along-wind response (Ilgin and Günel, 2007). The wind tunnel test of tall buildings demonstrates that maximum acceleration in cross-wind direction at design wind speed is more than along-wind direction (Gu & Quan, 2004).

When the building vibrates in along-wind direction (e.g., in Y-direction), cross-wind motion also happens simultaneously (in X-direction). For the same wind speed, actions responses of cross-wind (in X-direction) are more than the along-wind responses (in X-direction) and are less than the along-wind responses (in Y-direction). This obviously shows that response of cross-wind is comparable to the along-wind responses (Wu et al., 2007).

WIND DESIGN TYPES

For the structures that are sensitive to wind, there exist three main types of the wind effects that need to be considered:

1. **Environmental wind study**-investigate the wind effect on the surrounding environment caused by the high-rise buildings. This study is important in order to understand the effect that wind has on the pedestrians, motor vehicles and for instance, fountains that are present in the city and are in near position of the analyzed structure.
2. **Wind loads for façade**-is important to perform in order to understand what would be the best solution for designing the cladding system of the building. Having in mind the cost of typical façade system is significant in the proportion to the overall cost of constructing tall buildings. It is necessary, right from the beginning to perform well the cladding system, so that afterwards maintaining costs of the buildings would be low. Normally maintaining costs are high due to the leaking and/or structural failure.
3. **Wind loads for structure-**to determine the design wind load for designing the structure in order to satisfy various design criteria. (P. Mendis, T. Ngo, N. Haritos, A. Hira, 2007)

DESIGN CRITERIA

In order to design a building or a specific structure in an efficient way, for the lateral wind loads, the following criteria should be respected.

1- **Stability** against overturning, uplift and sliding of the structure as a whole.

2- **Strength** is important for the building in order to be stable and to resist the wind loading during the overall lifetime of the structure.

3- **Serviceability**- is important for buildings because overall deflection are expected to remain within acceptable limits. Keeping under control is a must in a case of tall buildings. Serviceability serves to limit damage and prevent cracking of non-structural elements such as: façades, ceilings or other inside-buildings fragile elements.

COMFORT CRITERIA

International standards for comfort criteria in tall buildings design, generally accepted-do not exist. Nevertheless, there were performed researches and analyzes in order to understand the psychological parameters affecting human perception. The frequency range of the human perception has been detected between 0-1 Hz. The parameters include inhabitant's expectancy and experience, activity, body posture and orientation, visual and acoustic cues, and the amplitude, frequency, and accelerations for both of the movements: translational and rotational. The following table showed the human comfort criteria. (Sigrid Reiter, 2010)

WIND TUNNEL TEST

Wind tunnel testing is now common practice for designing most of the tall buildings. As a matter of fact, the owners often are asked to allow the building for wind tunnel testing, as the costs made for these testing can be afterwards taken off from the costs that would be spent on building energy savings. In such way, costs would be lower due to the reduced design wind loading.

Wind tunnel testing is a powerful tool that helps engineers to determine the nature and intensity of wind forces acting on complex structures. This technique is especially useful when analyzing the complex built structures and complex surrounding terrains, which as a consequence gives complex wind flows.

There are two types of technique that can be performed while wind testing the building:

1. **Aero elastic modeling.** Aero-elastic modeling technique is used to directly measure the dynamic loads in the wind tunnel. The main objective of this technique is to obtain more accurate prediction of the wind loads.

2. **Interference.** Buildings of similar size located in close proximity to the proposed building can cause large increases in cross-wind responses. Therefore, as a guidelines

Table 6 Human perception levels

LEVEL	ACCELERATION (M/S^2)	EFFECT
1	<0.05	Humans cannot perceive motion
2	0.05-0.1	A) Sensitive people can perceive motion B) hanging objects may move slightly
3	0.1-0.25	A) majority of people will perceive motion B) Level of motion may affect desk work; C) Long-term exposure may produce motion sickness
4	0.25-0.4	A) Desk work becomes difficult or almost impossible; B) Ambulation still possible
5	0.4-0.5	A) People strongly perceive motion B) Difficult to walk naturally C) Standing people may love balance
6	0.5-0.6	Most people cannot tolerate motion and are unable to walk naturally
7	0.6-0.7	People cannot walk or tolerate motion
8	>0.85	Objects begin to fall and people may be injured

interference arose due to two of the buildings of a similar size, which are located within a distance equal to 1 times the building width, needs to be considered. (P. Mendis, T. Ngo, N. Haritos, A. Hira, 2007)

WIND TUNNEL TEST-WAY OF FUNCTIONING

Wind tunnel testing involves blowing air on the building model under observation and at building's surrounding at various angles relative to the buildings orientation representing the wind directions. This is performed in a way that entire model is placed on a rotating platform within the wind tunnel. Once a testing is completed for the desired wind direction, the platform is rotated and a testing for a new wind direction can befall.

NATURAL VENTILATION

In terms of building orientation, natural ventilation can be maximized by exposing windows and openings to prevailing breezes. In the case of Rio de Janeiro city, prevailing winds tend to be coming from the south, with occasional north winds. Buildings oriented on an east-west long axis could be expected to have the lowest possible solar gain whilst providing good opportunities for cross-ventilation. See the natural ventilation section of this toolkit for more information.

CASE OD RIO DE JANEIRO, BRAZIL

Cross-Sectional Shape: High Rise Buildings

For high-rise buildings, 87% of total annual solar insolation is incident on vertical surfaces. This means that manipulating the cross-sectional shape of a building can strongly influence solar gain.

Research suggests that a circular shape with a width to length ratio of 1:1 is optimal for minimizing total solar insolation in high-rise buildings. For square shaped buildings, a width to length ratio 1:1 in a north-south orientation receives the lowest annual total solar insolation. Square shaped high rise buildings can receive as much as 33% more solar radiation compared with buildings having a circular cross section. Building shape should be carefully considered when planning for high-rise developments in Rio de Janeiro.

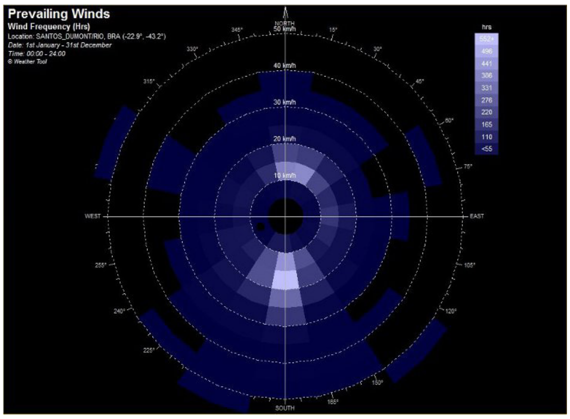


Figure 21 Cross-Sectional Shape

V. BUILDING MASSING, ORIENTATION, DENSITY AND SPACING

BUILDING MASSING

According to the **Guide from Singapore's Building and Construction Authority (2010),** for many building types, massing is one of the most important factors in passive heating, cooling, and daylighting, yet often these are not considered until after massing is finished. It is important to begin considering passive design strategies in the massing stage, so that the surface areas exposed to sun at different times of day, building height, and building width can all be optimized for passive comfort.

“Massing” is deciding on the overall shape and size of the building. Will the building be tall or short or perhaps long and thin are the questions that needs to be answered. Will it have significant cutouts, or be more solid? Successful massing uses the general shape and size of the building to minimize energy loads as much as possible and to maximize free energy from the sun and wind.

In the image below, “Opt 2” has the same area as “Opt 1” but uses less than half the energy, because of better massing.

Massing decisions depend on the specifics of the project site and goals. BIM tools can provide designers with early conceptual energy analysis to test different massing options. This analysis can take into account how site features like natural land formations, surrounding buildings, or vegetation affect the performance of the design. Such features can shade the sun and change wind patterns, so this is especially important for thermal comfort and daylighting comfort. They can also affect acoustics, rainwater harvesting, and other performance factors. (BIM-Building Information Modelling)

MASSING FOR BUILDING-PROGRAM AND BUILDING FOR SPECIFIC CLIMATES

The right massing depends on the building’s program. Sparsely populated buildings with little activity or equipment, such as many homes, generate relatively little heat from internal loads. In cold climates, they benefit from compact floor plans to avoid losing heat to the outside. This minimizes the ratio of surface area to volume, lowering heat loss to wind and radiant cooling.

On the other hand, densely populated buildings with high activity and/or

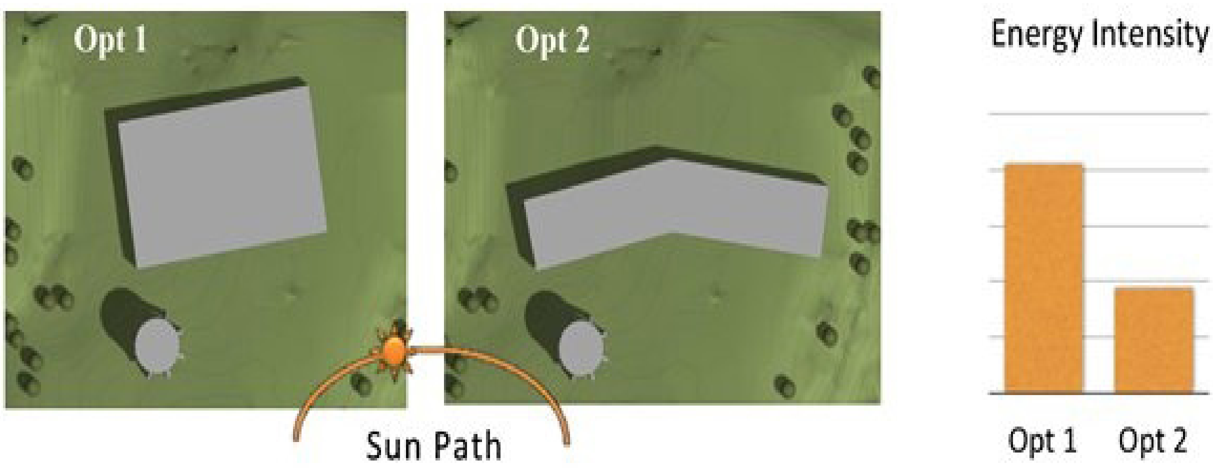


Figure 22 Building massing

energy-intensive equipment generate a great deal of heat, causing high internal cooling loads. Thus, even in colder climates it may be advantageous for such buildings to have thinner floor plans, to get more cooling for free.

Sophisticated massing can go even further to optimize heat gains or cooling. For instance:

- Roofs can be angled for optimal solar heating.
- Reveals and overhangs can shade parts of a building with other parts of the same building.
- Aerodynamic curves can reduce heat loss from infiltration.
- Interior buffer zones can be placed in a building's west side to protect living and working areas from the hot afternoon sun (for example stairs, restrooms, entry corridors, etc.)

  Whether your massing is simple or sculptural, you should perform basic energy modeling simulations of many different options.

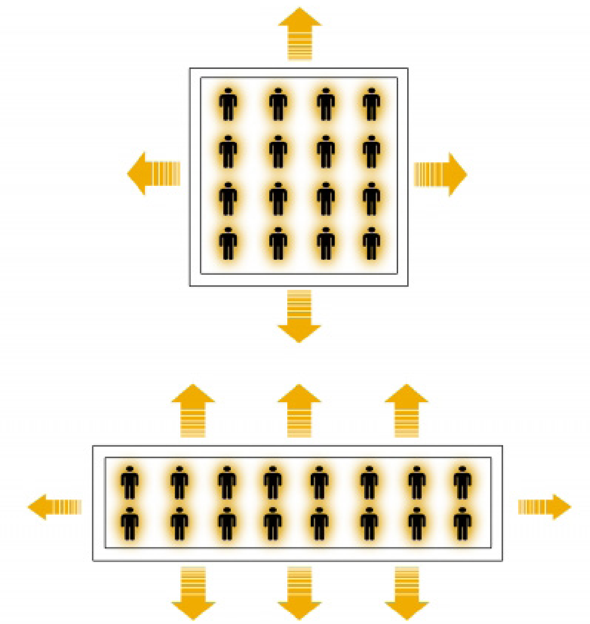


Figure 23 Thinner buildings lose more of their internal heat to the outside

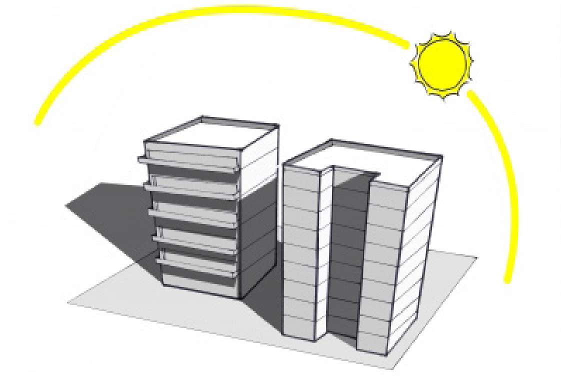


Figure 24 Using building mass or overhangs to create shade

BUILDING ORIENTATION

Orientation is simply what compass direction the building faces. Does it face directly south? 80° east-northeast? A desirable orientation varies to the climate and to the need for sun or shade and a cool breeze or wind shelter. Choosing the best orientation is not an easy task, especially, when a trade-off between hot and cold season performance is required.

The orientation with respect to the sun affects solar heat gains and air temperature of the area. The orientation with respect to wind affects ventilation heat losses. It is less predictable if compared to that of the sun since the path of sun is known all year round, but the direction or even the prevailing wind is likely to fluctuate either side of its principal and it changes from year to year.

- In urban design, there are two things that need to be considered. The first one is the most important one in the low-density urban areas: the orientation of the building. The second is the orientation of streets and open spaces, which could affect the sitting of buildings along the street.

In medium and high-density urban forms, orientation of urban street canyons definitely affects the overall orientation of the buildings. (EchoWho, NJ Green Building Manual)

Orientation is measured by the azimuth angle of a surface relative to true north. Successful orientation rotates the building to minimize energy loads and maximize free energy from the sun and wind.

URBAN BUILDING DENSITY

Building density has a complex effect on external air temperature because it depends on many other aspects. Building density is a ratio connected to other types of ratio such as: vegetation and building surface/volume ratio. It has an inverse relationship with each of them.

For instance, when building density increases-vegetation and surface/ration decreases. On the other side, it is

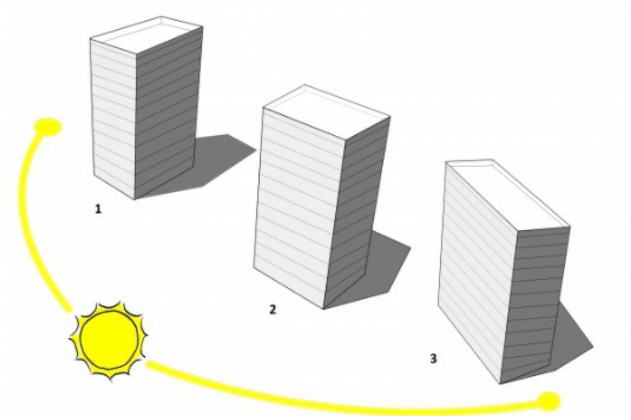


Figure 25 Different building orientations

directly proportional to anthropogenic heat release. Vegetation absorbs the temperature, which results in the decrease of the air temperature. That means that the decrease of vegetation area causes warmer temperatures during the day. Increasing building density normally means increasing population density. With increment of the population, the activities of the people increase, and that as a consequence increases the anthropogenic heat and consequently the external air temperature.

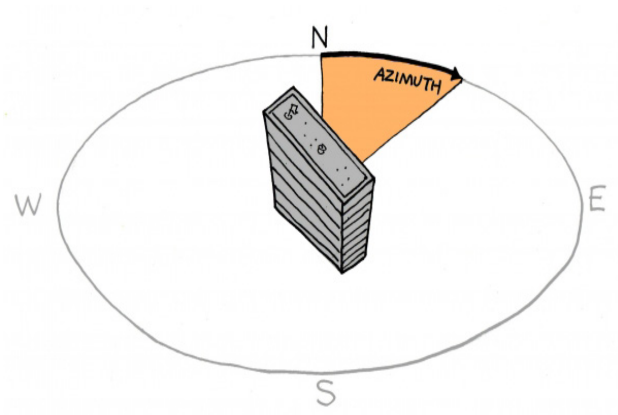


Figure 26 A building's orientation is measured by azimuth

Another term needs to be introduced: building thermal mass. Building thermal mass affects the night-time temperature pattern. As the building mass is greater, the temperature released during the night is greater too, and as much is stored during the day. Concluding, increasing the building mass causes warmer night time and cooler daytime temperatures. (Baruch Givoni, 1998, Mohamed M. Elnahas, 2003)

BUILDING SPACING

Building space is a term that is expressed with a ration between building height (H) and street width (W)-aspect ratio-H/W. Aspect ratio has a significant impact on air temperature variations.

Deeper canyons increase both thermal inertia and shaded areas, but decrease the sky factors. Decreasing a sky factor results in a roughly steady temperature increase over the course of the day. However, the increase of shaded areas cause a more noticeable temperature decline. (Mohamed M. Elnahas, 2003)

VI. When building…

TAKING SUN AS ADVANTAGE

This section will provide useful tips and offer the facts that should be followed when orientating the house.

The Sun rises in the East and sets in the West, no matter where you are in the world. The Sun is higher in the summer sky and lower in the winter sky.

The fact the sun is lower in the sky in winter than in summer allows us to plan and construct buildings that capture that free heat in winter and reject the heat in summer. The orientation of the whole building plays an important part in ensuring such a 'passive' process works. A diagram for better understanding is provided below. (EchoWho, 2015)

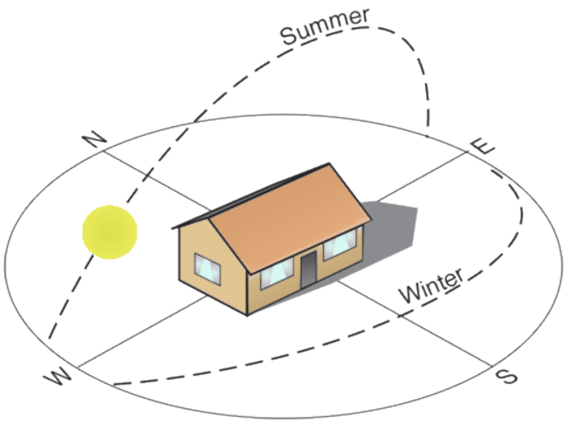


Figure 27 Building orientation sun path

IDEAL HOUSE ORIENTATION

The ideal house orientation is that the main long axis of the building runs East-West- the ridge line. We can move this by as much as 20 degrees without ill effect, but the most glass on the building must be facing towards the Sun. When deciding the building orientation also take into account the location of landscape features on your plot, such as trees and walls, which will impact on how we harness the Sun. Ideally you do not want them blocking the sun light as the sun tracks across the sky.

ROLE OF WIND

Wind provides natural ventilation and usually cools buildings and people because it accelerates the rate of heat transfer. Wind speed and direction changes throughout the day and year, and is not as universally predictable as the sun's movement.

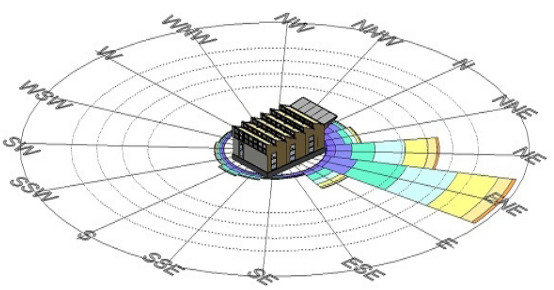


Figure 28 Wind speed and direction during a day

As an asset, wind can help facilitate natural ventilation and passively increase occupant comfort – think of a nice breeze on a hot day. The wind can also be harnessed to generate electricity via windmills, although this is typically not as efficient as solar energy for small scale applications.

As a hindrance, wind can drive moisture and water up through small gaps in your building envelope, resulting in potentially devastating consequences if not properly controlled.

PREDICTING WIND BEHAVIOR

Air flows from high pressure to low pressure. This is important to remember because this is the basic principle behind wind ventilation and stack ventilation.

When wind encounters an obstruction, it will flow around the object and continue moving in the same direction. This is similar to the flow of water (both air and water are fluids. It is important to note that if wind is blocked by a landform or surrounding building, the wind is not stopped, but rather just deflected.

Wind speed varies with height and terrain. As elevation increases, so does wind speed. As terrain becomes rougher, the rate at which wind speed increases slows. This means that the wind speed in an open, rural, environment will increase with height much more quickly than the wind speed in a dense urban center. This rate of increase is known as a wind gradient, or wind profile. As a result, wind velocity can vary between different terrains at the same elevation.

In dense urban environments, wind will reach 100% velocity at a much higher altitude than an open environment with no buildings. This can be seen in the image below.

WIND AND MICROCLIMATES

Environmental surroundings can create microclimates that could significantly alter the wind patterns on the site. Prevailing wind directions can change due to adjacent landforms, buildings, and/or other objects. If a person is in a different microclimate than the nearest weather station, he cannot reliably use that data to guide your design. Features to pay attention to are large bodies of water and changes in elevation. Modeling the surrounding area, and measuring conditions on the actual site, can provide better information on the exact wind conditions of that site.

While microclimates can lead to unpredictable winds, there are some general assumptions that can be made about the behavior of air flow. Near bodies of water, the land is hotter during the day, so as the air over the land gets warmer and rises, it is replaced by cooler air coming from over the water – so the wind blows from the water onto the land. At night, this effect is reversed. The water is warmer than the land, so the air over the water gets warmer and rises and is replaced by the cooler air coming from over the land – so the wind blows from the land to the water.

During the day in a valley, wind will blow uphill because the sun warms the air and causes it to rise. At night, wind will blow downhill because the air is cooled by the cold ground surface causing it to sink into the valley.

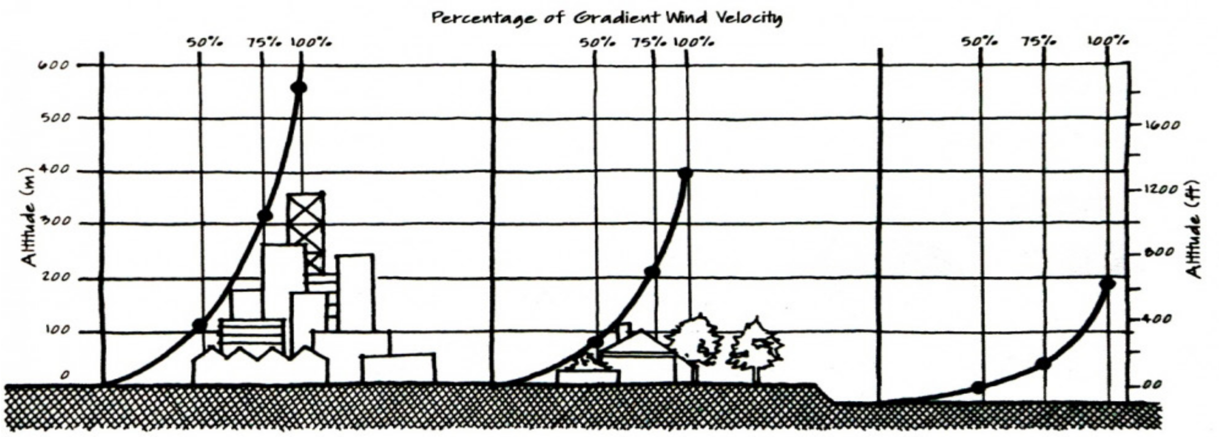


Figure 29 Percentage of gradient wind velocity

VII. Previous case studies on the urban comfort

The following part of the work is a review of an experimental study conducted in several cities, dealing with outdoor comfort. It describes the research procedures of the studies, presents certain selected experimental results and discusses the problems encountered in the conduction of the research and in the analysis of the data.

CASE STUDY 1- JAPAN PROFILE

The Fujita Corporation conducted research, monitoring the thermal sensation and overall comfort of subjects staying outdoors in Japan in 1994–1995. The objective of this research was to determine the quantitative effect on the comfort of Japanese persons dressed according to the common practice in the different seasons, of various design features of squares, which can modify the sun and wind exposure conditions during different seasons.

RESEARCH PROCEDURE

The research was consisted of a questionnaire surveys on the subjects' sensory responses and included physical measurement of outdoor climate data.

The subjects' group involved six persons, males and females, ranging from the twenties to the fifties. They worked in three pairs, each pair staying in one area for 20 min and moved to a different one. It meant that after 1 h a pair would finish staying in all the three areas: exposed to the sun and undisturbed wind, exposed but with reduced wind and in the shade and undisturbed wind. This procedure was repeated seven times a day. In each 'test' the subjects were asked to sit still in their chairs for 15 min to get used to the condition, and filled in a questionnaire in the remaining 5 min.

The common outdoor clothing in Japan for a given season was selected for each season:

1. Spring and autumn: long-sleeve shirt, jacket and trousers (CLO value ¼ 1:1).
2. Summer: short-sleeve T-shirt and trousers (CLO value ¼ 0:65).
3. Winter: long-sleeve shirt, knitted

jumper, thick jacket and trousers (CLO value ¼ 1:67).[3]

The questionnaire was mainly concerned with thermal sensation and overall comfort. Thermal sensation is the perception of heat or cold, on a scale of one (very cold) to seven (very hot). The scale of the overall comfort level is from one (very uncomfortable) to seven (very comfortable).

METHODOLOGY

The experiments were conducted under controlled solar insolation and wind speed in order to understand how these physical factors influence the thermal sensation and the comfort level of Japanese persons staying in outdoor spaces.

A grassed open space and an asphalt parking area in a park in Yokohama city were chosen as the sites for the experiments.

The subjects were divided into three groups with different exposure conditions at very small distances between them. The first group was sitting under a large shade tree (TREE). The second group was sitting in a nearby open area exposed to the sun (SUN). The third group was also in the open area but behind a vertical wind break made of transparent polyethylene sheets supported on wood frames (WIND BREAK). The groups were rotated between the three exposure sites so that, on the average, every subject was exposed to the same conditions. The groups were rotated between the three exposure sites every 20 min so that, on the average, every subject was exposed to about the same conditions.

The study was carried out through different seasons, starting from the summer of 1994 to the summer of 1995. It lasted 9 days. In each season experiments were conducted during 2 days, where every experimental day initiated at 9 am and ended at 5 pm.

The measured environmental physical factors were:

- Air temperature in the shade (Ta, 8^{o}C),
- horizontal solar radiation (SR, W/sqm),
- wind speed (WS, m/s),
- relative humidity (RH, %) and
- the surrounding ground surface temperature (ST, 8^{o}C).

The climatic measurements were carried out every hour in each test area.

RESULTS

By comparing rapid consequent measurements of the horizontal solar radiation intensity 'in the sun' and under the shade tree the shading effectiveness of the trees was evaluated. The radiation intensity under the tree was about 10% of the radiation at the exposed sites in the summer and fall seasons. In the winter and spring seasons, when the trees' foliage was less dense, the radiation under the tree was about 20%

*CLO VALUE=Cloth and Thermal Insulation
Nude person: CLO=0; the lowest CLO value
Eskimo: CLO=4; the highest CLO value due the thickness of the clothe

of the radiation in the open area. The wind speed behind the wind break was about 50% of the speed at the exposed site.

Thus, the experimental results of this study suggest that a hange of 59 W/sqm in solar radiation, and a change of 0.35 m/s in wind speed, had similar effect to a change of 1 ^{O}C in air temperature. (Mikiko Noguchi, Hadas Saaroni, 2003)

CASE 2-TEL AVIV, ISRAEL PROFILE

A number of experimental studies are being conducted at the Department of Geography of Tel Aviv University in Israel, dealing with the impact of green area on the microclimate.

These studies involved measurements of the air and surface temperatures, humidity, wind speed, and solar radiation.

Several of these investigations include also the monitoring of comfort sensations of the students engaged in the research. In this way, the correlation between the comfort sensations and the climatic condition measured at the same time can be analyzed.

RESEARCH

An experimental research, monitoring the climatic conditions, thermal sensation and overall comfort, of subjects staying outdoors, is being conducted in an urban park in Tel Aviv, Israel. The objectives of this research were to study the climatic effect of a small lake, during different warm weather systems, as well as its effect on human comfort.

RESEARCH PROCEDURE

The research involved climatic measurements in the park and a questionnaire surveys on the subjects' sensory responses. The park consists mainly from open grass areas with several areas of trees. A lake (4 hectar) is located at the south edge of the park surrounded by open area with minimal vegetation, i.e. several isolated trees. Two experimental days were chosen under two different weather conditions: 17th May and 1st June, 2000. Measurements were taken during daytime, from 07:30 am to 06:30 pm.

Four stations were located surrounding the lake (at a distance of 3–5 m from the waterside) on open grass surface. Two more stations were located 300 m on the upwind of the lake, one on open grass surface and the second under a tree with large canopy. All surfaces were not irrigated during the measurement day and the day previous to the day of measurement.

Shade was provided near the four stations in the open areas by umbrellas.

The measured environmental factors included air temperature (8C), horizontal solar radiation (W/sqm), wind speed (m/s), relative humidity and the surrounding ground surface temperature. Solar radiation was measured on exposed surface and under a three, whereas the other parameters were measured in six fixed stations in Stevenson screens that were set in the park.

RESULTS

Comparison of rapid consequent

measurements of the horizontal solar radiation intensity 'in the sun' and under the shade tree have demonstrated that the radiation intensity under the tree was about 10% of the radiation at the exposed sites. The radiation under the umbrellas was estimated to be 30 % of the radiation in the open area. The wind speed at the stations surrounding the lake was up to four times stronger than at the location far from the lake.

The research also utilized a questionnaire surveys on the subjects' sensory responses. The subjects' group consisted of 10 persons, males and females, in their twenties. The subjects wore light T-shirts, the common outdoor clothing in Tel Aviv.

The subjects worked in pairs. Each person of a pair stayed 15 min in the sun and 15 min under a shade. They filled the questionnaire every 30 min. In each 'test' the subjects were asked to sit still in their chairs for 10 min to get used to the condition, and to fill in the questionnaire in the remaining 5 min. Every 2 h the pairs of subjects changed their location. The questionnaire was mainly concerned with thermal sensation and overall comfort. Thermal sensation was marked on a scale of zero (very cold) to nine (unbearable heat) when a level four is neutral, when one does not feel any thermal discomfort, he feels well. The scale of the sensible perspiration is from zero (very dry) to seven (all cloth are wet).

The differences in air temperature and solar radiation between the five un-shaded stations were relatively small (up to 2.68 ^{o}C between the stations on the upwind and the stations at the downwind of the lake). (Oded Pochter, Yaron Yaacow, Noa Feller, 2003)

CASE STUDY 3-CAMBRIDGE PROFILE

In the case of Cambridge, four case study sites have been chosen, located in the city center. They have been designed for the external public use and they are urban squares, streets or parks with strong commercial activities. Moreover, they are popular in terms of public use. The four sites differ from the point of view of typology, geometry, orientation and intended use but all of them are a part of the urban context and are used as places for relaxation.

The study of the sites has took place during spring, summer and winter of the 1997. There were 1431 people in total involved and interviewed. One week was spent at each site, each season. 2h on the lunchtime, 3 weekdays and the weekend, to get the weekly pattern of use, since weekdays tend to be quite different from the weekends.

A portable mini station has been always put next to the person interviewed who was always sitting. The mini station has been recording environmental parameters as air temperature, solar radiation, wind and humidity. After the analysis was finished, the results were compared with behavior of the person in order to evaluate the thermal comfort conditions that people experience.

AIM OF RESEARCH

The first issue was to understand

whether the thermal and comfort conditions affect people's use of outdoor spaces. To do so, researchers counted the people who were using the spaces at various intervals and they calculated it for every day. It is understandable that warm conditions and presence of sun light are important factors in the use of the space.

RESULTS AND SOCIAL ASPECT

As the air temperature increases, average number of people sitting in the space increases too. During the winter days it is appreciated siting in the streets with no shadows, because of the higher exposer to the sun. However, absence of the shadow in the summer, it presents problems. Therefore, less people are sitting and if they do, they stay for shorter time than they would do otherwise.

The fact that the maximum number of people outside is found in the summer, suggest that most people enjoy feeling warm. Out from that, could be concluded that the situation would be reversed for the warmer climates. People in this case are used to the warm temperatures and they would feel more comfortable with the lower temperatures than averages. (Marielena Nikolopolou, Nick Baker, Koen Steemers, 2001)

CASE 4-KASSEL CITY, GERMANY PROFILE

Small scale micrometeorology measurements were made to get knowledge about the radiation, wind and temperature pattern in a traditional built structure in the German city of Kassel. The focus point was to determine the mean radiant temperature, since this is the main parameter having an effect on the comfort of the human being.

Aim of the study was to evaluate the influence of urban design on indoor and outdoor thermal conditions. There was used an instrument for measuring wind, air temperature, globe temperature, humidity and 3D short and long wave radiation that affect the human being.

LOCATION

Kassel is a typical German city with brig buildings having origin from the 19th century. Measurement was used to compare the mean temperatures estimated by measurements and model simulations and to study the influence of surrounding walls and surfaces on the radiation fluxes.

CONCLUSIONS

Measurements and modelling of the outdoor thermal conditions has to be seen as a tool that should be used as a guidance for urban planning and mitigation of a global climate change. In any planning process spatial distribution of microclimate conditions should be provided. (Lutz Katzschner and Sofia Thorsson, 2009)

CASE STUDY 5-DHAKA, BANGLADESH PROFILE

In the Tropics region, the comfort has been taken for granted. Therefore, built environments are increasingly becoming issue of public concern. Traditionally, in the Tropics outdoor environment has been regarded as important as indoors in the life of the population and which is remarkably evident in the architecture of the region. Despite that, many cities nowadays have experienced rapid urban growth without much concern about the evolving urban environment. Therefore, as a consequence, there is a strong demand now for the comfort requirements, referring to the design of the buildings.

Dhaka is the capital of Bangladesh, has grown rapidly and in order to provide the security, easy access and urban infrastructure to the millions if its citizens, much of the low lands, flood plains, green areas are being used for building. Progressive degradation of the physical environment is the most visible effect of such patterns of urbanization. Generally, ensuring an acceptable standard in the quality of urban life in the present dynamic urban environment is a great challenge for the architects, urban designers, planner and policy makers.

Comfortable outdoor spaces have a significant importance on the comfort perception of the indoor ambient. Therefore, demand for comfort conditions inside of the buildings is significantly increased as a result of exposure to uncomfortable outdoors. Concluding, a comfortable urban space can be considered to have a more direct influence on the perception of comfort indoors.

METHODOLOGY

The fieldwork on outdoor comfort was done with the objective to identify the conditions of comfort in the context of the dynamic environmental qualities of the urban outdoors. The field investigation was based on a survey of comfort judgments from a random sample in different urban situations.

The investigation was processed in the month of July and August. The range of temperatures was from 24.6 to 31.8 degrees Celsius. Humidity average was 70-80%. The fieldwork was conceived of three spots located in the urban core. One location was characterized by a high vegetal cover and low urban fabric presence. Another location was allocated where the vegetation was low and many tall buildings were present. Third place was near the river in the old part of the city, where there was a high density urban fabric.

Around 1500 persons were involved in the survey, wearing typical clothing for that climate conditions.

CONCLUSIONS

Regarding the energy use and the design of the buildings, the significance of the study of outdoor comfort can be coupled with the facts that a comfortable temperature regime indoors would be reasonably attenuated by a comfortable ambient outdoors. It is not essential to establish a single comfort value in the context of outdoor spaces as it has been found that comfort perception outdoors is a dynamic phenomenon and a person's comfort preference, keeping within a range, continually adjusts to ambient situations. This phenomenon clearly emphasizes that the issues of indoor comfort should not be perceived as isolated from the effects and influences of the outdoor conditions on a person.

It is important having in mind that outdoor parameters cannot be controlled as in the case of indoor ones. Moreover, the effects of some environmental factors can be influenced by the elements of urban design such as building geometry and orientation, materials of construction and vegetal mass bodies. Consequently, comfortable outdoors decrease a demand to make comfortable indoors. (Khandaker Shabbir Ahmed, 2003)

CASE STUDY 6-MENDOZA, ARGENTINA PROFILE

This was a study of green areas on the urban canopy layer heat island effect at the micro scale. It was analyzed in the summer in the period of 2003-2005. PET-Philological equivalent temperature index was used to determine the thermal comfort, showing that during the daylight-trees and parks improve thermal comfort through shading and evapotranspiration but at the same time, urban tree corridors delay night cooling by retaining warm air. Additionally, irrigation showed to have a positive effect on the extension and intensity of the cooling effect of rural areas and parks. The cooling influence of an urban park spreads out through the neighborhoods for 800-1000 m, with an average temperature decrease of 1.3 °C during daytime and >4 °C at nighttime.

PUPROSE OF THE STUDY

Purpose of the study was to understand how green areas can improve urban thermal comfort.

LOCATION

The city of Mendoza (32°S, 68°W, height: 750 meters above sea level) is an urban center with approximately one million inhabitants, located in an arid region on the east side of the Andes Mountain Range in western Argentina. The constructed area has a predominant North/South extension, following the foothills of the Andes Mountains. Relative humidity is low (<50%) with mostly sunny days and low incidence of fog. Precipitation rates are low (230 mm·yr−1), with rain mainly occurring during summer months (Dec. to Feb.).

According to the tree census of Mendoza , the urban metropolitan area is forested with about 650,000 trees, the main species being: Morus alba (422,500 trees), Platanus hispanica/acerifolia (97,500 trees), and Frax- inussp (pennsylvanica and excelsior; 130,000 trees), all of which provide shade along the streets, sidewalks and building facades. The trees are distributed as 1st and 2nd magnitude, depending on their height, canopy type and robustness. On the western edge of the city, bordering the foothills, there is an extensive park, i.e. San Martin Park, which covers 393 hectares.

CONCLUSION

Results of this study have shown that: PET is a relevant index for characterizing thermal comfort; and at summer midday trees and parks improve thermal comfort but delay night cooling. However, the day/night thermal comfort balance favors the use of large-medium trees. (Salvador Enrique Puliafito, Fabian Rolando Bochaca, David Gabriel Allende, Rafael Fernandez, 2013)

CASES STUDY 7-DUBLIN DOCKLANDS, IRELAND

PROFILE

Open public spaces are very suitable for cultural and recreational events and for promotion of social contact between citizens. Successful outdoor spaces foster comfort and invite people to go out, stay and spend quality time outdoors. Providing a thermal comfort outside is challenging because there are many environmental conditions to deal with.

This study examines whether climatic characteristics in Dublin facilitate exercising long-term outdoor activities during summer, and investigates the extent to which urban planning and the resulting urban morphology of the built environment influences microclimates created, from the point of view of the wind.

RESULTS

Result show for the dominant wind directions that 60% higher wind velocity than at Dublin Airport can occur around building corners and at restricted flow sections-preventing any kind of long-term outdoor activity during a 'typical' day.

CONCLUSIONS

Increasing urbanization dedicates increasingly important role to public spaces. With the urban growth of urban population, the number of people using these spaces increases as well. Putting aside social role, urban space helps maintain health and facilitates contact with nature. Additionally, urban space use involves decrease in energy use inside the buildings, since less energy is used indoors while urbanities stay outdoors.

Orientation, size and position of buildings, streets, vegetation type, emplacement, surface covering material choice all affect thermal and airflow characteristics that the pedestrians using urban spaces are exposed to.

The study demonstrated that the wind condition can be drastically changed by doing relatively small intervention in terms of installing a 2 m high vegetation wall that acts as protector and wind absorber. (Ágota Szűcs, 2013)

CASE STUDY 8-SEVILLE, SPAIN-METROPOL PARASOL

PROFILE

Metropol Parasol is located in the historic center of Seville, in the heart of the city. It presents a large area of the dense medieval fabric. The structure consists of an extensive canopy of 150 meters by 70 meters 25 meters above street level, which is supported by six extremely tall columns. The public space, which is the main focus of the study is located under the canopy on a platform raised 5 meters above street level. It covers a total area of 10.600 m^2 and is approximately 85 m wide and 140 m long. It is equipped with four concrete benches, three small fountains and a single playground. The material used are clear granite for the pavement, timber for the canopy, and concrete for the structure, which becomes visible at the bases of the pillars. The main purpose of the canopy was to create comfortable environment in the plaza, where people meet and spend time and where many events are organized. The canopy protects the square from the direct sunlight and in the surrounding there are fountains that are supposed to lower the temperature down.

CLIMATE OF SEVILLE

Seville area has a big issue and it is dealing with high temperatures and solar radiation, which are among the highest ones in Europe. For instance, on July the 25, 2012, was made an experiment and were tested measurements of temperature, humidity and wind speed every hour in the period from 10 am to 10 pm at Plaza Mayor. At the same time, were measured, the same parameters at Plaza del Cristo Burgos, a highly vegetated park. Temperatures recorded at Plaza de Cristo Burgos were similar to those at Plaza Mayor between 10 am and 1 pm, also between 6pm and 10 pm. However, they differed from 2 and 5 pm. When the sun is higher, the temperature were lower in Plaza del Cristo Burgos.

SOCIAL SIDE OF SEVILLE

It would be hard analyzing only thermal comfort and leaving people aside because they social and climate environment interfere. Therefore, social environment at Piazza Mayor was evaluated as well.

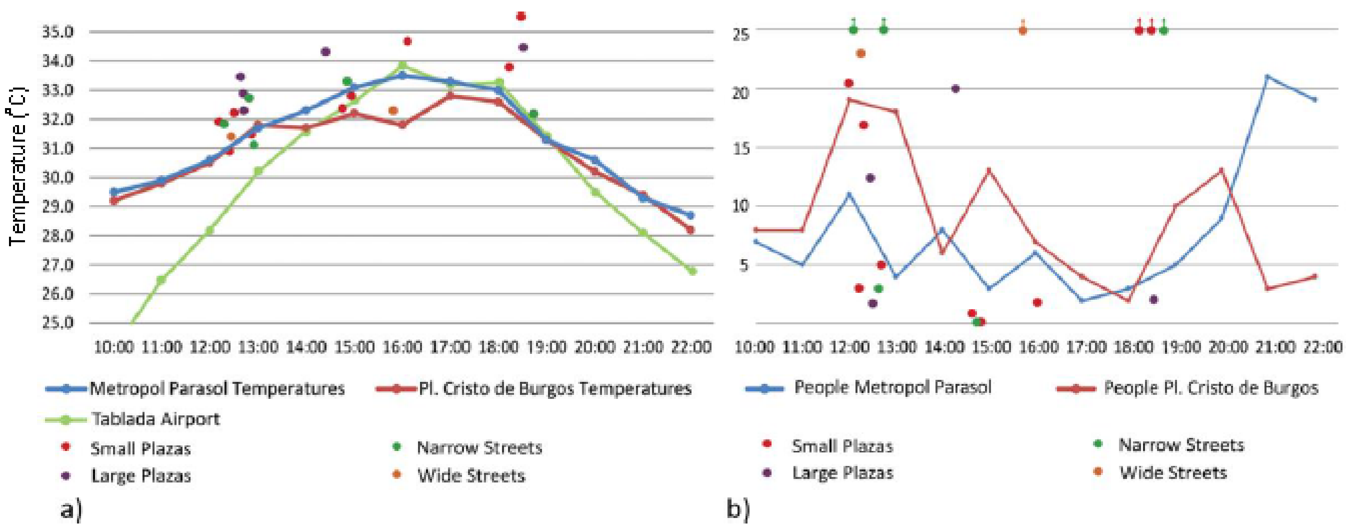
The number of the people present at Plaza Mayor was recorder in parallel to climatic measurements an compared to those at Plaza del Cristo Burgos. The number of people at Metropol Parasol was lower than at Plaza del Cristo Burgos. A total of 25 interviews were done where the questions focused on the two topics:

- the reasons for staying at Plaza Mayor and
- People's thermal perceptions.

According to the results, the reasons for staying at Metropol Parasol were:

1. More comfortable climatic

Figure 30 (A) TEMPERATURES MEASURED AT METROPOL PARASOL COMPARED TO TEMPERATURES MEASURED AT OTHER PUBLIC SPACES AND (B) PEOPLE RECORDER STAYING AT METROPOL PARASOL AND AT PLAZA DEL CRISTO BURGOS



conditions,

2. Attractiveness of the space
3. Playground.

All of the people, however, complained about the environment that was very warm, but they as well, outlined that it was still more comfortable than in the surrounding areas.

CONCLUSION

The climatic techniques applied at Metropol Parasol lowered temperature by over 3 degrees compared to surrounding areas. It seems, when compared to the surrounding, that Plaza Mayor performed better climate. Raising the plaza above the street level turned out to be a good decision because it resulted in more air flow and decreased temperatures. On the other side, separation of the space from the street, shops, bars etc discouraged people from going there so plaza was left empty at the major part of the day. Lack of benches, activities and attractions has an impact on the emptiness of the place, too.

CASE STUDY 9-MADRID, SPAIN-ECOBOULEVARD PROFILE

Located in the suburban development of Vallecas in Madrid, Ecobulevar is the redefinition of an existing 550 m by 50 m boulevard according to two objectives:

- social and
- environmental.

The design team, Ecosistema Urbano, considered trees to be the perfect tools to achieve both objectives. However, according to the project description, a tree could take 25 years to satisfy these social and climatic needs. Ecosistema Urbano proposed the construction of three artificial trees that would function climatically and socially from the start.

These are composed of cylindrical metallic structures that are around 18 m high with 25 m in diameter. Each structure improves climatic conditions using different strategies. The evaporative tree comprises 16 cylindrical wind towers surrounding the principal space formed by a larger cylindrical metallic structure. The wind towers, which are oriented to catch the prevailing winds in the area, inject atomized water to the air flow that passes through them. At the bottom, six nozzles drive the chilled air into the inner space. The second tree, the vegetal tree, is covered by vegetation to provide shadow and decrease temperatures. Finally, the recreational tree is enclosed by an inner screen that, while shading the interior, can be used as a TV screen for different activities. All three trees are located over a modified topography that confines the space and protects it from wind flows.

CLIMATE OF LOCATION

On-site temperature, relative humidity, and wind speed measurements were taken on July 19, 2012 between 12 pm and 9 pm, both inside and outside the artificial trees. The outdoor temperatures measured on the boulevard that day reached 41 °C, wind flew below 2m/s, and relative humidity levels remained at around 10 %. The temperatures were measured inside each tree and at the street hourly. The temperatures remained lower inside the trees than outside them over the course of the visit. The greatest differences were found inside the evaporative tree, which is surrounded by 16 wind towers. The maximum temperature difference between the interior of this tree and the outdoor temperature equaled 2.4 °C at 4 pm. On average, the evaporative tree created a thermal environment that was 1.42 °C cooler than outside. The average temperature measured inside the vegetal tree was merely 0.42 °C lower than the exterior temperature, and the highest difference registered was 0.6 °C at 6 pm. The recreational tree presented an average temperature of 1.05 degrees lower than the exterior temperature. The peak in thermal difference was recorded at 4 pm., with an environment that was 1.5 °C cooler inside. Inside the artificial trees, air velocity remained lower than outside, with a maximum value of 1.2m/s, while outside the maximum value recorded was 3.0 m/s.

SOCIAL SIDE

The number of people staying inside each artificial tree and in the space in between them was recorded in parallel to climatic measurements. Due to the high temperatures that day, the number of people staying outdoors was minimal. The total number of people increased significantly after 6 pm and reached its peak at 8 pm., with 27 people or groups of people sitting there. Among the artificial trees, the vegetal tree was preferred. It held more people in five out of the six measurements, with a total of 40 people or groups. The evaporative tree, however, hosted only five people or groups during the six hours of fieldwork and remained empty for most of the time. These measurements contrast radically with the climatic measurements that were recorded, where the evaporative tree provided the most comfortable thermal environment and the vegetal tree the less comfortable. The recreational tree remained vacant until 6 pm, but was then used by a total of nine people or groups until 9 pm. Similarly, the outdoor spaces between the trees were not occupied until 7 pm, when a total of 8 people or groups used the seating available there for the next two hours.

In order to understand individual environmental perceptions at Ecobulevar, a total of 25 people were interviewed inside and outside the artificial trees. The interviews followed the same questionnaire as in the previous case study. In this case, the main reasons for staying at Ecobulevar were:

- attractiveness of the space;
- more comfortable climatic conditions;
- the amenities offered in the space.

90 % of those who liked the artificial trees stated that the climatic conditions inside them were better than outside. Conversely, 75% of people who found the space inside the artificial trees to be unattractive stated that the climatic conditions inside were equal to those outside.

CONCLUSION

The fieldwork revealed that the artificial trees did provide a more comfortable thermal environment than that experienced outside of them, but the effects of the strategies varied, depending on the technique applied. Specifically, the evaporative tree was the most effective for decreasing air temperatures and protecting from solar radiation, while the vegetal tree barely modified the existing climatic conditions. However, when the study analyzed the social performance of the artificial trees, the vegetal tree was the most effective. The number of people staying inside the vegetal tree was considerably higher than those inside the other two trees. Based on the conversations and interviews carried out, people chose the vegetal tree for its facilities, specifically the benches and swings. Moreover, the direct connections between its interior and exterior in all directions and without architectural barriers offered a constant visual and physical relation with the outside, which facilitated the access and use of the tree. (Patricia Martin del Guayo, Simos Yannas, 2014)

VIII. Shadows

ROLE OF THE SUNLIGHT IN THE ARCHITECTURAL DESIGNS

Mankind has been always looking for a ways to use the power of the sun for their daily needs and practices. In designing the buildings and structures, architects have continuously focused their attention towards the sun. The sun has been both a nuisance but as well an aid for building designers.

On a clear and bright day, the sun, in combination with the reflective qualities of the clear sky, offers about 8,000 to 10,000 foot-candles of light. During any normal day, be it overcast or clear, there is almost always enough light available from the sun and sky to provide illumination for most human visual tasks. Nevertheless, as a result of constantly changing cloud cover, the amount of illumination varies from time to time. Therefore, it is almost impossible to predict with precision what the exterior daylighting conditions in any building will be like at any given moment. Nonetheless, an architect should always be in a situation to give a rough range of expected daylight conditions, which will be based on the sun's behavior at that particular location.

SHADOW DEFINITION

SHADOW. A shadow is the condition that results when a building or other built structure blocks the sunlight that would otherwise directly reach a certain area, space, or feature.

INCREMENTAL SHADOW. An incremental shadow is the additional, or new, shadow that a building or other built structure resulting from a proposed project would cast on a sunlight-sensitive resource during the year. (Ceqr Technical Manual, March 2014)

THE SHADING EFFECT

The sun will always cast a shadow on any object. Only the length, shape and size of the shadow will change with respect to the sun's position in the sky throughout the year. When designing buildings, it is important to notice the amount of shade cast on the building. This is crucial in order to know how the shadow will affect its surroundings. As outlined earlier above, at different latitudes, the sun will travel along different paths across the sky at different times of the year. The sun's peculiar behavior is a very important factor when designing and constructing buildings. For locations which are at latitudes away from the equator, during the summer months, the sun will cast relatively short shadows while during the winter months, the situation will be different and the sun will cast long shadows of objects. In the equatorial region, the sun's path remains fairly unchanged because the length of the shadows does not vary much throughout the year.

Depending on the function of the building sunlight is either filtered out or allowed to penetrate into the building envelope. Most of the time, sunlight is filtered out or prevented from reaching the interior facades of the building. This is done by using three main methods of shading using:

- natural objects,
- internal objects, and
- external objects.

Natural objects include shading by trees and shrubs. For example, deciduous plants have the advantage of providing shade during the winter and spring months- most trees give shade only during summer and early autumn as they shed most of their crown during the winter and spring. During the winter months (sun is low in the sky), these trees are able to block out the low rays and hence effectively shading the building.

Internal objects include curtains and blinds that are installed within the building itself. These objects are able to give inhabitants flexibility as to how much sunlight is allowed into the building because the occupants are able to physically control these devices.

Lastly, external objects include structural elements such as overhangs and louvers that are fixed to the building during construction. These objects are permanent and therefore they will have different effective shading qualities because the sun's position in the sky is constantly changing. Summarizing, architects and designers can apply some these 3 objects to effectively shield the building from the sun's rays.

With regards to the shadow that the building will cast on its surroundings, this is determined using a heliodon. This is down in a way that an entire model city landscape is constructed and is then exposed to testing against different angles of light. The effect of the shadow cast on the surrounding areas is quite obvious. Concluding from there, architects are able to determine shading effects on different buildings. The shading effects will be discussed in the following section. (Ceqr Technical Manual, March 2014)

SHADING

The effects of shading by one building upon another can be either positive or negative depending on the site-specific circumstances of the characteristics involved. A potential benefit of shading for neighboring structures may be a cooling effect gained during warm weather. Negative consequences of shading include the loss of natural light for passive or active solar energy applications or the loss of warming influences during cool weather. Factors influencing the relative impact of shadow effects depend from a location to a location and include many differences such as:

- Terrain elevation between involved characteristics,
- The height and bulk of structures,
- The time of year,
- The duration of shading in a day, and
- The sensitivity of surrounding land uses to loss of sunlight.

Shadows cast by structures can vary in length and direction throughout the day and from season to season. Shadow lengths increase during the "low sun" or winter season and are longest on December 21-22, the winter solstice. The winter solstice, therefore, represents the worst-case shadow condition and the potential for loss of access to sunlight, is the greatest. Shadow lengths are shortest on June 21-22, the summer solstice. Shadow lengths on the spring and fall equinoxes, March 20-21 and September 22-23 respectively, would fall midway between the summer and winter extremes.

Shadows are cast to the west by objects during the morning hours when the sun is coming up on the horizon in the east. During late morning and early afternoon the shadows of objects move northerly and by late afternoon they are cast easterly in response to the apparent movement of the sun across the sky from east to west. Shadows cast in winter are longer, and those at the winter solstice the longest. It is instructive, therefore, to map the daily shadow pattern cast by a proposed building on December 21st because it is illustrative of the "worst case" impacts a proposed structure may have upon nearby sensitive land uses.

Looking at the total amount of the sun's energy available during a daylight period, approximately 85% of it reaches the earth between 9:00 a.m. and 3:00 p.m. The California Energy Commission defines this time period as the useable solar sky-space. Useable sky-space, at the winter solstice, can be defined as the portion of the sky lying between the position of the sun (i.e., sun angle or azimuth) when it is 45 degrees to either side of true south—the portion of the sky covered or traversed by the sun between 9:00 a.m. and 3:00 p.m.

4. HOW TO PLAN EFFECTIVE SHADE; EARTH–SUN RELATIONSHIPS

SUN ANGLES AND THEIR EFFECTS ON SHADOW

The main goal of shade planning is to provide shade at the right place, at the right time of the day, at the right time of the year. Unfortunately, the location of shade structures and trees often produces a shadow pattern entirely different from that what was anticipated. Accurately predicting where a tree or structure will cast its shadow depends on an understanding of the sun's path.

Such an understanding is fundamental to effective shade planning. It is essential to know three things about a specific location of interests in order to precisely evaluate the effect of the sun's path. These characteristics are:

• Latitude
• Longitude
• The direction of true north.

If the mentioned properties are known, it is possible to use sun charts or commercially available computer softwares to find the position of the sun for any time of day throughout the year. To accurately predict the behavior of shadows cast by solid objects it is essential to know the solar azimuth angle and the solar altitude angle.

1. **Solar Azimuth Angle: Direction Of Shadow**

The azimuth determines the direction in which the shadow will fall on the ground. Solar azimuth is the angle, in a horizontal plane, between true north and the direction of the sun, measured clockwise from true north. It can have any value from 0° to 360°. The azimuth at solar noon in the southern hemisphere is always 0°.

2. **Solar Altitude Angle: Length Of Shadow**

The solar altitude angle determines the length of the shadow cast by a solid object on the ground. Solar altitude is the angle between the sun and the horizon at a given latitude. It can vary according to the time of the day and according to season.

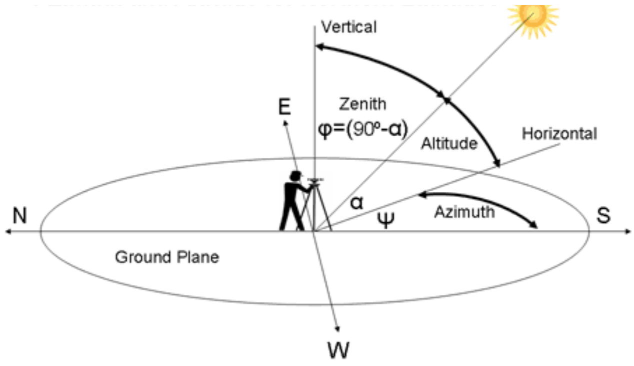


Figure 31 Azimuth and Altitude for Northern Latitudes

DAILY PATH

As the sun is continuously moving across the sky, the shadows cast by the sun are always moving. They slowly shift from sunrise to sunset in response to the altitude and azimuth of the sun as it passes from east to west. This basic pattern applies every day of the year, although the areas affected by shadow vary according to the time of the year. The sun's path changes throughout the year but always follows the same sequence year after year. (JS Greenwood, GP Soulos and ND Thomas, 2000)

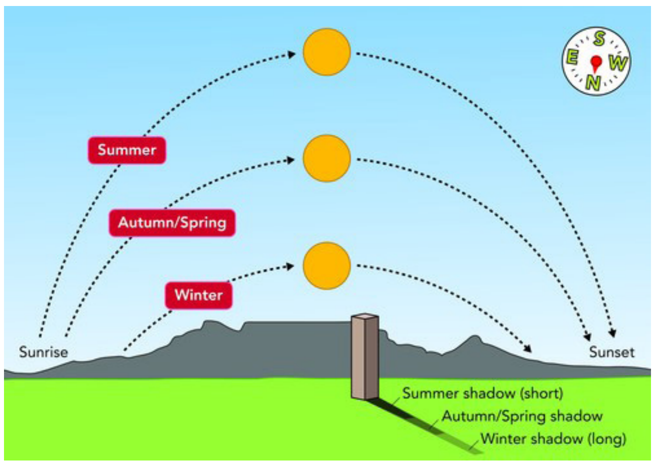


Figure 32 Daily path of the Sun in 4 seasons

ANNUAL PATH

Because the earth's axis is tilted to the plane of its solar orbit, the north–south angle of the sun (measured by the azimuth) moves according to the season. This is the main cause of seasonal changes.

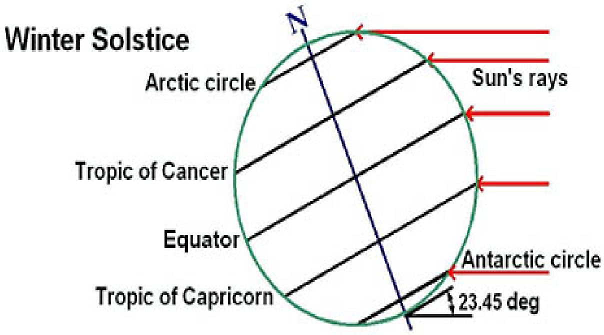


Figure 33 Winter Solstice

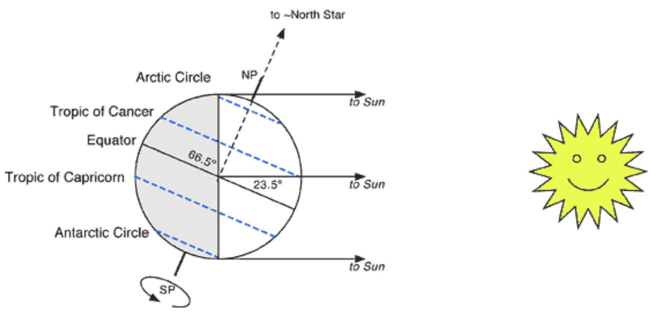


Figure 34 Summer Solstice

Sun's Daily Path

There are three basic shade patterns that occur every day:

MORNING – when the shadow will fall in a westerly direction away from the object casting the shadow

MIDDAY – when the shadow will be close beneath the object

AFTERNOON – when the shadow will fall in an easterly direction away

DESIGNING SHADE FOR CLIMATE AND COMFORT

It is important to become accustomed with the climatic elements of a location in order to design protective shade that is comfortable for human use at the right time of the day and at the right time of the year.

The four elements of a climate which have a prevailing impact on human comfort are:

• Air temperature
• Humidity, or water content of the air
• Air movement (breeze)
• Heat radiated from the sun and from the surroundings.

Each of these characteristics influence in some way the heat exchange processes between the human body and its environment. All must be considered together if the effects on people want to be anticipated.

For example, when the weather is cold the effect of humidity is barely noticeable, but when it is hot, high humidity becomes less tolerable. Air movement at our body surface causes evaporation of perspiration and has a cooling effect. At higher humidity levels, the evaporation is stopped or at least reduced. Wind does not change the air temperature but it makes us feel cooler. To some extent it can compensate for the effect of high humidity. JS Greenwood, GP Soulos and ND Thomas, 2000)

SHADE COMFORT

When climatic elements are understood, it is possible to design outdoor environments that provide increased levels of comfort by modifying the existing conditions. For example:

• if it is hot and humid, provide shading to exclude the sun and allow cross-ventilation to capture the breeze for cooling

if it is cold and windy, provide wind breaks to exclude the breeze, and select UV protective materials that block UV lights whilst transmitting light and heat (eg polycarbonate, glass).

Shade offers the physical sensation of a change of temperature. Sheltered from the direct heat of the sun's rays, shady areas are perceived as cooler. Direct sunshine usually feels hotter, so shade is required on a summer's day to escape the heat as much as to escape exposure to UV lights. On cooler days in the months around the equinoxes, people prefer to be warmed by the sun and will tend to avoid shady spots, even though risk of UV light exposure is still present. For these times of year, it is necessary to create warm outdoor environments which also offer protection against UVR. During the cooler months (May through August) when UV radiation levels are low, the main consideration is to provide outdoor spaces that are warm, light and protected from winds.

DESIGNING FOR COMFORT: GENERAL PRINCIPLES

In many locations, sun's warmth and light during winter will be necessary for thermal comfort. There are a few suggestions of how to ensure that design goes in a right way and provides better comfort:

1. Provide shade which excludes UVR but admits the sun's warmth and light. Luminous polycarbonate sheeting is ideal for this matter;
2. Adjustable objects may suit year-round use;
3. Deciduous trees and other plants will allow warmth and light to penetrate when they lose their foliage;
4. Alternative UVR protection may be needed for outdoor spaces during these periods;
5. Provide alternative external spaces for use in different seasons. Where space is available, this may be an easier and more economical solution;
6. Locate planned summer shade structures so as to not increase winter shade;
7. Planting can be used to form north-facing courtyards or outdoor enclosures for social gatherings or outdoor activities. Plant shelter belts or wind screens to the south, southwest and west, leaving open sunny lawns to the north, adjacent to covered outdoor paving that is warmed by the low winter sun.

However, during the summer months, cooling is recommended due to the high temperatures. Cooling can be provided by following the advices:

1. design the space to capture any prevailing breezes;
2. provide shade to the openings of shade structures during summer;
3. Projecting attics attached to buildings will cool the indoor and outdoor spaces during the summer months. Attics will also reduce direct UV radiation and indirect UV radiation, which could otherwise

reflect and scatter off wall surfaces. Shading of walls and covered areas can significantly increase summer comfort levels:

1. When exposed to direct sun, walls and paved surfaces gain heat, which is 'stored' and reradiated, increasing and maintaining the surrounding temperature. In summer, this can result in overheated, unpleasant outdoor spaces. By shading walls and paved areas, the heating of these surfaces can be significantly reduced and comfort levels enhanced
2. Brightness caused by the reflection of bright sunlight from hard surfaces such as walls and paving can be unpleasant and increase the perception of heat. Shading of such surfaces reduces glare and results in more comfortable outdoor spaces.

Cross-ventilation is the circulation or flow of air through openings, such as doors, windows, or grilles, which are on opposite sides of a room, referring to the indoor areas. Referring to the outdoor, cross-ventilation is the circulation or flow of air through openings in the buildings, such as open spaces. Cross-ventilation can provide relief from excessive humidity and prevent overheating of spaces.

• Where possible, orient openings towards the direction from which cooling breezes come.

However, if the requirements of a particular activity do not allow for the ideal orientation, take measures to channel the wind and change its direction.

• observe the direction of any unwanted cold winter winds and provide suitable windbreaks. These may take the form of built attachments (such as screens) or dense tree and shrub 'shelter belts' adjacent to the area requiring protection.

In many locations, structures must be able to withstand strong winds.

1. Gabled or hipped roof forms of pitch 30 produce the best chances for equal pressure spread over the building to avoid eddying and roof lift-off.
2. Trees located in proximity to a structure can significantly reduce wind loading on the structure
3. Select materials that are well suited to exposed locations

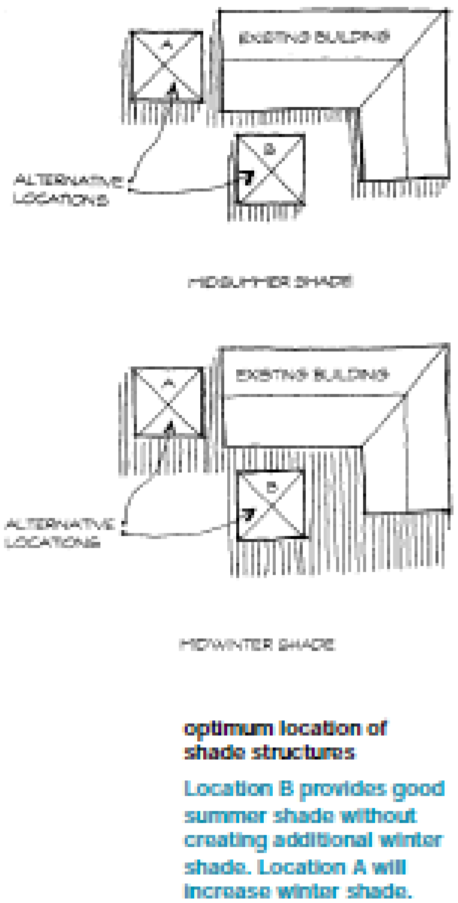


Figure 35 Optimum location of shade structures

with high winds (for example: metal roof sheeting) rather than those inherently more fragile (for example: low tensile shade cloth sails).

NATURAL SHADE BENEFITS

The use of natural shade can be one of the most effective and aesthetically appealing ways of providing shade. Vegetation offers seasonal variations in perfume, color and sounds. Many species produce colorful flowers or have attractive foliage or bark, some make good habitats for wildlife and many species can be used to screen unwanted views, give wind protection and provide privacy. Other materials cannot accomplish these things as well as vegetation can.

Vegetation advantages

The use of vegetation for shade also has a number of environmental benefits including:

- Less need to use non-renewable resources (used in many building materials);
- Energy saved in comparison with built shade systems;
- Fewer disposal problems as plants generally act as nutrients during decomposition;
- Absorption of carbon dioxide in the atmosphere, thereby potentially counter-balancing the 'greenhouse effect'.

The effectiveness of natural shade depends on the density of the foliage. Foliage and timber will block direct UVR, but gaps in the canopy will allow UVR to penetrate. The size of the canopy (of a tree or group of trees) is also an important consideration. The larger the canopy diameter, the greater the opportunity for protection from scattered or reflected UVR. The height of the branches from the ground can also influence the effectiveness of natural shade, with low

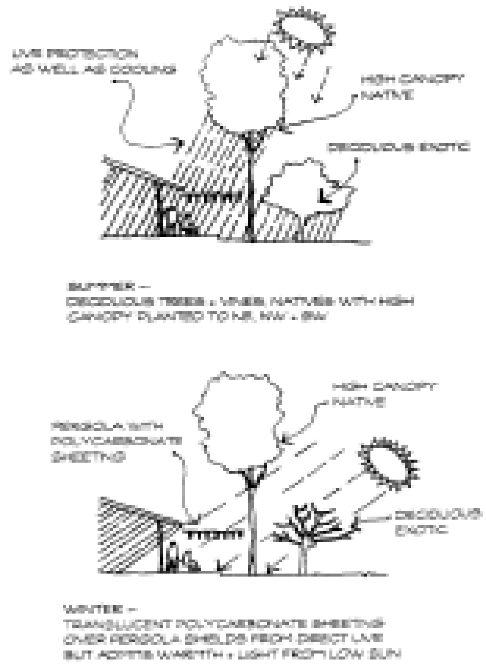


Figure 36 Way of protecting from the Sun

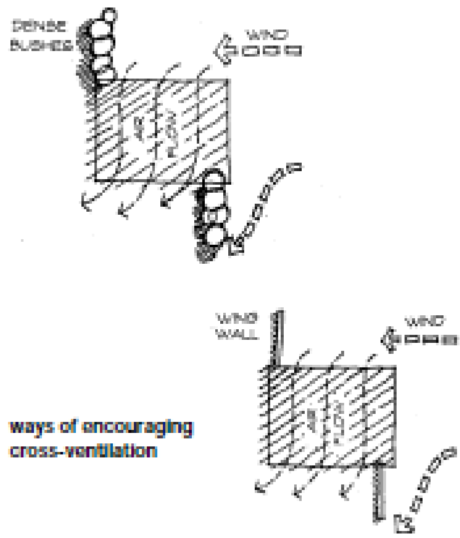


Figure 37 Way of encouraging cross-ventilation

branches providing better protection.

It should be noted that introducing complete, or even partial shading by vegetation may affect the viability of existing under-storey vegetation. The landscape of shaded areas, as a result, may need to be treated differently to that of non-shaded areas.

THE EFFECTS OF TALL BUILDINGS AND SOLAR ACCESS ON THE ENVIRONMENT

Solar access is the amount of solar radiation that reaches a building (Bronin, 2009) or the amount of direct solar energy on a building, and it is measured by the means of annual solar radiation and the amount of sun light hour (Anon., 2005).

The solar rays that reach indoors reduce the demand for artificial light and heat energy and increase the property value by enriching the quality of space. Similarly, the access of sunlight in outdoor areas is necessary and valuable for the growth of vegetation, quality of public space, and the encouragement of social activities. Solar access and its continuity are vital for systems reliant on solar energy and for the development of solar technologies (DOE, 1993).

Furthermore, access to sunlight enables the users of a building to perceive time and space by the sun's rhythmic movements. (Knowles, 2003) In short, beyond its rationalist benefits, sun provides significant value in a built environment, both for the functioning of the building and for the people who use its spaces. Solar access depends not

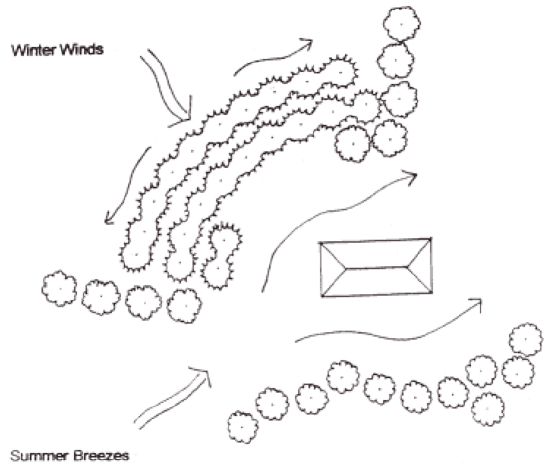


Figure 38 Summer and winter winds

only on the design of a certain building but also on adjacent construction that can interfere with access to sunlight. Preserving access to the sun, then, by controlling environmental shadowing is a key concern for the future (Rafiadeh, 2005).

As tall buildings have great mass, they reduce the solar access of their surrounding environment by overshadowing adjacent properties. Evaluating the effect of tall buildings on an environment's solar access will have profound importance on the future regulations regarding the solar right.

There are many factors that influence the sun access:

- Geographical location,
- The rhythmic movements of sun,
- Topographical properties of the area,
- The height difference between tall buildings and surrounding buildings,
- The directional position of tall buildings according to surrounding buildings,
- The distance between tall buildings and surrounding buildings,

- The form of the tall buildings' mass that determine the overshadow properties of tall buildings. (Esra Sakinç, Müjgan Şerefhanoğlu Sözen, 2012)

Because of the dynamic shadow regime and climatic, atmospheric conditions, it is usually hard to predict the effects that shadowing can have on daily life. However, assessing the quantity and the characteristics of shadowing is vital for understanding the effects of tall buildings on the solar access of their surrounding environment. Because shadows have a moving and changing character, it is important to analyze shadows with a holistic way in order to evaluate changes at the solar access.
To assess the total impact of overshadowing it is important to:

- find dimension;
- direction and duration of shadows on surrounding environment through the whole year and
- evaluate the findings all together.

SHADOW IMPACT SIGNIFICANCE

In the CEQR technical Manual (May 2014), a shadow is not considered significant when its duration is no longer than 10 minutes at any time of year and the resource continues to receive substantial direct sunlight. A significant shadow impact generally occurs when a shadow of 10 minutes or longer falls on a sunlight sensitive resource and results in one of the following:

- VEGETATION

A significant reduction in sunlight available to a sunlight-sensitive feature of the resource to less than the minimum time necessary for its survival (when there was sufficient sunlight in the future without the project). A reduction in direct sunlight exposure where the sensitive feature of the resource is already subject to substandard sunlight (i.e., less than minimum time necessary for its survival).

- HISTORIC AND CULTURAL RESOURCES

A substantial reduction in sunlight available for the enjoyment or appreciation of the sunlight-sensitive features of an historic or cultural resource.

- OPEN SPACE UTILIZATION

A substantial reduction in the usability of open space as a result of increased shadows.

- FOR ANY SUNLIGHT-SENSITIVE FEATURE OF A RESOURCE

Complete elimination of all direct sunlight on the sunlight-sensitive feature of the resource, when the complete elimination results in extensive effects on the survival, enjoyment, or, in the case of open space or natural resources, the use of the resource.

SHADOW MITIGATION

Where a significant impact is identified, potential mitigation strategies must be considered in order to reduce or eliminate, the effects caused by the shadows.
In all cases, additional mitigation strategies that involve modifications of the height, shape, size or orientation of the proposed building may be explored.

The strategies include:

- The reorientation of building bulk to avoid incremental shadow on sunlight-sensitive features of the open space, natural or historic resource.
- The reduction of the overall height of the project.
- The use of alternative technologies that may reduce the height of the project and reduce shadow impacts (e.g., the use of dry cooling towers vs. wet cooling towers).
- The relocation of the project to a different site, when appropriate.

For open space resources, the types of mitigation that may be appropriate include:

- relocating sunlight-sensitive features within an open space to avoid sunlight loss;
- relocating, replacing or monitoring vegetation for a set period of time;
- Undertaking additional maintenance to reduce the likelihood of species loss; or providing for replacement facilities on another nearby site.

Other potential mitigation strategies include the redesign or reorientation of the open space site plan to provide for replacement facilities, vegetation, or other features.

For historic resources, potential mitigation strategies include the use of artificial lighting to simulate the effect of sunlight on features such as stained glass windows.

On the following picture it is possible to see a proposal how to mitigate the shadow impact.

INTERPRETATION OF THE SECTION-REVIEW

A microclimate is the distinctive climate of a small-scale area, such as a garden, park, waterfront or any other small part of a city. The weather variables in a microclimate, and parameters such as temperature, rainfall, wind or sun. It can happen that these parameters, if analyzing a big area give quite different values than if measured only on a smaller part of a city. Therefore, microclimate is a mixture of many, but slightly different microclimates that actually makes up the climate for a town or a city.

When analyzing a specific city, it is important to involve the people and estimate an urban outdoor comfort on them. Urban comfort in certain cities can be good, in some others- not so good. That depends on many factors.

Local wind speeds and solar radiation are the most important microclimatic parameters for urban design and urban planning because they depend widely on the urban geometry.

Consequently, the geometry of streets and orientation directly influence the airflow and solar access in urban canyon and therefore thermal comfort at pedestrian level.

Therefore, in order to provide a pleasant microclimate in urban areas, designing urban streets in a way, which brings about appropriate airflow and utilize solar access, is vital and essential. This could affect global climate and energy consumption of buildings.

The idea of studying wind comfort and safety in urban area incorporate the aim of raising attention to available methods and tools that facilitate planning with health and comfort in mind.

The environmental chapter offers a broad introduction of three factors affecting the pedestrian comfort and safety: wind, sun and consequently- shadow. We have recognized the importance of these factors and therefore, we will test them on our study cases, analyze different results, and compare them.

Wind plays an important role in the urban comfort. At many cases the important of the wind while constructing new building is neglected. The accent is the create appealing building, high skyscrapers, or towers that will strive high in the sky. The problem appears when the wind analyses were not performed properly or not performed at all. It can be only concluded that human comort is at a low level and despite the attractiveness of the construction, it failed to meet its most important goal-functionality. Therefore, it is essential to be wise and implement wind analyses in the planning phase and analyze carefully the geographical position, climate characteristics, terrain roughness etc. This can be done using very popular technique-CFD.

A special attention should be paid when designing tall building, because they can provoke a complex situation and specific wind loading.

Another essential element that has an influence on the comfort is the building itself. It is very important while planning, to perform the necessary studies on building massing, orientation, density and overall spacing among different buildings in a neighborhood. In choosing, the proper orienting sun and wind help the most.

As mentioned above, the sun is another factor that has crucial role in urban comfort. That means, when designing buildings, it is important to estimate the amount of shadow a building will cast. This is extremely important in order to know how the shadow will affect the surrounding.

Therefore, in order to plan wisely, both of the factors: wind and sun need to be incorporated and studied at the same

Figure 39 Mitigation of shadow impact; BEFORE (left) and AFTER (right)

time. They cannot be separated in the analysis because the analysis will not be complete, and if performed as such, it will give bad results, and consequences can be unforeseeable. For instance, can we think of an example of designing a tall building on a terrain where there is a high wind speed present and in the surrounding area, a park is situated or a playground. It is inevitable that the wind loads will be high, and that building will cast a shadow on a park. This scenario would cause a not satisfying urban outdoor comfort.

In order to understand better, how the theoretical findings work in practice, we have analyzed a few study cases where fundamentally urban comfort was tested in terms of parameters such as wind, sun, shadow and green areas. This study cases gave us a deeper understand and an idea and inspiration in which way to focus our own practical part of the thesis. As the urban planners, we decided to test the wind, sun and shadow on six study cases by our choice and we wanted to give a contribution and profound our own knowledge on how to (urban)plan more efficiently. The analysis, findings, results and comparison will be presented in the following sections.

(Endnotes)

1 https://eo.ucar.edu/basics/wx_2_c.html

2 http://www.dictionaryofconstruction.com/definition/wind-load.html

3 *CLO VALUE=Cloth and Thermal Insulation

Nude person: CLO=0; the lowest CLO value

Eskimo: CLO=4; the highest CLO value due the thickness of the clothes

METHODOLOGY

SCOPE OF THE ANALYSIS

The aim of the work is to identify which morphological factors, if any, contribute to improving both social and environmental comfort. With this in mind, it was necessary to first define what social comfort is, and what environmental comfort is. This is particularly difficult in the case of social comfort, since definitions of social quality are highly subjective. A literature review was used to define various conceptions of public space, and by comparing the different authors, some parameters for social comfort were defined. An extensive literature review was also conducted in order to define the parameters that contribute to improved environmental comfort. In both cases, attention was focused on morphological factors, such as street grain, building height, etc, and their impact on social and environmental comfort.

The next step was to identify examples of diverse morphologies in existing urban environments. The methodology for pattern selection, use of computer programs, and the parameters for the social and environmental analyses are described below.

PATTERN SELECTION

CRITERIA

The patterns were intended to be diverse from each other is a standard set of ways, according to three types of variations. The patterns were selected according to block type, relation to open space, and street layout.

The different block types chosen were solid blocks, permeable blocks, and open blocks. Solid blocks are blocks with a defined perimeter, where the buildings line the streets to form a solid wall and there are no spaces between buildings. Permeable blocks are blocks where the buildings line the streets, but the buildings are detached, leaving spaces between them. Open blocks are blocks where the buildings are positioned in the green space, rather than defining the greenspace. The buildings and blocks are generally larger and the buildings do not line the streets.

The different open space layouts were interior courtyard spaces, private yards, and open courtyards. Interior courtyards are semi private spaces, shared between the a defined group of users. They are surrounded by solid blocks and are not accessible to the public. private yards are more common in permeable blocks with detached dwellings. Each dwelling has its own outdoor space, which is privately owned. Open courtyards can be found in open block structures, where the buildings are shaped to partially define the open space, but the open space is not bordered by buildings on all four sides, for instance, the building may have a U shape, forming a border on three sides of the green space, but leaving the third side open. These open courtyards may have public access, or they may be fenced, making them semi private spaces.

The street layouts chosen were regular grid, distorted grid, and organic grids. Regular grids are defined by a highly regular street layout, where the streets are lined up parallel and perpendicular to each other. Blocks are rectangular in shape. A distorted grid refers to semi regular grids in which distortions appear, causing irregularities in the pattern. Streets do not form right angles, and instead of being rectangular, blocks may become four-sided polygons. Organic street layouts are not technically grids. Streets are curvilinear and highly irregular, although there may be a kind of repeating street pattern.

Using these different classifications, the patterns were chosen in order to represent significant variety. It was also important to have samples with different building heights and densities.

SAMPLE SIZE

The sample size was defined as 500m by 500m. However, for the wind and solar studies, it was necessary to select a significant border around the intended sample in order to account for the "edge effect." For example, when conducting a wind analysis on a 3D model, the wind hits the edge of the model without interacting with any urban forms beforehand, but in the real world scenario, the sample is set inside a larger urban terrain. The real world sample has no edge; instead it is part of a continuous urban condition. Therefore, it is necessary to simulate this is the model as well by including a buffer of buildings around the intended sample. For this reason, the total area modeled was equal to 1 square kilometer, but the area where the results were evaluated consisted of a 500m by 500m sample, located at the center of the larger sample.

LOCATIONS

In the pattern selection process, two choices were available. One option was to use idealized examples of different morphological conditions, the other option was to use examples of actual urban forms. The difficulty with actual urban forms is that in the real world, there are always pattern irregularities, which complicate the results. By using real world examples, the results are more accurate for the specific examples studied, but they are less applicable to other cases, therefore, the results can not be generalized as well to a larger number of cases. With generic or idealized examples, the results are more general and can be applied to more cases, but a lot of the complexity of real life examples is lost.

It was considered important to maintain some real life complexity, so real world samples were chosen for the study. However, the real world examples were modified to some degree in order to reduce some of the variables. Patterns fitting the criteria mentioned were identified using Google Earth, and samples of 1 square kilometer were marked out. When areas of the sample broke from the recognizable pattern, these areas were modified in the models. For instance, in the case of Hannover, Germany, the pattern identified was a solid block pattern with large interior courtyards. In the Google Earth sample, a few of the blocks on the outskirts differ from this pattern because the blocks are broken instead of solid. In our models, the sample is modified in order to reduce variables and make the results more generalizable to other cases besides Hannover, Germany.

Programs

GOOGLE EARTH

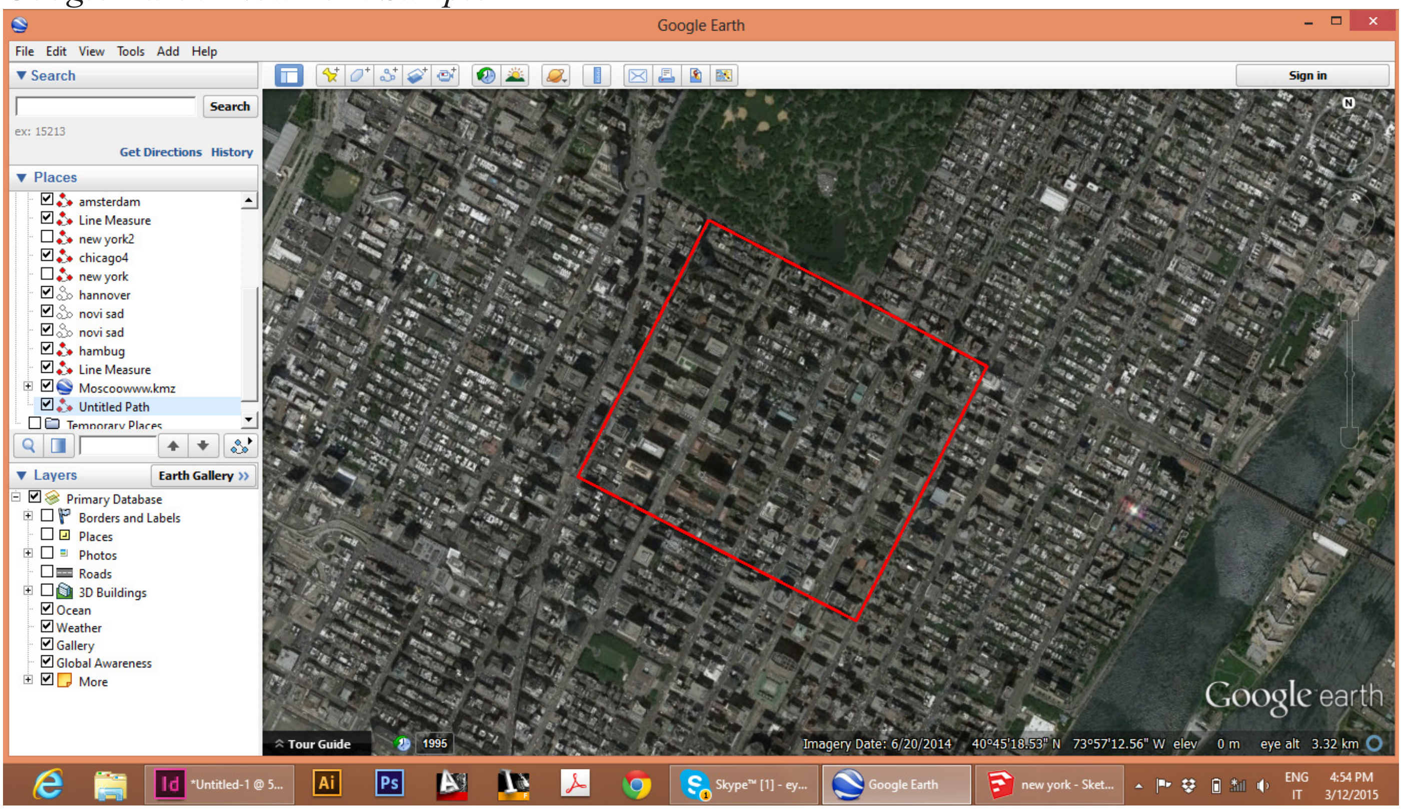
Google Earth was used to find and select the different samples. Google Earth is an open source program and can be downloaded for free. The program combines Google maps tools with many additional capabilities for measuring and surveying urban environments. Within Google Earth, the polygon tool was used to define an area of one square kilometer. Using the ruler tool, the length and width of each building and block was measured and copied into Google Sketchup. With the 3D buildings option selected inside Google Earth, it is possible to use the mouse to hover over buildings and determine their height, which was recorded and used to make the 3D Sketchup models.

GOOGLE SKETCHUP

Google Sketchup was used to make the six 3D models. A version of Google Sketchup, called Sketchup Make, is available for free, while the pro version, with additional capabilities, is available for sale.

The New York model drawn in Sketchup is shown below. The program is relatively simple to use, with a fast learning

Google Earth: New York Sample



curve, however, there are not as many options and shortcuts as in more advanced programs like 3D Max. Complications came up in producing "water tight" shapes in Sketchup, which might have been avoided using 3D Max.

The models were drawn primarily using the line and rectangle tools, and the extrude tool was used to give the buildings height. Once drawn, the models had to be exported to DWG format in order to be imported into Autodesk Vasari. Sketchup Pro has the ability to export Sketchup files to DWG format, while the free version of Sketchup Make does not. However, it is possible to download a plug-in for Sketchup Make in order to have this capability.

PHOTOSHOP

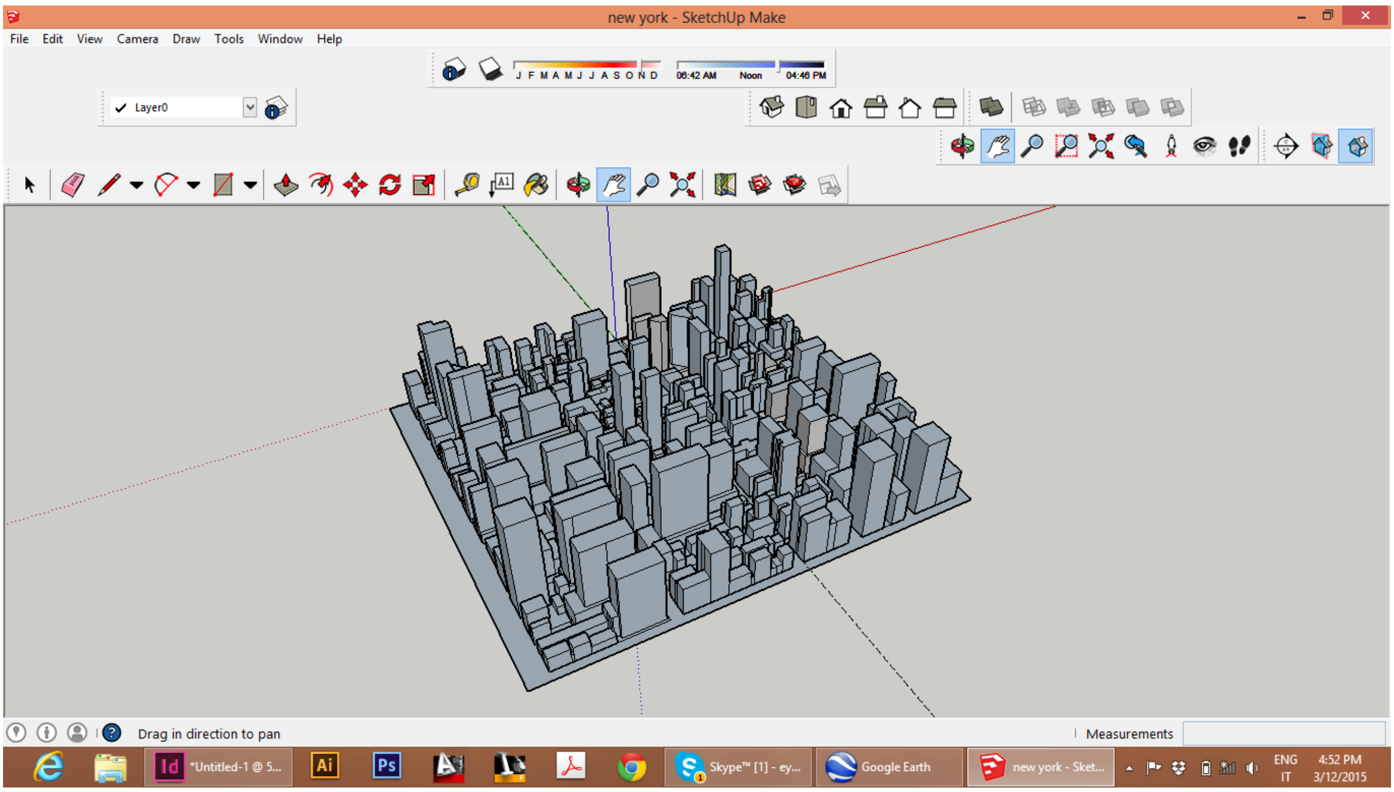
Photoshop was used to draw a 2D representation of the streets, building footprints, and green spaces in each of the six samples. To do this, a screenshot of the building footprints was imported into Photoshop and the diagrams were traced from this image.

AUTODESK VASARI

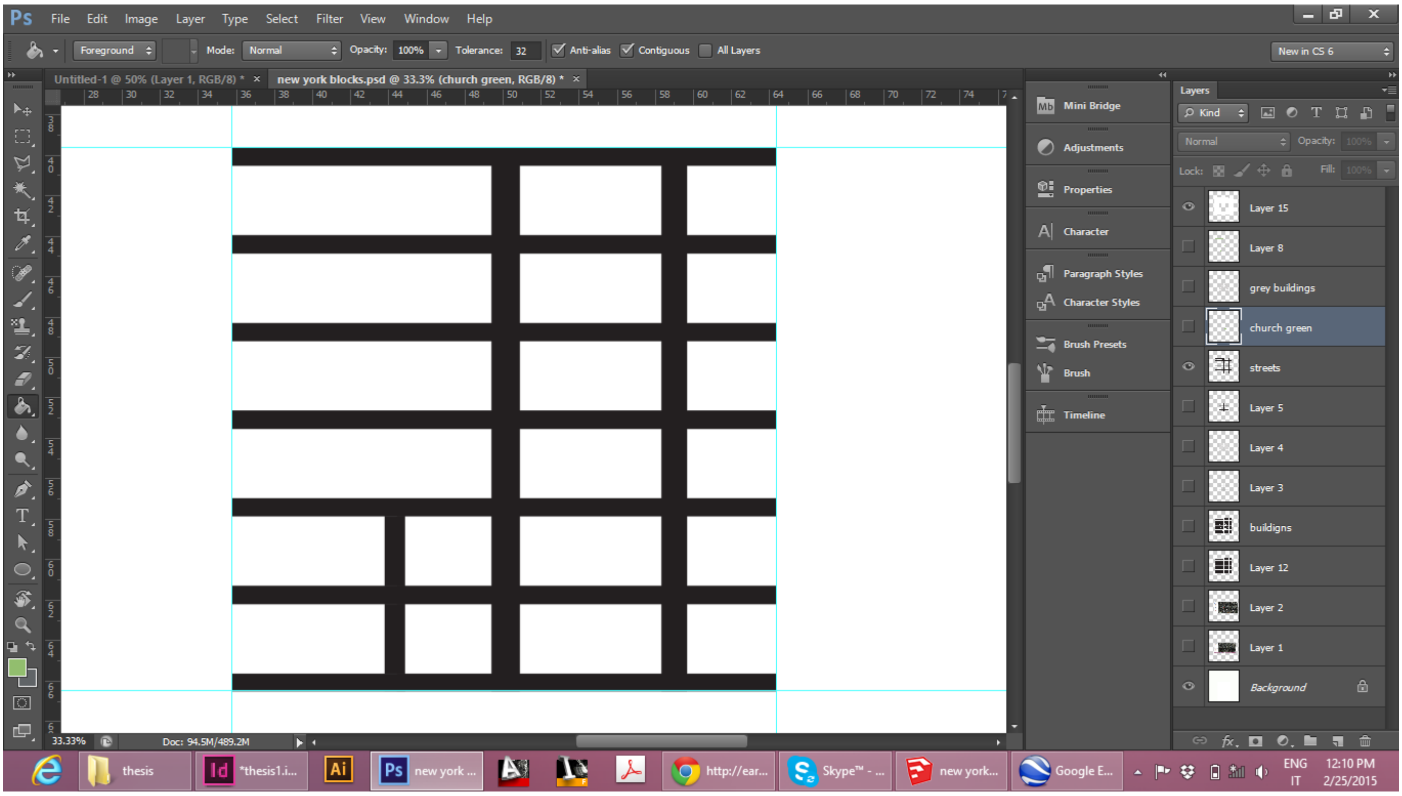
Project Vasari is a user-friendly design tool for creating building concepts, with integrated analysis for energy and carbon, wind tunnel simulations, solar radiation, and more. A variety of file types can be imported into Vasari, including DWGs, and it is fully compatible with the Revit platform. Buildings and models can also be easily drawn inside Vasari itself. Vasari is focused on conceptual building design, using both geometric and parametric modeling. It supports performance-based design via integrated energy modeling and analysis features.

Because the program is still under development, the Project Vasari Beta 3

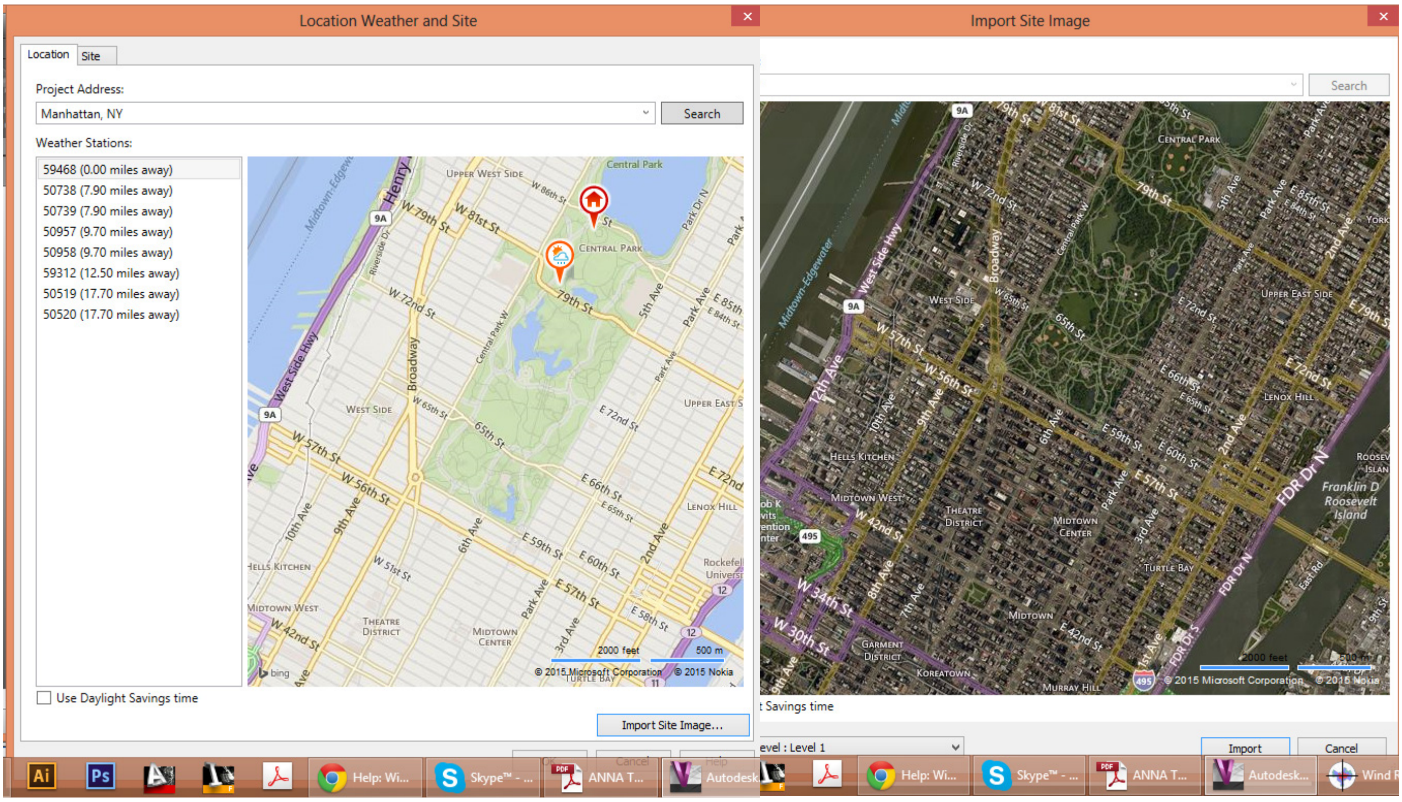
Google Sketchup: New York Sample



Photoshop: New York Streets



Vasari: Analysis Location



version was downloaded for free for a limited time. The program is easy and fast to use. However, as a test version, the program did have some glitches, including difficulty saving projects. Furthermore, Autodesk notifies users that Vasari analysis results are experimental and have not been fully validated.

The features used in Project Vasari include the Wind Rose, Wind Tunnel, sun settings, and shadows. It was not possible to use the Solar Radiation tool because this feature did not function, most likely because of an incompatibility with our imported Sketchup files.

Analysis Location

Vasari has the capability to automatically input local climate and weather data for a specific geographical location. Selecting a location for the project can be done using the Location tool found under the Analyze tab. A pop-up window allows you to search for a location and choose the nearest weather station. By choosing Import Site Image, a second pop-up window appears with a satellite image of the location. By selecting Import, this image will be displayed as a base for your Vasari model.

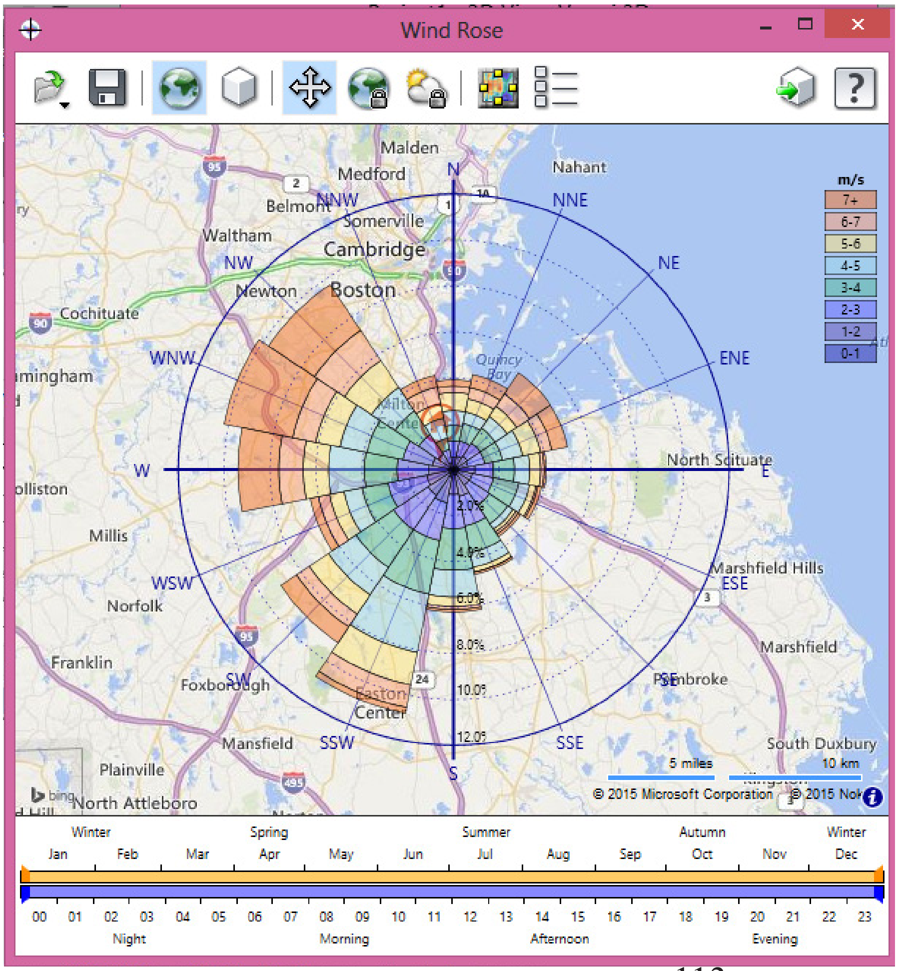
Wind Rose

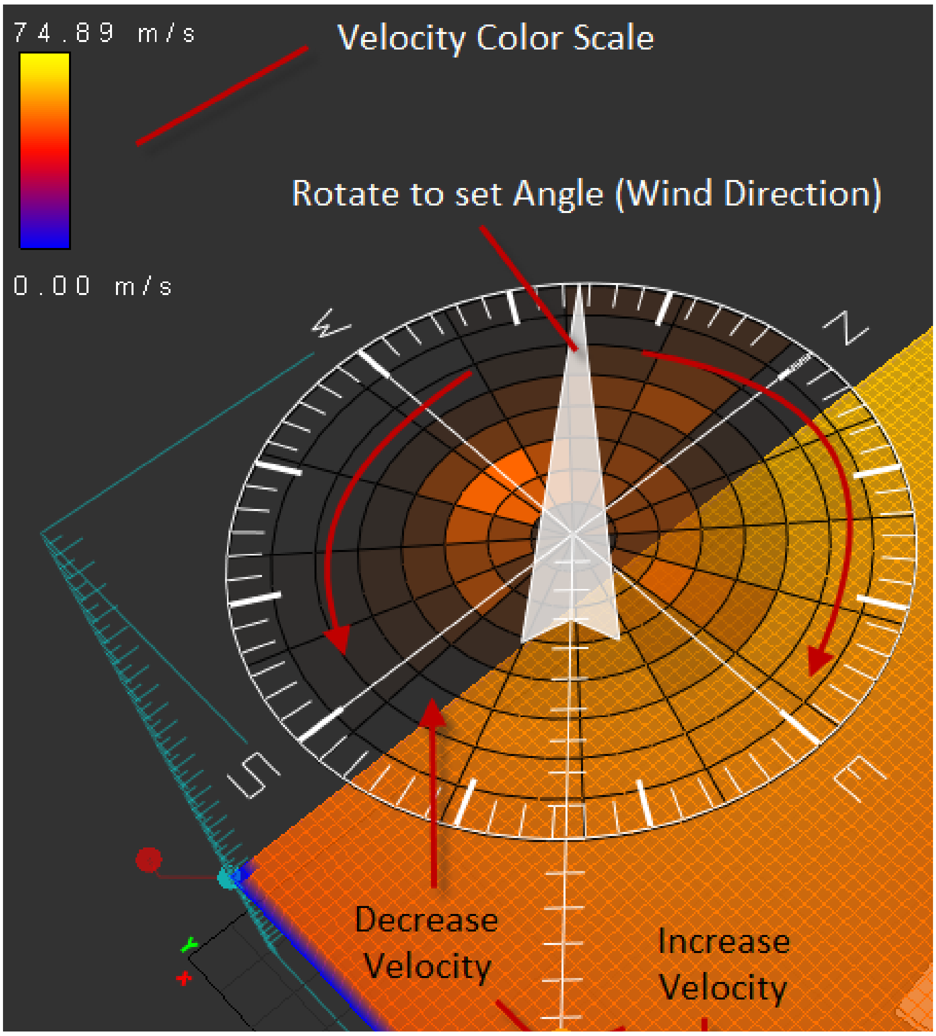
The wind rose chart shows the distribution of wind speed, wind direction and relative frequency for a given date and time range. The chart is made up of 16 wedges, representing 16 wind directions. The radius of each wedge represents the percentage of time that the wind came from that direction during the period under consideration.

Each wedge contains 8 different colored segments. The color of each segment represents the speed of the wind when it was coming from that direction, as shown in the legend in the top right corner. The size of each colored segment shows the percentage of time that the wind from that direction was within that speed range.

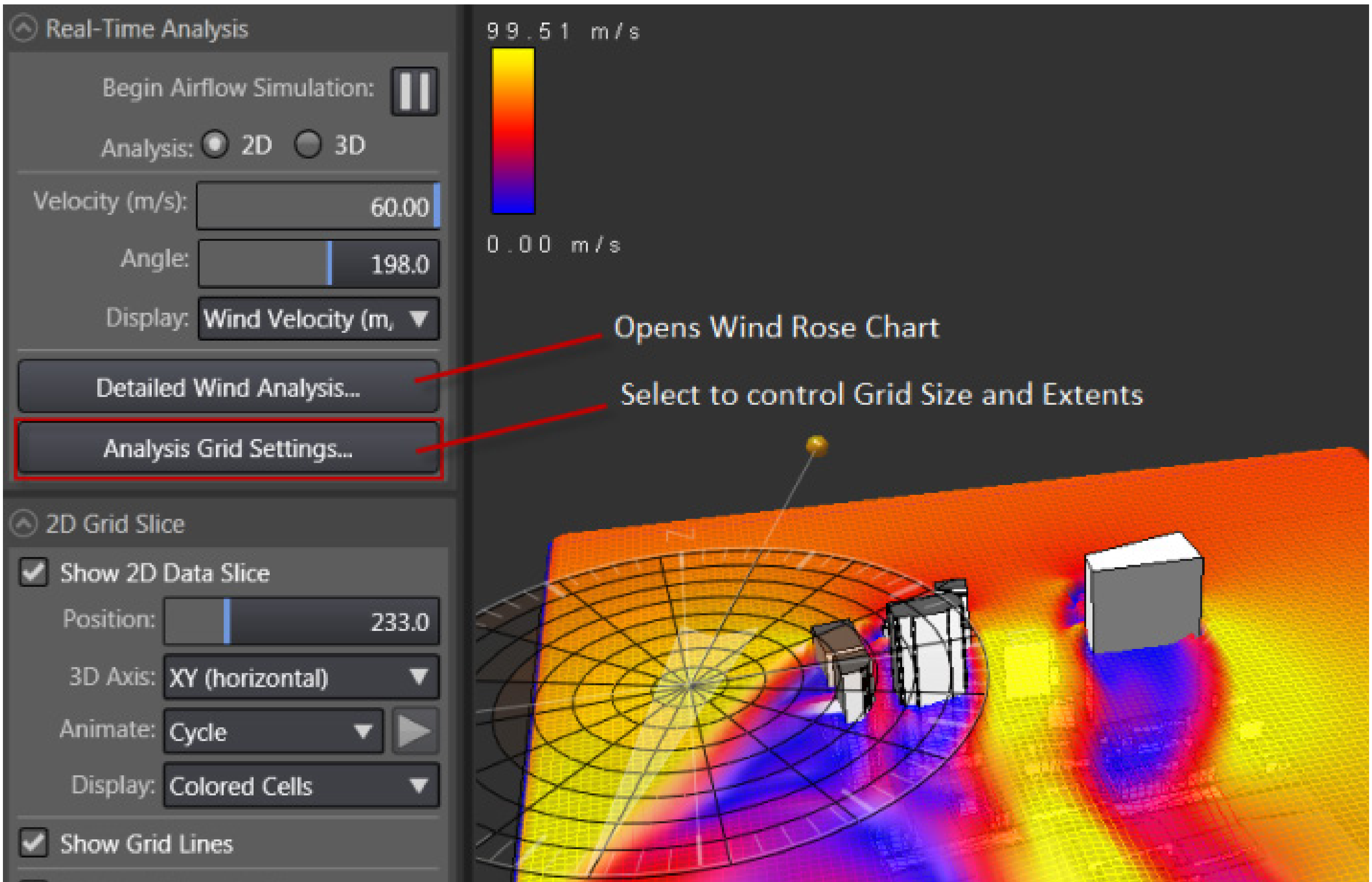
The chart is generated from hourly weather data retrieved from the weather station you selected for your project.

Vasari: Wind Rose Feature





Vasari: Wind Tunnel Feature
Source:http://help.autodesk.com/view/VASARI/B3/ENU/?guid=GUID-2BEF3653-9728-4E22-ABD0-D9F83F561193



Vasari: Wind Tunnel Feature
http://help.autodesk.com/view/VASARI/B3/ENU/?guid=GUID-E28B71EA-DFDF-4BB3-A526-FA9D95477F04

This data is downloaded automatically.

By adjusting the yellow and blue bars at the bottom of the chart, it is possible to set parameters for the time of year and time of day, so that the results displayed will reflect the time ranges you input.

Wind Tunnel

Wind Tunnel feature can be used to run computational fluid dynamics (CFD) simulations in order to analyze the potential impact of wind speed and direction on an urban area, or other project.

The Wind Tunnel feature allows you to run either 2D or 3D airflow analyses. The wind speed and direction can be modified by manually typing the inputs, or by using the circular Wind Frequency Chart (shown below). Rotating the arrow allows you to modify the wind direction, and stretching the arrow allows you to modify the wind speed. The wind velocity scale is shown in the top right corner of every analysis, represented in color, with blue having the lowest velocity and yellow the highest.

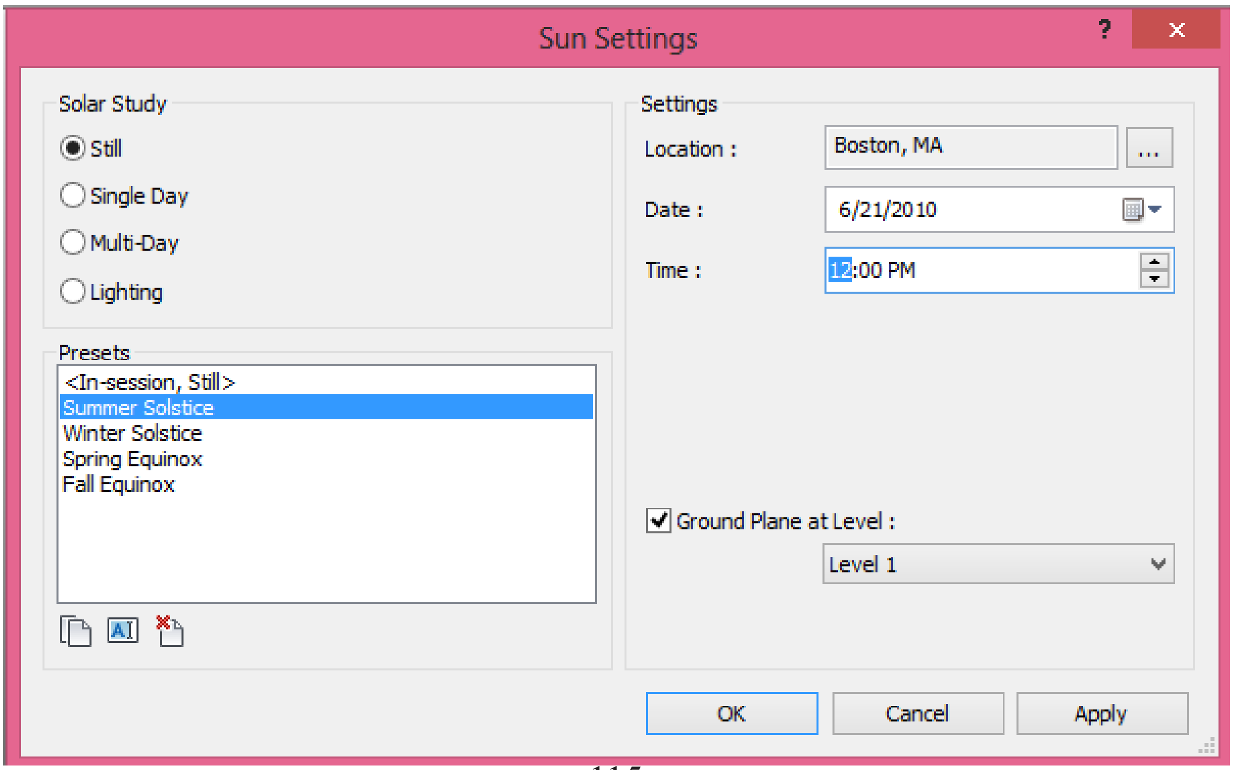
Grid size and extents can be controlled manually using the Analysis Grid Settings option, and the Wind Tunnel feature can be used in conjunction with the Wind Rose feature to simulate the impact of wind speed and direction according to a specified geographic location.

Sun Settings and Shadows

Sun settings and shadows can be modified using the icons on the toolbar at the bottom of the Vasari workspace. Alternatively, sun settings can be modified by selecting the Manage tab and then Sun Settings.

After selecting sun setting, a pop-up window will appear, allowing you to set up a specific solar study. The sun setting options are Still, Single Day, Multi-Day and Lighting. Still allows you to view the

Vasari: Sun Settings



sun path and shadows at a specific hour on one specific day of the year. The Single Day option allows you to analyze a range of hours on one specific day. The Multi-Day setting allows you to analyze a range of hours during a range of days or months. The Lighting option allows you to choose the angle the sunlight is coming from by inputting the azimuth and altitude.

Once the settings have been defined, select Apply, and the shadows will be displayed, as long as the shadows option is turned on.

It is also possible to view the sun path but turning on the sun path option, next to the shadow icon on the bottom toolbar.

Social analysis

The social analysis is divided into three sections: Streets, Buildings, and Open Spaces. In each section, a variety of parameters were defined as a result of the literature review. Each of the parameters is analyzed using one or more indicators. The indicators produce quantitative or qualitative values, which are then scored on a social comfort scale from 0 to 10. The score given represents how well that particular sample performs in a specific category in comparison to the other samples. The overall score for a given parameter is produced by averaging the scores of all the indicators in that category.

STREETS

In the streets section, the parameters analyzed were visual permeability, physical permeability, traffic flow, and walkability.

Visual Permeability

Grid type was used as an indicator for visual permeability. The more regular the grid type, the higher the visual permeability. The six samples were classified into separate categories: regular grid, and distorted or organic grid. The classification was decided based on a visual analysis of the street layout. The higher the visual permeability, the higher to social comfort score.

Physical Permeability

The physical permeability of the sample was based on two indicators, the average block size, and the number of intersections in the sample. The smaller the block size and the more intersections present, the higher the physical permeability of the grid, which results in a higher social comfort score.

Traffic Flow

Traffic Flow was measured using one indicator: the average number of traffic lanes. The average number of traffic lanes was calculated by adding the total number of traffic lanes in the sample area and dividing by the number of streets. The lower the number of traffic lanes, the higher the social comfort score.

Walkability

Walkability was measured using one indicator, the walk score found on walkscore.com. To find the walk score, a specific street address must be entered. An address was chosen near the center of each sample. The walk score is based on seven categories: dining and drinking, groceries, shopping, errands, parks, schools, culture and entertainment. Scores range from 0 to 100. The higher the walk score, the higher the social comfort score.

BUILDINGS

In the buildings section, the parameters analyzed were active fronts, building variety, mixed use, and building density.

Active Fronts

The activity level of the building fronts was based on two indicators, the percent of buildings with active facades, and the number of entrances to the street. One street, 500 meters in length, was chosen from each sample for the analysis. The higher the percentage of active fronts and the higher the number of entrances, the higher to social comfort score.

Building Variety

Three indicators were used to measure building variety: mix of old and new buildings, mix of renovated and un-renovated buildings, and mix of housing types.

All three indicators were estimated with a qualitative analysis. Using Google street view, a general visual survey was conducted on the building stock in each sample. Distinctions were made between traditional and modern building types, between apparently well-maintained buildings and un-renovated or unmaintained buildings, and between five housing types: detached single-family, multifamily, low-rise (1-4 floors), midrise (5-8 floors), and high-rise (9+ floors). The higher the variation in each category, the higher to social comfort score.

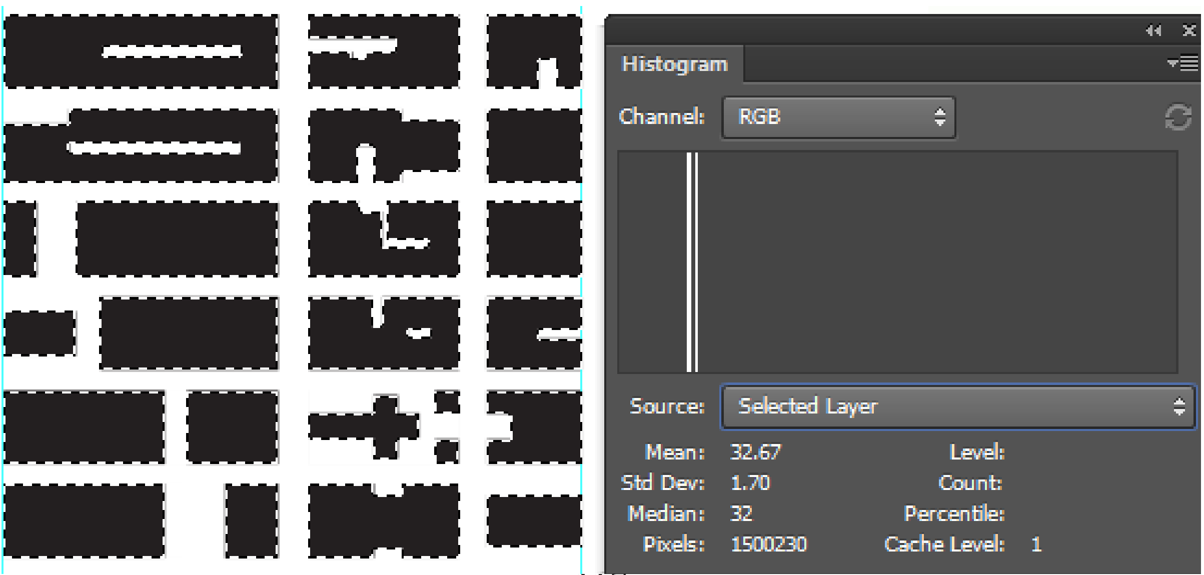
Mixed Use

Mixed Use was measured on a scale from one to five, considering four main neighborhood uses: residential, commercial, office, and entertainment. Samples with only one primary function receive the lowest score, while samples with all four functions receive the highest score.

Building Density

Building Density was measured using two indicators: typical building height,

Photoshop: Histogram Building Footprints



and ground coverage. Typical building height was calculated by selecting the most common building height in the sample. The ground coverage was calculated as the percent of build space out of the total ground area, including the streets. The estimation was done with the histogram tool in Photoshop. Using the building footprint map shown below, all of the buildings were selected and their combined area was calculated in pixels. The size of the building footprints (in pixels) was divided by the total sample area (in pixels), resulting in the percentage of build area. The higher the building density, the higher to social comfort score. Negative factors of high density, such as lack of building variety, green space, environmental comfort, etc., are considered separately.

OPEN SPACES

In the open spaces section, the parameters analyzed were size and number of open spaces, public access, and comfort.

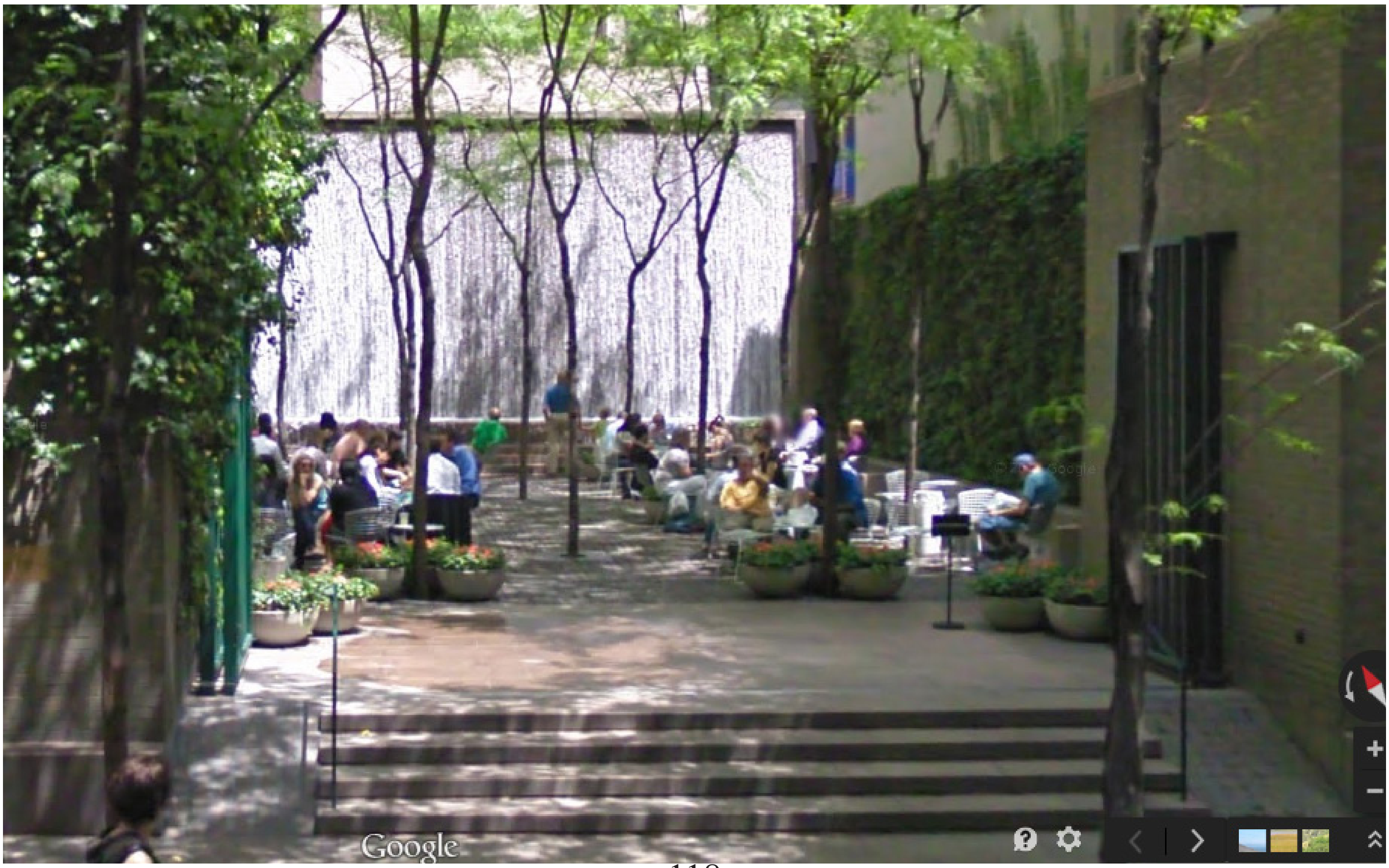
Size and Number

The area of each open space was calculated using Google Earth, which was used to find the average area. The number of open spaces refers to the number of spaces found inside the 500m by 500m sample.

Public Access

Public Access is calculated using two indicators, visual access and physical access. The number of open spaces that are visually accessible to the public are calculated as a percentage of the total, along with the number of open spaces that are physically accessible to the public. The higher the percentage of

Google Earth: New York Green Space



accessible spaces, the higher the social comfort score.

Comfort

Comfort is calculated using three indicators, protection, availability of comfortable seating and aesthetic quality. Protection refers to the ability of the space to protect users from unpleasant environmental conditions such as noise, pollution, heat and cold. Spaces bordered on three or more sides are considered more protected, along with spaces that are set back from the road to reduce noise and pollution. Availability of seating is analyzed with a visual analysis using Google Earth. Spaces are scored using three categories, limited seating, adequate seating, or well-equipped. Aesthetic quality is also calculated using a visual analysis, considering such factors as trees and green areas, design quality, maintenance, furniture, etc. Spaces are scored using three categories, poor quality, adequate quality, and good quality.

ENVIRONMENTAL ANALYSIS INPUTS

The environmental analysis was conducted in two parts, using two different studies, a wind study, and a solar study. The first part, consisting of both a wind and solar study, analyzed the wind and solar conditions of each sample in its natural context, during both summer and winter conditions. In the second part of the analysis, each sample was placed in a generic context and analyzed during summer and winter wind and solar conditions. The purpose of the first part is to see how well each sample performs in its natural environment, whereas the purpose of the second part is to compare the relative performance of each sample under common conditions.

Therefore, this section will be divided into two parts, and the wind and solar analyses will be discussed separately in each part.

LOCAL CONTEXT

In order to see how well each sample performed in its natural environment, each case was analyzed under somewhat different environmental conditions according to its specific location.

To do this, a 3D model of each sample was imported into the Autodesk Vasari program and the location of each sample was defined according to where that sample originated (i.e. the New York sample was set in New York, etc.).

After setting the location and importing the site image, the 3D model was rotated until the orientation of the model matched the orientation of the pattern in its urban context. This was sometimes required because the samples were cut according to the street grid, and the street grids in the samples chosen are not always aligned to the north.

Wind Rose

By selecting the Analyze tab, and choosing Wind Rose, a pop-up window allows you to select the parameters for the wind study, with the location already set, it is only necessary to set a time of year and time of day. In our study, the parameters were set to include June, July and August for the summer study, and December, January and February for the winter study. The time of day, in both the summer and winter studies was set to include the hours from 6:00 to 24:00. With these selections defined, the wind rose diagram displays the direction, speed and frequency of wind conditions for the time range specified.

Wind Tunnel

When the wind tunnel feature is opened, the information from the wind rose will be input automaticaly, but further modifications to the wind speed and direction can be made within the wind tunnel feature. The analysis grid is also set up automatically according to the size of the model, but it can be modified by selecting Analysis Grid Settings. In each of the six samples analyzed, the analysis grid was set to a standard size: X Axis: -3000, 3000; Y Axis: -3000, 3000; Z Axis: -3000, 3000; Z -300, 3000; Voxel Size: 60.

In each case, a 3D analysis was performed, and the results were displayed in a 2D data slice, which was set at a height of 15 units (appox. 5m), above ground level. The wind analysis was conducted for both the summer and winter studies by changing the wind direction, according to the results displayed in the wind rose diagram for each season.

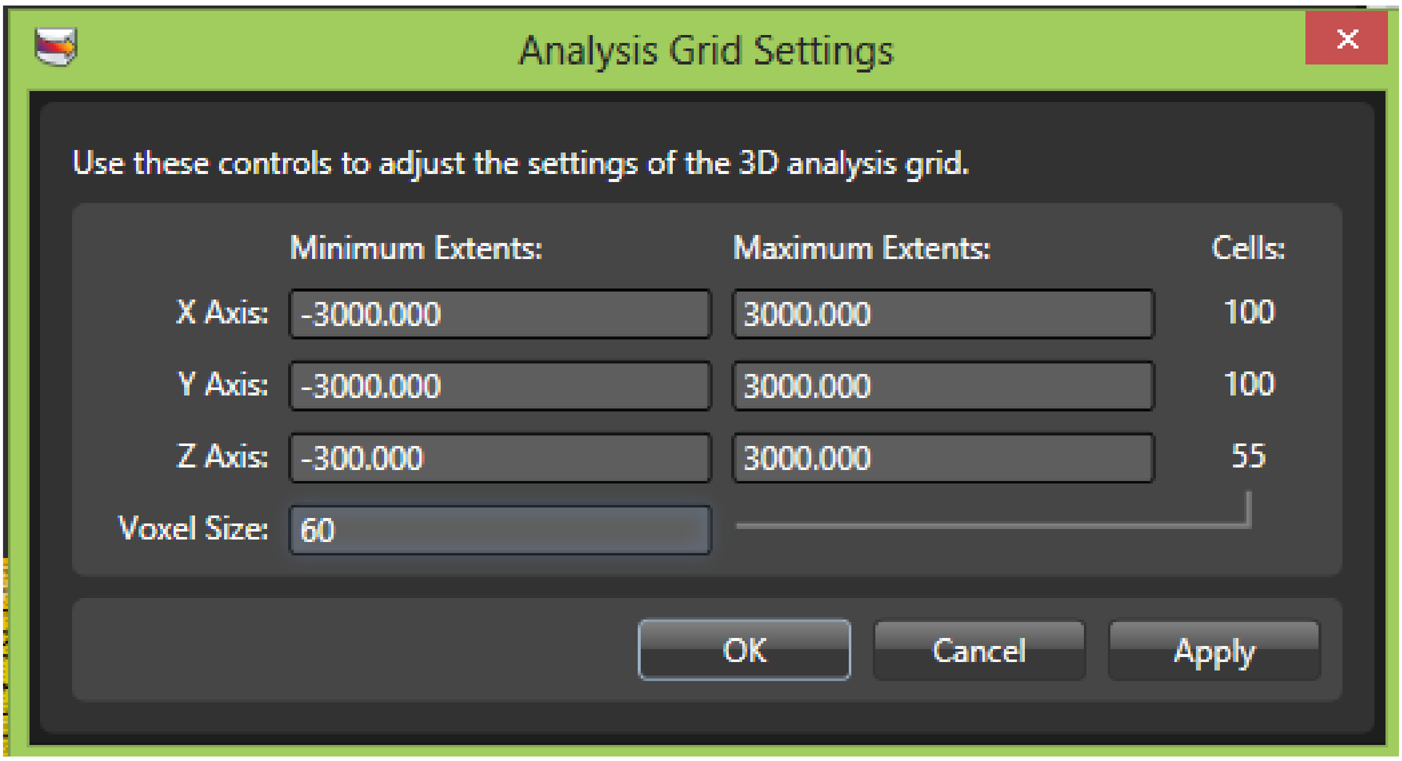
Shadows

To complete the shadow analysis, the sun settings were set to four different times of the day, 10:00, 12:00, 2:00, and 4:00. The solar study was conducted on a single day in both the summer and winter studies, the summer soltice, June 21st, and the winter solstice, December 21st.

GENERAL CONTEXT

In order to compare performance levels, all the models were set in a general

Vasari: Analysis Grid Settings



context. The wind study was conducted without a specifiec location, analyzing four specific wind directions, north, northwest, west, and southwest. The solar study was conducted by placing all the models in the same location, for which Boston was selected.

Wind Tunnel

The Wind Rose function was not necessary in this case because no location was specified. Instead, the models were placed inside the wind tunnel simulation and analyzed under four wind directions. These four wind directions were chosen because they allow the broadest analysis of wind conditions with the least number of simulations. In the generalized case, the models were not positioned according to the orientation they would have in their real context, like in the localized study. Instead, all the models were oriented according to their street layouts, so that in the case of a regular grid, the streets would run north-south, and east-west. The Analysis Grid Settings were maintained the same as in the localized study, along with the other settings described above.

Shadows

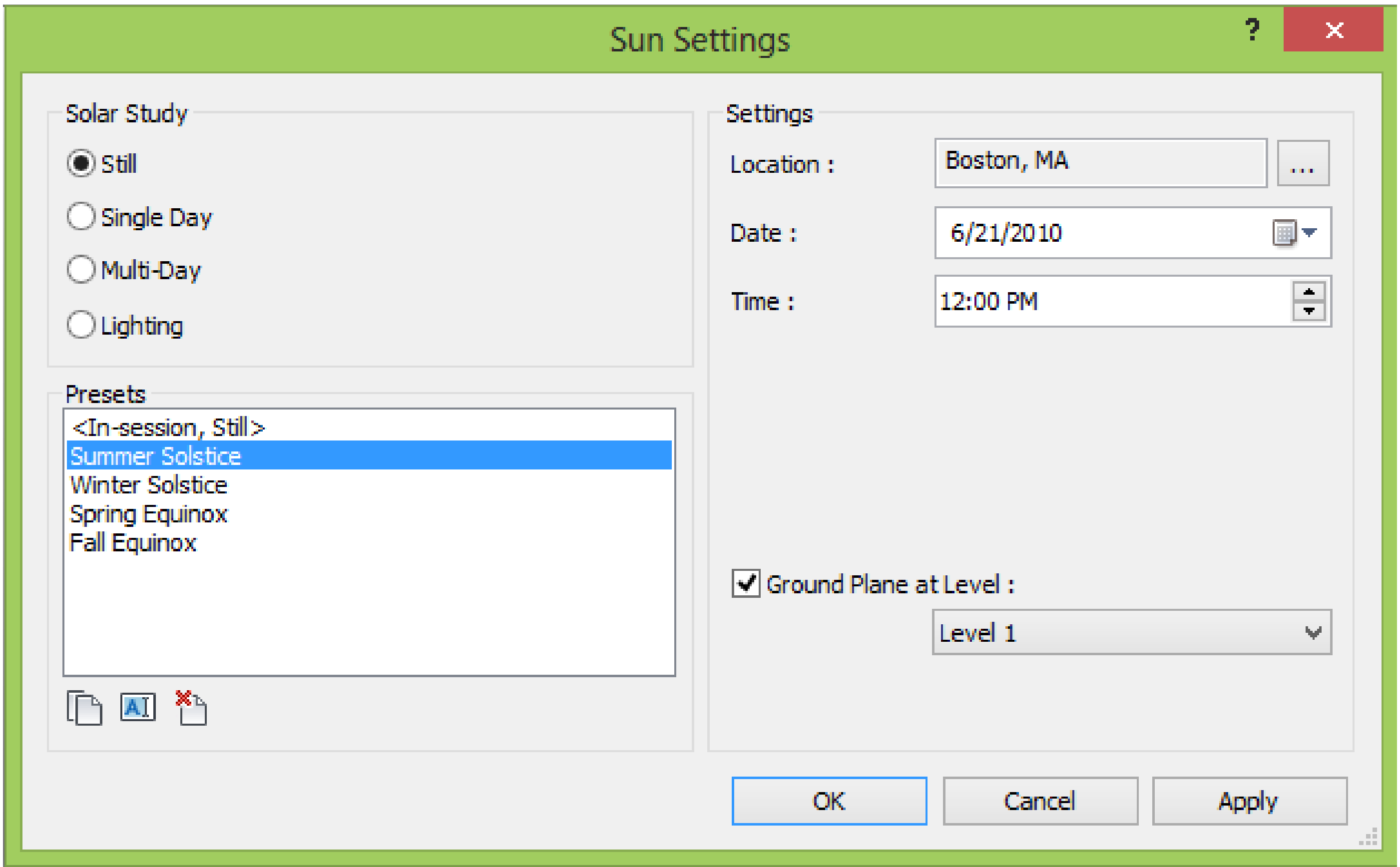
The shadow analysis was conducted in the same way as in the localized study, with the exception that all the model locations were set to Boston, and the street grids were oriented to the north.

Environmental Analysis Outputs

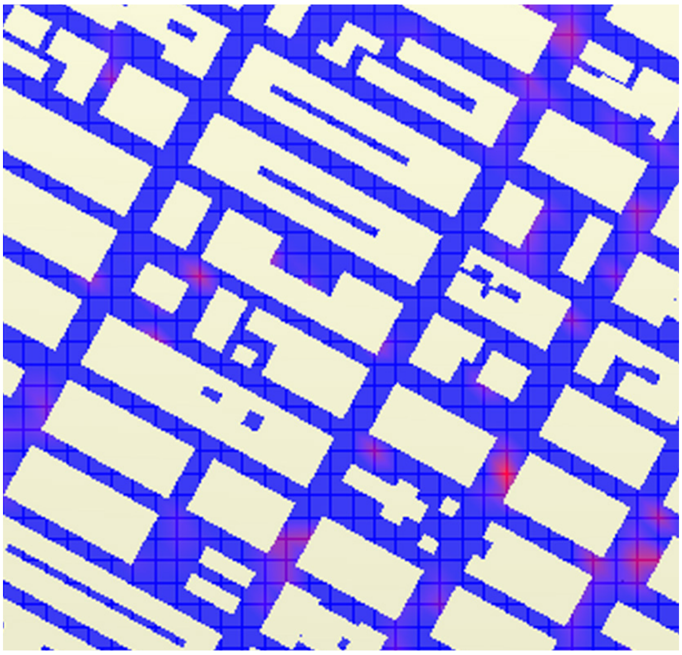
Wind Tunnel

The wind tunnel outputs from Vasari are show as 2D slices of the wind analysis. The color ranges in the slices show

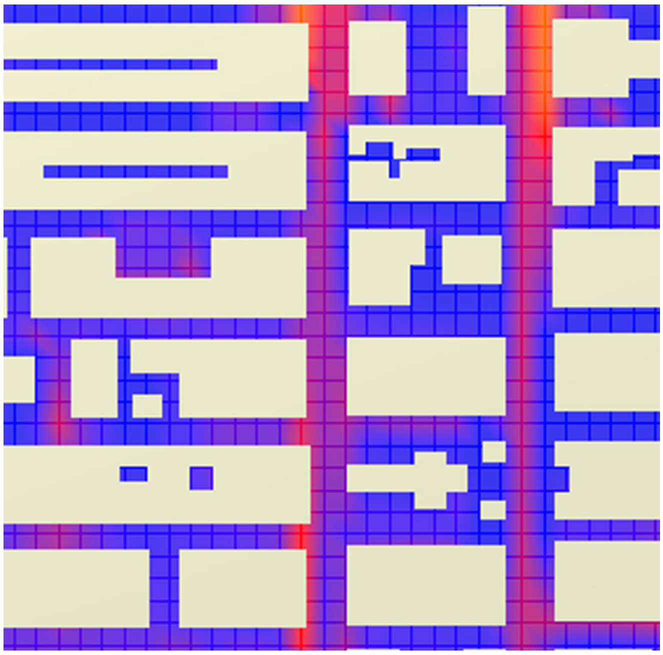
Vasari: Sun Settings



Vasari: New York--Local Context



Vasari: New York--General Context



the varying wind velocities. The outputs were divided into three categories, which were counted separately: North-South Streets, East-West Streets, and Open Spaces. In each category, the wind velocity outputs were measured in percentages by counting the cells in the underlying grid of each color. For instance, 50 blue, 20 red, 10 yellow. The total number of cells counted is 80; 50/80 = 0.625, so the result is 63% blue and so on. Only the 500m by 500m square at the center of the original 1sqkm is used in the analysis. The 250-meter border on all sides is disregarded because of the “edge effect” described previously.

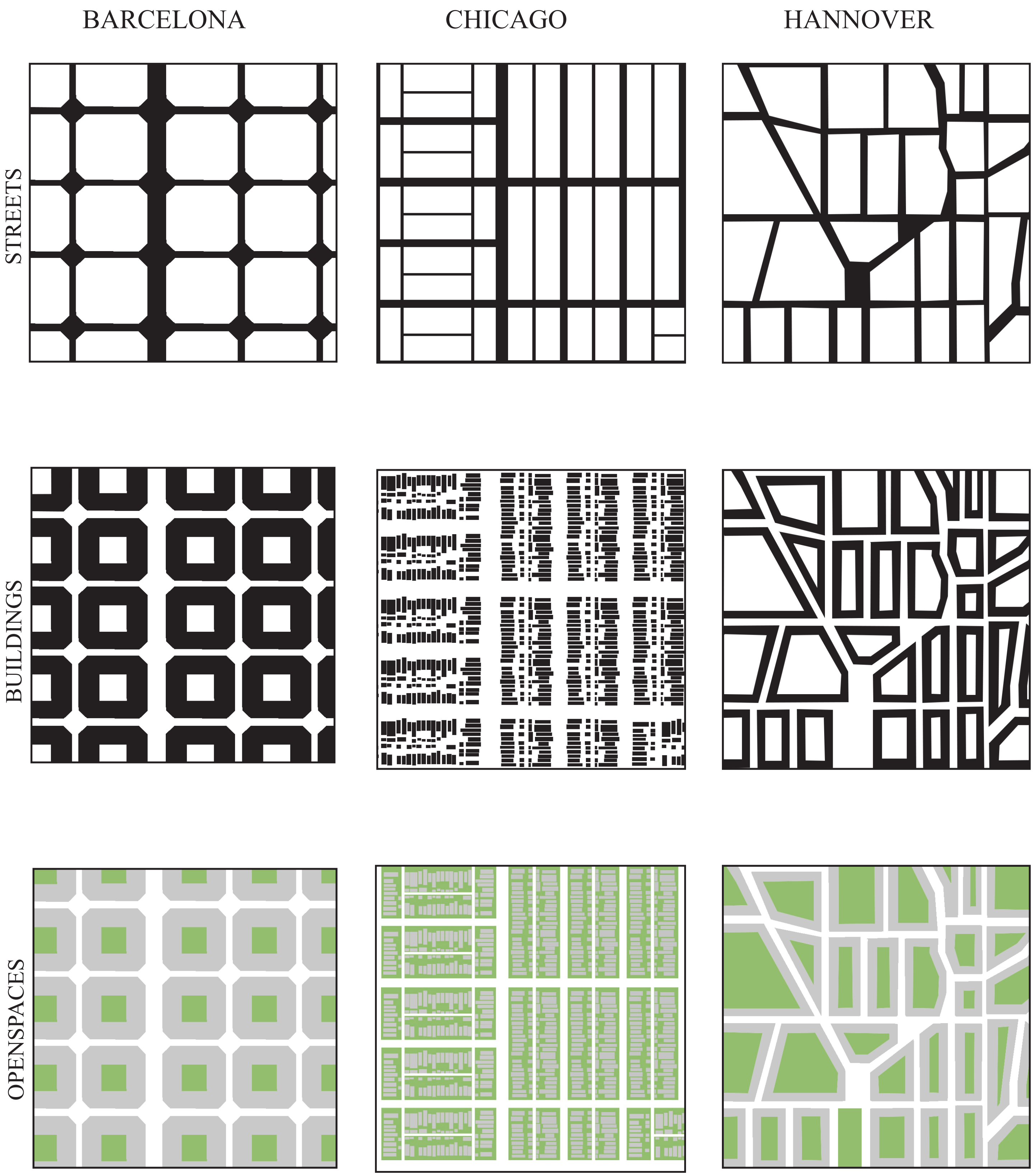
Shadows

The shadow outputs also appear as 2D data slices, but with only two colors, gray and white. Because there is no underlaying grid, the shadow outputs were analyzed using the histogram tool in Photoshop to count the number of pixels of each color. The shodow outputs were also divided into three categories: North-South Streets, East-West Streets and Open Spaces.

PART II
CASE STUDIES

CASE STUDY LOCATIONS


NOVER
MOSCOW
NOVI SAD
IA


BARCELONA
CHICAGO
HANNOVER
STREETS
BUILDINGS
OPENSPACES


MOSCOW
NEW YORK
NOVI SAD

Case Studies

Six case studies were chosen to represent a significant variety of morphological conditions. Specific patterns measuring 1K2 in area were selected from the following cites: Barcelona, Chicago, Hannover, Moscow, New York, and Novi Sad. Each pattern was analyzed in terms of social conditions, as well as environmental conditions. The social study was divided into three areas,

Social Analysis		
STREETS		
	VISUAL PERMEABILITY	
		Grid Type
	PHYSICAL PERMEABILITY	
		Block Size
		Number of Intersections
	TRAFFIC FLOW	
		Number of Traffic Lanes
	WALKABILITY	
		Walkscore
BUILDINGS		
	ACTIVE FRONTS	
		Percent of Buildings with Active Fronts per 500m
		Number of Entrances per 500m
	BUILDING VARIETY	
		Mix of Old and New Buildings
		Mix of Renovated and Unrenovated Buildings
		Mix of Housing Types
	MIXED USE	
		Number of Mixed Uses
	BUILDING DENSITY	
		Typical Building Height
		Ground Coverage
OPEN SPACES		
	SIZE AND NUMBER	
		Area in m2
		Number
	PUBLIC ACCESS	
		Visual Access
		Physical Access
	COMFORT	
		Climate and Noise Protection
		Comfortable Seating
		Aesthetic Quality

streets, buildings and open spaces, and specific criteria and indicators were analyzed in each area. The environmental analysis was divided into two sections, local context and general context. Each section included a wind and shadow study. Wind and shadow conditions for each city were analyzed during the summer and winter, and the shadows were measured at four times during the day: 10:00, 12:00, 14:00, and 16:00. The results were recorded in both streets and open spaces. The specifics of each analysis are shown in the tables below.

ENVIRONMENTAL ANALYSIS			
LOCAL CONTEXT --SIX CITIES			
	WIND		
		Summer	
			North-South Streets
			East-West Streets
			Open Spaces
		Winter	
			North-South Streets
			East-West Streets
			Open Spaces
	SHADOWS		
		Summer Hours: 10:00, 12:00, 14:00, 16:00	
			Streets
			Open Spaces
		Winter Hours: 10:00, 12:00, 14:00, 16:00	
			Streets
			Open Spaces
GENERAL CONTEXT-- BOSTON CASE			
	WIND		
		North, Northwest, West, Southwest	
			North-South Streets
			East-West Streets
			Open Spaces
	SHADOWS		
		Summer Hours: 10:00, 12:00, 14:00, 16:00	
			Streets
			Open Spaces
		Winter Hours: 10:00, 12:00, 14:00, 16:00	
			Streets
			Open Spaces

Barcelona
SPAIN

Barcelona is the capital city of the autonomous community of Catalonia in Spain and the country's second largest city, with a population of 1.6 million within its administrative limits.

Area: 101.9 km^2
Latitude: 41°23"
Longitude: 2°09"
Elevation above sea level: 47 m

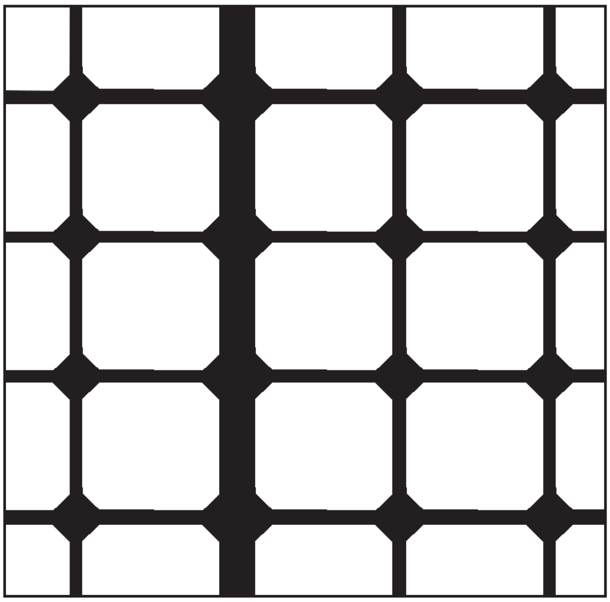
CLIMATE
Average January temperature: 12°C
Average July temperture: 28°C

Annual rainfall: 590mm.
On average, the warmest month is July and the coolest month is January. October is the wettest month. July is the driest month.

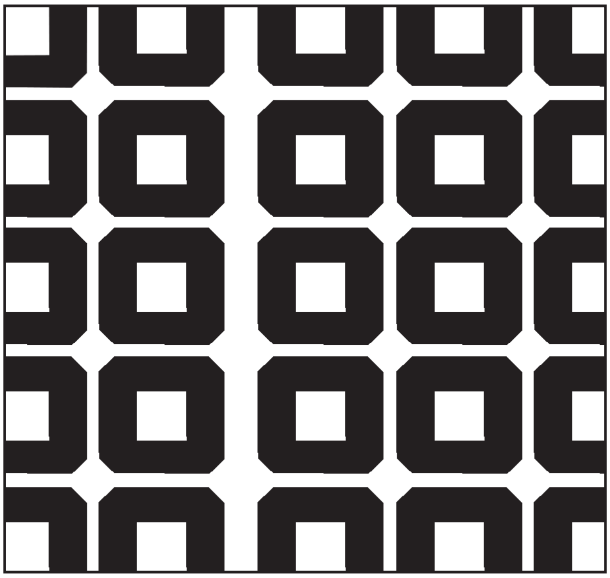
POPULATION
2012: 1.621 million

ETCHNICITY
Majority Catalan Spanish. Minorities (10%) include Roma and African

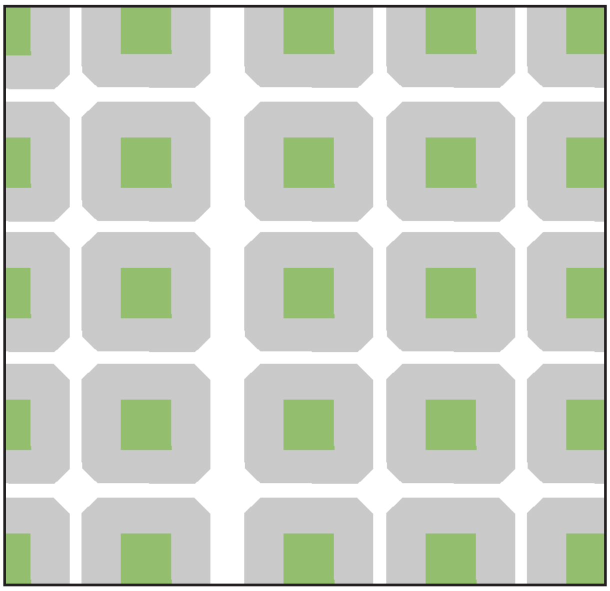
STREETS



BUILDINGS



OPEN SPACES



Barcelona

SOCIAL ANALYSIS

STREETS

Visual Permeability

The Barcelona sample is characterized by a regular grid type, with straight perpendicular streets. The regularity of the grid improves visual permeability and legibility in the city, therefore the score given is 10 out of 10.

Physical Permeability

The Barcelona block size is approximately 10.000 sqm, which is smaller than average compared to the other samples. The number of intersections is 16, which is close to the average. The overall score is 6 out of 10 on the social comfort scale.

Traffic Flow

The traffic flow is high in Barcelona, with an average of 2.5 traffic lanes. The high number of traffic lanes impedes pedestrian movement. Compared to the other samples, the number of traffic lanes is a little higher than average, therefore it receives a 4 on the social comfort scale.

Walkability

Walkability is highest in the Barcelona sample, with a walk score of 100, which means that all essential products and services can be reached within walking distance. In comparison with the other samples, Barcelona receives a score of 10 for walkability.

BUILDINGS

Active Fronts

Eighty-two percent of buildings have active facades with many shops along the street. The number of entrances to the street per 500m is 63, which is the highest among all the samples. Barcelona receives an overall score of 8.5 out of 10 on the social comfort scale.

Building Variety

Building variety is somewhat low in the Barcelona sample. The mix of old to

STREETS- BARCELONA			
Street Elements			Social Score (0-10)
Visual Permeability			10
	Grid Type	Regular Grid	10
Physical Permeability			6.5
	Typcial Block Size	10.000 sqm	8
	Number of Intersections	16	5
Traffic Flow			4
	Average Number of Traffic Lanes	2.5	4
Walkability			10
	Walk Score	100	10

BUILDINGS			
Building Elements			Social Score (0-10)
Active Fronts			8.5
	Percent of Buildings with Active Facades/500m	82 %	8
	Number of Entrances /500m	68	9
Building Variety			3
	Mix of Old and New Buildings	Low	3
	Mix of Renovated and Un-renovated Buildings	Medium	5
	Mix of Housing Types	Lowrise	2
Mixed Use			6
	Number of Mixed Uses	Residential, Commercial, Entertainment	6
Building Density			7.5
	Typical Building Height	22m	6
	Ground Coverage	62%	9

new buildings is low, since the majority of buildings are older in age. However there is some variety in building condition; some buildings are more renovated than others, which allows for a higher variety of rent levels and therefore business types. The mix of housing types is low; the building stock is made up of attached low-rise apartments with ground floor commercial uses. In comparison with the other samples, the overall score given is 3 out of 10.

Mixed Use

In the Barcelona sample, three primary uses were identified, residential, commerial, and entertainment. This is a relatively high mix and increases the activity at different times of the day. Barcelona receives a score of 6 out of 10.

Building Density

The building density is high in the Barcelona sample, with a typical building height of 22 meters and a ground coverage of aproximately 62%. This results in a score of 7.5 out of 10.

OPEN SPACES

Size and Number

Open spaces in the Barcelona sample are adaquate in number and size. There are 25 open spaces with an average size of 2.500 sqm. Barcelona receives an overall score of 8.5 because the spaces and neither too big nor too small and the number of spaces is higher than average compared to the other samples.

Public Access

Visual and physical access to the open spaces is extremely. All 25 of the open spaces are courtyard spaces, meaning that they are not accessible to the public, neither visually or physically. Therefore, public access to green spaces within the sample is 0%, resulting in a score of 0 out of 10.

Comfort

OPEN SPACES			
Open Space Elements			Social Score (0-10)
Size and Number			8.5
	Average Size	2.500 sqm	9
	Number	25	8
Access			0
	Visual Access	0%	0
	Physical Access	0%	0
Comfort			5
	Climate/Noise Protection	High Protection	8
	Comfortable Seating	Limited	4
	Aesthetic Quality	Low	3

The spaces have moderate to high protection from noise and unpleasant environmental conditions, since they are protected by walls on all four sides. The courtyards are semi-public spaces shared between the residents and users of the surrounding buildings, and there is a high variation in the seating comfort and aesthetic quality between the different spaces. Some have green elements and comfortable seating, while many lack aesthetic quality. The overall score given is 5 out of 10.

Environmental analysis

LOCAL WIND STUDY

Summer

During the summer season, the city of Barcelona is characterized by the wind coming from the South-South-West. After the simulation was performed the results are following:

In the north-south direction of the streets: the wind speed of 2 m/s was 82%, the speed of 4 m/s is 6%, wheare all greater speeds equal to 0.

In the east-west direction, the wind speed in the streets is diffused in the following way: wind speed of 2 m/s: 71%, speed of 4 m/s: 10%, speed of 6 m/s: 19% and greater wind speeds are equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s: 8%, 4 m/s: 20%, and the rest of wind speeds equal to 0.

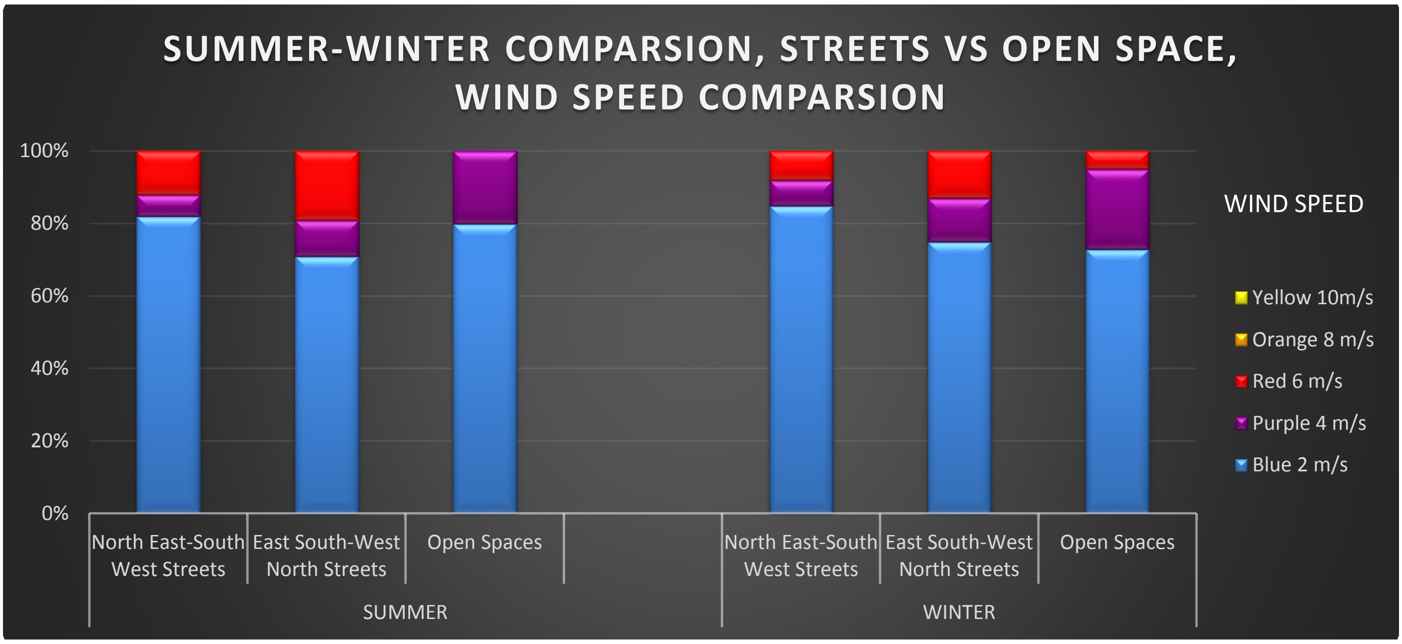
Overall, combining the streets and open spaces we can get a percentage of 78% the slowest wind speed and greater wind speed of 4 m/s : 12% and speed of 6 m/s: 11%.

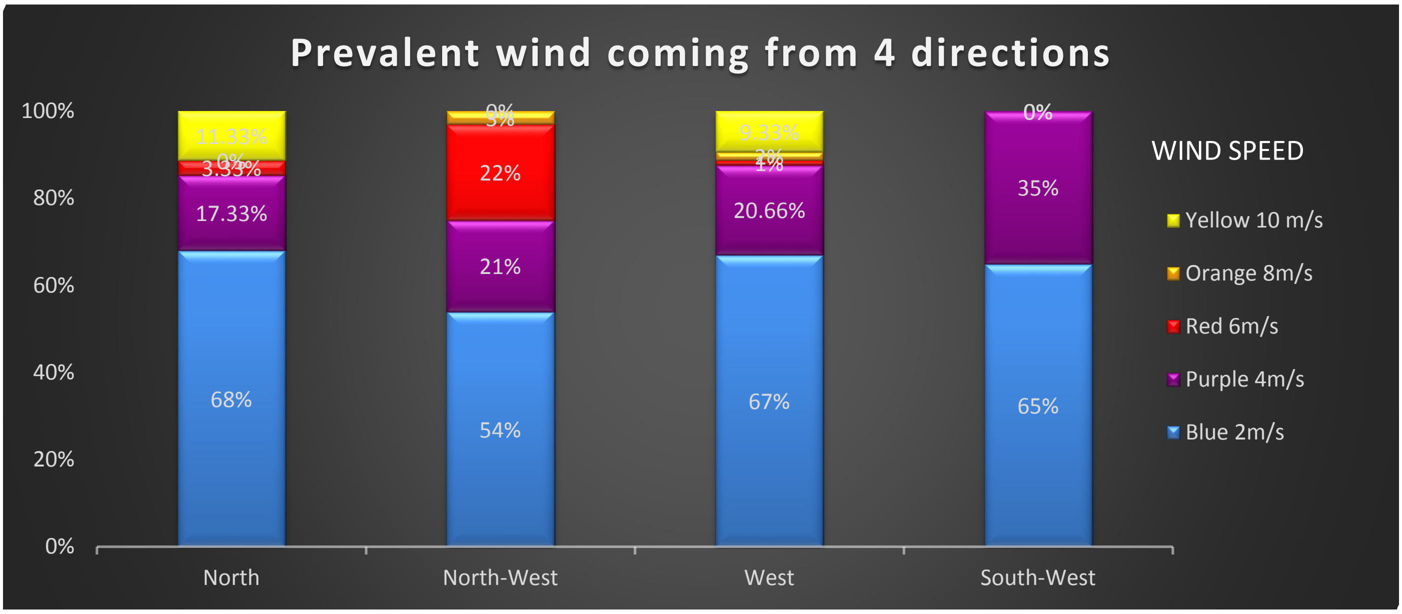
Winter

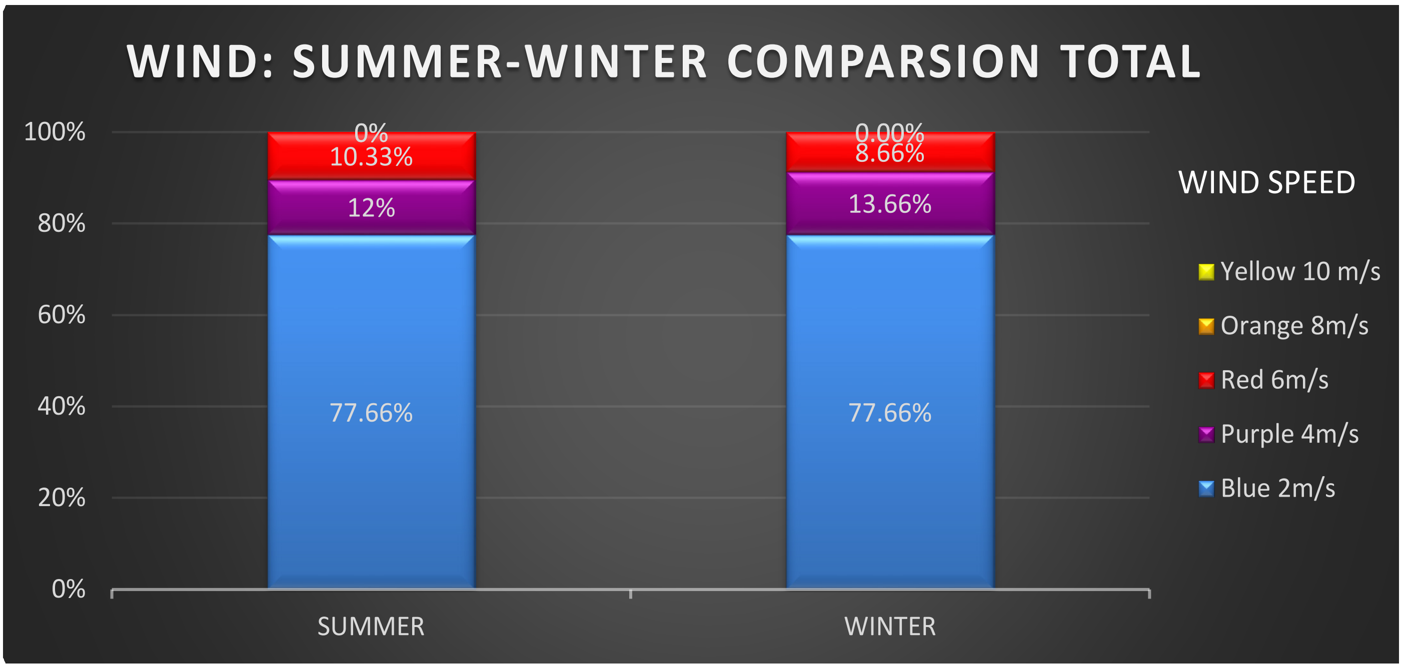
During the winter season, the city of Barcelona is characterized by the wind coming from the North. After the simulation was performed the results are following:

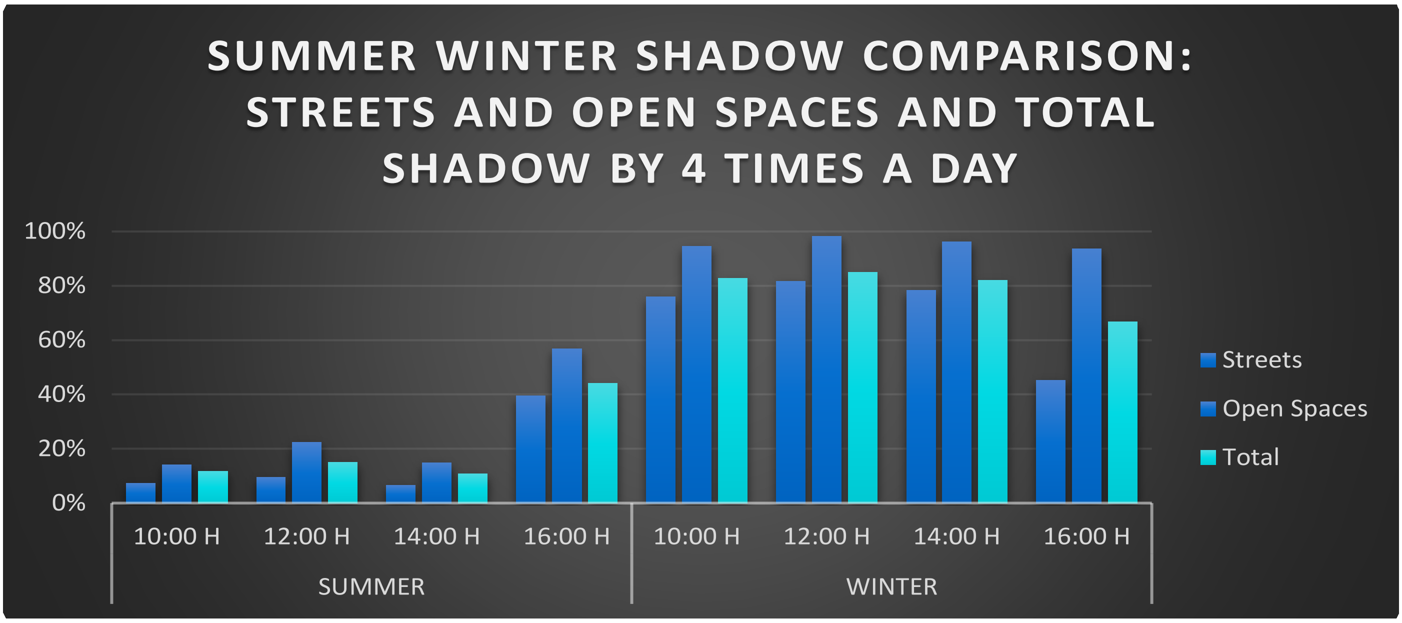
In the north-south direction of the streets: the wind speed of 2 m/s was 85%, the wind speed of 6 m/s is 7%, where all the greater wind speeds equal to 0.

In the east-west direction, the wind speed in the streets is diffused in the fol-


SUMMER-WINTER COMPARSION, STREETS VS OPEN SPACE, WIND SPEED COMPARSION
100%
80%
60%
40%
20%
0%
North East-South West Streets
East South-West North Streets
Open Spaces
SUMMER
North East-South West Streets
East South-West North Streets
Open Spaces
WINTER
WIND SPEED
Yellow 10m/s
Orange 8 m/s
Red 6 m/s
Purple 4 m/s
Blue 2 m/s


Prevalent wind coming from 4 directions
100%
80%
60%
40%
20%
0%
11.33%
3.33%
17.33%
68%
22%
21%
54%
9.33%
20.66%
67%
0%
35%
65%
North
North-West
West
South-West
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s


WIND: SUMMER-WINTER COMPARSION TOTAL
100%
80%
60%
40%
20%
0%
0%
10.33%
12%
77.66%
0.00%
8.66%
13.66%
77.66%
SUMMER
WINTER
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s



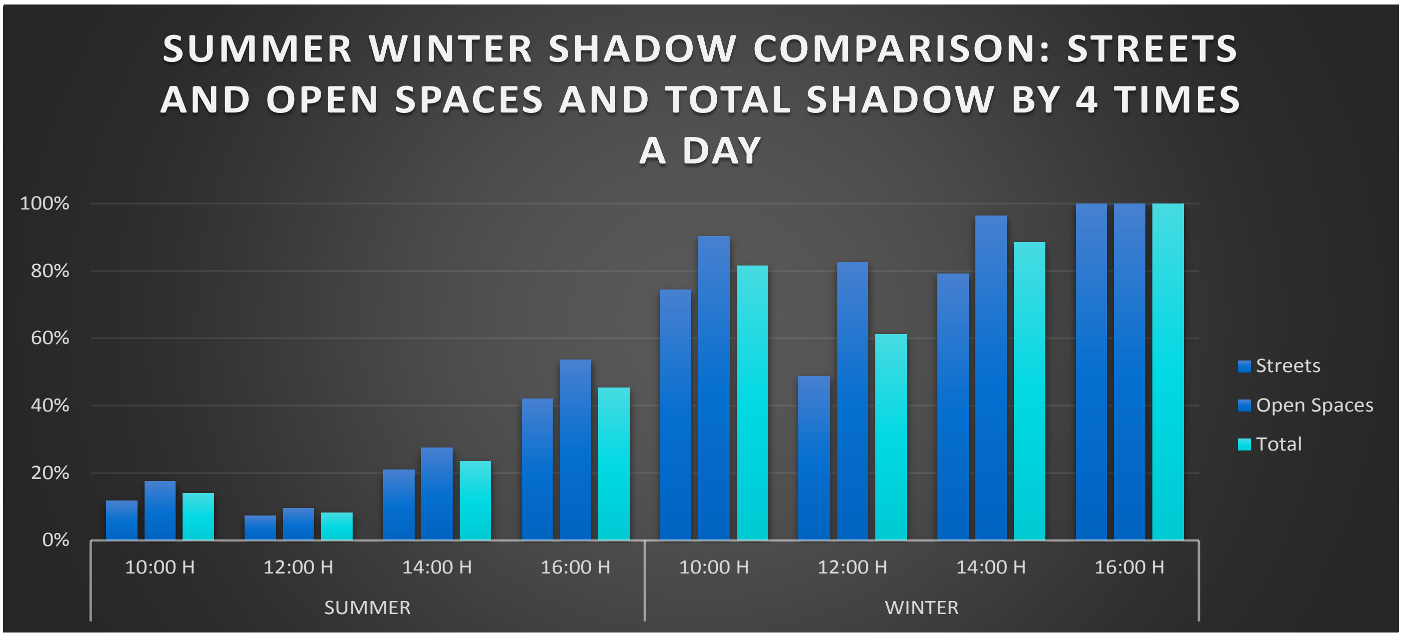
lowing way: 2 m/s speed: 75%, 4 m/s speed: 12%, 6 m/s: 13% and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s speed: 73%, 4 m/s speed: 22%, and greater wind speeds equal to 0.

Overall, combining the streets and open spaces we can get a percentage of the slowest wind speed of 78% and greater wind speed of 4 m/s : 14% and speed of 6 m/s: 9%. Greater wind speed equal to 0.

In order to understand and have a visual insight of the change of the wind throughout the year long, a comparison was made on the graph. From the graph it can be concluded that there is no big change going from summer towards winter. The prevalence of the wind remains almost the same.

Comparing again the situation in the summer and winter but going more into details and analyzing north-south, west-east streets and open spaces in both of the seasons, it can be noted that the wind speed of 6 m/s is more prevalent



in the streets while in the open spaces it barely exists. This can be explained with the fact the open spaces are placed within the buildings and from all four sides surrounded. Therefore, it is difficult for faster wind to go through.

GENERAL WIND STUDY

The wind speed is compared by doing an experiment where wind was coming from the four directions: North, North West, West and South West. Looking at the graph above, it can be concluded that the slowest wind speed is present at the highest percentage and it reflects very low wind speed, of just 2 m/h. The critical situation would happen in case the wind was coming from the north and west because that would cause a higher wind speed of 10 m/s (yellow color). A slightly better situation would be in case the wind was blowing from the North-West because it would provoke a formation of mid speed wind (red color) blowing of 6 m/s.

LOCAL SHADOW STUDY

The analysis of the sun effects and shadows that it leaves on the streets and open spaces was performed, as well. The measurements were done during the summer and winter season and at specific hours of the day in order to get the true picture and data how much shadow is actually present at the city throughout the day, from the morning until the afternoon. The measurements were done at the following hours: 10 am, 12 am, 2 pm and 4 pm.

Summer-Winter

In case of Barcelona, the amount of the shadow during the summer is lower, while in the winter is higher. (graph_) And paying attention specifically on the streets and open spaces, it can be noted that the amount of the shadows is higher at open space. This is justified with the walls of the buildings which are putting the shade on the open space much more the buildings putting the shade on the streets. In order to better understand the division of the shade per street and per open space, we made a following graph where we additionally put the total overall existence of the shadow for every specific hour. In can be concluded that the amount of shadow is the lowest at 10 am, and the highest at 4 pm, both in summer and winter.

GENERAL SHADOW STUDY

In case of placing a Barcelona city model into the geographical position of the Boston city, situation about the shadows does not change very much. The amount of shadows goes up going from the summer towards the winter. The slight change can be noted in the winter, at 4 pm where the presence of the shadow entirely covering the city in the percentage of 100%.

CHICAGO
UNITED STATES

Chicago is the third most populous city in the United States, after New York City and Los Angeles. With 2.7 million residents.

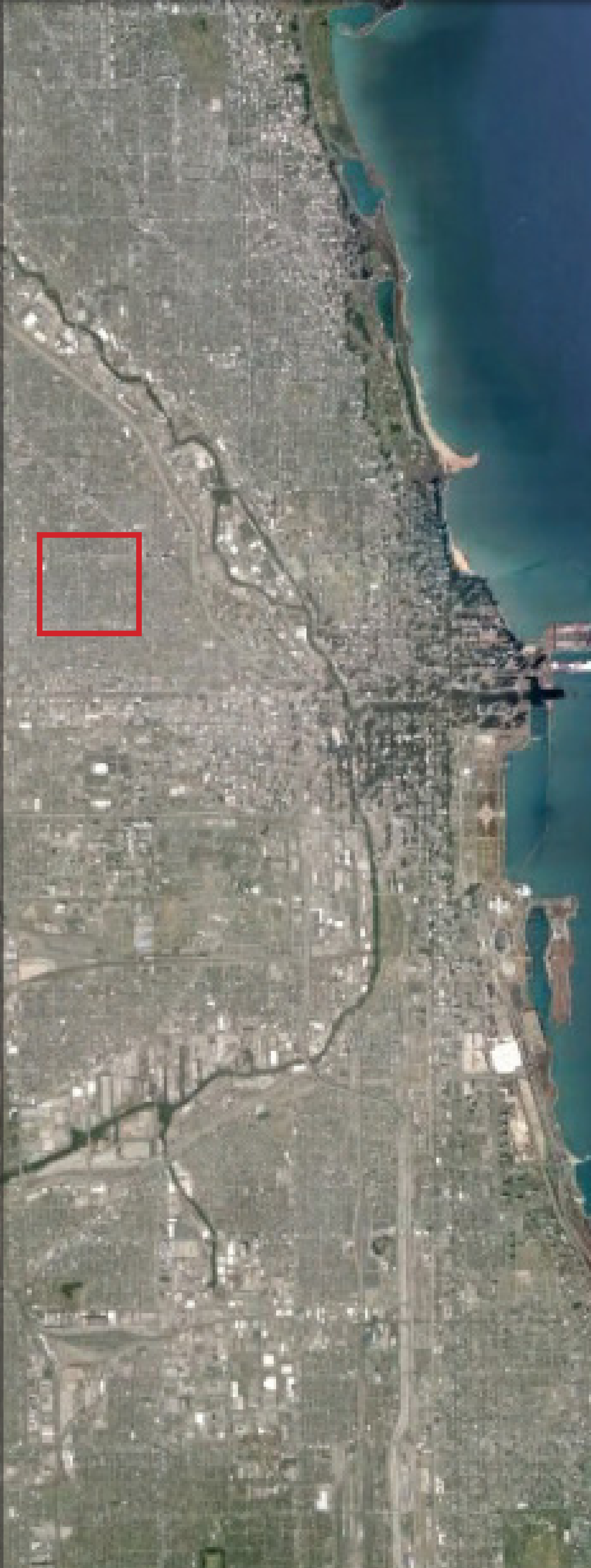
Area: 606.1 km²
Latitude: 41°51"
Longitude: 87°39"
Elevation above sea level: 180 m

CLIMATE
Winter in Chicago is variable. The average Chicago winter produces 94 cm of snow. Temperatures can vary wildly within the span of one week, but temperatures can often stay below freezing for several continues days or even weeks in January and February.
The temperature in January averages about - 2 degrees Celsius in the afternoon, and -10 degrees Celsius at night, while in summer temperatures ordinarily reach anywhere between 26°C to 33°C, and during the night drop to around 18°C.

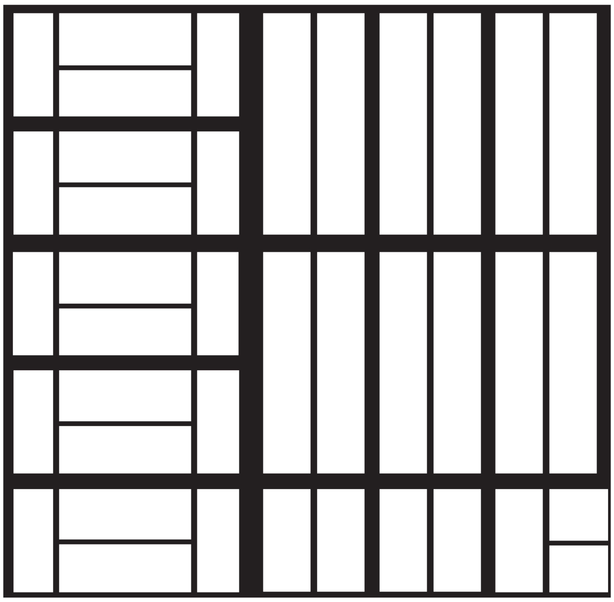
The months May, June, July, August and September have a comfortable average temperature. Most rainfall is in August. Cold season is in the months January and February.
On average, the warmest month is July, the coolest month is January. August is the wettest month. February is the driest month.

POPULATION
2013: 2.719 MILLION
Population density: 11,864

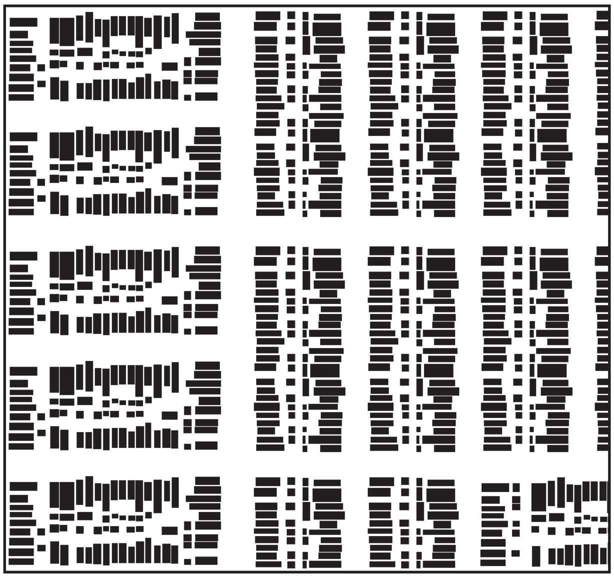
ETHNICITY
Foregin born: 36%
White: 45 %
Back: 32.9 %
Hispanic: 28.9 %

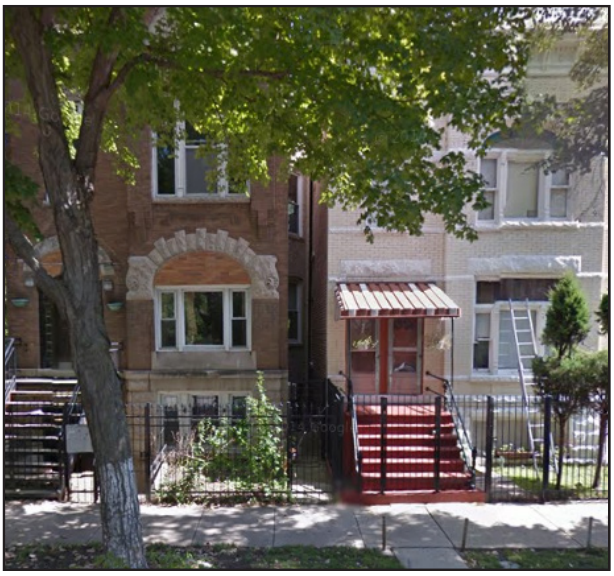


STREETS

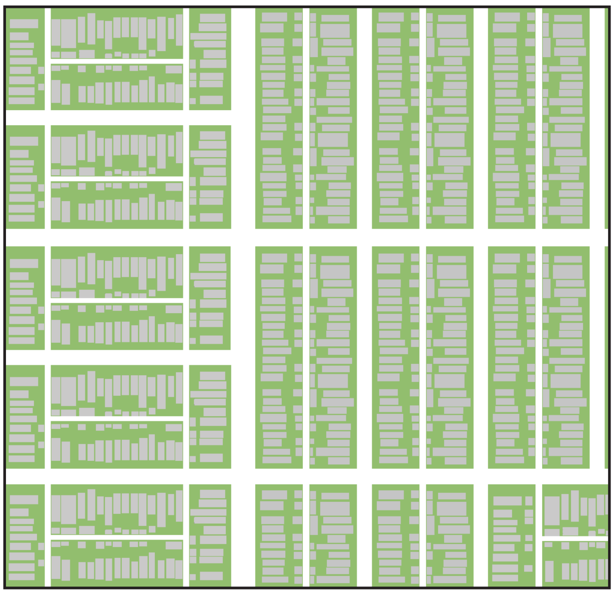


BUILDINGS





OPEN SPACES



CHICAGO

SOCIAL ANALYSIS

STREETS

Visual Permeability

The Chicago sample, like New York and Barcelona, is characterized by a regular grid type, therefore it receives the same score of 10 out of 10 for visual permeability.

Physical Permeability

The Chicago block size is approximately 15.000 sqm, which close to average compared to the other samples. The number of intersections is 10, which is lower than average. The overall score is 4 out of 10 for physical permeability.

Traffic Flow

The traffic flow is relatively low in Chicago, with an average of 2.25 traffic lanes. Most of the streets have only two lanes, while one larger street has four lanes. The lower levels of traffic allow pedestrians to cross streets more freely with more safety. A higher score is given for lower traffic flow, so chicago receives a 7 out of 10.

Walkability

Walkability is relatively low in chicago, with a walk score of only 78. This means that some products and services can be reached within walking distance, but others can only be reached by using a car or puclic transit. In comparison with the other samples, Chicago receives a score of 6 for walkability.

BUILDINGS

Active Fronts

Active ground floors are lacking in the Chicago sample; only twenty-five percent of buildings have active facades. These consist of a few lowrise apartment buildings with shops on the ground floor. Other parts of the street are faced by ground floor residences or by blank walls. The number of entrances to the street per 500m is 54, a relatively high number because the buildings are gen-

STREETS-CHICAGO			
Street Elements			Social Score (0)
Visual Permeability			10
	Grid Type	Regular Grid	10
Physical Permeability			4
	Typical Block Size	15.000 sqm	5
	Number of Intersections	10	3
Traffic Flow			7
	Number of Traffic Lanes	2.25	7
Walkability			6
	Walk Score	78	6

BUILDINGS			
Building Elements			Social Score (1-5)
Active Fronts			5
	Percent of Buildings with Active Facades/500m	25%	2.5
	Number of Entrances /500m	54	8
Building Variety			6.5
	Mix of Old and New Buildings	High	7
	Mix of Renovated and Unrenovated Buildings	High	8
	Mix of Housing Types	Detached, Lowrise	5
Mixed Use			3
	Number of Mixed Uses	Residential, Limited Commercial,	3
Building Density			3.5
	Typical Building Height	10m	2
	Ground Coverage	36%	5

erally detached and small in size. Chicago receives an overall score of 5 out of 10 for active fronts.

Building Variety

Building variety is somewhat high in the Chicago sample. There is a high mix of old to new buildings and a high mix of renovated to unrenovated buildings. The housing types consist of detached single and multi-families houses, and lowrise apartment buildings. In comparison with the other samples, the overall score given is 6.5 out of 10 for building variety.

Mixed Use

In the Chicago sample, two primary uses were identified, residential, and limited commericail. The low mix of uses makes the neighborhood less walkable and less active throughout the day. Chicago receives a score of 3 out of 10 for mixed use functions.

Building Density

The building density is low, with a typical building height of 10 meters and a ground coverage of aproximately 36%. This results in a score of 3.5 out of 10.

OPEN SPACES

Size and Number

Open spaces in the Chicago sample are large in number but small in size. There are 735 open spaces with an average size of 50 sqm. Chicago receives an overall score of 7.5 because the number of spaces is very large, but the spaces themselves are small private yards, which do not enhance the public realm.

Public Access

Visual and physical access to the open spaces is extremely limited. As private yards, the 735 open spaces are not physically accessible to the public. Limited visual access may be possible by looking over fences. Combines visual and physical access to green spaces

OPEN SPACES			
Open Space Elements			Social Score (1-5)
Size and Number			7.5
	Average Size	50 sqm	5
	Number	735	10
Access			1
	Visual Access	10%	1
	Physical Access	10%	1
Comfort			6
	Climate/Noise Protection	Moderate Protection	5
	Comfortable Seating	Adaquate	6
	Aesthetic Quality	Adaquate	6

within the sample is about 1%, resulting in a score of 1 out of 10.

Comfort

The spaces have moderate protection from noise and unpleasant environmental conditions, since they are generally protected on four sides by fences and walls. The yards privately owned spaces, therefore, the quality of each space varies. The spaces may have seating, green elements, etc. The overall score given is 5 out of 10 for open space comfort.

Environmental analysis

LOCAL WIND STUDY

Summer

During the summer season, the city of Chicago is characterized by wind coming from the South-South-West. After the simulation was performed the results are the following:

In the north-south direction of the streets: the wind speed of 2 m/s was 23%, the speed of 4 m/s is 77%, where all greater speeds equal to 0.

In the east-west direction of the streets the wind speed is diffused in the following way: the wind speed of 2 m/s: 29%, speed of 4 m/s: 71%, and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s: 43%, 4 m/s: 57%, and the rest of wind speeds equal to 0.

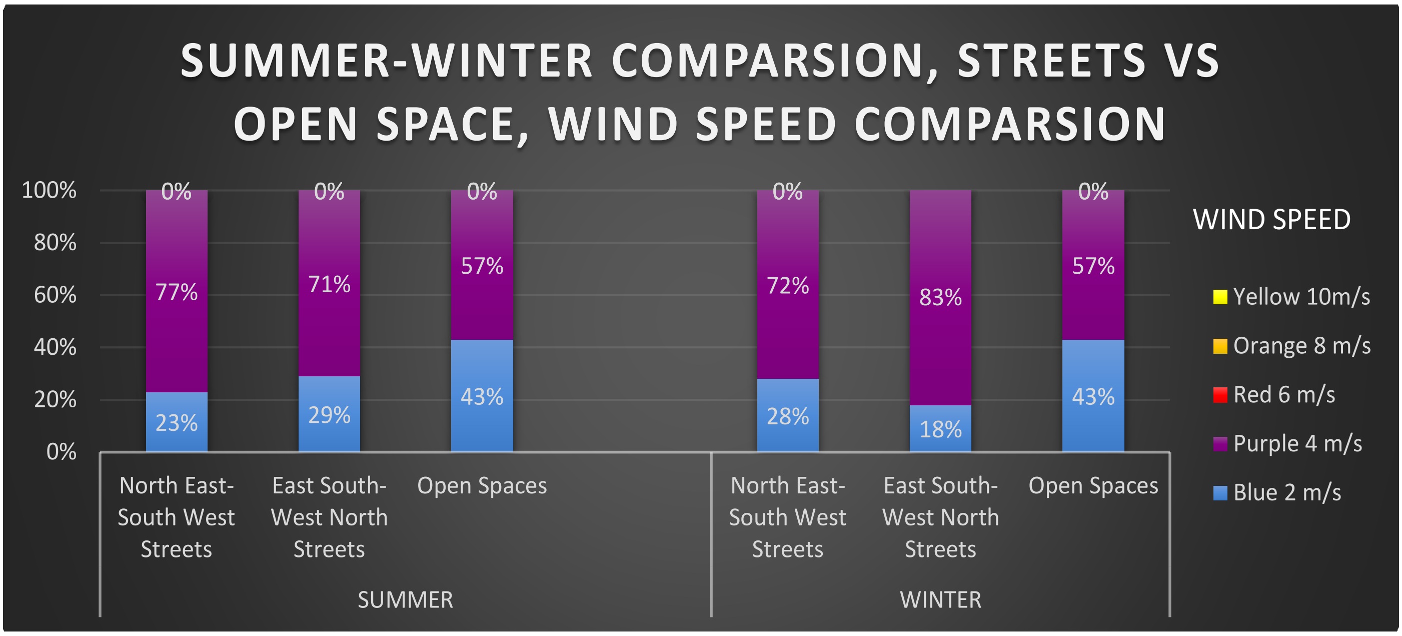
Overall, combining the streets and open spaces we can get a percentage of 32% as the slowest wind speed and greater wind speed of 69 m/s.

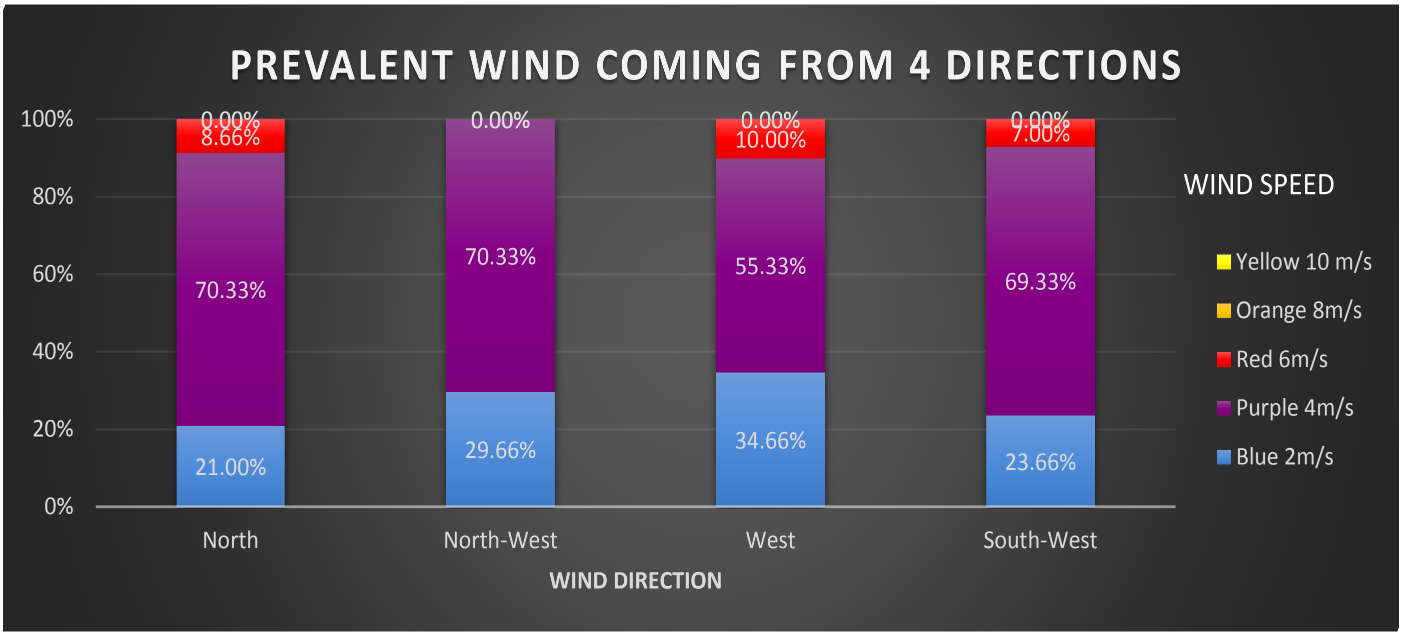
Winter

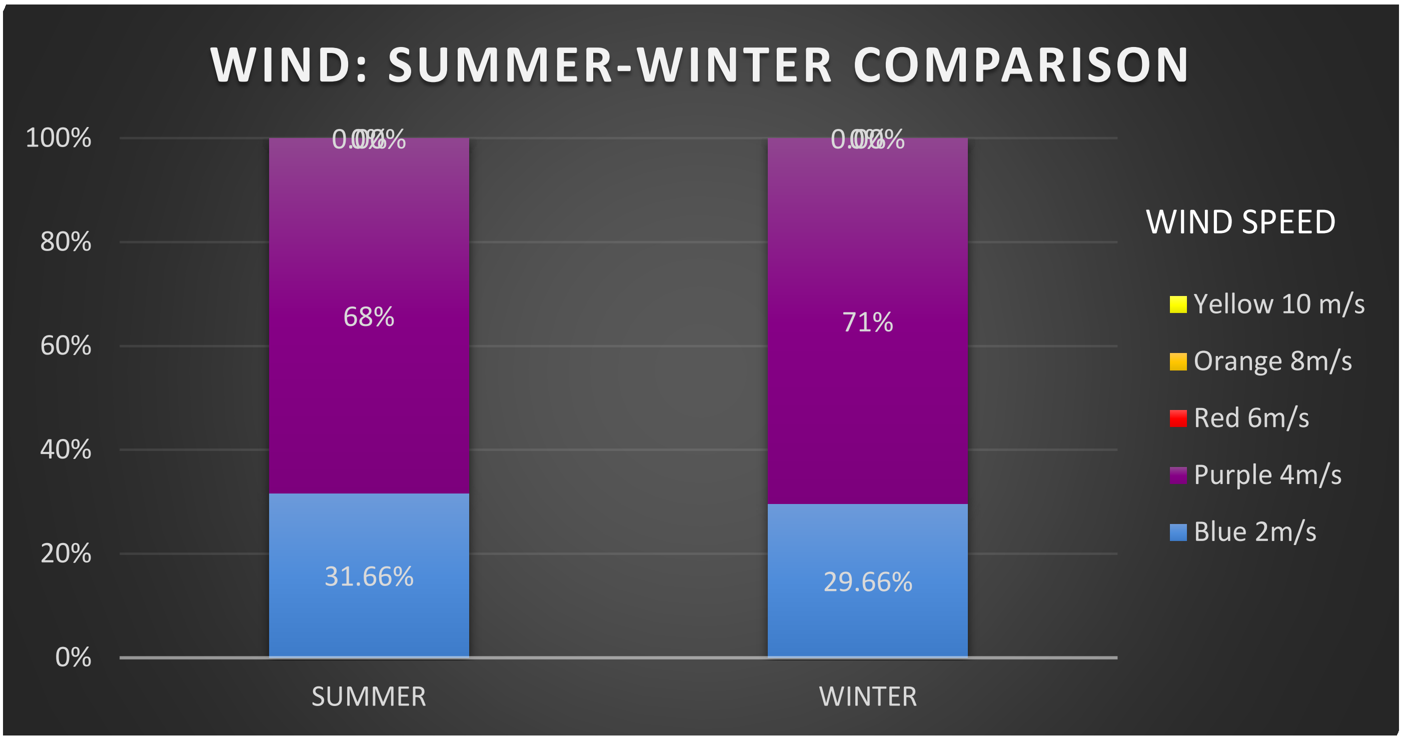
During the winter season, the city of is characterized by the wind coming from the North. After the simulation was performed the results are the following:

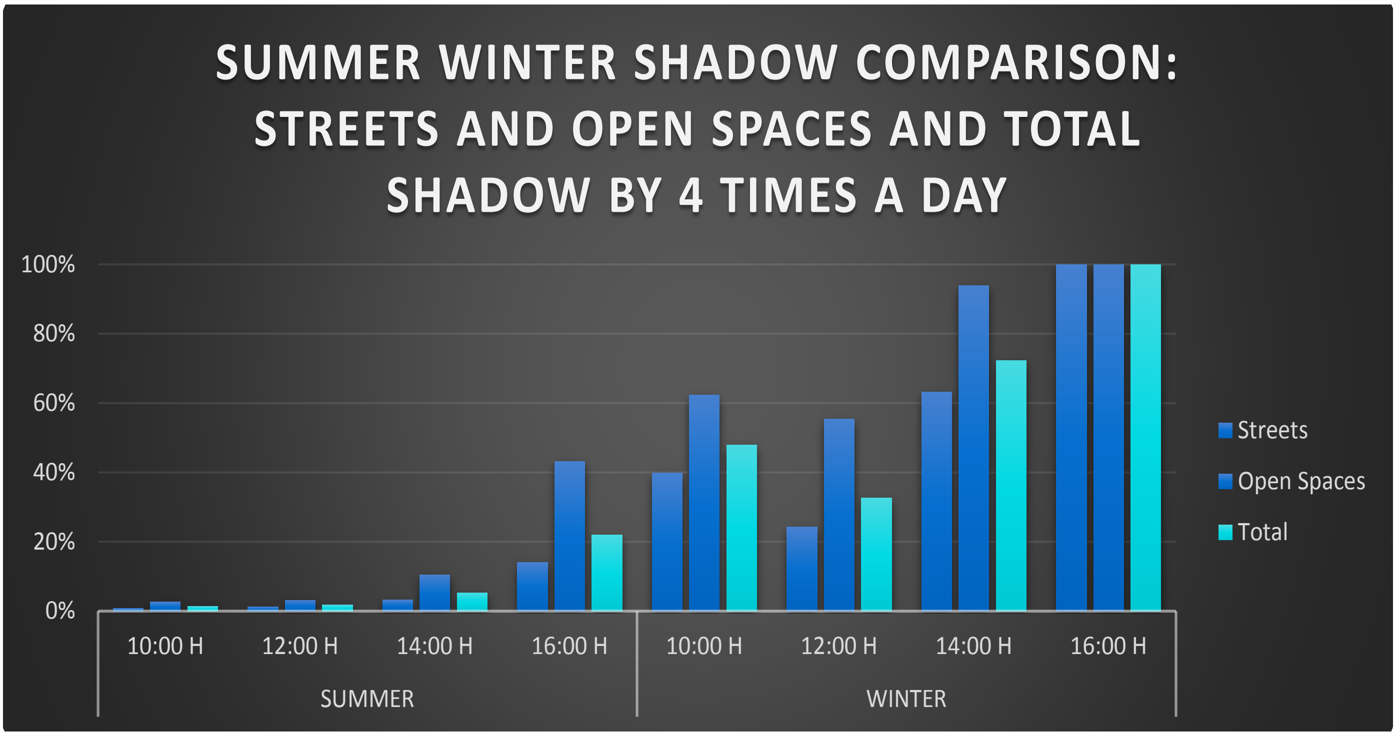
In the north-south direction of the streets: the wind speed of 2 m/s was 28%, the wind speed of 6 m/s is 72%, where all the greater wind speeds equal to 0.

In the east-west direction of the streets the wind speed is separated in the following way: 2 m/s speed: 18%, 4 m/s speed: 83%, and greater wind speeds


SUMMER-WINTER COMPARSION, STREETS VS OPEN SPACE, WIND SPEED COMPARSION
100%
80%
60%
40%
20%
0%
0%
77%
23%
0%
71%
29%
0%
57%
43%
0%
72%
28%
83%
18%
0%
57%
43%
North East-South West Streets
East South-West North Streets
Open Spaces
SUMMER
North East-South West Streets
East South-West North Streets
Open Spaces
WINTER
WIND SPEED
Yellow 10m/s
Orange 8 m/s
Red 6 m/s
Purple 4 m/s
Blue 2 m/s


PREVALENT WIND COMING FROM 4 DIRECTIONS
100%
80%
60%
40%
20%
0%
0.00%
8.66%
70.33%
21.00%
0.00%
70.33%
29.66%
0.00%
10.00%
55.33%
34.66%
0.00%
7.00%
69.33%
23.66%
North
North-West
West
South-West
WIND DIRECTION
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s


WIND: SUMMER-WINTER COMPARISON
100%
80%
60%
40%
20%
0%
68%
31.66%
71%
29.66%
SUMMER
WINTER
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s



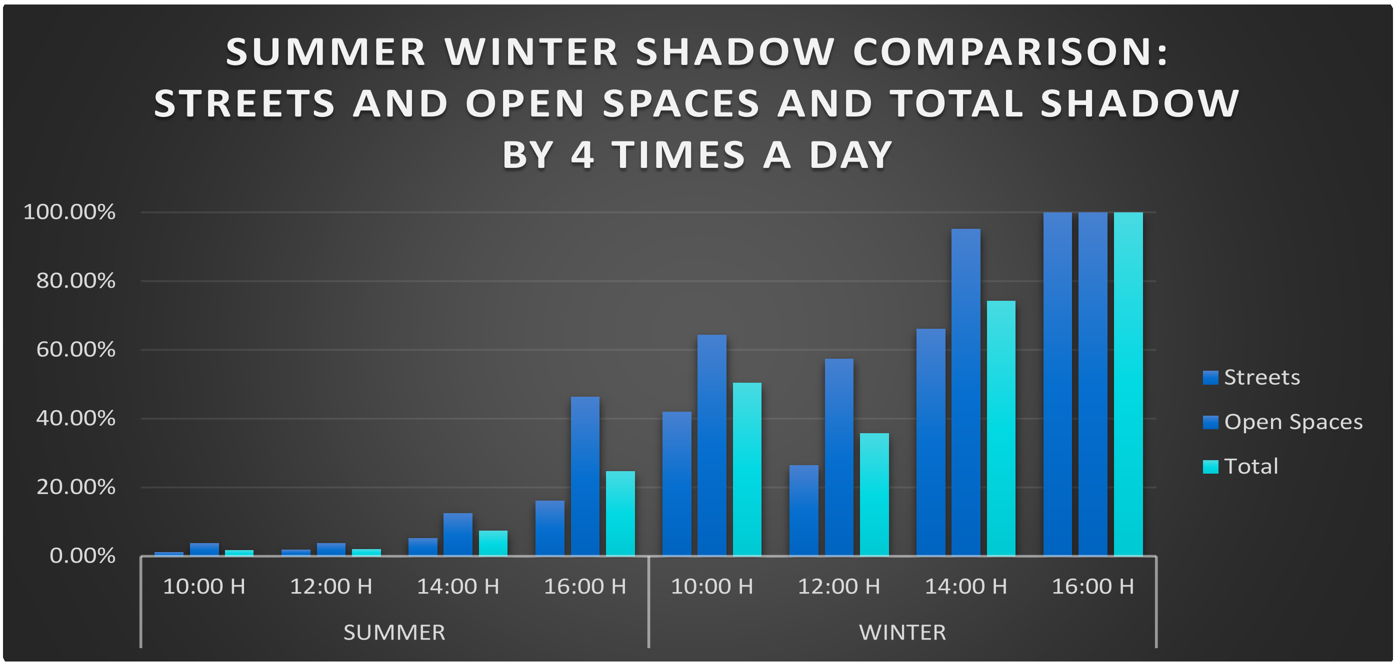
equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s speed: 43%, 4 m/s speed: 57%, and greater wind speeds equal to 0.

Overall, combining the streets and open spaces we can get a percentage of the slowest wind speed of 30% and greater wind speed of 4 m/s: 71%. Greater wind speed equal to 0.

In order to understand and have a visual insight of the change of the wind throughout the year, a comparison was made on the graph. From the graph it can be concluded that the most frequent wind blows at the speed of 4 m/s. (Purple color on the graph)

Comparing again the situation in the summer and winter but going more into detail and analyzing north-south, west-east streets and open spaces in both of the seasons, it can be noted that the



wind speed of 6 m/s is more prevalent in the streets while in the open spaces, the ratio of the wind speed of 4 m/s and 6 m/s is 40:60. This can be justified with the fact that open spaces are less exposed and therefore it is harder for faster wind to go through.

GENERAL WIND STUDY

The wind speed is compared by doing an experiment where wind was coming from the four directions: North, North West, West and South West. Looking at the graph (_) it can be concluded that the wind speed of 4 m/s is present at the highest percentage. A more serious situation would happen in case the wind was coming from the north and west because that would cause a higher wind speed of 6 m/s (red color).

LOCAL SHADOW STUDY

The analysis of the sun effects and shadows that it leaves on the streets and open spaces was performed, as well. The measurements were done

Hannover
GERMANY

Hannover, on the River Leine, is the capital of the federal state of Lower Saxony, Germany.

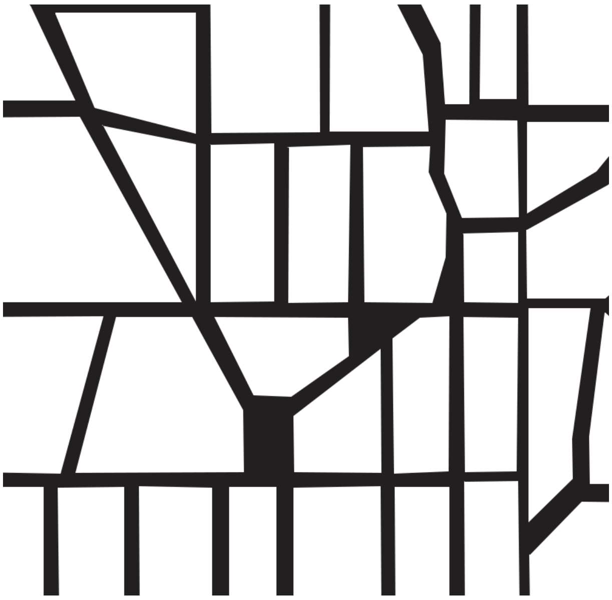
Area: 204.1 km²
Latitude: 52°22”
Longitude: 9°43”
Elevation above sea level: 57 m

CLIMATE
The months June, July and August have a comfortable average temperature.
On average, the warmest month is August. the coolest month is January. June is the wettest month.February is the driest month.

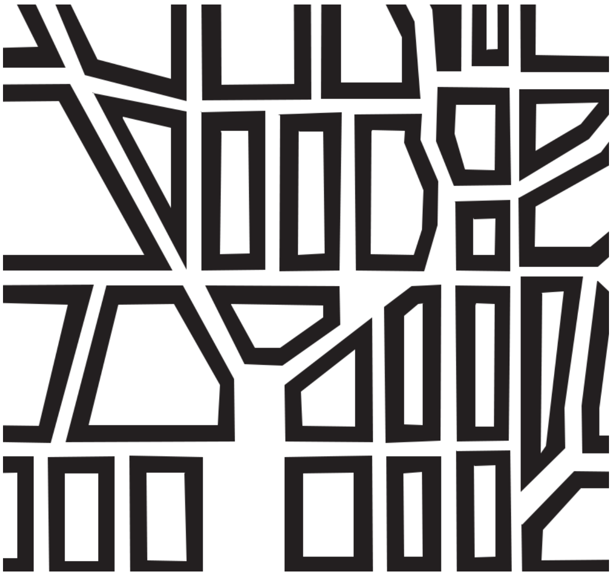
POPULATION
2012: 525,875
Population density: 2,518

ETHNICITY
Males: 48.2 %
Females: 51.8%
Foreigners: 0.0%
Average age: 42.1%

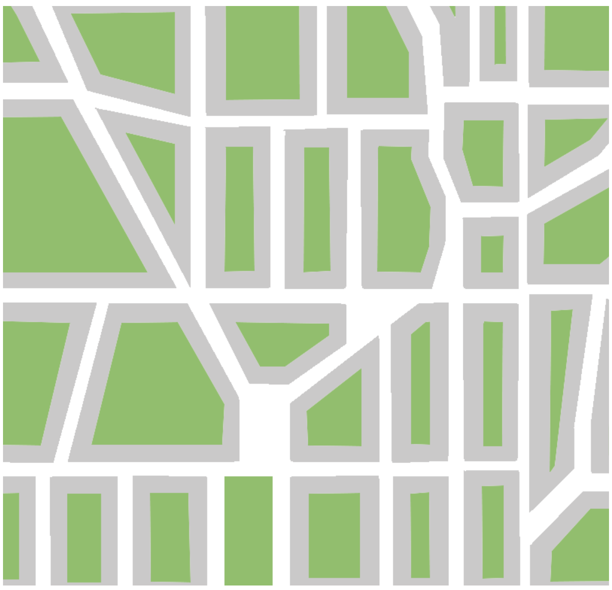
STREETS



BUILDINGS



OPEN SPACES



HANNOVER

SOCIAL ANALYSIS

STREETS

Visual Permeability

The Hannover sample is characterized by a distorted grid type. A significant portion of the streets are straight and perpendicular to each other, but some streets deviate from the regular grid pattern by bending, curving, or running in a diagonal direction to the grid. The visual permeability is reduced by the distorted grid type, making it more difficult to see down streets for long distances. Therefore, the score is 5 out of 10 for visual permeability.

Physical Permeability

The Hannover block size is approximately 10.000 sqm, which is smaller than average compared to the other samples. The number of intersections is 23, which is a little higher than average. The smaller blocks and more frequent intersections improve physical permeability, therefore, the overall score is 7.5 out of 10.

Traffic Flow

The traffic flow is low in Hannover. All the streets in the sample have only two lanes of traffic. This allows pedestrians to cross streets more freely and safetly. A higher score is given for lower traffic flow, so Hannover receives an 8 out of 10.

Walkability

Walkability is high in Hannover, with a walk score of 90, meaning that most products and services can be reached within walking distance. This results in a walkability score of 9 for Hannover.

BUILDINGS

Active Fronts

Active ground floors are limited in the Hannover sample; only twenty-three percent of buildings have active facades. Many buildings have residential uses on the ground floor, while a few others

STREETS- HANOVER			
Street Elements			Social Score (0-10)
Visual Permeability			5
	Grid Type	Distorted Grid	5
Physical Permeability			7.5
	Typical Block Size	10.000 sqm	8
	Number of Intersections	23	7
Traffic Flow			8
	Number of Traffic Lanes	2	8
Walkability			9
	Walk Score	90	9

BUILDINGS			
Building Elements			Social Score (0-10)
Active Fronts			2.5
	Percent of Buildings with Active Facades/500m	23%	2
	Number of Entrances /500m	21	3
Building Variety			3
	Mix of Old and New Buildings	Low	3
	Mix of Renovated and Un-renovated Buildings	Medium	5
	Mix of Housing Types	Townhouse,	2
Mixed Use			3
	Number of Mixed Uses	Residential, Limited Commercial	3
Building Density			5.5
	Typical Building Height	20m	5
	Ground Coverage	42%	6

have commercial uses. The number of entrances to the street per 500m is 21, a relatively low number. For the most part, streets are faced by apartment buildings with many small windows and few doors to the street. The overall score is 2.5 out of 10 for active fronts.

Building Variety

Building variety is somewhat low in the Hannover sample. There is a low mix of old to new buildings and a moderate mix of renovated to unrenovated buildings. The housing stock is somewhat homogeneous, consisting of attached lowrise apartment buildings. The overall score is 3 out of 10 for building variety.

Mixed Use

In the Hannover sample, two primary uses were identified, residential, and limited commericial. The low mix of uses makes the neighborhood less active at different times of the day. Hannover receives a score of 3 out of 10 for mixed use functions.

Building Density

The building density is moderate, with a typical building height of 20 meters and a ground coverage of aproximately 42%. This results in a score of 5.5 out of 10.

OPEN SPACES

Size and Number

Open spaces in the Hannover sample are relatively large in number and size. There are 31 open spaces with an average size of 5.000 sqm. Hannover receives an overall score of 8.5 because the number of spaces is adaquate, but the size of the spaces is a bit too large in terms of social comfort.

Public Access

Visual and physical access to the open spaces is limited. All but 1 of the 31 open spaces are semi-private courtyard spaces that are not accessible to the public. The one remaining space is fully acces-

OPEN SPACES			
Open Space Elements			Social Score (0-10)
Size and Number			8
	Typical Size	5.000 sqm	8
	Number	31	8.5
Access			1
	Visual Access	3%	1
	Physical Access	3%	1
Comfort			6
	Climate/Noise Protection	High Protection	8
	Comfortable Seating	Limited	2
	Aesthetic Quality	Adaquate	7

sible to the public, visually and physically. The resulting score is 1 out of 10 for access.

Comfort

The spaces have moderate protection from noise and unpleasant environmental conditions, since the majority of spaces are protected by buildings on four sides. Comfortable seating appears limited, however there is plenty of green space, which improves aesthetic quality. The overall score is 6 out of 10 for comfort.

ENVIRONMENTAL ANALYSIS

LOCAL WIND STUDY

Summer

During the summer season, the city of Hannover is characterized by the wind coming from the West and the maximum speed recorded was 8 m/s at specific areas.

After the simulation was performed the results are following:

In the north-south direction of streets: the wind speed of 2 m/s was 86%, the speed of 4 m/s is 10%, the speed of 6 m/s is 4%, where all greater speeds equal to 0.

In the east-west direction of streets the wind speed is diffused in the following way: the wind speed of 2 m/s: 88%, speed of 4 m/s: 9%, speed of 6 m/s: 3% and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s: 85%, 4 m/s: 12%, 6 m/s: 3%, and the rest of wind speeds equal to 0.

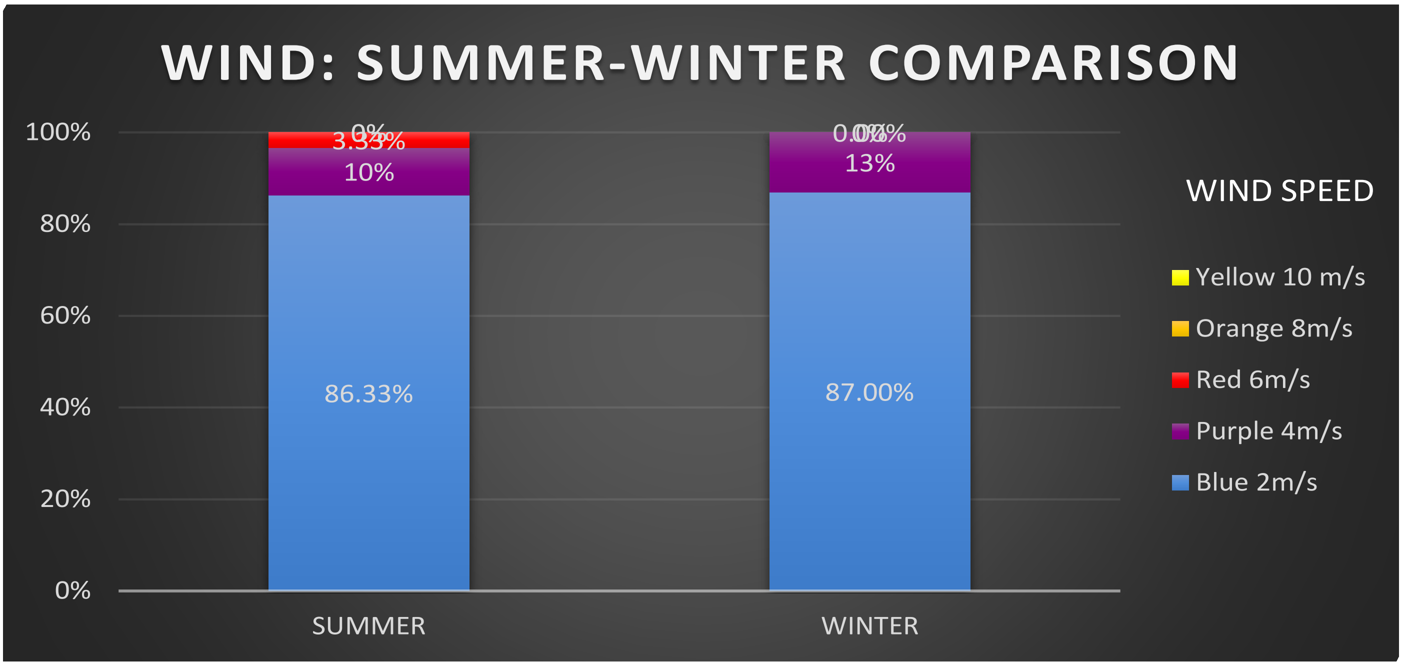
Overall, combining the streets and open spaces we can get a percentage of 87% the slowest wind speed and greater wind speed of 4 m/s : 11% and speed of 6 m/s: 3%.

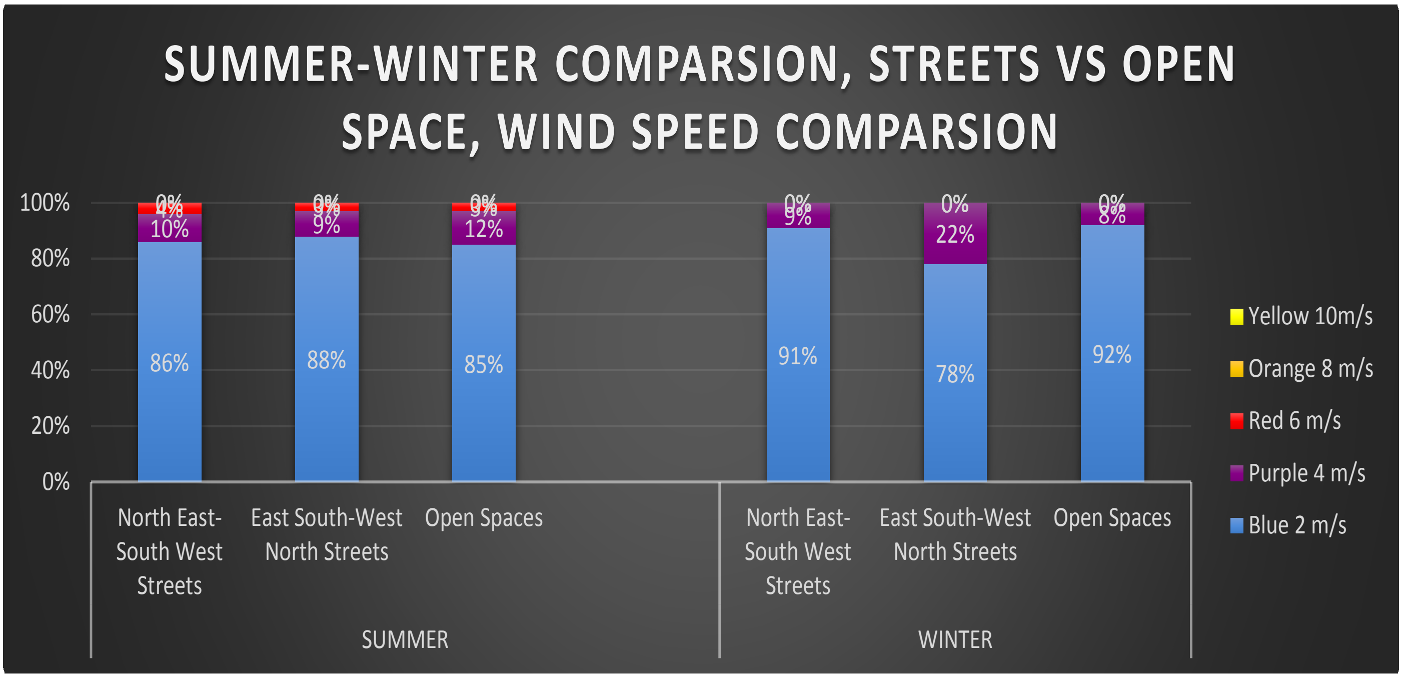
Winter

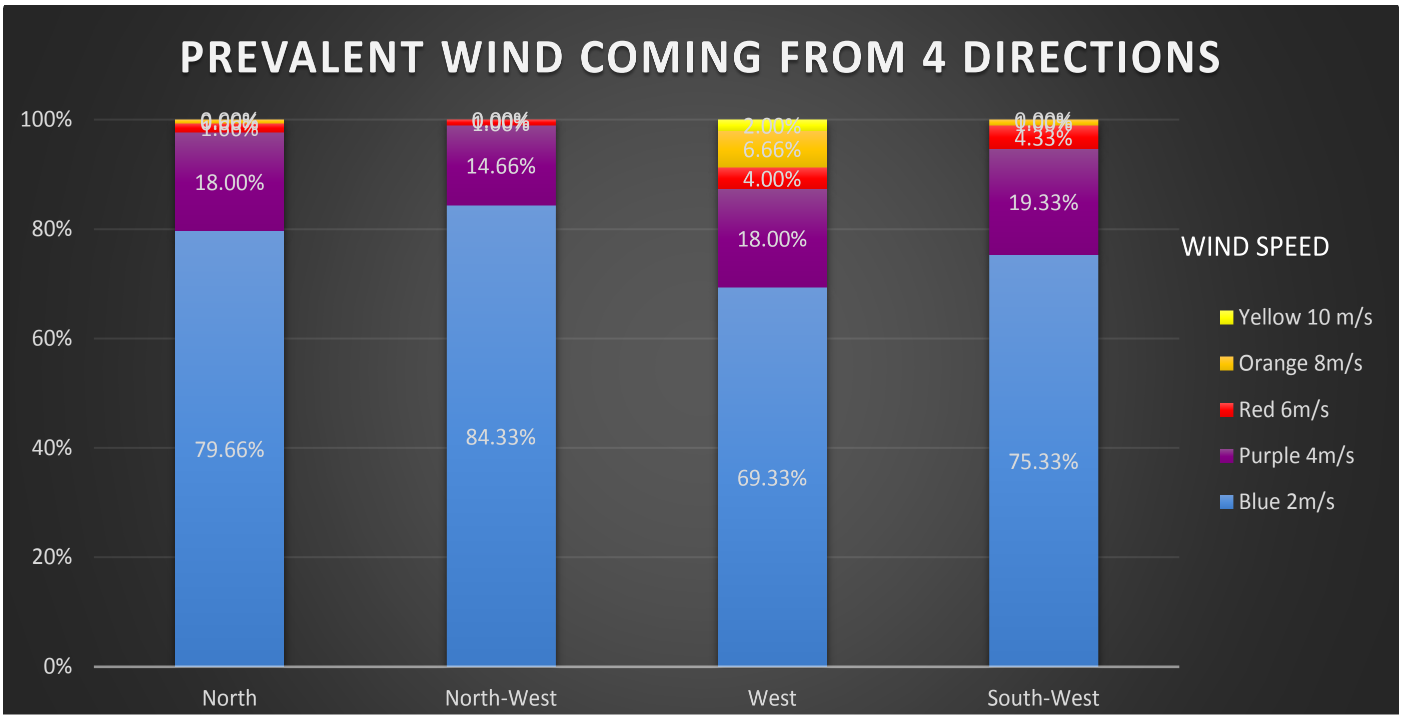
During the winter season, the city of Hannover is characterized by the wind coming from the South, South East and the maximum speed recorded was 8 m/s at specific areas.

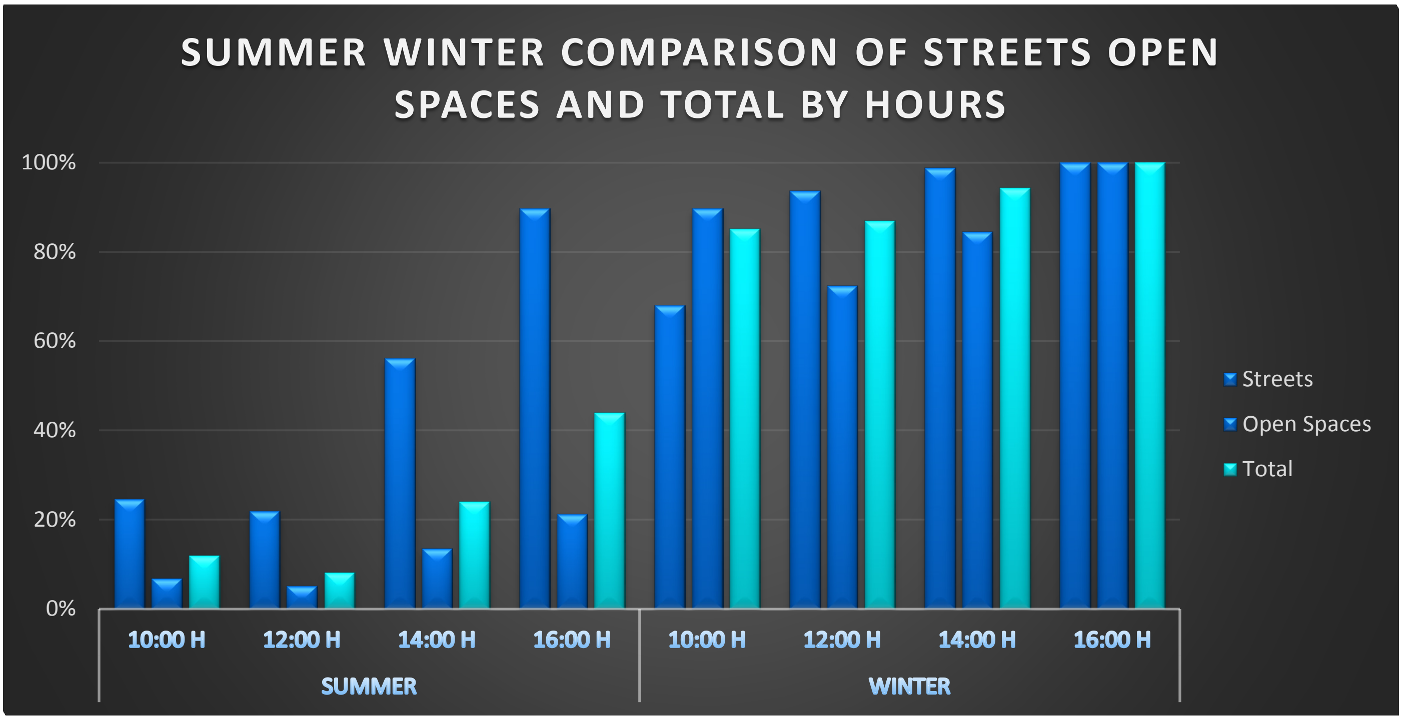
After the simulation was performed the results are following:

In the north-south direction of the streets: the wind speed of 2 m/s was 91%, the


WIND: SUMMER-WINTER COMPARISON
100%
80%
60%
40%
20%
0%
0%
3.33%
10%
86.33%
0.00%
13%
87.00%
SUMMER
WINTER
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s


SUMMER-WINTER COMPARSION, STREETS VS OPEN SPACE, WIND SPEED COMPARSION
100%
80%
60%
40%
20%
0%
10%
86%
9%
88%
12%
85%
9%
91%
0%
22%
78%
0%
8%
92%
North East-South West Streets
East South-West North Streets
Open Spaces
SUMMER
WINTER
Yellow 10m/s
Orange 8 m/s
Red 6 m/s
Purple 4 m/s
Blue 2 m/s


PREVALENT WIND COMING FROM 4 DIRECTIONS
100%
80%
60%
40%
20%
0%
18.00%
79.66%
14.66%
84.33%
6.66%
4.00%
18.00%
69.33%
4.33%
19.33%
75.33%
North
North-West
West
South-West
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s



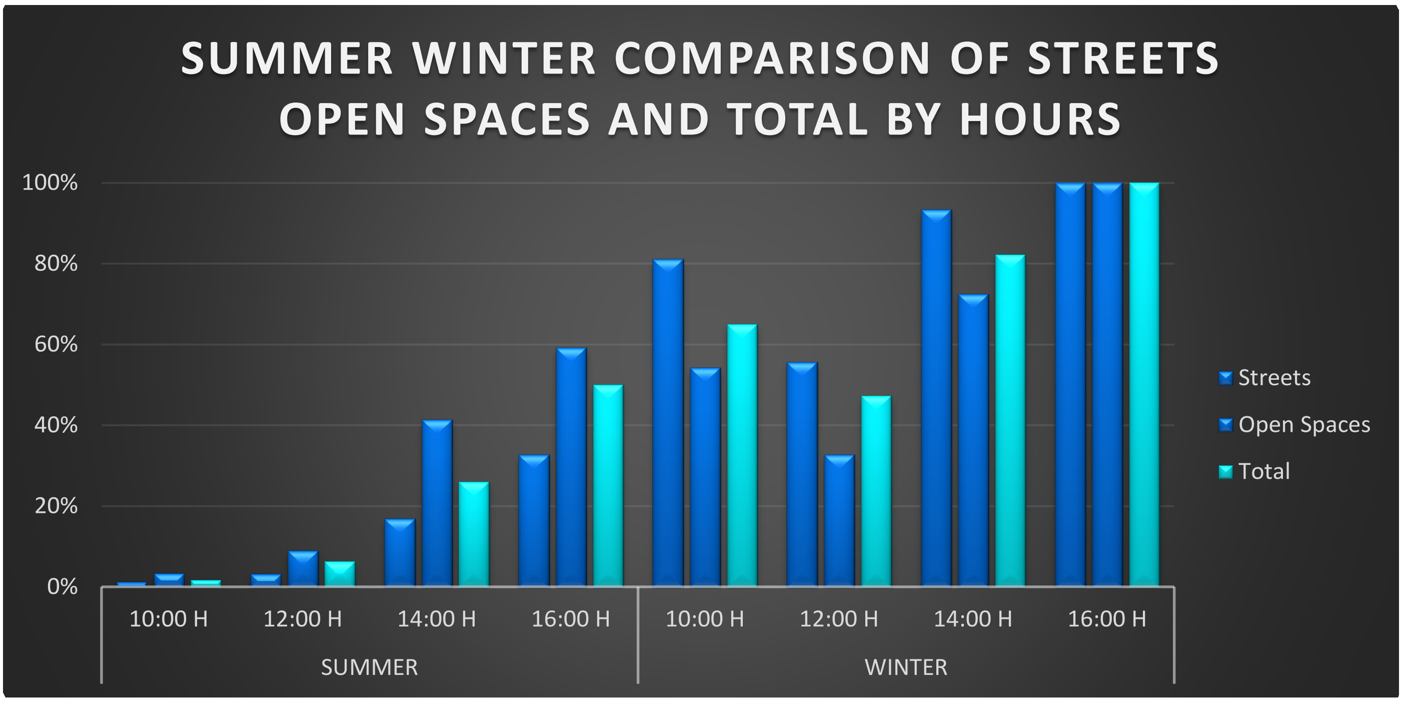
wind speed of 6 m/s is 9%, where all the greater wind speeds equal to 0.

In the east-west direction of the streets the wind speed is separated in the following way: 2 m/s speed: 78%, 4 m/s speed: 22%, and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s speed: 92%, 4 m/s speed: 8%, and greater wind speeds equal to 0.

Overall, combining the streets and open spaces we can get a percentage of the slowest wind speed of 87% and greater wind speed of 4 m/s: 13%. Greater wind speed equal to 0.

In order to understand and have a visual insight of the change of the wind throughout the year long, a summer-winter comparison was made on the graph. From the graph it can be concluded that there is no big change going from summer towards winter. The only difference



noted is that during the summer, the wind speed go up to 6 m/s but in winter the wind blows with the maximum speed of 4 m/s.

Comparing again the situation in the summer and winter but going more into details and analyzing north-south, west-east streets and open spaces in both of the seasons, it can be noted that the wind speed of 6 m/s blows equally in the streets as much as in the open spaces, during the summer. In the winter, the situation does not change. The wind speed is equally distributed in the streets and open spaces and it does not go higher than 4 m/s.

GENERAL WIND STUDY

The wind speed is compared by doing an experiment where wind was coming from the four directions: North, North West, West and South West. Looking at the graph (_) it can be concluded that the slowest wind speed is present at the highest percentage and it reflects very low wind speed, of just 2 m/h. The critical situation would happen in case the wind was coming from the west because that would cause a higher wind speed of 10 m/s (yellow color). A slightly better situation would be in case the wind was blowing from the North- and South West because it would provoke a formation of mid speed wind (red color) blowing of 6 m/s.

LOCAL SHADOW STUDY

The analysis of the sun effects and shadows that it leaves on the streets and open spaces was performed, as well. The measurements were done during the summer and winter season and at specific hours of the day in order to get the true picture and data how much shadow is actually present at the city throughout the day, from the morning until the aft

ernoon. The measurements were done at the following hours: 10 am, 12 am, 2 pm and 4 pm.

Summer-Winter

In case of Hannover, the amount of the shadow during the summer is lower, while in the winter is higher. (graph_) And paying attention specifically on the streets and open spaces, it can be noted that the amount of the shadows is higher in the streets. In order to better understand the division of the shade per street and per open space, we made a following graph where we additionally put the total overall existence of the shadow for every specific hour. In can be concluded that the amount of shadow is the lowest at 10 am, and the highest at 4 pm, both in summer and winter. However, situation is summer is much “brighter” than in winter, because in the summer the shadow remains around 20%, while during the winter it stay above 80% all day long.

GENERAL SHADOW STUDY

In case of placing a Hannover city model into the geographical position of the Boston city, situation about the shadows does not change very much. The amount of shadows goes up going from the summer towards the winter. The slight change can be noted in the winter, at 4 pm where the presence of the shadow entirely covering the city in the percentage of 100%.

Moscow
RUSSIA

Moscow is the capital city and the most populous federal subject of Russia. The city is a major political, economic, cultural and scientific center in Russia and in Eastern Europe.

Area: 2,511 km²
Latitude: 55°45”
Longitude: 37°36”
Elevation above sea level: 144 m

CLIMATE
Moscow’s climate changes dramatically with the seasons. The city experiences continental weather, typified by surprisingly hot and short summers, and extremely cold, long winters. The winter snows begin in October and often last well into spring.

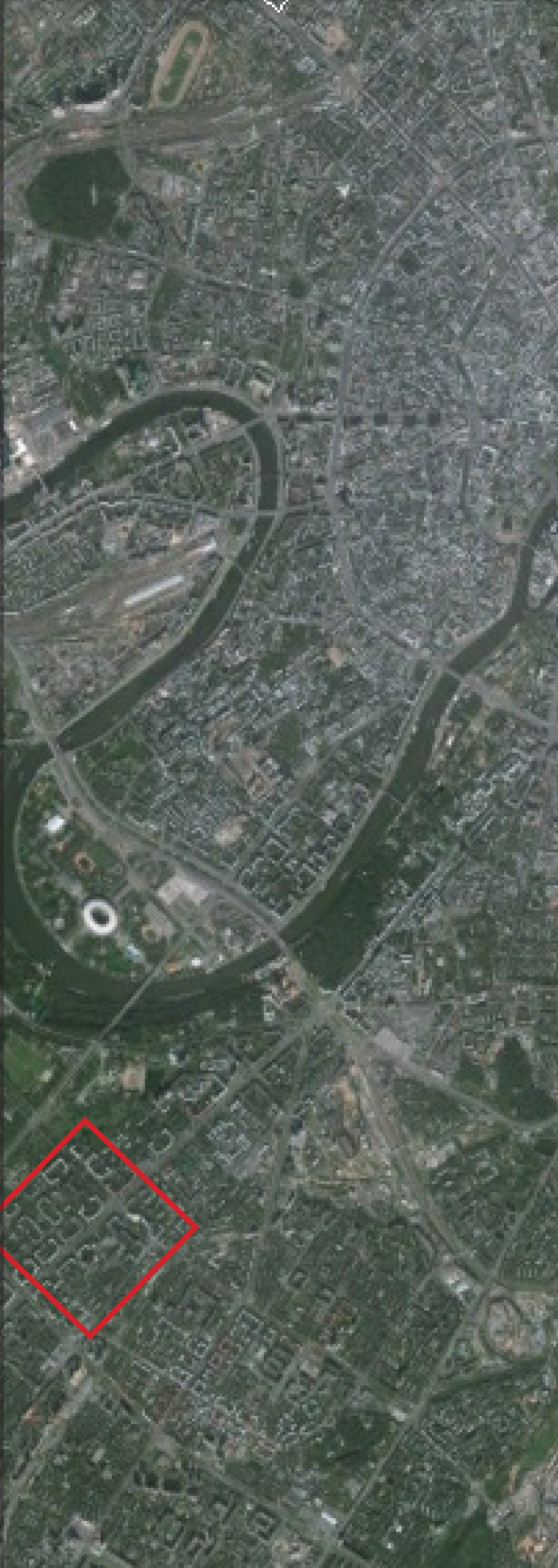
In summer, on the other hand, days are very long and the weather is nice and warm. Thunderstorms and heavy rain is common during July and August.

The months June, July and August have a nice average temperature.
Cold season / winter is in the months January, February, March and December.
On average, the warmest month is July.
On average, the coolest month is January.
July is the wettest month.
March is the driest month.

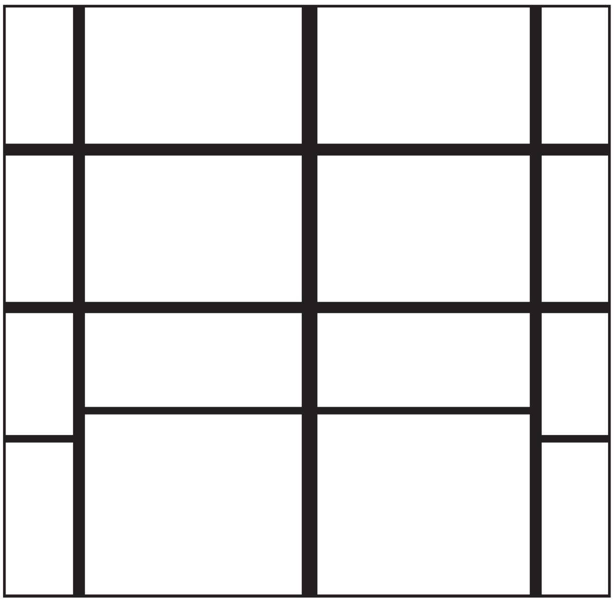
POPULATION
2013: 11,794,282.

ETHNICITY

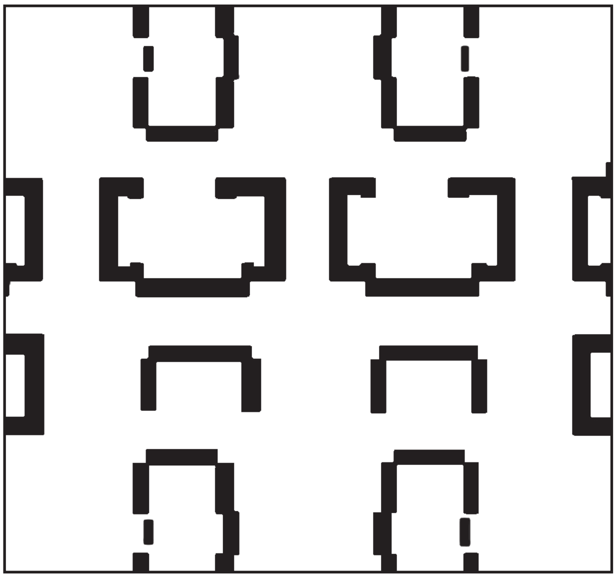
Russians	91.6%
Ukrainians	1.4%
Tatars	1.4%
Armenians	1.0%
Azerbaijanis	0.5%
Jews	0.5%



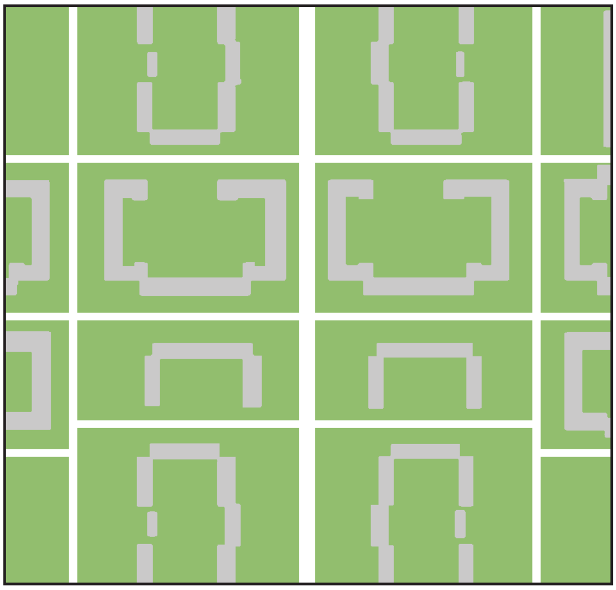
STREETS

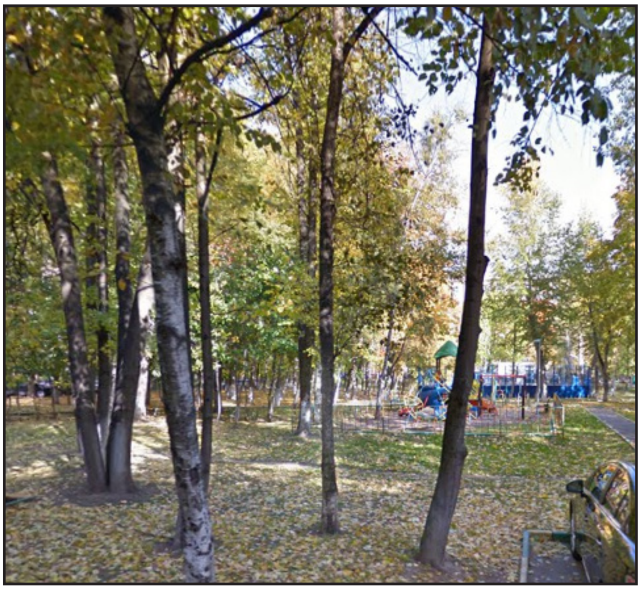


BUILDINGS



OPEN SPACES





Moscow

SOCIAL ANALYSIS

STREETS

Visual Permeability

The Moscow sample, has an almost regular grid type, with only small variations in the linearity of the streets. The broad and straight avenues increase visual permeability, resulting in a score of 9 out of 10.

Physical Permeability

The Moscow block size is ver large, approximately 36.000 sqm, which is the largest block size out of all the samples. The number of intersections is 9, which is lower than average compared to the other samples. The overall score is 2 out of 10 for physical permeability.

Traffic Flow

The traffic flow is high, with an average of 3.2 traffic lanes. The main streets in the sample have as many as 8 traffic lanes. The high level of traffic greatly reduces the walkability and pedestrian quality of the area. A lower score is given for higher traffic flow, so Moscow receives a 1 out of 10.

Walkability

Walkability is relatively low in Moscow, with a walk score of 88. This means that some products and services can be reached within walking distance, but others can only be reached by using motorized transportation. The low density of the area reduces the functionaly of a pulbic transportation system, which increases dependence on private automobiles. Moscow receives a score of 6 for walkability.

BUILDINGS

Active Fronts

Active ground floors are lacking in the Moscow sample; only twenty-two percent of buildings have active facades. The number of entrances to the street per 500m is 16, a relatively low number compared to the other samples. Moscow receives an overall score of 2 out of

STREETS- MOSCOW			
Street Elements			Social Score (0-10)
Visual Permeability			8
	Grid Type	Semi-Regular Grid	8
Physical Permeability			2
	Typical Block Size	36.000 sqm	1
	Number of Intersections	9	3
Traffic Flow			1
	Average Number of Traffic Lanes	3.2	1
Walkability			7
	Walk Score	88	7

BUILDINGS			
Building Elements			Social Score (0-10)
Active Fronts			2
	Percent of Buildings with Active Facades/500m	22 %	2
	Number of Entrances /500m	16	2
Building Variety			3
	Mix of Old and New Buildings	Low	3
	Mix of Renovated and Unrenovated Buildings	Low	3
	Mix of Housing Types	Lowrise	2
Mixed Use			3
	Number of Mixed Uses	Residential, Limited Commercial	3
Building Density			4
	Typical Building Height	20 m	6
	Ground Coverage	15%	2

10 for active fronts..

Building Variety

Building variety is low in the Moscow sample. There is a low mix of old to new buildings and a low mix of renovated to unrenovated buildings. The housing type is relatively homegeneous, consisting of detached lowrise aparemtne buildings. The overall score is 3 out of 10 for building variety.

Mixed Use

In the Moscow sample, two primary uses were identified, residential, and limited commericail. The low mix of uses negatively affects the walkability and liveliness of the area. Moscow receives a score of 3 out of 10 for mixed use functions.

Building Density

The building density is low, with a typical building height of 20 meters and a ground coverage of aproximately 15%. This results in a score of 4 out of 10.

OPEN SPACES

Size and Number

Open spaces in the Moscow sample are small number and very large in size. There are 16 open spaces with an average size of 11.400 sqm, the largest out of all the samples. Moscow receives an overall score of 2.5 because the optimal condition is many small spaces, while in the moscow sample there are a few large ones.

Public Access

In the Moscow sample, the open spaces are accessible visually and physically. The majority of the spaces can be seen and physically access from the street. The overall score is 8 out of 10 for public access.

Comfort

The spaces have moderate protection from noise and unpleasant conditions;

OPEN SPACES			
Open Space Elements			Social Score (0-10)
Size and Number			2.5
	Typical Size	11.400 sqm	1
	Number	16	4
Access			8
	Visual Access	85%	8.5
	Physical Access	75%	7.5
Comfort			6.5
	Climate/Noise Protection	Moderate Protection	6
	Comfortable Seating	Available	7
	Aesthetic Quality	Adaquate	6

most spaces are protected on three or more sides. The spaces are relatively comfortable, with playgrounds, seating furniture, and plenty of green space. The overall score given is 6.5 out of 10 for comfort.

ENVIRONMENTAL ANALYSIS

LOCAL WIND STUDY

Summer

During the summer season, the city of Moscow is characterized by the wind coming from the West and the maximum speed recorded was 8 m/s at specific areas.

After the simulation was performed the results are following:

In the north-south direction of the streets: the wind speed of 2 m/s was 27%, the speed of 4 m/s is 63%, and the speed of 6 m/s: 10%, where all greater speeds equal to 0.

In the east-west direction of the streets the wind speed is diffused in the following way: the wind speed of 2 m/s: 65%, speed of 4 m/s: 33%, speed of 6 m/s: 2% and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s: 64%, 4 m/s: 34%, wind speed of 6 m/s: 2% and the rest of wind speeds equal to 0.

Overall, combining the streets and open spaces we can get a percentage of 52% the slowest wind speed and greater wind speed of 4 m/s : 44% and speed of 6 m/s: 5%.

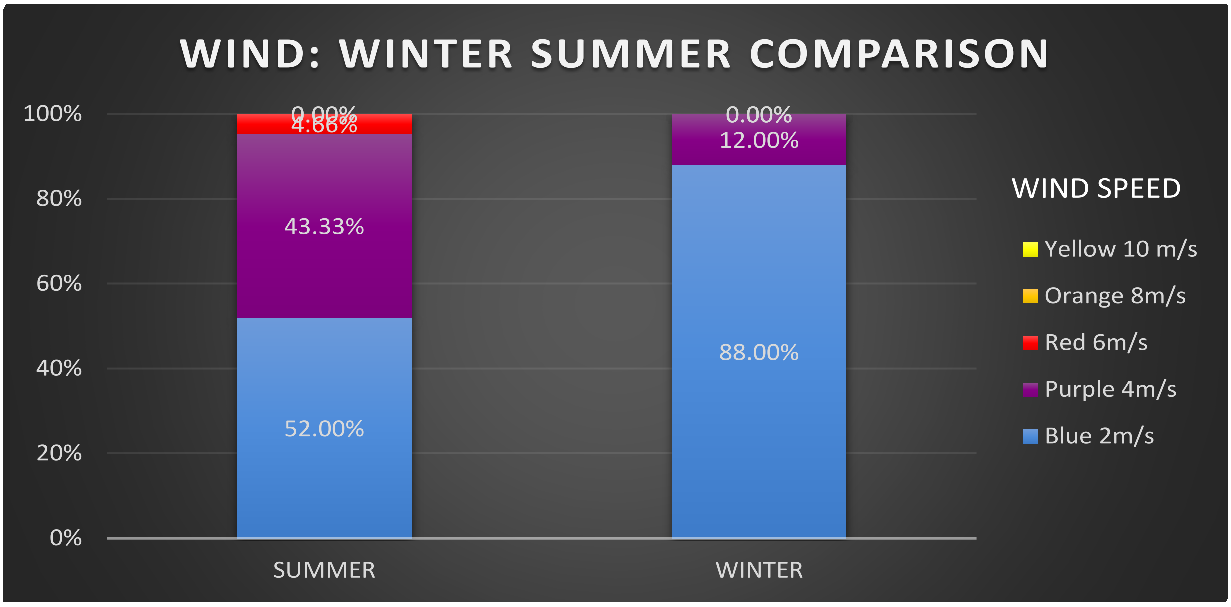
Winter

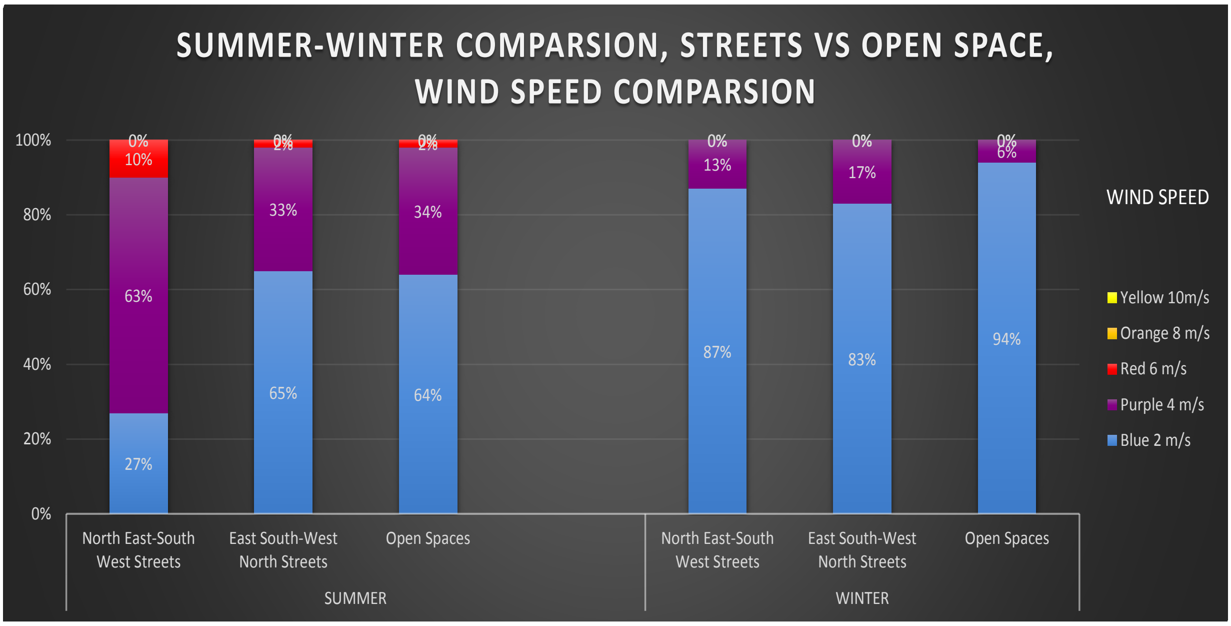
During the winter season, the city of Moscow is characterized by the wind coming from the South, South East and the maximum speed recorded was 8 m/s at specific areas.

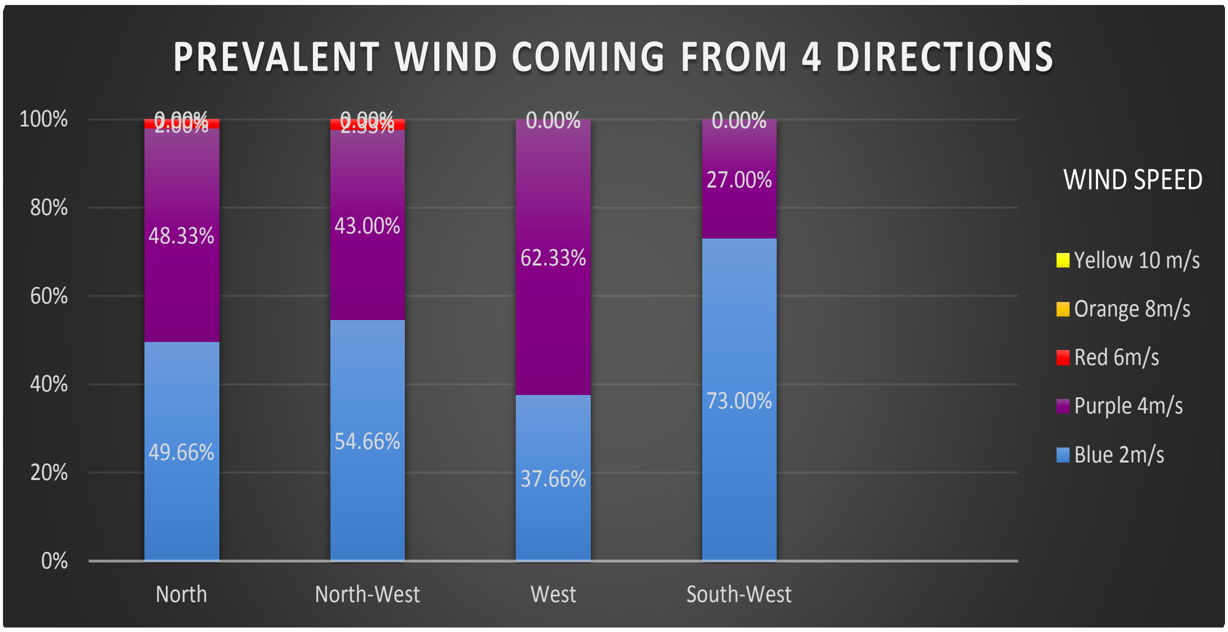
After the simulation was performed the results are following:

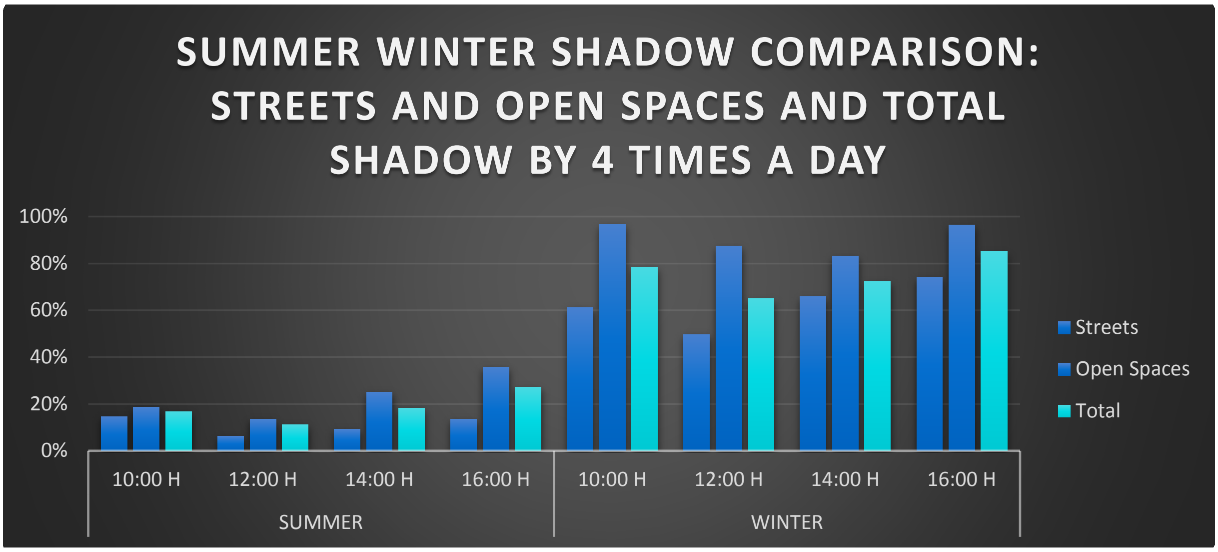
In the north-south direction of the streets: the wind speed of 2 m/s was 87%, the wind speed of 4 m/s is 7%, where all the greater wind speeds equal to 0.

In the east-west direction of the streets the wind speed is separated in the following way: 2 m/s speed: 83%, 4 m/s speed: 17%, 6 m/s: 13% and greater


WIND: WINTER SUMMER COMPARISON
100%
80%
60%
40%
20%
0%
0.00%
4.66%
43.33%
52.00%
0.00%
12.00%
88.00%
SUMMER
WINTER
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s


SUMMER-WINTER COMPARSION, STREETS VS OPEN SPACE, WIND SPEED COMPARSION
100%
80%
60%
40%
20%
0%
0%
10%
63%
27%
0%
2%
33%
65%
0%
2%
34%
64%
0%
13%
87%
0%
17%
83%
0%
6%
94%
North East-South West Streets
East South-West North Streets
Open Spaces
SUMMER
North East-South West Streets
East South-West North Streets
Open Spaces
WINTER
WIND SPEED
Yellow 10m/s
Orange 8 m/s
Red 6 m/s
Purple 4 m/s
Blue 2 m/s


PREVALENT WIND COMING FROM 4 DIRECTIONS
100%
80%
60%
40%
20%
0%
0.00%
2.00%
48.33%
49.66%
0.00%
2.33%
43.00%
54.66%
0.00%
62.33%
37.66%
0.00%
27.00%
73.00%
North
North-West
West
South-West
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s



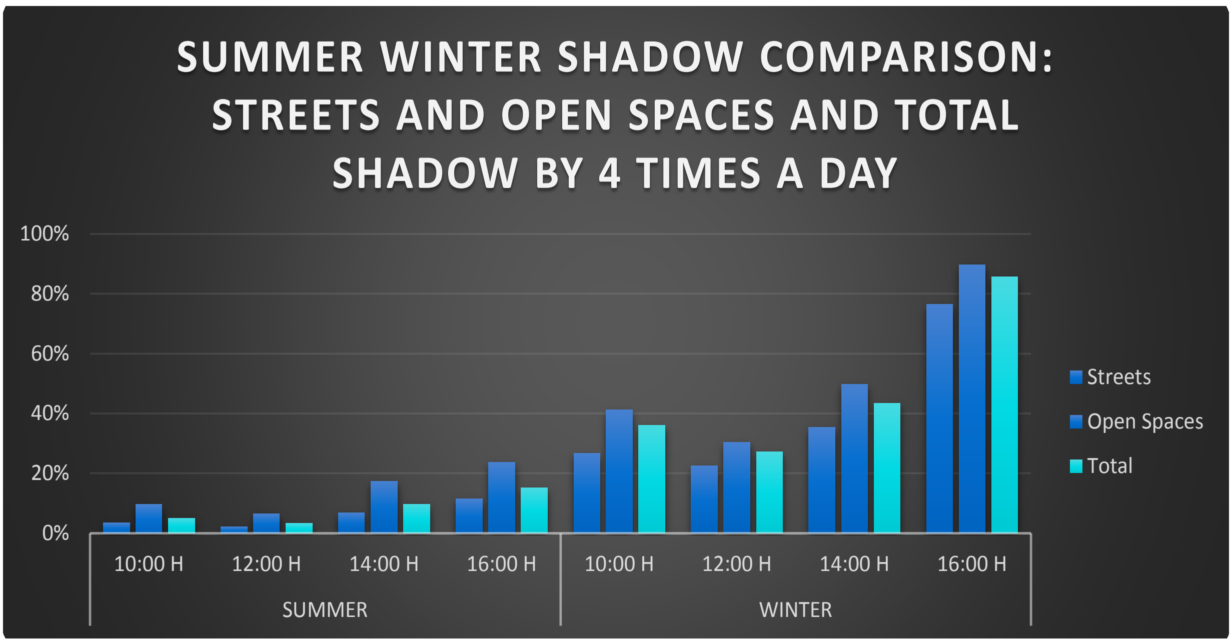
wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s speed: 94%, 4 m/s speed: 6%, and greater wind speeds equal to 0.

Overall, combining the streets and open spaces we can get a percentage of the slowest wind speed of 88% and greater wind speed of 4 m/s: 12%. Greater wind speed equal to 0.

In order to understand and have a visual insight of the change of the wind throughout the year long, a summer-winter comparison was made on the graph. From the graph it can be concluded that there is no big change going from summer towards winter. The only difference noted is that during the summer, the wind speed go up to 6 m/s but in winter the wind blows with the maximum speed of 4 m/s.

Comparing again the situation in the summer and winter but going more into details and analyzing north-south, west-



east streets and open spaces in both of the seasons, it can be noted that the wind speed of 6 m/s is more prevalent in the streets while in the open spaces it barely exists. Specifically, the wind speed of 6 m/s blows the most in the direction of North-South streets.

GENERAL WIND STUDY

The wind speed is compared by doing an experiment where wind was coming from the four directions: North, North West, West and South West. Looking at the graph (_) it can be concluded that the slowest wind speed is present at the highest percentage and it reflects very low wind speed, of just 2 m/h. The critical situation would happen in case the wind was coming from the north and west because that would cause a higher wind speed of 10 m/s (yellow color). A better scenario would be if wind blows from the North-West because it would develop a speed of 6 m/s. The best situation would be in case the wind was blowing from the South-West because it would blow with the maximum speed of 4 m/s.

LOCAL SHADOW STUYD

The analysis of the sun effects and shadows that it leaves on the streets and open spaces was performed, as well. The measurements were done during the summer and winter season and at specific hours of the day in order to get the true picture and data how much shadow is actually present at the city throughout the day, from the morning until the afternoon. The measurements were done at the following hours: 10 am, 12 am, 2 pm and 4 pm.

Summer-Winter

In case of Moscow, the amount of the shadow during the summer is lower, while in the winter is higher. (graph_) And paying attention specifically on the streets and open spaces, it can be noted that the amount of the shadows is higher at open space. This is justified with the walls of the buildings which are putting the shade on the open space much more the buildings putting the shade on the streets. In order to better understand the division of the shade per street and per open space, we made a following graph where we additionally put the total overall existence of the shadow for every specific hour. An interesting thing can be concluded and it is that the amount of the shadow does not change during the day at all. It remains the same in the morning and in the afternoon.

GENERAL SHADOW STUDY

In case of placing a Moscow city model into the geographical position of the Boston city, situation about the shadows does not change very much. The amount of shadows goes up going from the summer towards the winter and it is constantly increasing.

NEW YORK
UNITED STATES

New York City is the most populous city in the United States.

Area: 1,214 km^2
Latitude: 40°42”
Longitude: 74°00”
Elevation above sea level: 57 m

CLIMATE
The New York weather is very changeable with moderate precipitation all over the year, and some heat waves in summer and very cool weather in winter and even in the early spring. Snow is concentrated in winter months.

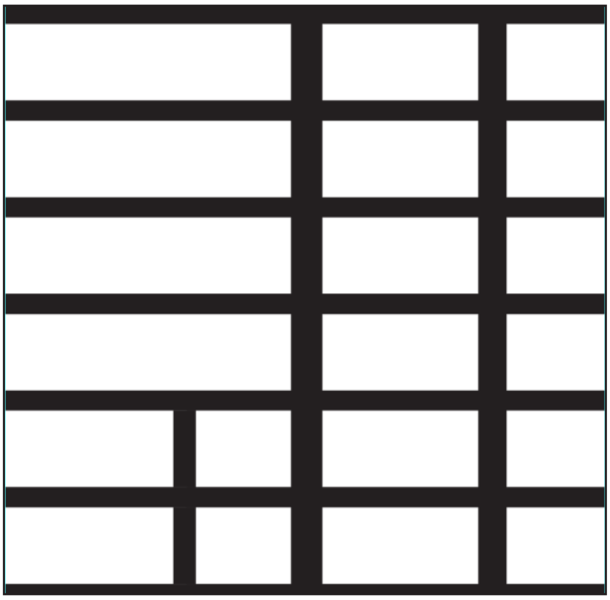
For many people summer should be avoided. Humidity and high temperatures may turn July and August into very uncomfortable months. However, these are also the months with the highest number of visitors.

The months June, July, August and September have a comfortable average temperature.
On average, the warmest month is July.
On average, the coolest month is January.
April is the wettest month.
October is the driest month.

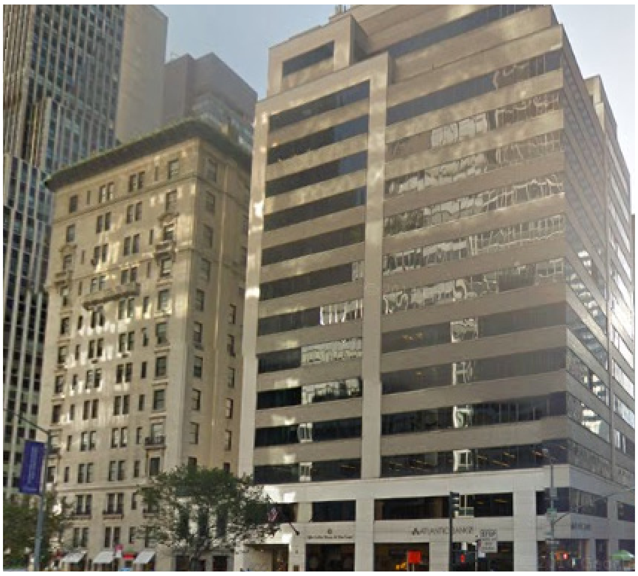
POPULATION
Population: 2012: 525,875
Population density: 27,012

ETHNICITY
Foregin born: 36%
White: 44.6%
Black: 25.1%
Hispanic: 27.5%
Asian: 11.5 %

STREETS



BUILDINGS



OPEN SPACES

NEW YORK
SOCIAL ANALYSIS
STREETS

Visual Permeability

The New York sample is characterized by a regular grid type. The streets are straight and spaced at regular intervals with few deviations. The regularity of the grid improves visual permeability and legibility in the city. Navigation is made easier because users are able to see for longer distances and because the street layout is easily memorized as a mental map. A regular grid optimizes visual permeability and legibility of the city space, therefore the score given is ten on the social comfort scale.

Physical Permeability

The New York block size has two variations, longer blocks and shorter blocks. The shorter block pattern creates more intersections which inproves the overall connectivity. The shorter blocks increase the number of possible routs that users can take to reach their destinations, providing them with more choices of paths to take, which can also result in more direct connections. The longer blocks reduce connectivity. The average block size in the sample is 12.000 sqm, and the number of intersections is 17. Compared to the other samples, the block size is smaller than average and receives a score of 7, the number of intersections is close to the average, receiving a score of 5. The overall score is 6 out of 10 on the social comfort scale.

Traffic Flow

The traffic flow is high in New York; two out of the ten streets have four or more lanes of traffic. The high number of lanes makes pedestrian connections more difficult, limiting the freedom of pedestrian travel. The average number of lanes in the New York sample is 2.4. Compared to the other samples, the number of traffic lanes is close to the average, therefore it receives a 5 on the social comfort scale.

Walkability

STREETS- NEW YORK			
Street Elements			Social Score (0-10)
Visual Permeability			10
	Grid Type	Regular Grid	10
Physical Permeability			6
	Typical Block Size	12.000 sqm	7
	Number of Intersections	17	5
Traffic Flow			5
	Average Number of Traffic Lanes	2.4	5
Walkability			10
	Walk Score	99	10

Walkability is high in the New York sample, with a walk score of 99. This means that all essential products and services can be reached within walking distance. In comparison with the other samples, New York receives a score of 10 for walkability.

BUILDINGS

Active Fronts

Eighty five percent of buildings have active facades with many windows facing the street. There are a few buildings, for instance a church, a museum, and a parking garage, which have blank walls and do not interact with the street. However, the buildings between them are active enough to maintain pedestrian interest and overall the streets are lively. The number of entrances to the street per 500m is 49, which is higher than average compared to the other samples. The overall score on the social comfort scale is 8 out of 10.

Building Variety

Building variety is relatively high in the New York sample. There is a large variation in the building typology where newer and taller buildings have been mixed in with an older building stock of much smaller and shorter buildings. However, even the older buildings have been renovated and rents are high in this area, reducing the possibilities for diverse businesses to locate in the area. The mix of housing types is relatively high, with lowrise, midrise, and highrise apartment buildings. In comparison with the other samples, the overall score given is 7 out of 10.

Mixed Use

In the New York sample four primary

BUILDINGS			
Building Elements			Social Score (0-10)
Active Fronts			8
	Number of Buildings with Blank Facades/500m	85%	8.5
	Number of Entrances /500m	49	7
Building Variety			7
	Mix of Old and New Buildings	High	9
	Mix of Renovated and Unrenovated Buildings	Low	3
	Mix of Housing Types	Lowrise, Midrise, Highrise	8
Mixed Use			8
	Number of Mixed Uses	Residential, Commercial, Office, Entertainment	8
Building Density			9.5
	Typical Building Height	115m	10
	Ground Coverage	63%	9

uses were identified, residential, commerial, office and entertainment. This is good in terms of attracting activity at different times of the day. Compared to the other samples, New York received the highest score, which was 8 out of 10.

Building Density

The building density is high in the New York sample, with a typical building height of 115 meters and a ground coverage of aproximately 63%. The density is possibly too high; buldings block light at the street level and open spaces are limited and very small. However, comfort and size of open spaces will be considered separately in this study. Therefore, the score for density alone is 9.5 out of 10.

OPEN SPACES

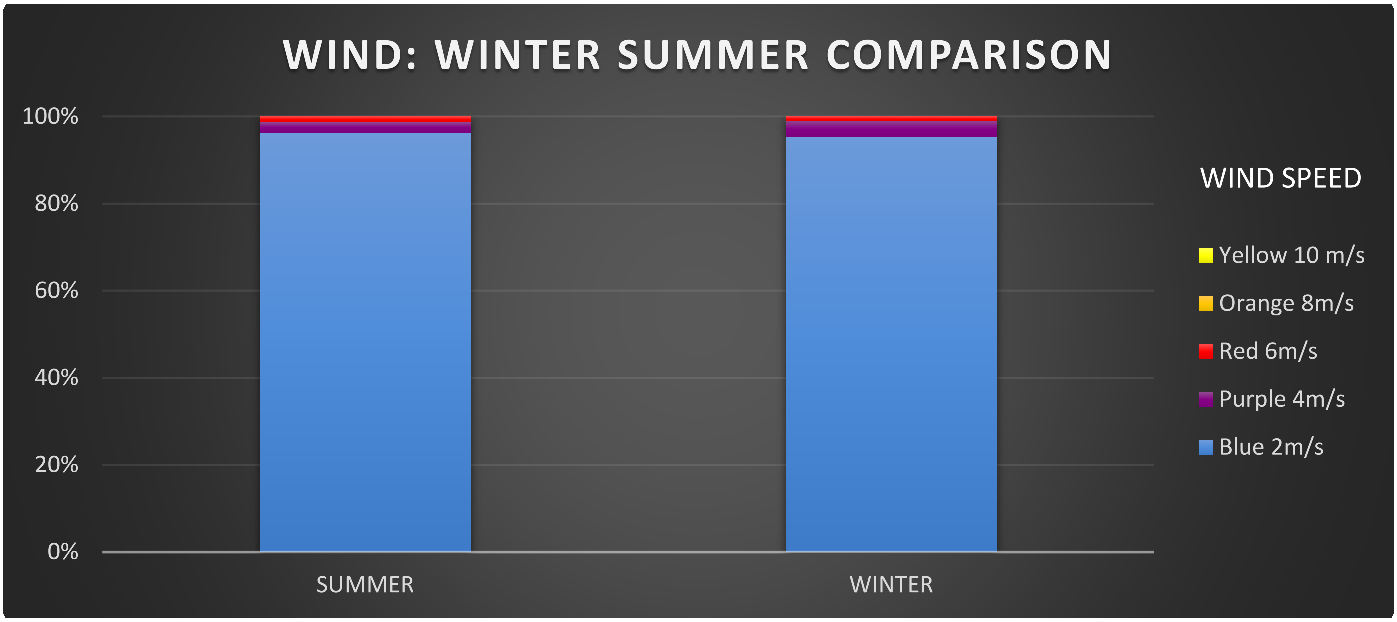
Size and Number

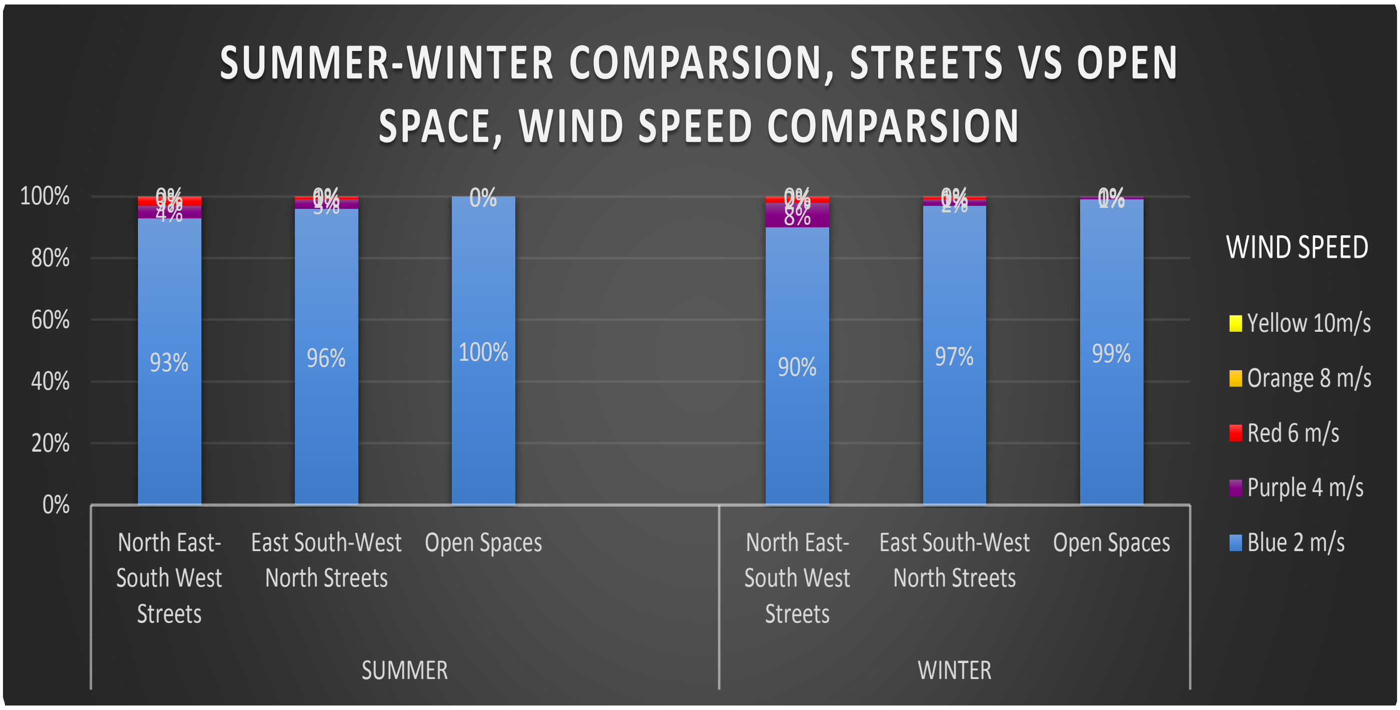
Open spaces in the New York sample are small in number and size. Most of the six open spaces found are small courtyards between buildings, with an average size of 1.500 square meters. It is worth noting that the sample is located on the southern border of central park, which has 341 hectares of green space. However, in terms of social comfort, Central Park may be too big, and the other spaces too small. Jane Jacobs and Jan Gehl call for "many small spaces," but how small is too small? The average size of green spaces in all the six samples was 3.500 sqm, which is about the size of a small neighborhood park. The samples which came closer to this average were scored higher, while the samples which were farther from the average scored lower. In terms of the number of green spaces, samples with a larger number scored higher. The overall score for the new york sample is 5 out of 10.

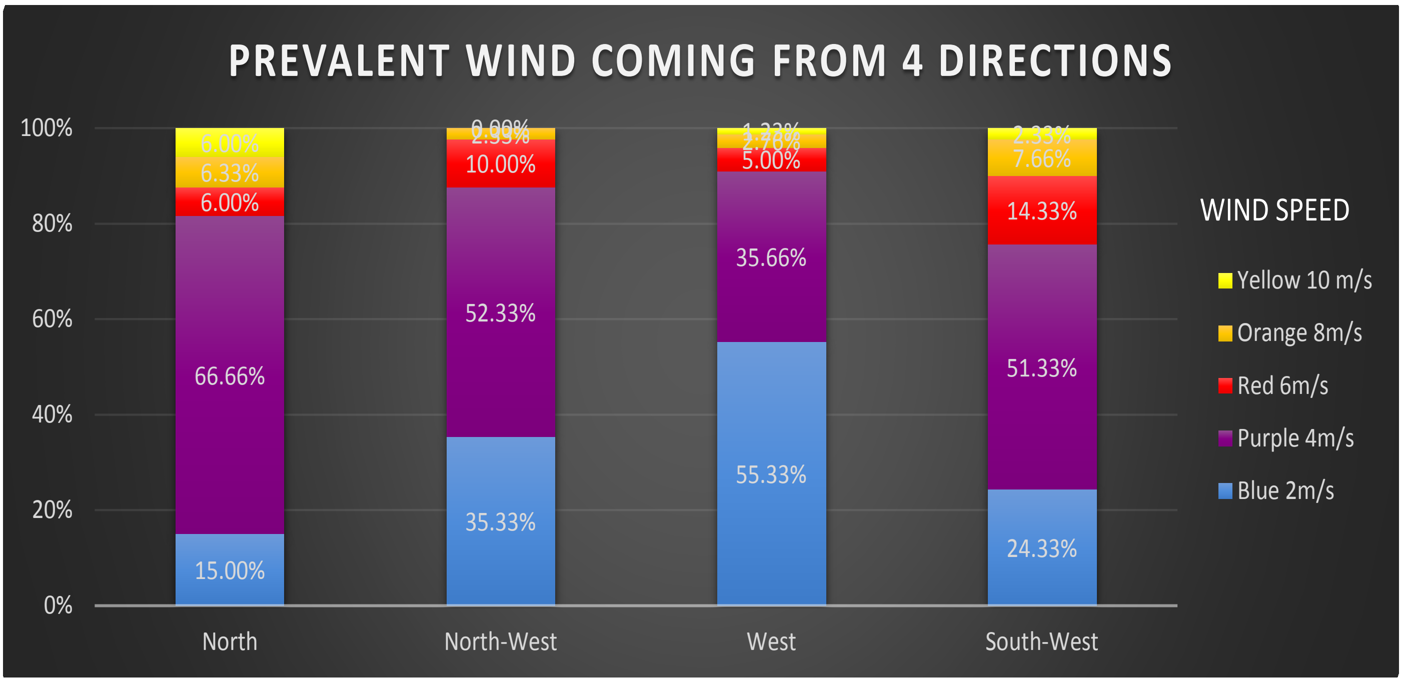
Public Access

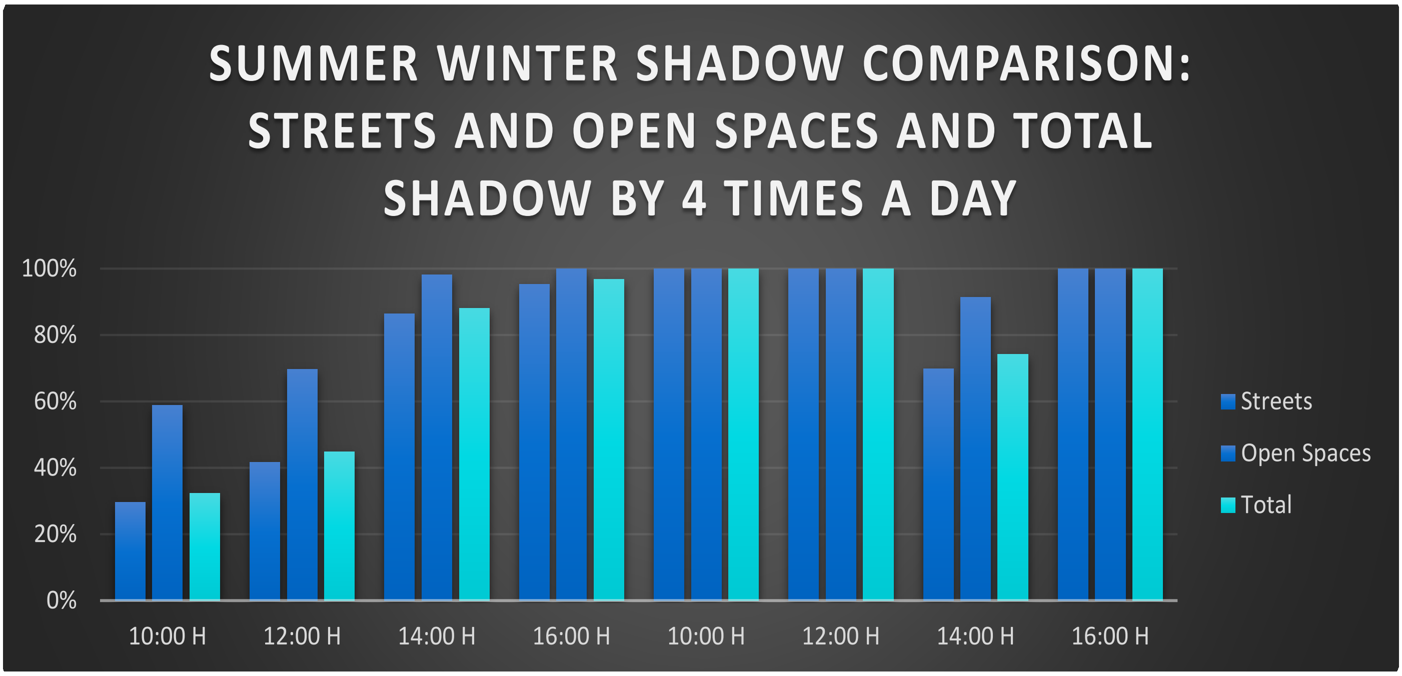
In the New York sample, visual and physical access to the open spaces is

OPEN SPACES			
Open Space Elements			Social Score (0-10)
Size and Number			5
	Average Size	1.500 sqm	8
	Number	6	2
Access			5.5
	Visual Access	60%	6
	Physical Access	50%	5
Mixed Users			4
	Users	Workers, Vistors, Residents	
Comfort			7
	Climate/Noise Protection	Moderate Protection	6
	Comfortable Seating	Available	7
	Aesthetic Quality	Good	8


WIND: WINTER SUMMER COMPARISON
100%
80%
60%
40%
20%
0%
SUMMER
WINTER
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s


SUMMER-WINTER COMPARSION, STREETS VS OPEN SPACE, WIND SPEED COMPARSION
100%
80%
60%
40%
20%
0%
93%
96%
100%
0%
90%
97%
99%
North East-South West Streets
East South-West North Streets
Open Spaces
North East-South West Streets
East South-West North Streets
Open Spaces
SUMMER
WINTER
WIND SPEED
Yellow 10m/s
Orange 8 m/s
Red 6 m/s
Purple 4 m/s
Blue 2 m/s


PREVALENT WIND COMING FROM 4 DIRECTIONS
100%
80%
60%
40%
20%
0%
6.00%
6.33%
6.00%
66.66%
15.00%
10.00%
52.33%
35.33%
5.00%
35.66%
55.33%
7.66%
14.33%
51.33%
24.33%
North
North-West
West
South-West
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s



limited. Two of the six areas are courtyard spaces, meaning that they are not accessible to the public; another is a rooftop green space, which also lacks public access. Therefore, public access to green spaces within the sample is 50%, receiving a score of 5 out of 10.

Comfort

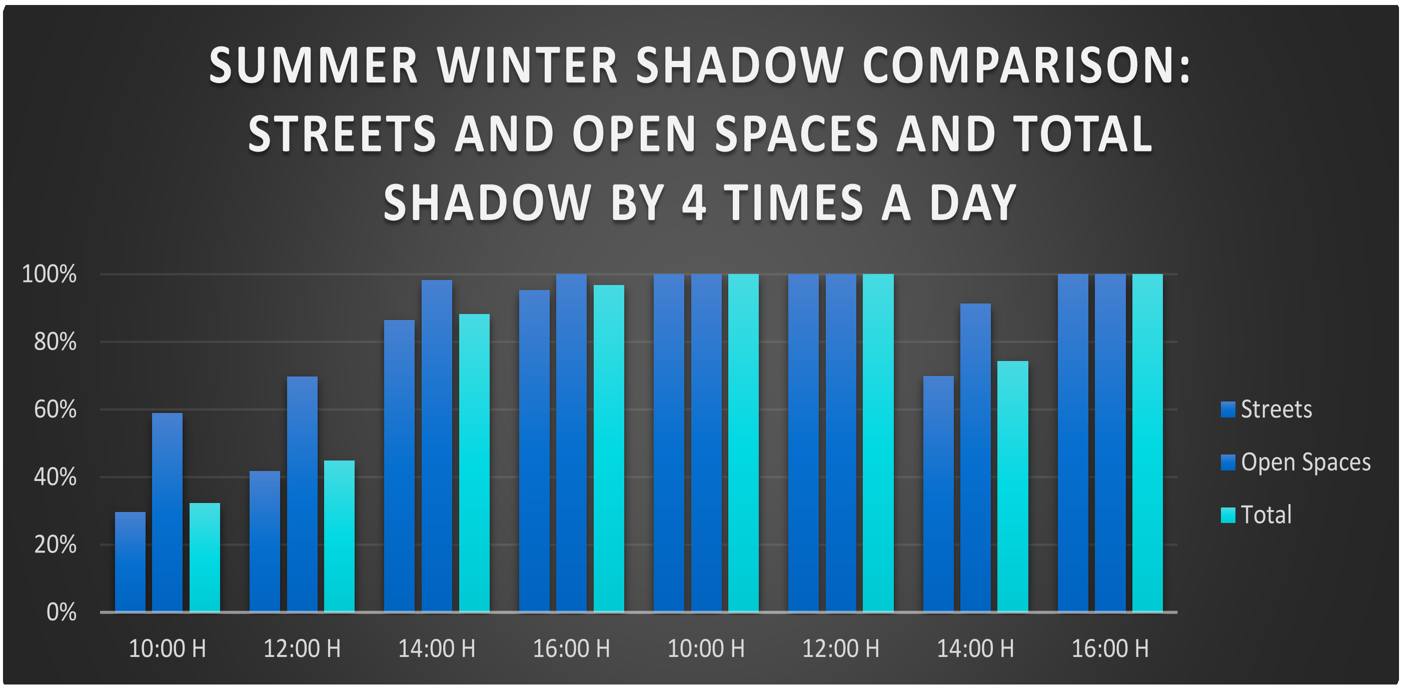
The spaces have moderate to high protection from noise and unpleasant environmental conditions. Most of the spaces are surrounded by three or more walls, which blocks wind and noise from entering the space. The spaces that do have public access are well designed, with comfortable seating and a pleasant aesthetic environment. The overall score given is 7 out of 10.

ENVIRONMENTAL ANALYSIS

LOCAL WIND STUDY

Summer

During the summer season, the city of New York is characterized by the wind coming from the South and the maxi-



LOCAL SHADOW STUDY

The analysis of the sun effects and shadows that it leaves on the streets and open spaces was performed, as well. The measurements were done during the summer and winter season and at specific hours of the day in order to get the true picture and data how much shadow is actually present at the city throughout the day, from the morning until the afternoon. The measurements were done at the following hours: 10 am, 12 am, 2 pm and 4 pm.

Summer-Winter

In case of New York, the amount of the shadow during the summer is lower, while in the winter is higher. (graph_) And paying attention specifically on the streets and open spaces, it can be noted that the amount of the shadows is higher at open space. This is justified with the walls of the buildings which are putting the shade on the open space much more the buildings putting the shade on the streets. In order to better understand the division of the shade per street and per open space, we made a following graph where we additionally put the total overall existence of the shadow for every specific hour. During the summer, the amount of shadow goes up from the morning towards the afternoon. It is interesting to note that during the winter, the amount of the shadow is almost at all times 100% despite the time of the day.

GENERAL SHADOW STUDY

In case of placing a New York City model into the geographical position of the Boston city, the amount of the shadow in the summer is lower than in the winter. It is interesting to have in mind that shadow amount does not depend from the time of the day, and it is not the lowest in the morning and highest in the afternoon. It remains the same throughout the day.

NOVI SAD
SERBIA

Novi Sad is the second largest city in Serbia, the administrative seat of the province of Vojvodina and of the South Bačka District.

Area: 106.2 km^2
Latitude: 45°33”
Longitude: 19°85”
Elevation above sea level: 87m

CLIMATE
Average wind speed: 9.35 m/s
Average annual temperature: 12.1 °C.
Annual average max. temperature: 17.8. °C.
Annual average min. temperature: 7.2 °C.
Average number of rainy days: 106.
Average number of days with snow: 20.

The months May, June, July, August and September have a comfortable average temperature.
On average, the warmest month is August, the coolest month is January. June is the wettest month. October is the driest month.

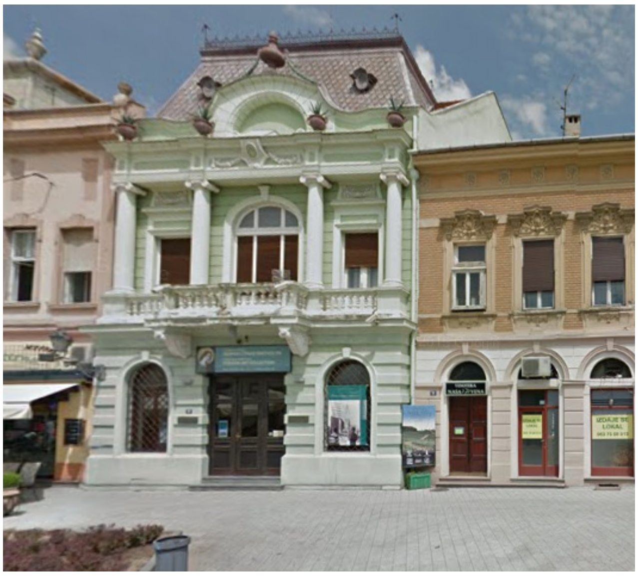
POPULATION
2011: 277,522 (with adjacent urban settlements of Petrovaradin and Sremska Kamenica).

ETHNICity

Serbs	78.79%
Hungarians	3.88%
Slovaks	1.93%
Croats	1.56%
Romani	1.06%
Others	12.78%

STREETS

BUILDINGS



OPEN SPACES

NOVI SAD
SOCIAL ANALYSIS
STREETS

Visual Permeability

The Novi Sad sample is characterized by a highly distorted or organic grid type. The streets are somewhat straight, but they do not intersect each other at right angles, and the blocks are irregularly shaped. The visual permeability is reduced by the distorted grid type, making it more difficult to see down streets for long distances. The score is 3 out of 10 for visual permeability.

Physical Permeability

The Novi Sad block size is approximately 9.500 sqm, which is smaller than average compared to the other samples. The number of intersections is 31, which is a higher than average. The smaller blocks and more frequent intersections improve physical permeability, therefore, the overall score is 9 out of 10.

Traffic Flow

The traffic flow is low in Novi Sad. All the streets in the sample have only two lanes of traffic, increasing pedestrian freedome of movement. A higher score is given for lower traffic flow, so Novi Sad receives an 8 out of 10.

Walkability

Walkability is high in Novi Sad, with a walk score of 93, meaning that most products and services can be reached within walking distance. This results in a walkability score of 9 for Novi Sad.

BUILDINGS

Active Fronts

Active ground floors are relatively high in the Novi Sad sample; fifty-five percent of buildings have active facades. Many buildings have commercial uses on the ground floor, while a few have residential uses. The number of entrances to

STREETS- NOVI SAD			
Street Elements			Social Score (0-10)
Visual Permeability			3
	Grid Type	Distorted Grid	3
Physical Permeability			9
	Typical Block Size	9.500 sqm	8.5
	Number of Intersections	31	10
Traffic Flow			8
	Average Number of Traffic Lanes	2	8
Walkability			9
	Walk Score	93	9

the street per 500m is 52, which is higher than average compared to the other samples. The overall score is 6.5 out of 10 for active fronts.

Building Variety

Building variety is adequate. There is a low mix of old to new buildings, but a high mix of renovated to unrenovated buildings. The housing stock consists of two housing types, two-story apartment buildings with ground floor commercial uses, and low-rise apartment buildings with two to four floors. The overall score is 5 out of 10 for building variety.

Mixed Use

In the Novi Sad sample, three primary uses were identified, residential, commericial and entertainment. The mix of uses is relatively high because the sample is located in the city center. Novi Sad receives a score of 6 out of 10 for mixed use functions.

Building Density

The building density is moderate, with a typical building height of 12 meters and a ground coverage of aproximately 47%. This results in a score of 5.5 out of 10.

OPEN SPACES

Size and Number

Open spaces in the Novi Sad sample are relatively high in number and small in size. There are 35 open spaces with an average size of 600 sqm. Novi Sad receives an overall score of 8 because the size of the spaces is a bit small when compared with the number of spaces available.

Public Access

Visual and physical access to the open spaces is somewhat limited. Most of the spaces are semi-private courtyard spac-

BUILDINGS			
Building Elements			Social Score (0-10)
Active Fronts			6.5
	Percent of Buildings with Active Facades/500m	55 %	5.5
	Number of Entrances /500m	52	7.5
Building Variety			5
	Mix of Old and New Buildings	Low	3
	Mix of Renovated and Unrenovated Buildings	High	8
	Mix of Housing Types	Two-Story Apartments, Lowrise Apartments	5
Mixed Use			6
	Number of Mixed Uses	Residential, Commerical, Entertainment	6
Building Density			5.5
	Typical Building Height	12m	4
	Ground Coverage	47%	7

OPEN SPACES			
Open Space Elements			Social Score (0-10)
Size and Number			8
	Average Size	600 sqm	7
	Number	35	9
Access			2
	Visual Access	20%	2
	Physical Access	20%	2
Comfort			6
	Climate/Noise Protection	High Protection	9
	Comfortable Seating	Limited	3
	Aesthetic Quality	Adaquate	5

es that are not accessible to the public. A few semi-enclosed spaces are accessible from the street. The resulting score is 2 out of 10 for access.

Comfort

The spaces have moderate protection from noise and unpleasant environmental conditions, since the majority of spaces are protected courtyards. In the spaces with public access, green elements improve the aesthetic quality. The overall score is 6 out of 10 for comfort.

ENVIRONMENTAL ANALYSIS

LOCAL WIND STUDY

Summer

During the summer season, the city of Novi Sad is characterized by the wind coming from the West and the maximum speed recorded was 8 m/s at specific areas. After the simulation was performed the results are following:

In the north-south direction of the streets: the wind speed of 2 m/s was 100%, the speed of 4 m/s is 0%, and the speed of 6 m/s: 0%, where all greater speeds equal to 0.

In the east-west direction of the streets the wind speed is diffused in the following way: the wind speed of 2 m/s: 100%, and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s: 100%, and the rest of wind speeds equal to 0.

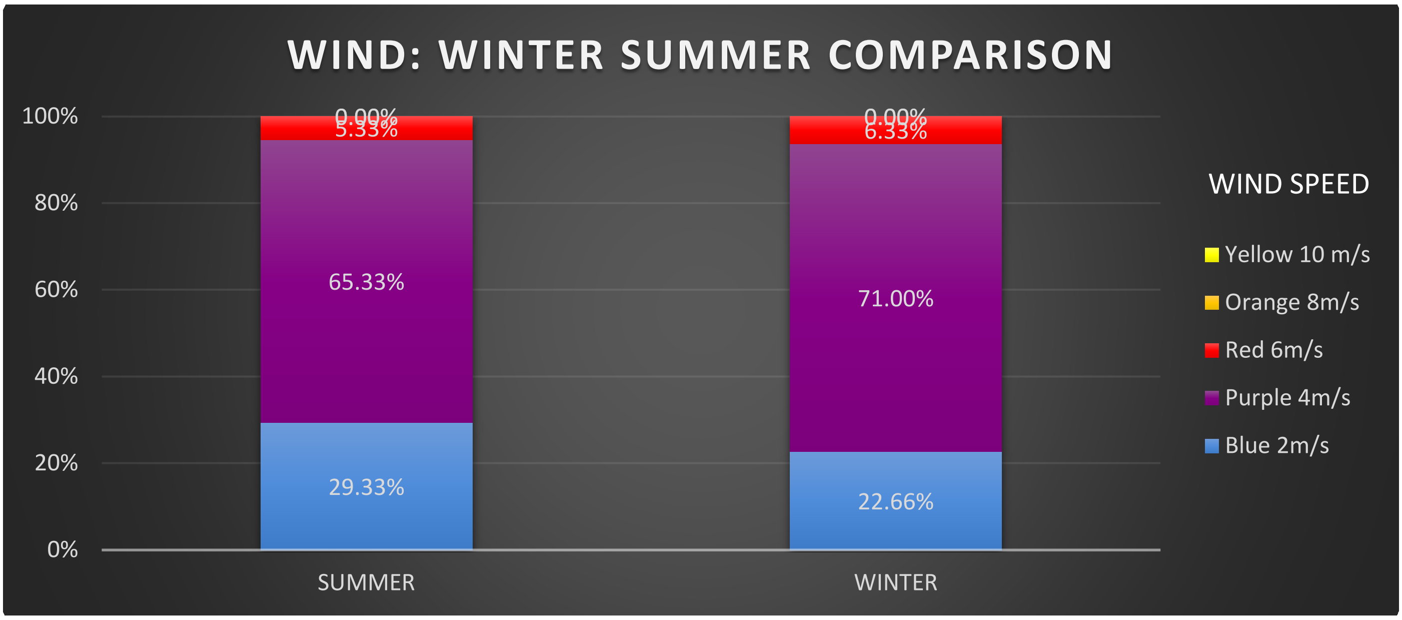
Overall, combining the streets and open spaces we can get a percentage of 100% the slowest wind speed and greater wind speeds equal to 0.

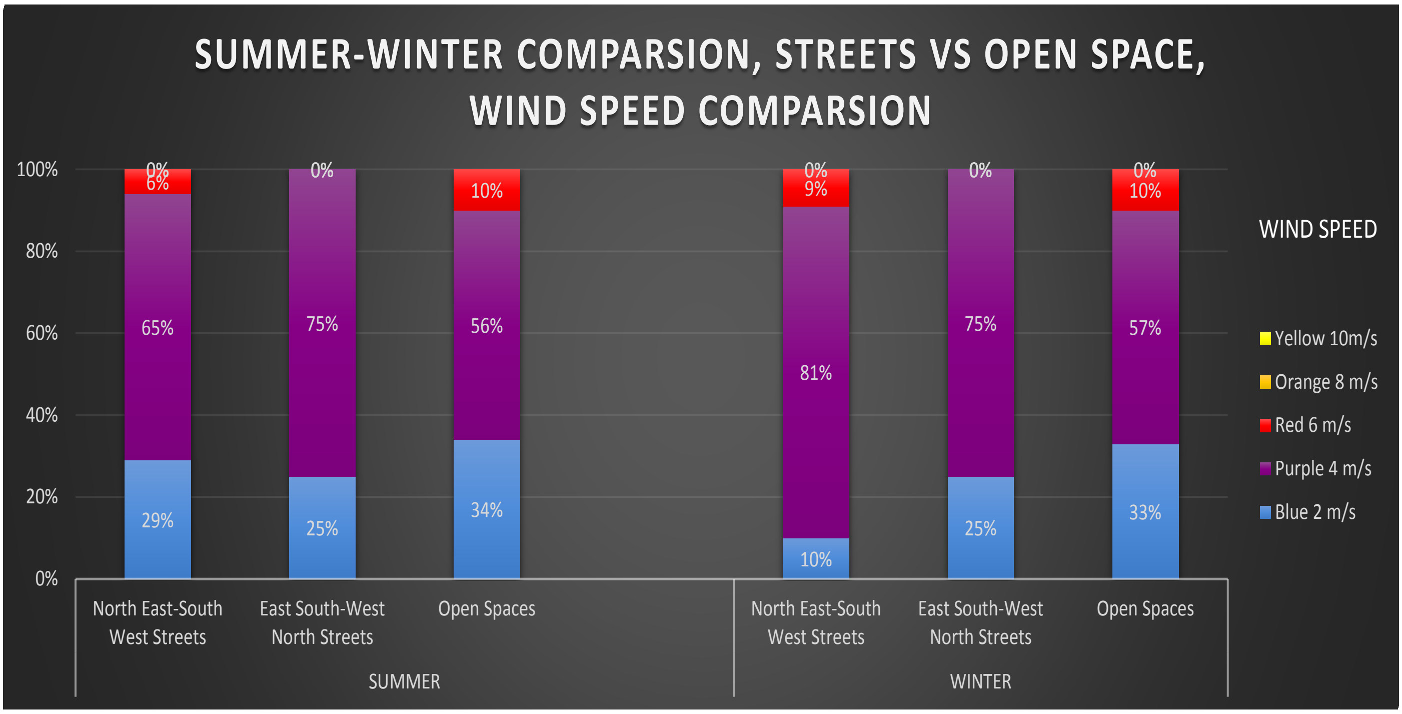
Winter

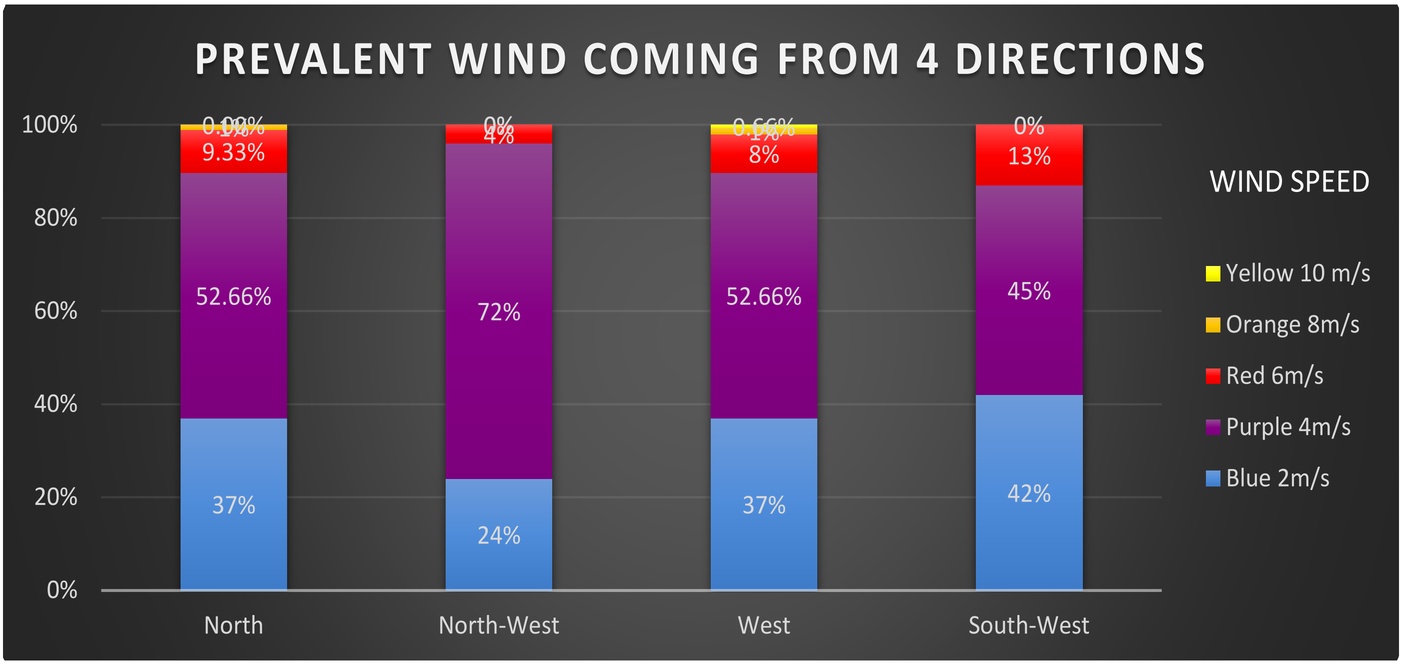
During the winter season, the city of Novi Sad is characterized by the wind coming from the South, South-East and the maximum speed recorded was 8 m/s at specific areas.

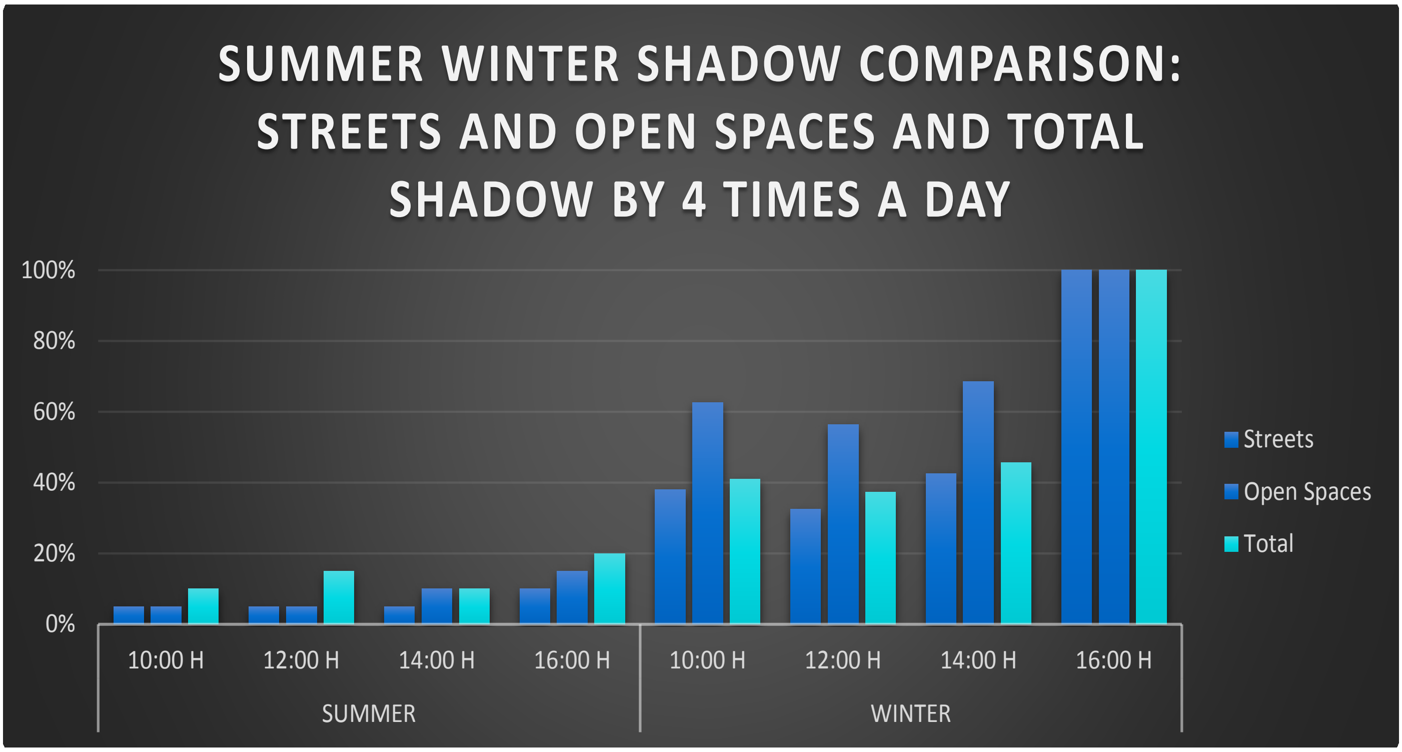
After the simulation was performed the results are following:

In the north-south direction of the streets: the wind speed of 2 m/s was 100%, the speed of 4 m/s is 0%, and the speed of 6 m/s: 0%, where all greater speeds equal to 0.


WIND: WINTER SUMMER COMPARISON
100%
80%
60%
40%
20%
0%
0.00%
5.33%
65.33%
29.33%
0.00%
6.33%
71.00%
22.66%
SUMMER
WINTER
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s


SUMMER-WINTER COMPARSION, STREETS VS OPEN SPACE, WIND SPEED COMPARSION
100%
80%
60%
40%
20%
0%
0%
6%
65%
29%
0%
75%
25%
10%
56%
34%
0%
9%
81%
10%
0%
75%
25%
0%
10%
57%
33%
North East-South West Streets
East South-West North Streets
Open Spaces
SUMMER
North East-South West Streets
East South-West North Streets
Open Spaces
WINTER
WIND SPEED
Yellow 10m/s
Orange 8 m/s
Red 6 m/s
Purple 4 m/s
Blue 2 m/s


PREVALENT WIND COMING FROM 4 DIRECTIONS
100%
80%
60%
40%
20%
0%
9.33%
52.66%
37%
0%
4%
72%
24%
8%
52.66%
37%
0%
13%
45%
42%
North
North-West
West
South-West
WIND SPEED
Yellow 10 m/s
Orange 8m/s
Red 6m/s
Purple 4m/s
Blue 2m/s

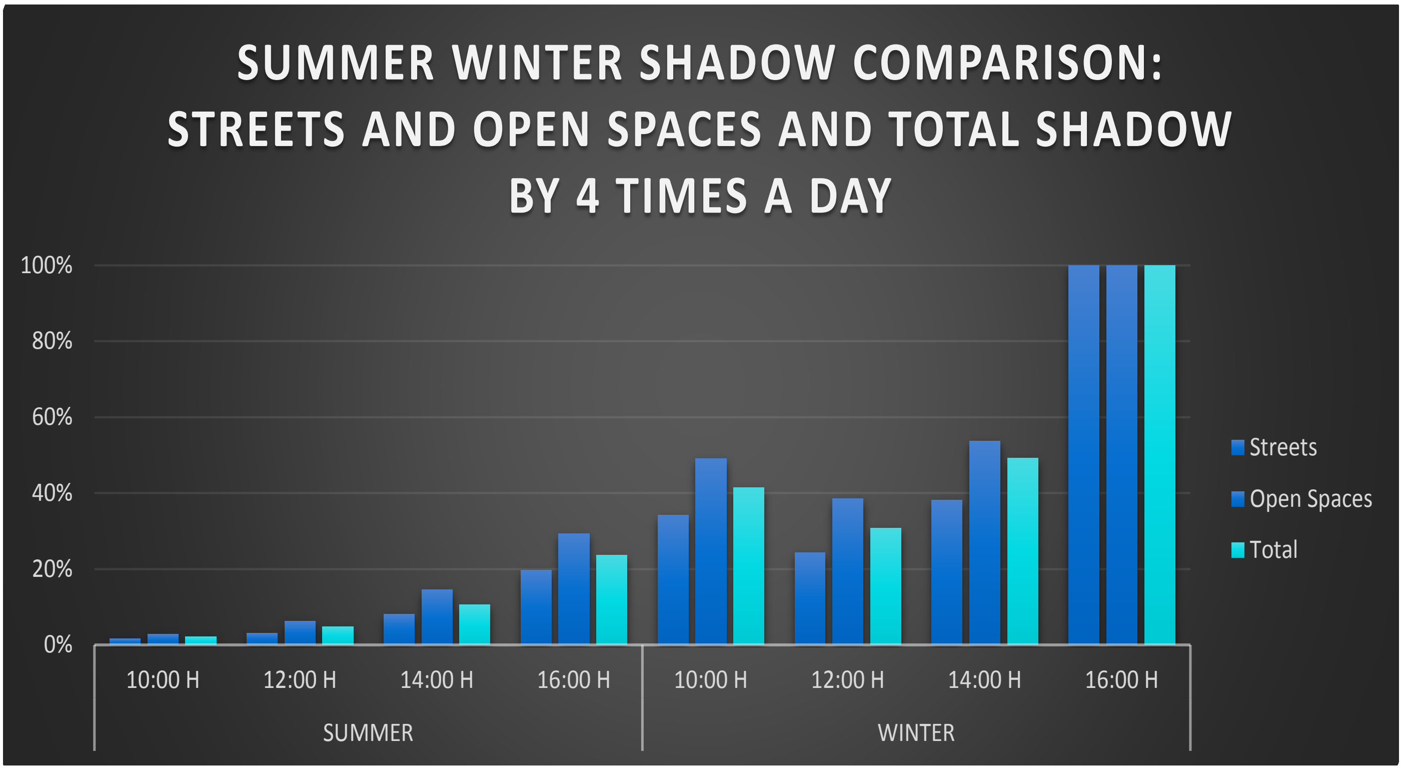


In the east-west direction of the streets the wind speed is diffused in the following way: the wind speed of 2 m/s: 100%, and greater wind speeds equal to 0.

When it comes to the analysis of the wind speed in the open spaces the representation is the following: 2 m/s: 100%, and the rest of wind speeds equal to 0.

Overall, combining the streets and open spaces we can get a percentage of 100% the slowest wind speed and greater wind speeds equal to 0.

In order to understand and have a visual insight of the change of the wind throughout the year long, a summer-winter comparison was made on the graph. From the graph it can be concluded that there is no big change going from summer towards winter. The most frequent



wind blows with speed of 2 m/s in both seasons.

Comparing again the situation in the summer and winter but going more into details and analyzing north-south, west-east streets and open spaces in both of the seasons, it can be noted that the wind speed of 2 m/s is the most prevalent wind speed.

GENERAL WIND STUDY

The wind speed is compared by doing an experiment where wind was coming from the four directions: North, North West, West and South West. Looking at the graph (_) it can be concluded the highest velocity of wind would happen in case the wind was coming from the south-west because that would cause a higher wind speed of 6 m/s (red color). Concluding, the most prevalent wind are blowing with speed of 2 m/s.

LOCAL SHADOW STUDY

The analysis of the sun effects and shadows that it leaves on the streets and open spaces was performed, as well. The measurements were done during the summer and winter season and at specific hours of the day in order to get the true picture and data how much shadow is actually present at the city throughout the day, from the morning until the afternoon. The measurements were done at the following hours: 10 am, 12 am, 2 pm and 4 pm.

Summer-Winter

In case of Novi Sad, the amount of the shadow during the summer is lower, while in the winter is higher. (graph_) And paying attention specifically on the streets and open spaces, it can be noted that the amount of the shadows is higher at open space. In order to better understand the division of the shade per street and per open space, we made a following graph where we additionally put the total overall existence of the shadow for every specific hour. During the summer, the amount of shadow goes up from the morning towards the afternoon. The amount of the shadow goes up from am until pm, in both of the seasons. Looking only the season, the amount of the shadow is much higher in the winter.

GENERAL SHADOW STUDY

In case of placing a Novi Sad City model into the geographical position of the Boston city, the amount of the shadow in the summer is lower than in the winter.

PART III

RESULTS AND CONCLUSIONS

The results are divided into three sections, social comfort, environment comfort, and a combined analysis, where each of the six case studies is discussed individually and scores from the social, wind, and shadow studies are compared. Finally, some conclusions are made comparing all six case studies in relation to social and environmental comfort.

MORPHOLOGY AND SCIAL COMFORT

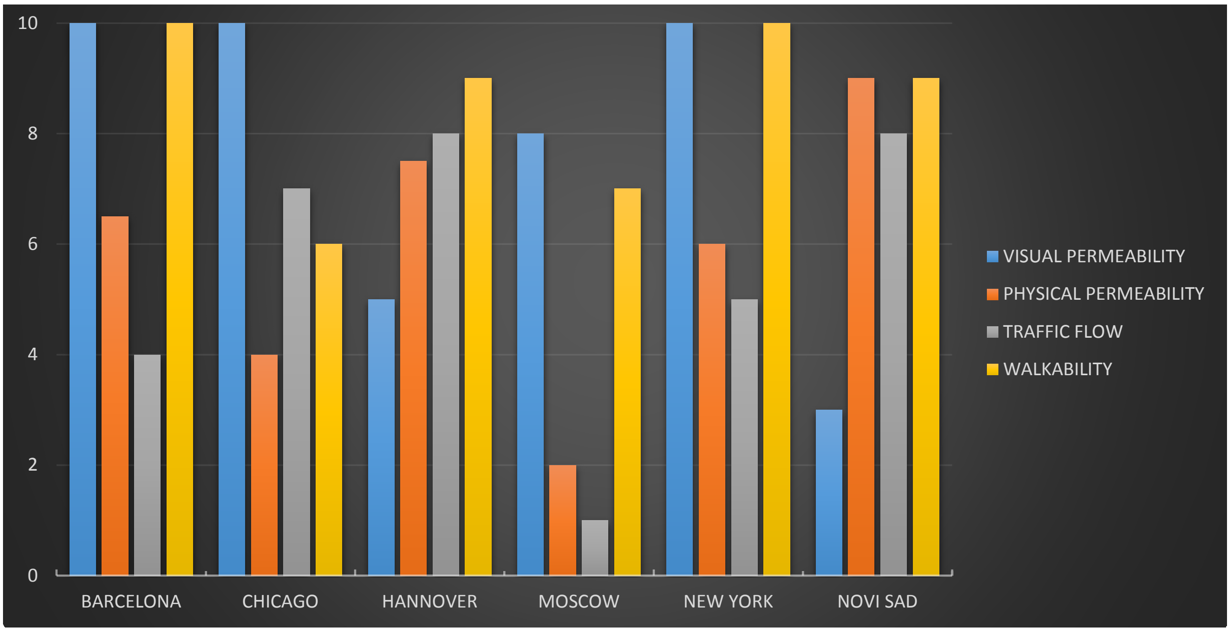
This section compares the social comfort results produced in all six case studies. The goal is to determine which morphological factors contributed to higher social comfort scores, according to the specific criteria analyzed.

In the streets category, New York, Barcelona and Chicago received the highest score for visual permeability; all three received 10 out of 10 because they are characterized by regular grid types. Novi Sad received the lowest score for visual permeability because of its highly irregular grid type. However, Novi Sad received the highest score for physical permeability, followed by Hannover, due to the smaller block sizes in these samples. Moscow received the lowest score for physical permeability due to its large block size. Novi Sad also received the highest score for traffic flow, followed by Hannover; Moscow received the lowest score due to the high number of traffic lanes in the Moscow sample. New York and Barcelona received the highest score for walkability; Chicago received the lowest score, followed by Moscow.

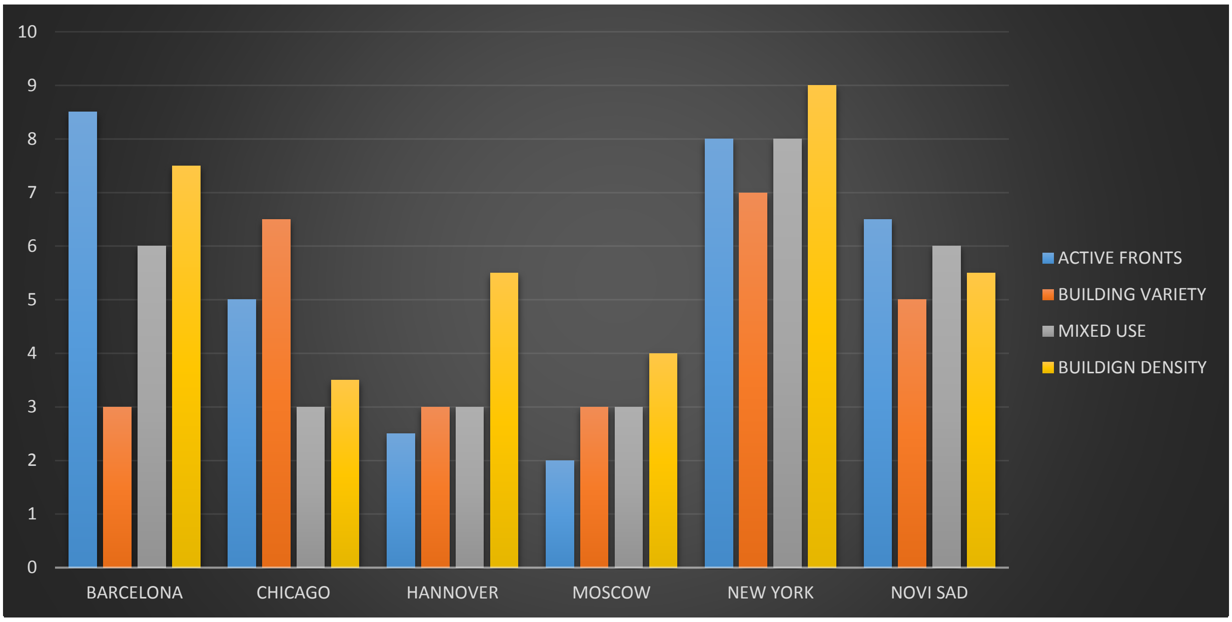
In the buildings category, Barcelona receives the highest score for active fronts, followed by New York. Moscow receives the lowest score, followed by Hannover. New York receives the highest score for building variety, and Chicago recieves the second-highest score, due to the mix of building age, condition, and housing types in these samples. The lowest score goes to Moscow, Hannover, and Barcelona, which all receive 3 out of 10. New York receives the highest score for mixed use, followed by Barcelona and Novi Sad. The lowest score goes to Moscow, Hannover and Chicago, which all receive a 3. The highest score for building density also goes to New York, followed by Barcelona. The lowest score goes to Chicago, and Moscow receives the second-lowest.

In the open spaces category, Barcelona receives the highest score for size and number, followed by Hannover. It should be noted that the open spaces in Hannover are considered to be a good size for public spaces, but existing as semi-private spaces, they could be considered too large. The number may also be too high considering the size of the spaces. In the scoring, a higher number a spaces was considered to be a positive, but this may not always be true. Moscow received the lowest score for size and number because the open spaces in the sample were very large. However, Moscow received the highest score for access to open spaces, while Barcelona received the lowest score be-

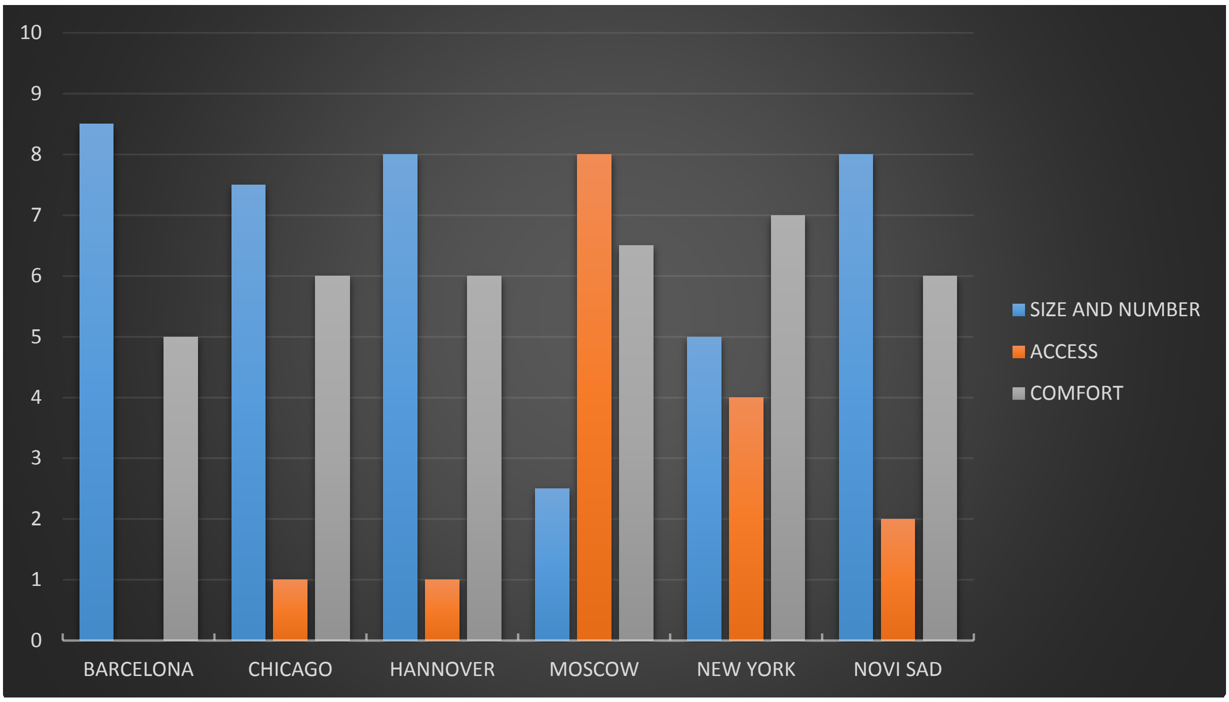
MORPHOLOGY AND SOCIAL COMFORT



STREETS



BUILDINGS



OPEN SPACES

cause none of the open spaces in the Barcelona sample have public access. New York received the highest score for comfort, because the spaces are limited and small, but well designed. Moscow received the second highest score for comfort because the open spaces have playgrounds, seating, and abundent green space. The lowest comfort score also went to Barcelona because the courtyard spaces often lack green elements and aesthetic quality.

Combining the three categories, the New York sample receives the overall highest score for social comfort of approximately 8 out of 10. Followed by Barcelona and Novi Sad with an overall score of approximately 6 out of 10, Chicago and Hannover with an overall score of approximately 5 out of 10, and Moscow receives the lowest score of approximately 4 out of 10.

MORPHOLOGY AND ENVIRONMENTAL COMFORT

The environmental comfort section is divided into local and general context, and wind and shadows are discussed separately in each section.

LOCAL CONTEXT

WIND

In the local context, the wind analysis is divided into summer and winter conditions. The summer wind conditions are analyzed in three categories, north-south streets, east- west streets, and open spaces, which are graphed across all the six case studies. The wind results were displayed at five different wind speeds, 2m/2 (blue), 4m/s (purple), 6m/s (red), 8m/s (orange) and 10m/s (yellow). Wind speeds over 2m/s (purple to yellow) are considered beneficial in the summer situation, while in the winter situation they are considered detrimental.

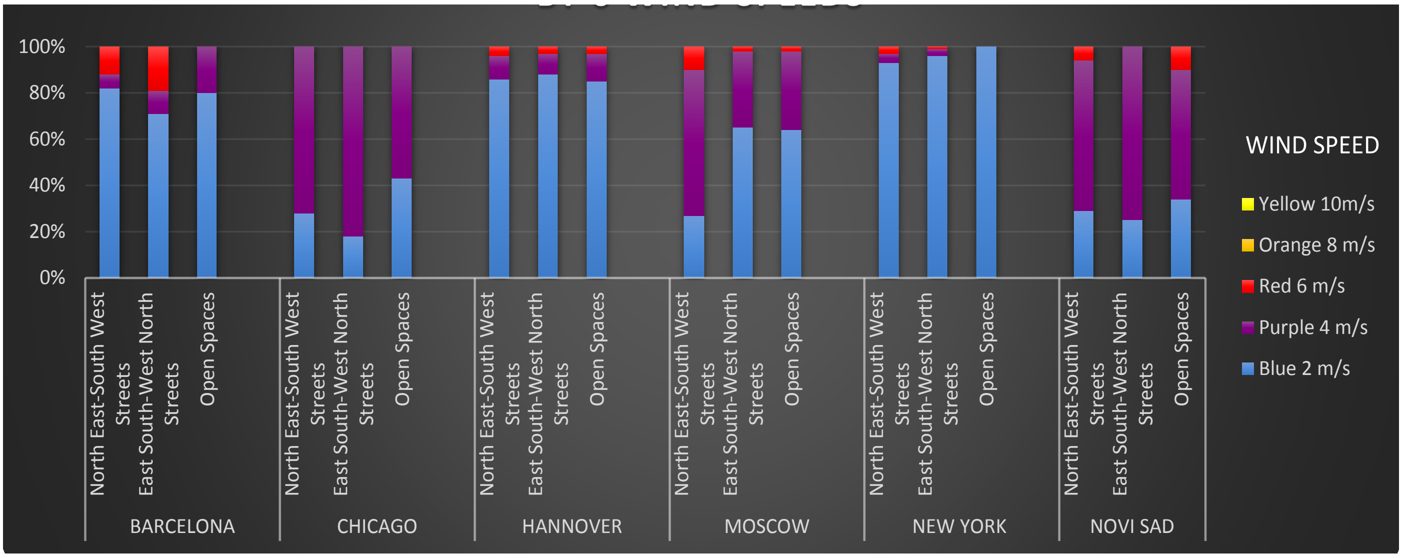
In the summer case, the cities with the highest amount of ventilation (percentage of areas with wind speeds over 2m/s) were Chicago and Moscow. In the Chicago case, the open spaces showed less ventilation compared with the streets. In the Moscow sample, North-south streets showed more ventilation than both east-west streets and open spaces. The cities with the least ventilation were Novi Sad and New York. In these two cases, the direction of the streets did not have a significant affect on ventilation.

In the winter case, the cities with the lowest amount of ventilation were Novi Sad, New York, Moscow. The cities with the highest amount of ventilation in the winter were Chicago and Barcelona. Chicago showed a higher percentage of ventilation (areas with wind speeds over 2m/s), but lower wind speeds (only 4m/s). Barcelona showed a lower percentage of ventilation at higher speeds (up to 6m/s). While wind speeds in the other five samples remained relatively unchanged from summer to winter, wind speeds in Moscow were significantly lower in winter than in summer, which demonstrates a good fit between the Moscow pattern and its local context.

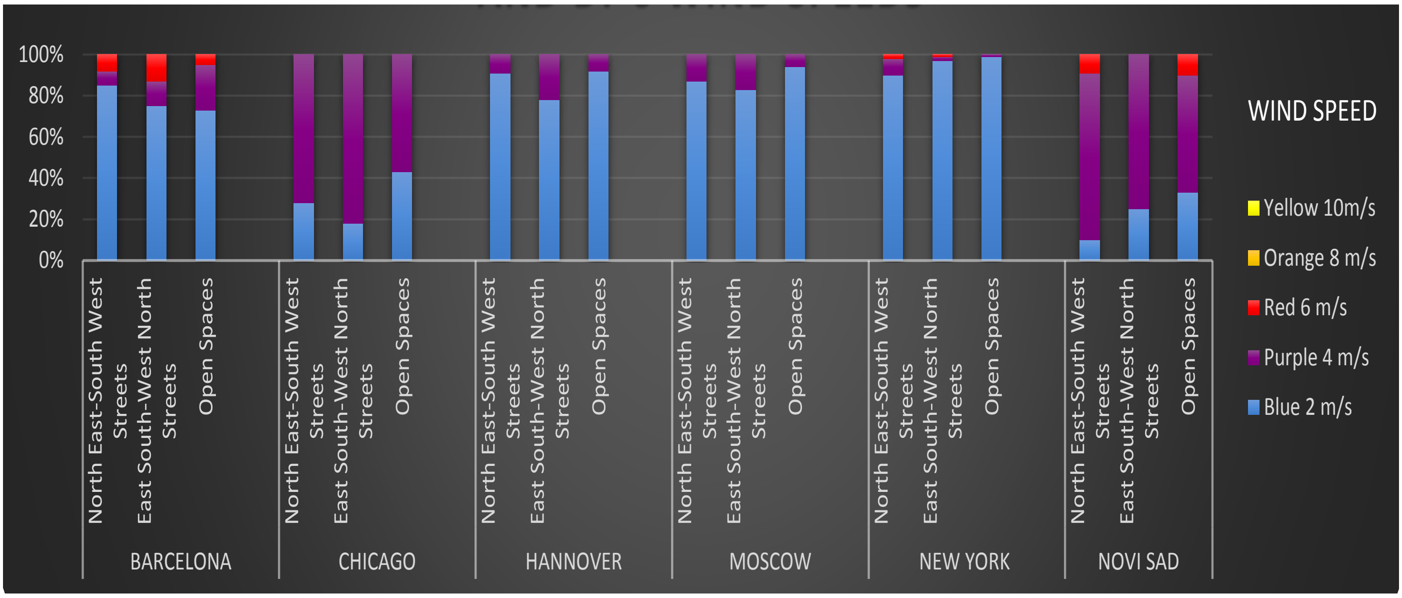
SHADOWS

In the local context, the shadow analysis was analyzed under summer and winter conditions. In both cases, the shadows

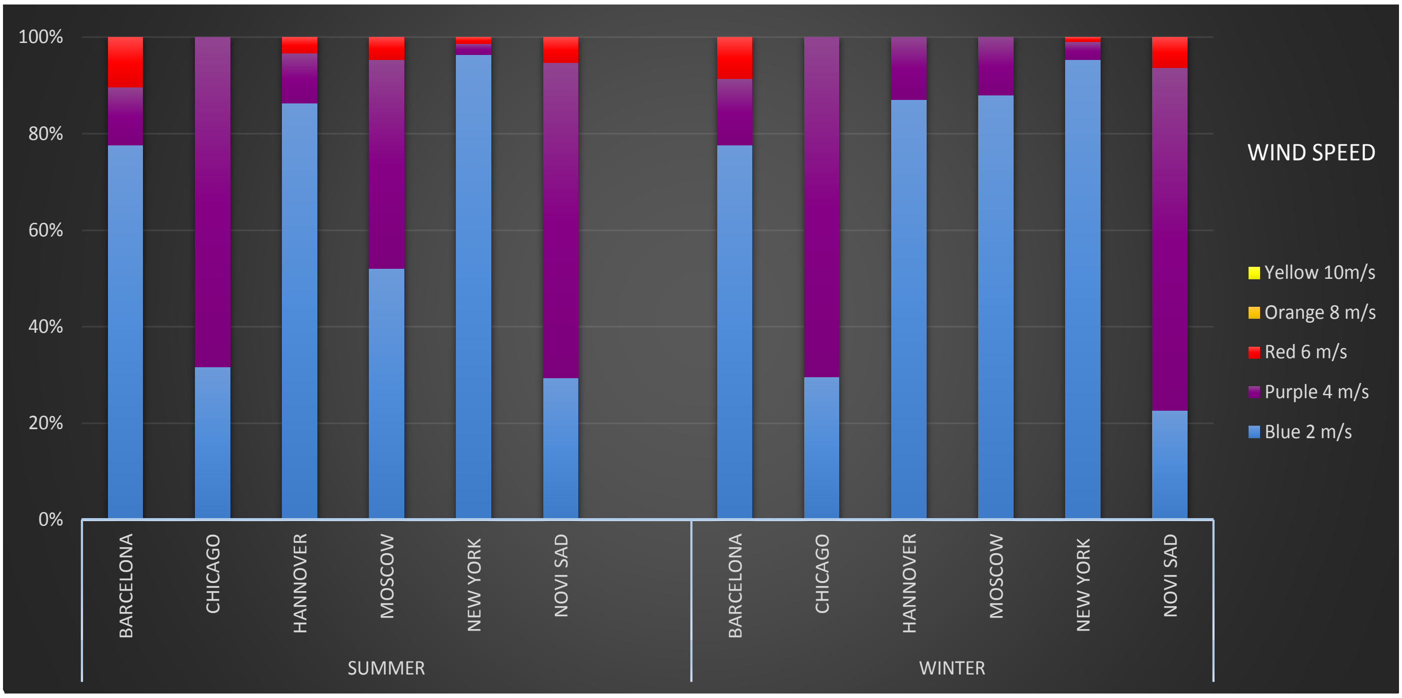
MORPHOLOGY AND ENVIRONMENTAL COMFORT
LOCAL CONTEXT: WIND



SUMMER



WINTER



TOTALS

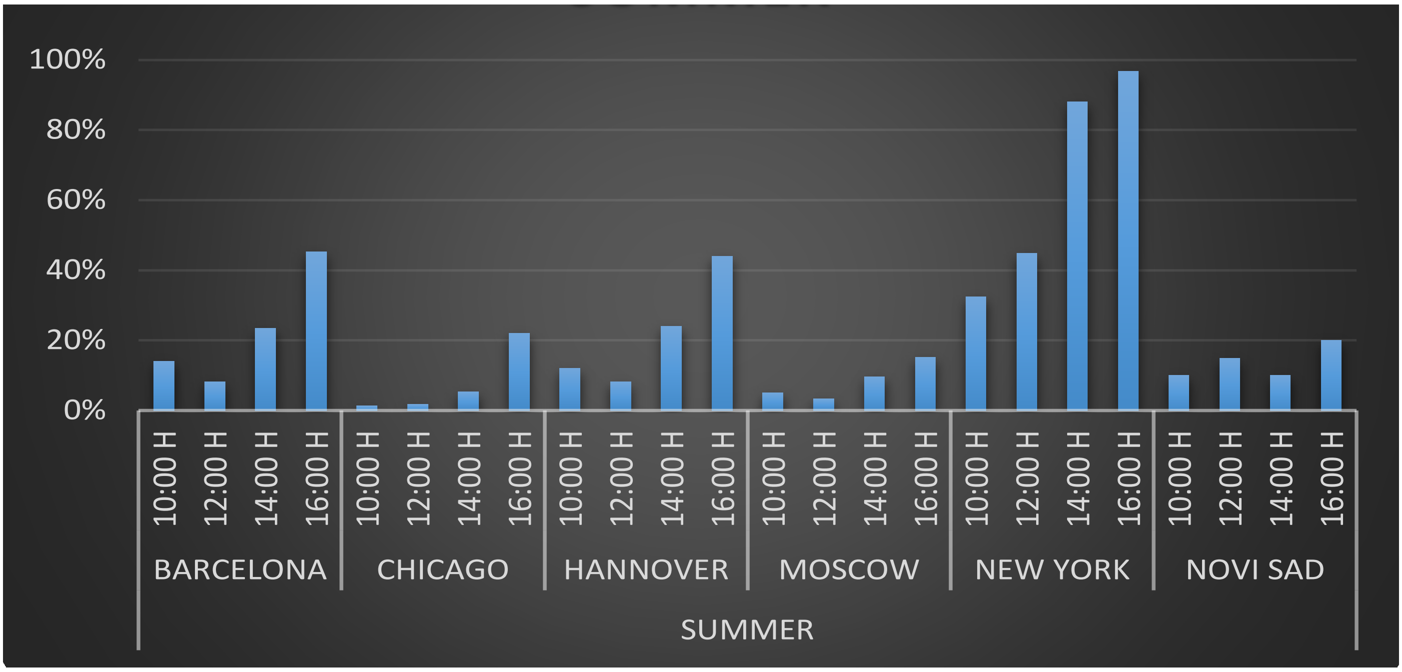
were analyzed at four different times of the day, 10:00 in the morning, 12:00 noon, 2:00 in the afternoon, and 4:00 in the afternoon. The results are displayed for three categories, streets, open spaces, and total, which includes both streets and open spaces but not buildings.

In the summer condition, the city with the highest percentage of shadows is by far New York. In New York, combining the four times of day, the average shadows in streets and open spaces during mid summer is about 50%. In Barcelona, average shadows in streets and open spaces during mid summer are about 20%. The other four samples average less than 20% shadows.

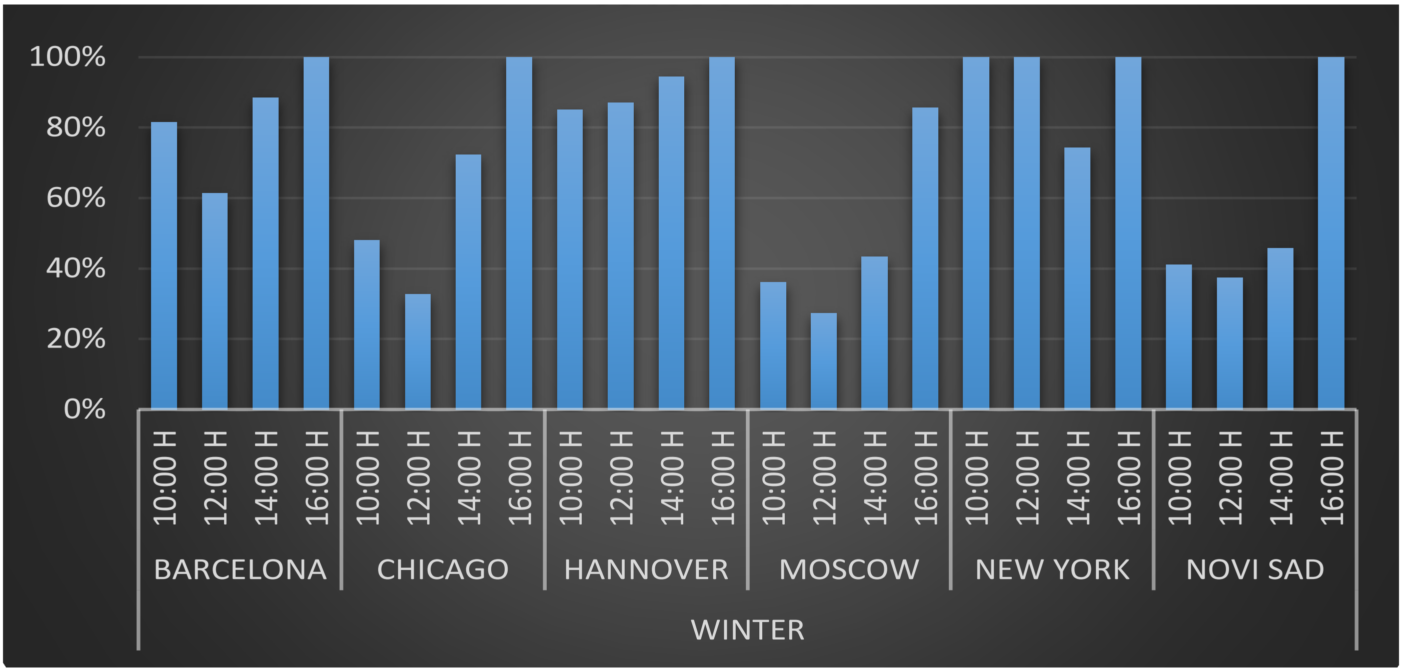
In the winter condition, the city with the

MORPHOLOGY AND ENVIRONMENTAL COMFORT
LOCAL CONTEXT: SHADOWS

SUMMER



WINTER



highest percentage of shadows is again New York. At 10:00, 12:00, and 4:00, the streets of New York are 100% in shadow. At 2:00 in the afternoon, the angle of the sun and the angle of the street grid allows some sun to reach the ground level. This produces a very negative environmental condition in the winter, when sunlight needs to be maximized. Hannover is also very dark in winter, with streets and open spaces more than 85% in shadow throughout the day. Moscow and Novi sad have the least amount of winter shadows. Low ground coverage could be an explanation for less shadows in Moscow, while the low building heights appear to improve the condition in Novi Sad. However, low density is not always effective. The chicago sample had the lowest overall density but the percentage of winter shadows in Chicago were more than in Moscow and Novi Sad.

GENERAL CONTEXT

WIND

In the general context, the case studies were not analyzed in a specific location, or in a specific season. By selecting a location, it is possible to determine which direction the wind comes from most often in each season, but summer and winter wind directions are different for every location. Therefore, if a specific location was selected for the general study, such as Boston, wind directions in summer and winter could be determined, but the results would only be applicable to that specific location. In order to make the results more generalized, the case studies were analyzed using the four primary wind directions, north-south, northwest-southeast, west-east, southwest-northeast.

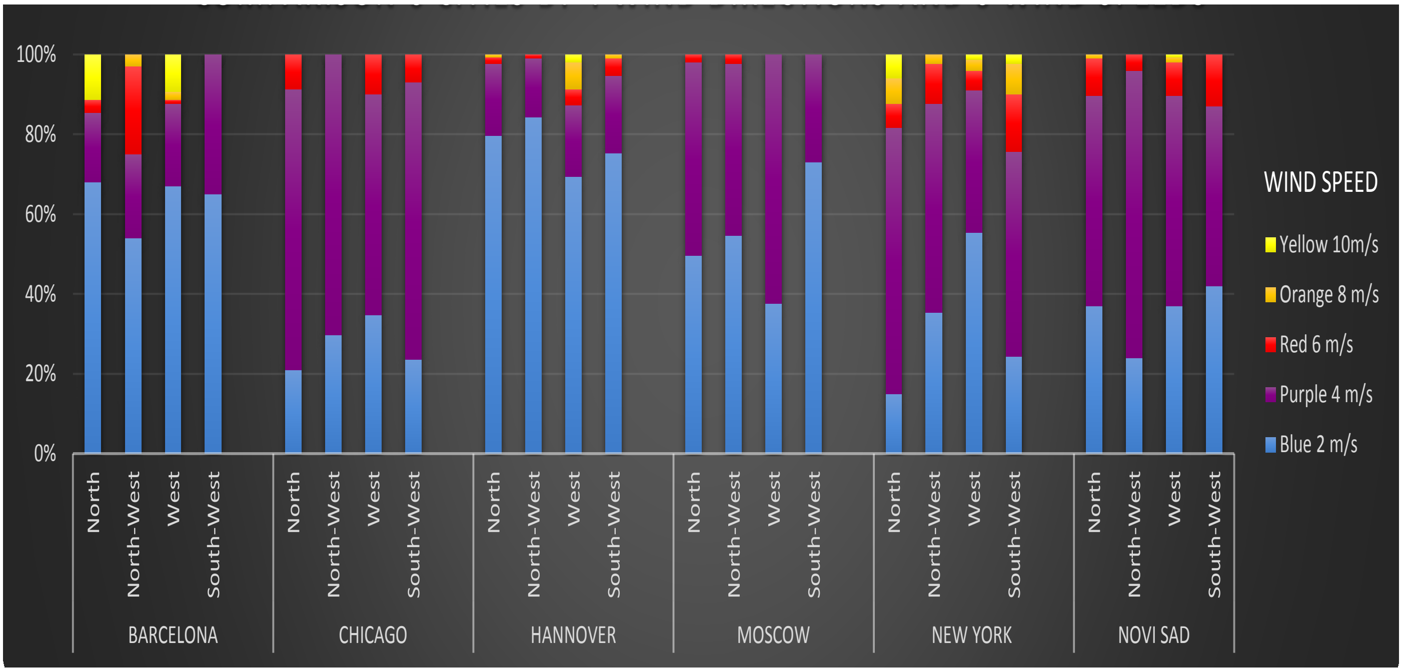
According to this analysis, Barcelona, Chicago, Hannover, and Novi Sad showed the least amount of variation. Wind speeds remained relatively stable despite the changing wind direction, with a variation of only 10-15% in most cases. The cities that showed the most amount of variation were Moscow and New York. In New York, ventiltion varied as much as 40%, with the highest ventilation occuring when the wind comes from the North, and the lowest ventilation occuring when the wind comes from the West.

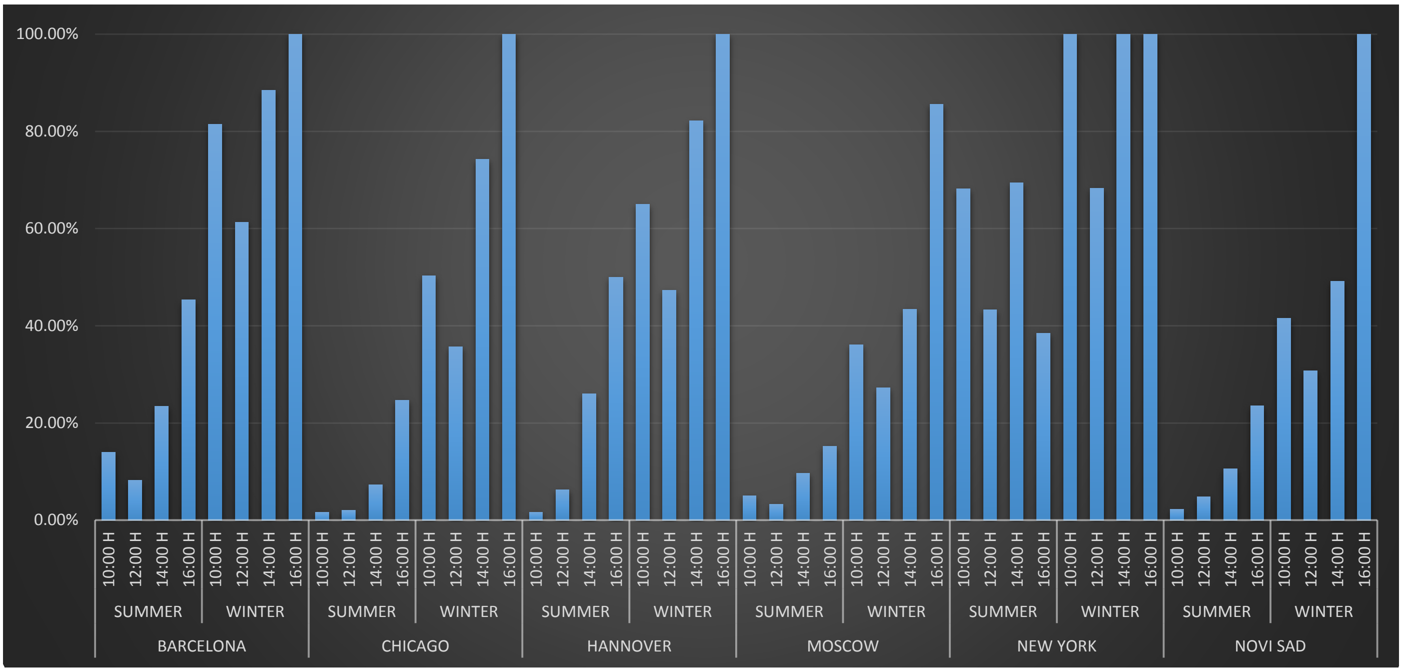
SHADOWS

In the general context, all the case studies were set in the same location, Boston MA. The reason for this was to remove variables related to location. In other words, all the case studies needed to be analyzed under the same solar conditions in order to directly compare the different morphologies. Boston was chosen because it is the default location in the Vasari program and its climate is similar to many of the case studies chosen.

The shadow results were relatively similar to the results in the local context. The largest variation occurred in the case of winter shadows in Hannover. In the local study, the average shadows in Hannover were approximately 90%. In the general shadow study, the average shadows decreased to 70%.

THE EFFECT OF MORPHOLOGY ON SOCIAL





AND ENVIRONMENTAL COMFORT

This section combines the three studies, social, wind and shadows and compares them in each case study. For this purpose, the six case studies are first analyzed separately and then some final conclusions are made.

NEW YORK

SOCIAL

The New York sample received the overall highest score for the social study. New York's best scores are achieved in the buildings category, where New York scores higher than all the other samples in three of the four parameters: building variety, mixed use, and building density. The fourth parameter, active building fronts, is highest in Barcelona, but

New York receives the second highest score. In the streets category, New York receives a 10 out of 10 for both visual permeability and walkability, which is also true in the Barcelona case. In New York, traffic flow and physical permeability receive average scores of 5 and 6 respectively. Three of the other case studies receive higher scores than New York on these two parameters. In the open spaces category, New York receives the highest score for comfort, 7 out of 10. In terms of public access, New York receives a 4 out of 10. However, Moscow is the only sample with a higher score for public access, which is 8 out of 10. In terms of size and number of open spaces, New York receives a 5 out of 10, which is the second lowest score. Therefore, the more negative factors in the New York sample were the open spaces, in particular the size and number of spaces and public access. Relatively high traffic flow was also an issue, and long blocks reduced physical permeability in part of the sample.

WIND

In the localized wind study, New york had the lowest ventilation in both the summer and winter cases. This gave New York the highest score for the winter case, when less ventilation is beneficial, and the lowest score in the summer case, when more ventilation is beneficial. The fact that natural ventilation in the New York sample is on the extreme low end of the scale, and the fact that there is little variation between summer and winter, makes it difficult for New York sample to meet the requirements for good environmental comfort in both summer and winter. A higher level of environmental comort could be reached if the sample was able to invite more wind in the summer while deflecting wind in the winter.

In the generalized wind study, where four different wind directions where studied, New York, along with Moscow, had the highest amount of variation in ventilation levels between the four wind directions. Wind from the North produced the highest level of ventilation, while wind from the West produced the lowest. This could be a result of wider streets in the North-South direction. The wider streets and tall buildings produce a canyon effect, while the smaller streets in the West to east direction are more effective at blocking wind penetration. These results indicate that with a different orientation, a sample like New York could produce more ventilation in summer and less in winter. However, a street canyon effect, where wind is funneled down broad avenues, is not necessarily a good ventilation condition. Wind velocities may become too high even in summer, causing unpleasant pedestrian conditions. Therefore, the context that the sample is placed in should be carefully considered.

SHADOWS

In the localized shadow study, New York had the highest shadow percentages of all the case studies in both summer and winter conditions. Although higher percentages of shadows may be beneficial in the summer season, the winter shadow condition in New York is problematic, since shadows cover 100% of the streets for most of the day. Because

New York winters are cold and snowy, this produces very unpleasant street conditions and also hinders the snow from melting.

In the generalized shadow study, where the New York sample was set in Boston and oriented according the street grid, the results were quite similar. The New York sample had the highest percentage of shadows in both the summer and winter conditions, and in winter, streets are shaded through most of the day, with the exception of 12:00 noon. The results of the two shadow studies indacate a problem of density in the New York Sample. As Jan Gehl notes, urban density should not be so high that the sun does not reach the streets, which appears to be the problem in this case.

BARCELONA

SOCIAL

The Barcelona sample, along with Novi Sad, received the second-highest overall score for the social study. Barcelona's best scores are achieved in the streets category, where Barcelona scored similar to New York. Like New York, Barcelona receives a 10 out of 10 for both visual permeability and walkability. Barcelona received the second lowest score for traffic flow, meaning the number of traffic lanes is relatively high. Physical permeability in Barcelona received a moderate score of 6.5. In The buildings category, Barcelona received the highest score for active fronts, and the second highest score for building density. Barcelona also tied with Novi Sad for the second highest score for mixed use. The weakest score for Barcelona was building variety, for which Barcelona, Hannover, and Moscow, all received the lowest score of 3 out of 10. In the open spaces category, Barcelona received the highest score for size and number. However, Barcelona received the lowest score for both comfort and pubic access. Barcelona received 0 out of 10 for public access because all of the spaces are semi-private courtyards. The lack of green elements, design quality, and seating in many of the open spaces resulted in the low comfort score. Overall Barcelona scored well in visual permeability, walkability, active fronts, mixed use, and size and number of open spaces. Weaker areas were high traffic flow, moderate physical permeability, low building variety, and lack of comfort and public access to open spaces.

WIND

In the localized wind study, Barcelona had moderate ventilation in both the summer and winter cases. In Barcelona there is little difference between the summer and winter ventilation conditions. However, because the ventilation level is moderate, it does not produce extremely bad conditions in either case.

In the generalized wind study, variation in ventilation levels based on the four wind directions was also relatively low. Wind coming from the North and West directions produced the highest wind velocities (8-10m/s). This was a result of the street canyon effect caused by the straight, wide streets in both the north-south, and east-west directions. The open spaces, however, are well protected and remain relatively unchanged. If the Barcelona sample was modified to have wider streets in only one direction, this could increase the change in ventilation from different wind directions, and therefore different seasons.

SHADOWS

In the localized shadow study, Barcelona and Hannover had the second-highest shadow percentages in summer, after New York. The summer shadows in Barcelona are at a comfortable level, averaging about 20% throughout the day. In winter the shadows in Barcelona are relatively high, with an average of about 80% throughout the day. However both New York and Hannover have a higher percentage of winter shadows.

In the generalized shadow study, the results were very similar in both summer and winter. The results of the two shadow studies indicate that Barcelona has a relatively good shadow condition in relation to density. The shadow percentage is comfortably high in summer; but in relation the density in Barcelona, the shadow percentages may be acceptable.

CHICAGO

SOCIAL

The Chicago sample received moderate scores in all three categories. In the streets category, Chicago received a 10 for visual permeability, while physical permeability received only a 4, the second lowest score among all the samples. Traffic flow received the third highest score, after Hannover and Novi Sad, because most streets in the Chicago sample are only two lanes. In terms of walkability, Chicago received the lowest score from all the samples.

In the streets category, Chicago received the second highest score for building variety, after New York. Active fronts received a moderate score of 5, the third lowest among the samples. Chicago, along with Hannover and Moscow received the lowest score of 3 for mixed use. And Chicago also received the lowest score for building density.

In the open spaces category, Chicago received moderately good scores the size and number of open spaces and comfort, but Chicago and Hannover tied for second-lowest score for public access, after Barcelona.

Overall, Chicago performed well in the areas of visual permeability and building variety; scores were moderately good for traffic flow, active fronts, comfort, and size and number of open spaces. The weakest areas were physical permeability, walkability, mixed use, building density, and access to open spaces.

WIND

In the local context, Chicago showed a high percentage of natural ventilation in the summer, and winter, however the wind velocity was not very high, only 4m/s. This produces relatively comfortable environmental conditions, since there is there is air movement but no strong winds in the winter. The ventilation is somewhat lower in the open spaces than in the streets because the yards are partially protected by the surrounding houses.

In the general condition, there is not a lot of variety between the four wind directions. With wind coming from the North and West directions some differences can be seen between the streets and built areas; a street canyon effect produces higher wind speed in the streets, but the situation is less severe than in New York and Barcelona.

SHADOWS

In the local context, the percentage of shadows is very low in Chicago in the summer condition. Between the hours of 10:00 and 16:00, an average of about 5% of the streets are in shadow, which is the lowest of all the samples. In the winter condition, an average of about 65% of the streets are in shadow between the hours of 10:00 and 16:00, which is higher than the winter shadow percentages for both Moscow and Novi Sad. In the general context, the conditions are very similar. Overall, Chicago does not perform as well as expected in the shadow studies, considering it is the sample with the lowest density. Chicago has the lowest shadow pecentages in summer, but in winter, when less shadows are beneficial, Chicago shows higher shadow percentages than the Moscow and Novi Sad samples, which have higher density.

HANNOVER

SOCIAL

The Hannover sample performed best in the streets category. Hannover tied with Novi Sad for the highest score for traffic flow, and the second highest score for walkability. After Novi Sad, Hannover received the second highest score for physical permeability. On the other hand, Hannover received the second lowest score for visual permeability, because of the deformed grid structure.

In the buildings category, Hannover did not perform as well. A moderately good score was given for building density, while low scores were given for active fronts, building variety, and mixed use.

In the open spaces category, Hannover received the second highest score for size and number of open spaces. A moderately good score was given for comfort in open spaces, but Hannover tied with Chicago for the second lowest score for public access.

Overall Hannover performed well in the areas of physical permeability, traffic flow, walkability, and received moderately good scores for building density, comfort, and size and number of open spaces. Low scores were received in the areas of visual permeability, active front, building variety, mixed use, and access to open spaces.

WIND

In the local context, ventilation is slightly higher in the summer condition, where winds reach speeds of 6m/s, than in the winter condition, where speeds only reach 4m/s. However, the areas with higher wind speeds are mostly located in the large open spaces and represent a very small portion of the entire sample, only about 5%. For the most part, ventilation is low in Hannover, both in the summer and winter. The tight blocks and small streets block most of the wind.

In the general context, there is not a lot of variation between the four wind directions. Ventilation is generally higher in the interior open spaces than in the streets, with the exception of the central area where the two unenclosed open spaces and the street between them are characterized by higher wind speeds.

SHADOWS

In the local context, shadow percentages average about 20% in the summer between

the hours of 10:00 and 16:00. In the winter, shadows average about 90%. The winter situation, like in New York, is problematic. Despite the much lower density in Hannover compared to New York, the shadow percentages are still very high.

In the general context, the situation is a bit different. The summer shadows still average about 20%, but the winter shadows average only 70% rather than 90%. In the general study, the Hannover sample is placed in the Boston location, rather than in the Hannover location, therefore the difference appears to be a result of different solar conditions in the two locations.

NOVI SAD

SOCIAL

The Novi Sad sample performed relatively well in all three categories. In the streets category, Novi Sad received the highest score for physical permeability, due to the small block size, and the lowest score for visual permeability, due to the highly irregular grid pattern. Novi Sad tied with Hannover for the highest score for traffic flow, and the second highest score for walkability.

In the buildings section, Novi Sad tied with Barcelona for the second-highest score for mixed use, and also received moderately good scores for active fronts, building variety, and building density.

In the open spaces category, Novi Sad received moderately good scores for size and number, and comfort, while public access received a relatively low score.

Overall, Novi Sad performed well in the areas of physical permeability, traffic flow, walkability and mixed use. Moderately good scores were achieved in the areas of active fronts, building variety, building density, comfort, and size and number of open spaces. The only weak areas were visual permeability and public access to open spaces.

WIND

In the local context, ventilation is very low in Novi Sad, in both the summer and the winter. Remaining around 2m/s in both of the street directions and in the open spaces. In the general context, ventilation is also low, with little variation between the four wind directions. The dense urban fabric of Novi Sad and the small winding streets block most of the wind. Ventilation could be increased by laying straight streets in the direction of summer winds, but this would partially destroy the historic fabric of the city.

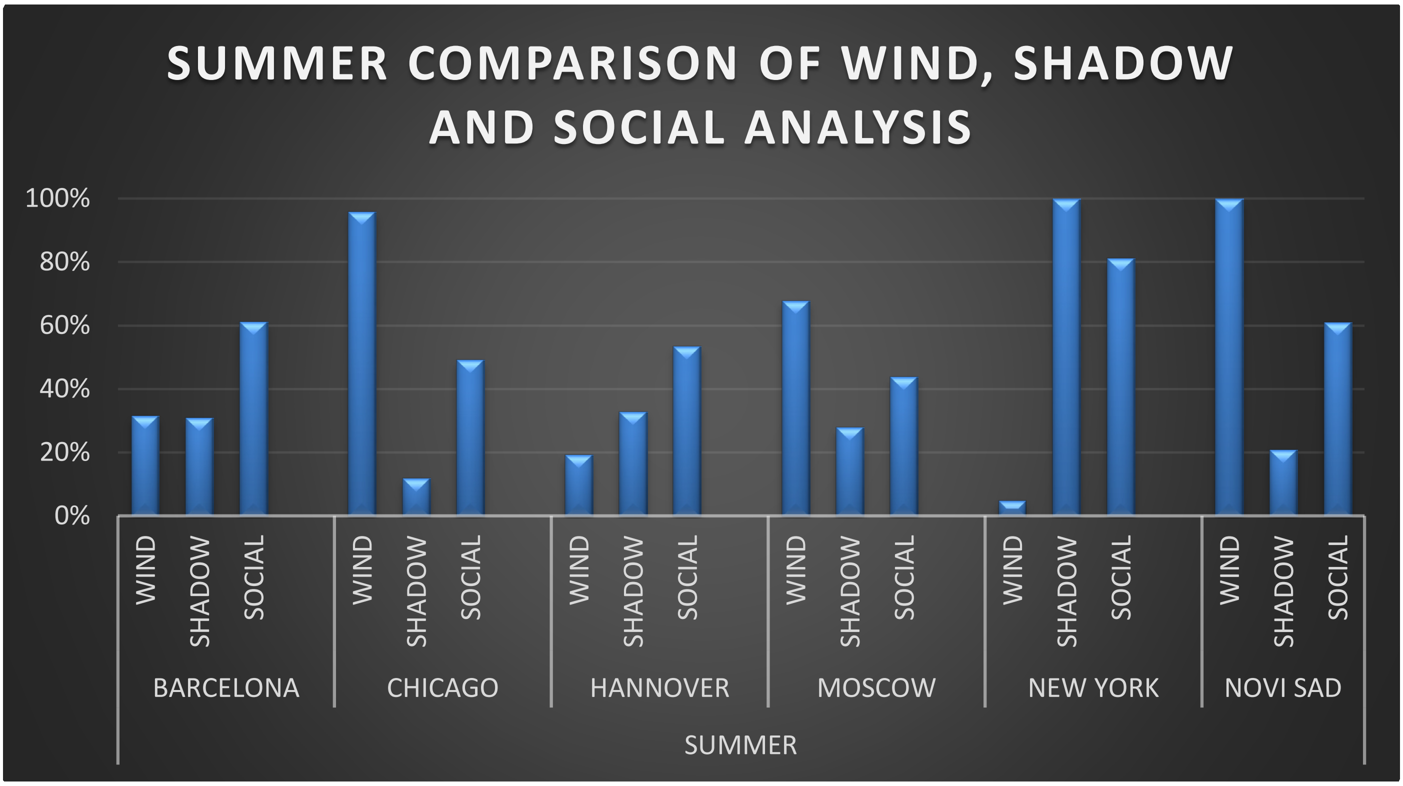
SHADOWS

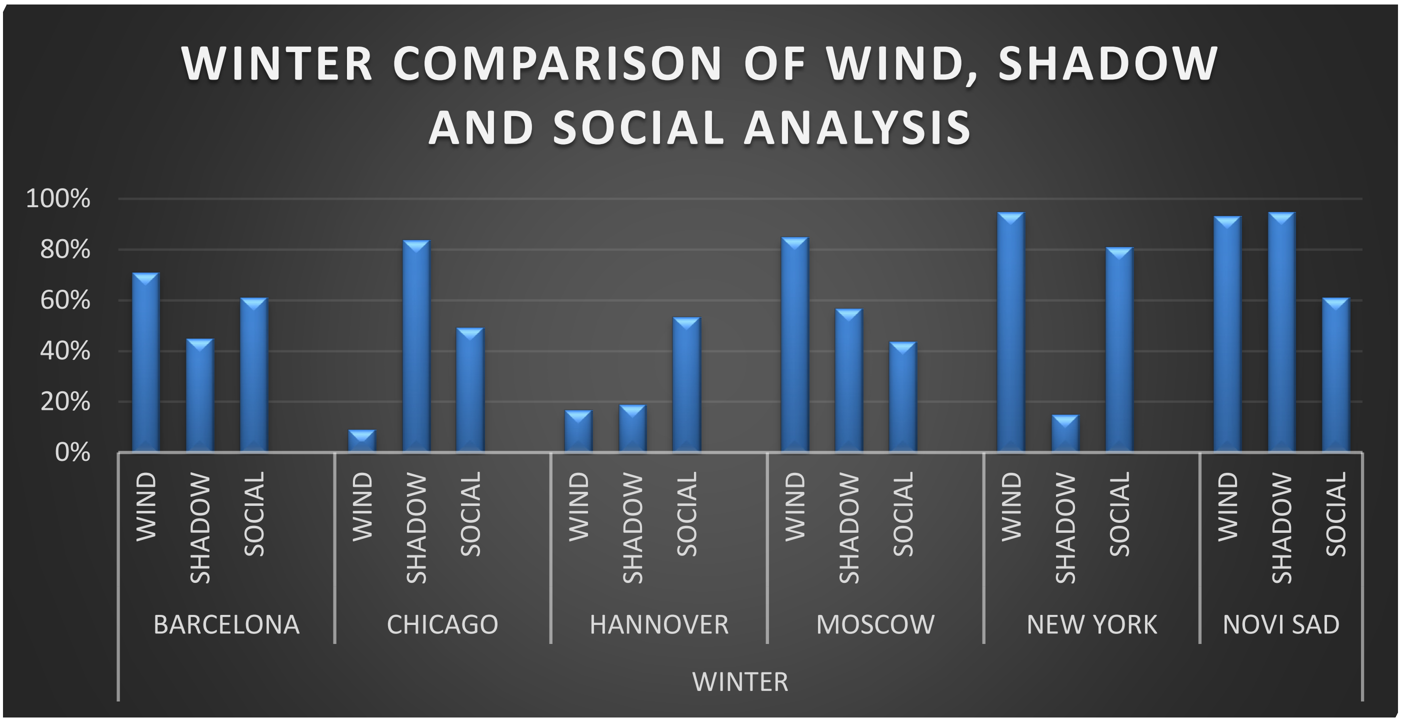
In the local context, shadows in Novi Sad average less than 20% in the summer, which is low, but winter shadows are around 50%, lower than all of the other samples except Moscow. The low building heights in Novi Sad allow sun to reach the streets throughout the day, which is very beneficial in winter. In the general context, the results are similar.

MOSCOW

Social

The Moscow case received the lowest overall score for the social study. In the


SUMMER COMPARISON OF WIND, SHADOW AND SOCIAL ANALYSIS
100%
80%
60%
40%
20%
0%
WIND
SHADOW
SOCIAL
BARCELONA
CHICAGO
HANNOVER
MOSCOW
NEW YORK
NOVI SAD
SUMMER


WINTER COMPARISON OF WIND, SHADOW AND SOCIAL ANALYSIS
100%
80%
60%
40%
20%
0%
WIND
SHADOW
SOCIAL
BARCELONA
CHICAGO
HANNOVER
MOSCOW
NEW YORK
NOVI SAD
WINTER

streets category, Moscow received a moderately good score for visual permeability, due to the semi-regular grid type. However, Moscow received the second lowest score for walkability, and the lowest scores for physical permeability and traffic flow.

In the buildings category, Moscow received the second lowest score for building density, tied for the lowest score in building variety and mixed use, and received the lowest score for active fronts.

In the open spaces category, Moscow performed the best, receiving the highest score among all the samples for public access, and the second highest score for comfort, but the lowest score for size and number.

Overall, Moscow performed well in the areas of comfort and public access to open spaces, and received a moderately good score for visual permeability. However the Moscow samples performed poorly in all the other the areas including, walkability, physical permeability, traffic flow, building density, building variety, mixed use, active fronts, and size and number of open spaces.

Wind

In the local wind study, Moscow performs the best among all the samples. Ventilation in the summer is higher, at about 50%, and lower in the winter, around 10%. In the summer condition, ventilation is higher in the North-south streets and lower in the east-west streets and open spaces, which are more protected. The results demonstrate a good fit between the Moscow sample in its local context, because the wider streets are oriented towards the summer winds.

In the general context, Moscow, along with New York, are the samples with the most variation between the four wind directions. Wind coming from the North produces the highest ventilation, followed by wind from the West, while wind coming from the northwest and southwest produce the lowest ventilation. Wind from the North produces a street canyon effect, and also from the west, to a lesser degree. Winds from the northwest and southwest hit the sample at an angle and are mostly deflected.

Shadows

In the local context, shadows in Moscow are low in the summer, less than 20%, and in the winter, about 45%. The low ground coverage reduces the shadow coverage, which is beneficial considering the Moscow climate. The results are similar in the general context.

CONCLUSIONS

Considering all three categories, the samples that performed the best were Novi Sad, New York. The samples that performed the worst were Moscow and Chicago. Novi Sad may be the overall strongest case; although Novi Sad did not score the highest in the social study, it received the lowest number of negative scores. Novi Sad also performed well in the shadow study, with one of the lowest shadow percentages in winter. In the wind study, Novi Sad had very little ventilation because of the tight blocks and winding streets, so the largest negative for Novi Sad is the lack of ventialation in the summer.

The qualities that helped Novi Sad score well were mixed use, high ground coverage, and small blocks. The benefit came from having enough density and mixed use on the ground floor to maintain social activities, without the buildings becoming too tall. But this type of morphology is typical of a small city center, which must be surrounded by more residential areas in order to have enough people to support the density of activities in the center. It is surely possible that small city centers represent the best morphologies in terms of social and environmental sustainability, but facing growing urbanization and megacities, we may need other solutions as well.

The New York sample received the overall highest score for social comfort, however, in the winter shadow study, New York performed the worst. Similar to Novi Sad, New York also lacked adequate summer ventilation, but according to the generalized wind study, the New York sample could perform better in a different context.

The main issue in New York resulted from too much density. Other negatives included long blocks, high traffic flow and lack of open spaces. However, it should be noted that the sample was taken from midtown Manhattan near Times Square, which is one of the densest areas of New York.

In conclusion, there may be some tradeoffs between environmental and social comfort, but this is true even within the area of environmental comfort, where there are conflicts between the requirements for summer and winter conditions. In general, social and environmental comfort are complimentary, in that higher environmental comfort increases social activity and enjoyability in public spaces, therefore increasing social comfort.

Second, it will not be possible to define an image of the perfect city. The requirements for social and environmental comfort necessarily change from one location to another, not only because of changing environmental conditions, but also changing demographic conditions, and varying existing morphological contexts. We do not need an image of the perfect city, we need diverse cities, both large cities and small ones. The fact that both Novi Sad and New York showed promising results demonstrates that good urban form can come in a variety of shapes and sizes.

The most important effort may involve defining a methodology and criteria for studying social and environmental comfort. In order to produce a diversity of good urban forms, it is not necessary to define a formula; instead, decision makers need an easy-to-use toolbox of references to draw from. It is necessary to keep in mind that there will always be tradeoffs between social comfort, environmental comfort, and other desirable goals. Therefore, local decision makers need to have the tools to analyze the local condition, in terms of wind, solar, and social factors, and make good decisions accordingly. This paper has defined some tools for studying social and environmental comfort, which could be expanded and improved upon.

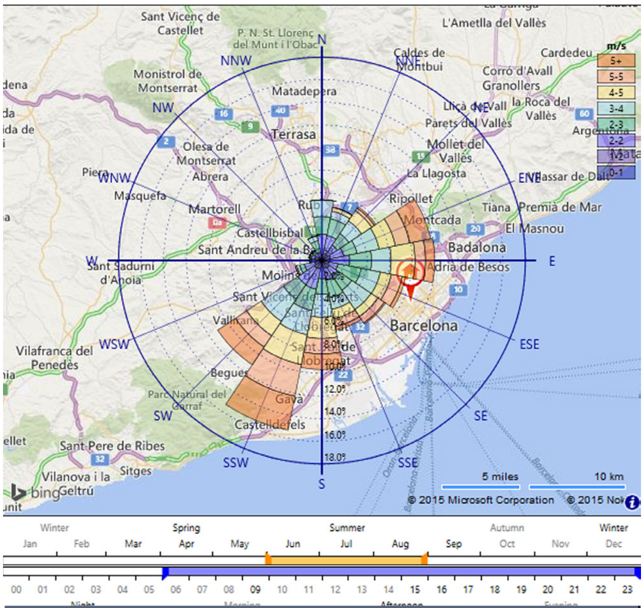
Some factors should be considered in terms of the results. First, the Vasari program, used for the wind and shadow analyses, is experimental and has not been fully validated, therefore the results should also be considered experimental. Second, the models used for the analyses are generalized representations of the actual urban forms; therefore the results do not the exact environmental conditions in those locations. In the social comfort section, it should be noted that none of the authors selected are strong supporters of moderinst urban forms. Social comfort is a somewhat subjective analysis; therefore a different selection of authors would have resulted in different criteria and results. Furthermore, some of the criteria used, such as traffic flow, were only based on one indicator (number of lanes), which decreases the reliability of the results.

Further work in this area could involve more case studies, in order to study more variations of urban forms. Only one of the case studies chosen, New York, had high-rise buildings, so more results are needed in this category. Further reseach could also include a more detailed social analysis, involving more criteria and more indicators. More weight could also be given to studying diverse cultures and climates in relation to urban form; in this study, diverse cultural considerations were not emphasized. In terms of environemental comfort, a solar radiation analysis could be conducted, in addition to the shadow study; other factors in environmental comfort such as presense of water, vegetation, albedo effect, etc. could also be considered.

APPENDIX

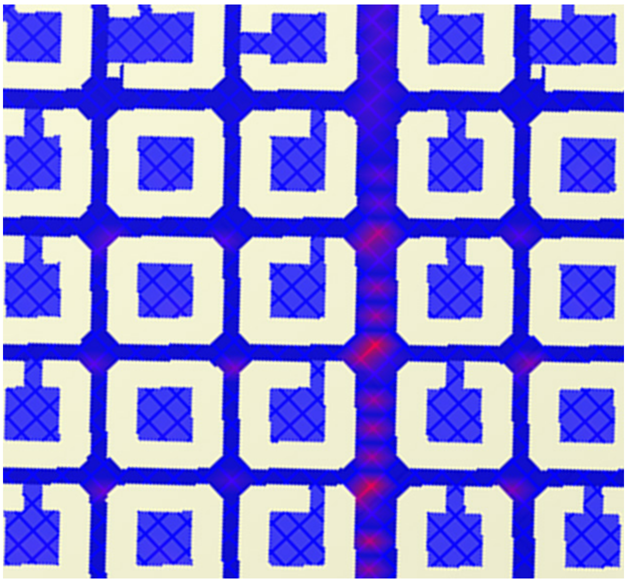
LOCAL CONTEXT / WIND STUDY / SUMMER

BARCELONA WIND ROSE



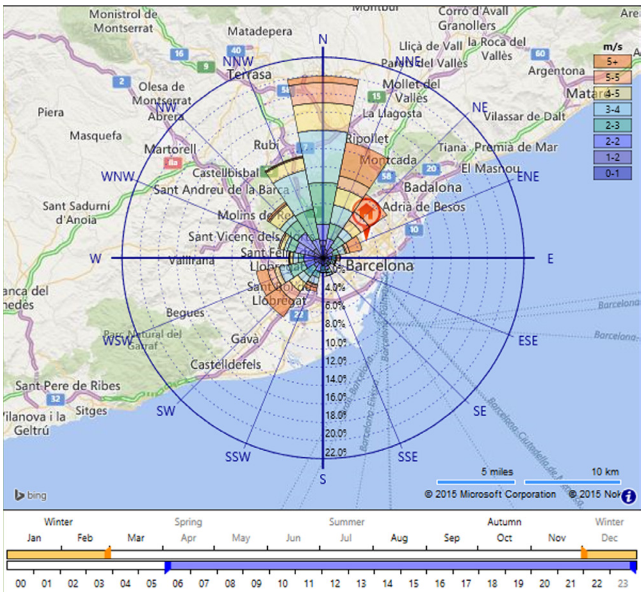
INPUTS	
Location	Barcelona, Spain
Time of Year	June - August
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	South South West
Wind Speed	8+ m/s

BARCELONA WIND TUNNEL

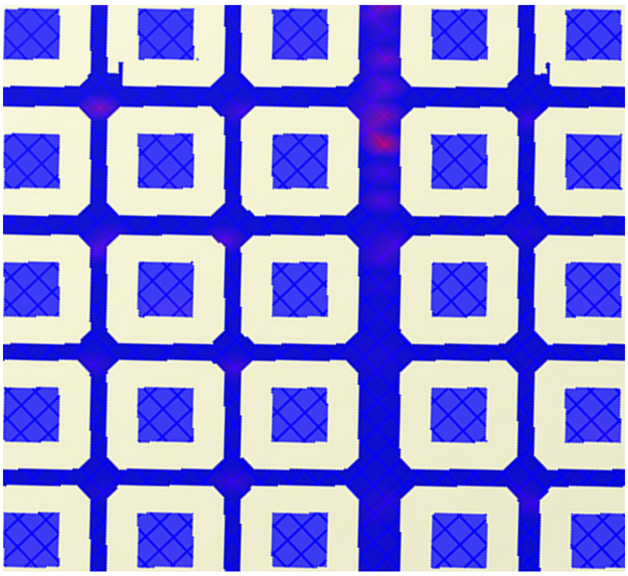


INPUTS		
Wind Direction	South South West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

LOCAL CONTEXT / WIND STUDY / WINTER



INPUTS	
Location	Barcelona, Spain
Time of Year	December - February
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	North
Wind Speed	8+ m/s



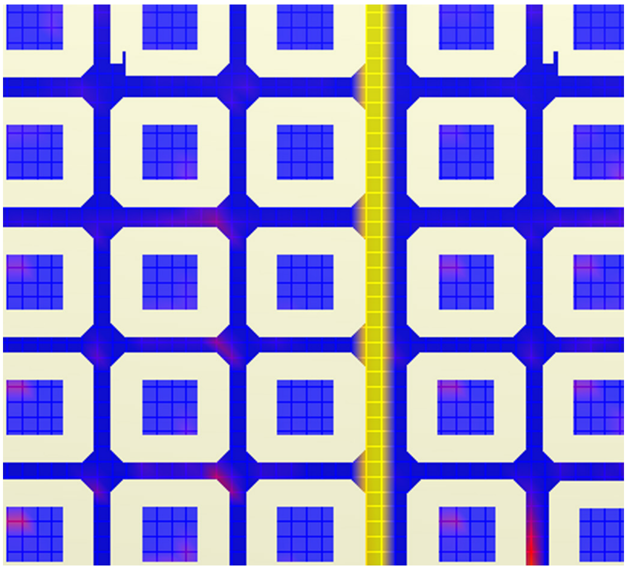
INPUTS		
Wind Direction	North	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

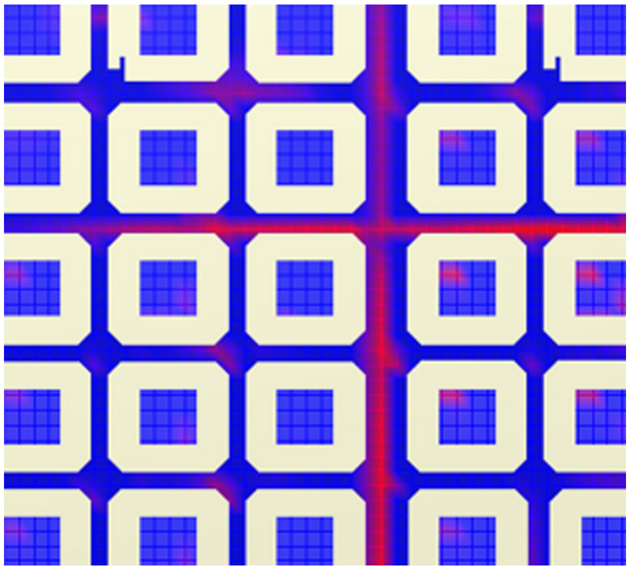
BARCELONA WIND TUNNEL OUTPUTS

SUMMER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	123	9	18	0	0	150
	Color Percentages	82%	6%	12%	0%	0%	100%
East-West Streets							
	Color Ratios	65	9	18	0	0	92
	Color Percentages	71%	10%	19%	0%	0%	100%
Open Spaces							
	Color Ratios	115	28	0	0	0	143
	Color Percentages	80%	20%	0%	0%	0%	100%
TOTAL %		77.66%	12%	10.33%	0%	0%	100%

WINTER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	127	11	12	0	0	150
	Color Percentages	85%	7%	8%	0%	0%	100%
East-West Streets							
	Color Ratios	69	11	12	0	0	92
	Color Percentages	75%	12%	13%	0%	0%	100%
Open Spaces							
	Color Ratios	104	32	7	0	0	143
	Color Percentages	73%	22%	5%	0%	0%	100%
TOTAL %		77.66%	13.66%	8.66%	0%	0%	100%

GENERAL CONTEXT / WIND STUDY / SUMMER

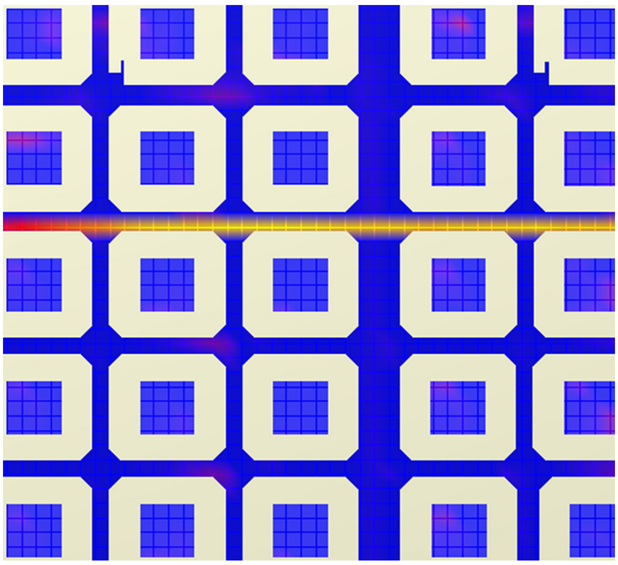


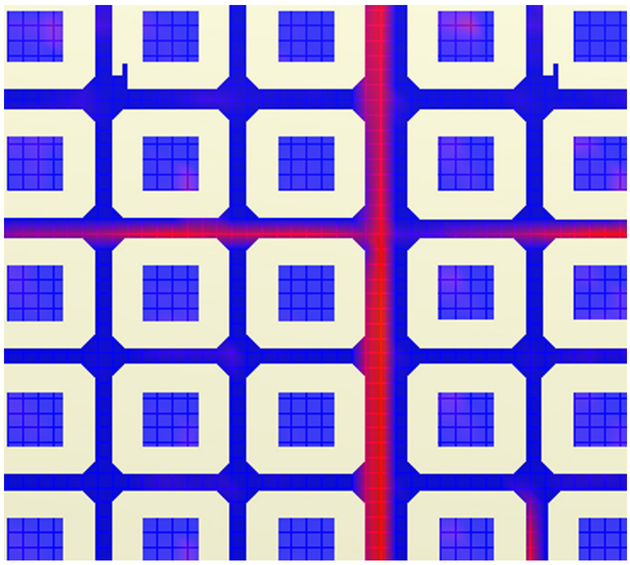


INPUTS		
Wind Direction	North	10 m/s – 0 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	

INPUTS		
Wind Direction	Northwest	10 m/s – 0 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	

GENERAL CONTEXT / WIND STUDY / WINTER





INPUTS		
Wind Direction	West	10 m/s – 0 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	

INPUTS		
Wind Direction	Southwest	10 m/s – 0 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	

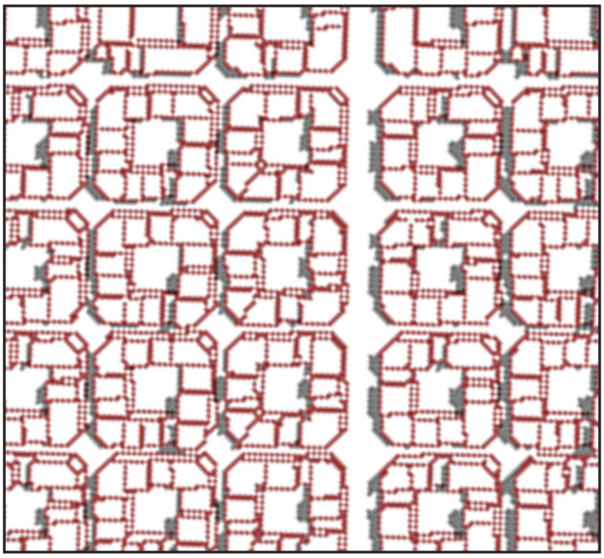
NORTH		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	84	8	8	0	50	150
	Color Percentages	56%	5%	5%	0%	34%	100%
East-West Streets							
	Color Ratios	138	4	8	0	0	92
	Color Percentages	92%	3%	5%	0%	0%	100%
Open Spaces							
	Color Ratios	188	149	0	0	0	337
	Color Percentages	56%	44%	0%	0%	0%	100%
TOTAL %		68%	17.33%	3.33%	0%	11.33%	100%

NORTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	90	10	50	0	0	150
	Color Percentages	60%	7%	33%	0%	0%	100%
East-West Streets							
	Color Ratios	48	10	26	8	0	92
	Color Percentages	52%	11%	28%	9%	0%	100%
Open Spaces							
	Color Ratios	170	151	16	0	0	337
	Color Percentages	50%	45%	5%	0%	0%	100%
TOTAL %		54%	21%	22%	0%	0%	100%

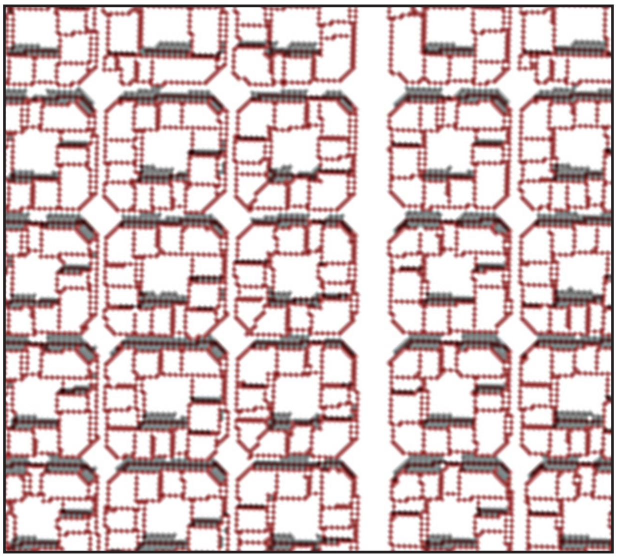
WEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	126	12	0	3	9	150
	Color Percentages	84%	8%	0%	2%	6%	100%
East-West Streets							
	Color Ratios	54	12	2	4	20	92
	Color Percentages	59%	13%	2%	4%	22%	100%
Open Spaces							
	Color Ratios	195	138	4	0	0	337
	Color Percentages	58%	41%	1%	0%	0%	100%
TOTAL %		67%	20.66%	1%	2%	9.33%	100%

SOUTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	127	11	12	0	0	150
	Color Percentages	85%	7%	8%	0%	0%	100%
East-West Streets							
	Color Ratios	69	11	12	0	0	92
	Color Percentages	75%	12%	13%	0%	0%	100%
Open Spaces							
	Color Ratios	104	32	7	0	0	143
	Color Percentages	73%	22%	5%	0%	0%	100%
TOTAL %		77.66%	13.66%	8.66%	0%	0%	100%

LOCAL CONTEXT / SHADOW STUDY / SUMMER

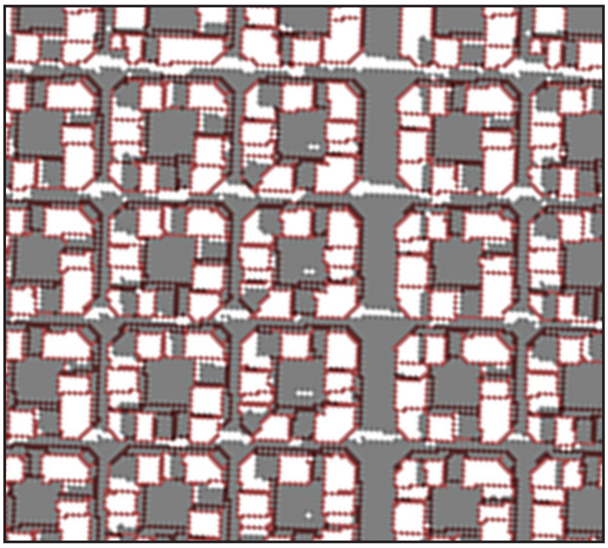


Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	7.4%
Open Spaces	14.2%
Total	11.8%

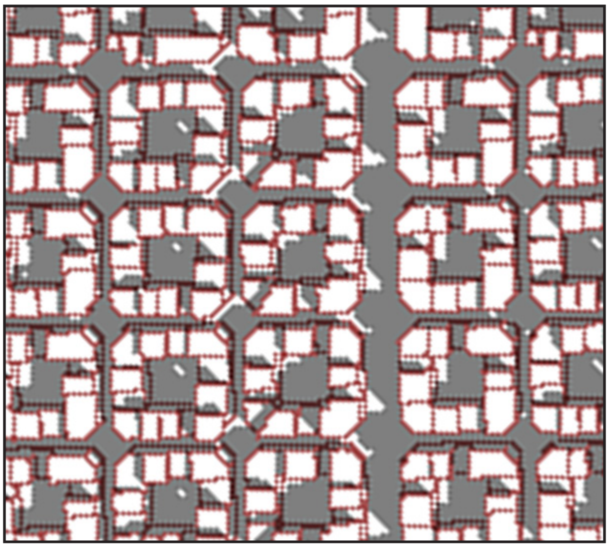


Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	9.5%
Open Spaces	22.4%
Total	15.1%

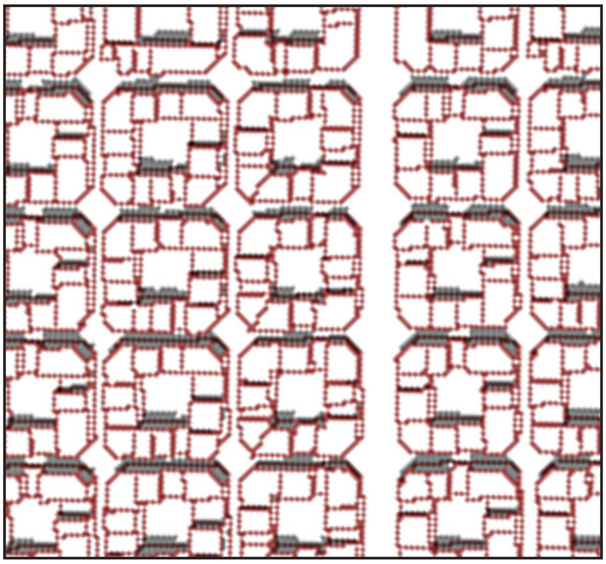
LOCAL CONTEXT / SHADOW STUDY / WINTER



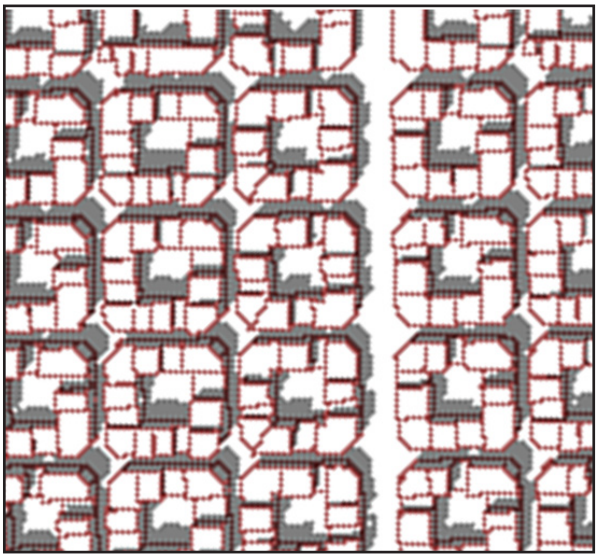
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	75.9%
Open Spaces	94.5%
Total	82.8%



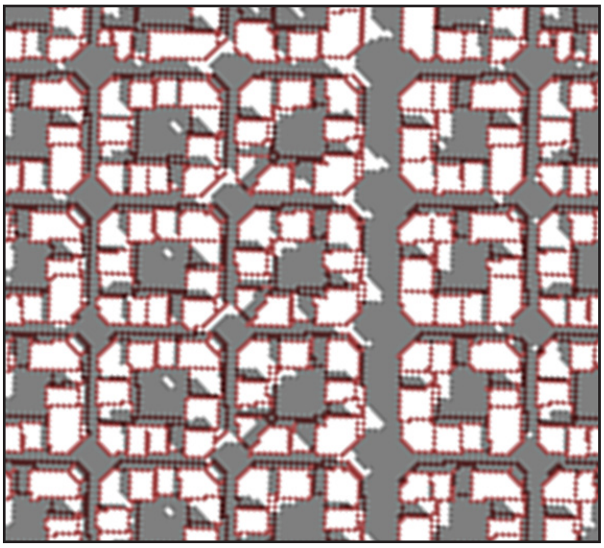
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	81.7%
Open Spaces	98.2%
Total	84.9%



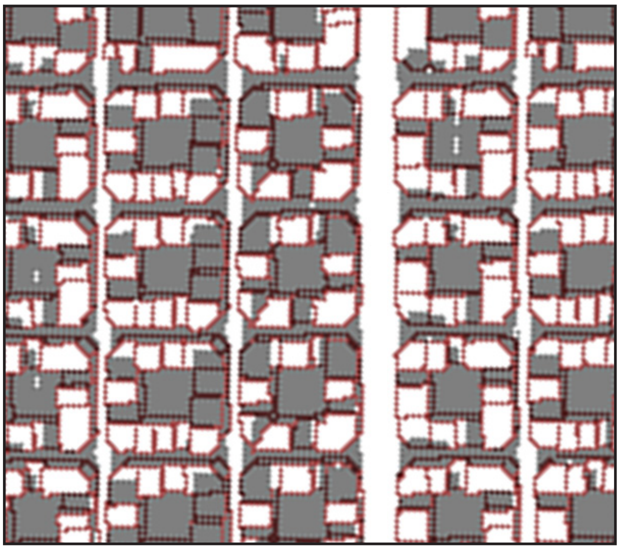
Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	6.7%
Open Spaces	14.8%
Total	10.8%



Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	39.5%
Open Spaces	56.7%
Total	44.1%

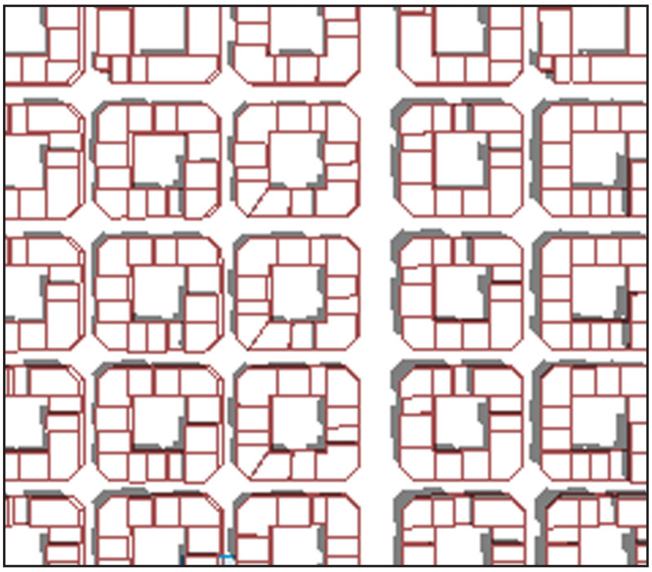


Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	78.3%
Open Spaces	96.2%
Total	82.0%

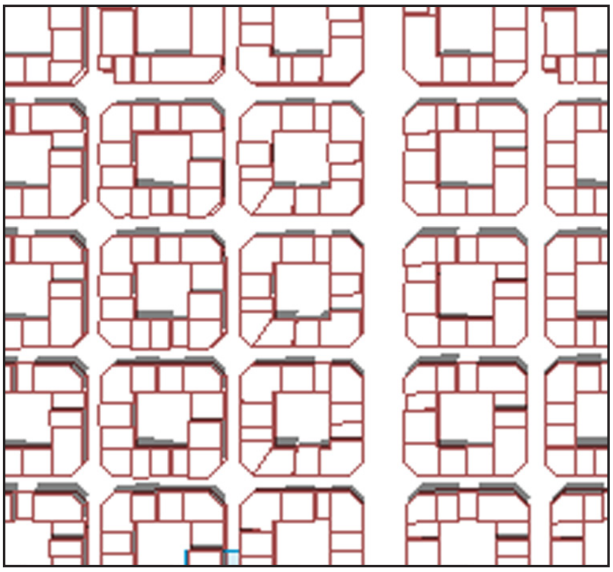


Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	45.3%
Open Spaces	93.6%
Total	66.7%

GENERAL CONTEXT / SHADOW STUDY / SUMMER

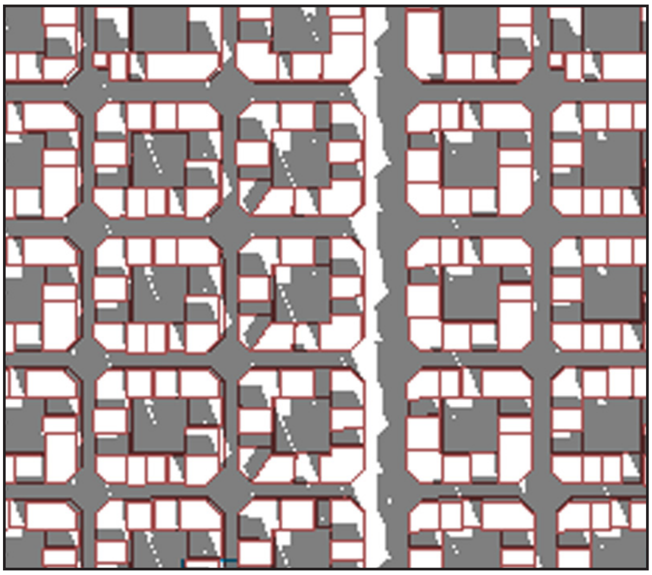


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	11.7%
Open Spaces	17.6%
Total	14.0%

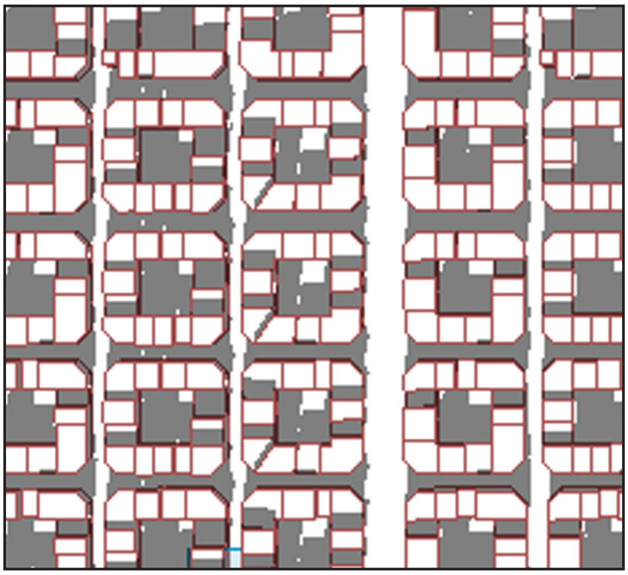


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	7.3%
Open Spaces	9.6%
Total	8.2%

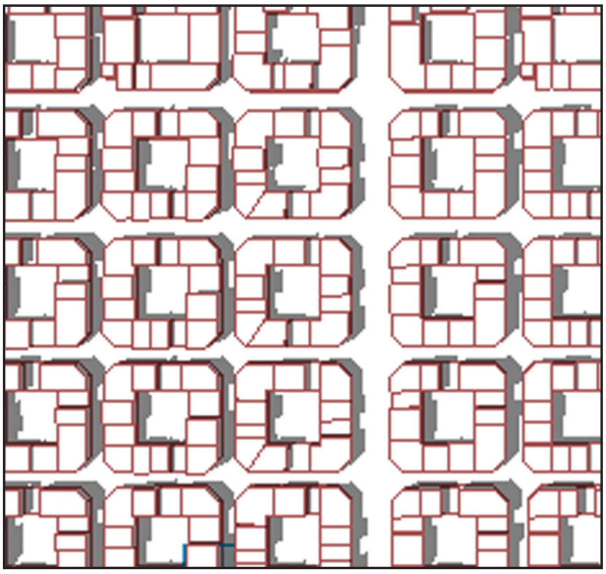
GENERAL CONTEXT / SHADOW STUDY / WINTER



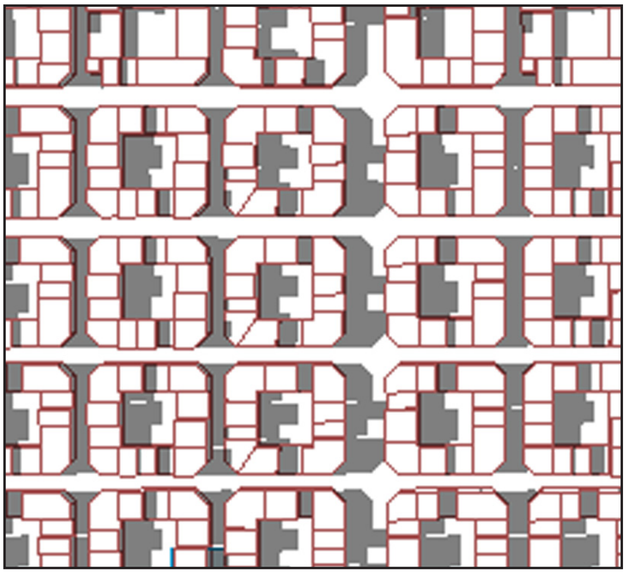
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	74.4%
Open Spaces	90.3%
Total	81.5%



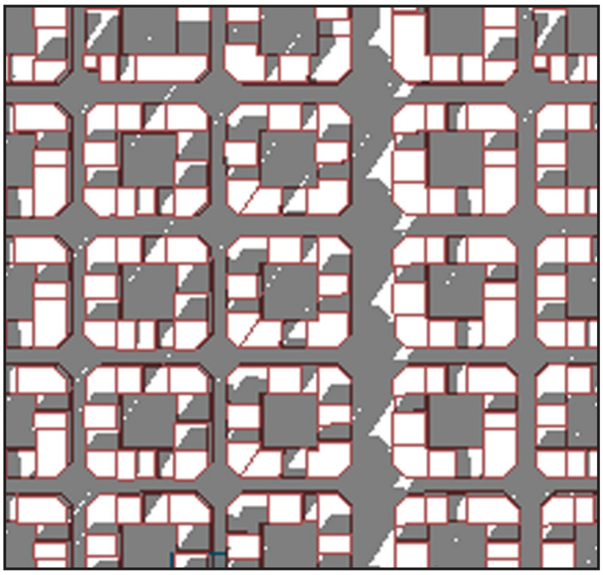
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	48.7%
Open Spaces	82.6%
Total	61.3%



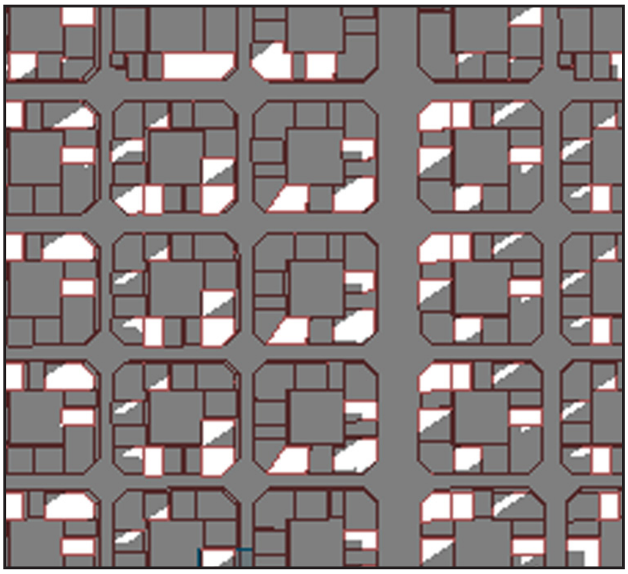
Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	21.0%
Open Spaces	27.6%
Total	23.5%



Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	42.1%
Open Spaces	53.7%
Total	45.3%



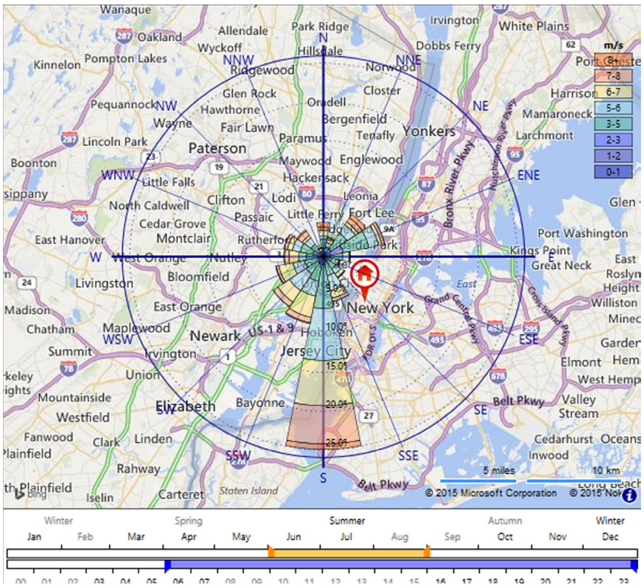
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	79.2%
Open Spaces	96.4%
Total	88.5%



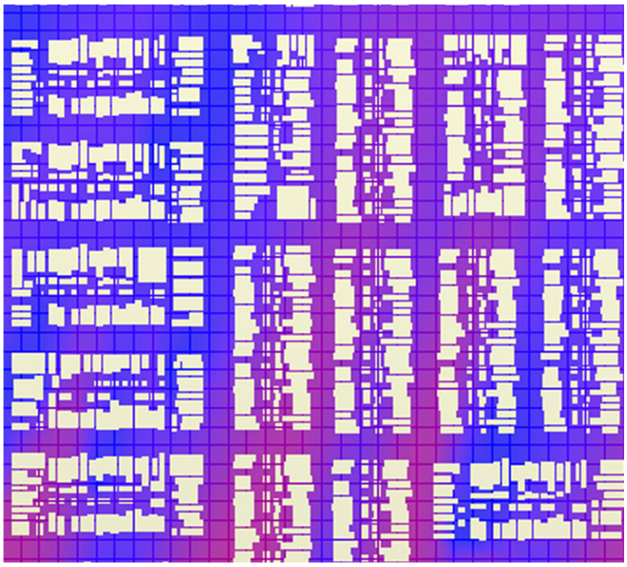
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

LOCAL CONTEXT / WIND STUDY / SUMMER

WIND ROSE



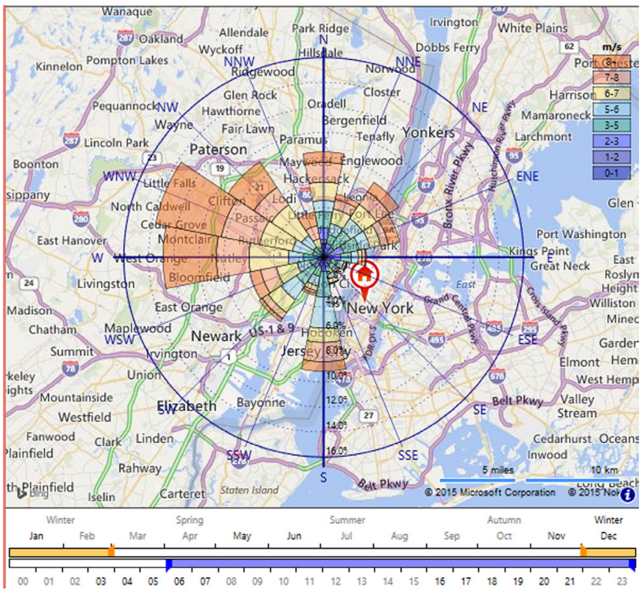
WIND TUNNEL

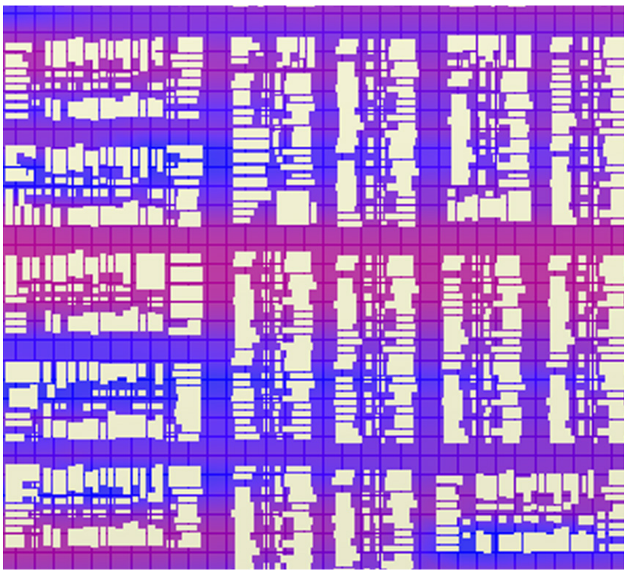


INPUTS	
Location	Chicago, IL
Time of Year	June - August
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	South- Southwest
Wind Speed	8+ m/s

INPUTS		
Wind Direction	South- Southwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

LOCAL CONTEXT / WIND STUDY / WINTER





INPUTS	
Location	Chicago, IL
Time of Year	December - February
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	West
Wind Speed	8+ m/s

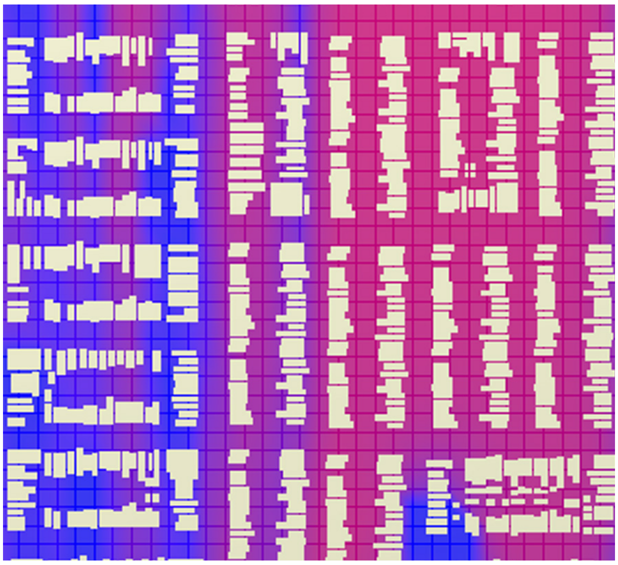
INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

WIND TUNNEL OUTPUTS

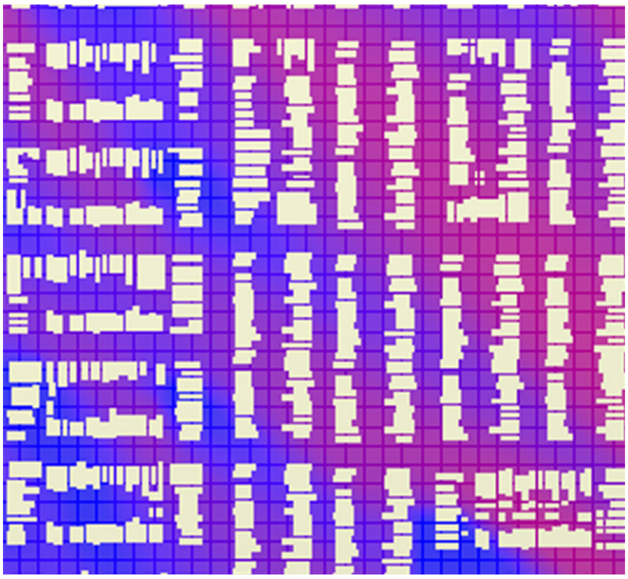
SUMMER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	25	83	0	0	0	108
	Color Percentages	23%	77%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	46	114	0	0	0	160
	Color Percentages	29%	71%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	36	48	0	0	0	84
	Color Percentages	43%	57%	0%	0%	0%	100%
TOTAL%		31.66%	68.33%	0%	0%	0%	100%

WINTER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	30	78	0	0	0	108
	Color Percentages	28%	72%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	28	132	0	0	0	160
	Color Percentages	18%	83%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	36	48	0	0	0	84
	Color Percentages	43%	57%	0%	0%	0%	100%
TOTAL %		29.66%	70.66%	0%	0%	0%	100%

GENERAL CONTEXT / WIND STUDY / SUMMER

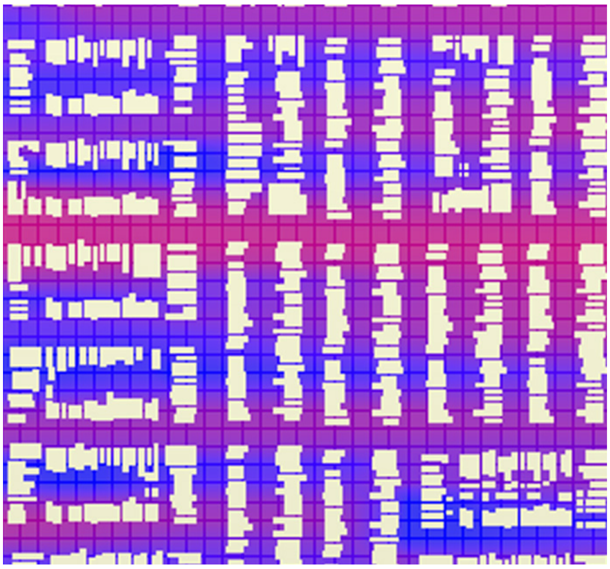


INPUTS		
Wind Direction	North	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

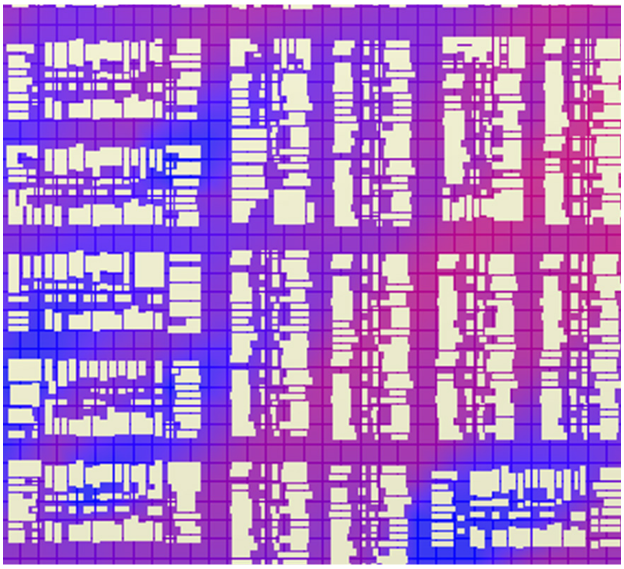


INPUTS		
Wind Direction	Northwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

GENERAL CONTEXT / WIND STUDY / WINTER



INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s



INPUTS		
Wind Direction	Southwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

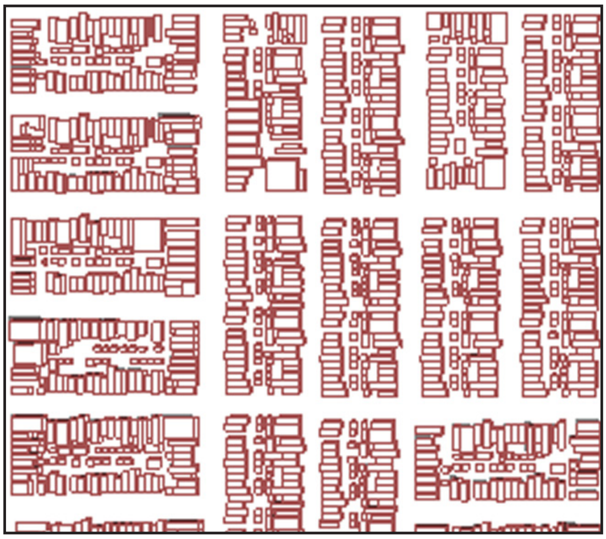
NORTH		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	50	144	0	0	0	199
	Color Percentages	22%	78%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	0	105	30	0	0	135
	Color Percentages	0%	78%	22%	0%	0%	100%
Open Spaces							
	Color Ratios	32	43	3	0	0	78
	Color Percentages	41%	55%	4%	0%	0%	100%
TOTAL %		**21%**	**70.33%**	**8.66%**	**0%**	**0%**	**100%**

NORTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	51	148	0	0	0	199
	Color Percentages	26%	74%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	40	95	0	0	0	135
	Color Percentages	30%	70%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	26	52	0	0	0	78
	Color Percentages	33%	67%	0%	0%	0%	100%
TOTAL%		**29.66%**	**70.33%**	**0%**	**0%**	**0%**	**100%**

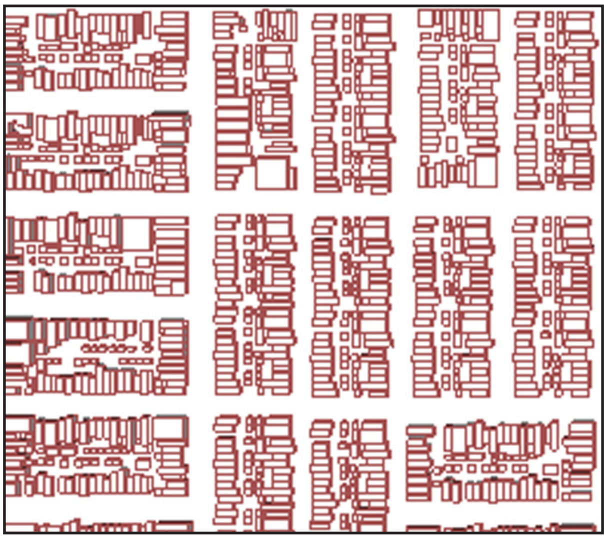
WEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	84	100	15	0	0	199
	Color Percentages	42%	50%	8%	0%	0%	100%
East-West Streets							
	Color Ratios	0	105	30	0	0	135
	Color Percentages	0%	78%	22%	0%	0%	100%
Open Spaces							
	Color Ratios	48	30	0	0	0	78
	Color Percentages	62%	38%	0%	0%	0%	100%
TOTAL%		**34.66%**	**55.33%**	**10%**	**0%**	**0%**	**100%**

SOUTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	34	138	27	0	0	199
	Color Percentages	17%	69%	14%	0%	0%	100%
East-West Streets							
	Color Ratios	42	84	9	0	0	135
	Color Percentages	31%	62%	7%	0%	0%	100%
Open Spaces							
	Color Ratios	18	60	0	0	0	78
	Color Percentages	23%	77%	0%	0%	0%	100%
TOTAL%		**23.66%**	**69.33%**	**7%**	**0%**	**0%**	**100%**

GENERAL CONTEXT / SHADOW STUDY / SUMMER

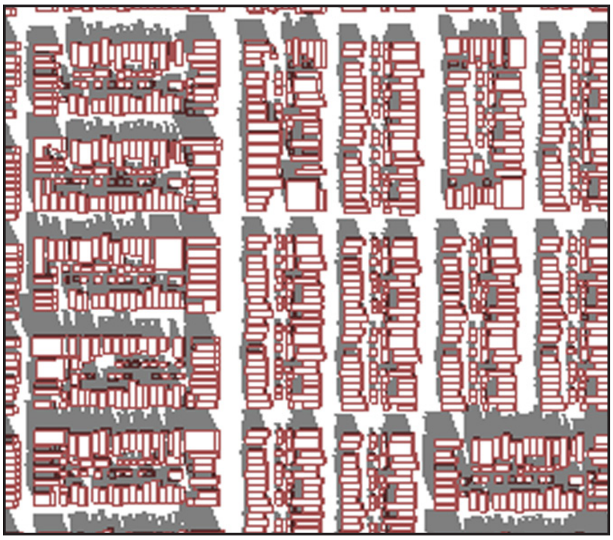


Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	0.8%
Open Spaces	2.6%
Total	1.3%

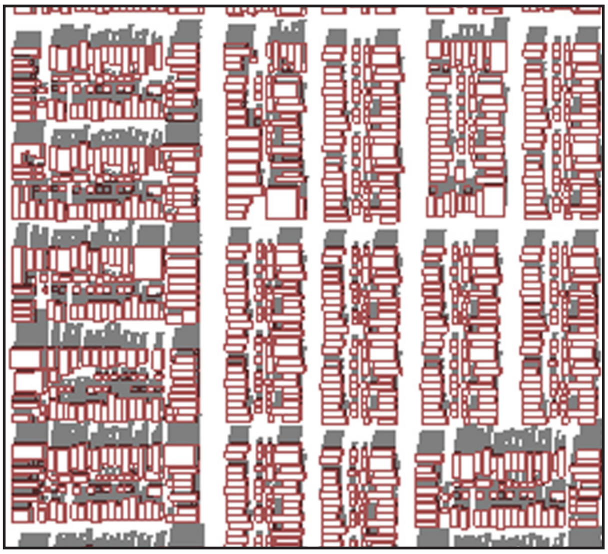


Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	1.2%
Open Spaces	3.1%
Total	1.8%

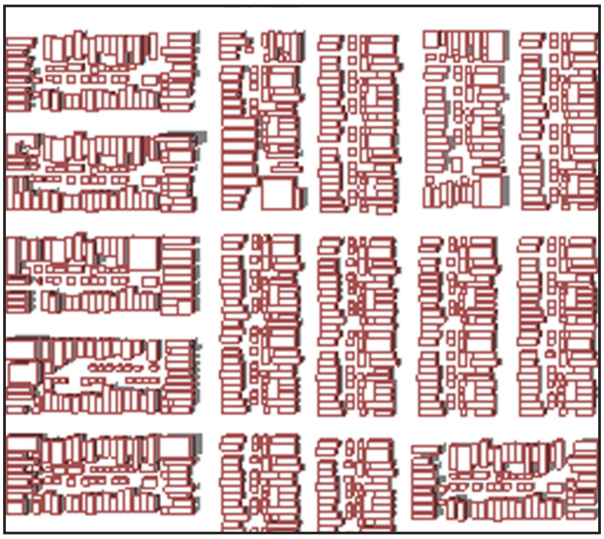
LOCAL CONTEXT / SHADOW STUDY / WINTER



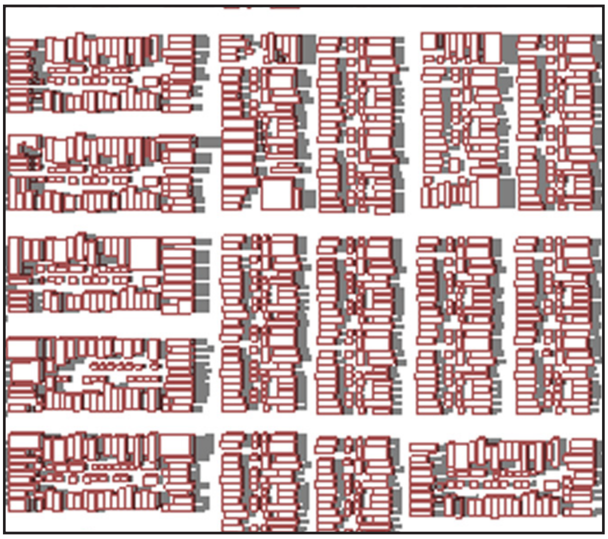
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	39.9%
Open Spaces	62.3%
Total	48.0%



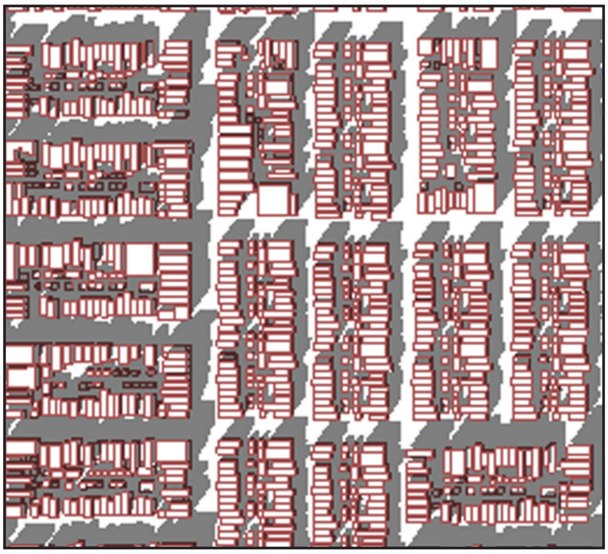
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	24.3%
Open Spaces	55.4%
Total	32.7%



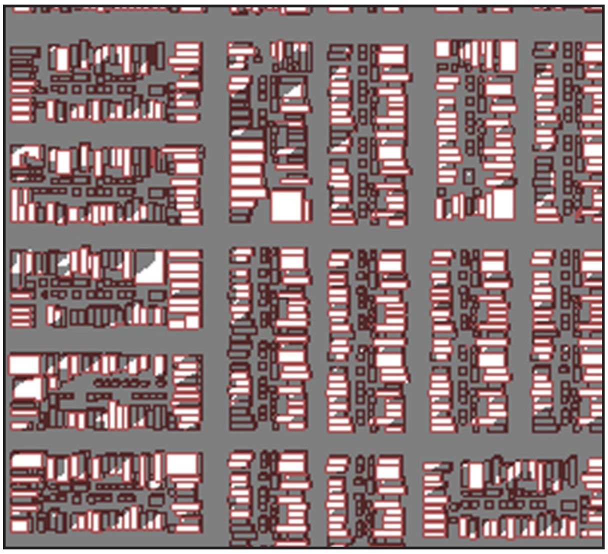
Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	3.2%
Open Spaces	10.4%
Total	5.3%



Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	14.1%
Open Spaces	43.2%
Total	22.0%



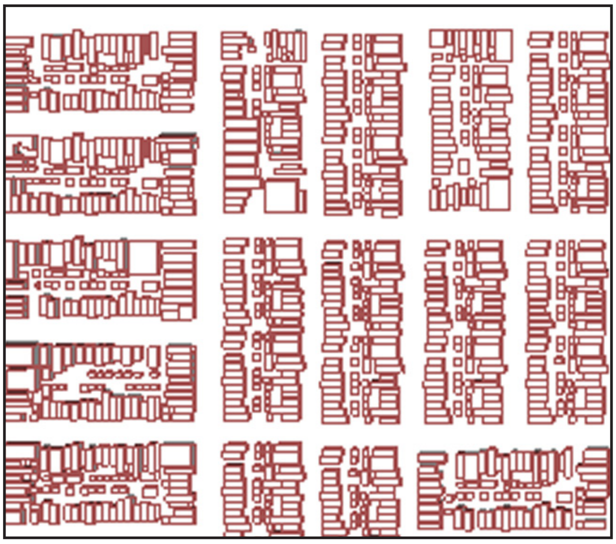
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	63.1%
Open Spaces	93.9%
Total	72.3%



Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

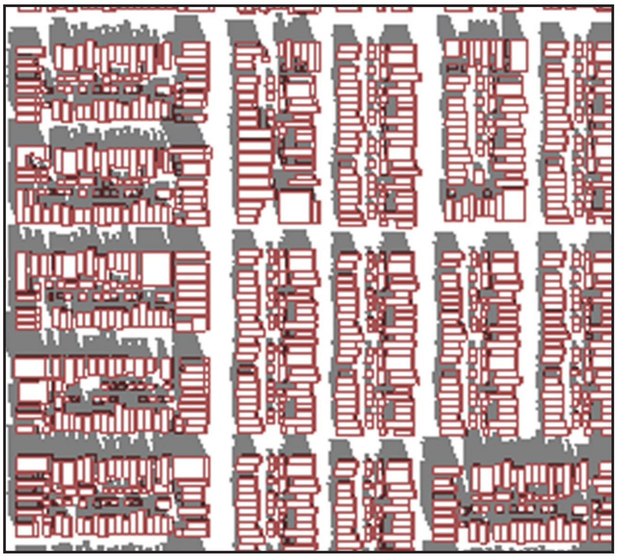
GENERAL CONTEXT / SHADOW STUDY / SUMMER

Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	1.1%
Open Spaces	3.6%
Total	1.7%

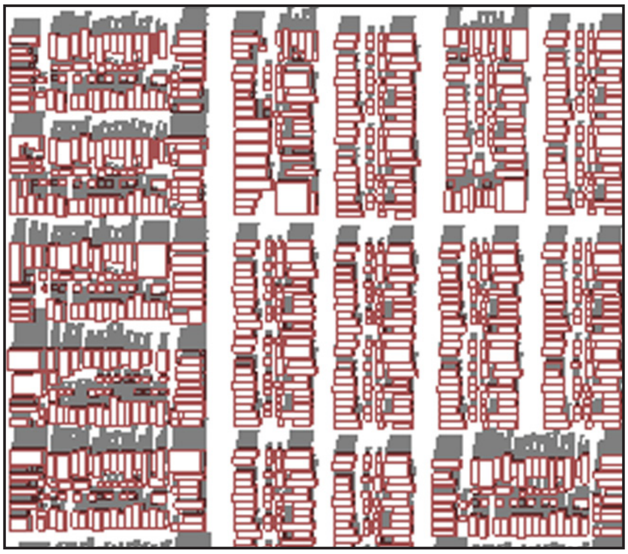


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	1.8%
Open Spaces	3.6%
Total	2.0%

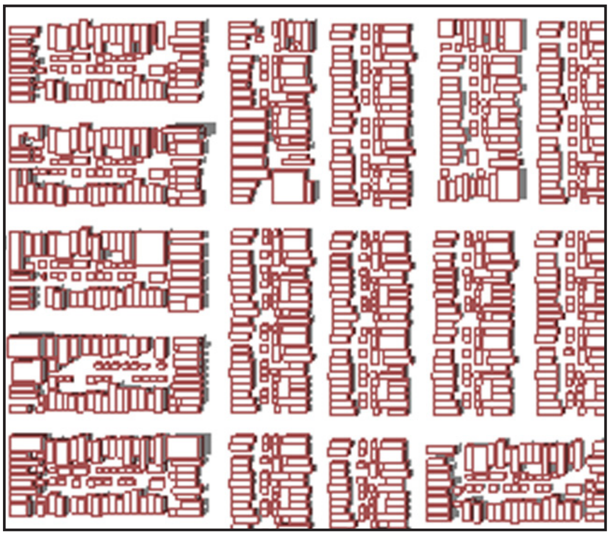
GENERAL CONTEXT / SHADOW STUDY / WINTER



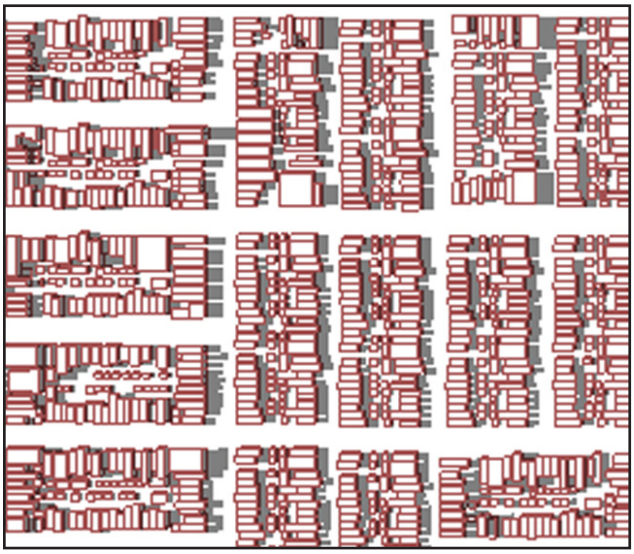
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	41.9%
Open Spaces	64.3%
Total	50.3%



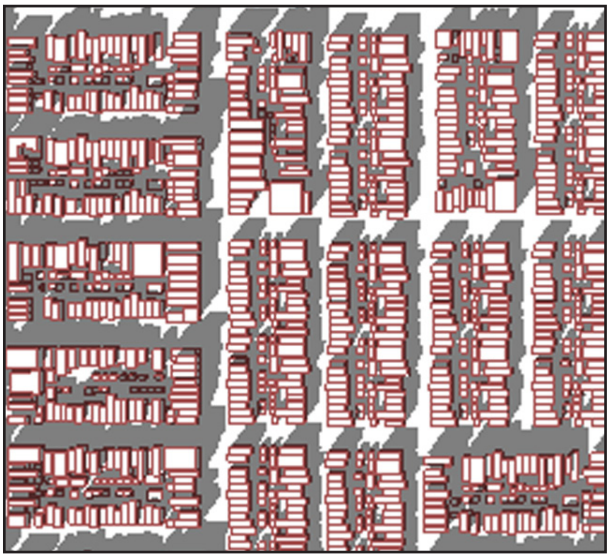
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	26.3%
Open Spaces	57.4%
Total	35.7%



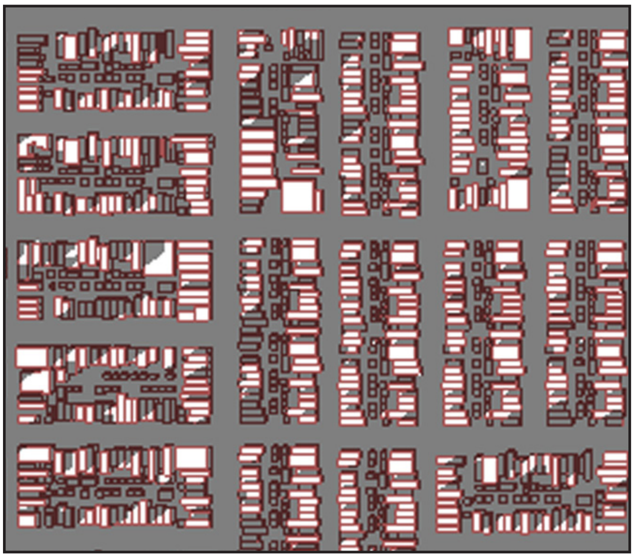
Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	5.2%
Open Spaces	12.4%
Total	7.3%



Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	16.1%
Open Spaces	46.2%
Total	24.7%



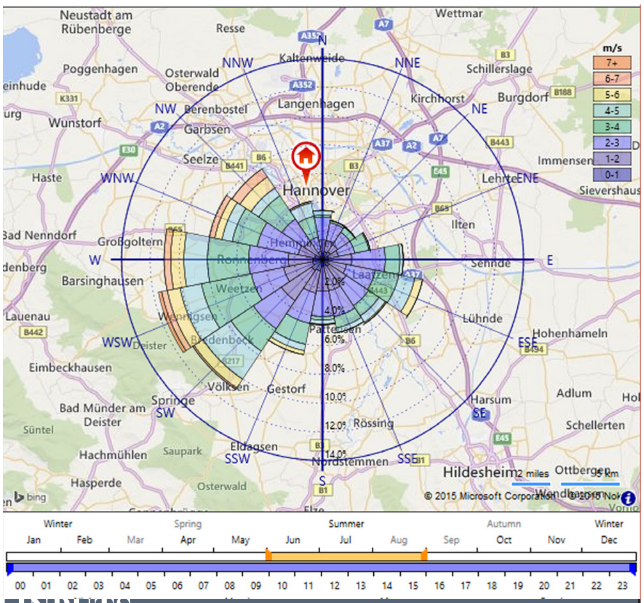
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	66.1%
Open Spaces	95.1%
Total	74.3%



Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

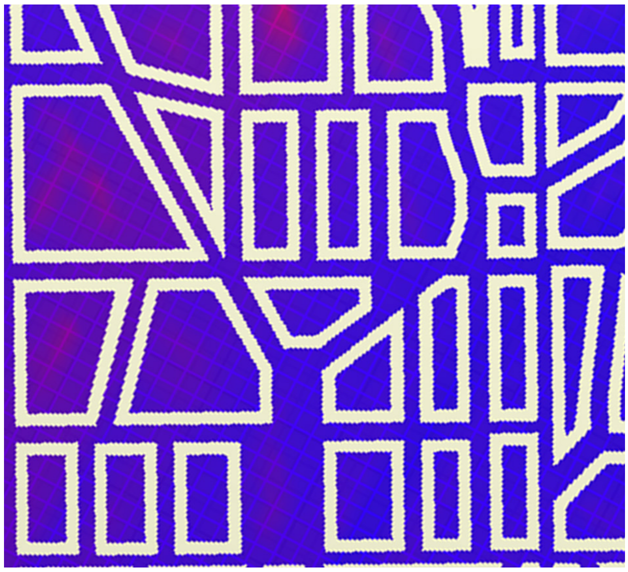
LOCAL CONTEXT / WIND STUDY / SUMMER

WIND ROSE



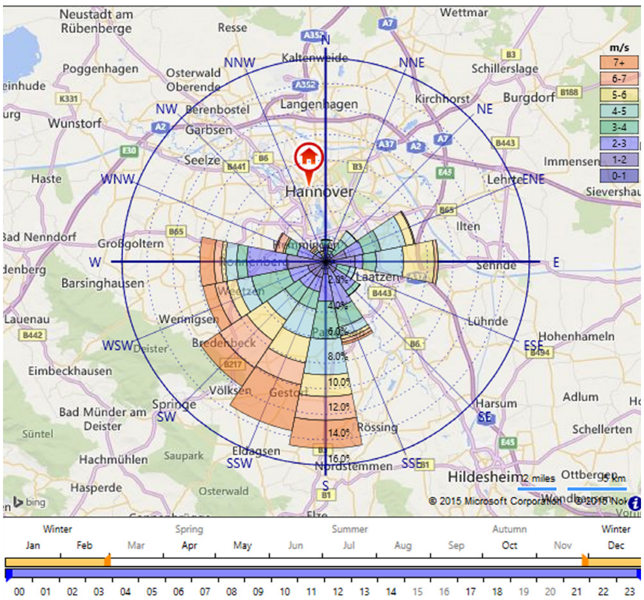
INPUTS	
Location	Hannover, Germany
Time of Year	June - August
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	West
Wind Speed	8+ m/s

WIND TUNNEL

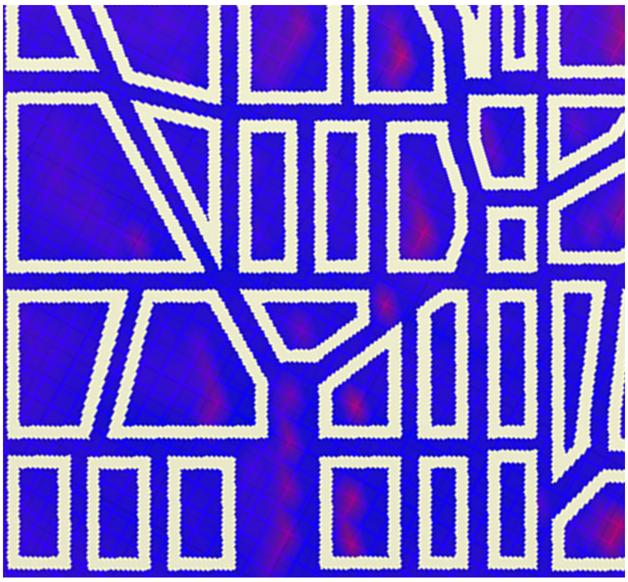


INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

LOCAL CONTEXT / WIND STUDY / WINTER



INPUTS	
Location	Hannover, Germany
Time of Year	December - February
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	South-Southeast
Wind Speed	8+ m/s



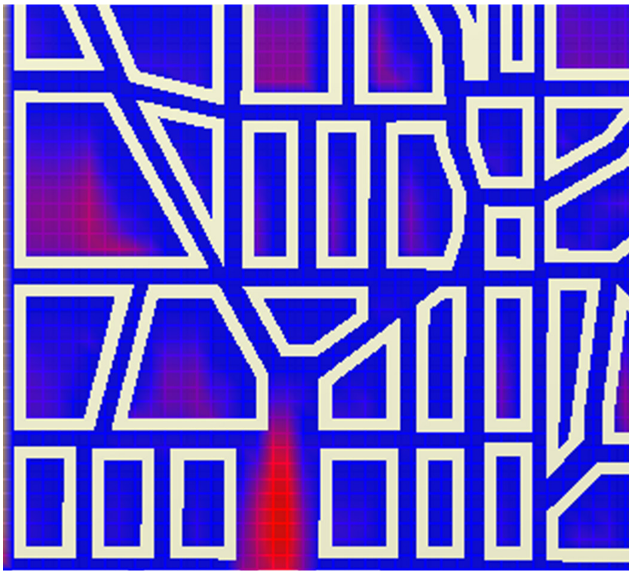
INPUTS		
Wind Direction	South Southeast	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

WIND TUNNEL OUTPUTS

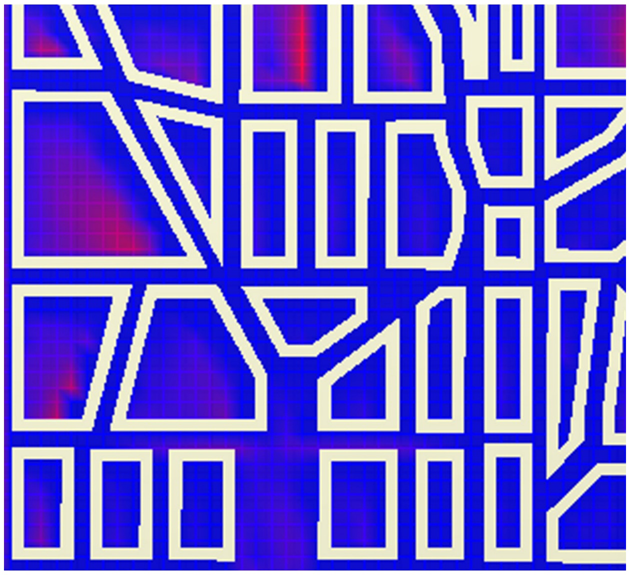
SUMMER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	89	10	4	0	0	103
	Color Percentages	86%	10%	4%	0%	0%	100%
East-West Streets							
	Color Ratios	61	6	2	0	0	69
	Color Percentages	88%	9%	3%	0%	0%	100%
Open Spaces							
	Color Ratios	133	18	6	0	0	157
	Color Percentages	85%	12%	3%	0%	0%	100%
TOTAL%		86.33%	10.33%	3.33%	0%	0%	100%

WINTER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	94	9	0	0	0	103
	Color Percentages	91%	9%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	54	15	0	0	0	69
	Color Percentages	78%	22%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	145	12	0	0	0	157
	Color Percentages	92%	8%	0%	0%	0%	100%
TOTAL%		87%	13%	0%	0%	0%	100%

GENERAL CONTEXT / WIND STUDY / SUMMER

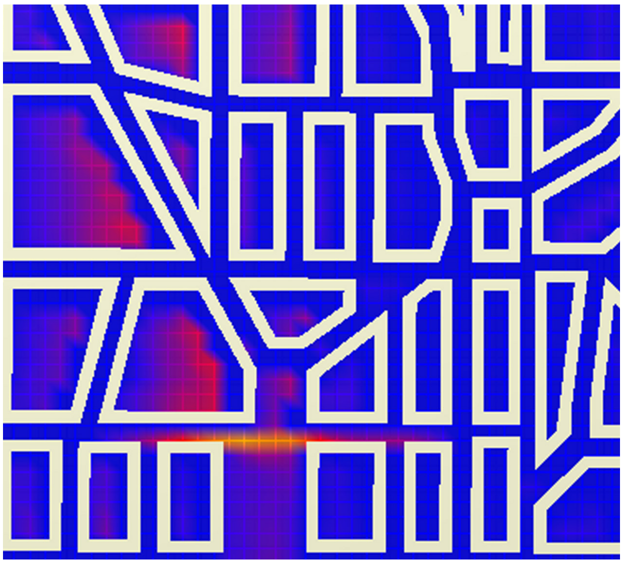


INPUTS		
Wind Direction	North	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

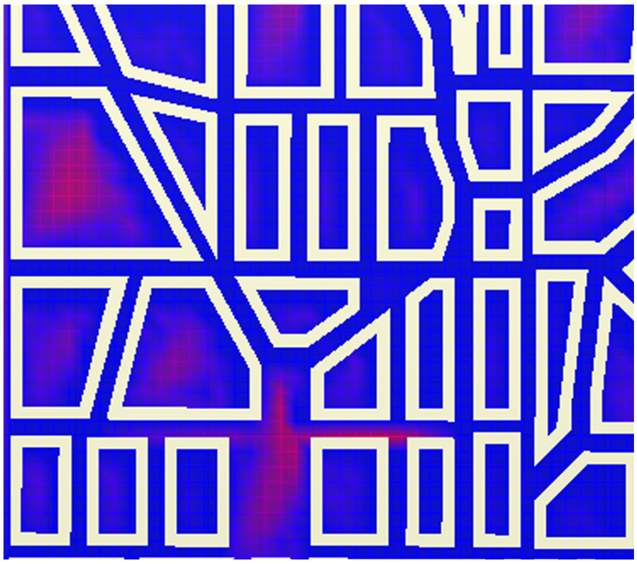


INPUTS		
Wind Direction	Northwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

GENERAL CONTEXT / WIND STUDY / WINTER



INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s



INPUTS		
Wind Direction	Southwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

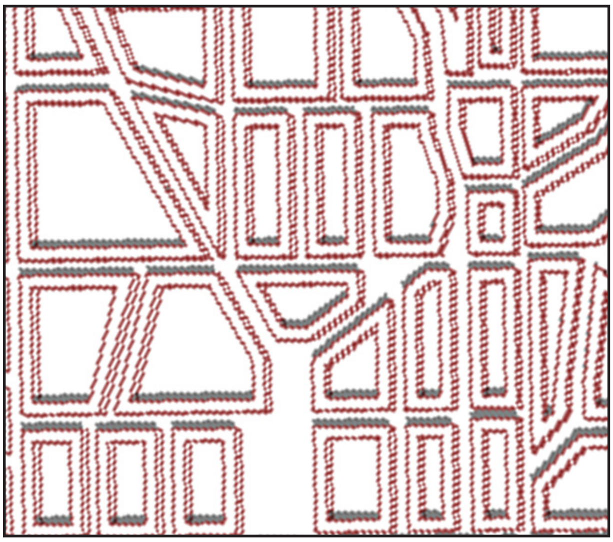
NORTH		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	93	10	0	0	0	103
	Color Percentages	90%	10%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	67	2	0	0	0	69
	Color Percentages	97%	3%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	81	64	8	4	0	157
	Color Percentages	52%	41%	5%	2%	0%	100%
TOTAL%		**79.66%**	**18%**	**1.66%**	**0.66%**	**0%**	**100%**

NORTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	103	0	0	0	0	103
	Color Percentages	100%	0%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	55	14	0	0	0	69
	Color Percentages	80%	20%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	115	38	4	0	0	157
	Color Percentages	73%	24%	3%	0%	0%	100%
TOTAL%		**84.33%**	**14.66%**	**1%**	**0%**	**0%**	**100%**

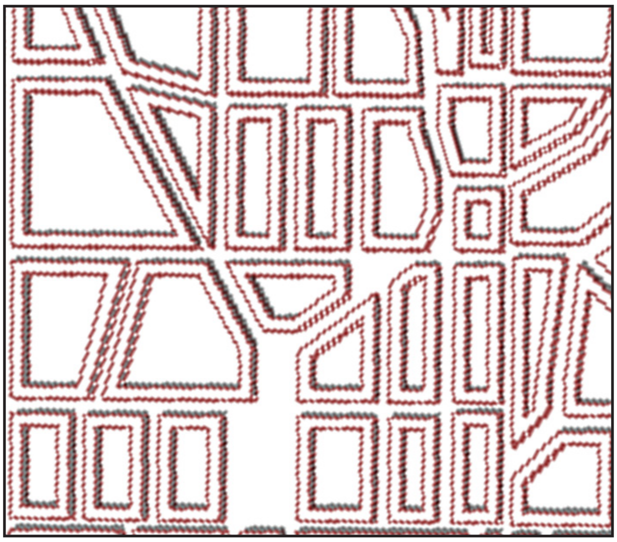
WEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	93	8	0	2	0	103
	Color Percentages	90%	8%	0%	2%	0%	100%
East-West Streets							
	Color Ratios	39	14	6	6	4	69
	Color Percentages	57%	21%	8%	8%	6%	100%
Open Spaces							
	Color Ratios	96	40	5	16	0	157
	Color Percentages	61%	25%	4%	10%	0%	100%
TOTAL%		**69.33%**	**18%**	**4%**	**6.66%**	**2%**	**100%**

SOUTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	72	24	7	0	0	103
	Color Percentages	70%	23%	7%	0%	0%	100%
East-West Streets							
	Color Ratios	52	11	4	2	0	69
	Color Percentages	75%	16%	6%	3%	0%	100%
Open Spaces							
	Color Ratios	127	30	0	0	0	157
	Color Percentages	81%	19%	0%	0%	0%	100%
TOTAL%		**75.33%**	**19.33%**	**4.33%**	**1%**	**0%**	**100%**

LOCAL CONTEXT / SHADOW STUDY / SUMMER

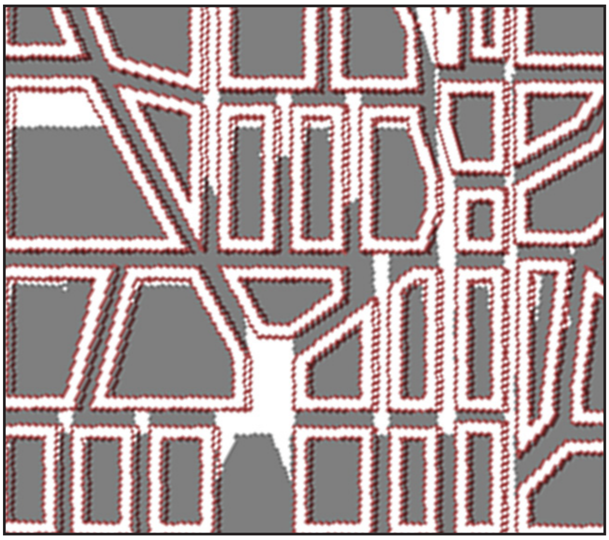


Inputs	
Location	Hannover, Germany
Time of Year	June 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	24.6%
Open Spaces	6.8%
Total	12.0%

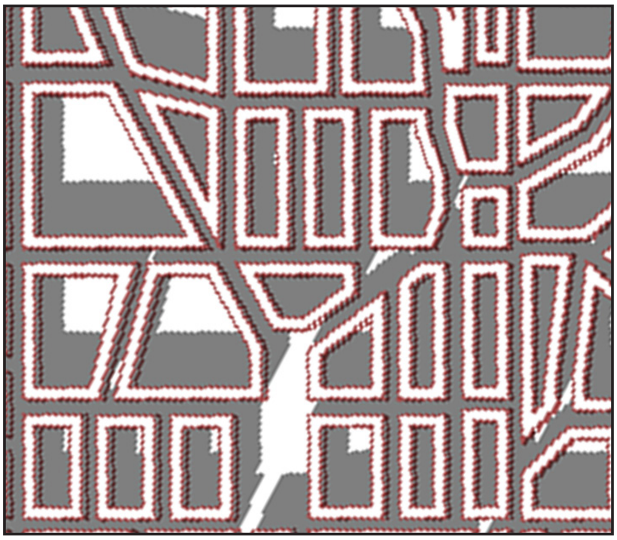


Inputs	
Location	Hannover, Germany
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	21.9%
Open Spaces	5.2%
Total	8.1%

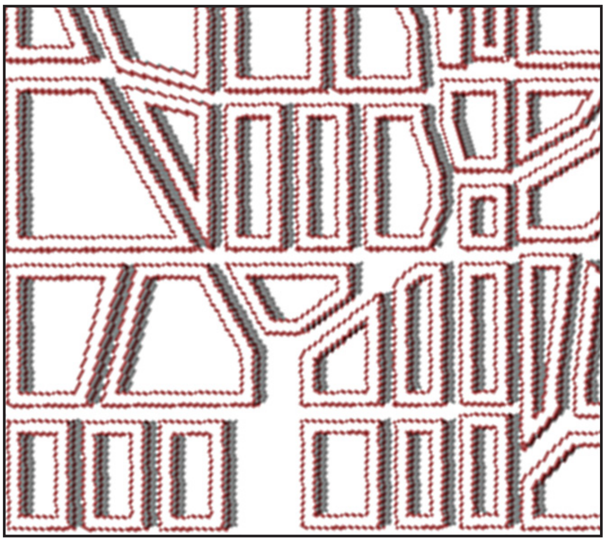
LOCAL CONTEXT / SHADOW STUDY / WINTER



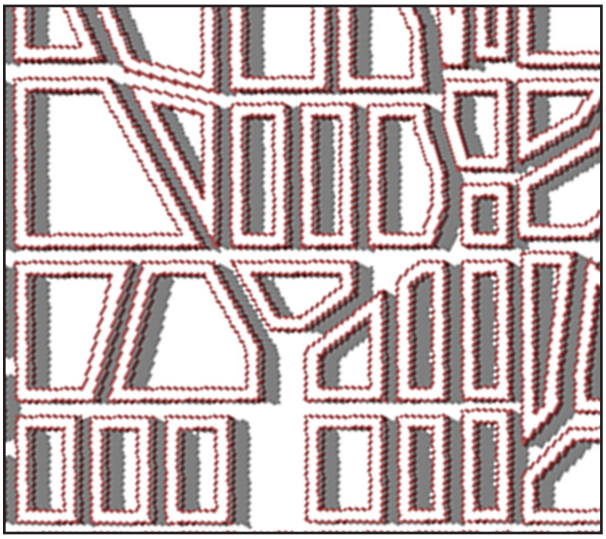
Inputs	
Location	Hannover, Germany
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	68.0%
Open Spaces	89.7%
Total	85.1%



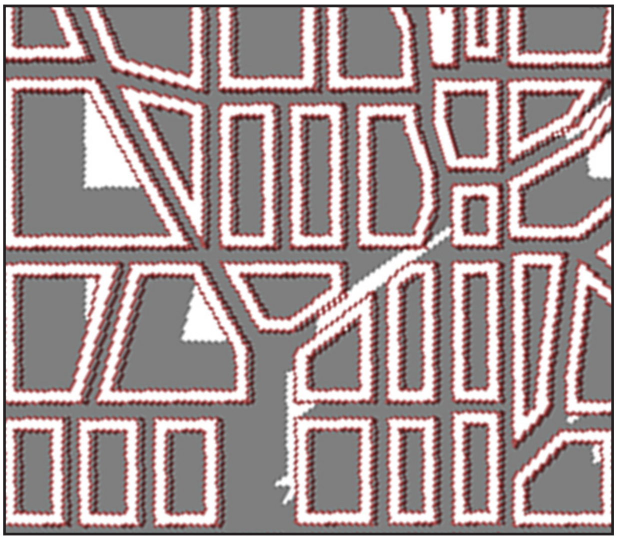
Inputs	
Location	Hannover, Germany
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	93.7%
Open Spaces	72.4%
Total	87.8%



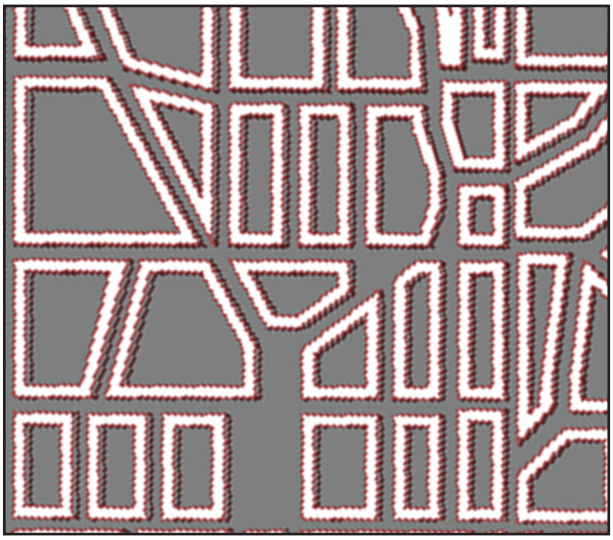
Inputs	
Location	Hannover, Germany
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	56.2%
Open Spaces	13.5%
Total	24.1%



Inputs	
Location	Hannover, Germany
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	89.7%
Open Spaces	21.3%
Total	44.0%

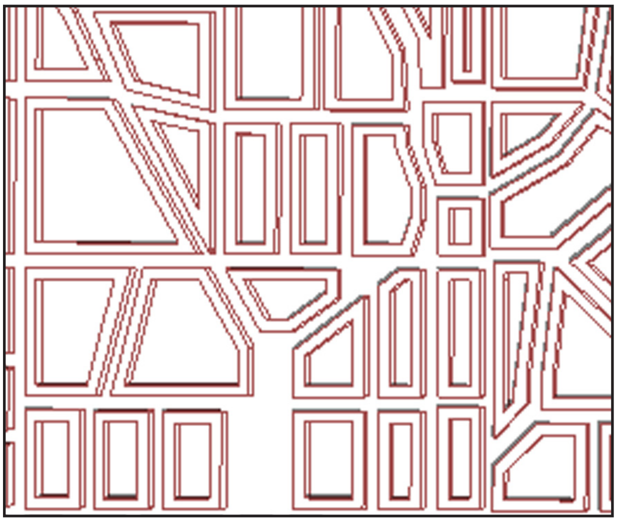


Inputs	
Location	Hannover, Germany
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	98.8%
Open Spaces	84.5%
Total	94.4%

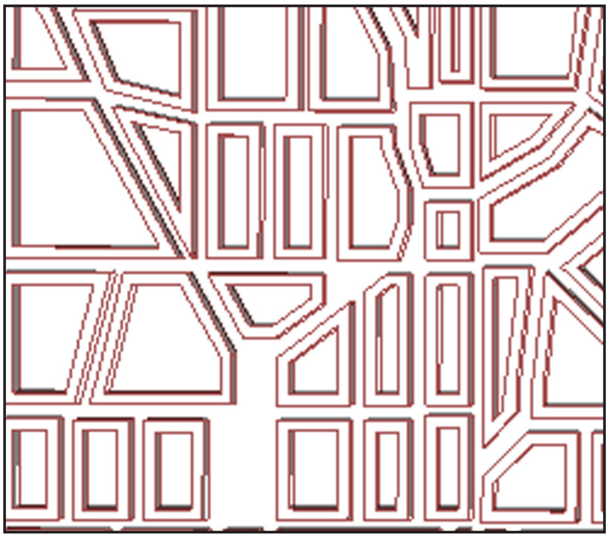


Inputs	
Location	Hannover, Germany
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

GENERAL CONTEXT / SHADOW STUDY / SUMMER

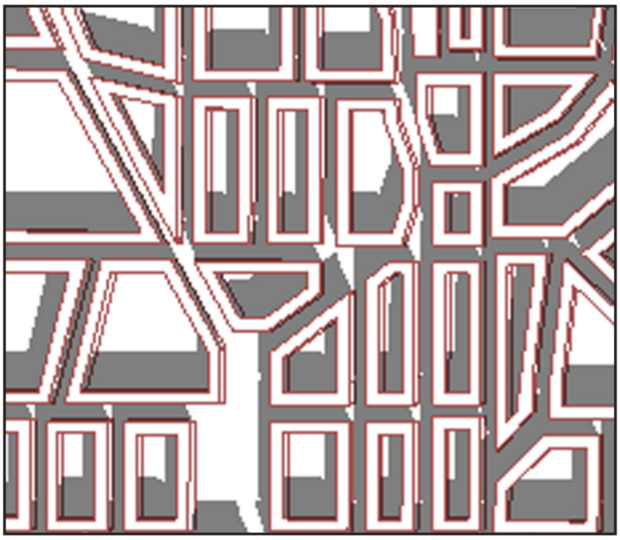


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	1.2%
Open Spaces	3.4%
Total	1.7%

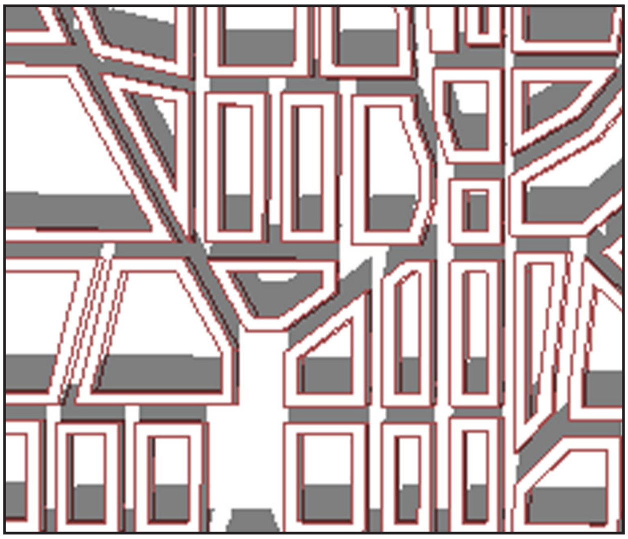


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	3.2%
Open Spaces	9.0%
Total	6.3%

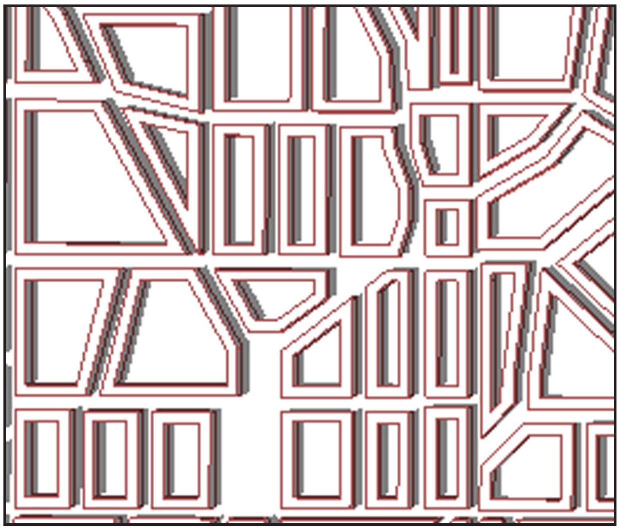
GENERAL CONTEXT / SHADOW STUDY / WINTER



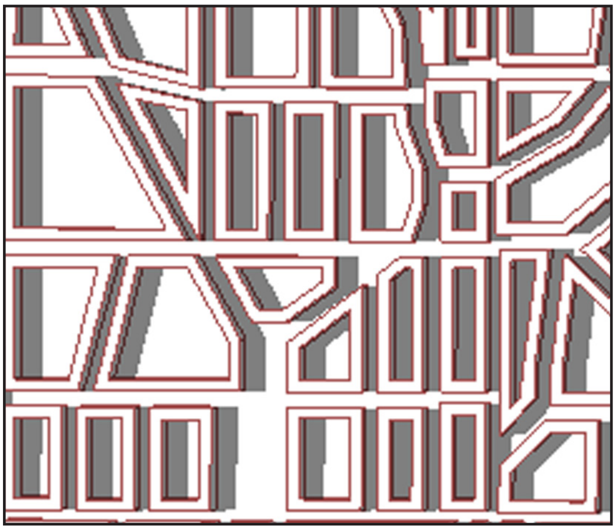
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	81.1%
Open Spaces	54.2%
Total	65.0%



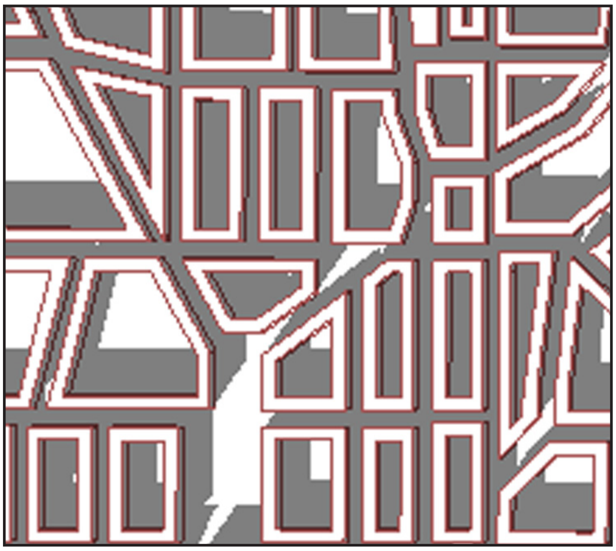
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	55.6%
Open Spaces	32.7%
Total	47.3%



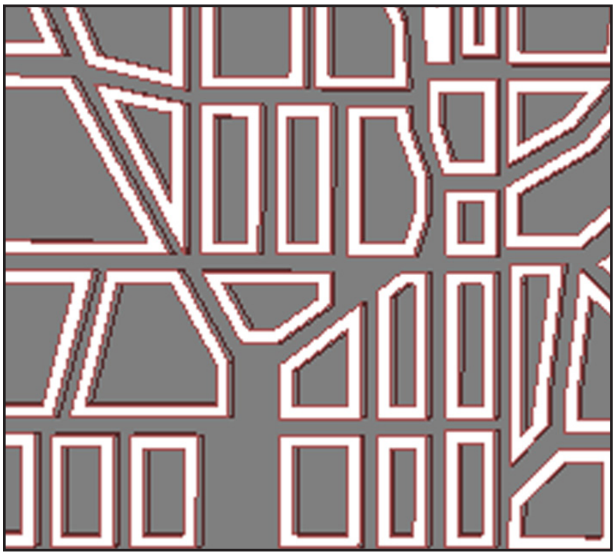
Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	16.9%
Open Spaces	41.4%
Total	26.0%



Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	32.7%
Open Spaces	59.3%
Total	50.0%



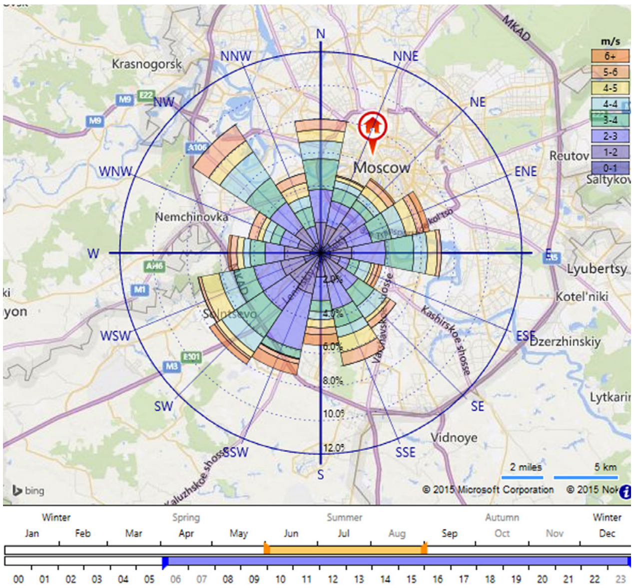
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	93.3%
Open Spaces	72.5%
Total	82.2%



Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

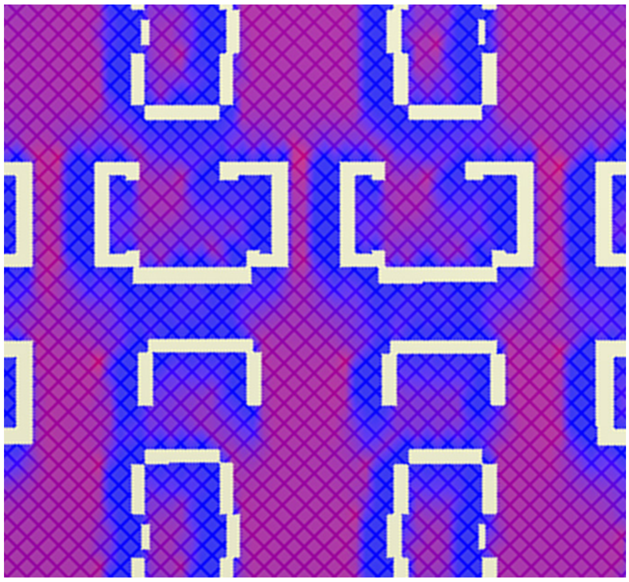
LOCAL CONTEXT / WIND STUDY / SUMMER

WIND ROSE



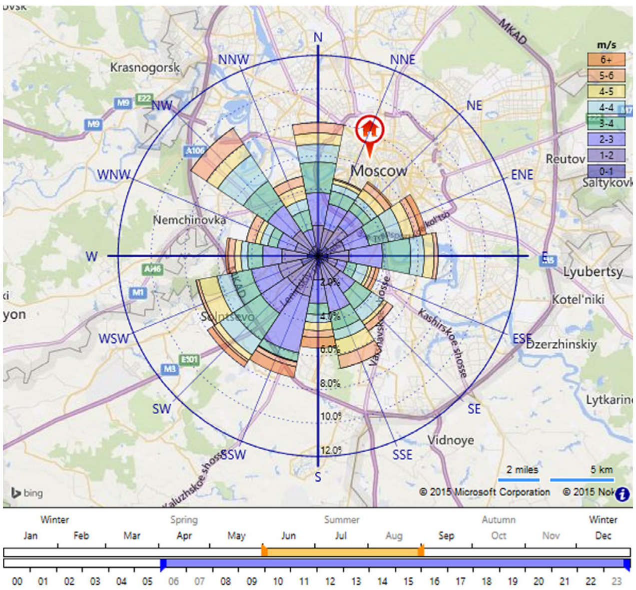
INPUTS	
Location	Moscow, Russia
Time of Year	June - August
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	West
Wind Speed	8+ m/s

WIND TUNNEL

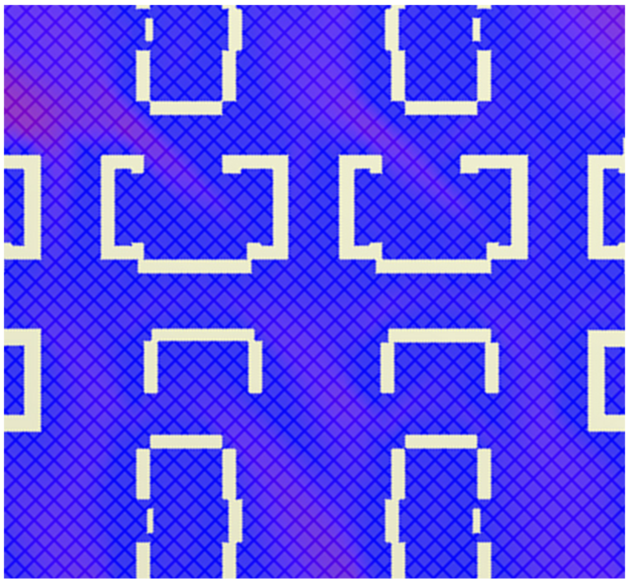


INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

LOCAL CONTEXT / WIND STUDY / WINTER



INPUTS	
Location	Moscow, Russia
Time of Year	December - February
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	South-Southeast
Wind Speed	8+ m/s



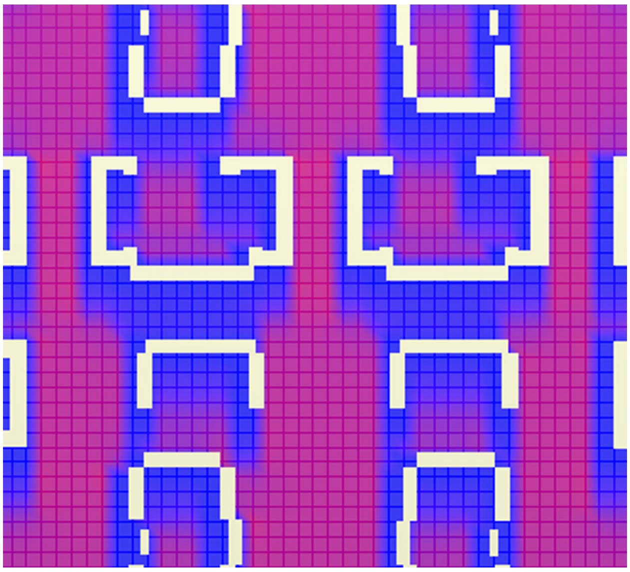
INPUTS		
Wind Direction	South Southeast	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

WIND TUNNEL OUTPUTS

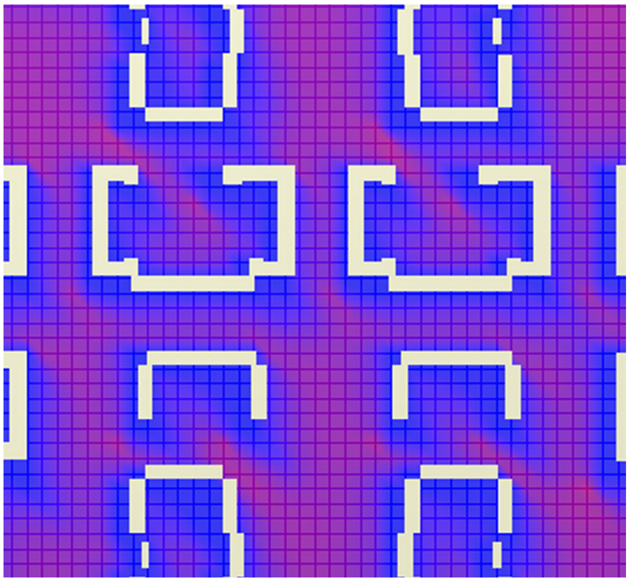
SUMMER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	82	190	28	0	0	300
	Color Percentages	27%	63%	10%	0%	0%	100%
East-West Streets							
	Color Ratios	128	64	4	0	0	196
	Color Percentages	65%	33%	2%	0%	0%	100%
Open Spaces							
	Color Ratios	122	64	5	0	0	191
	Color Percentages	64%	34%	2%	0%	0%	100%
TOTAL%		52%	43.33%	4.66%	0%	0%	100%

WINTER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	262	38	0	0	0	300
	Color Percentages	87%	13%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	162	34	0	0	0	196
	Color Percentages	83%	17%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	179	12	0	0	0	191
	Color Percentages	94%	6%	0%	0%	0%	100%
TOTAL%		88%	12%	0%	0%	0%	100%

GENERAL CONTEXT / WIND STUDY / SUMMER

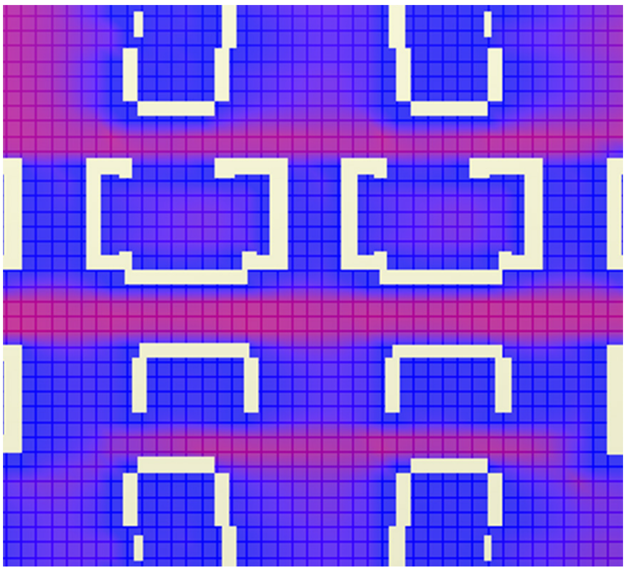


INPUTS		
Wind Direction	North	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

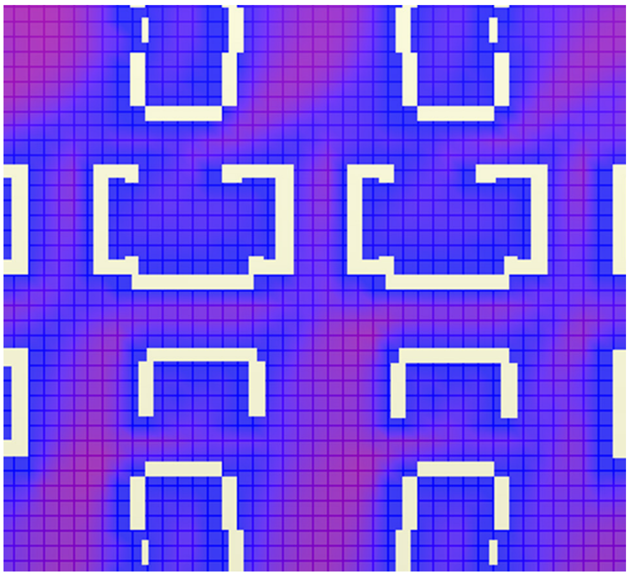


INPUTS		
Wind Direction	Northwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

GENERAL CONTEXT / WIND STUDY / WINTER



INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s



INPUTS		
Wind Direction	Southwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

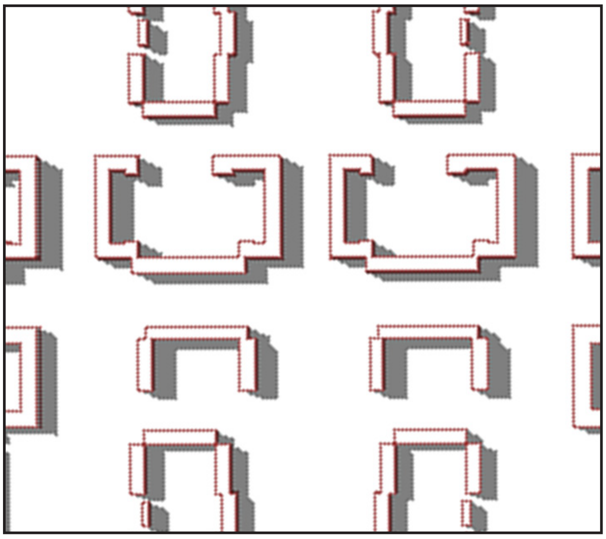
NORTH		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	126	348	20	0	0	494
	Color Percentages	26%	70%	4%	0%	0%	100%
East-West Streets							
	Color Ratios	222	176	0	0	0	398
	Color Percentages	56%	44%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	168	78	6	0	0	252
	Color Percentages	67%	31%	2%	0%	0%	100%
TOTAL%		**49.66%**	**48.33%**	**2%**	**0%**	**0%**	**100%**

NORTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	152	336	6	0	0	494
	Color Percentages	31%	68%	1%	0%	0%	100%
East-West Streets							
	Color Ratios	164	220	14	0	0	398
	Color Percentages	41%	55%	4%	0%	0%	100%
Open Spaces							
	Color Ratios	237	15	5	0	0	252
	Color Percentages	92%	6%	2%	0%	0%	100%
TOTAL%		**54.66%**	**43%**	**2.33%**	**0%**	**0%**	**100%**

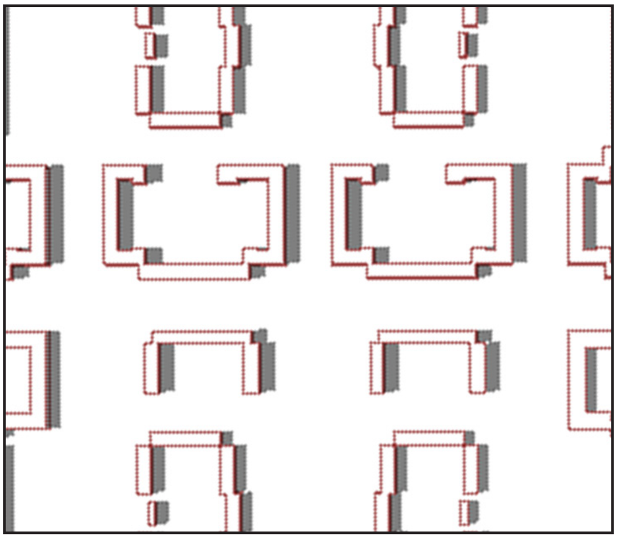
WEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	542	157	0	0	0	699
	Color Percentages	78%	22%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	51	274	0	0	0	325
	Color Percentages	16%	84%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	40	168	0	0	0	208
	Color Percentages	19%	81%	0%	0%	0%	100%
TOTAL%		**37.66%**	**62.33%**	**0%**	**0%**	**0%**	**100%**

SOUTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	661	34	0	0	0	699
	Color Percentages	94%	6%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	258	67	0	0	0	325
	Color Percentages	79%	21%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	95	113	0	0	0	208
	Color Percentages	46%	54%	0%	0%	0%	100%
TOTAL%		**73%**	**27%**	**0%**	**0%**	**0%**	**100%**

LOCAL CONTEXT / SHADOW STUDY / SUMMER

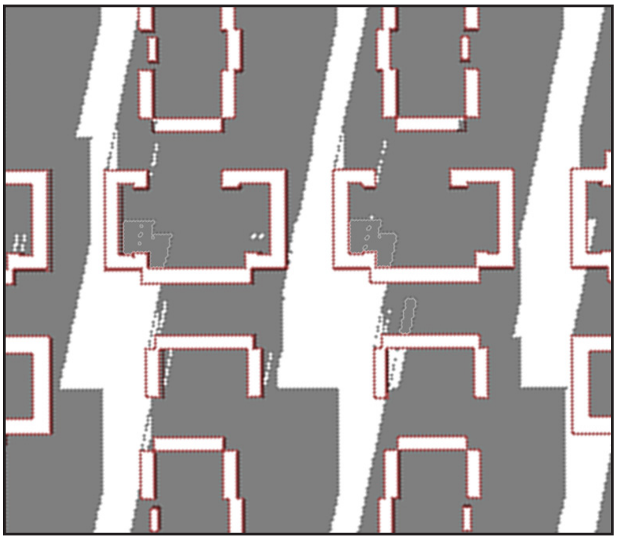


Inputs	
Location	Moscow, Russia
Time of Year	June 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	14.7%
Open Spaces	18.6
Total	16.8%

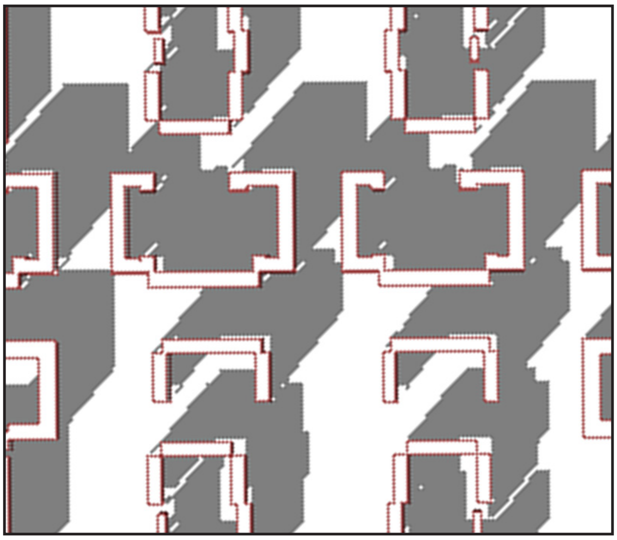


Inputs	
Location	Moscow, Russia
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	6.4%
Open Spaces	13.5%
Total	11.2%

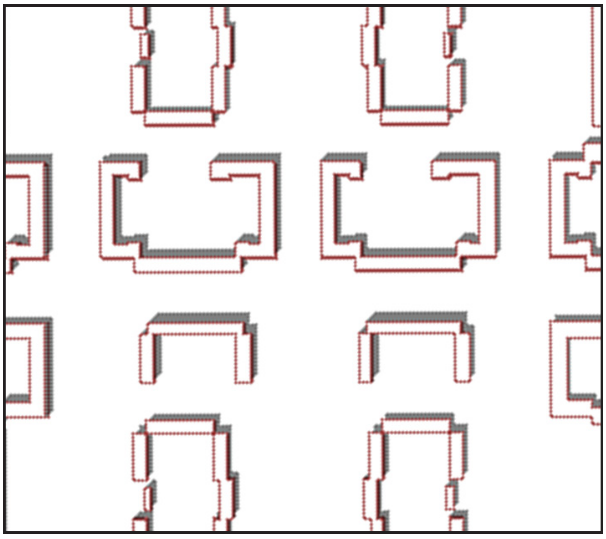
LOCAL CONTEXT / SHADOW STUDY / WINTER



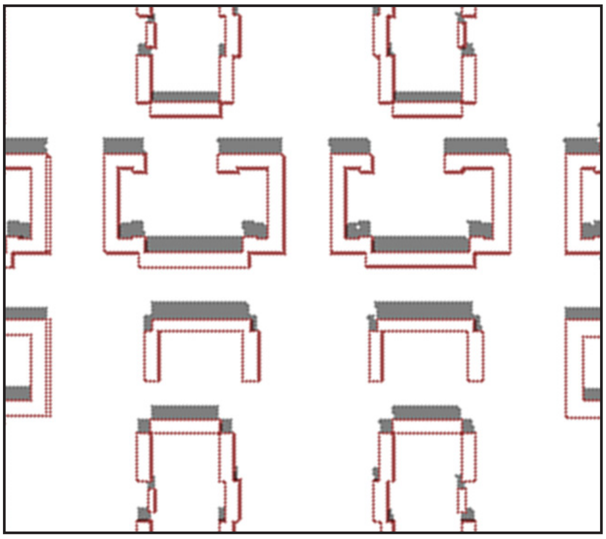
Inputs	
Location	Moscow, Russia
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	61.2%
Open Spaces	96.7%
Total	78.5%



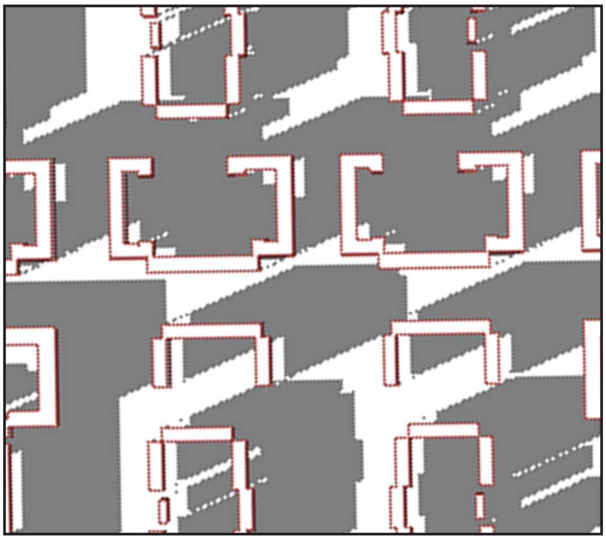
Inputs	
Location	Moscow, Russia
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	49.6%
Open Spaces	87.5%
Total	64.9%



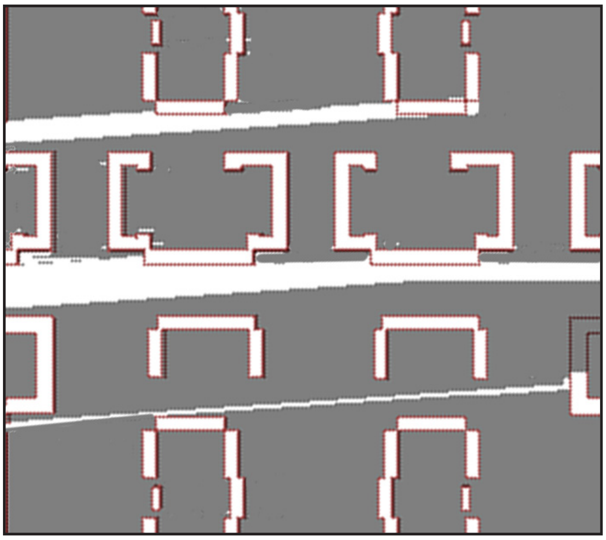
Inputs	
Location	Moscow, Russia
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	9.3%
Open Spaces	25.2%
Total	18.2%



Inputs	
Location	Moscow, Russia
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	13.5%
Open Spaces	35.7%
Total	27.2%

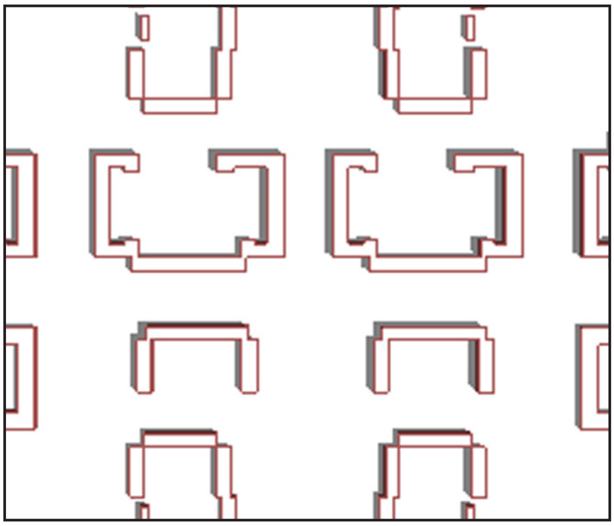


Inputs	
Location	Moscow, Russia
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	65.8%
Open Spaces	83.2%
Total	72.2%

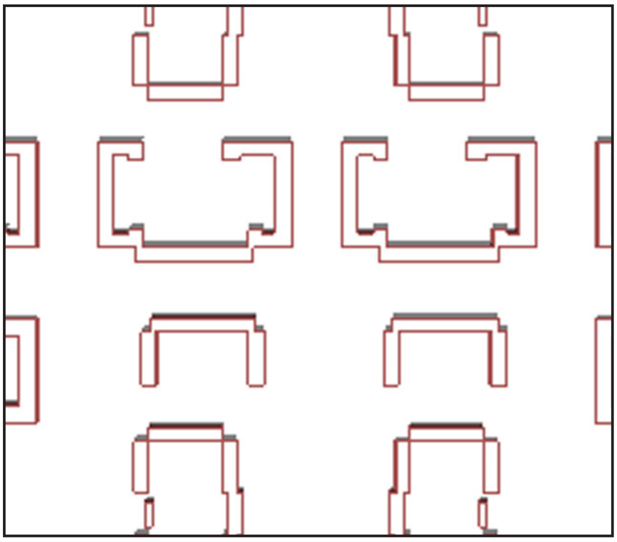


Inputs	
Location	Moscow, Russia
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	74.3%
Open Spaces	96.5%
Total	85.0%

GENERAL CONTEXT / SHADOW STUDY / SUMMER

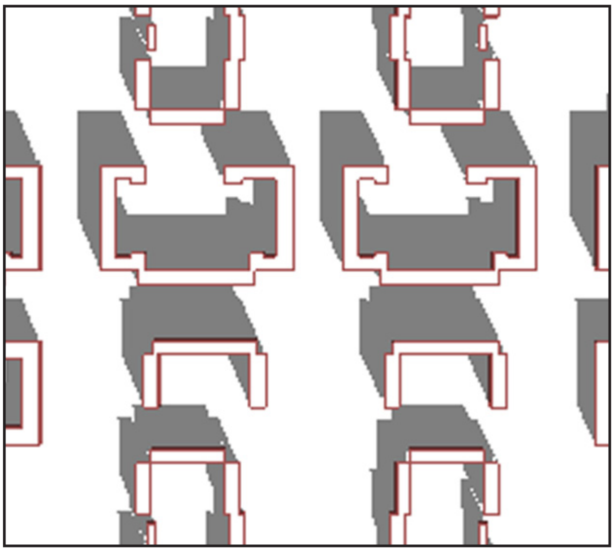


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	3.5%
Open Spaces	9.6%
Total	5.1%

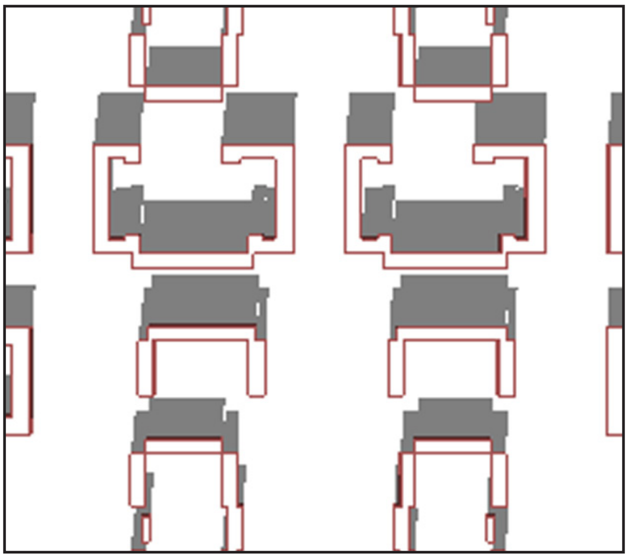


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	2.2%
Open Spaces	6.4%
Total	3.3%

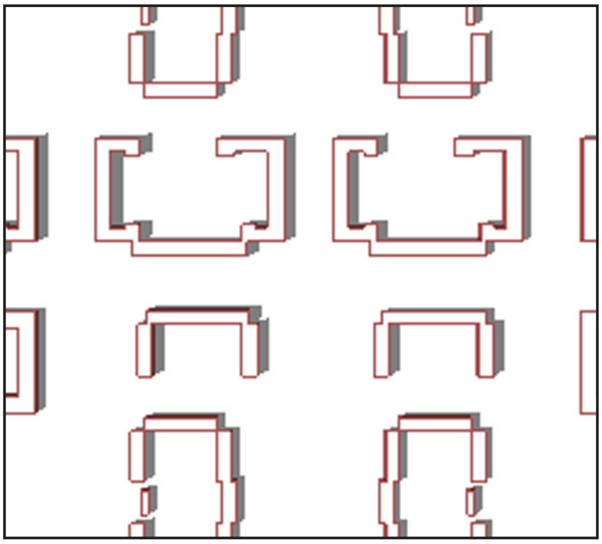
GENERAL CONTEXT / SHADOW STUDY / WINTER



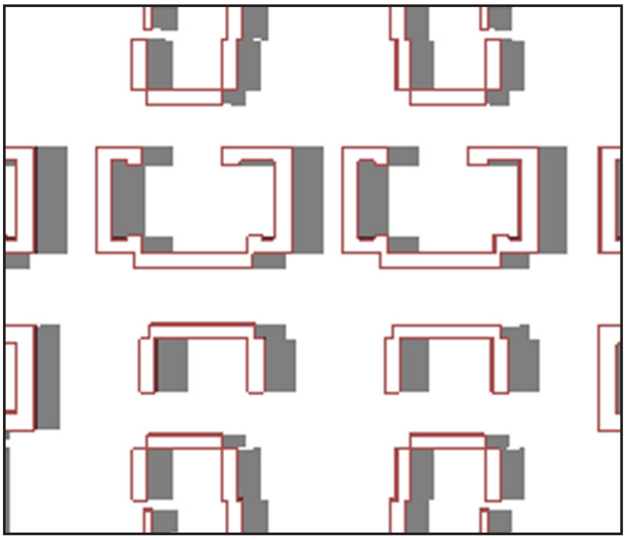
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	26.7%
Open Spaces	41.2%
Total	36.1%



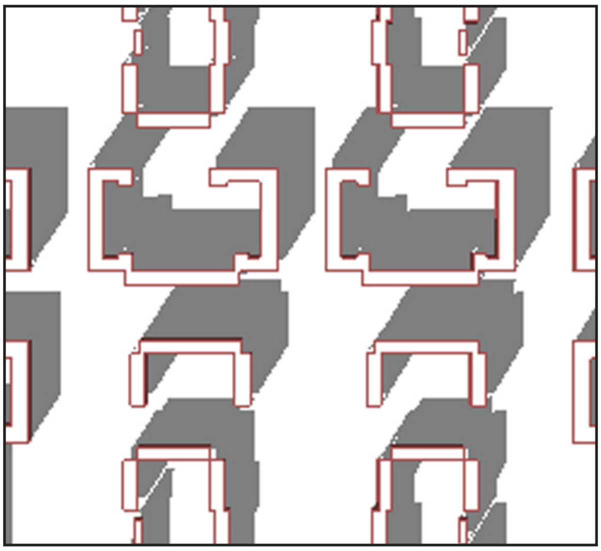
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	22.6%
Open Spaces	30.3%
Total	27.3%



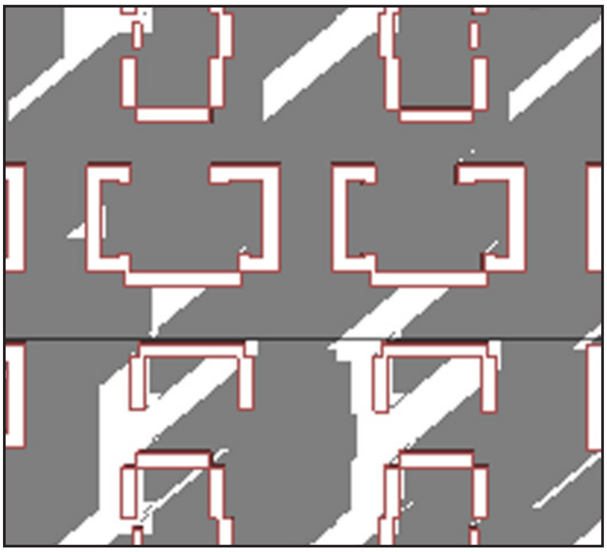
Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	6.9%
Open Spaces	17.3%
Total	9.7%



Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	11.5%
Open Spaces	23.6%
Total	15.2%



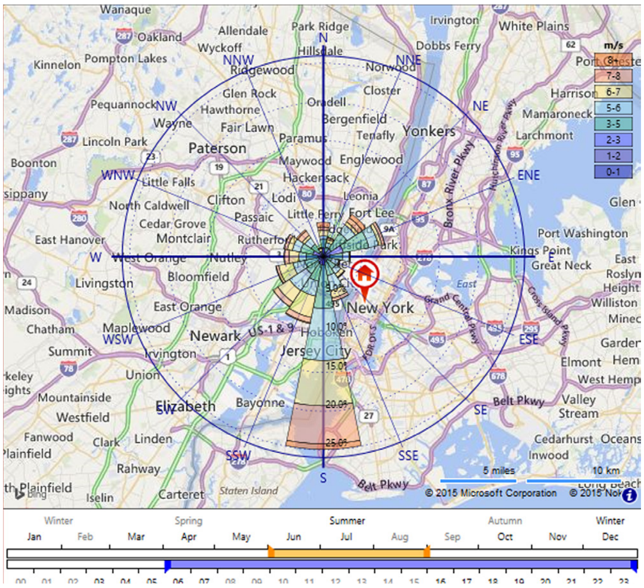
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	35.4%
Open Spaces	49.8%
Total	43.4%



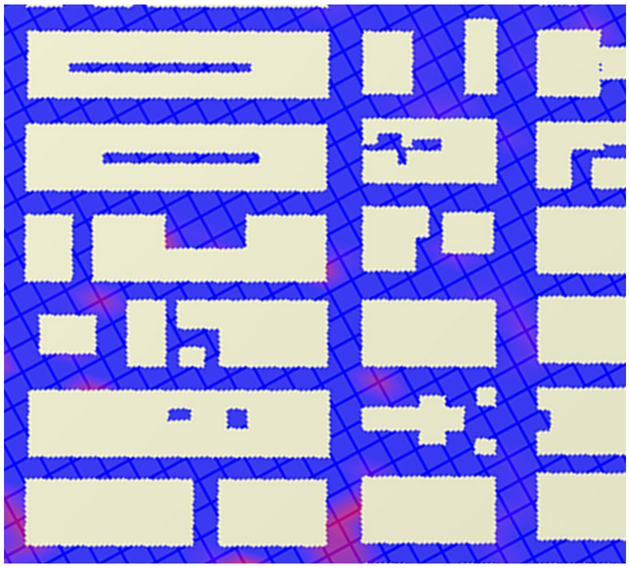
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	76.4%
Open Spaces	89.7%
Total	85.6%

LOCAL CONTEXT / WIND STUDY / SUMMER

WIND ROSE



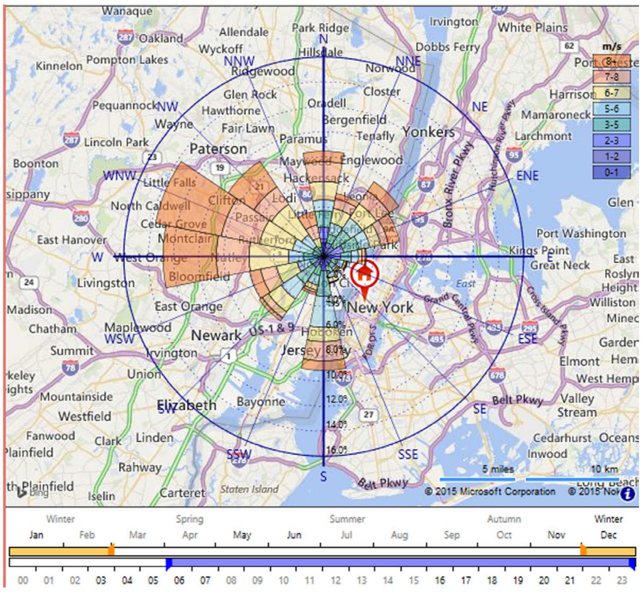
WIND TUNNEL

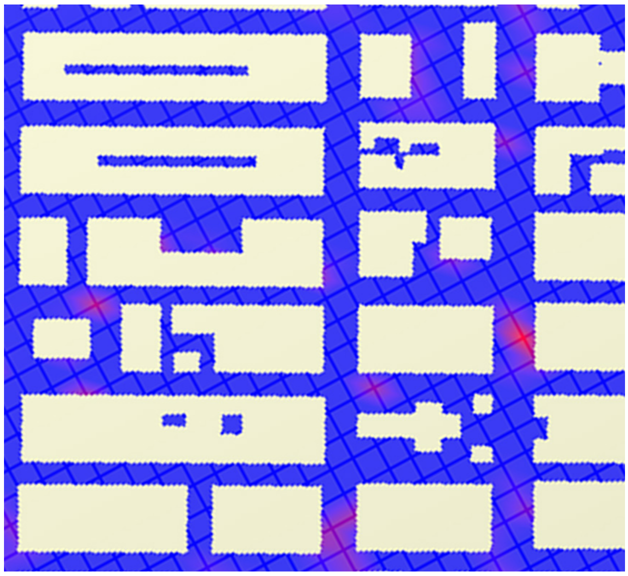


INPUTS	
Location	New York, NY
Time of Year	June - August
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	South
Wind Speed	8+ m/s

INPUTS		
Wind Direction	South	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

LOCAL CONTEXT / WIND STUDY / WINTER





INPUTS	
Location	New York, NY
Time of Year	December - February
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	West-Northwest
Wind Speed	8+ m/s

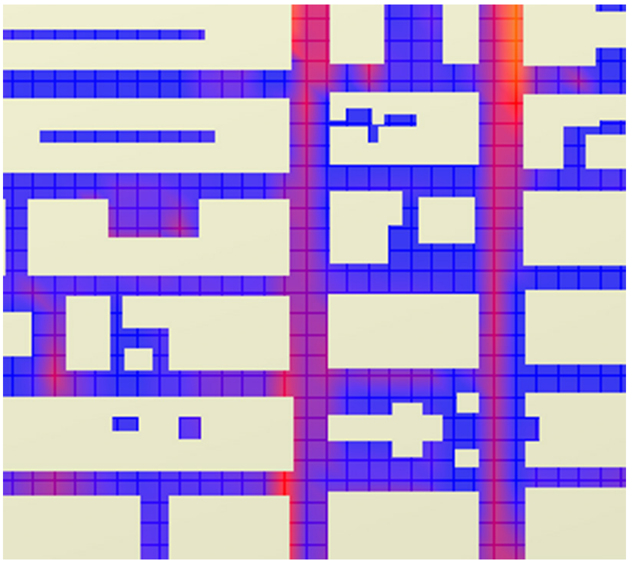
INPUTS		
Wind Direction	West-Northwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

WIND TUNNEL OUTPUTS

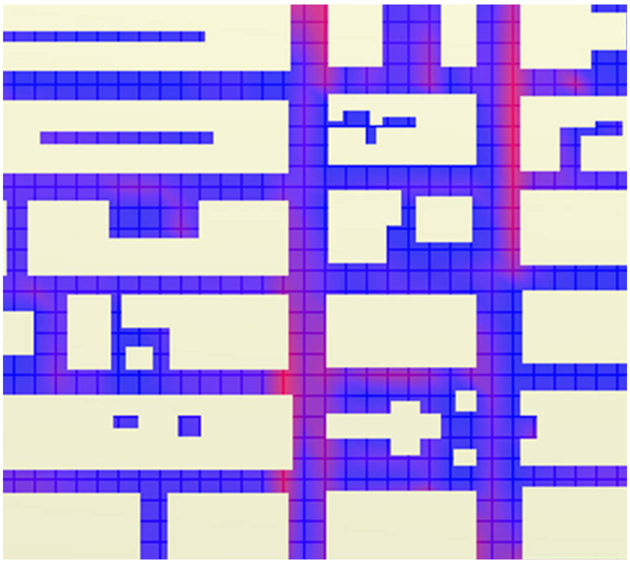
SUMMER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	69	3	2	0	0	74
	Color Percentages	93%	4%	3%	0%	0%	100%
East-West Streets							
	Color Ratios	147	4	2	0	0	153
	Color Percentages	96%	3%	1%	0%	0%	100%
Open Spaces							
	Color Ratios	9	0	0	0	0	9
	Color Percentages	100%	0%	0%	0%	0%	100%
	TOTAL%	96.33%	2.33%	1.33%	0%	0%	100%

WINTER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	96	9	2	0	0	108
	Color Percentages	90%	8%	2%	0%	0%	100%
East-West Streets							
	Color Ratios	168	4	2	0	0	174
	Color Percentages	97%	2%	1%	0%	0%	100%
Open Spaces							
	Color Ratios	23	1	0	0	0	24
	Color Percentages	99%	1%	0%	0%	0%	100%
TOTAL%		95.33%	3.66%	1%	0%	0%	100%

GENERAL CONTEXT / WIND STUDY / SUMMER

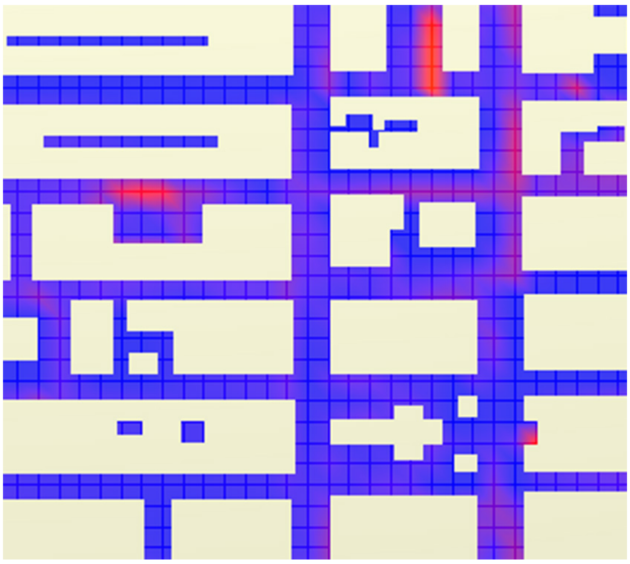


INPUTS		
Wind Direction	North	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

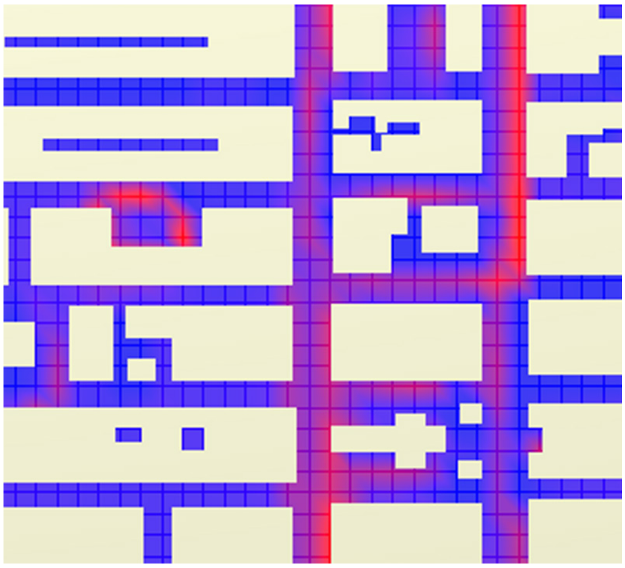


INPUTS		
Wind Direction	Northwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

GENERAL CONTEXT / WIND STUDY / WINTER



INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s



INPUTS		
Wind Direction	Southwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

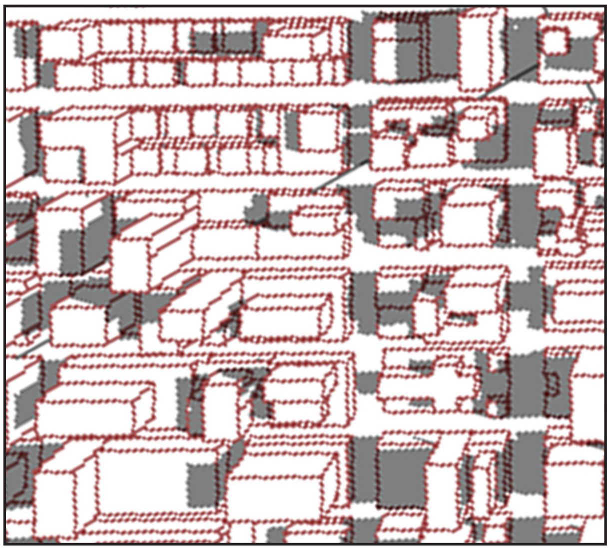
NORTH		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	6	55	3	13	6	83
	Color Percentages	7%	66%	4%	16%	7%	100%
East-West Streets							
	Color Ratios	10	119	11	5	6	151
	Color Percentages	7%	79%	7%	3%	4%	100%
Open Spaces							
	Color Ratios	10	119	11	5	6	151
	Color Percentages	7%	79%	7%	3%	4%	100%
TOTAL%		15%	66.66%	6%	6.33%	6%	100%

NORTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	32	44	24	5	0	105
	Color Percentages	30%	42%	23%	5%	0%	100%
East-West Streets							
	Color Ratios	138	86	16	4	0	244
	Color Percentages	56%	35%	7%	2%	0%	100%
Open Spaces							
	Color Ratios	5	20	0	0	0	25
	Color Percentages	20%	80%	0%	0%	0%	100%
TOTAL%		35.33%	52.33%	10%	2.33%	0%	100%

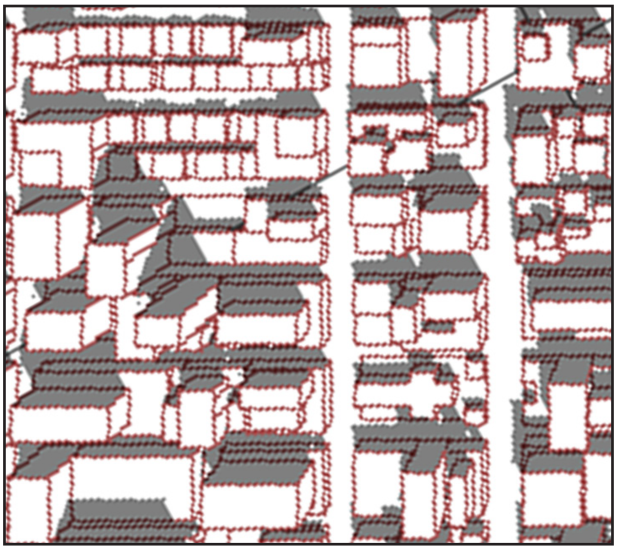
WEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	68	52	7	2	0	129
	Color Percentages	53%	40%	5%	2%	0%	100%
East-West Streets							
	Color Ratios	182	92	12	1	2	289
	Color Percentages	63%	32%	4%	0.3%	0.7%	100%
Open Spaces							
	Color Ratios	17	12	2	2	1	34
	Color Percentages	50%	35%	6%	6%	3%	100%
TOTAL%		55.33%	35.66%	5%	2.76%	1.23%	100%

SOUTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	6	86	26	18	8	144
	Color Percentages	4%	60%	18%	13%	5%	100%
East-West Streets							
	Color Ratios	28	118	24	9	4	183
	Color Percentages	15%	65%	13%	5%	2%	100%
Open Spaces							
	Color Ratios	22	12	5	2	0	41
	Color Percentages	54%	29%	12%	5%	0%	100%
TOTAL%		24.33%	51.33%	14.33%	7.66%	2.33%	100%

GENERAL CONTEXT / SHADOW STUDY / SUMMER

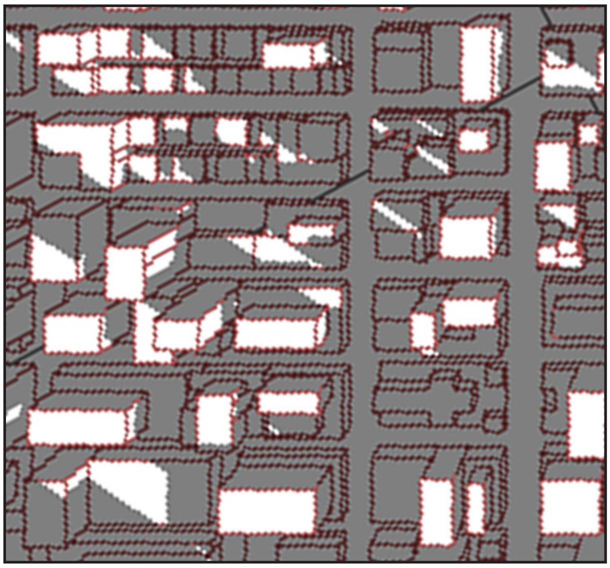


Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	29.6%
Open Spaces	58.9%
Total	32.4%

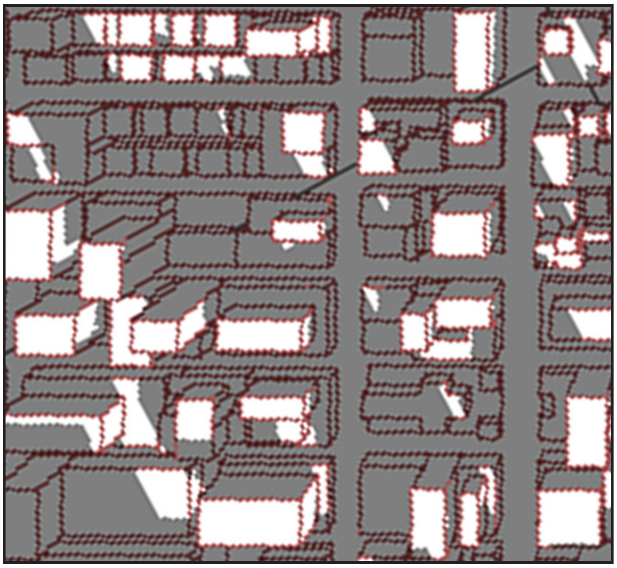


Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	41.7%
Open Spaces	69.7%
Total	44.8%

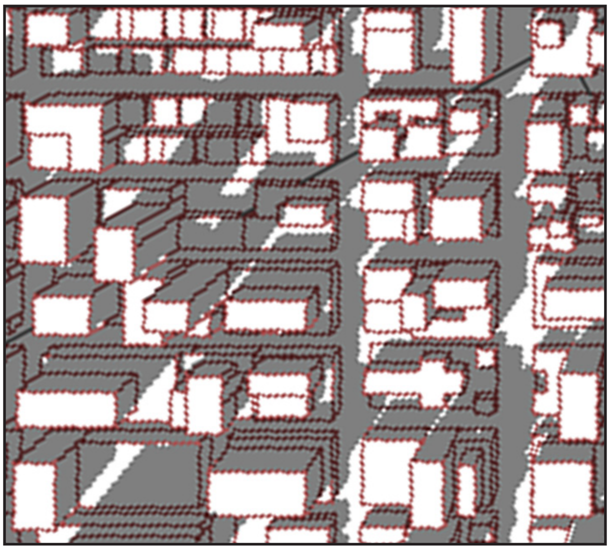
LOCAL CONTEXT / SHADOW STUDY / WINTER



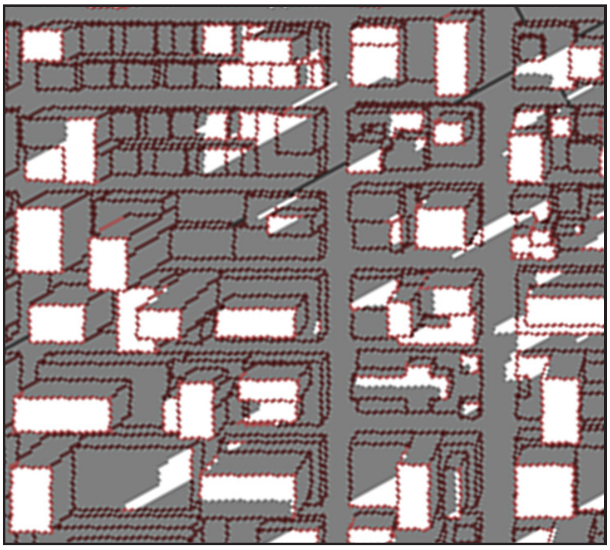
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%



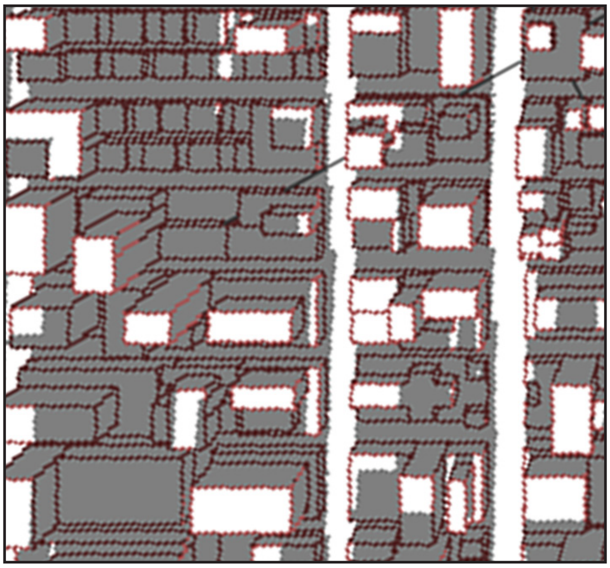
Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%



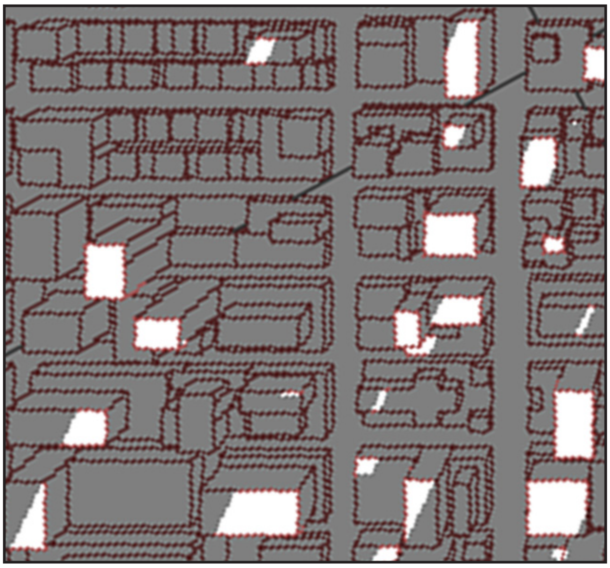
Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	86.5%
Open Spaces	98.2%
Total	88.1%



Inputs	
Location	Barcelona, Spain
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	95.4%
Open Spaces	100%
Total	96.8%

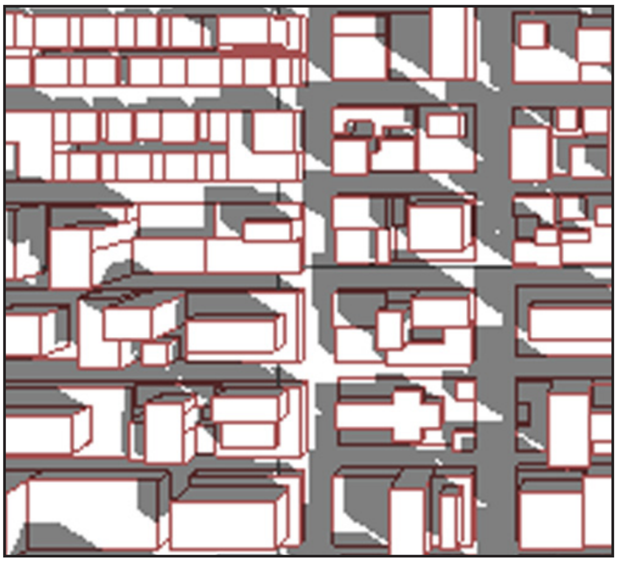


Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	69.9%
Open Spaces	91.3%
Total	74.2%

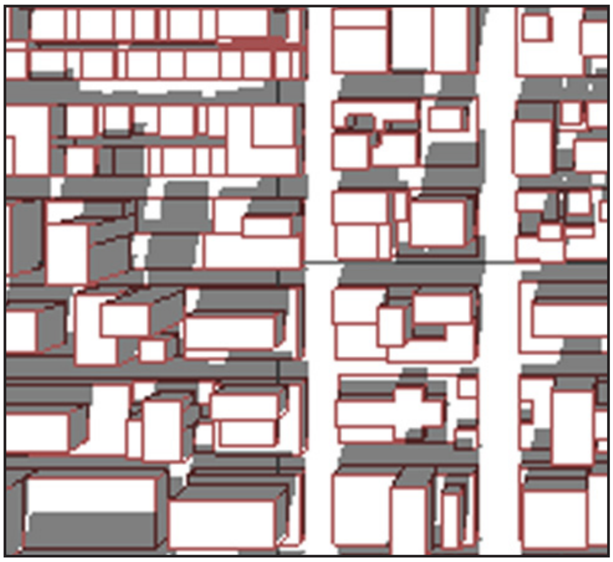


Inputs	
Location	Barcelona, Spain
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

GENERAL CONTEXT / SHADOW STUDY / SUMMER

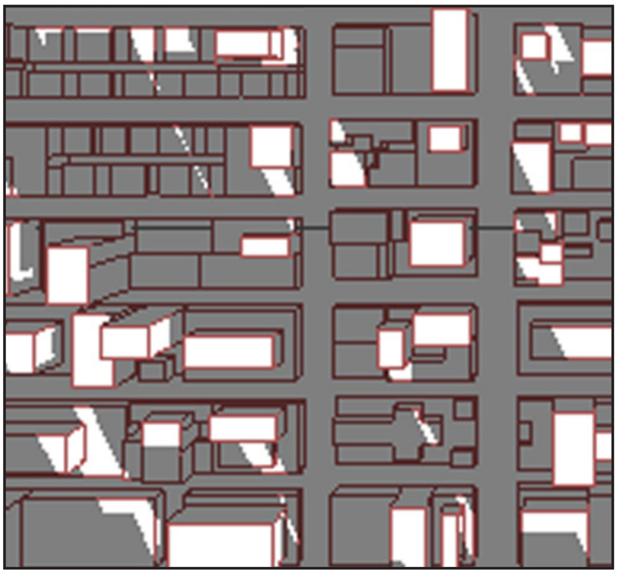


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	66.3%
Open Spaces	76.4%
Total	68.2%

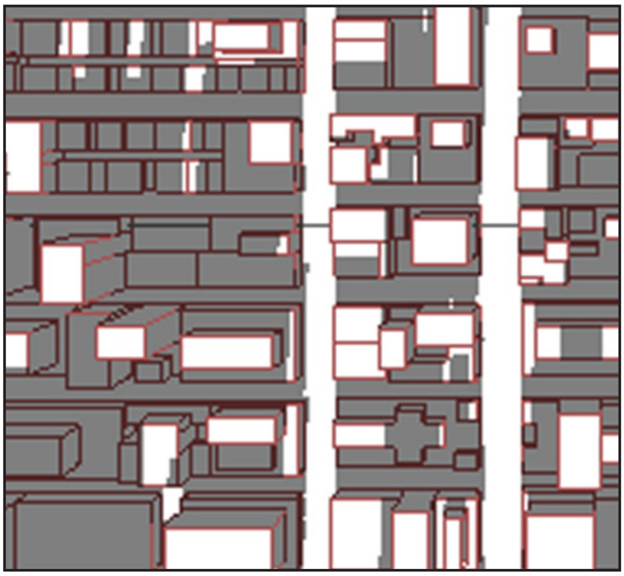


Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	39.8%
Open Spaces	64.2%
Total	43.3%

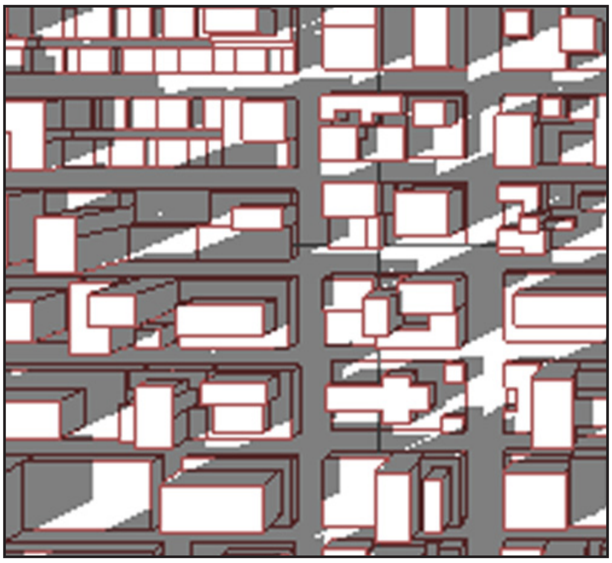
GENERAL CONTEXT / SHADOW STUDY / WINTER



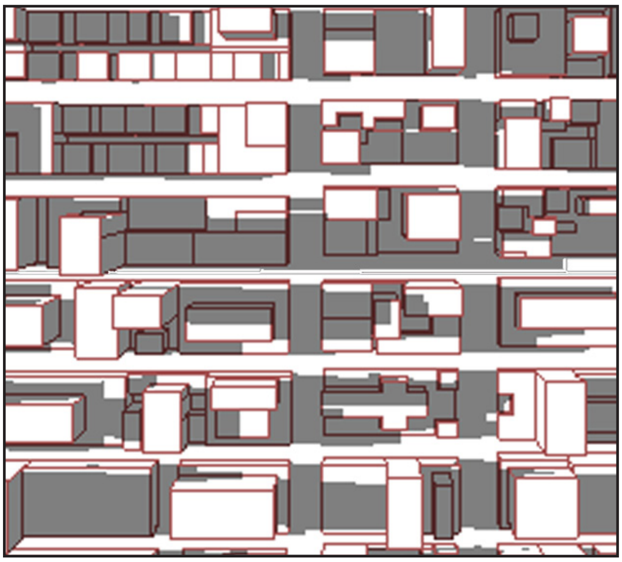
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%



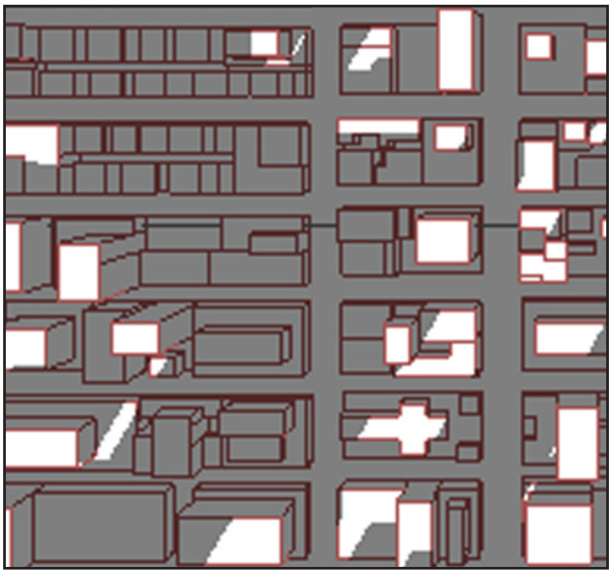
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	65.9%
Open Spaces	89.0%
Total	68.3%



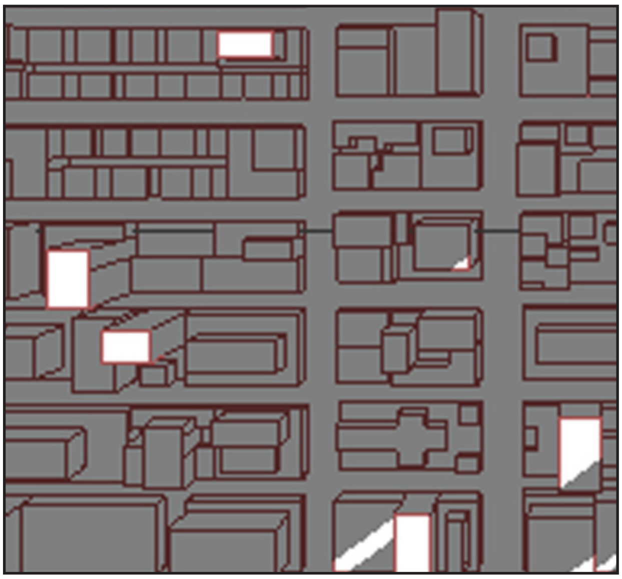
Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	67.3%
Open Spaces	78.9%
Total	69.4%



Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	35.4%
Open Spaces	45.8%
Total	38.5%



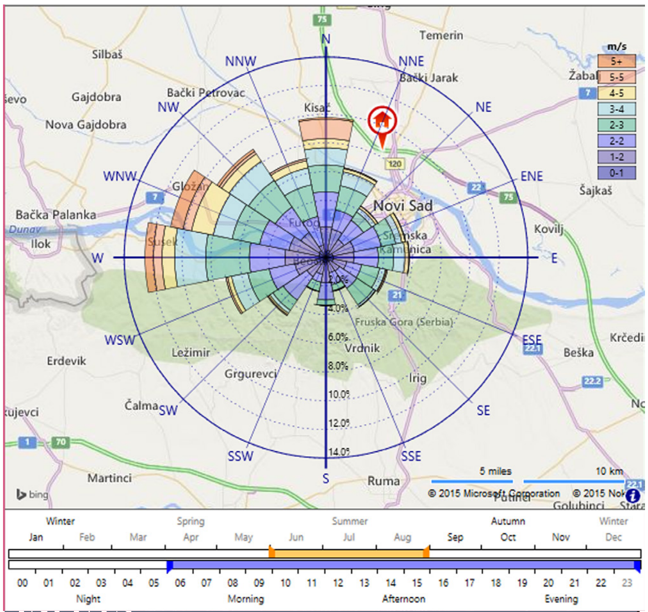
Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%



Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

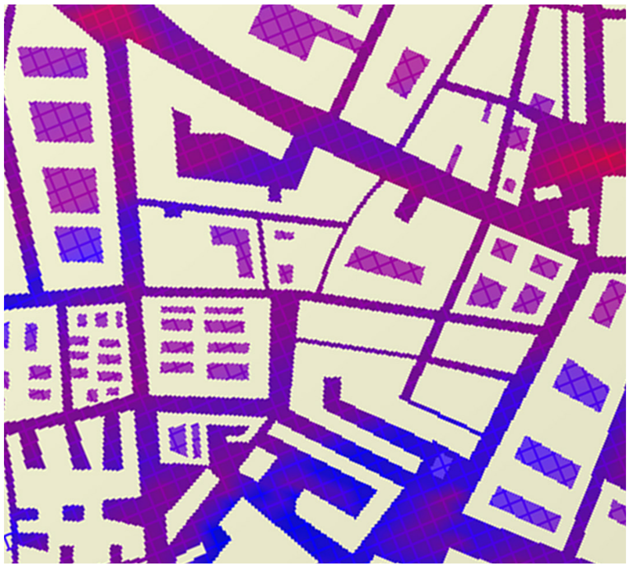
LOCAL CONTEXT / WIND STUDY / SUMMER

WIND ROSE



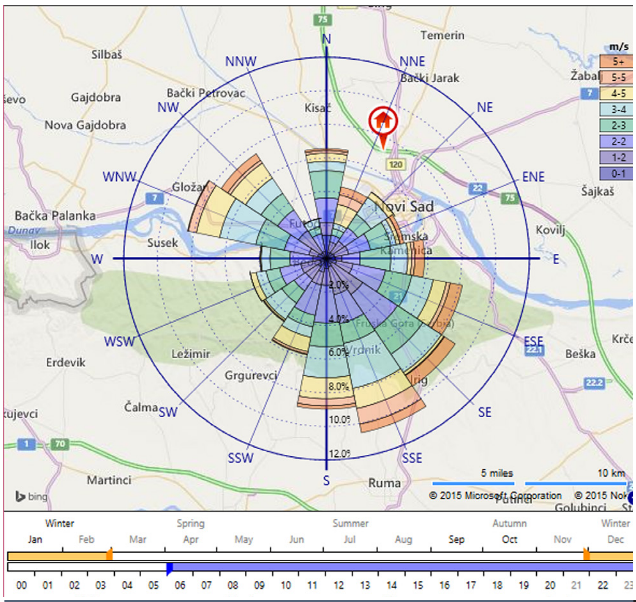
INPUTS	
Location	Novi Sad, Serbia
Time of Year	June - August
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	West
Wind Speed	8+ m/s

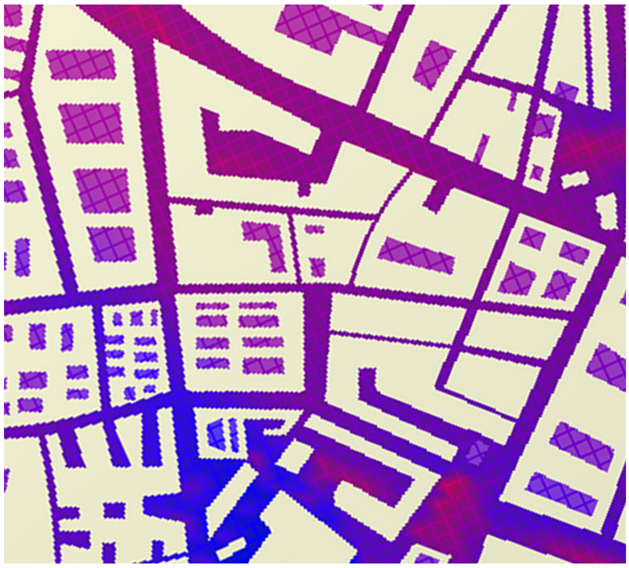
WIND TUNNEL



INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

LOCAL CONTEXT / WIND STUDY / WINTER





INPUTS	
Location	Novi Sad, Serbia
Time of Year	December - February
Time of Day	6-24 hours
OUTPUTS	
Wind Direction	South-Southeast
Wind Speed	8+ m/s

INPUTS		
Wind Direction	South Southeast	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

WIND TUNNEL OUTPUTS

SUMMER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	40	92	8	0	0	140
	Color Percentages	29%	65%	6%	0%	0%	100%
East-West Streets							
	Color Ratios	28	84	0	0	0	112
	Color Percentages	25%	75%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	43	71	12	0	0	126
	Color Percentages	34%	56%	10%	0%	0%	100%
TOTAL%		29.33%	65.33%	5.33%	0%	0%	100%

WINTER WINDSPEED		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios (Num. of cells)	11	90	10	0	0	111
	Color Percentages	10%	81%	9%	0%	0%	100%
East-West Streets							
	Color Ratios	22	68	0	0	0	90
	Color Percentages	25%	75%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	41	73	12	0	0	126
	Color Percentages	33%	57%	10%	0%	0%	100%
TOTAL%		22.66%	71%	6.33%	0%	0%	100%

GENERAL CONTEXT / WIND STUDY / SUMMER

INPUTS		
Wind Direction	North	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

INPUTS		
Wind Direction	Northwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

GENERAL CONTEXT / WIND STUDY / WINTER

INPUTS		
Wind Direction	West	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

INPUTS		
Wind Direction	Southwest	10 m/s
Wind Speed	10m/s	
Height of Horizontal Section	15 units (5m)	0 m/s

NORTH		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	55	48	24	3	0	132
	Color Percentages	43%	36%	18%	3%	0%	100%
East-West Streets							
	Color Ratios	51	89	0	0	0	140
	Color Percentages	34%	66%	0%	0%	0%	100%
Open Spaces							
	Color Ratios	43	71	12	0	0	126
	Color Percentages	34%	56%	10%	0%	0%	100%
TOTAL%		**37%**	**52.66%**	**9.33%**	**1%**	**0%**	**100%**

NORTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	25	107	0	0	0	132
	Color Percentages	19%	81%	0%	0%	0%	100%
East-West Streets							
	Color Ratios	26	110	4	0	0	140
	Color Percentages	19%	79%	2%	0%	0%	100%
Open Spaces							
	Color Ratios	43	71	12	0	0	126
	Color Percentages	34%	56%	10%	0%	0%	100%
TOTAL%		**24%**	**72%**	**4%**	**0%**	**0%**	**100%**

WEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	40	55	1	0	0	96
	Color Percentages	41%	58%	1%	0%	0%	100%
East-West Streets							
	Color Ratios	35	31	12	3	2	83
	Color Percentages	43%	37%	14%	4%	2%	100%
Open Spaces							
	Color Ratios	28	65	11	0	0	104
	Color Percentages	27%	63%	10%	0%	0%	100%
TOTAL%		**37%**	**52.66%**	**8.33%**	**1.33%**	**0.66%**	**100%**

SOUTHWEST		Blue 2m/s	Purple 4m/s	Red 6m/s	Orange 8m/s	Yellow 10m/s	Totals
North-Sourth Streets							
	Color Ratios	50	49	12	0	0	111
	Color Percentages	45%	44%	11%	0%	0%	100%
East-West Streets							
	Color Ratios	34	25	10	0	0	69
	Color Percentages	49%	36%	15%	0%	0%	100%
Open Spaces							
	Color Ratios	29	50	12	0	0	91
	Color Percentages	32%	55%	13%	0%	0%	100%
TOTAL%		**42%**	**45%**	**13%**	**0%**	**0%**	**100%**

LOCAL CONTEXT / SHADOW STUDY / SUMMER

Inputs	
Location	Novi Sad, Serbia
Time of Year	June 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	3.6%
Open Spaces	6.8%
Total	5.2%

Inputs	
Location	Novi Sad, Serbia
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	4.3%
Open Spaces	8.2%
Total	6.8%

LOCAL CONTEXT / SHADOW STUDY / WINTER

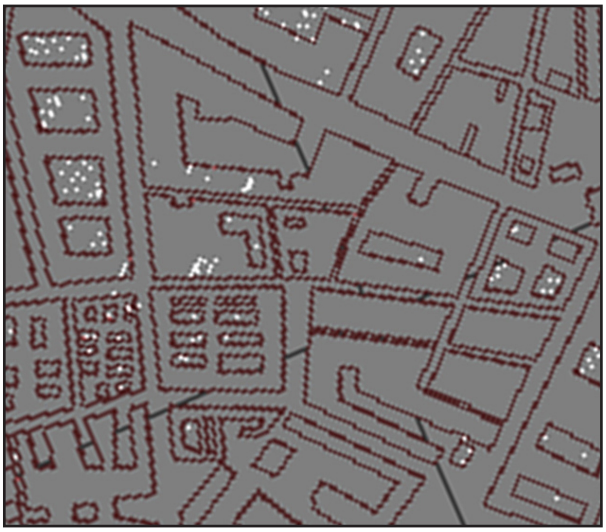
Inputs	
Location	Novi Sad, Serbia
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	38.0%
Open Spaces	62.6%
Total	41.0%

Inputs	
Location	Novi Sad, Serbia
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	32.5%
Open Spaces	56.3%
Total	37.4%

Inputs	
Location	Novi Sad, Serbia
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	11.2%
Open Spaces	17.6%
Total	14.8%

Inputs	
Location	Novi Sad, Serbia
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	28.8%
Open Spaces	37.3%
Total	32.6%

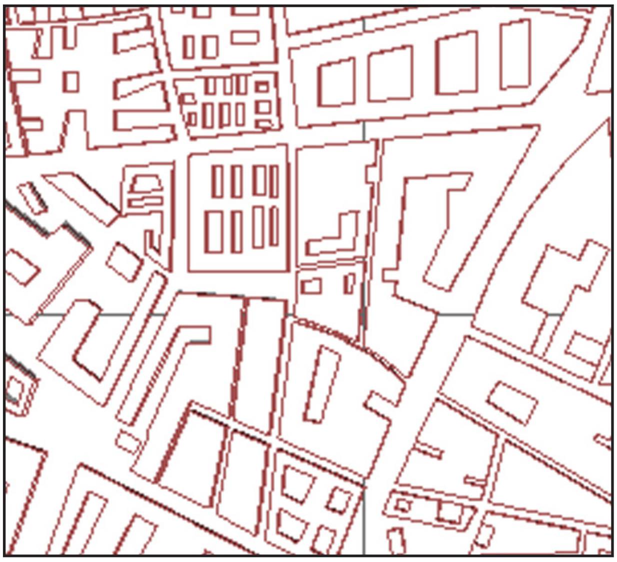
Inputs	
Location	Novi Sad, Serbia
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	42.6%
Open Spaces	68.6%
Total	45.7%



Inputs	
Location	Novi Sad, Serbia
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

GENERAL CONTEXT / SHADOW STUDY / SUMMER

Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	1.6%
Open Spaces	2.8%
Total	2.2%



Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	3.1%
Open Spaces	6.2%
Total	4.8%

GENERAL CONTEXT / SHADOW STUDY / WINTER

Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	10:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	34.2%
Open Spaces	49.1%
Total	41.5%

Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	12:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	24.3%
Open Spaces	38.6%
Total	30.8%

Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	8.2%
Open Spaces	14.6%
Total	10.6%

Inputs	
Location	Boston, MA
Time of Year	June 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	19.8%
Open Spaces	29.3%
Total	23.6%

Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	14:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	38.1%
Open Spaces	53.7%
Total	49.2%

Inputs	
Location	Boston, MA
Time of Year	December 21st
Time of Day	16:00
Outputs	
Shadows in Streets and Open Spaces (%)	
Streets	100%
Open Spaces	100%
Total	100%

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