HUMANIZING STREETS

THE SUPERBLOCKS IN THE EIXAMPLE, BARCELONA

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Msc Thesis Landscape Architecture
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ABSTRACT

People's behavior is affected by the combination of sight, sounds, smells, textures, tastes, and thermal conditions, which can determine how long a place will be used. The built environment, due to its population growth over the centuries and with its consequent reduction of green urban areas, has deprived citizens of many pleasures and introduced new unpleasant sensations. The urban space should diminish these discomforts and affect the human experience positively. Therefore environmental comfort is essential for the design of urban areas.

Furthermore, superblocks, with their priority towards pedestrians and its reduction in air and noise pollution, aim to improve the human experience in the urban environment. The intersections of superblocks bring new functions and uses for citizens. Yet, the design of the intersections of the pilot urban superblock of El Poblenou, Barcelona, has little consideration for microclimatic factors. This situation is more concerning considering that, with the increase in temperature due to climate change, the heat-related issues will increase.

Therefore, the purpose of this thesis is to generate knowledge for the intersections of superblocks, which present a deficiency in providing citizens with a comfortable and positive sensory experience. This thesis fills the knowledge gap by inferring a new multi-sensory approach, which aims towards a pleasurable human experience. First, with the use of techniques and an evaluation matrix, I determined which tools are more efficient for achieving environmental comfort. Then, I generate new knowledge by establishing spatial configurations with different sensory issues. Finally, I determine the integrated strategies for the different types of space of each intersection to produce the final design guidelines. And, with this new approach, unpleasant stimuli can be diminished while pleasant stimuli can be enhanced. These guidelines can be applied in intersections of future urban superblocks all over the Eixample, Barcelona, to improve the multi-sensory experience.

KEYWORDS: *Superblocks, environmental comfort, comfort, expressiveness, techniques, control, masking, enhancing, visual comfort, acoustic comfort, olfactory comfort, thermal comfort, urban microclimate, sense, pleasure, displeasure.*

PREFACE

This thesis is part of the MSc program Landscape Architecture at Wageningen University & Research. With this thesis, I aim to create a more humanized approach for outdoor spaces by integrating the knowledge of the different senses and superblocks. As an architect, I'm inclined to work in urban settings, and as a landscape architect, I am drawn into creating pleasant outdoor public spaces for people to enjoy.

Through my bachelor's and master's studies, I was always interested in thermal comfort and human experience. During my masters, I followed the climate track within my optional courses. In the course "Climate responsive planning and design", I learned about urban climate systems and how to implement climate-sensitive design into urban spaces. This knowledge was essential for this thesis. Additionally, the guidance and advice from Sanda Lenzholzer, my supervisor, during this process were fundamental to achieve this result, which is why I want to thank her for her help.

Also, I am very thankful to the Climatelier group, who helped me with their feedback. A special thanks go to my friends Jian Long, Eleonora Fiorin, Michiel Bakx, Kathrin Merkelbach, Kareena Kochery, Begoña Arellano, Estefania Giesecke, Iris Cornejo, and Gabriel Figari, who helped me with their feedback, support, and patience.

Finally, but not least, I want to thank Carolina del Castillo, Susana Benavides, Catalina Hidalgo, and especially my family for their support during this process.

I hope that with my thesis, I inspire other designers to improve the sensory experience, not only through the visual sense but through the combination of senses to create a more comfortable and pleasurable space for people.

CONTENT

1. INTRODUCTION

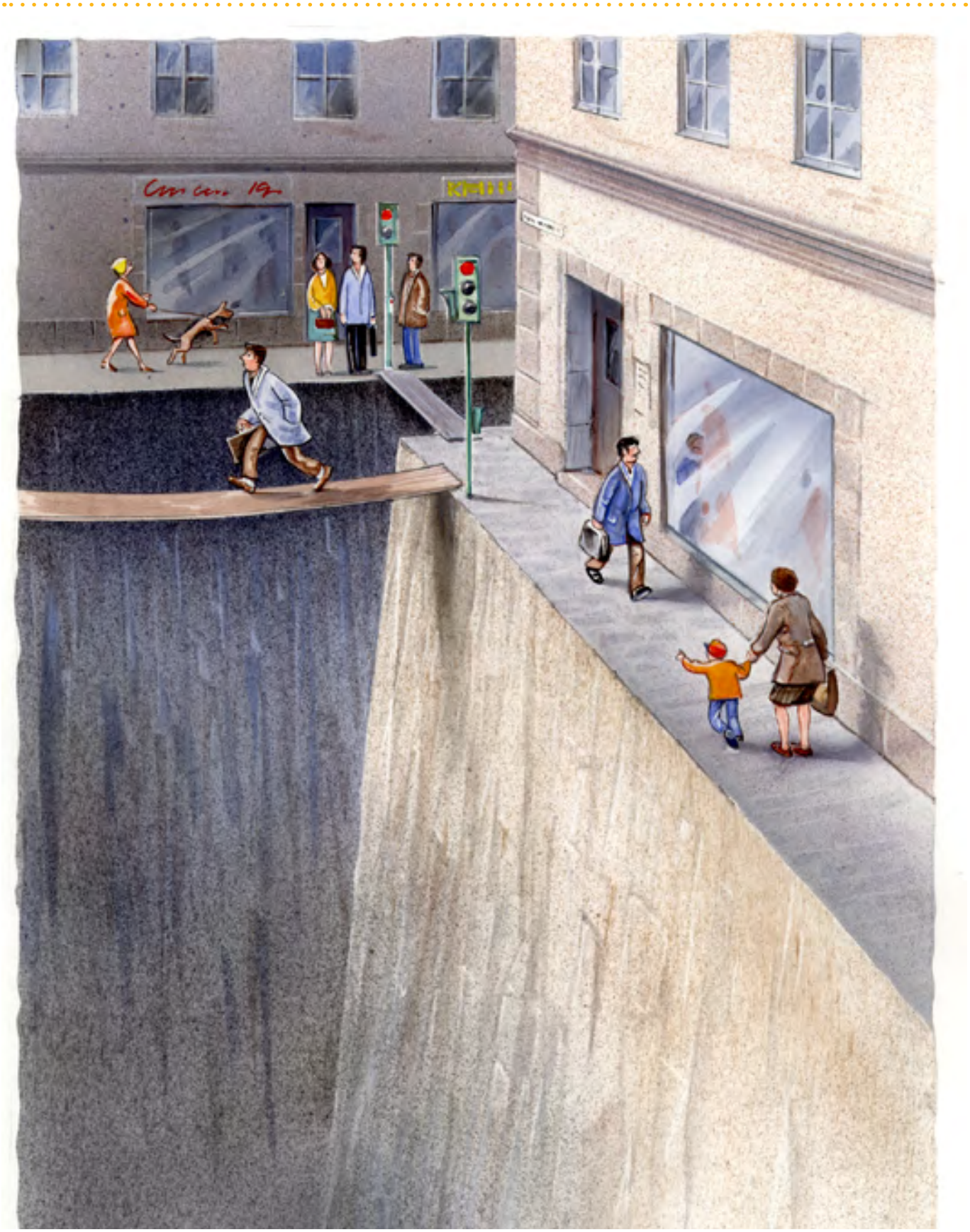


Fig 1.1 Limited amount of space left for pedestrians because of priority towards motorized traffic. Source: (Jilg, 2015)

1.1 INTRODUCTION

Urban environment

Due to the population growth of the eighteenth and nineteenth centuries, the built environment, with its consequent reduction of green urban areas, has deprived citizens of many pleasures and created new unpleasant sensations among the citizens' urban lifestyle (Classen, 2013).

Physical comfort and convenience given by modern technology came with harm towards the inhabitants' physical well-being by contributing to noise pollution, air pollution (Classen, 2013), and an increase in temperature due to climate change (Àrea d'Ecologia Urbana, 2018).

Air pollution is placed as the highest-burden of disease followed by noise pollution (as cited in World Health Organization, 2018). Worldwide, air pollution brings more than 2 million premature deaths each year (World Health Organization, 2006). Furthermore, noise pollution generated by traffic affects at least 100 million people in the European Union, leading "to auditory effects such as hearing loss and tinnitus" (World Health Organization, 2018, p. 1). Moreover, an increase in temperature can affect citizens in health and in quality of life by increasing mortality in vulnerable population, the emergence of new sicknesses, and by producing heat stress among citizens (Àrea d'Ecologia Urbana, 2018).

Currently, more than half of the world's population lives in an urban environment. It is expected that this tendency to move to urban areas will increase substantially in the following decades (Ruijsunk, 2015), aggravating the previously mentioned issues if nothing is done. For these reasons, cities need to become more environmentally friendly, giving to pedestrians and cyclists more public space.

Cities as sensescape

Classen (2013) mentions,

> Whether deliberately planned as such or not, cities are inevitably "sensescapes"- landscape of sound and sights, smells and textures, and the flavors of its characteristic foods. As we rethink urban design within a context of ecological sustainability, we need to look for urban models that can fruitfully sustain our sensory lives. (p. 176)

People experience the city every day, which makes sensory experience essential when designing the urban environment (Degen & Rose, 2012). The combination of sights, sounds, smells, textures, tastes, and thermal conditions creates the experience and ambiance of urban space (as cited by Wankhede & Wahurwagh, 2016), which affects people's behavior. Additionally, open public spaces are exposed to the increase in temperature (Wilson *et al.*, 2007); traffic noises; bad odors; and visual discomfort. Many urban designs of public spaces are developed disregarding the aforementioned problems, with little consideration for climate (Djekic *et al.*, 2018), sonic, tactile, and olfactory factors (Classen, 2013).

Comfort in the built environment

Comfort is one of the most important criteria for creating quality spaces (Djekic *et al.*, 2018). The most influential factor that determines the level of comfort of users of public space is thermal comfort. Thermal comfort can influence how often inhabitants use open space and do outdoor activities (Djekic *et al.*, 2018).

Thermal conditions in urban areas are influenced by the physical shape of the immediate environment, leading to different microclimates (Hirashima et al., 2018). Increase in temperature and extended heatwaves can have an impact on pedestrians' outdoor comfort, having a negative effect on citizens health (Piselli et al., 2018). Additionally, an outdoor environment presenting thermal stressful situations can provoke people to use climatically controlled vehicles, increasing energy consumption, and pollution. (Pearlmutter et al., 2014). Use of climatically controlled vehicles contributes to an increment on motorized traffic. As a consequence, there is a loss of public spaces of importance to pedestrians (as cited by Cortesao *et al.*, 2009)(Figure 1.1).

A new model for the city

As a response to the noise and air pollution issues, the increase of temperature, and the loss of public space, Salvador Rueda, director of BCNecologia, the agency of ecology of Barcelona, created a new urban model called superblock (Rueda, 2016). Superblocks consist of an area limited by major arterial roads and deal with some of the main urban issues. Strategies of the superblocks include removing cars to reduce air and noise pollution and considers increasing the amount of green area in the city (Rueda, 2016). These strategies aim towards a more environmentally friendly city, giving space for a new sensescape to be developed.

1.2 THEORETICAL FRAMEWORK

The theoretical framework explains, first, the concept of environmental comfort, its connection with the senses, its values, and describes how to achieve environmental comfort values with each sense. Then it explains the concept of the superblock, with its differences between models, phases, and components.

1.2.1 Environmental comfort

Environmental comfort can be defined as utilizing "comfort criteria in the design of built environment - in particular, in terms of heat, light, and sound" (Ong, 2013, p. 1). Within the scientific community, the term environment is used for large scale, and comfort is used to refer to human experience, it is more personal. Environmental comfort is in-between those concepts (Ong, 2013), it is the experience between the body and the built space.

As mentioned by Wankhede & Wahurwagh (2016):

> The ambiances of urban spaces are created and experienced as a product of different, sometimes unique, blends of sights, sounds, smells, textures, tastes and thermal conditions (Thibaud, 2011), resonating with our individual and collective memory. (p. 741)

According to Cabanac (2013), there are four dimensions to sensations: quality, intensity, duration, and pleasure/displeasure. The qualitative dimension helps understand the nature of the stimulus, it identifies its color, shape melody, between others. The dimension of intensity helps to determine how strong the stimulus is, for instance, the intensity of a sound, brightness of a light, accumulation of odors, among others. The third dimension is related to time, and it describes the duration of the stimulus. Finally, the fourth dimension is pleasure/displeasure, this dimension helps understand the usefulness of a stimulus.

The senses help us experience the built environment with different spatial ranges (Figure 1.2). For instance, vision and hearing can sense a distant stimulus, while smell, touch, and taste require a closer range (Wankhede & Wahurwagh, 2016).

Senses usually are studied as individual systems, nevertheless "there is an interplay between the senses." (Clements-Croome, 2013a, p. 40)

Heschong (1978) mentions that as more senses are involved in an experience, the richer it becomes. This experience happens because each sense gives us different impressions from the world, combining them at once would create "the most powerful experiences" (Heschong, 1978, p.41).

Amongst professionals in urban design, architecture, and landscape architecture, there is a bias towards the visual sense. This situation neglects the other senses, such as tactile sense, the sense of movement, the sense of smell, taste, and temperature (Lucas & Romice, 2008).

Values of environmental comfort

As part of his contribution, Schmid (2005) presents in his book, *A Idéia de Conforto: Reflexões Sobre o Ambiente Construído*, an alternative approach to environmental comfort. It consists of three values: comfort, adequacy, and expressiveness.

The value of comfort is considered as the absence of pain. In a physical context, the relationship between elements, like the air, light, sound, heat, or surfaces, and the body should not cause any suffering (Schmid, 2005). Comfort then becomes "the state of physiological normality and of indifference towards the environment" (Cabanac, 2013, p. 22). As long as the subject and the environment remain in stable conditions, it can be said that comfort is in a steady-state (Cabanac, 2013).

The second value, known as adequacy, is the adaptation of the environment, by reducing some levels of comfort, to increase productivity. This value relates to the workplace (Schmid, 2005). With the right working environment, employees can have a sense of well-being, be comfortable, and get inspired (Clements-Croome, 2013b), making them more productive.

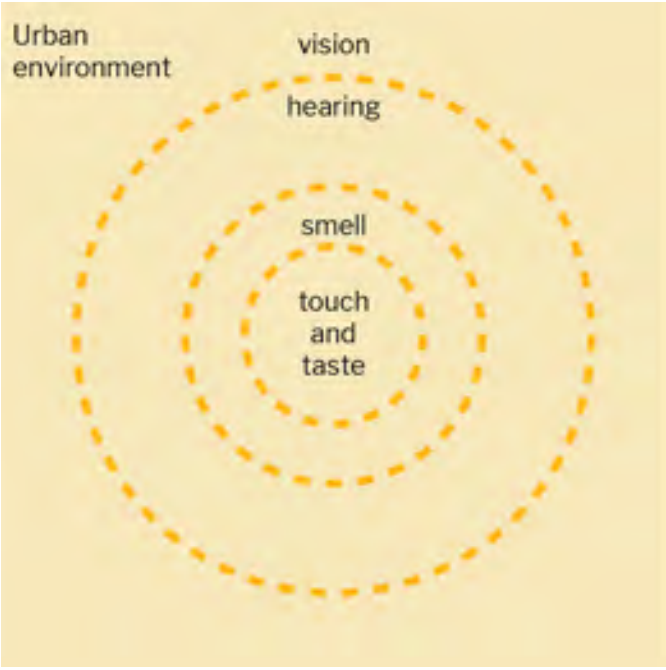


Fig 1.2 Range proximity of senses in an urban space
Source: Based on Wankhede & Warhurwagh, 2016

The last value is the one of expressiveness, which relates to pleasure (Schmid, 2005). Pleasure is limited and it can be achieved through chemical, thermal, and mechanical stimuli (Cabanac, 2013). When a stimulus is useful it can arouse pleasure, however, it is temporal, and it will last "as long as the physiological state has returned to normal" (Cabanac, 2013, p. 22).

With these values, environmental comfort can obtain a new meaning of enjoyment (Schmid, 2005). Although these values are meant for the inside of buildings, comfort and expressiveness are values that should also be achieved in outdoor public space.

Sensory experience within environmental comfort

People experience space through their senses (Schmid, 2005; Wankhede & Wahurwagh, 2016). According to Aristotle's division, five senses collect information: sight, hearing, smell, taste, and touch (Malnar & Vodvarka, 2004). Nonetheless, the scientific community recognizes more senses, some are associated to touch, such as cold, warm, pressure and pain; other associated to hearing, such as the sense of equilibrium (Schmid, 2005).

In this section, I will discuss the comfort and expressiveness according to the senses of sight, hearing, smell, and temperature. The senses of touch and taste will not be addressed since they have different ranges and scale than the other senses.

Visual comfort and expressiveness

Sight is the dominant sense, allowing to gather more information and stimuli from the environment (Carmona *et al.*, 2010; Schmid, 2005). Through sight, humans can learn to identify objects, materials, places, and patterns (Schmid, 2005). "Visual perception is also a highly complex phenomenon and relies on space, distance, colour, shape, textural and contrast gradients, etc." (Carmona *et al.*, 2010, p. 111).

For visual comfort, the optimum is to see without stress or hurting the eyes. Neutral stimuli can be achieved by adjusting the absolute and relative levels of glare (Schmid, 2005). Five situations can cause glare: "Unusually clear facades, unusually dark facades, clear furniture, translucent roofs and clear ground material" (Compagnon & Goyette-Pernot, 2004, p.3).

A strategy used to control glare disability is the use of shadows (Corica & Ruiz, 2018a). There is no recognized international standard for visual comfort (Ong, 2013).

Sight also considers the aesthetic part of space.

Therefore a strategy to improve sensory experience for sight could be to use pleasurable elements to mask "ugly" visuals of a scene (Thayer & Atwood, 1978). As cited by Lopez-Martinez (2017), there are visual preferences towards many general landscape attributes such as "water features (Arriaza *et al.*, 2004; Wu *et al.*, 2006), vegetation (Misgav, 2000; Dramstad *et al.*, 2006), cultural man-made elements (Bulut and Yilmaz, 2008; Arriaza *et al.*, 2004; Tempesta, 2010), [and] slopes (Bulut and Yilmaz, 2008; Bishop and Hulse, 1994)" (p. 206).

To achieve expressiveness, these natural elements could also be used to increase pleasurable sensations towards a place.

Acoustic comfort and expressiveness

Hearing allows to monitor the environment. It can help identify presences, constants, sudden changes, and dangers (Schmid, 2005). Sounds relate to the time dimension (Schmid, 2005), "a song, or a melody, to be remembered, must be remembered in time" (Heschong, 1978, p. 41).

There are two approaches to the outdoor acoustic environment: environmental noise management and the soundscape approach. Environmental noise management relates to the value of comfort, considers sound like a waste product from the environment, it can be removed or reduced. The soundscape approach relates to the value of expressiveness, focuses on the more subjective listener-centered model. (Brown *et al.*, 2015)

There is a standard for city noise levels established by the World Health Organization (WHO). In the case of traffic, the average noise exposure during the day should be below 53 dB (World Health Organization, 2018).

Acoustic comfort can be achieved through three strategies: control, mind masking and sound masking.

"Control" refers to managing a sound, it relates to the environmental noise management approach, where the sound is reduced or eliminated. "Control" is directed towards sounds that generate discomfort, and that affects the health of the citizens. Nevertheless, the reduction or elimination of a sound will happen without consideration towards a wanted or unwanted sound, which could reduce or eliminate those that contribute to the well-being of the citizen. (Bento Coelho, 2015). Therefore, "reducing sound levels does not necessarily lead to improved quality of life, especially in urban areas." (Bento Coelho, 2015, p. 202).

Noise control should be used when unwanted sounds are possible to eliminate or reduce, especially ones related to traffic or other mechanical sources (Bento Coelho, 2015).

The next strategy is mind masking, which distracts the listener, with a pleasant sound or element, from the source of discomfort (Bento Coelho, 2015). For instance, the use of silent water features can produce mind masking. The masking effect of the element is achieved by diverting attention with the visual effect of the silent water feature (Hao, 2014).

Sound masking, as the following strategy, has a similar response, nonetheless, instead of using an element to distract, sound masking uses or enhances preferable sounds. (Bento Coelho, 2015)

To achieve expressiveness, pleasant sounds can be introduced into the environment.

"Enhance" is a strategy that increases the levels of wanted sounds. People mainly prefer human noises, such as people talking, or natural sounds, such as moving water, wind, and birds (Bento Coelho, 2015).

Olfactory comfort and expressiveness

According to Schmid (2005), smell is the most primitive and fundamental sense, since it cannot be suppressed. It is emotionally rich (Carmona *et al.*, 2010) since smells are connected to memories, and its vital function is identification (Schmid, 2005). Smell can complete contextualization for the other senses (Schmid, 2005). It is essential to know that warm weather can increase the intensity of an odor. Additionally, at a micro-level, a person can detect smells, due to its intensity, in localized points in space and time (Henshaw, 2013).

Henshaw (2013) establishes four strategies to improve the olfactory experience. Three strategies can be categorized as olfactory comfort: separation, deodorization, and masking.

Separation considers the physical separation of odors, such as relocation of industry away from the city center; through displacement, for instance, a pedestrianized street; through ventilation or mechanical means, such as chimney; and temporal separation during season changes (Henshaw, 2013).

The strategy of deodorization aims at removing or reducing odors of dirt or waste, this is managed through a range of jobs, such as, maintenances activities. This strategy can be achieved by people or through vegetation. Trees and plants can help deodorize the environment through their ability to absorb pollutants. Additionally, water is believed to also have a cleansing and refreshing effect on the air (Henshaw, 2013).

Masking reduces the perceived intensity of an odor by introducing another smell. This reduced intensity of an odor does not mean that one will be eliminated, it just creates a combination of scents. Trees and plants can be considered for masking since it has a perceived ability to reduce other odors (Henshaw, 2013).

Olfactory expressiveness can be achieved through the strategy of scenting.

Scenting means to introduce an odor due to its specific qualities or characteristics. A smell can be added with aromatic trees and plants, which increases the perceived odors positively; and water elements, which are known to bring 'freshness' and cleanse the air. These elements are appreciated by people (Henshaw, 2013).

Thermal comfort and expressiveness

Thermal comfort happens when individuals feel no need to adjust their environment, alter their clothing or activity levels (Oke *et al.*, 2017). There are three factors that influence thermal comfort: 1) the individual physical and physiological factors, which cannot be altered through urban design; 2) external physical stimuli, which can be influenced with the built environment; and 3) psychological, which can also be changed through urban design (Lenzholzer, 2015).

Outdoor spaces have less human control and present a more variable climatic conditions (Oke *et al.*, 2017; Nikolopoulou & Steemers, 2003). Thermal conditions in urban areas are influenced by the physical shape of the immediate environment, which can lead to different microclimates (Hirashima *et al.*, 2018). Due to urban configuration, air temperature in cities can rise to 1º Celsius. Also it loses up to 10% of relative humidity, and wind speed can decrease between 30 and 50% (Lenzholzer, 2015). The increase of temperature, the loss of humidity, and the decrease in wind speed will have an impact on outdoor comfort.

Comfort and expressiveness can be achieved by influencing four variables in the built environment: air temperature, wind velocity, air humidity, and direct or reflected radiant heat sources (Schmid, 2005). The factors that influence the most the perceived difference are wind and solar radiation (Rodríguez Algeciras & Matzarakis, 2016). There is a wind criterion established by the American Society of Civil Engineers (ASCE) for different levels of activity (Table 1.1) (Oke *et al.*, 2017). Furthermore, many thermal indices have been established, one of them is the PET index, which illustrates "the importance of the radiation environment to human (dis)comfort in the outdoors" (Oke *et al.*, 2017, p. 402). There is a PET index table for the climate region (Cohen *et al.*, 2013) of Barcelona.

Besides the climatic conditions, the response towards a stimulus is both physiological and psychological. For instance, one way to suggest thermal sensation is through the visual sense (Schmid, 2005), by using warm colors in the Dutch context, it can enhance the feeling of thermal comfort (Lenzholzer & van der Wulp, 2010).

Thermal comfort can be achieved by influencing sun and shade, which has a significant effect on people experiencing temperature. This effect can be attained by using elements that cast shadows (Lenzholzer, 2015). It is important to remember that shadows are not static in time; therefore, the shadows need to be considered through a time-lapse.

Another strategy is to influence evaporation. It is less efficient than influencing shadows, nevertheless, it can be achieved through the evapotranspiration of plants, through water elements and the water of the soil (Lenzholzer, 2015).

A third strategy is to influence reflection of shortwave radiation, or albedo. The use of certain materials can have an impact on the storage of heat. Influencing reflection by using lighter colors can have a significant effect in lowering surface temperature. Nevertheless, using a significant amount of materials with high albedo will increase the reflection of shortwave radiation onto the people. Therefore, it is better to use this strategy when there are no other options (Lenzholzer, 2015).

A fourth strategy is to influence emissivity and conductivity. Using materials that store less or more heat can also have an impact on the urban energy balance.

ACTIVITY	COMFORT RANGES (MS^{-1})
Sitting	0 - 2.5
Standing	0 - 3.9
Walking	0 - 5.0

Table 1.1 wind criterion from ASCE
Source: based on Oke *et al.*, 2017

Materials store heat and transfer it at different speeds and extents. Depending on the situation, the designer should choose the material that works best, such as a material that stores less heat in a summer situation (Lenzholzer, 2015).

A final strategy is to slow wind. Wind can be diminished in situ (Lenzholzer, 2015). Slowing wind can be achieved by adding different elements in its typical direction.

Expressiveness can be achieved by ventilation, which relates to channel and guide wind towards the desired location (Lenzholzer, 2015).

Techniques to improve environmental comfort

By linking the different strategies per sense, three techniques can be applied to help improve environmental comfort: "Control", which is defined as removing or reducing the problem; "Masking", which reduces or blocks the perceived intensity of the problem by adding something; and "Enhancing", which adds something for its specific qualities or characteristics.

Control and masking relate to the value of comfort while enhancing relates to the value of expressiveness. Each sense have different strategies that will help achieve comfort and expressiveness (Figure 1.3).

For the visual sense, according to Compagnon & Goyette-Pernot (2004), glare discomfort occurs when there is too much brightness or too much contrast. A strategy to solve this issue is visual comfort. This strategy can be within the technique of control.

Furthermore, according to Robinette (1972), vegetation elements can be used to mask "ugly views", therefore it can be within the technique of masking. In addition, the evolutionary theory, considers that vegetation and water elements are seen as pleasant since they are favorable for human survival (Appleton, 1975; Kaplan & Kaplan, 1989). This strategy can be used for enhancing (Table 1.2).

For the acoustic sense, Bento Coelho (2018), establishes noise control, mind masking, sound masking, and enhance as strategies to improve the human experience. Noise control can be within the technique of control, mind and sound masking will continue within the technique of masking and enhance will be within the technique of enhancing (Table 1.2).

The olfactory sense considers separation, deodorization, masking and scenting as strategies to deal with odors. Separation and deodorization can be within the technique of control, masking will continue within the technique of masking, and scenting will be within the technique of enhancing (Table 1.2).

The thermal sense uses six strategies to improve human experience. These six strategies can be within control, with the strategies of slowing wind, reflectivity, and emissivity and conductivity; masking, with the strategies of evaporation and shading; and enhancing, with the strategy of ventilation (Table 1.2).

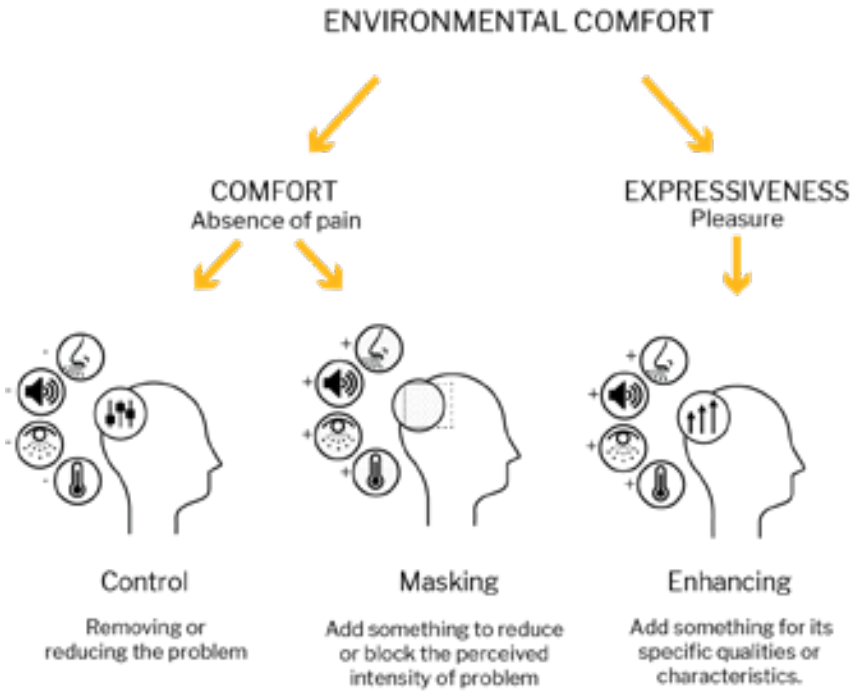


Fig 1.3 Techniques explanation according to thermal and visual comfort

SENSE	NEW TECHNIQUES	STRATEGIES	EXPLANATION	SOURCE
Visual sense	Control	Glare control	Disability or discomfort glare occurs when the field of view contains too large luminance values or too large luminance contrasts.	Compagnon & Goyette-Pernot (2003)
	Masking	Masking	Relative to screening, control or heighten aesthetic pleasure	Robinette (1972)
	Enhancing	Enhance	Introduce preferred visual in context. Landscape characters favorable to human survival, such as water and plants, have a great consensus in aesthetics judgment.	Evolutionary theory, Appleton (1975) and Kaplan and Kaplan (1989)
Acoustic sense	Control	Noise control	When and where is possible to reduce or eliminate unwanted sounds	Bento Coelho (2018)
	Masking	Mind masking	The attention of the listener is diverted to other sounds that are found more pleasant.	
		Sound masking	Enhancing or introducing sounds of preference that will mask unwanted sounds components.	
	Enhancing	Enhance	Introduce preferred sounds in context	
Olfactory sense	Control	Separation	The spatial or temporal separation of odors through planned activity or displacement	Henshaw (2013)
		Deodorization	The planned removal of odors of dirt or waste of one form or another	
	Masking	Masking	The overlaying of one odor with another (focus on hiding or changing original odors)	
	Enhancing	Scenting	The introduction of an odor for its specific odor qualities or characteristics (focus on introduced odors)	
Thermal sense	Control	Reflectivity	Avoid materials with high albedo, since it will increase the reflection of shortwave radiation onto the people.	Lenzholzer (2015)
		Emissivity and conductivity	For warm places, use different materials that don't store heat	
		Slowing wind	Slowing wind or create protection	
	Masking	Evaporation	Use of vegetation or water elements to lower air temperature through evaporation	
		Shading	Influence sun and shadow pattern	
	Enhancing	Ventilation	Channeling wind and guiding it to the desired locations	

Diminish stimuli | Enhance stimuli

TABLE 1.2 TECHNIQUES EXPLANATION ACCORDING TO EACH SENSE

1.2.1 Superblocks

A superblock consists of an area limited by major arterial roads. Superblocks come in different shapes and sizes. The interior of the superblock will present urban blocks and local streets (Peponis *et al.*, 2017). These local streets are usually dead-ended or looped (Salat, 2017).

Original superblocks vs. new model

The original superblocks were introduced in the 1920s by Le Corbusier (Salat, 2017). These superblocks create large and homogenous cells in the urban fabric (Monson, 2008); therefore, there is a car dependency with this model and discouragement towards walking (Salat, 2017). Also, "because the typical superblock morphology is cellular, it is not a type that blends well with its environment, and it inherently tends to diminish the possibility of cohesive public space or the stewardship of natural systems» (Monson, 2008, p. 47).

These types of superblocks can be found all over the world. Examples include cities such as Chandigarh, Punjab, India; Brasilia, Brazil; New York, United Stated; Islamabad, Pakistan; Milton Keynes and Netherfield, England; Gangnam, Seoul (Peponis *et al.*, 2017), among others.

Nowadays, a new type of superblock has emerged, one that is part of the current urban context, and that has different challenges to solve. Salvador Rueda, director of BCNecologia, the agency of ecology of Barcelona, introduced this superblock as part of a mobility plan, and him and his team have improved upon it for 20 years (Echave, 2019). In this superblock, motorized vehicles cannot pass through the unit turning the inner streets into neighbor streets (Rueda, 2016; Echave, 2019). The new function of the inner streets will free 70% of the space for pedestrians and bicycles, and the intersections or nodes will have new uses and functions for citizens (Rueda, 2016).

This type of superblock has been implemented in various cities such as Buenos Aires, Argentina; Quito, Ecuador; Barcelona, Madrid, and Vitorio-Gasteiz, Spain (Rueda, 2016).

It is crucial to understand that the superblock defined by Le Corbusier is not the same as the one described by Salvador Rueda. Le Corbusier implemented his superblock into new urbanizations, and it was made for traveling distances by car, while the ones of Salvador Rueda are executed in an existing urban context and it gives space back to the pedestrians. Even though, both models share the same essential elements, it has opposing urban contexts and aims towards different usage of space.

This thesis will focus on the new superblock model in Barcelona, Spain.

Environmental comfort in the new superblock model

Superblocks in Barcelona have as a primary objective to humanize streets (Ajuntament de Barcelona, n.d.b.). To humanize means "to make something less unpleasant and more suitable for people" ("Humanize", n.d.). It implies using different strategies to reach an outcome that would affect the human experience positively. In superblocks, to humanize streets, they implement strategies of noise and air pollution reduction, and strategies to improve pedestrian mobility.

Noise pollution reduction

Noise pollution is one of the most significant issues for the superblock project (Rueda, 2016; Podjapolskis, 2017). It has been established by Rueda (2016), that in the district of the Eixample only 54% of the people lives within the standards for city noise levels established by the World Health Organization (WHO). With the superblock project, people living within the standards for city noise levels will increase up to 73,3% (Rueda, 2016).

Air pollution reduction

Another significant issue is air pollution. It is intended that, with the superblock, the number of people exposed to admissible levels will increase from 56% to 94%, hoping to reduce premature deaths and other health problems related to this issue (Rueda, 2016).

Pedestrian mobility

Salvador Rueda (2016), proposes to introduce speed limits for cars inside superblocks, to make them pedestrian-friendly. Pedestrian mobility is managed by reducing noise pollution, avoiding accidents by separating transport modes, combining sojourn activities with shops, and reducing architectural barriers like height difference in the street pavement (Podjapolskis, 2017).

Implementation of superblocks

Before implementing the superblocks, according to Rueda (2016), it is essential to redesign and implement new public transport and bicycle network following the grid of the basic network. The objective of the basic network is to cover distances in less amount of time (Rueda, 2011).

Superblocks in Eixample consists of an area of three by three blocks, 400 by 400 meters (Rueda, 2016). Traffic inside the superblock is restricted to pedestrian speed, and outside the superblock, on the perimetrical streets, also known as basic streets, the speed limit is 50 km/h (Podjapolskis, 2017; Echave 2019). Besides, vehicles cannot cross the superblock (Rueda, 2016; Echave 2019). The priority is for bicycle and pedestrians, although everyone is permitted, as long as they respect the speed limit (Echave, 2019).

There are two phases for the superblocks, phase 1 with the functional superblock and phase 2 with the urban superblock (Echave, 2019).

The difference between functional superblocks and the urban superblocks is that the speed limit in the inner streets is 20 km/h for the functional superblock and 10 km/h for the urban superblock (Figure 1.4) (Echave, 2019). Additionally, functional superblocks have temporary low-cost interventions. In figure 1.6, it can be seen that the implementation includes painting on floors and small trees in pots. While urban superblocks require more investment, maintenance, and is a more permanent solution. Figure 1.7 shows that the implementation includes a change of surface, bigger trees, and other types of vegetation. It is crucial to know that the urban superblock will have a more significant impact on humanizing the streets, which is why this second phase of the superblock is chosen for this thesis.

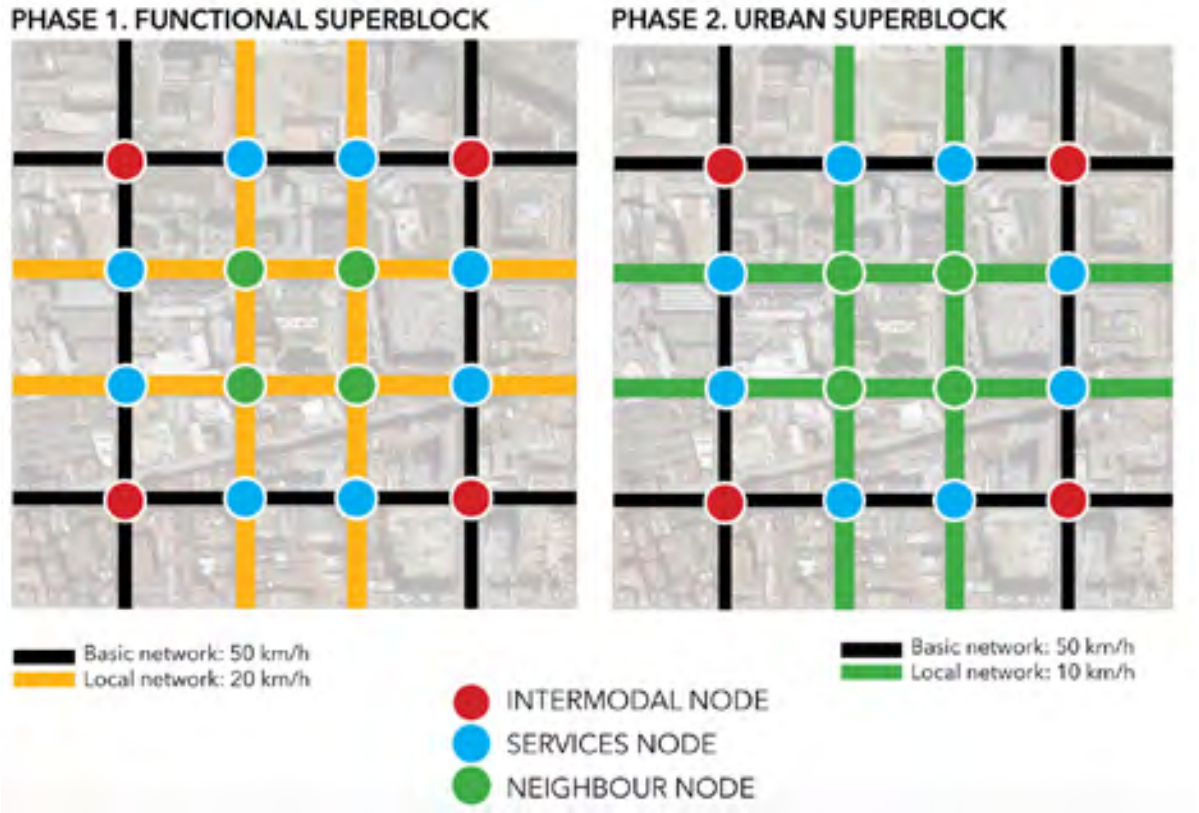


Fig 1.4 functional and urban superblock
Source: Echave, 2019

Fig 1.5 Before superblocks in El Poblenou
Source: Ajuntament d' Barcelona, 2018

Fig 1.6 Phase 1 functional superblock in El Poblenou, with speed limit set at 20 km/h. Functional superblocks have temporary low-cost interventions and it includes painting on floors and small trees in pots.

Source: Ajuntament de Barcelona, 2018

Fig 1.7 Phase 2 urban superblock in El Poblenou, with speed limit set at 10 km/h. Urban superblocks includes more permanent solutions such as change of surface, bigger trees, and other types of vegetation.

Source: Ajuntament d' Barcelona, 2018

Spatial composition of the superblock

The superblock is composed of roads and nodes (Rueda, 2016; Echave, 2019):

There are two types of roads (Figure 1.8): *basic* and *inner roads*.

Basic roads are the perimetrical roads of the superblocks. The streets connect origins and destinations all over the city, and it takes advantages of its orthogonality. The roads, with a speed limit of 50 km/h, are for public transport, private transport, and bicycles when the section permits it. Pedestrians can use the sidewalk.

Inner roads are the roads inside the superblock and are mainly used by residents' vehicles, bicycles, service, and emergency vehicles. The organization of the streets does not allow cars to cross the superblock, and it will make them go around the block, back to the basic network. All vehicles need to match the pedestrians speed, which is 10 km/h. Pedestrians can use all the space.

There are three types of nodes: *intermodal*, *service*, and *neighbor node*.

Intermodal nodes (Figure 1.9) are the intersection of two basic roads. This node includes services of public biking, electric scooter sharing, taxis, and public transport stops.

Service nodes (Figure 1.10) are the intersection of a basic road with an inner road. This node considers loading/unloading zones and public parking.

Neighbor nodes (Figure 1.11) are plazas of approximately 1900 m2. This node is created for new functions and uses for citizens. The possible functions are related to recreation such as playgrounds, resting, festivities and sports; exchange, such as markets; expression and participation; culture and knowledge; and displacement.

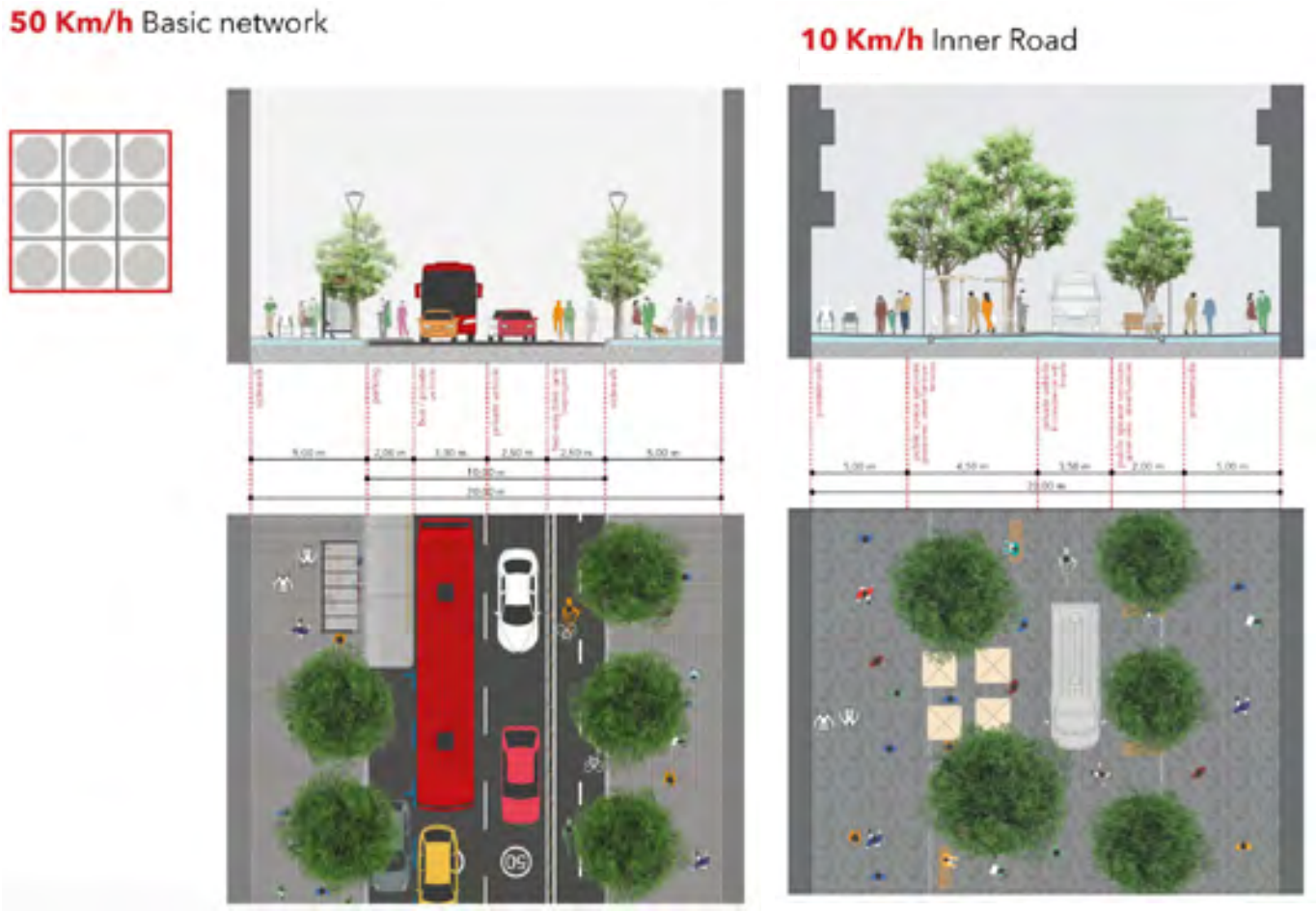


Fig 1.8 Urban superblock: basic network and inner road
Source: Echave, 2019

FIG 1.9 URBAN SUPERBLOCK: INTERMODAL NODE
SOURCE: ECHAVE, 2019

FIG 1.10 URBAN SUPERBLOCK: SERVICE NODE
SOURCE: ECHAVE, 2019

FIG 1.11. URBAN SUPERBLOCK: NEIGHBOR NODE
SOURCE: ECHAVE, 2019

Superblock pilot in Barcelona

Salvador Rueda (2016) mentions that there are four superblocks in Barcelona until 2016. One of them is on Cerdà's grid, located in the district of Sant Martí, and phase 1 was implemented on September 2016 as an experimental pilot (EFE, 2016) to test internal issues of Cerdà's grid (Rueda, 2016). The future design of the pilot urban superblock of El Poblenou, Barcelona (phase 2), is shown in figure 1.13.

Figures 1.14 and 1.15 show the shadow analysis of the plan for the pilot urban superblock of El Poblenou, Barcelona, on June 21st during the hottest hours of the day (12:00 - 18:00) to determine if the area is thermally comfortable. As can be appreciated, there are between 2 to 5 hours of sun exposure on the intersections of the superblock, making it a vulnerable area for pedestrians to be.

As mentioned before, people's behavior is affected by the combination of sight, sounds, smells, textures, tastes, and thermal conditions. Thermal comfort is the most important factor to determine comfort. The design of the pilot urban superblock of El Poblenou, Barcelona, has little consideration for microclimatic factors, which could determine if people will use it or not. In addition, superblocks applies control strategies to reduce air and noise pollution. Nonetheless, it does not consider improving the sensory experience with the application of other techniques to create a multi-sensory experience.

Furthermore, in figure 1.12, there are over 50 possible new superblocks, which includes 120 potential neighbor nodes to be free from traffic. Since the design of the pilot has thermal comfort deficiencies, it could be inferred that the rest of the superblocks will have similar issues.

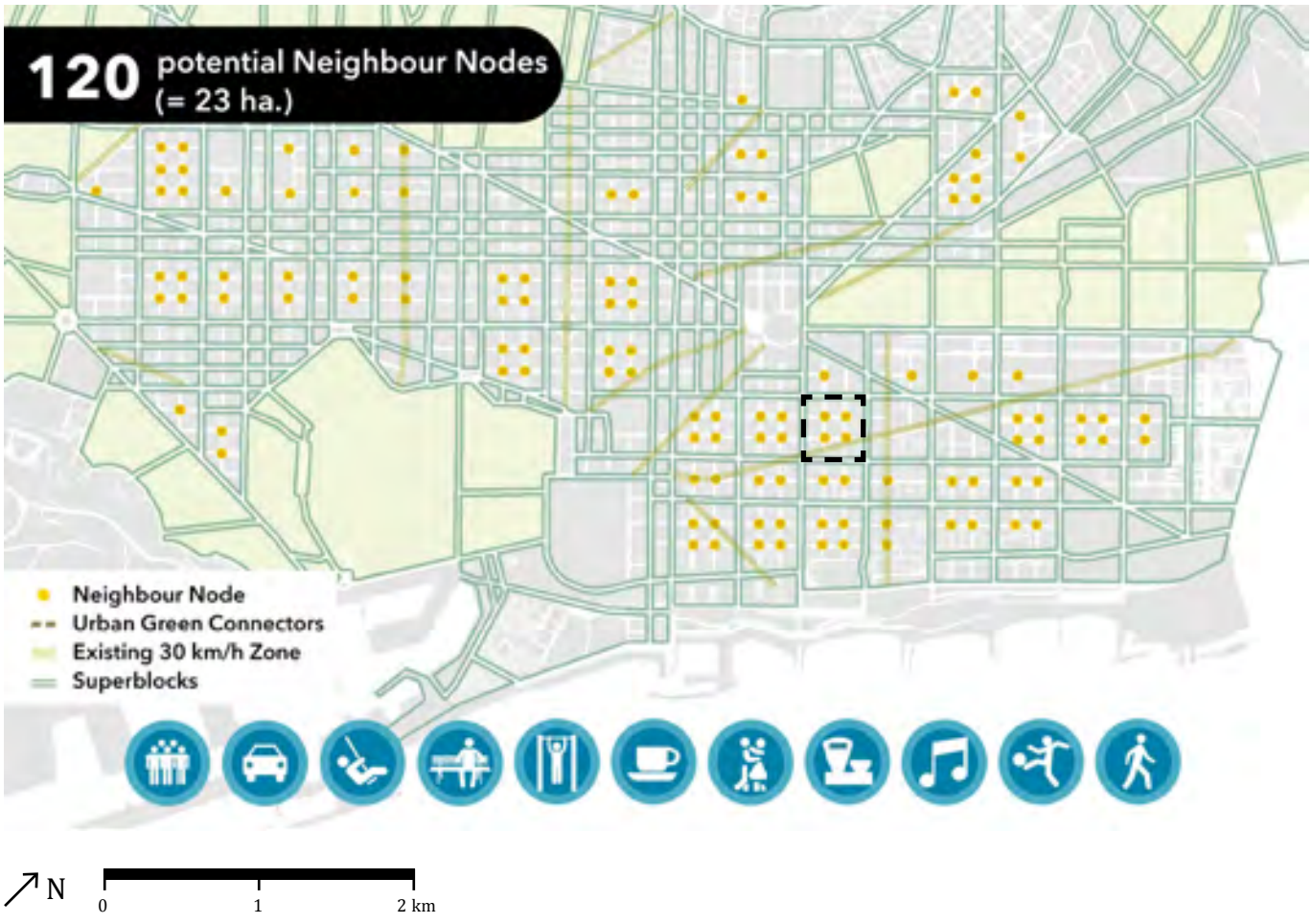


Fig 1.12 Future superblocks of the Urban mobility plan
Source: Echave, 2019

Fig 1.13 Design of the future urban superblock El Poblenou
Source: Based on Ajuntament de Barcelona (2017)

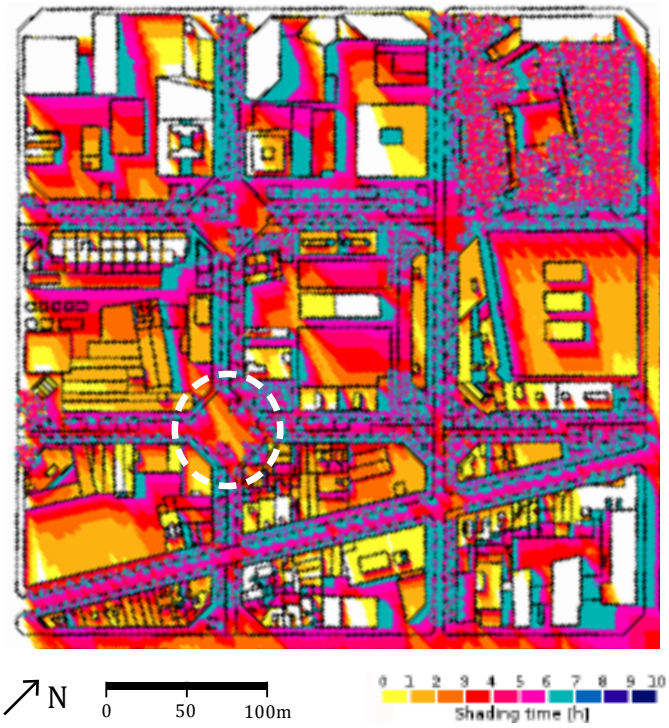


Fig 1.14 Shadow analysis of the urban superblock El Poblenou

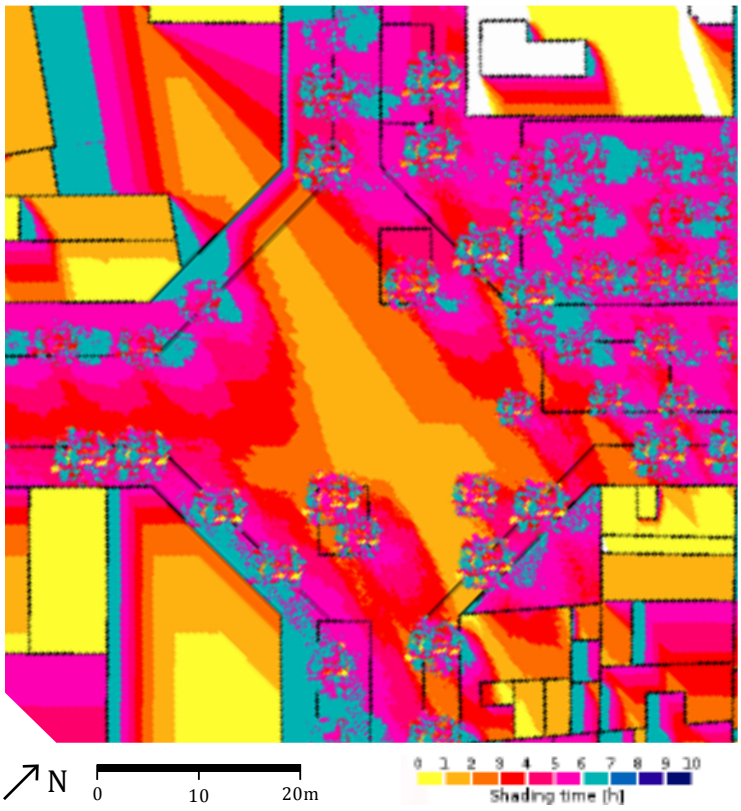


Fig 1.15 Zoom of shadow analysis of the neighbor node in the urban superblock El Poblenou

1.3 KNOWLEDGE GAP

The literature establishes that the concept of environmental comfort obtains a new meaning of enjoyment (Schmid, 2005) instead of only neutrality. Furthermore, the senses usually are studied as individual systems even though they complement each other (Clements-Croome, 2013a). Besides, many urban designs of public spaces are developed with little consideration for climate (Djekic *et al.*, 2018), sonic, tactile, and olfactory factors (Classen, 2013).

Moreover, the literature establishes that superblocks, with their priority towards pedestrians and their reduction on air and noise pollution (Rueda, 2016), aim to improve the human experience in the urban environment. Yet, the design of the neighbor node of the pilot urban superblock of El Poblenou, Barcelona, has little consideration for microclimatic factors and improving sensory experience with a multi-sensory approach. Additionally, there is a plan with 120 neighbor nodes, which could be inferred to present the same issues as the pilot.

Therefore, there is a knowledge gap within neighbor nodes of the urban superblock of the Eixample, Barcelona, regarding a multi-sensory approach, which aims towards a pleasurable human experience.

2. Research design and methods

2.1 RESEARCH QUESTIONS

The objective of this thesis is to generate transferable knowledge through design guidelines, which will help designers solve problems related to sensory experience in the superblocks of the Eixample, Barcelona.

The information gathered from the combination of the superblock, and environmental comfort theories will be used on a model, which will be prototypical to the Eixample area. This model will help establish the specific design strategies according to each sense, which will then be integrated into design guidelines for a multi-sensory experience. These guidelines are specific to the spatial situation yet gives freedom to the designer on which elements and which vegetation species to implement. Finally, these guidelines will be tested in a site design.

To achieve the objective and fill the knowledge gap, the following research question and sub-research questions are asked.

Main Research Question

What design guidelines could help to improve the sensory experience in neighbor nodes of the future superblocks of the Eixample?

Sub-Research Questions

1. Which general design tools improve environmental comfort according to each technique?

2. What are the sensory issues for the different type of spaces for each neighbor node of the superblock?

3. What are the integrated strategies for the different type of spaces for each neighbor node of the superblock?

2.2 METHODS

This research is based on a pragmatic worldview. Pragmatism focuses on issues and its solutions within a specific context. Additionally, pragmatism uses different or combined knowledge claims to solve the problem (Lenzholzer *et al.*, 2013). This research aims to create a fully as possible integrated approach by gathering valuable data from a variety of knowledge and resources.

"The strength of a pragmatic approach is that the qualities of various knowledge claims and methods can enhance and complement each other" (Lenzholzer *et al.*, 2013, p. 125).

2.2.1 Research process

The research process consists of two main parts, the research for design and research through designing. These two parts, individually and combined, will help answer each sub-research question.

Sub-research question 1 uses a literature study as a base. The techniques for the different senses (chapter 1.2.1) from the theoretical framework are used in combination with the evaluation matrix (chapter 3.2) to establish the general design tools that will improve environmental comfort according to each technique (chapter 3.3).

Sub-research question 2 uses the analysis per sense, and spatial analysis from the case study to identify spaces with sensory problems. The thermal sense analysis (chapter 4.3) has a post-positivism approach. The microclimatic conditions are determined with the use of meteorological data from weather stations, data from the website https://www.suncalc.org (Hoffman, 2015-2019), and a shadow analysis. The rest of the analysis per sense (chapter 4.3) relates more to a constructivist approach, which is based on my results of the field research made on the pilot superblock of El Poblenou (see Appendix A) and educated guesses based on the theoretical framework. The spatial analysis (chapter 4.3) is based on information gathered from the combination of the thermal sense analysis, and the spatial composition of superblocks explained in chapter 1.2.2.

Sub-research question 3 is answered with the combined answers of sub-research questions 1 (chapter 3) and 2 (chapter 4). The design strategies per sense (chapter 5.2) are tested on different models (Appendix C) based on the prototype. Then summary tables (chapter 5.2.1) are made to identify possible combinations for the integrated design strategies (chapter 5.2.2). Finally, these are tested on the site design (chapter 5.4).

Figure 2.1 is a graphic overview of the design process. Chapters 3, 4, and 5 present an introduction with a more extensive explanation of the methodology used to answer each sub-research question.

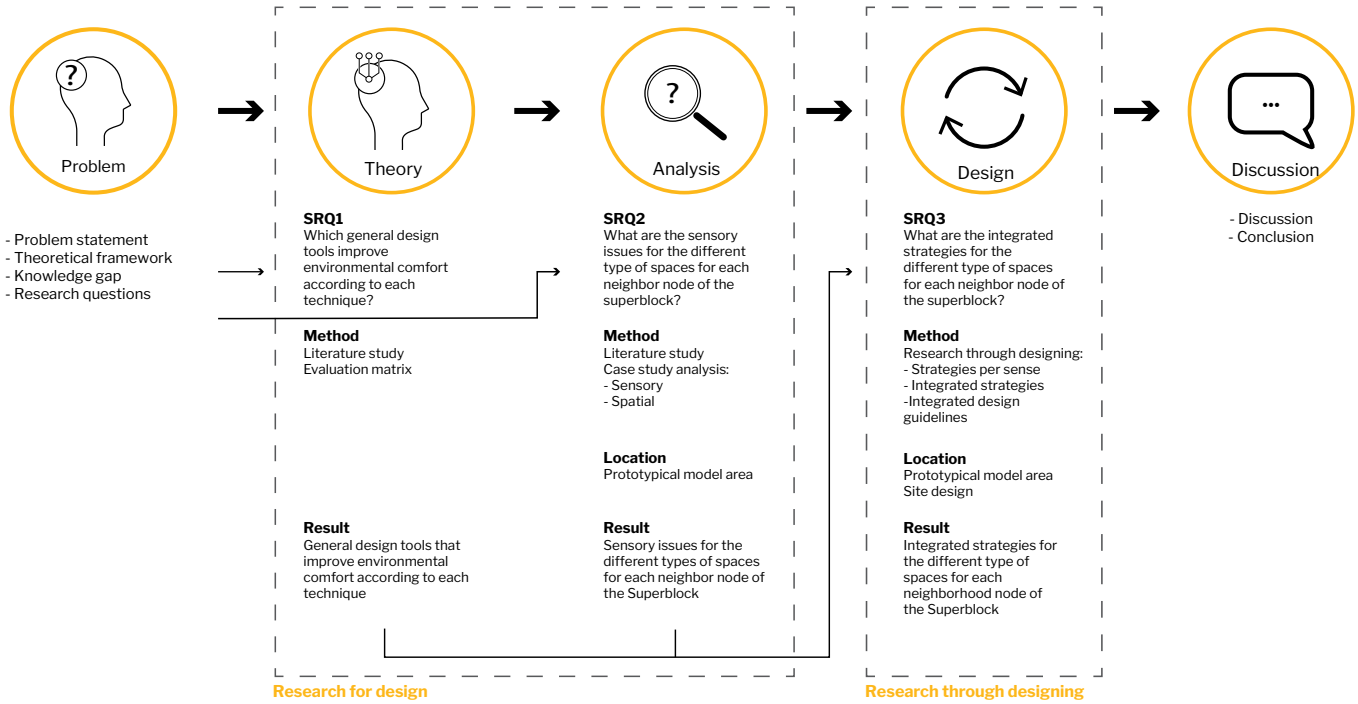


Fig 2.1. Design process

2.2.2 Research location

The research location consists of three parts, the pilot area, the prototypical model area and site design.

The pilot area helps establish the knowledge gap and is used for the phenomenological method. The pilot is on Cerdà's grid, located in the district of Sant Martí, and phase 1 was implemented on September 2016 as an experimental pilot (EFE, 2016) to test internal issues of Cerdà's grid (Rueda, 2016). It has a future design for the urban superblock of El Poblenou, Barcelona (phase 2).

The prototypical model area will be used in chapter 4 and 5 and is part of a qualitative single case study, which will be used to understand in-depth the concept of the superblock in Eixample, Barcelona. Case studies aim to have a holistic and in-depth exploration of a situation. A case study needs to provide as much information as possible and be very representative or atypical. A case study is handy when the aim is to fully understand a situation instead of quantifying it (Kumar, 2014). The prototypical model area has no real location.

Finally, the site design will be used in chapter 5.4. The site is a real location within the Eixample grid and is chosen to test the guidelines in context.

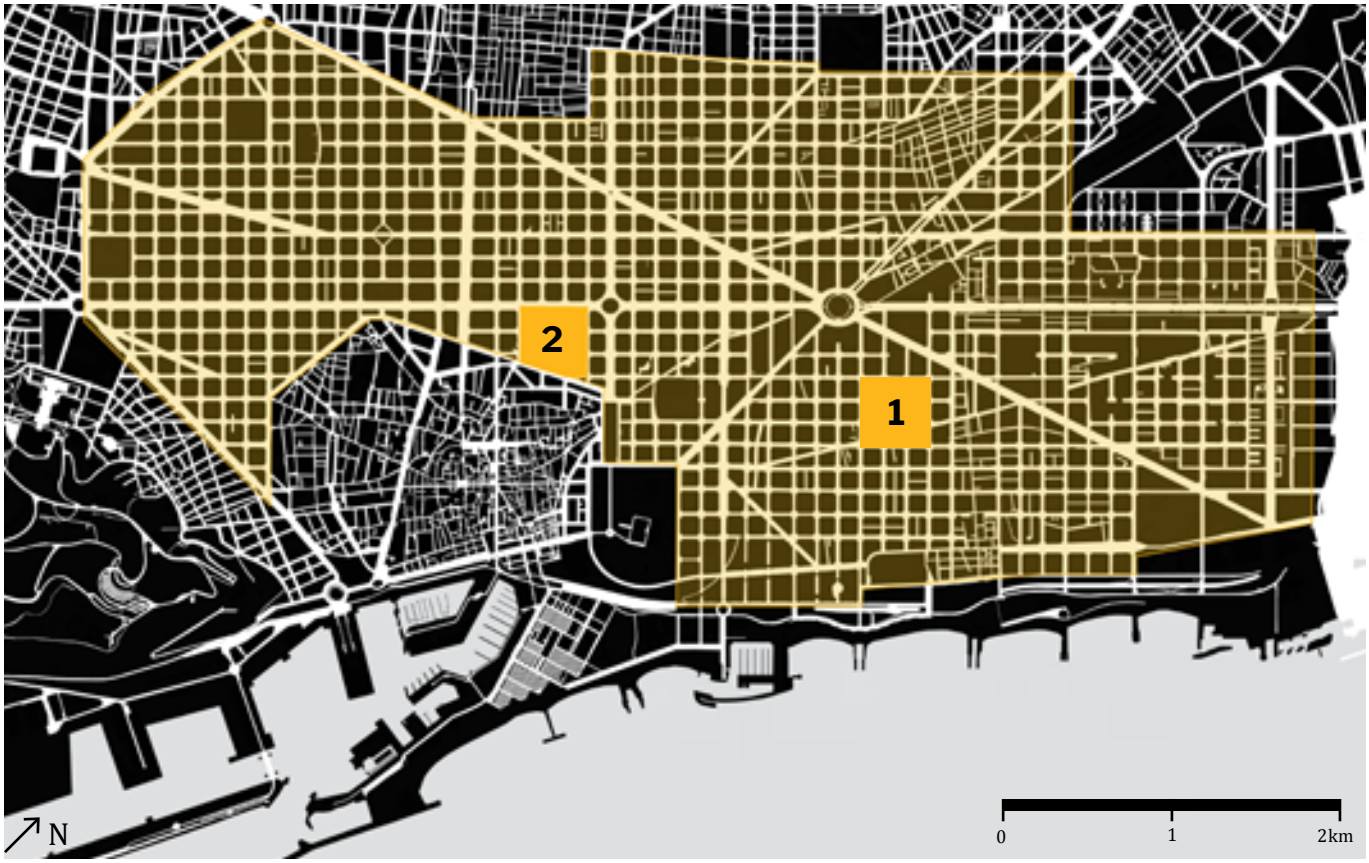


Fig 2.2 Location for pilot area (1) and site design (2). The prototypical model area has no real location.

3. ANSWERING SRQ 1: General design tools to improve environmental comfort according to each technique

3.1 METHOD

This chapter answers sub research question 1. It uses the techniques from the theoretical framework and the evaluation matrix. The combined information will help determine the general design tools that will improve environmental comfort according to each technique.

As established before, thermal comfort is the most influential factor that determines how often inhabitants use public open space and do outdoor activities (Djekic *et al.*, 2018). For this reason, the design tools chosen for this thesis are used as measures for influencing the microclimate. These tools are selected from the book *Weather in the City* from Sanda Lenzholzer (2015) and were adjusted to the context of Barcelona, leaving 30 tools to be used after this process (see table 3.1). Finally, with the information gathered from the theoretical framework and a literature study for the tools, the evaluation matrixes are established (Tables 3.1, 3.2 and 3.5-3.7).

The literature study is based on books from Wageningen University Library, Google books, and searches in Google Scholar. Search terms included different names for the senses, environmental comfort according to each sense, and techniques, such as *visual sense, sight, vision, visual comfort, visual control, visual masking, sight masking, smell, olfactory sense, hearing, sound, acoustic sense, acoustic comfort, sound masking, thermal sense, heat sense, thermal comfort,* among others.

3.2 EVALUATION MATRIX 1

The evaluation matrix 1 is created to determine which general design tool has an influence on the four senses through the different techniques of environmental comfort. These four senses in the matrix are visual, acoustic, olfactory, and thermal sense.

To manage this, the 30 design tools are categorized into three techniques (control, masking, and enhancing), for each sense, to determine which ones contribute to creating a holistic sensory design (Table 3.1).

DESIGN TOOLS	TECHNIQUES												# OF SENSES IT INFLUENCES	# OF TECHNIQUES
	VISUAL			ACOUSTIC			OLFACTORY			THERMAL				
	C	M	E	C	M	E	C	M	E	C	M	E		
Low plants	x	x	x	x	x	x	x	x	x	x	x	x	4	12
Green demarcation elements	x	x	x	x	x	x	x	x	x	x	x		4	11
Hedges	x	x	x	x	x	x	x	x	x	x	x		4	11
Perennial plants with very large leaves	x	x	x	x	x	x	x	x	x	x	x		4	11
Shrubs	x	x	x	x	x	x	x	x	x	x	x		4	11
Wind plus shadow elements	x	x	x	x	x	x	x	x	x	x	x		4	11
Gradation works	x	x	x	x	x	x	x		x	x	x		4	10
Planted pergolas	x		x	x	x	x	x	x	x	x	x		4	10
Waterfalls	x	x	x	x	x	x	x		x	x	x		4	10
Green pavilions and arbors	x	x	x		x	x	x	x	x		x		4	9
Trees	x		x	x	x	x	x	x	x		x		4	9
Waterfall pergolas	x	x	x		x	x	x	x	x		x		4	9
Green masts			x		x	x	x	x	x		x	x	4	8
Green ponds		x	x		x	x	x	x	x		x		4	8
Fountains		x	x		x	x			x		x		4	6
Water mist			x				x		x		x		3	4
Wind/Shadow screens	x	x*								x	x		2	4
Collonades and pavilions	x										x		2	2
Groundwater driven wind protection		x								x			2	2
Parasol/Umbrella	x										x		2	2
Photochromic glass roof	x										x		2	2
Shadow roof	x										x		2	2
Materials with low albedo	x												1	1
Materials with low conductivity										x			1	1
Materials with low density										x			1	1
Warm-windscreen bench										x			1	1
Wind protective street furniture										x			1	1
Glass canopies													0	0

C= CONTROL M= MASKING. E= ENHANCING

TABLE 3.1. EVALUATION MATRIX 1

3.3 General design tools to improve environmental comfort

As a result from evaluation matrix 1, the tools that did not have an influence with the four senses were eliminated, leaving only 15 tools (Table 3.2). All of the tools are either water elements (3), vegetation elements (10), or both (2).

In the following paragraphs, the general design tools are clustered according to the type of element. Each cluster contains information that needs to be considered when implementing the general design tools. Then each general design tool is explained, with its effects and specific considerations.

3.3.1 Water elements

Water elements are seen as pleasurable (Arriaza *et al.*, 2004; Wu *et al.*, 2006). These elements can be used to mask traffic noises at a distance of 50 meters (Hao, 2014) and are "thought to have a cleansing and freshening effect on the air" (Henshaw, 2013, p. 182). Water elements are not very effective in lowering air temperature (Lenzholzer, 2015; Cortesão *et al.*, 2017). Nevertheless, evaporation through water bodies is more efficient when the drops are fine, and the water is not still (Lenzholzer, 2015). There are three elements in this group: fountains, gradation works, and waterfalls.

Fountains

Fountains are artificially created jets of water with or without a structure. Fountains come in all sizes and shapes. It requires a specialist for installation and regular maintenance (Lenzholzer, 2015). Fountains have a big range of loudness and pleasantness. It can be considered as an efficient noise masker for traffic due to its wideband sound (Hao, 2014). To enhance masking in the soundscape, the water feature should be visible. Additionally, in a study made by Xue *et al.* (2015), he mentions that "for the largest droplet, the max height is about 4.2 m due to the small air drag force, while the horizontal range is only about 1.5 m. However, the air drag force has greater influence on smaller droplets, which float as far as 2.5 m away from the nozzle." This means that fountains with a maximum water height of 4.2 meters, the maximum

DESIGN TOOLS	TECHNIQUES												# OF SENSES IT INFLUENCES	# OF TECHNIQUES
	VISUAL			ACOUSTIC			OLFACTORY			THERMAL				
	C	M	E	C	M	E	C	M	E	C	M	E		
Low plants	x	x	x	x	x	x	x	x	x	x	x	x	4	12
Green demarcation elements	x	x	x	x	x	x	x	x	x	x	x		4	11
Hedges	x	x	x	x	x	x	x	x	x	x	x		4	11
Perennial plants with very large leaves	x	x	x	x	x	x	x	x	x	x	x		4	11
Shrubs	x	x	x	x	x	x	x	x	x	x	x		4	11
Wind plus shadow elements	x	x	x	x	x	x	x	x	x	x	x		4	11
Gradation works	x	x	x	x	x	x	x		x	x	x		4	10
Planted pergolas	x		x	x	x	x	x	x	x	x	x		4	10
Waterfalls	x	x	x	x	x	x	x		x	x	x		4	10
Green pavilions and arbors	x	x	x		x	x	x	x	x		x		4	9
Trees	x		x	x	x	x	x	x	x		x		4	9
Waterfall pergolas	x	x	x		x	x	x	x	x		x		4	9
Green masts			x		x	x	x	x	x		x	x	4	8
Green ponds		x	x		x	x	x	x	x		x		4	8
Fountains		x	x		x	x			x		x		4	6

Table 3.2 Evaluation matrix with final tools C= CONTROL M= MASKING. E= ENHANCING

cooling effect can reach 2.5 meters depending on wind. Furthermore, fountains can reduce wind speed by 0.6 m/s (Xue *et al.*, 2015).

Gradation works

"Gradation works consist of a vertical construction with a netting of fine twigs (usually hawthorn) on which water falls. The netting refines the water into smaller drops so it evaporates faster" (Lenzholzer, 2015, p. 168). An example of this can be found in Revierpark Mattlerbusch, Duisburg, Germany. It is beneficial for lowering temperature (Lenzholzer, 2015). It could also be used as a sound barrier. Even though gradation works efficiency is unknown, it could lower sound by 5 decibels (see table 3.3).

Waterfalls

Waterfalls are defined as water falling from a height. The falling water turns into fine drops, lowering air temperature reasonably. It needs a specialist for plan and construction (Lenzholzer, 2015). The wall supporting the waterfall can be constructed as a sound barrier. Although the efficiency of waterfalls as sound barrier is unknown, it could probably lower sound by 5 decibels (See table 3.3).

3.3.2 Vegetation elements

Vegetation elements are visually pleasing (Thayer & Atwood, 1978; Misgav, 2000; Dramstad *et al.*, 2006) and can be used to block an unpleasant view (Thayer & Atwood, 1978). Furthermore, vegetation can attract birds and generate sounds with the wind, which are pleasant sounds for the human ear (Bento Coelho, 2015). Bird songs can mask traffic noise through attention abstraction. Bird songs can be considered a sound mark of nature and be implemented to increase the values of pleasantness and naturalness (Hao, 2014). Besides, vegetation elements can absorb pollutants and "have a cleansing and freshening effect on the air" (Henshaw, 2013, p. 182). The vegetation should be hairy and have a large area index to increase the amount of deposition of particles and improve air quality (Janhall, 2015). Finally, vegetation can lower temperature through shadow casting and evapotranspiration (Lenzholzer, 2015). There are ten elements in this cluster: green demarcation elements; green masts; green pavilions and arbors; hedges; low plants; perennial plants; planted pergolas; shrubs; trees and wind plus shadow elements.

Green demarcation elements

Green demarcation elements can be fences with climbing vegetation or a green wall. These elements can be a noise barrier, as long as it uses low-density soil and considers which "type of plant, leaf angle, amount of foliage on the plant, and total leaf area in a unit volume" they use (Nilsson *et al.*, 2013, p.11). Although the efficiency of green demarcation elements is unknown, based on information from Nilsson *et al.* (2013) it could lower sound by 5 decibels (See table 3.3). In addition, demarcation elements as green walls can optimize pollution removal as long as it is maintaining an effective air circulation (Tallis *et al.*, 2015). Green demarcation elements can help reduce winter winds and cast shadows. A green wall would cast shadows in winter, while a fence with deciduous vegetation allows solar radiation in winter (Lenzholzer, 2015).

Green masts

Greening masts is not as effective as trees, nevertheless having plants grow up masts can have a significant effect lowering surface temperature (Lenzholzer, 2015).

Green pavilions and arbors

Green pavilions and arbors are lightweight architectural elements with plants growing on them. The shadow effect and sound absorption of green pavilions and arbors are dependent on the density of the vegetation. The shadow can reduce a little more than 50% of solar radiation (Lenzholzer, 2015).

Hedges

A hedge is a line of bushes, or small trees planted very close together. Hedges can be a noise barrier as long as they are thick and very dense, and underneath has an acoustically soft soil to avoid sound from propagating under them. A hedge will reduce sound up to 3 decibels (Nilsson *et al.*, 2013)(See table 3.3). Besides, hedges can be considered to optimize pollution removal as long as it is maintaining an effective air circulation (Tallis *et al.*, 2015) Furthermore, it can also help reduce winter winds (Lenzholzer, 2015).

Low plants

Low plants include vegetation such as grasses, perennial plants, flowers, vegetables, and mosses. Low vegetation can be used for noise absorption, as long as the vegetation has a minimum of 1-meter height and width. Low plants will lower sound by 5 decibels (Nilsson *et al.*, 2013)(See table 3.3). Additionally, low plants can be used for blocking particle and car fumes, as long as it has a minimum 1-meter height and width (Xiao *et al.*, 2017). Due to its size, smaller plants have lower evapotranspiration, nevertheless, it can add the evaporation from the soil. To avoid heating from parched lawns, it is recommended that trees are planted to cast shadows over low plants (Lenzholzer, 2015). Furthermore, aromas from low vegetation, such as roses, that are above flower beds of 1-meter height can have an effect of a maximum of 2.5 meters radius (Xiao *et al.*, 2017).

Perennial plants

Perennial plants with large leaves can cast shadows, reducing radiation up to 50% and lower air temperature through evaporation. These plants retrieve during winter, casting no shadows (Lenzholzer, 2015).

Planted pergolas

Planted pergolas are lightweight construction with climbing vegetation. This element can cast shadows, depending on the density of foliage. The effect of a pergola can easily be the reduction of 50% of solar radiation. The climbing vegetation can be deciduous, to allow solar radiation in winter (Lenzholzer, 2015). Although the efficiency of planted pergolas is unknown, it could probably lower sound around 2 decibels or less (See table 3.3).

Shrubs

Shrubs can serve for noise absorption as long as there is sufficient biomass close to the ground. Shrubs will lower sound by 3 decibels (Nilsson *et al.*, 2013) (See table 3.3). Additionally, shrubs can block particles and car fumes when they have a height and width of 1 meter (Xiao *et al.*, 2017). Furthermore, it can cast small shadows (Lenzholzer, 2015).

Trees

Trees can reduce solar radiation by up to 50% (Lenzholzer, 2015). Also, big trees are considered more effective for filtering the air rather than small trees (as cited by Tallis *et al.*, 2015). Nevertheless, urban trees can also have an adverse effect on air pollution (Jeanjean *et al.*, 2016), which is why trees must be considered on a case-by-case basis. When winds are parallel to urban canyons (as cited by Jeanjean *et al.*, 2016) or there is low traffic, then air pollutants can be diminished (Pugh *et al.* 2012). Also, trees can reduce sound up to 2 decibels (Nilsson *et al.*, 2013)(See table 3.3).

Wind plus shadow elements

Wind plus shadow elements combine strategies for wind and sun protection. These elements can be a plant container, a small hill or earth berm with vegetation or an earthen wall that can provide seating while protecting from the wind and sun. It can be considered as an impermeable barrier for sound. Additionally, "earth berms with non-flat surfaces on their slopes and top can reduce noise more than can conventional, smooth trapezoidal berms" (Nilsson *et al.*, 2013, p.15). It will lower sound up to 5dB (Nilsson *et al.*, 2013) (see table 3.3).

3.3.3 Combined elements

Water elements (Arriaza *et al.*, 2004; Wu *et al.*, 2006) and vegetation elements (Thayer & Atwood, 1978; Misgav, 2000; Dramstad *et al.*, 2006) are seen as pleasurable elements. By combining these elements it could be used to masked traffic noises at a distance of 50 meters and could be "thought to have a cleansing and freshening effect on the air" (Henshaw, 2013, p. 182). Additionally, it could create extra evaporation due to the combination of water and shadows (Lenzholzer, 2015) through vegetation elements.

Green ponds

Green ponds combine the use of a water body with vegetation. Having water reflecting sunlight towards the plants can accelerate the transmissions of aromas (Xiao *et al.*, 2017). The combination of water and a dense vegetation can help to lower the air temperature, by plants casting shadows on the water (Lenzholzer, 2015).

Waterfall pergolas

Waterfall pergolas are "pergola-type, green construction with splashing water down from it" (Lenzholzer, 2015, p. 200). Combining shadow elements with water elements can create extra evaporation. The maintenance is intensive, and a specialist is needed for the construction (Lenzholzer, 2015).

3.4 EVALUATION MATRIXES PER TECHNIQUE

The next evaluation matrixes are divided per technique, and they establish which of the 15 design tools can improve environmental comfort more efficiently with an integrated approach (Figure 3.5 - 3.7).

The evaluation will be ranked from 0 to a maximum of 3, dependent on the case. The 0 value is used when there is no effect on the technique, while the positive values will determine the effectiveness of the technique based on literature inference from the theoretical framework (Chapter 1.2.1) and the literature study.

Design tools that score twice have a double function within the technique. In the case of visual control, a tool can cast big shadows and depave an area. In the case of olfactory masking, a tool can be a combination of water and vegetation. In the case of thermal control a tool can block winter winds and depave an area. Lastly, for thermal masking, a tool can lower temperature by casting shadows and evaporation.

3.4.1 Evaluation matrix criteria

Visual sense

Control

Matrix: A design tool is considered as part of visual control when it can eliminate or reduce the reflective surface.

The values are determined based on their effectiveness of controlling glare. A design tool would be rated as 2 in case it can cast a big shadow since it would protect from glare at surface level and from the buildings. A design tool that can affect the surface, by depaving, will score 1, since it would only affect one cause of glare. The 0 value is used when there is no effect on the technique.

Masking

Matrix: A design tool is considered as part of visual masking when it can block a negative view.

The values are determined based on their effectiveness of masking views. A design tool would be rated as 2 in case it can block an unpleasant view (solid) . A design tool that can block partially an unpleasant view (porous or translucid) will score 1. The 0 value is used when there is no effect on the technique.

Enhancing

Matrix: A design tool is considered as part of visual enhancing when it has natural elements, such as vegetation and water.

The values are determined based on their effectiveness of creating pleasurable views. A design tool would be rated as 2 in case it would have two natural elements (water and vegetation). A design tool that would have one natural element will score 1.

Acoustic sense

Control

Matrix: A design tool is considered as part of sound control when it will reduce excessive sound levels at pedestrian height.

The values are determined based on their effectiveness of reducing sound. A design tool would be rated as 3 in case it can reduce 5 or more decibels. A 2 in case it can reduce 3 or 4 decibels. A 1 in case it can reduce 1 or 2 decibels. The 0 value is used when there is no effect on the technique.

Note: Waterfalls and graduation works are included since it needs a wall to be supported and it is the wall which would reduce sound. Waterfall pergolas are not included because the structure to support the waterfall would be the columns and beams from the pergola.

Masking

Matrix: A design tool is considered as part of sound masking when it can enhance or introduce sounds that are pleasant and will mask unwanted sounds.

The values are determined based on their effectiveness of enhancing or introducing sounds of preference that will mask unwanted sound components, like traffic sounds. A design tool would be rated as 2 in case it would introduce a sound related to water (continuous sound). Design tools that can introduce bird songs (temporarily) or sounds from trees and vegetation (temporarily and dependent on wind) will score 1.

Enhancing

Matrix: A design tool is considered as part of sound enhancing when it can introduce sounds that are pleasant.

The values are determined based on their effectiveness of introducing pleasurable sounds. A design tool would be rated as 2 in case it would introduce bird songs. Design tools that can introduce water sound will score 1.

STRATEGY	DESIGN TOOLS	SCORE
Absorb noise	Gradation works	Unknown, probably higher then -5db
	Waterfalls	Unknown, probably higher then -5db
	Green demarcation elements	Unknown, probably higher then -5db
	Wind + shadow elements	-5 db
	Low plants	-5 db
	Hedges	-3db
	Perennial plants	Unknown, probably -3db
	Shrubs	-3db
	Trees	-2 db
	Planted pergolas	Unknown, probably -2 db or less

Table 3.3. Efficiency of design tools for noise absorption
Source: based on Nilsson *et al.*, 2013

Olfactory sense

Control

Matrix: A design tool is considered as part of smell control when it will absorb pollutants or dilute odor concentration.

The values are determined based on their effectiveness of controlling a smell, in this case based on traffic fumes of vehicles entering the superblock. A design tool would be rated as 2 in case it can dilute odor concentration (wind) or absorb pollutants (barriers with vegetation). Design tools that can affect the wind speed, such as trees, will score 1 since depending on how they are positioned it could lower wind speed and give a negative effect concerning air pollution (Vos *et al*, 2013).

Note: Wind plus shadow elements are considered as impermeable barrier, which scores high in dealing with pollutants (Vos *et al*, 2013). Therefore the score of the element is 2.

Masking

Matrix: A design tool is considered as part of smell masking when it introduces smells that can screen off other odors.

The values are determined according to the effectiveness of the design tool in masking traffic fumes. A design tool would get a 2 in case it is reflective water with vegetation, since it can enhance the masking effect by reflecting shortwave radiation onto vegetation, releasing aromas. It would get a 1 if it is related to vegetation since it improves the quality or "freshness of the air" (Henshaw, 2013, p.171). The 0 value is used when there is no effect on the technique.

Enhancing

Matrix: A design tool is considered as part of smell enhancing when it can introduce new aromas, improve the quality of the air and can increase aromas.

The values are determined by the effectiveness of the design tool in enhancing the smellscape of an area. A design tool would get a 2 when there is vegetation with reflective water, since it can release the aroma in combination with heat. It would get a 1 when there is vegetation that releases aroma or a water element by itself since it can increase the perceived "freshness" of the air (Henshaw, 2013).

STRATEGY	DESIGN TOOLS	SCORE	SOURCE
Absorb air pollution	Wind + shadow elements	+++	Based on Gallagher et al. 2015
	Trees	++	Tallis et al., 2015
	Low plants	+	Tallis et al., 2015
	Green demarcation elements	+	Based on Tallis et al., 2015
	Hedges	+	Based on Tallis et al., 2015
	Perennial plants	+	Based on Tallis et al., 2015
	Shrubs	+	Based on Tallis et al., 2015

Table 3.4. Efficiency of design tools for absorbing air pollution

Thermal sense

Control

Matrix: A design tool is considered as part of heat control when it can control heat conductivity, emissivity and reflectivity (materials), and can decrease winter winds (wind). Shadows are not considered as part of control since it would be considered masking.

The values are determined based on the design tools' heat transfer and their control on winter winds. Since the design tools that were related to heat transfer didn't work for all the senses most of them were eliminated from the evaluation matrix 1 (Table 3.1). However, since the current material is asphalt, a design tool would be rated as 2 in case it could be used for depaving the area. Design tools that can reduce winter winds will score 1. The 0 value is used when there is no effect on the technique.

Note: Fountains have a minimum effect on wind reduction. Therefore, they are not considered for control.

Masking

Matrix: A design tool is considered as part of heat masking when it can lower temperature through evaporation or shadows.

The values are determined based on their effectiveness of lowering temperature through shadows or evaporation. A design tool would be rated as 2 in case it can cast a large shadow and has evaporation qualities. Design tools that can cast a small shadow or have only evaporation qualities will score 1. The 0 value is used when there is no effect on the technique.

Enhancing

Matrix: A design tool is considered as part of enhancing when it can lower temperature by maintaining summer breeze.

In order to enhance the experience of users related to heat, wind increasing elements would have to be included in the list. However since it didn't score high in the evaluation matrix 1 (Table 3.1), it cannot be evaluated with the highest score. Nevertheless, since there are some tools that one could use without disrupting the wind, those score as 1. The 0 value is used when there is no effect on the technique.

DESIGN TOOLS	VISUAL			ACOUSTIC				OLFACTORY			THERMAL			GRADE
	0	1	2	0	1	2	3	0	1	2	0	1	2	
Hedges		x	x			x			x			x	x	9
Perennial plants with very large leaves		x	x			x			x			x	x	9
Wind plus shadow elements		x					x			x		x	x	9
Low plants		x					x			x			x	8
Green demarcation elements			x				x		x			x		7
Shrubs		x				x			x			x	x	7
Gradation works			x				x	x				x		6
Waterfalls			x				x	x				x		6
Planted pergolas			x		x					x	x			5
Trees			x		x				x			x		5
Waterfall pergolas			x	x						x	x			4
Green pavilions and arbors			x	x						x	x			4
Green masts	x			x						x	x			2
Green ponds	x			x						x	x			2
Fountains	x			x				x			x			0

Table 3.5 Evaluation matrix for control

DESIGN TOOLS	VISUAL			ACOUSTIC			OLFACTORY			THERMAL			GRADE
	0	1	2	0	1	2	0	1	2	0	1	2	
Gradation works			x			x	x				x	x	7
Green demarcation elements			x		x			x			x	x	7
Green ponds		x				x		x	x		x		7
Hedges			x		x			x			x	x	7
Perennial plants with very large leaves			x		x			x			x	x	7
Waterfalls			x			x	x				x	x	7
Waterfall pergolas		x				x		x			x	x	7
Green pavilions and arbors		x			x			x			x	x	6
Planted pergolas	x				x			x			x	x	5
Shrubs			x		x			x			x		5
Trees	x				x			x			x	x	5
Wind plus shadow elements			x		x			x			x		5
Fountains		x				x	x				x		4
Low plants		x			x			x			x		4
Green masts	x				x			x			x		3

TABLE 3.6 EVALUATION MATRIX FOR MASKING

DESIGN TOOLS	VISUAL			ACOUSTIC			OLFACTORY			THERMAL			GRADE
	0	1	2	0	1	2	0	1	2	0	1	2	
Green masts		x				x		x			x		5
Green ponds			x		x				x	x			5
Low plants		x				x		x			x		5
Green demarcation elements		x				x		x		x			4
Green pavilions and arbors		x				x		x		x			4
Hedges		x				x		x		x			4
Planted pergolas		x				x		x		x			4
Perennial plants with very large leaves		x				x		x		x			4
Shrubs		x				x		x		x			4
Trees		x				x		x		x			4
Waterfall pergolas			x		x			x		x			4
Wind plus shadow elements		x				x		x		x			4
Fountains		x			x			x		x			3
Gradation works		x			x			x		x			3
Waterfalls		x			x			x		x			3

TABLE 3.7 EVALUATION MATRIX FOR ENHANCING

3.3 RESULTS

For control, the most efficient tools are hedges, perennial plants, wind plus shadow elements and low plants. Hedges and perennial plants score higher in the matrix because they have a double function for visual and thermal control. Nevertheless, they score lower for acoustic and olfactory control. Wind plus shadow elements and low plants only score low in visual control since they cannot cast big shadows, reducing the effect of diminishing glare. Nevertheless, these tool can be paired with elements that cast shadows to improve their effectiveness. It is recommended to use wind plus shadow elements and low plants for control, since both score high in most of the senses and its efficiency can be improved by implementing an element that cast big shadows.

For masking, seven tools proof to be the most efficient. Green ponds score high for the acoustic and olfactory senses, however, ponds scores low for visual and thermal masking. Nevertheless, this tool can be combined with elements such as wind plus shadow elements and trees to improve the effectiveness of the element. Waterfall pergolas score high for acoustic and thermal masking. To improve their efficiency, they can be combined with elements that score high for visual masking, such as shrubs. Green demarcation elements, hedges and perennial plants score high in visual and thermal masking. Nevertheless, they score low for acoustic and olfactory masking. This elements can be combined with other elements, such as fountains to improve their score. In addition, gradation works, and waterfalls score high in all senses except the olfactory sense. These elements cannot reflect sunlight therefore have no effect on masking smells. Consequently, it is recommended to use tools that can be improved by combining with other elements.

For enhancing, green ponds, low plants, and green masts can enhance the sensory experience. Green ponds seem to have a better effect than the water elements or the vegetation elements. Nevertheless, green ponds do not enhance the thermal sense. Therefore, low plants and green mast are more efficient for providing pleasure, even though they do not score the highest in the visual, olfactory, and thermal senses.

CONTROL	MASKING	ENHANCING
Wind plus shadow elements	Green demarcation elements	Green mast
Low plants	Green ponds	Low plants
Hedges	Hedges	Green ponds
Perennial plants	Perennial plants	
	Waterfall pergolas	
	Gradation works	
	Waterfalls	

Recommended

TABLE 3.8 HIGH SCORING DESIGN TOOLS PER TECHNIQUE

4. Answering SRQ 2: Sensory issues for the different type of spaces for each neighbor node of the superblock

4.1 METHOD

This chapter answers sub research question 2. First, it introduces the prototypical model area. Then, an analysis per sense and a spatial analysis is made in the model area. The combined information will help determine the sensory issues for the different types of spaces of each neighbor node in the superblock.

The analysis per sense uses, as a reference, the information gathered from the phenomenological method applied in the pilot superblock El Poblenou (See Appendix A). In addition, the thermal sense analysis uses, for the sun path, the data collected from the website https://www.suncalc.org (Hoffman, 2015-2019); a shadow analysis from SketchUp to determine the reflective radiant heat sources; and for wind, the meteorological data from port station number 2 from the period 2008-2015 (Port de Barcelona, 2019), the data gathered from the automatic meteorological station El Raval from the period 2016-2018 (Servei Meteorològic de Catalunya, 2019) and educated guesses. The data from the automatic meteorological station El Raval was measured every half hour. This station is located at the height of 33 meters, and wind speed is measured 10 meters above that. This station has no obstacles in the surroundings and is representative of the study area.

The spatial analysis is based on the information gathered from the combination of the thermal sense analysis and the spatial composition of the superblocks (Chapter 1.2.2).

As a result of the analysis, the sensory issues are established for the different type of spaces for each neighbor node of the superblock.

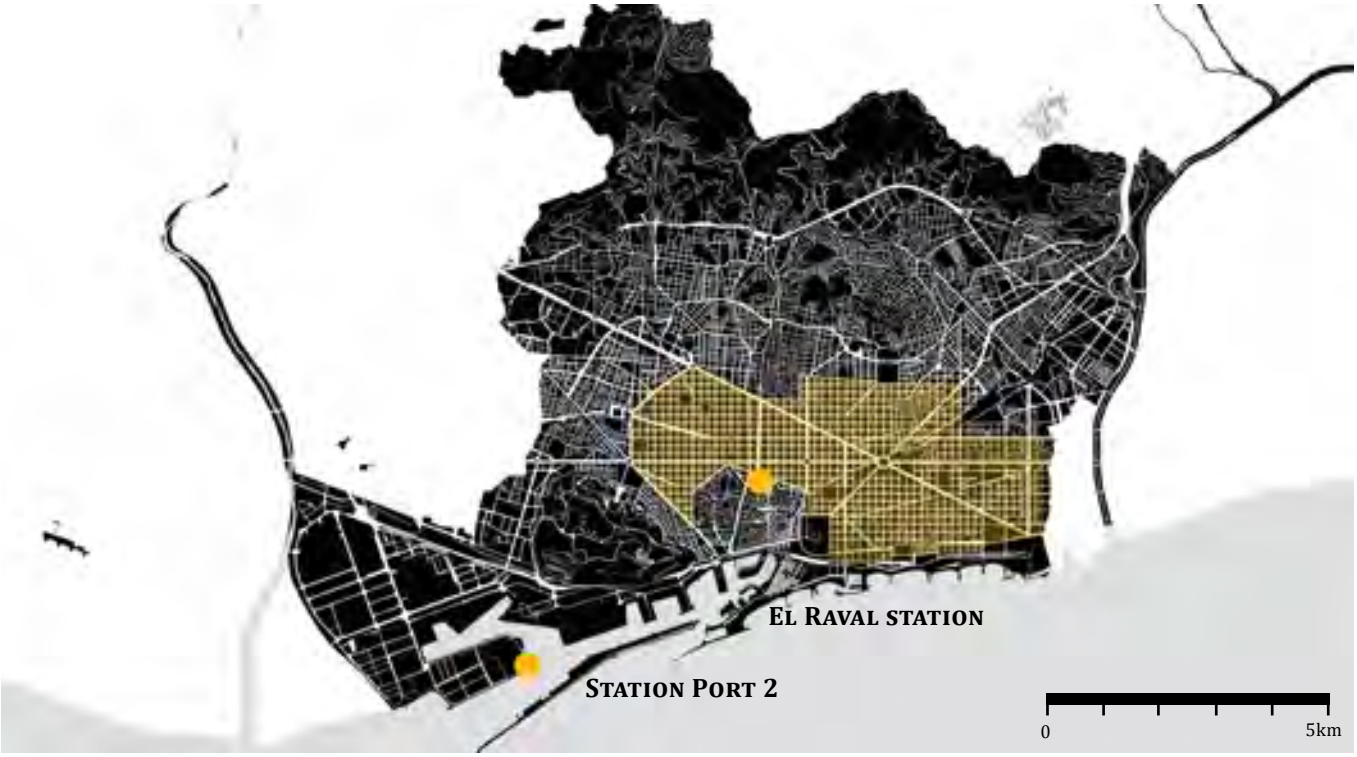


Fig 4.1 Location of weather stations

4.2 PROTOTYPICAL MODEL AREA

A qualitative single case study is used to understand in-depth the concept of the superblock in Eixample, Barcelona. To fully understand the situation some challenges about the location must be explored.

Barcelona

Barcelona is a compact city and is considered as one of the densest cities in Europe. It is located in the Mediterranean coast, at a latitude of 41° North, and has a temperate climate, which is dry and warm in summer and cool and humid in winter (Rojas-Cortorreal *et al.*, 2017). Temperature can reach an average of 8º to 11º Celsius during winter and 22º to 28º Celsius during summer (Rodríguez & Matzarakis, 2016). Due to the proximity to the sea and the urban heat island effect, Barcelona's city center is one of the most sweltering centers of the country, reaching temperatures above 30° Celsius during summer (as cited in Ajuntament de Barcelona, n.d.a).

Its urban morphology is formed of several street patterns. "The most recognizable is the Eixample, not only because of its urban design but also because of its remarkable extension" (Rojas-Cortorreal *et al.*, 2017, p.369-370) (Figure 4.2).

Eixample: Cerdà's Grid

In 1854 a new plan was established for the outside area of the wall of Barcelona, it was commissioned to Ildefons Cerdà (Urbano, 2016). This new urban plan helped the hygiene and sanitation of Barcelona. It "evolved into its full structure from the end of the nineteenth century through mainly the first half of the twentieth century" (Pallares-Barbera *et al.*, 2011, p. 124). By the twenty-first century, the city consisted of four parts. The medieval city; the Eixample, which was an area of residency and services; the old villages; and new neighborhoods due to special events (Pallares-Barbera *et al.*, 2011).

According to Curreli and Coch (2010), Eixample is composed of a grid of chamfered blocks of 113.3 meters by 113.3 meters (Figure 4.3). It is oriented NW-SE and SW-NE, for all facades to have direct sunlight, except the north facade, and take advantage of the predominant wind direction (Curreli & Coch, 2010). Standard streets measure 20 meters wide (UN-Habitat, 2015).

As years past and new regulations were established, Cerdà's vision changed. With the regulation of 1891, a maximum building height was set at 22 meters for standard streets and with a maximum depth of 28 meters, resulting in blocks with perimetrical occupation and interiors that could be build-up to one floor (UN-Habitat, 2015) (Figure 4.3).

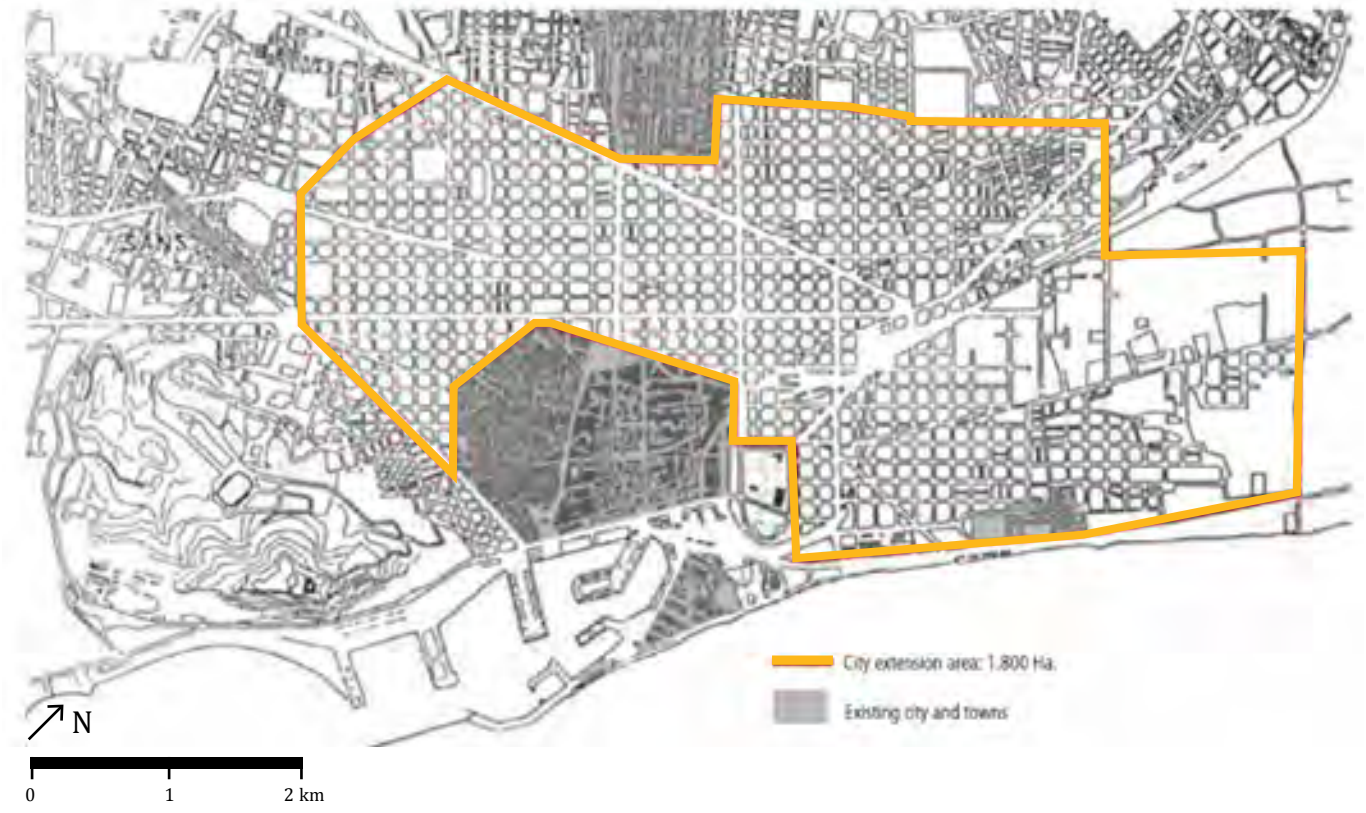


Fig 4.2 Cerda's grid extension
Source: UN-Habitat, 2015

Urbano (2016) states the following:

> The blocks had buildings and sidewalks cut at a 45º angle in all corners for higher visibility at street intersections, improving mobility and allowing for a small central plaza for services and complementary activities (shops, kiosks, toilets, etc.). With this design solution, Cerdà had intersections take a prominent role in the city's structure. (p. 48)

Prototypical model area definition

The model area (Figure 4.4) consists of a superblock of nine chamfered blocks, each with a dimension of 113.3 by 113.3 meters. The street orientation is NW-SE and SW-NE and has a width of 20 meters. As mentioned in chapter 1.2.2, a superblock is composed of streets and nodes. The focus of this thesis is on neighbor nodes.

There are two types of neighbor nodes, one with the inner roads on the east and west sides, known as neighbor node 1 (Figure 4.5); and another with the inner roads on the north and south sides, known as neighbor node 2 (Figure 4.6).

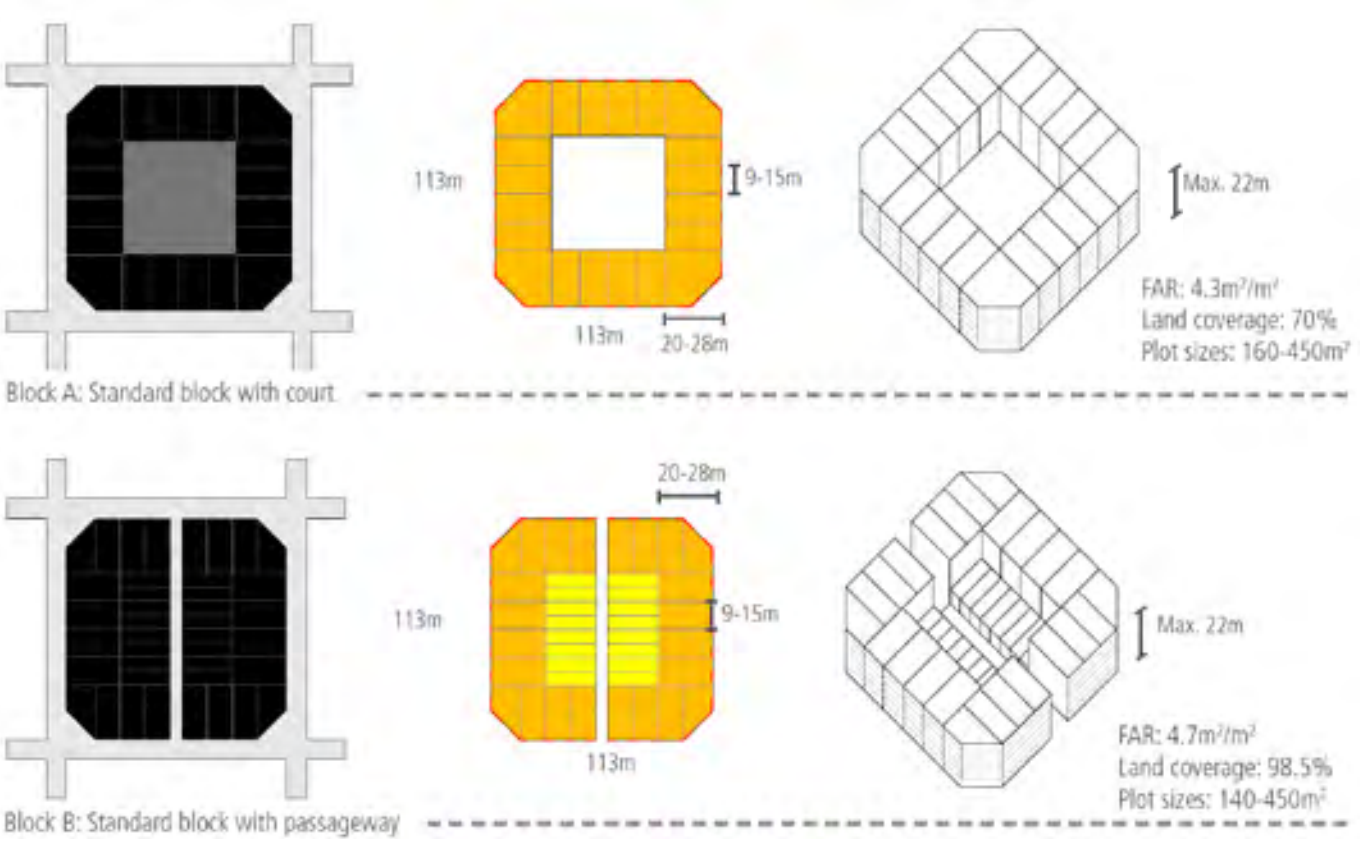


Fig 4.3 Eixample blocks
Source: UN-Habitat, 2015

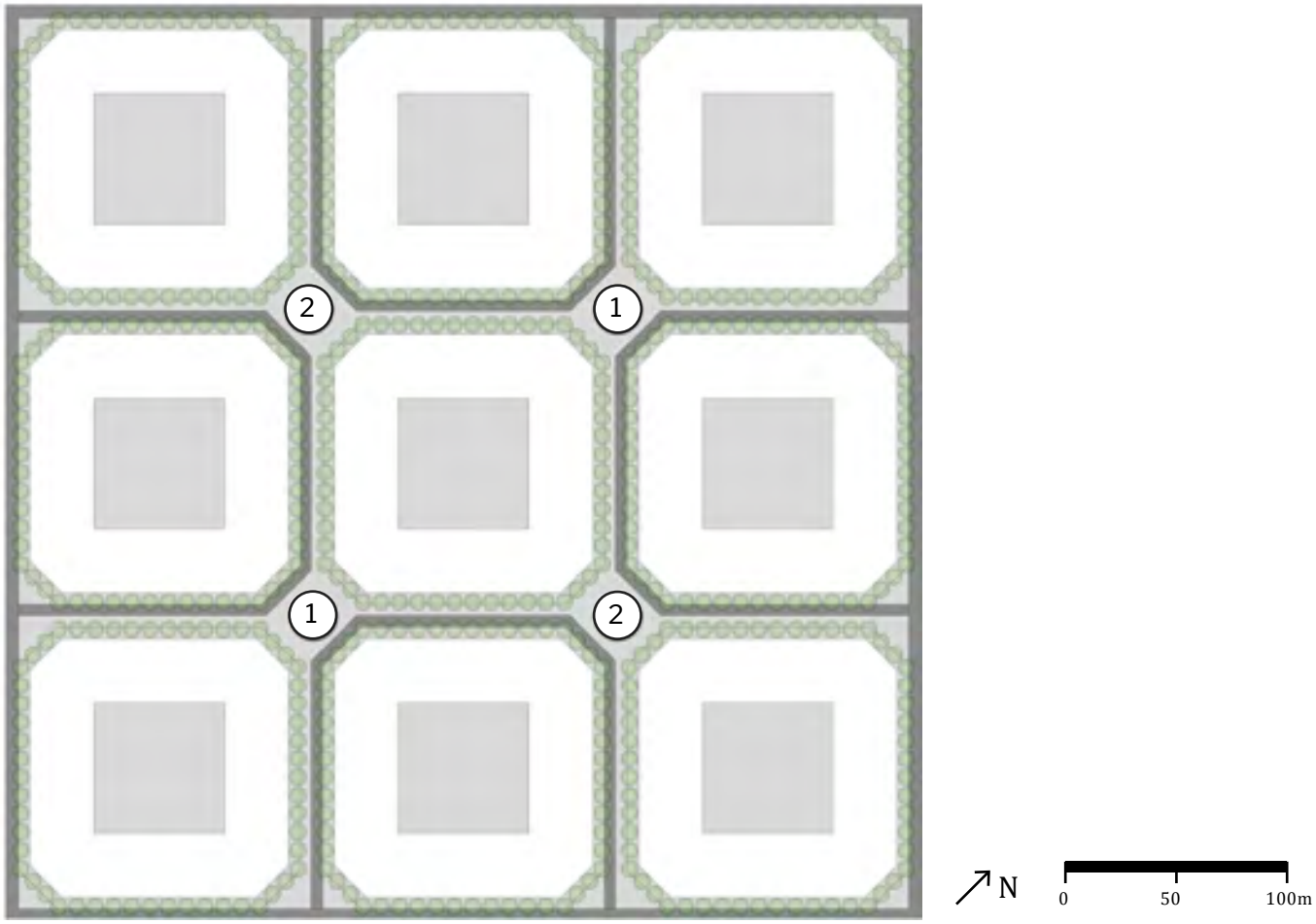


FIG 4.4 PROTOTYPICAL MODEL AREA PLAN

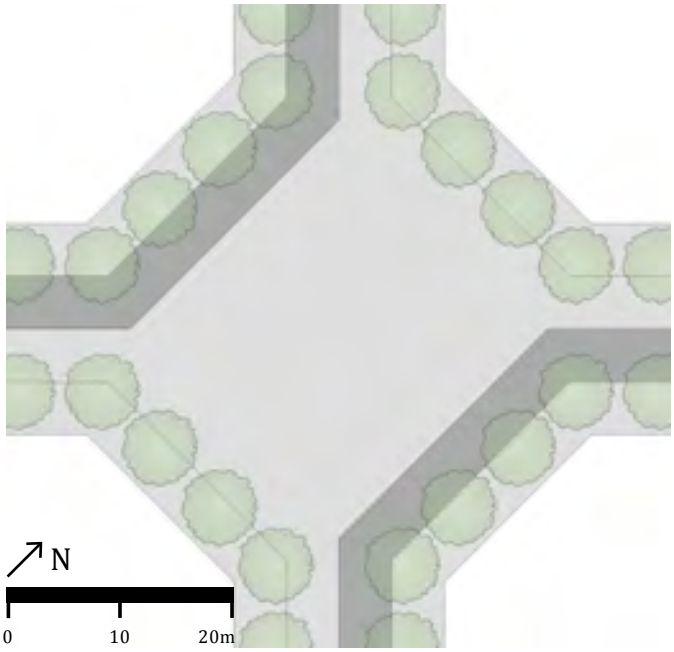


FIG 4.5 NEIGHBOR NODE 1 PRESENTS THE INNER ROADS ON THE WEST AND EAST SIDE.

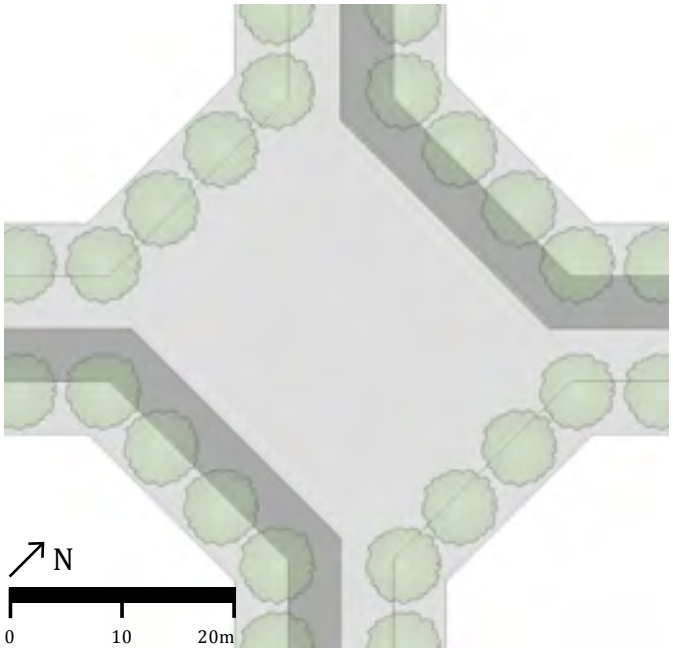


FIG 4.6 NEIGHBOR NODE 2 PRESENTS THE INNER ROADS ON THE NORTH AND SOUTH SIDE.

4.2 ANALYSIS

Thermal sense

Solar radiation modifies the thermal balance of the built environment. By knowing its behavior, the urban environment could be improved (Rojas-Cotorreal *et al*., 2017). To do so, some indicators, such as latitude; street orientation; urban canyon morphology; and others, need to be known (Rojas-Cotorreal *et al*., 2017).

Barcelona is located at 41º23'N. The level of incidence of solar radiation reaches high levels during the summer months (as cited by Rojas-Cotorreal *et al*., 2017).

The NW-SE and SW-NE orientation were chosen by Cerdà for its improvement on natural ventilation and for all facades to have direct sunlight, except the north facade (Curreli & Coch, 2010).

The meteorological data from port station number 2, indicates that the predominant wind during winter and autumn are westerly winds, associated with storms coming from the Atlantic. The prevailing wind during spring and, especially, summer come from the south with the cool morning wind from the coastal system (Port de Barcelona, 2019).

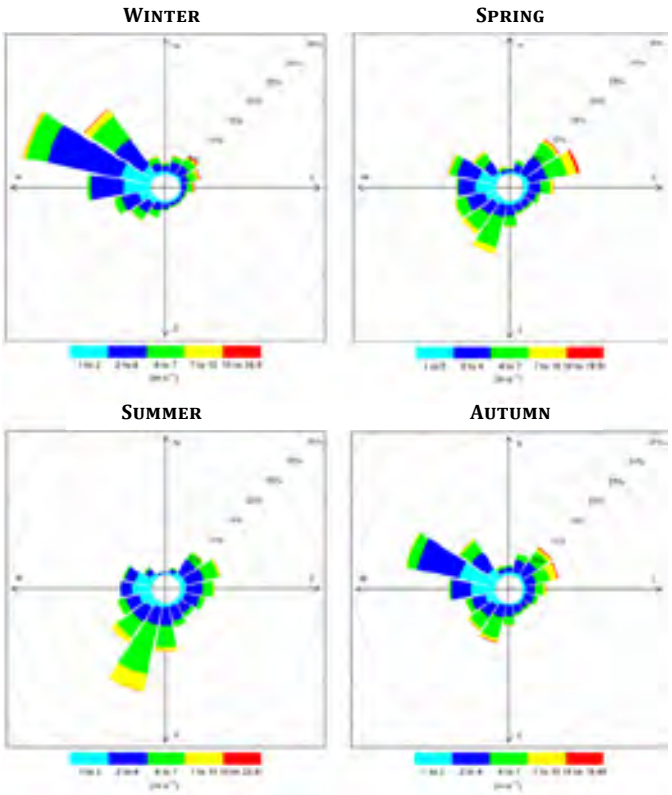


Fig 4.7 Wind Roses
Source: Port de Barcelona, 2019

Furthermore, the model area has a height/width ratio of 1.1, which creates a skimming flow. Having this flow means that the space between buildings is protected while the wind flow above the rooftops will continue to flow at that height (Lenzholzer, 2015). In urban canyons, when the flow approaches 30º direction, it can generate a channeling flow (Oke *et al*., 2017). This flow is possible in the superblocks of Barcelona and has to be taken into consideration for the summer and winter winds.

In addition, the data gathered from the automatic meteorological station El Raval (Servei Meteorològic de Catalunya, 2019) was used to calculate wind speed at the pedestrian level.

This calculation is based on the formula cited by Rodriguez & Matzarakis (2016).

$WS_{1.1}=WS_h*(1.1/h)^{\alpha}$ $\alpha=0.12*Z_0+0.18$

$WS_{1.1}$ = wind speed (m/s) at core body height
$WS_{h=}$ wind speed (m/s) at the height of 43 m (station)
α= 0.30 (Rodriguez & Matzarakis, 2016)
Z_0= 1 (Rodriguez & Matzarakis, 2016)

The values of Z_0 and α are based on Rodriguez & Matzarakis (2016) study. This study is based in Barcelona on Cerda's grid, therefore I will be using the same parameters as them. The study area and its surroundings are dense but with large open spaces.

The result of this analysis is that wind speed at a pedestrian level will reach a maximum velocity of 3.23 m/s during winter. All other values are below this number. Therefore, it can be established that wind speed at a pedestrian level is low, which compared to the wind criteria of ASCE (Table 1.1) it is comfortable for sitting and standing. Consequently, it can be established that for winter winds, even though the wind is not strong, it still feels uncomfortable for people walking.

As it can be seen in figures 4.8 and 4.9, sun, during the hottest hours of the day, is starting from the south-east and ends at the west. This means that shadows from the south and west buildings will be cast into the pedestrian space. In addition, winter winds will come from the north-west street and summer breezes will come from the south-west street.

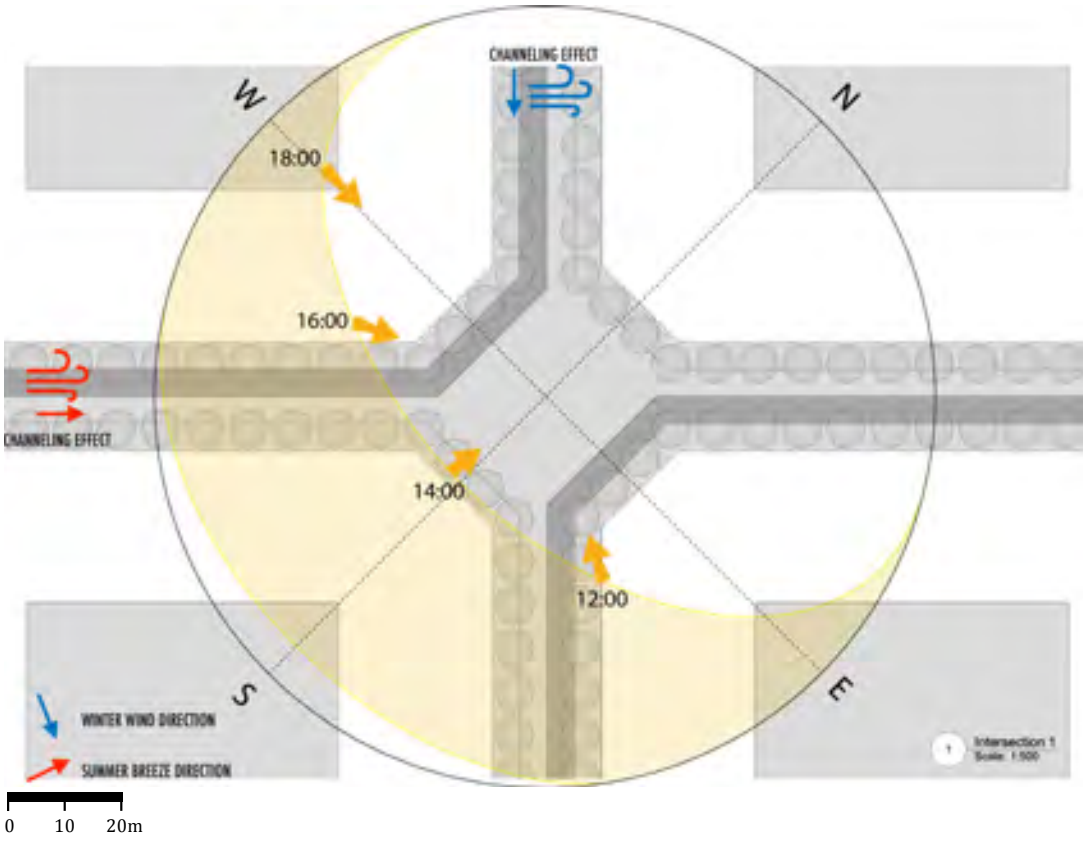


FIG 4.8 MICROCLIMATE ANALYSIS: NEIGHBOR NODE 1

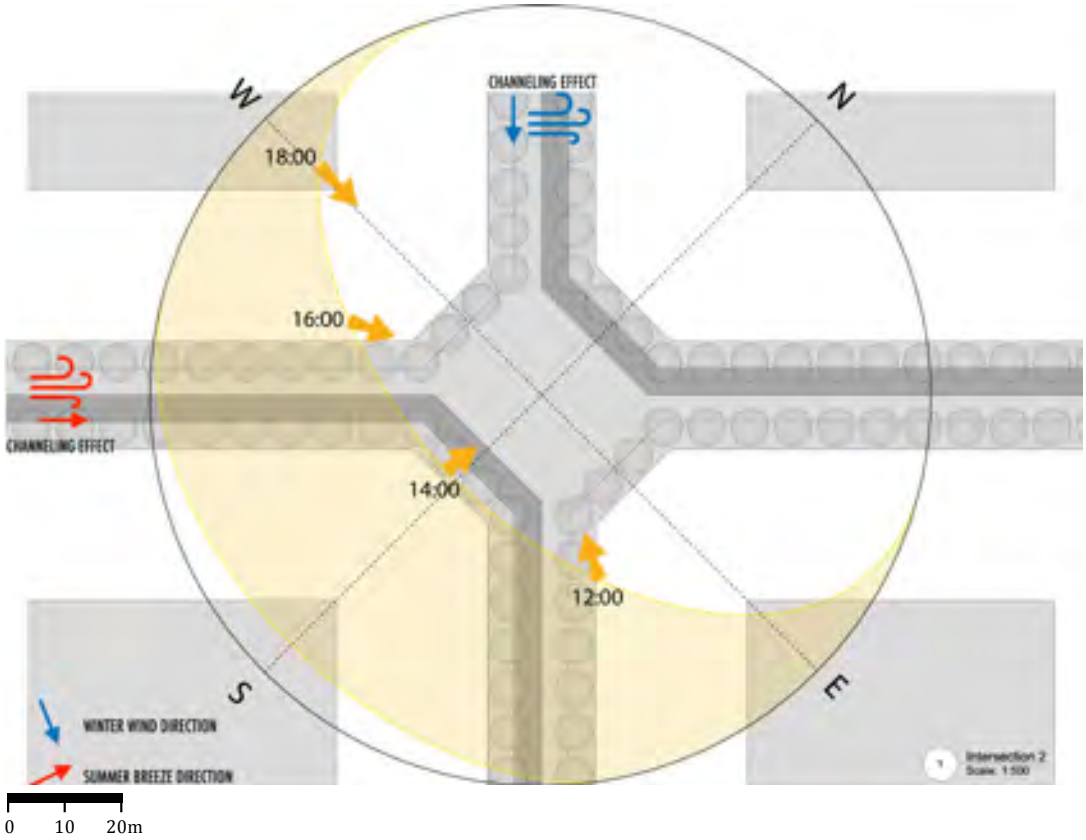


FIG 4.9 MICROCLIMATE ANALYSIS: NEIGHBOR NODE 2

Moreover, reflective radiant heat sources can be established with a shadow analysis determining the number of sun hours on a surface. This analysis is done during the hottest hours of the day, 12:00 to 18:00, on June 21st.

Figure 4.10 and 4.11 show the result of this analysis with areas that are exposed to sunlight between four and six hours.

As it can be seen, the sun exposure for figure 4.10 starts on the west side after the inner road. Therefore, the entire pedestrian area is affected. In the case of figure 4.11, the pedestrian area starts on the west side next to the building, which means it will be protected from sun exposure at the west end.

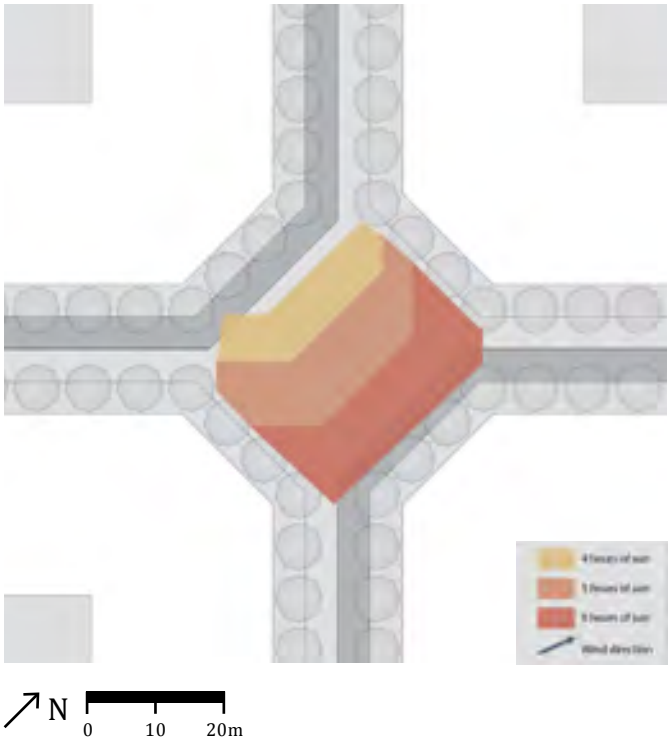


FIG 4.10 THERMAL ANALYSIS: NEIGHBOR NODE 1

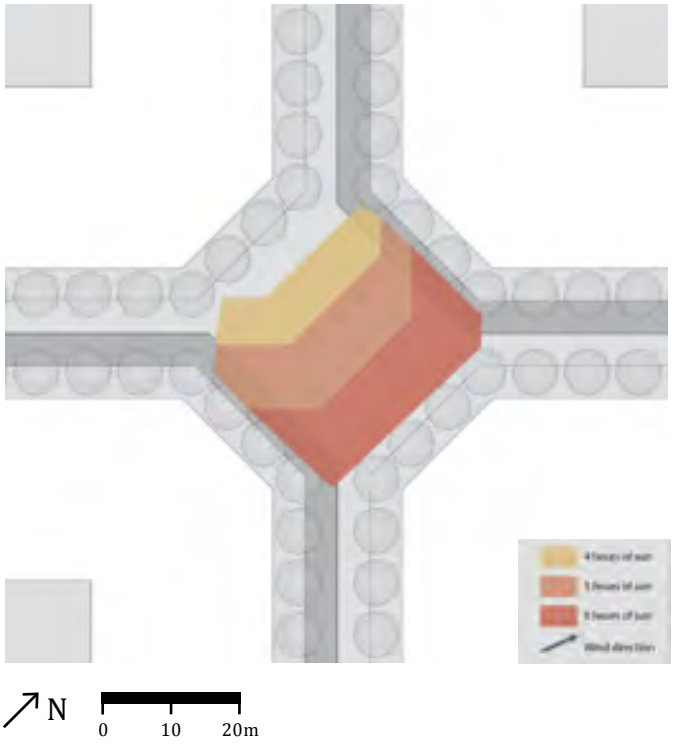


FIG 4.11 THERMAL ANALYSIS: NEIGHBOR NODE 2

Visual sense

The neighbor node consists of facades (vertical planes), four trees on each side of the node and the ground (horizontal plane). The trees on each side partially block the vertical planes, reducing the amount of reflected sunlight. Therefore, the primary source of glare will be considered from the ground.

Figures 4.12 and 4.13 show the analysis for glare, the area in light blue shows the amount of exposed horizontal area that could induce glare disability. Additionally, some important visual connections or disconnections can be established, such as the connection with the other neighbor node of the superblock and the blocking of the "ugly" visuals, such as traffic.

As it can be seen in figure 4.12 the pedestrian area between the inner roads shows glare in most of its surface, since the shadow of the west building is cast mainly into the inner road. In the case of figure 4.13, by having the inner roads on the north and south side, shadows from the west building are cast directly into the pedestrian area, having less sunlight reflection towards the west.

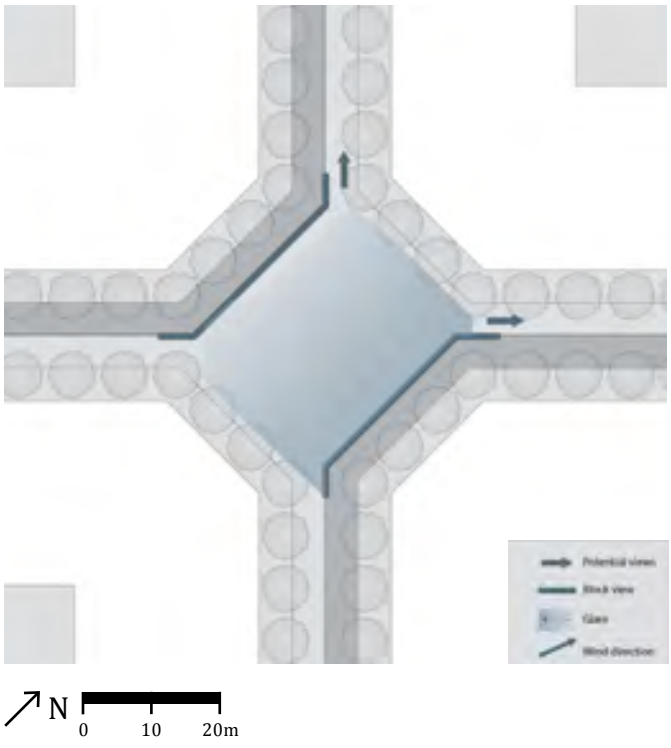


Fig 4.12 Visual analysis: neighbor node 1

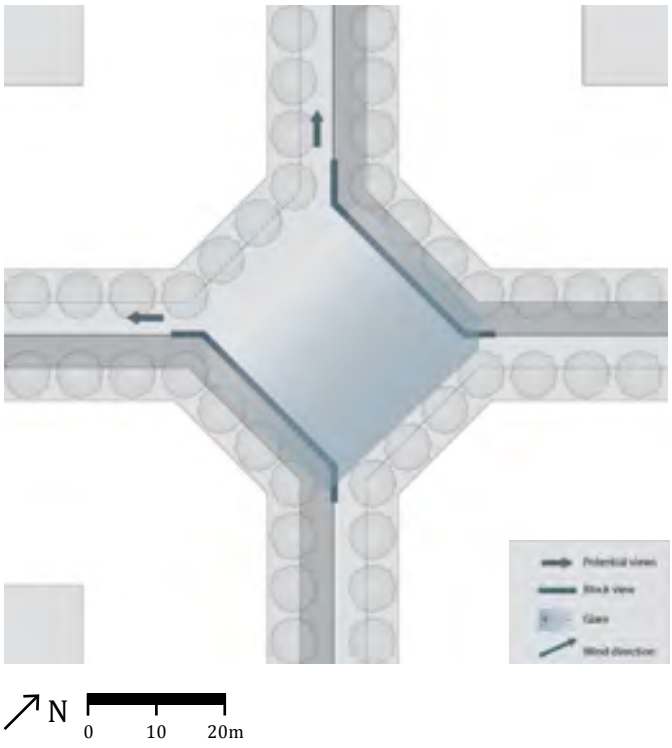


Fig 4.13 Visual analysis: neighbor node 2

Acoustic sense

There are two primary sources of noise for the superblock: the basic networks and the inner roads. Due to the distance between the intersection and the basic network, most sound will not be loud enough at the junction to be the main problem. This situation is based on the phenomenological analysis made in the superblock of El Poblenou (Appendix A). The inner roads, however, by allowing motorized vehicles inside the superblock, would be the primary source of noise pollution.

Figures 4.14 and 4.15 illustrates the acoustic analysis, where most of the noise is concentrated in the intersection. Sound can travel with the wind. Nevertheless, its effect is minimum to be taken into account.

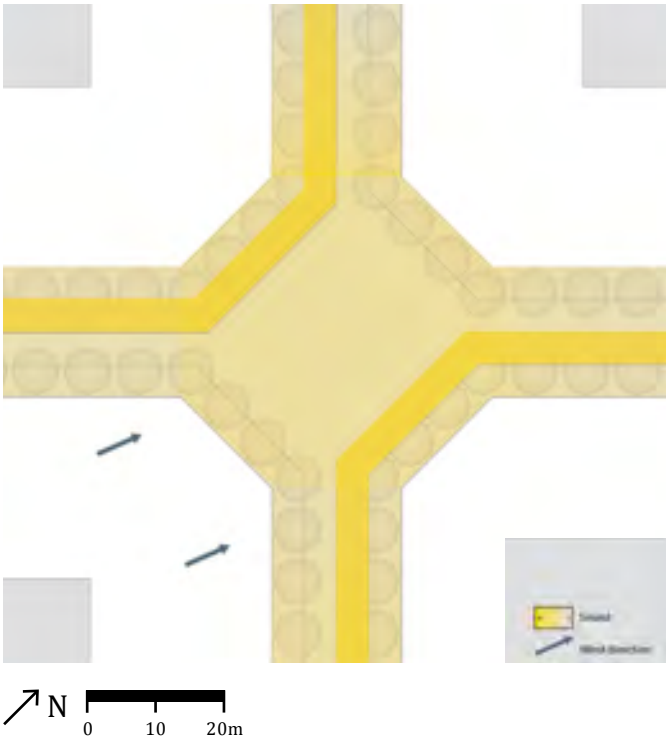


Fig 4.14 Acoustic analysis: neighbor node 1

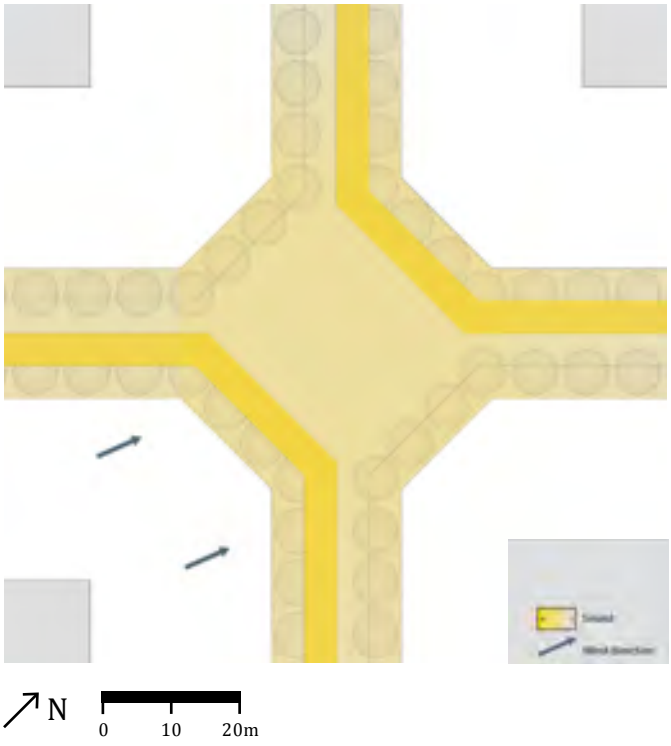


Fig 4.15 Acoustic analysis: neighbor node 2

Olfactory sense

As with sound, the primary source is traffic. It has two sources: the basic network and the inner road. Odor can be diluted or transported by wind, depending on its intensity. Since wind speed is low, the primary source of smell pollution will be considered from the inner roads.

Figures 4.16 and 4.17 show the olfactory analysis, where the pollution is concentrated near the inner roads.

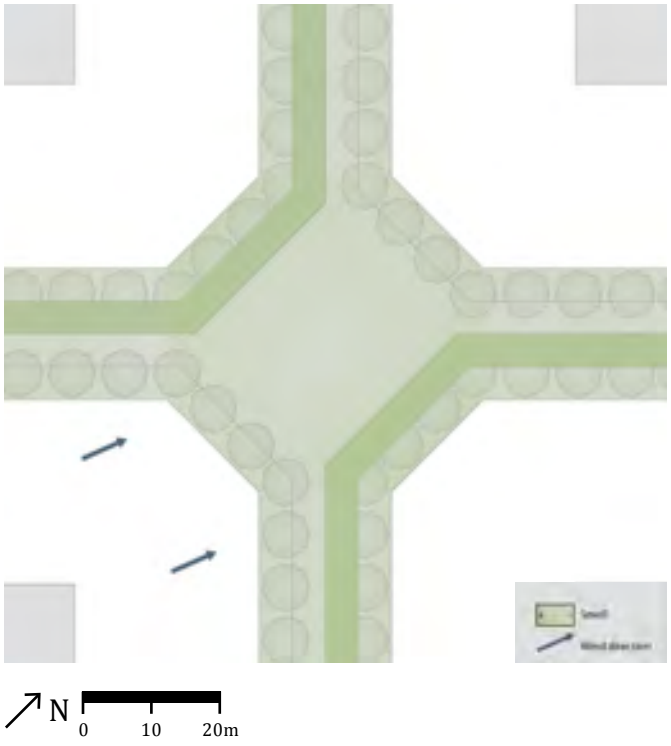


Fig 4.16 Olfactory analysis: neighbor node 1

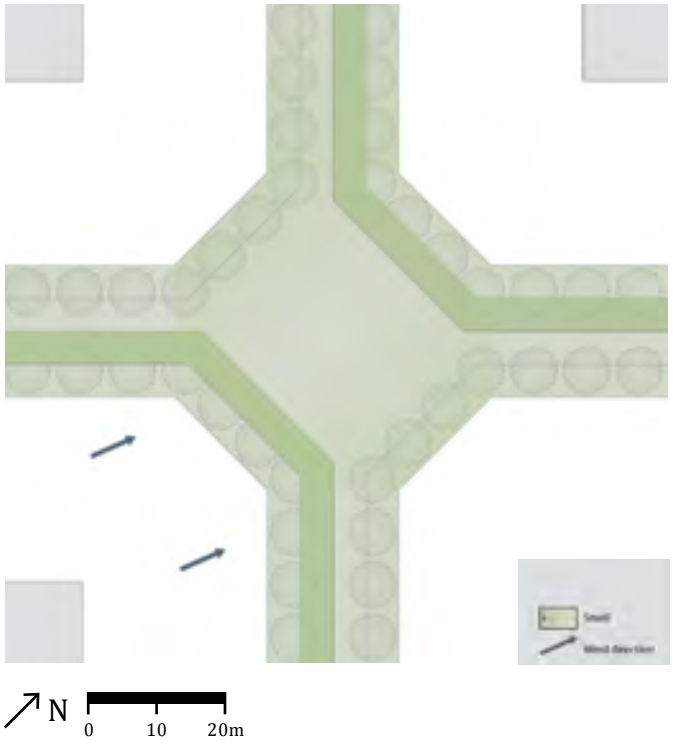


Fig 4.17 Olfactory analysis: neighbor node 2

Spatial analysis

As mentioned before, there are two types of neighbor nodes, one with the inner roads on the east and west, called neighbor node 1; and another with the inner roads on the north and south sides, called neighbor node 2.

Neighbor node 1 has five types of sub-spaces (Figure 4.18), dependent on the inputs of its spatial configuration, the sun projections between the hours of 12:00 and 18:00, and wind flow direction.

Neighbor node 2 has four types of new sub-spaces (Figure 4.19), dependent on the inputs of its spatial configuration, the sun projections between the hours of 12:00 and 18:00, and wind flow direction. The middle space of each node repeats, therefore the strategies implemented in 1B will work on neighbor node 2 middle space.

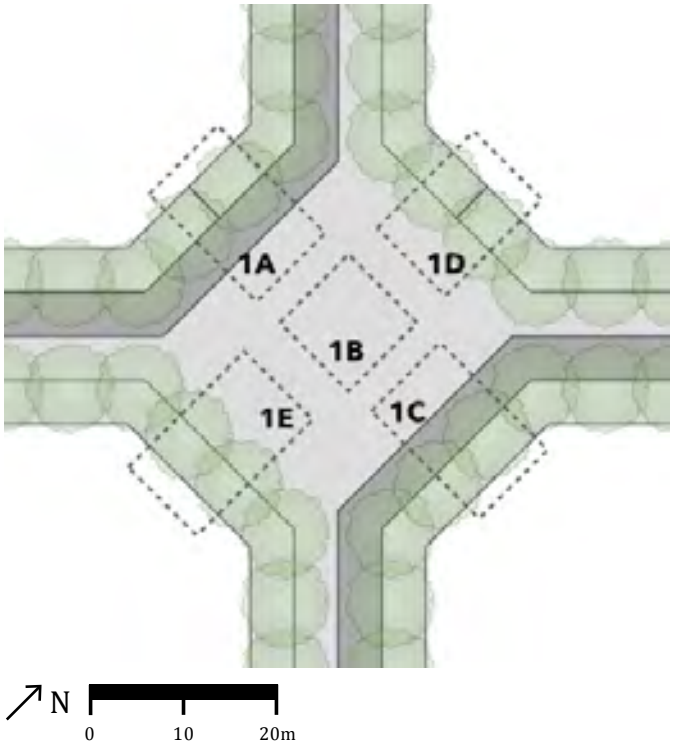


Fig 4.18 Spaces for neighbor node 1

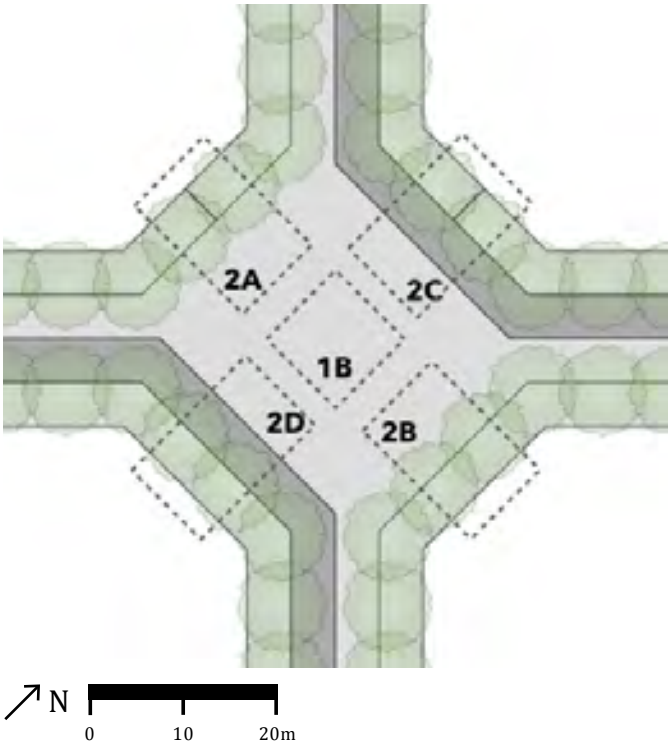
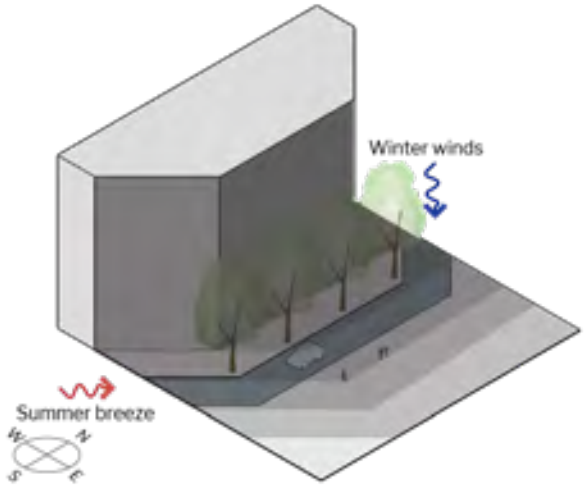


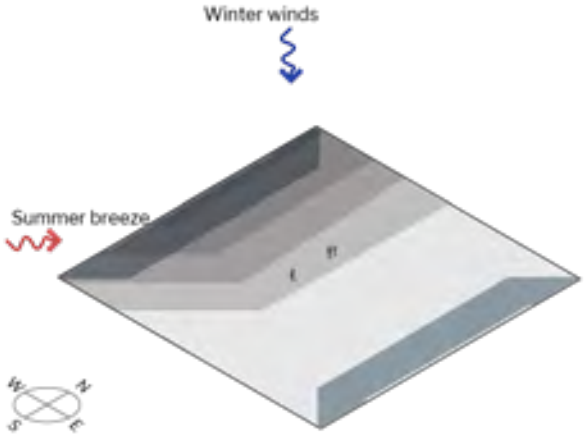
Fig 4.19 Space for neighbor node 2

Neighbor node 1



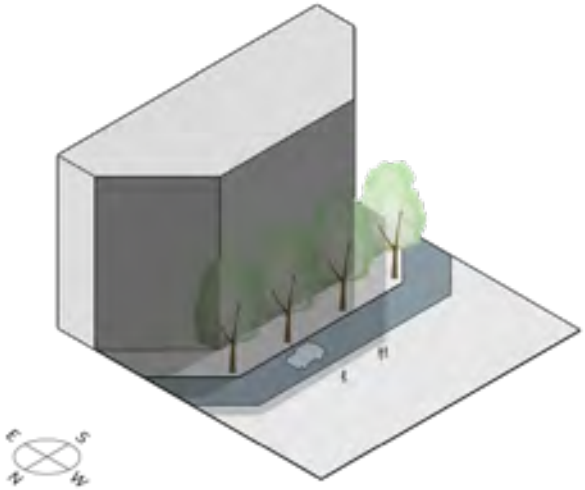
1A. Inner road + pedestrian area + shadows

The spatial composition of this sub-type includes the inner road and the pedestrian area. Due to the building located on the west side and according to the sun projections, the pedestrian space has 3 hours of shadows. Additionally, it has summer breezes coming from the south-west street, and winter winds coming from the north-west street.



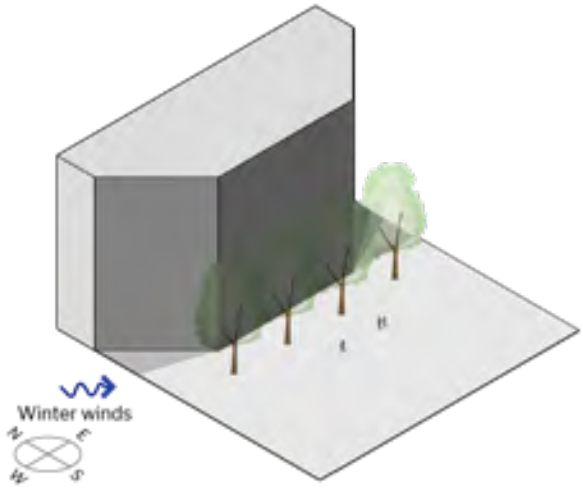
1B. Pedestrian area + little shadows

The spatial composition of this type includes only the pedestrian area. Buildings are far from this space, nevertheless, they can cast minor shadowing (3 hours) onto the west side of the pedestrian space. In addition, summer breezes are welcome while winter winds should not reach this space.



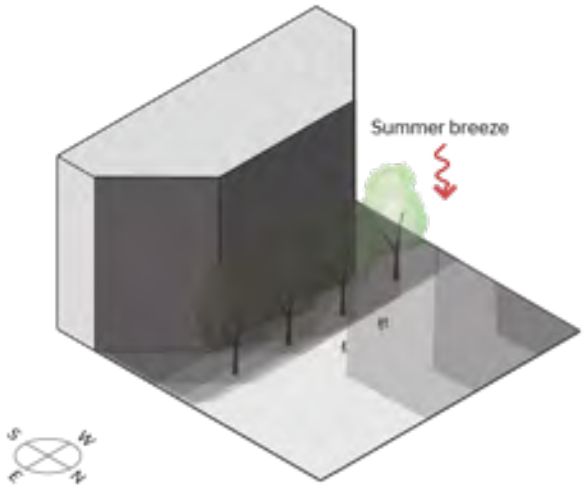
1C. Inner road + pedestrian area + little shadow

The spatial composition of this type includes the inner road and the pedestrian area. Due to the positioning of the building, located at the east side, and the projections of the sun during the hottest hours, minor shadows (1 hour) are cast into the pedestrian space. The wind has no influence in this space.



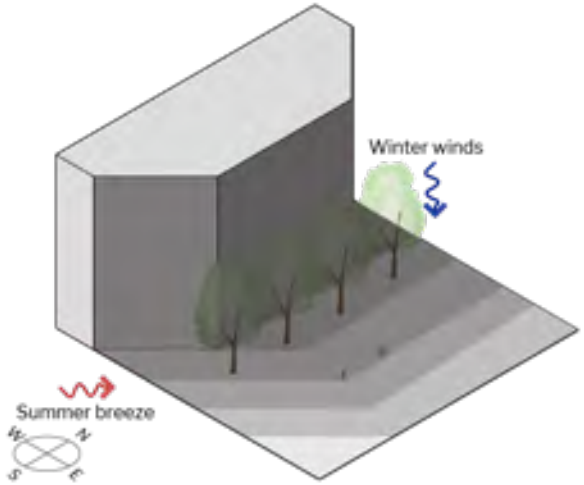
1D. Pedestrian area + no shadow

The spatial composition of this type includes only the pedestrian area. Due to the location of the building at the northern side and the sun projection during the hottest hours, there is no shadow cast onto the pedestrian space. Additionally, winter winds are coming from the north-west street.



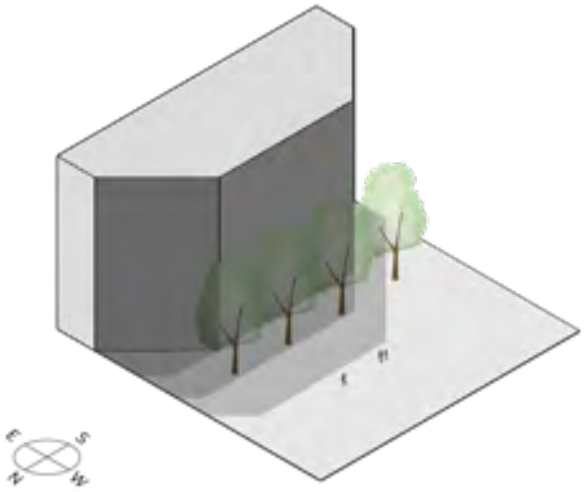
1E. Pedestrian area + some shadow

The spatial composition of this type includes only the pedestrian area. Due to the building located at the southern side and according to the projection of the sun, some small shadows (7 hours) are cast onto the pedestrian space. Also, the building from the west side cast shadows for 3 hours onto the pedestrian space starting at 16:00. Additionally, it has summer breezes coming from the south-west street.



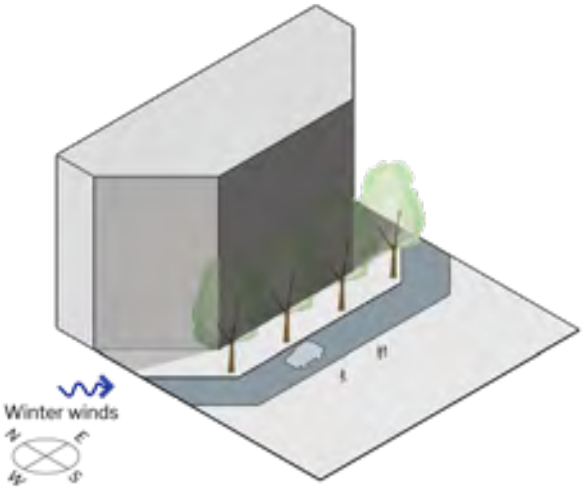
2A. Pedestrian area + shadows

The spatial composition of this type includes only the pedestrian area. Due to the building located at the western side and according to the projection of the sun during 12:00 and 18:00, shadows (4 hours) are cast onto the pedestrian space. Additionally, it has summer breezes coming from the south-west street and winter winds coming from the north-west street.



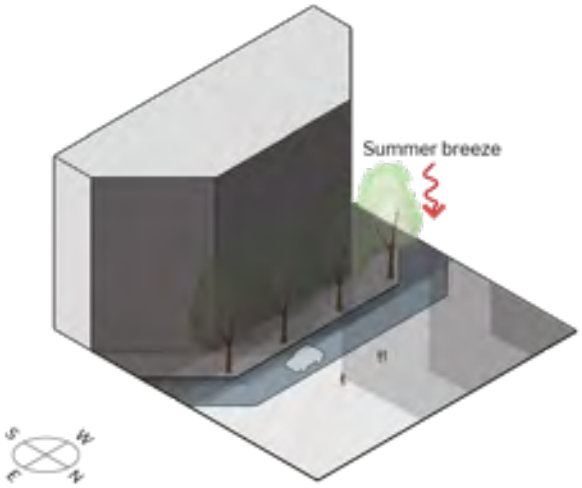
2B. Pedestrian area + little shadow

The spatial composition of this type includes only the pedestrian area. Due to the building located at the eastern side and the projections of the sun during the hottest hours, minor shadows (2 hours) are cast onto the pedestrian space. The wind has no influence in this space.



2C. Inner road + pedestrian area + no shadow

The spatial composition of this type includes the inner road and the pedestrian area. Due to the building location at the northern side and the sun projection during the hottest hours, there is no shadow cast onto the pedestrian space. Additionally, winter winds are coming from the north-west street.



2D. Inner road + pedestrian area + little shadow

The spatial composition of this type includes the inner road and the pedestrian area. Due to the building located at the southern side and according to the projection of the sun, some shadows (3 hour) are cast onto the pedestrian space, which comes from the building on the west side. Additionally, it has summer breezes coming from the south-west street.

4.3 RESULTS

The analysis provides the opportunity to determine the sensory issues for the different type of spaces for each neighbor node of the superblock.

Neighbor node 1

Neighbor node 1 has the inner roads on the west (1A) and east sides (1C). Additionally, buildings on the west side (1A) cast shadows onto space. This situation suggests that most of the shadow is cast into the sidewalk and the inner roads. Therefore this node will have visual and thermal issues in most of its pedestrian area (1B, 1D, and 1E). Additionally, winter winds come from the north-west and summer breeze from the south-west. These circumstances indicate that the design elements that will be used for the west area (1A) need to be able to block wind on the north end and allow ventilation on the south end.

Furthermore, the west (1A) and east sides (1C) share the issues of visual, acoustic, and olfactory discomfort, due to motorized vehicles. To avoid these issues, there should be an emphasis on comfort by using the techniques of control and masking. Whereas the north (1D), center (1B), and south (1E) spaces can focus on creating expressiveness with the technique of enhancing.

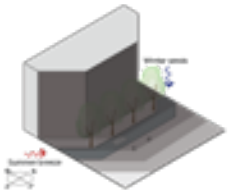
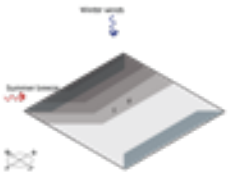
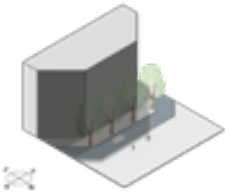
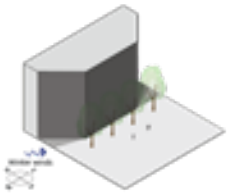
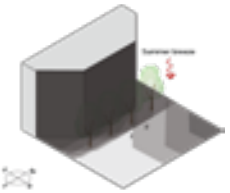
TYPE OF SPACE	 *1A. Inner road + pedestrian area + shadows*	 *1B. Pedestrian area + little shadows*	 *1C. Inner road + pedestrian area + little shadow*	 *1D. Pedestrian area + no shadow*	 *1E. Pedestrian area + some shadow*
SENSORY ISSUES – VISUAL	- Unpleasant views (motorized vehicles)	- Glare discomfort from 12:00 to 17:00	- Unpleasant views (motorized vehicles) - Glare discomfort from 12:00 to 18:00	- Glare discomfort from 12:00 to 18:00	- Glare discomfort from 12:00 to 17:00
SENSORY ISSUES – ACOUSTIC	- Noise pollution (motorized vehicles)		- Noise pollution (motorized vehicles)		
SENSORY ISSUES – OLFACTORY	- Air pollution (motorized vehicles)		- Air pollution (motorized vehicles)		
SENSORY ISSUES – THERMAL	- Winter winds	- High temperature from 12:00 to 17:00	- High temperature from 12:00 to 18:00	- High temperature from 12:00 to 18:00 - Winter winds	- High temperature from 12:00 to 17:00

Table 4.20 Neighbor node 1: Type of spaces with issues per sense

Neighbor node 2

Neighbor node 2 presents the inner roads on the north (2C) and south (2D) sides. This positioning of roads indicates that most of the shadow is on the sidewalk and inner roads. In addition, space 2D presents shadow from the west building starting at 16:00. Due to this situation, the reflective radiant heat sources are affecting most of the pedestrian area. Furthermore, the areas next to the inner roads (2C & 2D) present visual, acoustic, olfactory, and thermal issues on both sides, which determines that these spaces require more emphasis on comfort with the techniques of control and masking. The west (2A), center (1B), and east (2B) areas present thermal and visual discomforts that are stronger near the east (2B). Due to this situation, the techniques for control, masking, and enhancing are needed and should increase in effectiveness towards the east side.

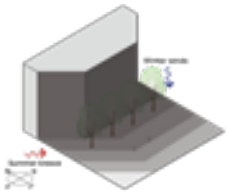
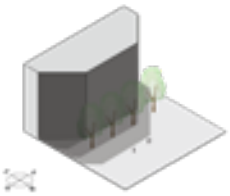
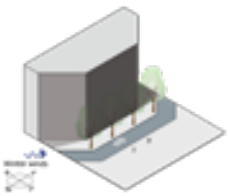
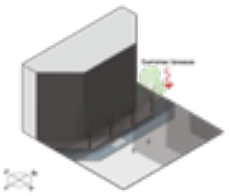
TYPE OF SPACE	 *2A. Pedestrian area + shadows*	 *2B. Pedestrian area + little shadow*	 *2C. Inner road + pedestrian area + no shadow*	 *2D. Inner road + pedestrian area + little shadow*
SENSORY ISSUES – VISUAL		- Glare discomfort from 13:00 to 18:00	- Unpleasant views (motorized vehicles) - Glare discomfort from 12:00 to 18:00	- Unpleasant views (motorized vehicles) - Glare discomfort from 12:00 to 17:00
SENSORY ISSUES – ACOUSTIC			- Noise pollution (motorized vehicles)	- Noise pollution (motorized vehicles)
SENSORY ISSUES – OLFACTORY			- Air pollution (motorized vehicles)	- Air pollution (motorized vehicles)
SENSORY ISSUES – THERMAL	- Winter winds	- High temperature from 13:00 to 18:00	- High temperature from 12:00 to 18:00 - Winter winds	- High temperature from 12:00 to 17:00

Table 4.21 Neighbor node 2: Type of space with issues per sense

5. Answering SRQ 3: Integrated strategies for the different type of spaces for each neighbor node of the superblock

5.1 METHOD

This chapter answers sub research question 3. It uses the combined information from research questions 1 and 2 to determine the integrated strategies for the different type of space for each neighbor node of the superblock. These strategies were tested in models to determine which can be applied in a real context.

There are three loops for this chapter: Loop 1, which establishes the design strategies per sense (Chapter 5.2); loop 2, which establishes integrated strategies (Chapter 5.3); and loop 3, which test the guidelines into a real context (Chapter 5.4)(See figure 5.1).

Loop 1 uses the design strategies per sense (Chapter 5.2), which are determined from a literature study, the evaluation matrixes (Chapter 3 and Appendix B) and the sensory issues per space established in chapter 4. The strategies per sense and their tools are tested in different models (See Appendix C). The design tools for each strategy were evaluated through the evaluation matrix per technique (Chapter 3.2). This part of research through designing is an iterative process, which continued until the strategies for all the senses were determined.

In Loop 2, summary tables (Tables 5.1 and 5.2) were used, where the individual sense design strategies were merged into integrated strategies (Chapter 5.3). Then this integrated strategies are tested in integrated models (Appendix D).

In Loop 3 the integrated design guidelines (Chapter 5.3) are tested in a real design (Chapter 5.4), and the reflection of this will produce the final design guidelines.

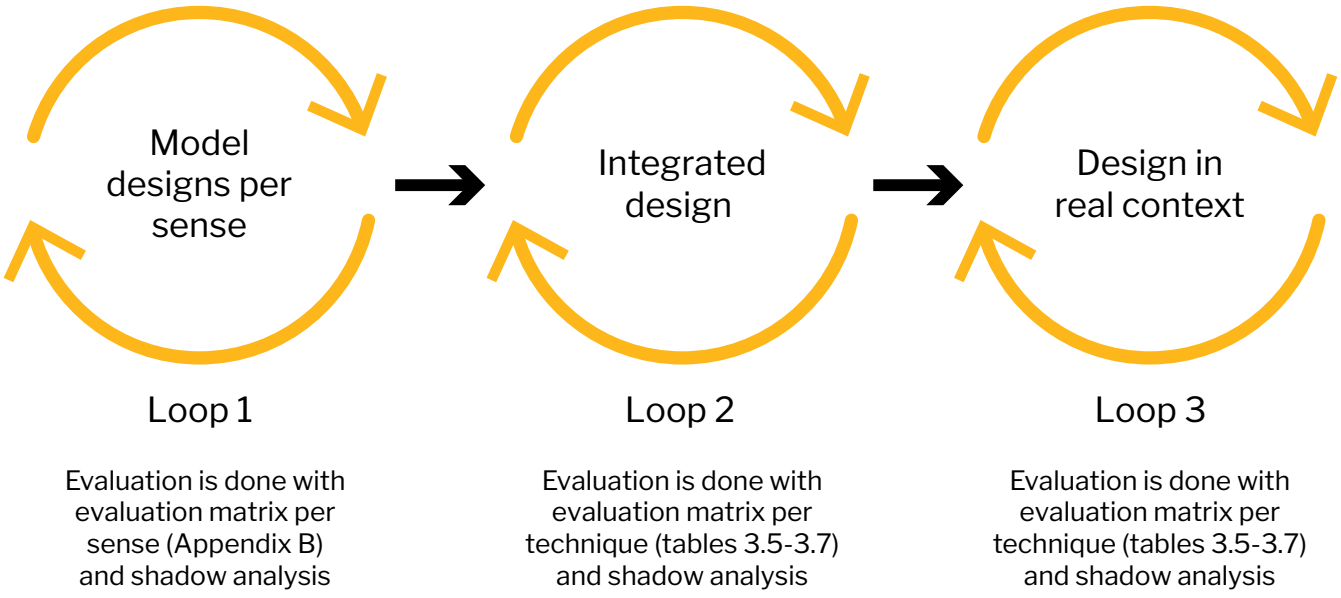


FIG 5.1. RESEARCH THROUGH DESIGNING PROCESS

5.2 STRATEGIES PER SENSE

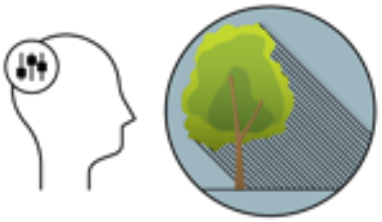
In this section, I introduce the design strategies per sense. These strategies are grouped by sense and subdivided by technique. There are 19 strategies in total. Four belong to sight; three to hearing; seven to smell; and five to temperature. Each strategy comes with a set of design tools. The efficiency of the tool can be checked on the evaluation matrix per sense (Appendix B).

The application of techniques can vary according to the different type of spaces and their requirements. In the following figure (5.2), the design guidelines are established and subdivided in senses and organized according to techniques. These guidelines per sense are later combined to create integrated strategies.

VISUAL COMFORT & EXPRESSIVENESS

ACOUSTIC COMFORT & EXPRESSIVENESS

TECHNIQUES STRATEGIES



Shadows

Use of elements that cast shadows to reduce glare.

Tools

1) Green demarcation elements
2) Hedges
3) Perennial plants
4) Graduation works
5) Trees
6) Waterfalls
7) Waterfall pergolas
8) Green pavilions and arbors
9) Planted pergolas

Depaving

Replacing hard surface with vegetation to reduce glare.

Tools

1) Hedges
2) Perennial plants
3) Low plants
4) Shrubs
5) Wind plus shadow elements

Block a view

Use of a pleasurable element to avoid seeing an unpleasant one.

Tools

1) Green demarcation elements
2) Hedges
3) Perennial plants
4) Shrubs
5) Wind plus shadow elements
6) Graduation works
7) Waterfall
8) Low plants
9) Green ponds
10) Waterfall pergolas
11) Fountains
12) Green pavilions and arbors

Pleasurable elements

Use of pleasurable elements.

Tools

1) Green ponds
2) Waterfall pergolas
3) Low plants
4) Green demarcation elements
5) Hedges
6) Perennial plants
7) Shrubs
8) Wind plus shadow elements
9) Graduation works
10) Trees
11) Waterfalls
12) Fountains
13) Green pavilions and arbors
14) Planted pergolas
15) Green masts

Absorb noise

Reduce the number of decibels (dB).

Tools

1) Green demarcation elements
2) Wind plus shadow elements
3) Graduation works
4) Waterfalls
5) Low plants
6) Hedges
7) Perennial plants
8) Shrubs
9) Trees
10) Planted pergolas

Pleasant sounds

Introduce new pleasant sounds.

Tools

1) Graduation works
2) Waterfalls
3) Green ponds
4) Waterfalls pergolas
5) Fountains
6) Low plants
7) Green demarcation elements
8) Hedges
9) Perennial plants
10) Shrubs
11) Wind plus shadow elements
12) Trees
13) Green pavilions and arbors
14) Planted pergolas
15) Green masts

Pleasant sounds

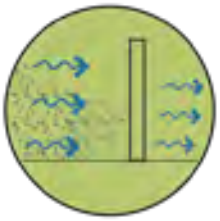
Introduce new pleasant sounds.

Tools

1) Low plants
2) Green demarcation elements
3) Hedges
4) Perennial plants
5) Shrubs
6) Trees
7) Planted pergolas
8) Wind plus shadow elements
9) Green pavilions and arbors
10) Green masts
11) Graduation works
12) Waterfalls
13) Green ponds
14) Waterfalls pergolas
15) Fountains

OLFACTORY COMFORT & EXPRESSIVENESS

TECHNIQUES STRATEGIES

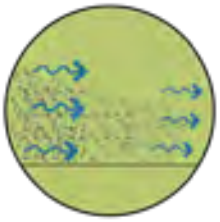


Absorb air pollution

Reduce the number of pollutants in the air through vegetation.

Tools

1) Wind plus shadow elements
2) Trees
3) Low plants
4) Green demarcation elements
7) Hedges
8) Perennial plants
9) Shrubs



Dilute odors

Use of wind to diminish the intensity of a smell.

Tools

1) Low plants
2) Green masts

Intensify a smell

Use of water body to reflect heat to increase a scent.

Tools

1) Green ponds
2) Waterfall pergolas
3) Fountains*

New smell

Use of a new source of smell for its characteristics.

Tools

1) Green ponds
2) Low plants
3) Hedges
4) Perennial plants
5) Shrubs
6) Wind plus shadow elements
7) Trees
8) Green pavilions and arbors
9) Planted pergolas
10) Green demarcation elements
11) Green masts

Intensify a smell

Use of a water body to reflect heat to increase a scent.

Tools

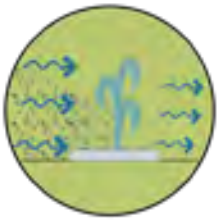
1) Green ponds
2) Waterfall pergolas
3) Fountains*

New smell

Use of a new source of smell for its characteristics.

Tools

1) Green ponds
2) Waterfall pergolas
3) Fountains
4) Low plants
5) Perennial plants
6) Shrubs
7) Hedges
8) Trees
9) Planted pergolas
10) Wind plus shadow element
11) Green demarcation elements
12) Green pavilions and arbors
13) Green masts
14) Graduation works
15) Waterfalls

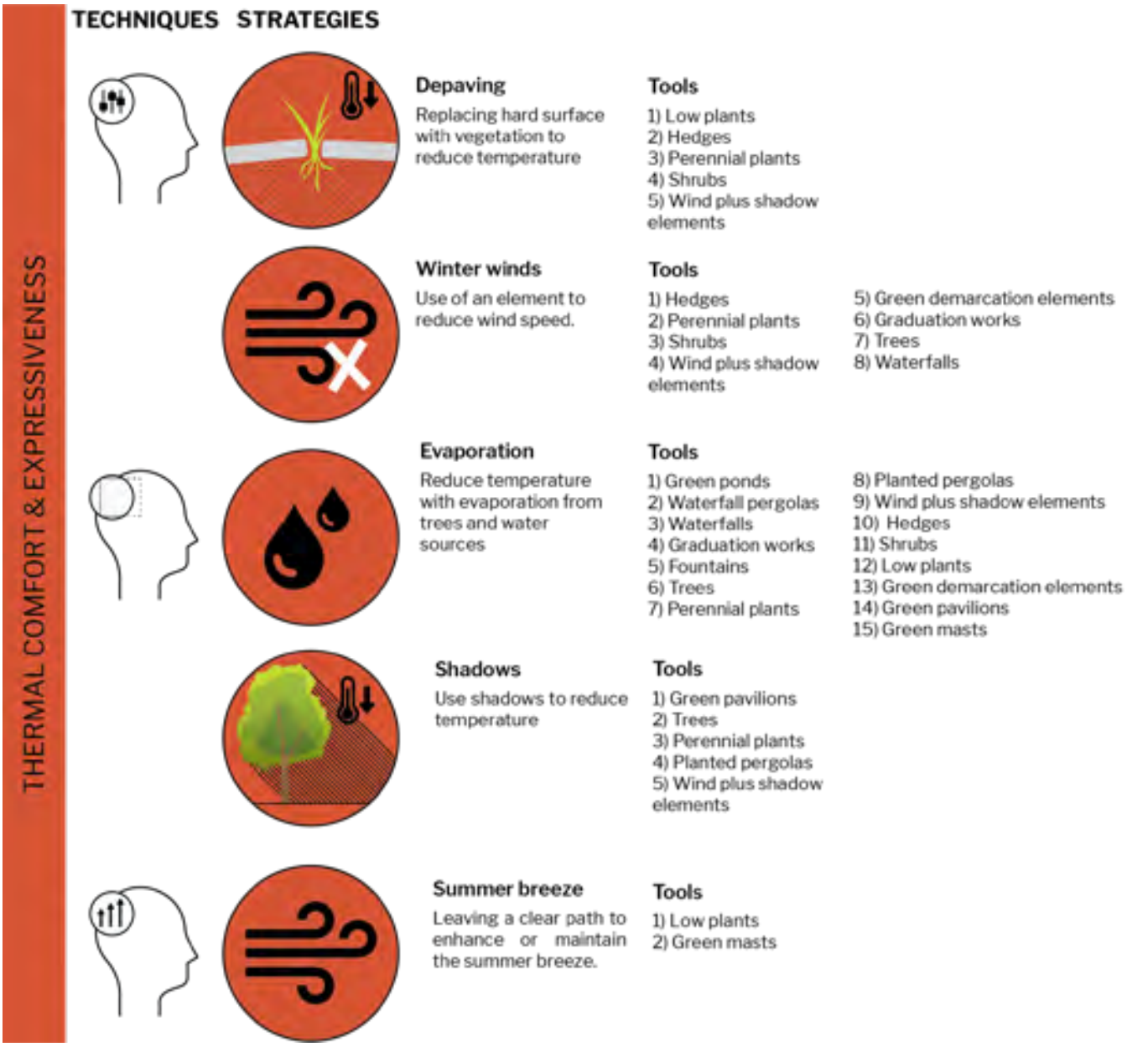


Cleanse the air

Use of water to increase the perceived freshness of the air.

Tools

1) Green ponds
2) Waterfall pergolas
3) Fountains



Note: The guideline "Pleasant sounds" repeats for masking and enhancing. Nevertheless, the design tools have different efficiencies depending on the technique.

FIGURE 5.2 DESIGN STRATEGIES PER SENSE

5.3 INTEGRATED DESIGN GUIDELINES

In this section, the design strategies per sense (Chapter 5.2) merge to elaborate the integrated design guidelines (figure 5.3). These integrated guidelines are divided into techniques. Each guidelines comes with an explanation and a set of design tools. Then, the spatial analysis from the prototypical model is used to present integrated design guidelines in space.

SUMMARY TABLES

The summary tables, help establish the integrated design guidelines per technique. The explanation for each integrated strategy with its corresponding design tools can be found in the section after tables 5.1 and 5.2

Table 5.1 and 5.2, for the technique of control, shows that there are seven strategies per sense: two for the visual sense, one for the acoustic sense, two for the olfactory sense, and two for the thermal sense. The strategies "Absorb air pollution" and "Absorb noise" are combined to create the integrated design guideline "Absorb pollution". The strategy of "Depaving" has been merged and has a double function now, to reduce glare and heat. The strategies "Winter winds" and "Shadows" are maintained. The strategy "Dilute odors" is eliminated from the integrated strategies since, for "Dilute odors", winds are not strong enough (Chapter 4.2).

TECHNIQUES	SENSES	1A. INNER ROAD + PEDESTRIAN AREA + SHADOWS	1B. PEDESTRIAN AREA + LITTLE SHADOWS	1C. INNER ROAD + PEDESTRIAN AREA + LITTLE SHADOW	1D. PEDESTRIAN AREA + NO SHADOW	1E. PEDESTRIAN AREA + SOME SHADOW
Control	**Visual**		Shadows	Shadows	Shadows	Shadows
			Depaving	Depaving	Depaving	Depaving
	Acoustic	Absorb noise		Absorb noise		
	Olfactory	Absorb air pollution		Absorb air pollution		
		Dilute odors				Dilute odors
	Thermal	Winter winds			Winter winds	
			Depaving	Depaving	Depaving	Depaving
Integrated design guidelines for control		Absorb pollution	Shadows	Absorb pollution	Shadows	Shadows
		Winter winds	Depaving	Shadows	Depaving	Depaving
				Depaving	Winter winds	
Masking	**Visual**	Block a view		Block a view		
	Acoustic	Pleasant sounds		Pleasant sounds		
	Olfactory			Intensify smell		
		New smell		New smell		
	Thermal		Shadows	Shadows	Shadows	Shadows
			Evaporation	Evaporation	Evaporation	Evaporation
Integrated design guidelines for masking		New smell/block view	Lower temperature	New smell/block view	Lower temperature	Lower temperature
		Pleasant sounds		Pleasant sounds		
				Intensify a smell		
				Lower temperature		
Enhancing	**Visual**		Pleasurable elements		Pleasurable elements	Pleasurable elements
	Acoustic		Pleasant sounds		Pleasant sounds	Pleasant sounds
	Olfactory	Cleanse the air		Cleanse the air		
			Intensify smell		Intensify smell	
			New smell		New smell	New smell
	Thermal	Summer breeze				Summer breeze
Integrated design guidelines for enhancing			Intensify smell		Intensify smell	Intensify smell
			New smell		New smell	New smell
		Summer breeze	Pleasurable views/ sound		Pleasurable views/ sound	Pleasurable views/ sound
						Summer breeze

TABLE 5.1 SUMMARY TABLE NEIGHBOR NODE 1

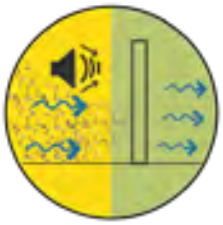
For masking, there are six strategies: two for the olfactory sense; one for the visual sense, one for the acoustic sense and two for the thermal sense. Strategies “Block a view” and “New smell” are merged into “New smell/ block view”. Furthermore, the strategies “Evaporation” and “Shadows” are combined into the strategy “Lower temperature”. The strategies “Pleasant sounds” and “Intensify smell” are maintained.

For enhancing, there are six strategies: one for the visual sense, one for the acoustic sense, three for the olfactory sense and one for the thermal sense. The strategies “Pleasurable elements” and “Pleasant sounds” are merged into “Pleasurable views/sounds”. The strategies “Intensify smell”, “New smell”, and “Summer breeze” are maintained. The strategy “Cleanse the air” is eliminated from the integrated design guidelines since it requires the use of water elements next to the inner roads. This situation will cause conflict with the other strategies.

TECHNIQUES	SENSES	2A. PEDESTRIAN AREA + SHADOWS	2B. PEDESTRIAN AREA + LITTLE SHADOW	2C. INNER ROAD + PEDESTRIAN AREA + NO SHADOW	2D. INNER ROAD + PEDESTRIAN AREA + LITTLE SHADOW
Control	**Visual**		Shadows	Shadows	Shadows
			Depaving	Depaving	Depaving
	Acoustic			Absorb noise	Absorb noise
	Olfactory			Absorb air pollution	Absorb air pollution
		Dilute odors			Dilute odors
	Thermal	Water winds		Water winds	
			Depaving	Depaving	Depaving
Integrated design guidelines for control			Shadows	Absorb pollution	Absorb pollution
		Water winds	Depaving	Shadows	
				Depaving	Shadows
				Water winds	Depaving
Masking	**Visual**			Block a view	Block a view
	Acoustic			Pleasant sounds	Pleasant sounds
	Olfactory			Intensify smell	Intensify smell
				New smell	New smell
	Thermal		Shadows	Shadows	Shadows
			Evaporation	Evaporation	Evaporation
Integrated design guidelines for masking			Lower temperature	New smell/block view	New smell/block view
				Pleasant sounds	Pleasant sounds
				Intensify smell	Intensify smell
				Lower temperature	Lower temperature
Enhancing	**Visual**	Pleasurable elements	Pleasurable elements		
	Acoustic	Pleasant sounds	Pleasant sounds		
	Olfactory			Cleanse the air	Cleanse the air
			Intensify smell		
		New smell	New smell		
	Thermal	Summer breeze			Summer breeze
Integrated design guidelines for enhancing		Intensify smell	Intensify smell		Summer breeze
		New smell	New smell		
		Pleasurable views/sounds	Pleasurable views/sounds		
		Summer breeze			

TABLE 5.2 SUMMARY TABLE NEIGHBOR NODE 2

TECHNIQUES STRATEGIES



Absorb pollution

Reduces the number of pollutants in the air and the number of decibels.

Tools

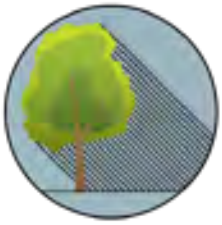
1) Green demarcation elements
2) Hedges
3) Low plants
4) Perennial plants
5) Shrubs
6) Trees
7) Wind plus shadow elements

Winter winds

Use of an element to reduce wind speed.

Tools

1) Graduation works
2) Green demarcation elements
3) Hedges
4) Perennial plants
5) Shrubs
6) Trees
7) Waterfalls
8) Wind plus shadow elements

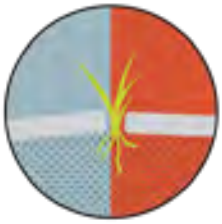


Shadows

Use of shadows to reduce glare.

Tools

1) Graduation works
2) Green demarcation elements
3) Green pavilions and arbors
4) Hedges
5) Perennial plants
6) Planted pergolas
7) Trees
8)Waterfall pergolas



Depaving

Replace hard surfaces with vegetation to reduce glare and lower air temperature.

Tools

1) Low plants
2) Shrubs
3) Wind plus shadow elements

New smell/block view

Adds new smell for its characteristics while blocking an unpleaseant view.

Tools

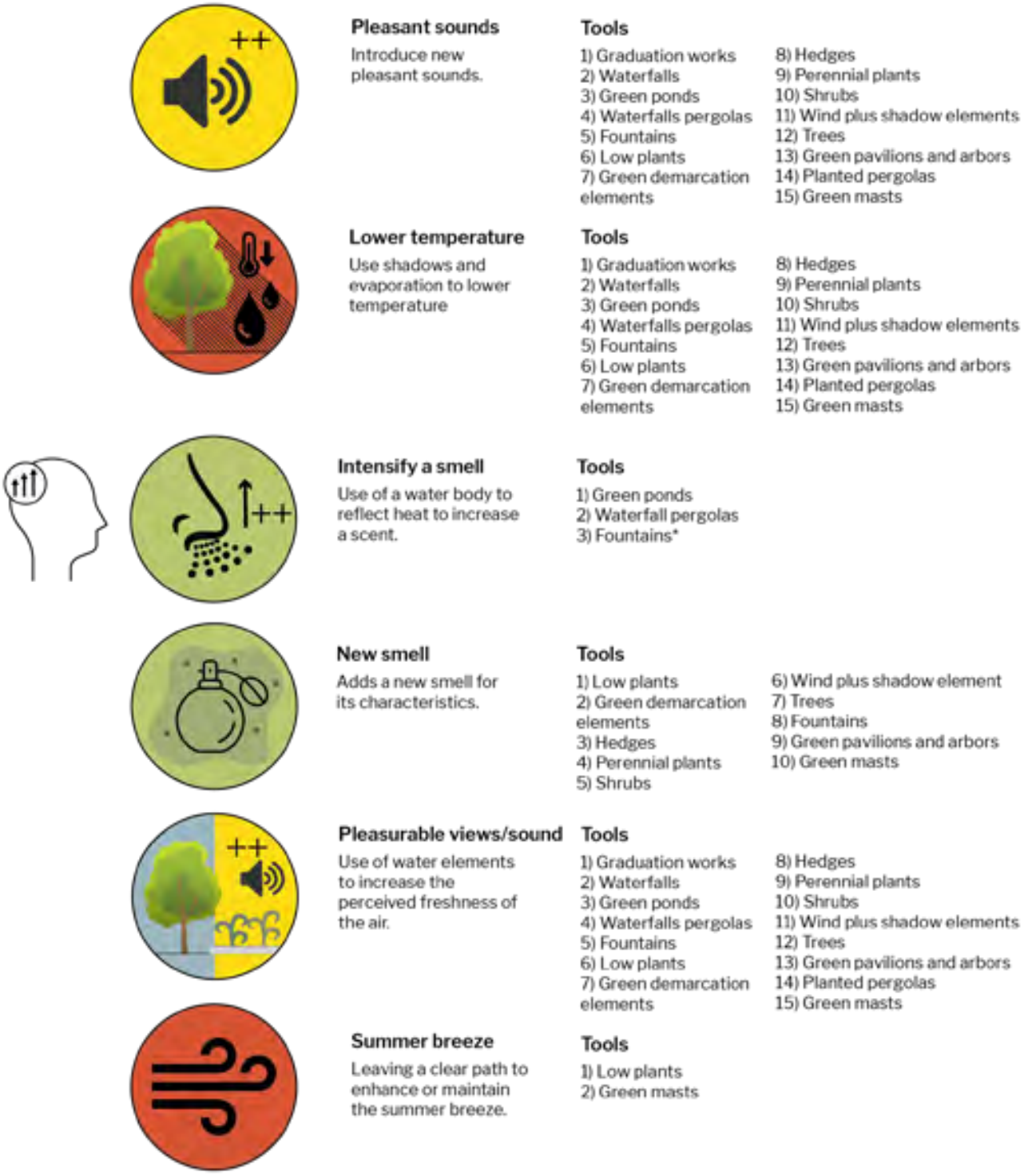
1) Green demarcation elements
2) Green pavilions and arbors
3) Hedges
4) Low plants
5) Perennial plants
6) Shrubs
7) Wind plus shadow elements

Intensify a smell

Use of a water body to reflect heat to increase a scent.

1) Green ponds
2) Waterfall pergolas
3) Fountains*

TECHNIQUES STRATEGIES



Note: For the tool "Intensify a smell", it should only be used, for masking, if there are motorized vehicles and limited amount of shadows. For enhancing, it should be used if the area has limited amount of shadows.

FIGURE 5.3 INTEGRATED DESIGN STRATEGIES

5.3 RESULTS

Integrated strategies for the different type of spaces for neighbor node 1 and 2

There are five types of spaces to consider when designing neighbor node 1. Each one of these spaces has different techniques that can be applied to them. Each technique presents a different set of integrated design strategies.

These three elements are combined to determine which guidelines will be applied in the design for neighbor node 1.

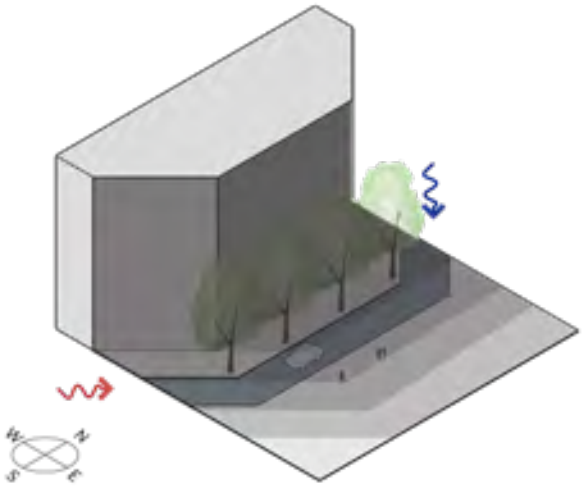
Neighbor node 1

1A. Inner road + pedestrian area + shadows

Techniques: control, masking, and enhancing.

Issues: unpleasant views from motorized vehicles; noise pollution; air pollution and traffic fumes; and cold stress from winds in winter.

Potentials: summer breeze.

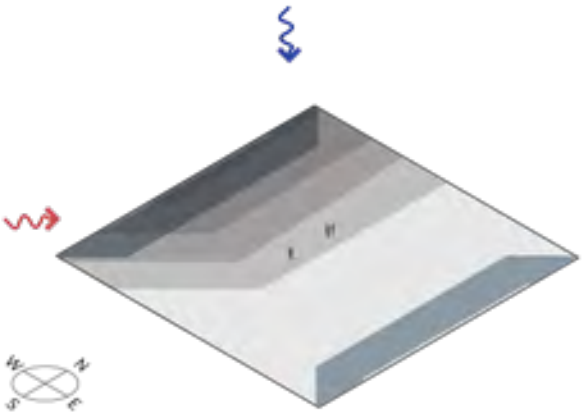


1B. Pedestrian area + little shadows

Techniques: control, masking, and enhancing.

Issues: glare disability; and heat stress from shortwave radiation.

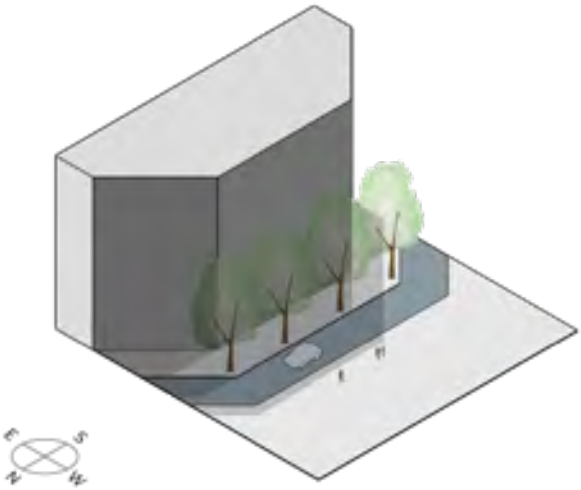
Potentials: increase of pleasure for the visual, acoustic and olfactory senses.



1C. Inner road + pedestrian area + little shadow

Techniques: control and masking

Issues: unpleasant views from motorized vehicles and glare disability; noise pollution; air pollution and traffic fumes; and heat stress from shortwave radiation in summer.

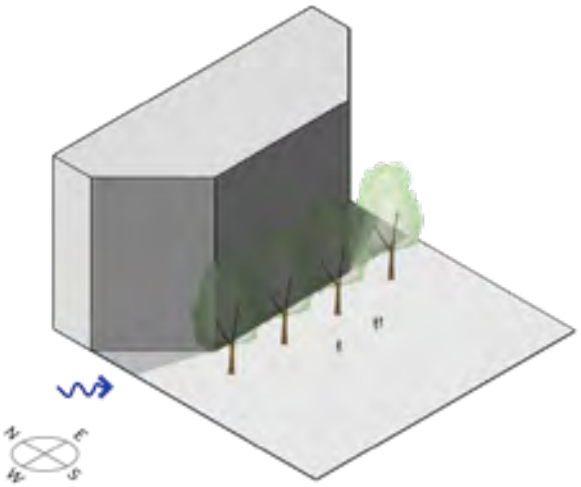


1D. Pedestrian area + no shadow

Techniques: control, masking, and enhancing.

Issues: glare disability; and heat stress from shortwave radiation and cold stress from winter winds.

Potentials: increase of pleasure for the visual, acoustic and olfactory senses.

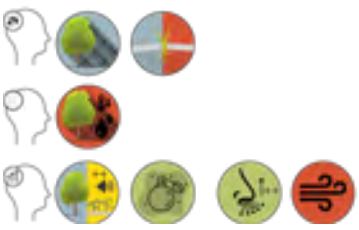


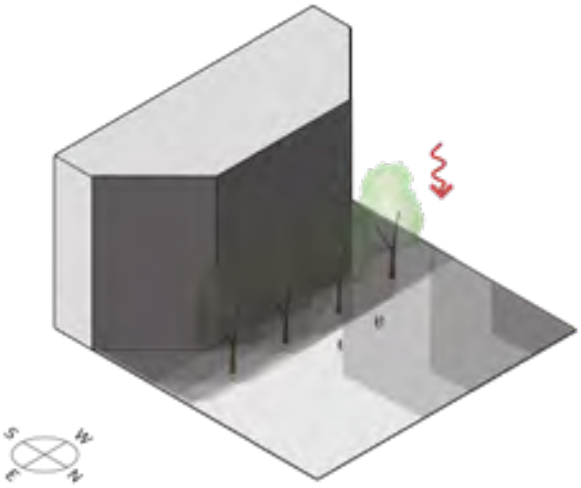
1E. Pedestrian area + some shadow

Techniques: control, masking and enhancing.

Issues: glare disability; and heat stress from shortwave radiation.

Potentials: summer breeze and increase of pleasure for the visual, acoustic and olfactory senses.





Summary Neighbor Node 1

For the west side (1A) of neighbor node 1, three techniques need to be used: control, masking, and enhancing. For control, the integrated strategies applied are “Absorb pollution”, and “Winter winds”. For masking, the use of “Pleasurable sounds” and “New smell/block view” is recommended. For enhancing, the strategy of “Summer breeze” is suggested.

For the east side (1C), the techniques of control and masking are being used. The technique of enhancing is not being used since, in the space next to the inner roads, the priority is to control and mask for comfort. Using the strategies for enhancing will have the same effect as using the technique of masking, therefore, it is not used. Additionally, since the “Summer breeze” does not come from the north-east or the south-east, it is not considered as a strategy to be implemented. The strategies used for control are “Depaving”, “Shadows”, and “Absorb pollution”. For masking, the strategies chosen are “Pleasant sounds”, “New smell/block view”, and “Lower temperature”.

For the north (1D), the center (1B) and south space (1E), three techniques are applied: control, masking, and enhancing. The strategies that these spaces have in common are “Shadows” and “Depaving”. Additionally, the north side (1D) uses “Winter winds” as a strategy. For masking, all spaces use “Lower temperature”. For enhancing, the strategies “Pleasurable views/ sounds”, “New smell”, and “Intensify smell” are being used. Moreover, the south space (1E) uses “Summer wind” for ventilation.

To conclude, it can be established that the pedestrian spaces (1B, 1D, and 1E) present basically the same strategies. Additionally, 1E includes the strategy of “Summer winds”, which is determined due to its connection with the south-west street. As for the spaces 1A and 1C, both share “Absorb pollution”, “New smell/block view”, and “Pleasant sounds” due to their connection to the inner roads. The other strategies are dependent on the microclimatic conditions, such as the exposure to sun and the wind direction.

Neighbor node 2

For neighbor node 2, there are four new types and one common type of spaces to consider. Techniques will be applied to them, which will be followed by integrated design strategies.

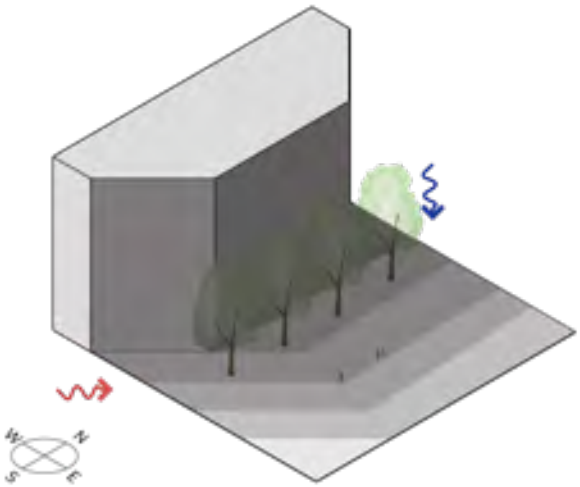
These three elements are put together to determine the design guidelines that will be applied in the design for neighbor node 2.

2A. Pedestrian area + shadows

Techniques: control and enhancing.

Issues: cold stress from winds in winter.

Potentials: summer breeze and increase of pleasure for the visual, acoustic and olfactory senses.

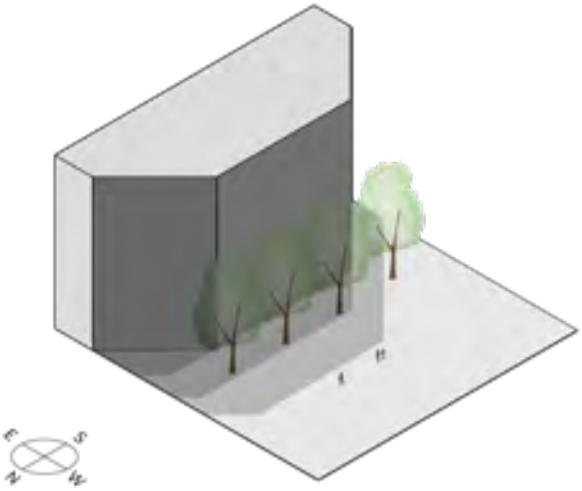


2B. Pedestrian area + little shadow

Techniques: control, masking, and enhancing.

Issues: glare disability; and heat stress from shortwave radiation.

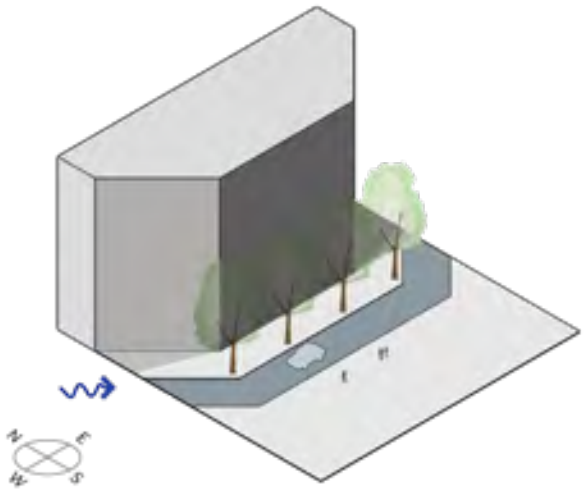
Potentials: increase of pleasure for the visual, acoustic and olfactory senses



2C. Inner road + pedestrian area + no shadow

Techniques: control and masking.

Issues: unpleasant views from motorized vehicles and glare disability; noise pollution; air pollution and traffic fumes; heat stress from shortwave radiation and cold stress from winter winds.

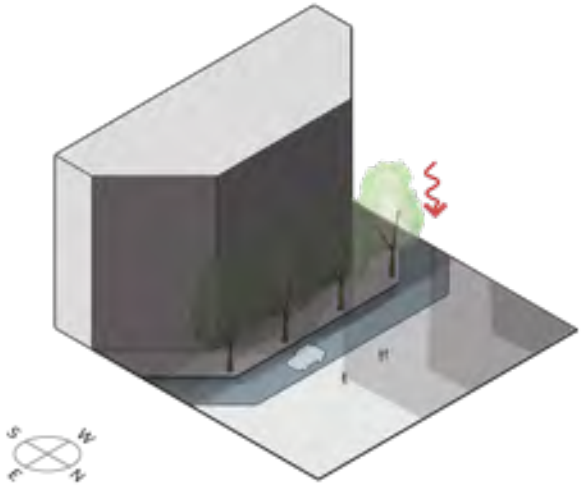


2D. Inner road + pedestrian area + little shadow

Techniques: control, masking, and enhancing.

Issues and potentials: unpleasant views from motorized vehicles and glare disability; noise pollution; air pollution and traffic fumes; and heat stress from shortwave radiation.

Potentials: summer breeze.



Summary Neighbor Node 2

It is established in the west area (2A) the use of two techniques: control and enhancing. There is no need for masking since there is a lack of motorized vehicles, and shadows are cast into space. For control, the strategy “Winter winds” is used. For enhancing, the implementation of “Pleasurable views/sounds”, “New smell”, “Intensify a smell”, and “Summer winds” is recommended.

The east area (2B), uses three techniques. For control, “Shadows” and “Depaving” are recommended. For masking, the use of “Lower temperature” is suggested. For enhancing, “Pleasurable views/sounds”, “Intensify a smell”, and “New smell” are being implemented.

The north (2C) and south (2D) sides have two techniques in common: control and masking. For control, these spaces share the strategies of “Shadows”, “Depaving”, and “Absorb pollution”. Additionally, the north side (2C) uses “Winter winds”. For masking, both spaces use “Pleasant sounds”, “New smell/block view”, “Intensify a smell”, and “Lower temperature”. Furthermore, the north (2C) and south space (2D) do not use all strategies for enhancing, due to their positioning next to the inner roads. Only 2D uses “Summer breeze” due to the wind direction.

To summarize, the spaces next to the inner roads (2C and 2d) share basically the same strategies. In addition, due to wind directions, both spaces include strategies related to wind. As for the pedestrian spaces (1B and 2B), both share the same strategies. Due to the exposure to the sun, the space 2A does not require glare control or thermal masking. Nevertheless, it does require wind protection from the north-west and takes advantage of summer winds at the south-west end.

5.4 DESIGN

This section explains the implementation of the integrated design guidelines, generated in section 5.3, into a real site design. First, some design considerations will be explained. Then, the location of the site, the components and characteristics of this superblock will be presented.

5.4.1 Design considerations

For the design of the neighbor nodes, there are a few considerations that must be taken into account.

As mentioned in chapter 1.2.2, neighbor nodes are created for new functions and uses for citizens. Possible functions for the neighbor nodes include recreation areas, such as playgrounds, resting area, festivities, and sports; exchange areas, for instance, market; areas for expression and participation; for culture and knowledge; and displacement. These functions are dependent on the existing urban context. Therefore, the design must consider the activities planned for the space and the current context before using the integrated design guidelines.

As the design intends to integrate all senses, it is imperative to know that some of the strategies could alter the effectiveness of others. Therefore, the use of the evaluation matrix (Chapter 3.2) can help determined which design tools are more applicable and combinable.

5.4.2 Site design

The south-west area of the Eixample grid has some of the highest temperatures during heatwaves (Àrea d'Ecologia Urbana, 2018). Furthermore, due to the obstacles of the dense tissue of the medieval city and the prominent hill called Montjuic, the south-west area of the Eixample cannot take advantage of the coastal wind system to lower air temperature.

Therefore, the site design is located in the south-west Eixample area, between the streets Carrer Roger de Lluria and Bailen; and between Gran via de Les Cort Catalanes, Ronda de San Pere and Carrer d' Ali Bei (Figure 5.2). This site is one of the potential superblocks chosen by the Municipality of Barcelona that has the four neighbor nodes to be freed from traffic.

The site has nine blocks and four neighbor nodes. Seven blocks are consistent with the 113.3 by 113.3 meters block from Cerda's grid, while two of them are smaller in size. Carrer del Bruc, between Carrer d' Ausias Marc and Ronda de Sant Pere, is approximately 50 meters long.

The junction of Carrer d' Ausias Marc and Carrer del Bruc will be known as neighbor node 1 (NN1), and the intersection of Carrer de Casp and Carrer del Bruc will be known as neighbor node 2 (NN2). Each neighbor node represents a type, with inner roads on the east and west side for NN1, and roads in the north and south side for the NN2.

Fig 5.4 Site design location: NN1 and NN2

5.4.3 Neighbor node 1 (NN1)

Analysis

Context analysis

The area of the superblock is characterized for being a residential and commercial area. There are many shops and restaurants, and some hotels near the site. Above the commercial ground floor there are apartments. Neighbor node 1 has on the ground floor the post office on the west side, restaurants on the north side, and clothing shops on the east and south side.

Analysis per sense

The analysis per sense differs slightly from the analysis in chapter 4.2. In NN1, there is a building on the west side of the node that is higher than the rest of the buildings. This difference will affect the microclimate due to the larger shadow that it will cast. In the case of wind, due to the wind direction and the wind speed, there is no change.

In the case of the visual comfort analysis, there is a reduction of glare discomfort due to the large shadow cast by the building on the west side. Additionally, noise pollution coming from the basic network (Ronda de San Pere) will increase in comparison to the original analysis. The street length has diminished by 50%. It is expected that air pollution will be higher due to the proximity of 50 meters to the basic network. Finally, the thermal discomfort will lower due to the shadow cast by the building on the west side.

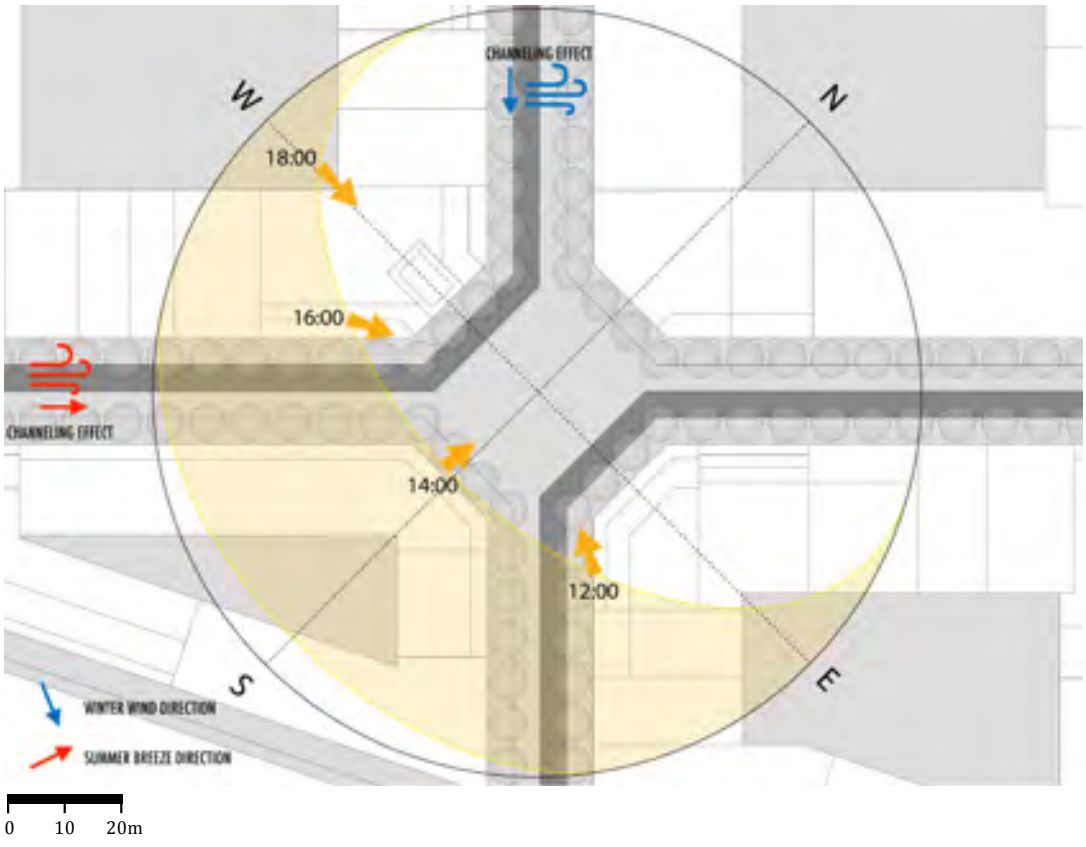


Fig 5.5 Microclimate analysis: NN1

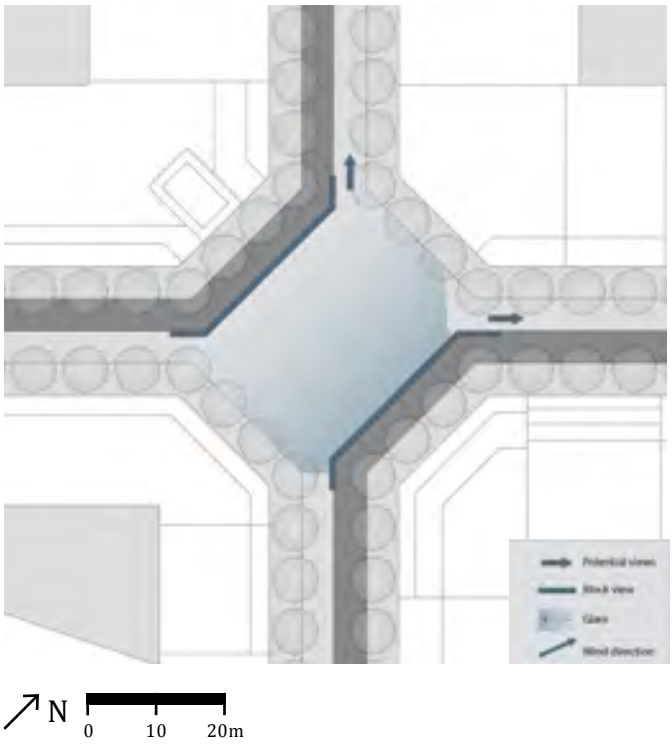


Fig 5.6 Visual analysis: NN1

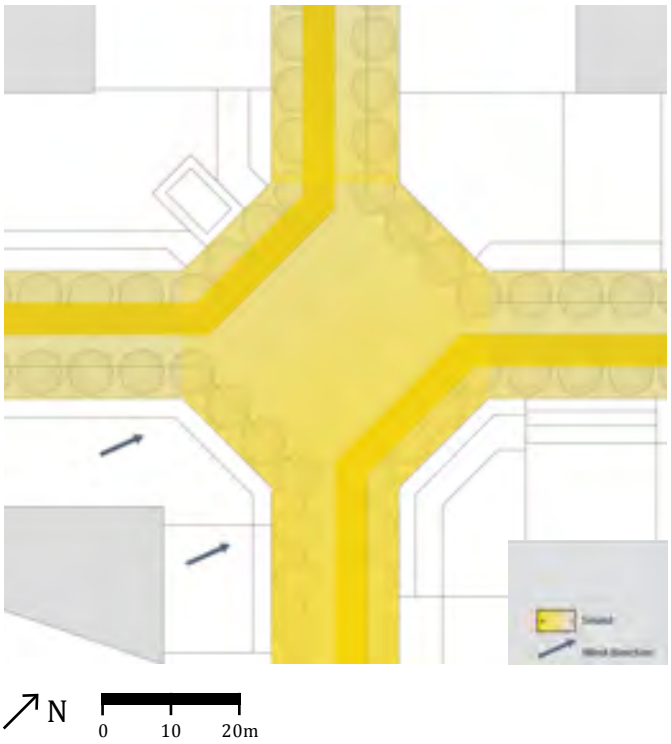


Fig 5.7 Acoustic analysis: NN1

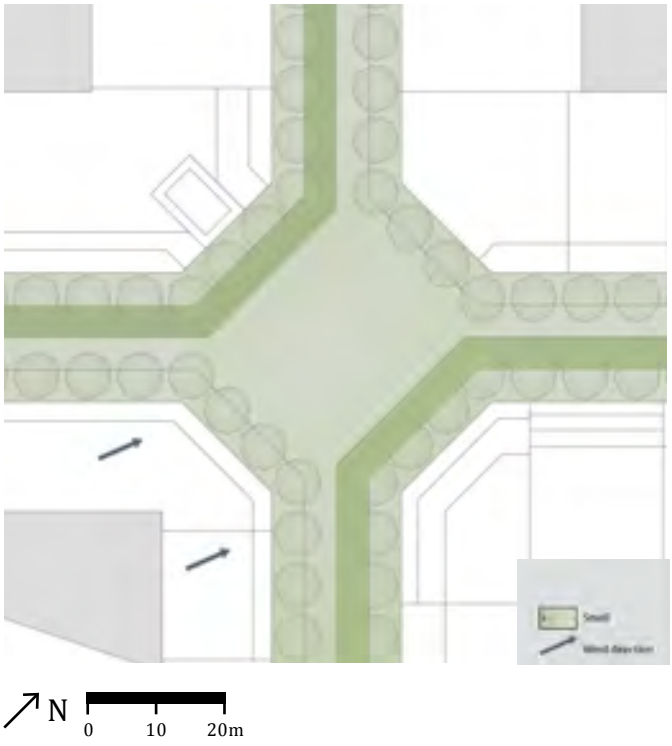


Fig 5.8 Olfactory analysis: NN1

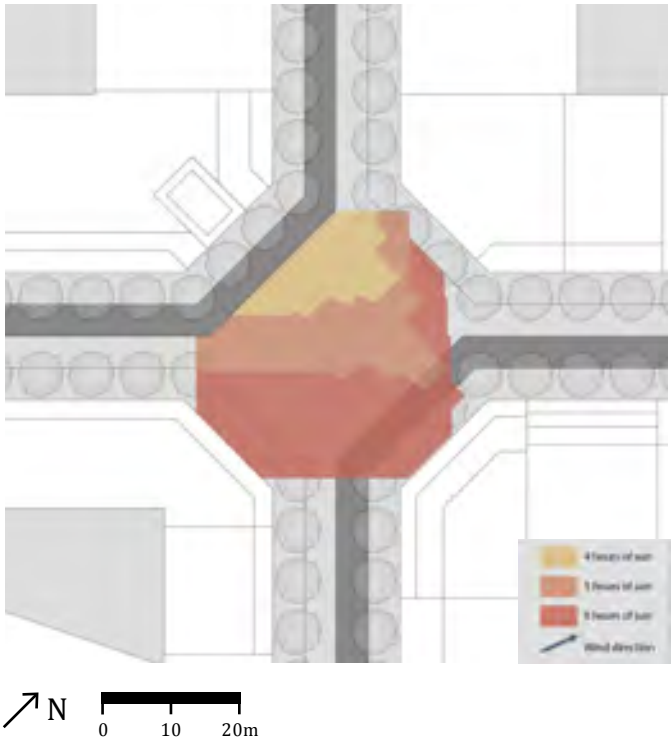


Fig 5.9 Thermal analysis: NN1

Sensory issues

The spaces 1A, 1B, and 1E of the spatial analysis will change. The west building casts a larger shadow onto the Space 1A during the hottest hours of the day. This change will affect the positioning of trees that cast shadows on other spaces. Space 1B has 4 hours of shadows during the hottest hours of the day. These shadows are more extensive due to the height of the west building. Finally, space 1E has 3 hours of shadow during some of the hottest hours of the day. This is related to the west building. Additionally, close to the south side, there are 7 hours of shadows cast onto the pedestrian area. Nevertheless, the biggest impact comes from the shadows cast from the west building.

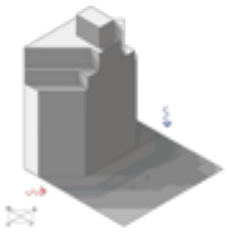
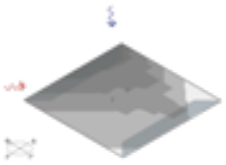
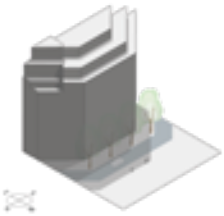
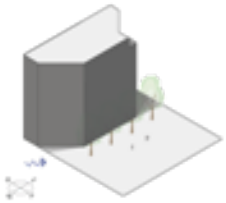
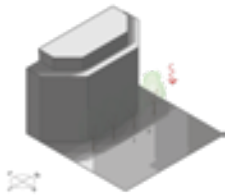
TYPE OF SPACE	 *1A. Inner road + pedestrian area + shadows*	 *1B. Pedestrian area + little shadows*	 *1C. Inner road + pedestrian area + little shadow*	 *1D. Pedestrian area + no shadow*	 *1E. Pedestrian area + some shadow*
SENSORY ISSUES – VISUAL	- Unpleasant views (motorized vehicles)	- Glare discomfort during the hours of 12:00 and 15:00	- Unpleasant views (motorized vehicles) - Glare discomfort during the hours of 12:00 and 17:00	- Glare discomfort during the hours of 12:00 and 18:00	- Glare discomfort during the hours of 12:00 and 15:00
SENSORY ISSUES – ACOUSTIC	- Noise pollution (motorized vehicles)		- Noise pollution (motorized vehicles)		
SENSORY ISSUES – OLFACTORY	- Air pollution (motorized vehicles)		- Air pollution (motorized vehicles)		
SENSORY ISSUES – THERMAL	- Winter winds	- High temperature during the hours of 12:00 and 15:00	- High temperature during the hours of 12:00 and 17:00	- High temperature during the hours of 12:00 and 18:00 - Winter winds	- High temperature during the hours of 12:00 and 15:00

Fig 5.10 Sensory issues per sense in space

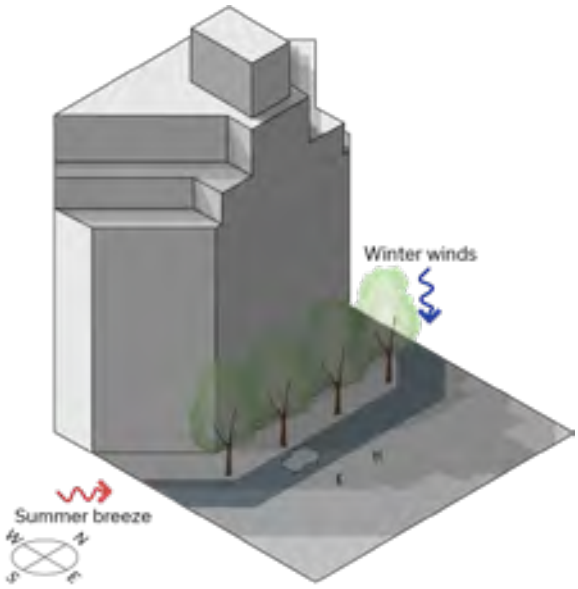
Guidelines

1A. Inner road + pedestrian area + shadows

Techniques: control, masking, and enhancing.

Issues: unpleasant views from motorized vehicles; noise pollution; air pollution and traffic fumes; and cold stress from winds in winter.

Potentials: summer breeze.

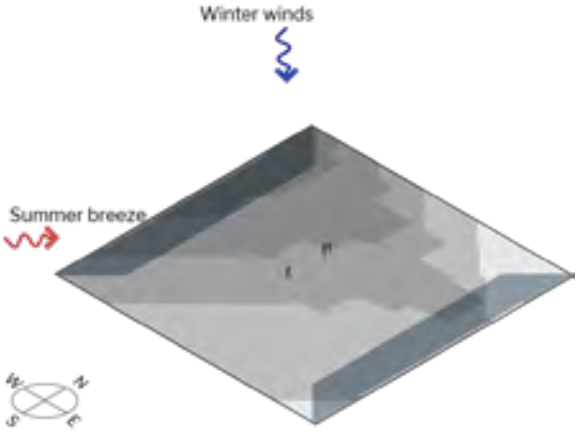


1B. Pedestrian area + little shadows

Techniques: control, masking, and enhancing.

Issues: glare disability; and heat stress from shortwave radiation.

Potentials: increase of pleasure for the visual, acoustic and olfactory sense.



1C. Inner road + pedestrian area + little shadow

Techniques: control and masking

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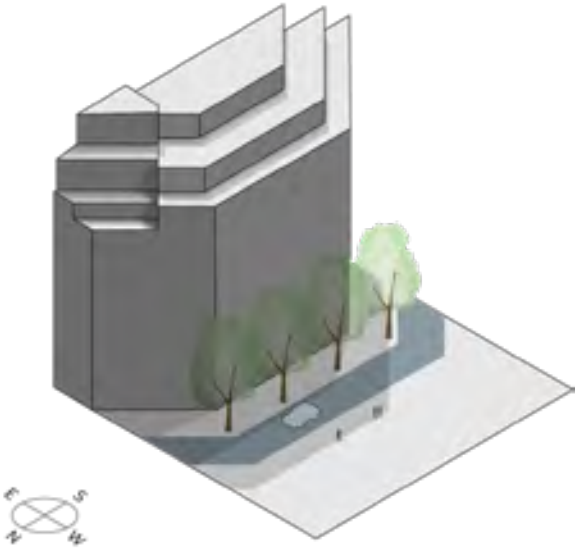
Issues: unpleasant views from motorized vehicles and glare disability; noise pollution; air pollution and traffic fumes; and heat stress from shortwave radiation in summer.

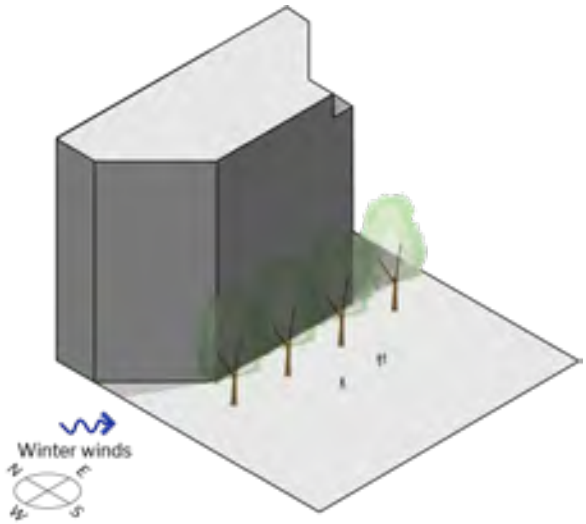


1D. Pedestrian area + no shadow

Techniques: control, masking, and enhancing.

Issues: glare disability; and heat stress from shortwave radiation and cold stress from winter winds.

Potentials: increase of pleasure for the visual, acoustic and olfactory sense.

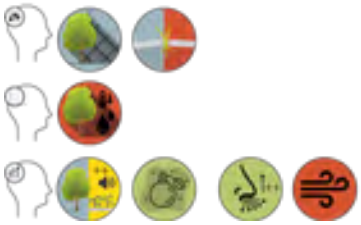


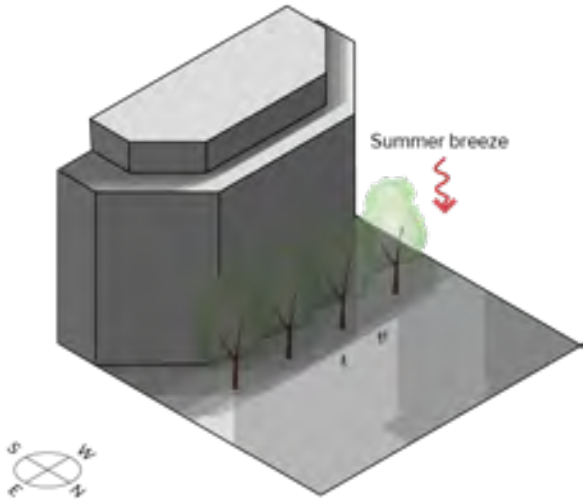
1E. Pedestrian area + some shadow

Techniques: control, masking and enhancing.

Issues: glare disability; and heat stress from shortwave radiation.

Potentials: summer breeze and increase of pleasure for the visual, acoustic and olfactory sense.





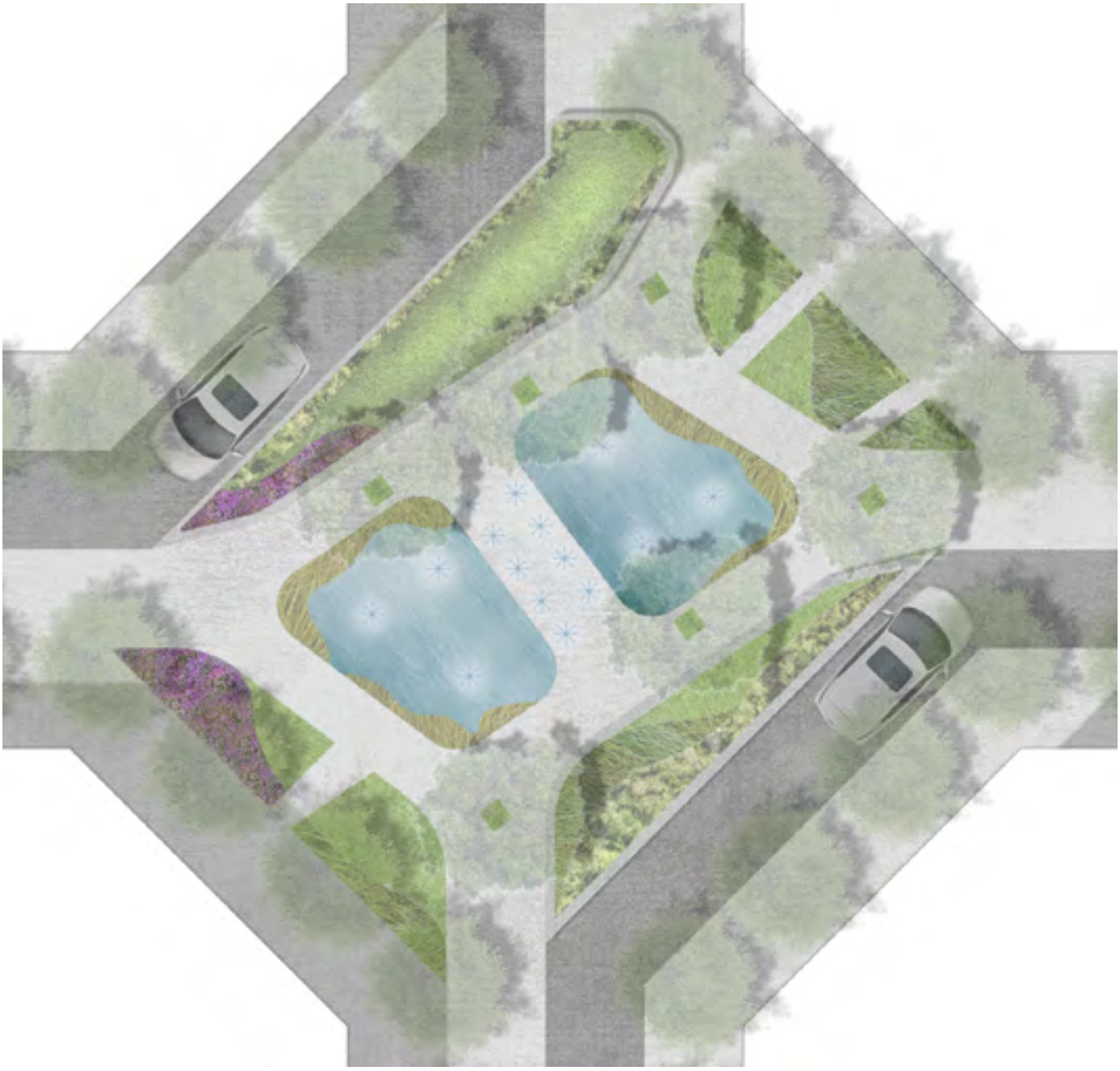


FIG. 5.11 SENSESCAPE DESIGN FOR NN1

Design

The design contemplates having solid elements next to the inner roads to reduce discomfort from the motorized vehicles. Meanwhile using more porous elements on the north and south side allows a connection with restaurants, and shops. Additionally, curves have been used in different elements for fluidity and as a reference towards the sea. Furthermore, to improve the environmental comfort, three techniques have been used on site.

For control, there is a need to block car fumes, air pollution, and applied noise control due to the cars in the inner roads. Therefore, the guideline "Absorb pollution" has been chosen to solve the previous issues. For the west side, the tool implemented is the wind plus shadow element. This tool, due to the vegetation, can absorb the decibels from the motorized vehicles from the inner road and can absorb air pollution. Additionally, the wind plus shadow element helps reduce "Winter winds", which is the second guideline applied on site.

On the east side, shrubs and grasses were implemented. Furthermore, shrubs near the road were added to increase the efficiency in absorbing air and noise pollution. The next guideline is "Shadows". This guideline reduces glare by using trees. In this case, I apply *Broussonetia papyrifera* (See Appendix E for more information about trees). Finally, especially for the north and south side, "Depaving" is used to reduce glare and heat. Furthermore, the north side uses hedges (*Buxus sempervirens*) to lower winter winds (See Figure 5.12).

For masking, motorized vehicles generate discomforts due to air, sound and visual pollution, which is why on the west side, the guideline "New smell/block view" was applied. The introduction of a new smell and blocking a view is managed with the tool wind plus shadow element. While the height of the hill will block the view of the car, the vegetation on top can offer a new smell. Additionally, a pond with jets was chosen to help mask the sound of motorized vehicles. The guideline applied is "Pleasant sounds".

On the east side, there is a flower bed with shrubs and grasses to block the view of cars while introducing a "New smell". Additionally, as with the case of the west side, the jets of the ponds help mask noise while increasing "Pleasant sounds". Finally, three trees are added on the sides, to "Lower temperature" through shading and evaporation. Also, the water jets of the ponds help "lower temperature" through evaporation (See Figure 5.13).

For enhancing, the guideline "Summer breeze" is chosen to take advantage of the wind coming from the south-west street. The use of lavender is implemented in the shadow plus wind element on the west side and on the depaved area on the south, to introduce a "New smell". Additionally, the corner without a tree will help maintain the "Summer breeze". The trees implemented in the design are meant to attract birds to add "Pleasurable views/sounds". All elements help "Lower temperature" by depaving, shadow casting, and evaporation (See Figure 5.14).

Fig. 5.12 Sensescape design for NN1

Fig. 5.13 Sensescape design for NN1

Fig. 5.14 Sensescape design for NN1

5.4.4 Neighbor node 1 (NN2)

Analysis

Context analysis

Neighbor node 2 has on the ground floor a restaurant on the west side; cafes and shops on the north and east sides; and a bank on the south side.

Analysis per sense

Sun, during the hottest hours of the day, is starting from the south-east and ends at the west. This means that shadows from the south and west buildings will be cast into the pedestrian space. In addition, winter winds will come from the north-west street and summer breezes will come from the south-west street (Figure 5.15).

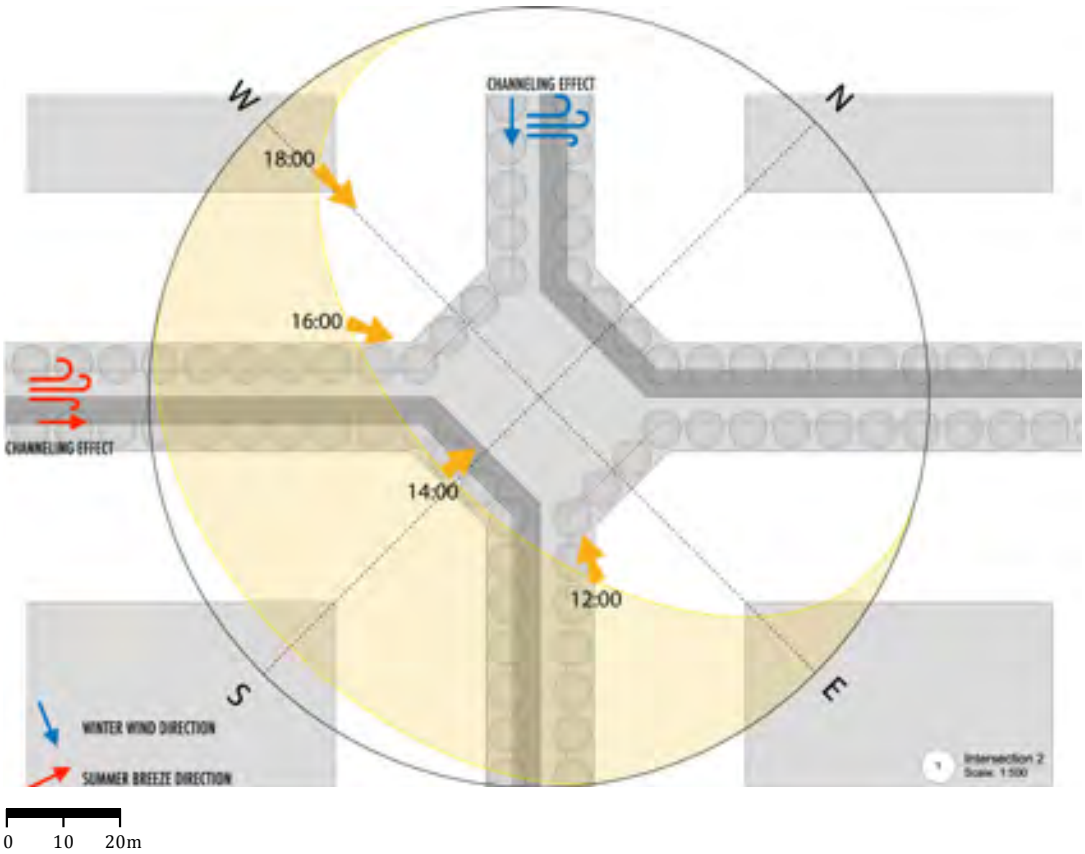


Fig. 5.15 Sun and wind analysis: neighbor node 2

Moreover, it can be seen in figure 5.16 which areas are exposed to sunlight between four and six hours. The pedestrian area close to the west side starts next to the building, which means it will be protected from reflected radiant heat sources at the west end.

Furthermore, the trees on each side partially block the vertical planes, reducing the amount of reflected sunlight. Therefore, the amount of exposed horizontal area that could induce glare disability is shown in figure 5.17. Additionally, some important visual connections or disconnections can be established, such as the connection with the other neighbor node of the superblock and the blocking of the "ugly" visuals, such as traffic.

By having the inner roads on the north and south side, shadows from the west building are directly cast into the pedestrian area, having less sunlight reflection towards the west.

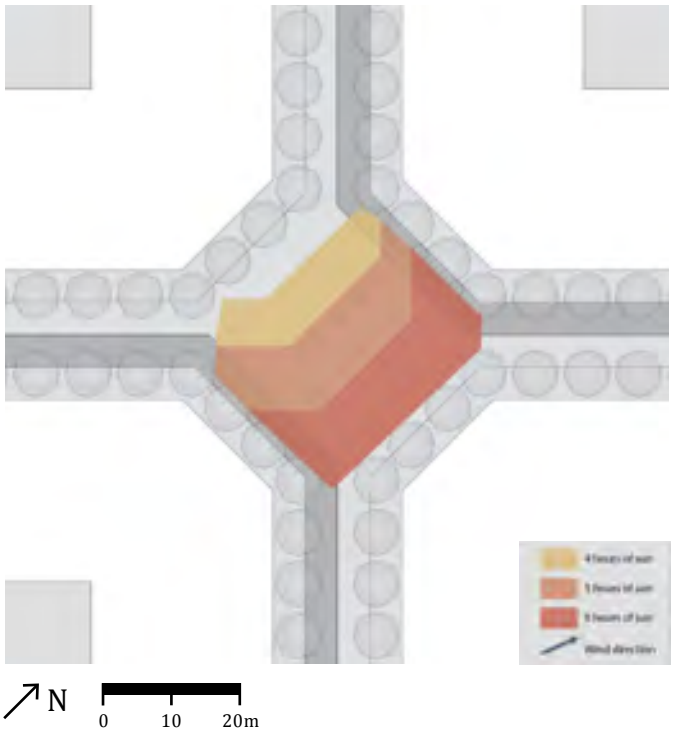


FIG 5.16 THERMAL ANALYSIS: NEIGHBOR NODE 2

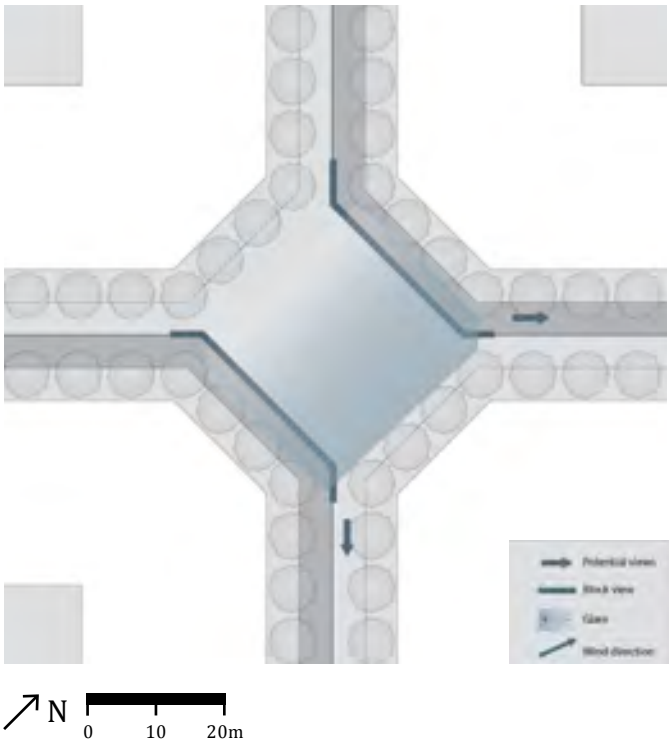


FIG 5.17 VISUAL ANALYSIS: NEIGHBOR NODE 2

Figure 5.18 shows where most of the noise is concentrated in the neighbor node 2. Most of the sound pollution comes from the inner roads.

Figure 5.19 shows where air pollution is concentrated in the neighbor node 2. The primary source of smell pollution will be considered from the inner roads.

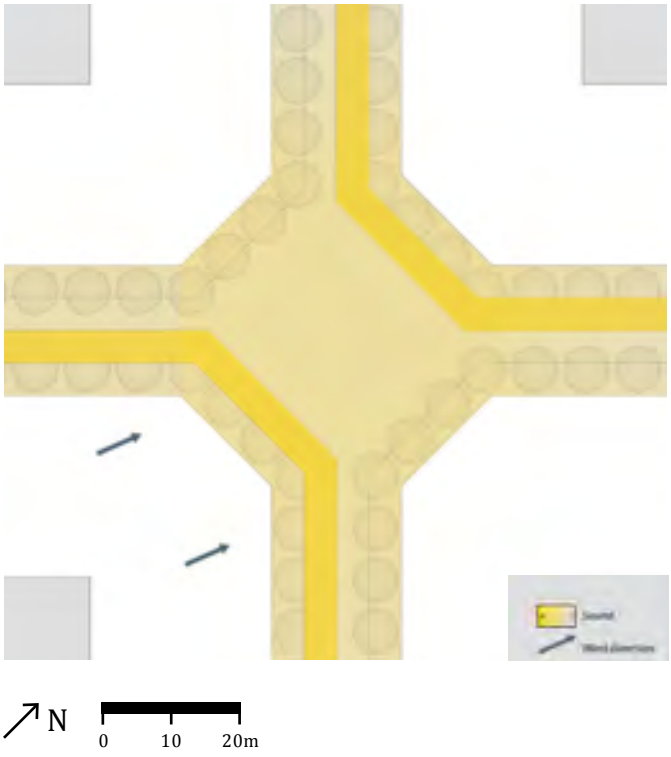


FIG 5.18 ACOUSTIC ANALYSIS: NEIGHBOR NODE 2

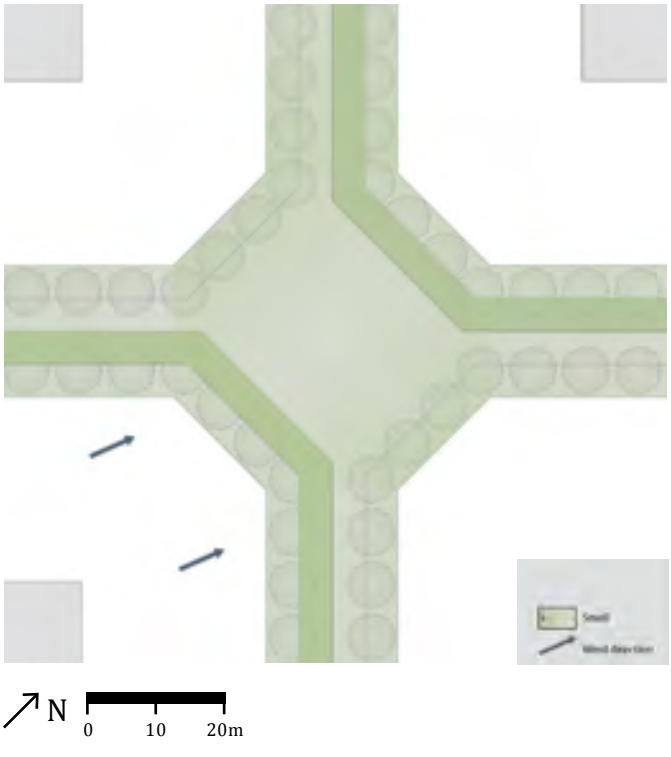


FIG 5.19 OLFACTORY ANALYSIS: NEIGHBOR NODE 2

Neighbor node 2 presents the inner roads on the north (2C) and south (2D) sides. This positioning of roads indicates that most of the shadow is on the sidewalk and the inner roads. In addition, space 2D presents shadow from the west building starting at 16:00. Due to this situation, the reflective radiant heat sources are affecting most of the pedestrian area. Furthermore, the areas next to the inner roads (2C & 2D) present visual, acoustic, olfactory, and thermal issues on both sides, which determines that these spaces require more emphasis on comfort with the techniques of control and masking. The west (2A), center (1B), and east (2B) areas present thermal and visual discomforts that are stronger near the east (2B). Due to this situation, the techniques for control, masking, and enhancing are needed and should increase in effectiveness towards the east side.

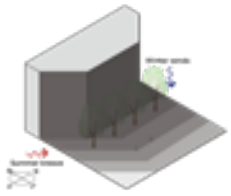
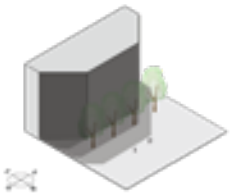
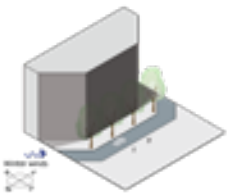
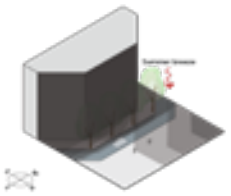
TYPE OF SPACE	 *2A. Pedestrian area + shadows*	 *2B. Pedestrian area + little shadow*	 *2C. Inner road + pedestrian area + no shadow*	 *2D. Inner road + pedestrian area + little shadow*
SENSORY ISSUES – VISUAL		- Glare discomfort during the hours of 12:00 and 18:00	- Unpleasant views (motorized vehicles) - Glare discomfort during the hours of 12:00 and 18:00	- Unpleasant views (motorized vehicles) - Glare discomfort during the hours of 12:00 and 17:00
SENSORY ISSUES – ACOUSTIC			- Noise pollution (motorized vehicles)	- Noise pollution (motorized vehicles)
SENSORY ISSUES – OLFACTORY			- Air pollution (motorized vehicles)	- Air pollution (motorized vehicles)
SENSORY ISSUES – THERMAL	- Winter winds	- High temperature during the hours of 12:00 and 18:00	- High temperature during the hours of 12:00 and 18:00 - Winter winds	- High temperature during the hours of 12:00 and 17:00

Fig 5.20 Spatial analysis: NN2

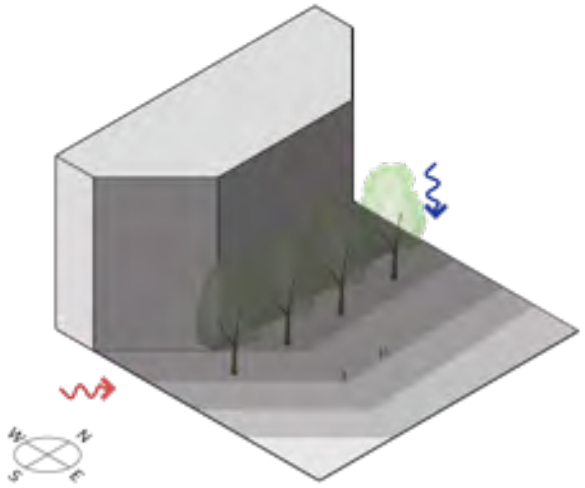
Guidelines

2A. Pedestrian area + shadows

Techniques: control and enhancing.

Issues: cold stress from winds in winter.

Potentials: summer breeze and increase of pleasure for the visual, acoustic and olfactory senses.

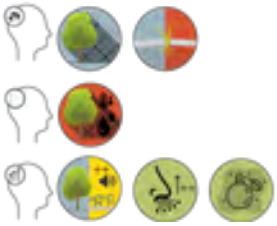


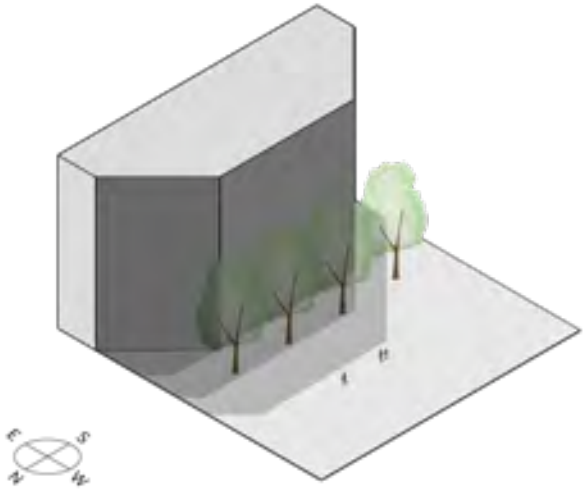
2B. Pedestrian area + little shadow

Techniques: control, masking, and enhancing.

Issues: glare disability; and heat stress from shortwave radiation.

Potentials: increase of pleasure for the visual, acoustic and olfactory senses

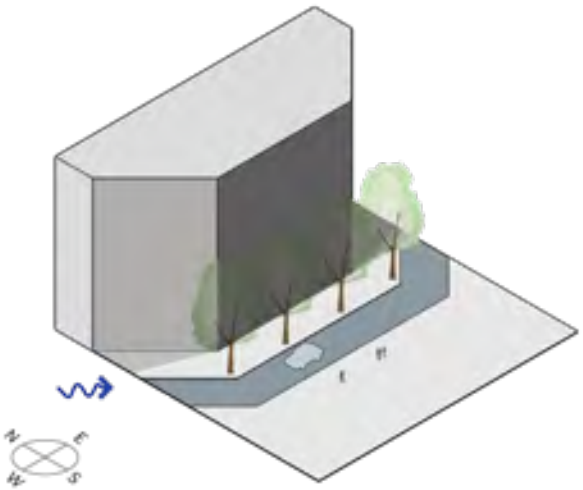




2C. Inner road + pedestrian area + no shadow

Techniques: control and masking.

Issues: unpleasant views from motorized vehicles and glare disability; noise pollution; air pollution and traffic fumes; heat stress from shortwave radiation and cold stress from winter winds.

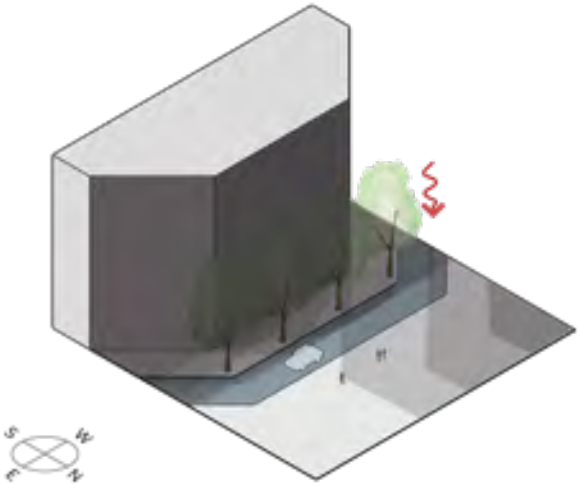


2D. Inner road + pedestrian area + little shadow

Techniques: control, masking, and enhancing.

Issues and potentials: unpleasant views from motorized vehicles and glare disability; noise pollution; air pollution and traffic fumes; and heat stress from shortwave radiation.

Potentials: summer breeze.



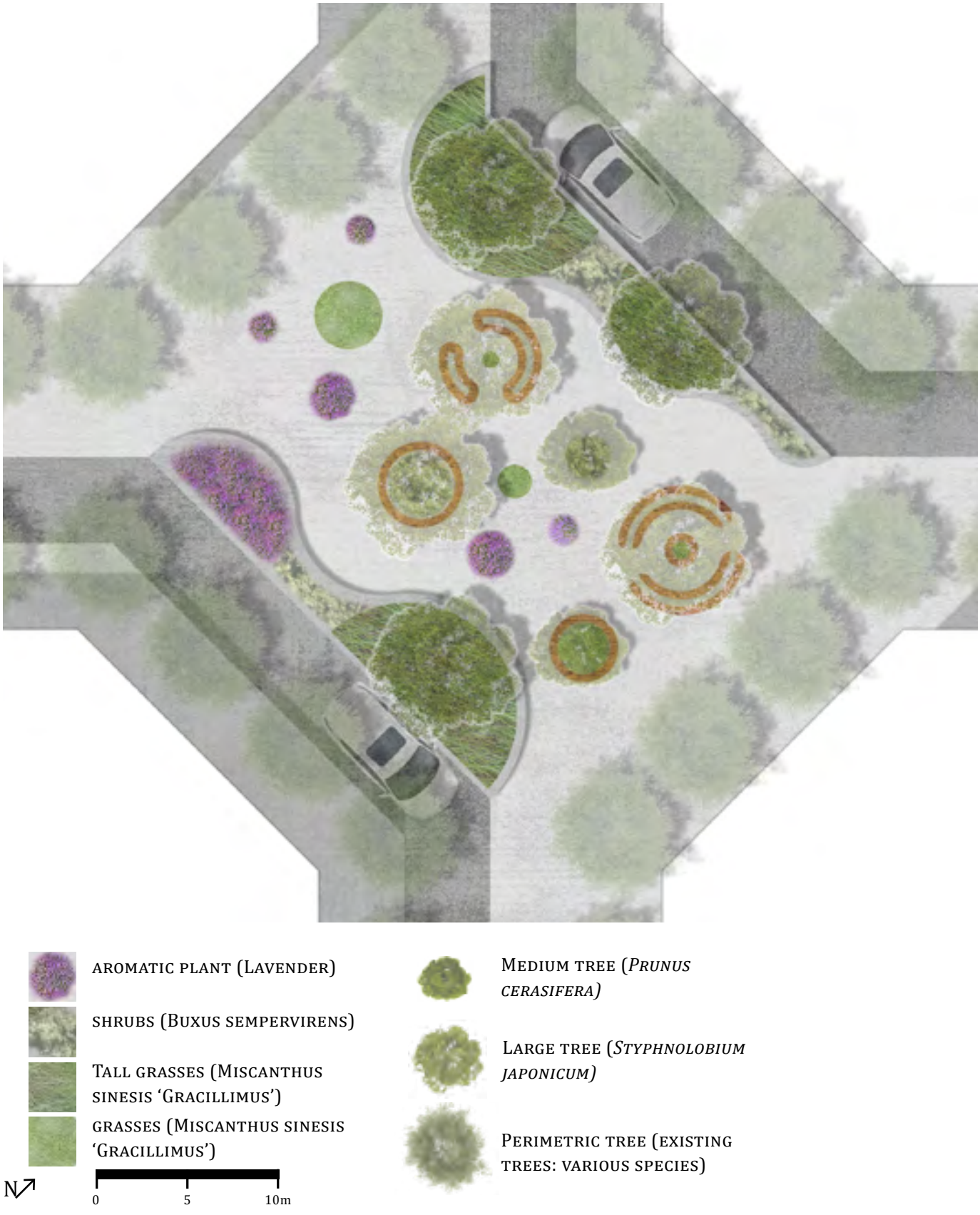


FIG 5.21 SENSESCAPE DESIGN FOR NN2

Design

The design contemplates having solid elements next to the inner roads to reduce discomfort from the motorized vehicles. This design uses the circle as the main element. It connects the west and east facades, where restaurants, cafes and clothing shops are located. Additionally, I use curves in different elements for fluidity. Furthermore, to improve the environmental comfort, I apply the three techniques on site.

For control, I use the guideline "Absorb pollution" to reduce air and noise issues for both areas next to the inner roads. The plant container is larger on the north side, blocking part of the street to reduce winter winds. Additionally, a *Styphnolobium japonicum* (Appendix E) is implemented in this element to reduce winds even further. Also, trees, low vegetation, and shrubs are used to minimize glare discomfort by applying the guidelines "Shadows" and "Depaving" (See Figure 5.22). The number of trees increases as the eastern side is reached. The species used are *Styphnolobium japonicum* and *Prunus cerasifera* (Appendix E).

For masking, the inner roads are hidden from the pedestrian by using a 1-meter height flower bed bench. Additionally, it considers at least 50 centimeters of height of shrubs and low vegetation to block the view of motorized vehicles. The guideline used is "New smell/ block view". Furthermore, "Lower temperature" has been used by adding vegetation and trees in the middle space. The trees are mainly concentrated on the north and east side since the building of the west side is casting some shadows over the pedestrian area. Additionally, these trees can add "Pleasant sounds" by attracting birds (See Figure 5.23).

For enhancing, I use lavenders to introduce a "New smell". Additionally, I leave the corner without a tree to maintain the "Summer breeze". Finally, all vegetation applied is adding to "Pleasant views/sounds" (See Figure 5.24).

Fig 5.22 Sensescape design for NN2

Fig 5.23 Sensescape design for NN2

Fig 5.24 Sensescape design for NN2

6. Discussion and conclusions

6.1 DISCUSSION

Theoretical limitations

A limitation of the theoretical framework is the little regard towards the senses of touch and taste. In order to establish a real holistic approach, these senses should be taken into account. Due to the different scales and ranges between the senses, touch and taste, could not be integrated into the design guidelines. Nevertheless, in an attempt to make this design as holistic as possible, some materials chosen for the different elements take into consideration some aspects of the sense of touch in its design.

Furthermore, the visual sense has been developed extensively in literature. Finding the right theories to establish the techniques was a challenge for this research. Due to the limitation of time, not all theories for the visual sense were explored, which could have led to more guidelines related to this sense.

Finally, the information gathered about vegetation that can be used in the design is limited. This information is based on the document *Street tree management in Barcelona* (Ajuntament de Barcelona, 2011), which has a section on tree species currently growing in the street of Barcelona (see Appendix E). Nevertheless, it would have helped to talk to a specialist and create a list of trees according to its effect on the senses.

Methodological limitations

As for the research methodology, the pragmatic approach allows generating new knowledge by combining theories and site analysis to create guidelines. Nevertheless, these guidelines would be more effective if a more extensive post-positivism approach would have been taken into account. The evaluation of most design tools is based on evidence from scientific papers and books but are not tested quantitatively in the case study context. Through educated guesses, they were adapted into the superblock context. This predicament is one of the limitations of the thesis. The design tools could have been tested with programs such as ENVI-met or Rayman to establish its real effect in context. Unfortunately, due to limitations in time, this was not possible.

Additionally, since the guidelines are generated through research through designing, much of the information coming into the guidelines is dependent on my criteria and preferences as a designer. This situation creates a bias in the process that cannot be avoided.

Moreover, when I was generating knowledge about the superblock in El Poblenou, I did communicate with BCNecologia, an entity that advices municipalities on how to apply the theory of the superblock. This communication helped me understand some of the reasoning behind the superblock of El Poblenou. Nevertheless, it would have aided to have the information from the Municipality of Barcelona. Even though some information can be found on their website, an interview with the designer of the urban superblock of El Poblenou could have been insightful to understand their motivations behind its design.

Furthermore, part of the methodology should have included a participatory design. By involving the citizen in participatory design and establishing a community, new approaches could be taken, such as including an urban farm in the design. By doing so, the sense of taste could also be part of the sensory experience of the superblock.

Finally, a questionable element of my design could be the use of water elements in a hot climate like Barcelona. It is a known problem that Barcelona can have water limitations, and nevertheless, to make the design guidelines richer in elements, I decided to implement them. The decision to use water does not mean that all neighbor nodes would include water elements, it will be dependent on the functions. Nevertheless, when using water elements, a recirculating system is advised, and the use of sustainable water sources.

6.2 CONCLUSIONS

The objective of this thesis is to create transferable knowledge through design guidelines. This new knowledge would help designers to create more pleasant spaces and solve multi-sensory issues related to the superblocks in the Eixample, Barcelona. The aim of the thesis has been achieved with the new approach created from the combination of theories of the superblocks and environmental comfort.

During this research, knowledge was produced and turned into applicable design guidelines. The case study of prototypical superblock was used to explore the potential of the superblock as a new urban model with a multi-sensory experience that can improve the health and pleasantness of citizens.

Answers to Sub-Research Question 1: Which general design tools improve environmental comfort according to each technique?

The knowledge gathered to answer this question came from the literature study. The techniques (control, masking, and enhancing) and the evaluation matrix, helped to establish which tools are more efficient and can be used to solve different sensory issues.

I found 15 tools, which can help to improve environmental comfort according to each sense. These tools are divided into water elements (3), vegetation elements (10), and combined elements (2). None of the tools have a perfect score for all senses, nevertheless, the tools can still improve the sensory experience of citizens.

For control, the most efficient tools are hedges, perennial plants, wind plus shadow elements and low plants. Hedges and perennial plants score higher in the matrix because they have a double function for visual and thermal control. Nevertheless they score lower for acoustic and olfactory control. Wind plus shadow elements and low plants only score low in visual control since they cannot cast big shadows, reducing the effect of diminishing glare. Nevertheless, these tools can be paired with elements that cast shadows to improve their effectiveness. It is recommended to use wind plus shadow elements and low plants for control, since both score high in most of the senses and its efficiency can be improved by implementing an element that cast big shadows.

For masking, seven tools proof to be the most efficient. Green ponds score high for the acoustic and olfactory senses, however ponds scores low for visual and thermal masking. Nevertheless, this tool can be combined with elements such as wind plus shadow elements and trees to improve the effectiveness of the element. Waterfall pergolas score high for acoustic and thermal masking. To improve their efficiency, they can be combined with elements that score high for visual masking, such as shrubs. Green demarcation elements, hedges and perennial plants score high in visual and thermal masking. Nevertheless, they score low for acoustic and olfactory masking. Nevertheless, they can be combined with other elements, such as fountains to improve their score. Moreover, gradation works, and waterfalls score high in all senses except the olfactory sense. These elements cannot reflect sunlight therefore have no effect on masking smells. Consequently, it is recommended to use tools that can be improved by combining with other elements.

For enhancing, green ponds, low plants, and green masts can improve the sensory experience. Green ponds seem to have a better effect than the water elements or the vegetation elements. Nevertheless, green ponds do not enhance the thermal sense. Therefore, low plants and green mast are more efficient for providing pleasure, even though they do not score the highest in the visual, olfactory, and thermal senses. Only in this case, it is not possible to achieve a perfect score by combining elements since all other tools could block summer winds. Nevertheless, in areas where summer winds are above comfort standards, the design tools green ponds and waterfall pergolas can be used to enhance the human experience. The wind would be lowered making it pleasant for citizens.

To summarize, even though none of the tools manages a perfect score, it can still be improved by combining tools. This works for all techniques, as long as winds are strong. In case the wind speed is low, then for enhancing, to achieve an effect in all senses, the designer should use the tools of low plants and green masts since the other tools cannot stop blocking summer winds as part of their effects.

Answer to Sub-Research Question 2: What are the sensory issues for the different type of spaces for each neighbor nodes of the superblock?

The knowledge gained to answer this question came from the analysis per sense, and spatial analysis. By using the information gathered from the case study, I generated new knowledge by establishing spatial configurations with its issues. These spatial configurations can be divided into neighbor node 1 and 2.

Neighbor node 1 has the inner roads on the west (1A) and east sides (1C). Additionally, buildings on the west side (1A) cast shadows onto space. This situation means that most of the shadow is cast into the sidewalk and the inner roads. Therefore this node will have thermal issues in most of its pedestrian area. Additionally, winter winds come from the north-west and summer breeze from the south-west. These circumstances indicate that the design elements that will be used for the west area (1A) need to be able to block wind on the north end and allow ventilation on the south end. Furthermore, the west (1A) and east sides (1C) share the issues of visual, acoustic, and olfactory discomfort. These conditions mean that to avoid these issues, there should be an emphasis on comfort by using the techniques of control and masking on the west (1A) and east (1C) sides. While the north (1D), center (1B), and south (1E) spaces can focus on creating expressiveness with the technique of enhancing.

Neighbor node 2 presents the inner roads on the north (2C) and south (2D) sides. This condition indicates that most of the shadow is on the sidewalk and part of the pedestrian area. Due to this situation, the pedestrian area diminishes its thermal issues, starting from the west side, as shadows are cast towards the north-east. The areas next to the inner roads (2C & 2D) present visual, acoustic, olfactory, and thermal issues on both sides, which means that these spaces require more emphasis on comfort with the techniques of control and masking. The west (2A), center (1B), and east (2B) areas present thermal and visual discomforts that are stronger near the east (2B). Due to this situation, the techniques for control, masking, and enhancing are needed and should increase in effectiveness towards the east side.

In summary, I determine that the spaces with the inner roads (1A, 1C, 2C & 2D) have more issues than pedestrian areas. Inner roads areas present problems related to visual, acoustic, olfactory, and thermal comfort, while the pedestrian spaces (1B, 1D, 1E, 2A & 2B) have issues related to visual and thermal comfort. Neighbor node 1 has more thermal and visual discomforts than neighbor node 2. Therefore, the designer must apply different strategies when designing these spaces.

Answer to Sub-Research Question 3: What are the integrated strategies for the different type of spaces for each neighbor node of the superblock?

The answer to this question is part of the research through designing process. The gained knowledge from the answers of the previous questions was used to determine the integrated strategies for the different type of space for each neighbor node of the superblock. These were tested in models to determine which can be applied in a real context.

For each type of space, I determine which techniques are used. Control and masking will solve the comfort issues established in SRQ2 while enhancing will provide the citizens with pleasurable experiences as part of the value of expressiveness.

The pedestrian areas (1B, 1D, 1E, and 2B) share the same strategies: for control, “Depaving” and “Shadows”; for masking, “Lower temperature”; and, for enhancing, “Pleasurable views/sound”, “Intensify smell” and “New smell”. In addition, 1D has the strategy “Winter winds” for control and 1E has the strategy “Summer breeze” for enhancing. The pedestrian area 2A uses two techniques: control and enhancing. There is no need for masking since there is a lack of motorized vehicles, and shadows are cast into space. For control, I use the strategy “Winter winds”. For enhancing, I use “Pleasurable views/sounds”, “New smell”, “Intensify a smell”, and “Summer winds”.

The areas that include inner roads (1C, 2C and 2D) also share the same strategies: for control, “Depaving”, “Shadows” and “Absorb pollution”; and for masking, “Pleasant sounds”, “New smell/block view”, “Lower temperature”, and “Intensify smell”. I do not use enhancing for 1C and 2C since, in the space next to the inner roads, the priority is to control and mask for comfort. Using the strategies for enhancing will have the same effect as masking, therefore, is not used. In 2D enhancing is used due to summer breezes.

In summary, by establishing the strategies in space, I determine that all pedestrian area (1B, 1D, 1E, and 2B), except the west area (2A) in neighbor node 2, have basically the same strategies. These circumstances indicate that the difference between spaces is determined by the side with the extended shadow (1A and 2A). Additionally, some areas (1D and 1E) have an extra strategy related to wind. These circumstances suggest that the microclimatic conditions will alter which strategies can be used and where. Furthermore, the spaces with inner roads (1C, 2C, and 2D) also have the same strategies between them. Only the south space (2D), includes “Summer winds”. As with the previous case, wind conditions will require extra strategies. Moreover, the west space (1A and 2A) for neighbor node 1 and 2 differ in techniques. The spaces next to the inner road (1A) require techniques to solve comfort issues while the pedestrian area (2A) can focus more on creating pleasure for expressiveness.

Furthermore, the techniques of control and masking create a change in the space next to the inner roads by reducing and distracting from noises and visual discomforts. In addition, the techniques of control and masking diminishes the levels of acoustic, olfactory and thermal discomfort by creating a comfortable atmosphere for the citizens. Lastly, the technique of enhancing is implemented into the pedestrian areas to increase the pleasurable experience of citizens. This is managed by increasing the amount of vegetation.

Main research question: What design guidelines could help to improve the sensory experience in neighbor nodes of the future superblocks of the Eixample?

The outcome of this thesis is the generation of design guidelines that will improve the sensory experience in the neighbor nodes of the future urban superblocks of the Eixample, Barcelona.

This outcome was achieved by combining the answer of sub-research questions 1, 2, and 3. First, with the techniques and the evaluation matrix, I determined which tools are more efficient to solve the different sensory issues to achieve environmental comfort. Then, I generate new knowledge by establishing spatial configurations with sensory issues. Finally, I determine the integrated strategies for the different type of space of each neighbor node to generate the final design guidelines (Table 6.1).

The integrated design guidelines can be used in the neighbor nodes of the future superblocks in Eixample, Barcelona. The use of the guidelines does not mean that a good design would come by itself. Design guidelines require a skilled landscape architect or urban designer to apply them (Prominski, 2017).

In addition, my research added to the existing superblock theory by providing additional sensory solutions to their model. They implement the technique of control for air and noise pollution, which only diminishes the negative stimuli. Nevertheless, with environmental comfort, a new meaning of enjoyment can be reached, increasing the pleasant stimuli in the urban environment. This is managed with the integrated design guidelines, where designers can enhance the human sensory experience of citizens of Eixample, Barcelona by increasing the amount of greenery with the different design tools. This will help lower air temperature in the city and improve the health of citizens.

TECHNIQUES	AREAS NEXT TO INNER ROADS (1A*, 1C,2C AND 2D)	PEDESTRIAN AREAS (1B, 1D, 1E, 2A* AND 2B)	AREAS WITH EXTRA STRATEGIES
Control	Absorb pollution	Depaving	Winter winds (1A, 1D, 2A and 2C)
	Shadows	Shadows	
	Depaving		
Masking	Pleasant sounds	Lower temperature	
	New smell/block a view		
	Lower temperature		
	Intensify a smell		
Enhancing		Pleasurable views/sounds	
		Intensify a smell	
		New smell	Summer breeze (1A, 1E, 2A and 2D)

Table 6.1 Integrated design guidelines for the urban superblock of the Eixample, Barcelona

Scientific and societal relevance

It has been established within this thesis that the design of the future urban superblock of El Poblenou has thermal comfort deficiencies (chapter 1.2). Additionally, in the Eixample area, 120 potential intersections can be transformed into neighbor nodes, and it could be inferred that they will have the same deficiencies (chapter 1.2). This situation is more concerning considering that, with the increase in temperature due to climate change, the heat-related issues will increase.

Furthermore, the theory of urban Superblocks applies control strategies to reduce air and noise pollution. Nevertheless, it does not consider improving the sensory experience with the application of other techniques to create a multi-sensory experience. The focus is on diminishing negative stimuli. Therefore, this thesis fills the knowledge gap by inferring a new approach towards multi-sensory design. And, with this new approach, guidelines are created to diminish unpleasant stimuli and enhance pleasant ones. The Municipality of Barcelona can apply these guidelines in neighbor nodes of the design of future urban superblocks, all over the Eixample, to improve multi-sensory experience.

Moreover, this thesis integrates the knowledge of the different senses and the superblocks in a research through designing process. This process showed the potential of using climate-sensitive design while improving the sensory experience of citizens. Hopefully, this will inspire other professionals to consider enhancing the human experience in their design practice, not only through the visual sense but also through the experience of other senses.

Finally, superblocks have the potential to become a new urban model that can be implemented to make cities more environmentally friendly all over the world. The superblock from Barcelona has inspired other governments to implement this model in their cities. For instance, new implementations have been appearing in cities in Latin America, such as Lima, Peru; Buenos Aires, Argentina; and Quito, Ecuador. Through this research, I have established a method to create design guidelines that can be reproduced for other superblocks in the world. These superblocks will not only create environmentally friendly cities, but also contributes to creating spaces with multi-sensory experiences that would benefit citizens in health and motivate them to use public space more often.

Recommendations

This thesis is a start towards a more humanized approach for the superblock. I hope that with this practical knowledge, new designs can be implemented in the different superblocks coming in the future. And that with this thesis as a base, more guidelines for different superblocks around the world can be produced.

Further research could involve a more post-positivism approach to gather more empirical information about the effects of the guidelines. Additionally, a more in-depth research about the effect of different types of vegetation related to the senses can be produced. Furthermore, the senses of touch and smell need to be developed in order to create a truly holistic approach. This research could be a follow-up from this thesis, working with a detail scale.

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APPENDIX

Appendix A: Phenomenological method: El Poblenou

The phenomenological method established by Rudi Van Etteger *et al*. (2016) consists of first, walking the area just experiencing to later describing it without explaining and finish by reflecting on this experience. Afterward return for a systematic stop-and walk with descriptions, photographs, and audio recording of the experience. By doing this, one can establish the sensation in the area and determine if it was positive or negative. Finally, a critical evaluation of the experience is made reflecting on the bracketing of one's own bias. "Adopting the phenomenological attitude requires us to engage in epoché or bracketing, the temporary suspension of the "natural attitude", our taken-for-granted assumption and preconceptions surrounding a particular phenomenon or phenomena" (Allen-Collinson & Hockey, 2015, pp. 65).

Visit to Supermanzana El Poblenou (23-07-2018)

Perez IV

It was 15:30 as I approached the "Supermanzana" of El Poblenou through the street of Perez IV, I notice the lack of shadow in the space. It is an industrial area, empty, no maintenance on sidewalk (uneven). Cars are serving as a barrier between the sidewalk and the empty street. Eventually one bus passed by, later another car. The brightness making me close my eyes is coming from the reflection of parked cars. As I reach the end of the first block I see a construction in Ciutat de Granada. The area feels unsafe.

It was then when I sensed the smell of sewage, they were breaking the street and installing new pipes. I continue walking and I felt the floor uneven. Shops are closed. No cars parked, it felt more open. It was very warm and no place to hide from the heat. As I reached the end of the block I could see and hear people talking. A nice cool wind passed as I reached the corner.

There was a little restaurant, in the corner of Roc Boronat. There were tables and three men drinking and talking. It felt more alive. As I continued, I noticed that the texture on the floor has changed and it is more even. I see a second restaurant. I hear the voice of a woman approaching and she sits with the man at the first restaurant. The tables had shadow, which seemed to made it comfortable to stay. Closer to the end, you can see and hear the cars driving. It becomes cooler as a the wind increases near the open space across the street.

As I crossed the street I see a big open space, with place for sitting. I see different vegetation, a place to drink water. The sidewalk felt narrowed. The planters created a barrier. The heat felt lower, there was wind to help cool down. Shadow of the buildings also helped. There were people sitting, waiting and walking in the area. As I approached the corner I could hear the cars waiting for the light to change.

In the next block, between Ciutat de Granada and Roc Boronat, I was scared by a bicycle that passed right next to me. It made the sidewalk feel even smaller. The parked cars were already a barrier and a wall that would not allow me to see into the streets. As I reached the corner, the sound of construction was getting louder. I found a little restaurant with tables outside.

Strong noise coming from the construction from Ciutat de Granada. There is heat again, shadow from the wall is too small. Cars work as a barrier again and reflects sunshine into my eyes. The sidewalk feels small. Floor was uneven.

Almogavers

I see the tree pots and floor design of the "Supermanzana". There is a height difference between the two spaces and it feels like two different things. The floor is even and has a pattern. The street feels less open than Perez IV but it is wide and empty. Heat is strong, no wind, no shadow. Is still an industrial area. It is light, but it doesn't hurt my eyes. I hear construction sounds. The area is empty, no cars but has some mobile trees. There is wind close to the intersections.

As I cross the street I see people resting in the shadowed area of the intersection. I see motorcycles parked in the sidewalk. I notice that the sidewalk is bigger than in Perez IV, but it feels cosier and more enclosed. The trees are barely making a shadow, it help very little with the heat. I hear construction sounds coming from across the street.

I cross the street and I reach the open space. Everything is at sidewalk level, and it is oriented for the benefit of the pedestrians. There is vegetation. I can hear a song coming from a house and some construction sounds. There are people sitting at the end of this open space and others are walking. I hear the cars at the end of the street. The floor has a different texture than before, is more smooth.

When coming back I feel the shadow of the building helping me cool down. There is wind that also helps to cool down. There is nature and this time you can get a hint of lavender in the air. There are a few restaurants in this area and it is mainly residential. One car used the street to distribute merchandise but did not interrupted or disturbed the pedestrians in the area. As I reach the corner I can hear and see people resting, walking and eating. Cars are also passing again.

I cross the street and I have a shadow from the building. It is this side that is extended as part of the "Supermanzana". There is no people using it. The difference in height makes it feel like something different. There is more wind. As I approach the corner I can see people walking and resting in the shadow part. Everything on the sunny part is unused. I hear construction noise from the middle of the block. The closer I get to the corner, the windier it gets.

As I pass the corner the sidewalk feels not too wide. Cars work as a barrier, and emptiness is the first thing you see. There are a few people in shops and I can hear them talk. Also I heard water because of cleaning. From time to time, one car passes by. The floor feels uneven again. Because of the shadow of the building it was cool and the wind kept it cool. It got hotter at the corner, where the gas station is, and there was no shadow.

Sancho de Avila

There is shadow from trees. People are eating, walking, talking. There is a big office building and many parked motorcycles. Next to the sidewalk and under the building there is another walking area, which makes this area feel very wide but cozy because of the trees. It is not bright. I can hear cars driving behind me. Sometimes, one car or motorcycle passes next to me. I smell marihuana and see teenagers smoking. There is not much heat and shadows and wind keeps the area cool.

There are open shops next to the sidewalk, it feels safe. There is less shadow than before but the trees from the pots make a little shadow in the sidewalk. There are people walking and eating. I can hear construction in the area. I see sitting places with no shadow. It is warm, but closer to the intersection it gets windy.

There is a small white fence, the entire area is for pedestrians. It feels comfortable and protected. It is not as bright as in Perez IV. People are walking, talking and sitting. The floor is even. I can hear birds and also the construction from the previous block. It is warm with no shadow on this side but some winds helps cool down. As I cross to the other side, I feel cooler. I hear and see people talking and cars in front of me.

As I get to the next block, the buildings retire and the sidewalk is very big. It is light, and I can see people talking and walking. I hear construction noise. It smells like a sewer sometimes. As I approach I feel cooler because of the shadow of the buildings. There are different textures in the floor.

It is less open than the other side. It is comfortable and not bright. People are eating and talking. I hear people talking and cars passing by. Also, I hear electricity buzzing from the electrical station. As I approach the corner I get the shadow from the publicity banners. It is cool because of that. The floor is even but with texture.

Visit to Supermanzana El Poblenou (24-07-2018)

Roc Boronat

As I started walking, the first thing I see are the trees and the patterns draw in the pavement by the shadow. It felt safe and cozy. It is not too wide. The shadow made it not too light. As I continued walking I could see people and tables next to the sidewalk. There was a little restaurant at the end. I can hear them talking and also cars driving by. I also see people walking down the street. I can sense the smell of cigarette. The area felt cool, however as I reach the corner and the shadow was gone, it was very warm.

On the other side of the corner, there is one building with no trees in front. It was very warm and bright and there was no shadow. As I continued walking I found a pedestrian street with vegetation. I see people sitting, waiting, talking, walking and smoking. On the other side of the pedestrian street there is a small restaurant. People are sitting outside having drinks and talking. It was very warm but with the wind it was comfortable. As I continued walking, I found shadow. It was more cool also because of the wind. I see people sitting and also people walking. I sense the smell of rubber and cigarette. I can hear cars driving and construction noise.

Close to the intersection, there is a restaurant and later a children's playground. I see people walking, talking and cycling. The street is pedestrian. I can hear motorcycles driving next to extended area from the "supermanzana". I also hear the cars passing by on my left side. It smelled like the trees mainly, but at some point like the sewer. It is warm but shadows from the trees helps to cool down. In the sun it was very warm, but the wind keeps it comfortable.

As I cross the street I find shadow again, the buildings project a big shadow over the sidewalk. As I continue I see people talking, cycling and walking. I can hear cars passing by and a little construction noises. It is comfortable under shadow but at the sun is too warm.

As I reach the next block the sidewalk feels cozy and comfortable. It is light but not bright, unless you are at the intersection and then you feel the brightness. There are people walking, talking, sitting and eating. The wind makes a sound when hitting the tree branches. I could also hear little noise from the construction site. I can here people talking and smell the smoke of their cigarette as they pass me by. It is a little warm under the shadow, but wind makes it comfortable. In the sun was very warm. As I reach the end of the block, the shadow disappears and it is hot. There was trash near the trash can and dog excrement as well. On the other side of the street it is cool again, there is shadow from the building. The floor at this part is uneven and broken.

On the other block, there is shadow again. It is light, but not bright. I see people walking. I hear cars driving next to me. As I reach the corner the sound of cars get louder. It is not warm because of the shadow cast by the building.

Ciutat de Granada

The street is semi open due to construction on the area. It seems they are changing the pipes. I can smell dirt. The sidewalk is constrained due to the construction. It is small. It is warm under the sun but comfortable in the shadow. There are trees. It is noisy. The sound is overwhelming. I pass quickly this area.

As I cross the street I come to a restaurant in the corner. They have tables out and plants to make it nicer. It feels cozy. It is light and trees help to not make it bright. People are sitting down, eating and talking. I can hear them and also the trees moving because of the wind. I hear construction noise. There are also people walking. In the shadows, it is fresh, however, when in the sun even the wind won't help to cool down.

There is construction at the end. It can get too bright in the corners. People are walking and talking. I can hear cars, construction and people. It is not too warm under the shadows. The sidewalk is broken in some parts because of the pipe they are changing. On the other side it smelled like sewer.

The scale of the street is nice, it feels comfortable. In general it is light but at the intersections it can get bright. I see people walking and talking. I can hear the trees being moved by the wind and people talking. I hear very little construction noise. Near the dumpster it was dirty. I saw pigeons eating the garbage. It was cool but in the intersections got warm. There was a lack of shadows.

The sidewalk was constrain, it was dirty and smelled like dirt. You could see people walking and hear construction sounds. It was overwhelming. Under the sun it was warm but when there was shadow it was ok.

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Perez IV a1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	It is an industrial area, with many parked cars. No trees. Cars delimits the space, there is construction at the end of the block and construction material next to side walk.
	Empty, open, not safe, industrial, wide	No sound	No scent	Floor uneven	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Light (no shadow), colorful	Cars	Car scent	Very warm, almost no shadow	
	Action/people	*Societal sounds*	*Societal smells*		
	Talking, walking	People talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Perez IV a2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	A little bit of housing, mostly industrial. Many cars. Restaurants on corners
	Predominance car, bus passing, industrial, empty	No sound	No scent	Even floor	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright	Construction, motor vehicles	Scent of cars, trash	Very warm, little wind, no shadow	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking	No sound	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Perez IV a3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	More business related to people
	Wider, more cozy, trees	No sound	No scent	Different floor texture, more even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Darker color on floor, not bright	Construction and motor vehicles	Sewage	Very warm, little wind, no shadow	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, eating, talking on phone	People talking, cleaning	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Perez IV b1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Poles and cars makes sidewalk feel smaller. Tighter.	No sound	No scent	Same texture little uneven	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Cars makes it brighter	Construction and cars	Sewage	Very warm, little shadow from wall, wind helps to cool a little	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking	People talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Perez IV b2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Buildings shadow helps cool down. Wind cools.
	Compressed because of cars, not a nice view, bar at end	No sound	No scent	Floor uneven in texture and level	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not bright	Construction and cars	No scent	Not warm (shadows)	
	Action/people	*Societal sounds*	*Societal smells*		
	Dog walking, walking, cycling	Talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Perez IV b3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Most business at this side is closed
	At the beginning open space with small sidewalk, later bigger	No sound	No scent	Floor more even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not too bright	Construction far away, motor vehicles	No scent	Very warm, cooler in shadow	
	Action/people	*Societal sounds*	*Societal smells*		
	Cycling, meeting, talking, resting	People talking	Food smell		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Almogavers a1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Industrial area, mechanical shops/ atelier makes noise. Not many people.
	Pots makes limit feel ok, not big enough	No sound	No scent	Uneven in level. different floor levels	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright	Motorised vehicles, industrial sounds	No scent	Very warm, trees don't help much (are not big enough), wind helps	
	Action/people	*Societal sounds*	*Societal smells*		
	Working, walking	Children laughing and talking, Adults talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Almogavers a2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	More residential. People's noise comes from apartments
	Wider. Pots as limit, poles are not in the way. Motorcycles makes it feel wider	No sound	No scent	Uneven, but same texture	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not too bright	Motor vehicles, construction	No scent	Very warm, tree helps a little, wind helps more	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking	Child crying, people talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Almogavers a3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Open space/ place to stay/ priority pedestrians	No sound	Soft plant smell	Different textures in different areas	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright but ok	Construction	No scent	Very warm, wind cools a little, trees help a little.	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking, getting together	Music, people talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Almogavers b1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	More trees on pots, shadows
	Cars as limit, wall. Feels enclosed. Empty	No scent	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Brightness ok	Motor vehicles, construction, industrial	No scent	Its ok, wind makes it fresh	
	Action/people	*Societal sounds*	*Societal smells*		
	Cycling	People talking in far distance	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Almogavers b2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Open but level difference divides space	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Brightness ok	Motor vehicles, construction	No scent	Comfortable because of wind and shadow	
	Action/people	*Societal sounds*	*Societal smells*		
	Dog walking, walking, cycling, smoking	People talking	Cigarette smoke		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Almogavers b3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Open space/ place to stay/ priority pedestrians	No sound	Soft plant smell	Different textures in different areas	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright but ok	Construction	No scent	Very warm, wind cools a little, trees help a little.	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking, getting together	Music, people talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Sancho de Avila a1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Many trees for shadows. More offices in the area, more people
	More space, sidewalk seems wider, motorcycles as limit	Wind blowing leaves	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Light, not bright	Motorised vehicles, bicycle	No scent	Not too warm, wind makes it fresh and bearable	
	Action/people	*Societal sounds*	*Societal smells*		
	Smoking, Walking, Cycling	Children playing	Cigarette		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Sancho de Avila a2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	More residential and office buildings. Benches on sun
	Feels wide, it complements with additional space, but height difference turns it into two spaces	Wind blowing leaves	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright	Construction	No scent	Warm, but acceptable because of tree shadows	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, cycling	People talking, children laughing	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Sancho de Avila a3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide street, is for pedestrians, two levels	Birds (seagowls), wind and trees	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright	Construction, motor vehicles	No scent	Warm, not much wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking, roller skating, cycling	People talking, children playing and talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Sancho de Avila b1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Less tree coverage on this side
	Wide. You get two spaces because of floor height difference	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Light	Motor vehicles	No scent	More warm, wind helps	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking, waiting	Children playing, people walking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Sancho de Avila b2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Buildings retrieved, windy
	Very wide, big scale, cars far from pedestrians	No sound	No scent	Smooth, two textures, one a little uneven	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Light	Motor vehicles, construction	No scent	Wind cools down. Not too warm	
	Action/people	*Societal sounds*	*Societal smells*		
	Sitting, eating, waiting, walking	People talking, children playing	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Sancho de Avila b3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide street, is for pedestrians, two levels	Birds (seagowls), wind and trees	Scent of trees	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not bright	Construction, motor vehicles	No scent	Warm, not much wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking, roller skating, cycling	People talking, children playing and talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Roc Boronat a1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	A lot of wind, shadow of trees help
	Wide, limit is cars	Tress and wind	No scent	Little uneven	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Light, not bright	Motor vehicles	No scent	Cool because of wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, eating, talking, cycling	People talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Roc Boronat a2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide, limit by cars	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Very bright	Motor vehicles, construction	No scent	Very warm, no shadow	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, talking	talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Roc Boronat a2b	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide, limit by cars	Wind and trees	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not so bright	Motor vehicles, restaurant	No scent	Mere shadow, wind helps to make it bearable	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, talking	talking	Food		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Roc Boronat a3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Building creates shadow. At the end trees make shadow
	Wide, plus extra space to sit	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Green. It's not bright	Construction, motor vehicles	Sewer, rubber	Warm when no wind, but not too warm	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, cycling	People walking, talking	Food		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Rec Boronat b1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Shadows of buildings help
	Wide	Wind and leaves	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Ok not bright	Motor vehicles, construction far	No scent	Warm but ok, wind cools down	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking	Talking across the street	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Rec Boronat b2+b2b	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide	Birds far away	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not bright	Construction cars	Car	Ok in shadow, warm in sun	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking, sitting	Talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Rec Boronat b3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Building creates shadow.
	Wide, plus extra space to sit	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Green. It's not bright	Construction, motor vehicles	Sewer, rubber	Warm when no wind, but not too warm	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, cycling	People walking, talking	Food		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada a1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Construction in block
	Not wide because of construction	Wind and leaves	No scent	A little uneven	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	ok, not bright	Construction	No scent	Warm but ok. Shadows helps	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, working	Talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada a2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide	Wind and trees	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not to bright	Construction, motor vehicles	Car smell	Fresh. A lot of wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, cycling	Talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada a2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide	Wind and trees	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Not to bright	Construction	Car smell	Warm with wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, cycling	Talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada a3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Construction at the end. Moving materials.
	Wide, motorcycles makes space smaller	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright but ok	Construction	Car smell, sewer	Warm but cool with wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, working	Talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada b1	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Construction area
	Not too wide because of construction	No sound	Dirt	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Ok	Construction	Car smell	Ok, little wind to cool	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, working	No sound	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada b2	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide	Wind and trees	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Brightness ok	Little construction	No scent	Warm but wind helps. Not too much wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking on phone	People talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada b2b	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	
	Wide	Wind and trees	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Brightness ok	Motor vehicles, construction	No scent	Warm but wind helps. String wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, talking on phone	People talking	No scent		

STREET	VISION	AUDIO	SMELL	TOUCH	OBSERVATIONS
Ciutat de Granada b3	*Space/flow*	*Natural Sounds*	*Natural smells*	*Active touch (texture, relief)*	Construction at the end. Moving materials. People talking advantage of the situation (example, parking)
	Because of construction side walk is smaller	No sound	No scent	Even	
	Color/light	*Mechanical sounds*	*Mechanical smells*	*Passive touch (wind/warmth)*	
	Bright but ok	Construction	Car smell, sewer	Warm but cool with wind	
	Action/people	*Societal sounds*	*Societal smells*		
	Walking, sitting, working	Talking	No scent		

Summary

The area used to be an old industrial site. Currently, the neighborhood is under renovation. There are many construction sites. The visual, noise, and smell discomforts from the construction sites are temporal, therefore are not considered in this summary.

Perez IV

For sight, the street of Perez IV presents glare discomfort from the parked vehicles on the roads due to the lack of trees in the area.

For sound, the noise coming from the basic network can be heard close to the end of the superblocks.

For temperature, due to the lack of trees, there is no protection from the heat. Temperature can lower when there are open spaces.

Almogavers

For sight, the street feels bright however, there is no visual discomfort. There is still a lack of trees. The trees in pots barely make shadow to help with the brightness.

For sound, as I reach the corner, the motorized vehicles' sound is stronger.

For heat, temperature feels high. There is no wind and no shadows. As I reach the intersections, it becomes cooler due to the wind. Shadows from the buildings help cool down.

Sancho de Avila

For sight, there is no brightness issue due to the trees in the street.

For sound, the noise comes from the basic network and the motorized vehicles inside the superblocks in the inner roads. As I reach the park at the end of the street, birds are singing.

For temperature, the first area, where all the trees are and the street is not too wide, there are shadows and wind, which helps cool down. In the other blocks, the buildings have a more significant distance. There are heat and little shadow, nevertheless, it is windy, and this helps to cool down.

Roc Boronat

For sight, there is no brightness unless you reach the intersection.

For sound, the streets of Perez IV and Roc Boronat allow cars passing through the superblock. Noise from motorized vehicles could be heard near and from the inner streets of both these streets. Furthermore, near the end of the superblock, the sound of traffic can be heard from the basic network. Additionally, the wind made noise when pushing the tree branches.

For smell, there is discomfort due to the cigarette smell. This situation happens due to the people using the space. There is no control for this situation. Additionally, near the park, there was the smell of trees.

For temperature, the areas that presented trees were comfortable, nevertheless, the intersections had no trees, and it was warm. In these situations, the wind at the junctions helped cool down. However, the sunny areas were too warm.

Ciutat de Granada

For sight, it was not too bright in the street; nevertheless, in the intersections, it was bright.

For sound, I could hear the tree branches moving due to the wind.

For temperature, the areas under shadow were comfortable, nevertheless the sunny areas, even with the wind, was too hot.

Conclusions

When there are trees, it is not too bright. The intersections have a brightness issue due to the lack of trees.

The noise coming from the basic network could be heard only close to the end of the superblock. In the streets were cars were passing, the noise was an issue.

There was a smell coming from the trees of the park. Only there it could be sensed. Smell discomfort happened near people that were smoking and close to traffic.

For temperature, the streets with trees were comfortable. Nevertheless, the sunny areas were too warm. Sometime wind could help lower temperature, but other times it was not enough.

Appendix B: Evaluation Matrix per sense

The next evaluation matrixes are divided per sense, and they establishe which of the 15 design tools can improve environmental comfort more efficiently (Tables B1-B4). The evaluation criteria is in chapter 3.4.

DESIGN TOOLS	CONTROL		
	0	1	2
Green pavilions and arbors			x
Planted pergolas			x
Waterfall pergolas			x
Perennial plants with very large leaves		x	x
Trees			x
Hedges		x	x
Gradation works			x
Green demarcation elements			x
Waterfalls			x
Shrubs		x	
Wind plus shadow elements (mini hills with vegetation)		x	
Low plants		x	
Fountains	x		
Green masts	x		
Green ponds	x		

DESIGN TOOLS	MASKING		
	0	1	2
Green demarcation elements			x
Hedges			x
Perennial plants with very large leaves			x
Shrubs			x
Wind plus shadow elements (mini hills with vegetation)			x
Gradation works			x
Waterfalls			x
Low plants		x	
Green ponds		x	
Waterfall pergolas		x	
Fountains		x	
Green pavilions and arbors		x	
Green masts	x		
Planted pergolas	x		
Trees	x		

DESIGN TOOLS	ENHANCE		
	0	1	2
Green ponds			x
Waterfall pergolas			x
Low plants		x	
Green demarcation elements		x	
Hedges		x	
Perennial plants with very large leaves		x	
Shrubs		x	
Wind plus shadow elements (mini hills with vegetation)		x	
Gradation works		x	
Trees		x	
Waterfalls		x	
Fountains		x	
Green pavilions and arbors		x	
Planted pergolas		x	
Green masts		x	

Table B1. Evaluation matrix for visual sense

DESIGN TOOLS	CONTROL			
	0	1	2	3
Green demarcation elements				x
Wind plus shadow elements (mini hills with vegetation)				x
Gradation works				x
Waterfalls				x
Low plants				x
Hedges			x	
Perennial plants with very large leaves			x	
Shrubs			x	
Trees		x		
Planted pergolas		x		
Fountains	x			
Green masts	x			
Green pavilions and arbors	x			
Green ponds	x			
Waterfall pergolas	x			

DESIGN TOOLS	MASKING		
	0	1	2
Gradation works			x
Waterfalls			x
Green ponds			x
Waterfall pergolas			x
Fountains			x
Low plants		x	
Green demarcation elements		x	
Hedges		x	
Perennial plants with very large leaves		x	
Shrubs		x	
Wind plus shadow elements (mini hills with vegetation)		x	
Trees		x	
Green pavilions and arbors		x	
Planted pergolas		x	
Green masts		x	

DESIGN TOOLS	ENHANCE		
	0	1	2
Low plants			x
Green demarcation elements			x
Hedges			x
Perennial plants with very large leaves			x
Shrubs			x
Wind plus shadow elements (mini hills with vegetation)			x
Trees			x
Green pavilions and arbors			x
Planted pergolas			x
Green masts			x
Gradation works		x	
Green ponds		x	
Waterfall pergolas		x	
Waterfalls		x	
Fountains		x	

Table B2. Evaluation matrix for Acoustic sense

DESIGN TOOLS	CONTROL		
	0	1	2
Green ponds			x
Green masts			x
Green pavilions and arbors			x
Low plants			x
Planted pergolas			x
Waterfall pergolas			x
Wind plus shadow elements (mini hills with vegetation)			x*
Green demarcation elements		x	
Hedges		x	
Perennial plants with very large leaves		x	
Shrubs		x	
Trees		x	
Fountains	x		
Gradation works	x		
Waterfalls	x		

DESIGN TOOLS	MASKING		
	0	1	2
Green ponds		x	x
Green demarcation elements		x	
Green masts		x	
Green pavilions and arbors		x	
Hedges		x	
Low plants		x	
Perennial plants with very large leaves		x	
Planted pergolas		x	
Shrubs		x	
Trees		x	
Waterfall pergolas		x	
Wind plus shadow elements (mini hills with vegetation)		x	
Gradation works	x		
Waterfalls	x		
Fountains	x		

DESIGN TOOLS	ENHANCE		
	0	1	2
Green ponds			x
Fountains		x	
Green demarcation elements		x	
Green masts		x	
Green pavilions and arbors		x	
Gradation works		x	
Hedges		x	
Low plants		x	
Planted pergolas		x	
Perennial plants with very large leaves		x	
Shrubs		x	
Trees		x	
Waterfalls		x	
Waterfall pergolas		x	
Wind plus shadow elements (mini hills with vegetation)		x	

TABLE B3. EVALUATION MATRIX FOR OLFACTORY SENSE

DESIGN TOOLS	CONTROL		
	0	1	2
Low plants			x
Hedges		x	x
Perennial plants with very large leaves		x	x
Shrubs		x	x
Wind plus shadow elements (mini hills with vegetation)		x	x
Green demarcation elements		x	
Gradation works		x	
Trees		x	
Waterfalls		x	
Fountains	x		
Green masts	x		
Green pavilions and arbors	x		
Green ponds	x		
Planted pergolas	x		
Waterfall pergolas	x		

DESIGN TOOLS	MASKING		
	0	1	2
Green pavilions and arbors		x	x
Planted pergolas		x	x
Waterfall pergolas		x	x
Perennial plants with very large leaves		x	x
Trees		x	x
Hedges		x	x
Gradation works		x	x
Green demarcation elements		x	x
Waterfalls		x	x
Green masts		x	
Green ponds		x	
Fountains		x	
Low plants		x	
Shrubs		x	
Wind plus shadow elements (mini hills with vegetation)		x	

DESIGN TOOLS	ENHANCING		
	0	1	2
Low plants		x	
Green masts		x	
Green demarcation elements	x		
Hedges	x		
Perennial plants with very large leaves	x		
Shrubs	x		
Wind plus shadow elements (mini hills with vegetation)	x		
Gradation works	x		
Trees	x		
Waterfalls	x		
Green ponds	x		
Waterfall pergolas	x		
Fountains	x		
Green pavilions and arbors	x		
Planted pergolas	x		

TABLE B4. EVALUATION MATRIX FOR THERMAL SENSE

Appendix C: Design models per sense

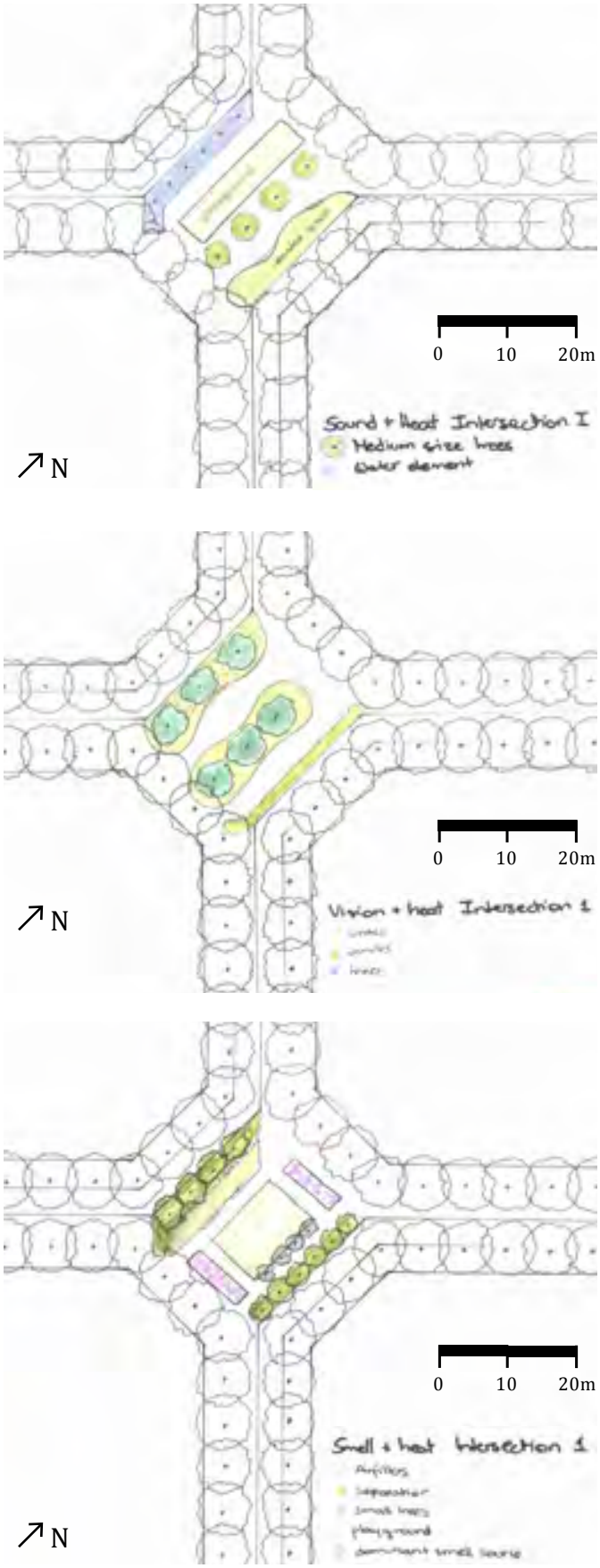


Fig. B1. Some design models per sense for neighbor node 1

The design strategies per sense (Chapter 5.2) are tested in different models. The models were evaluated with shadow analysis and the evaluation matrix per sense (Appendix B).

The evaluation matrix per sense was used to determined which tools could be applied to create the “best” design for each combination with the thermal sense.

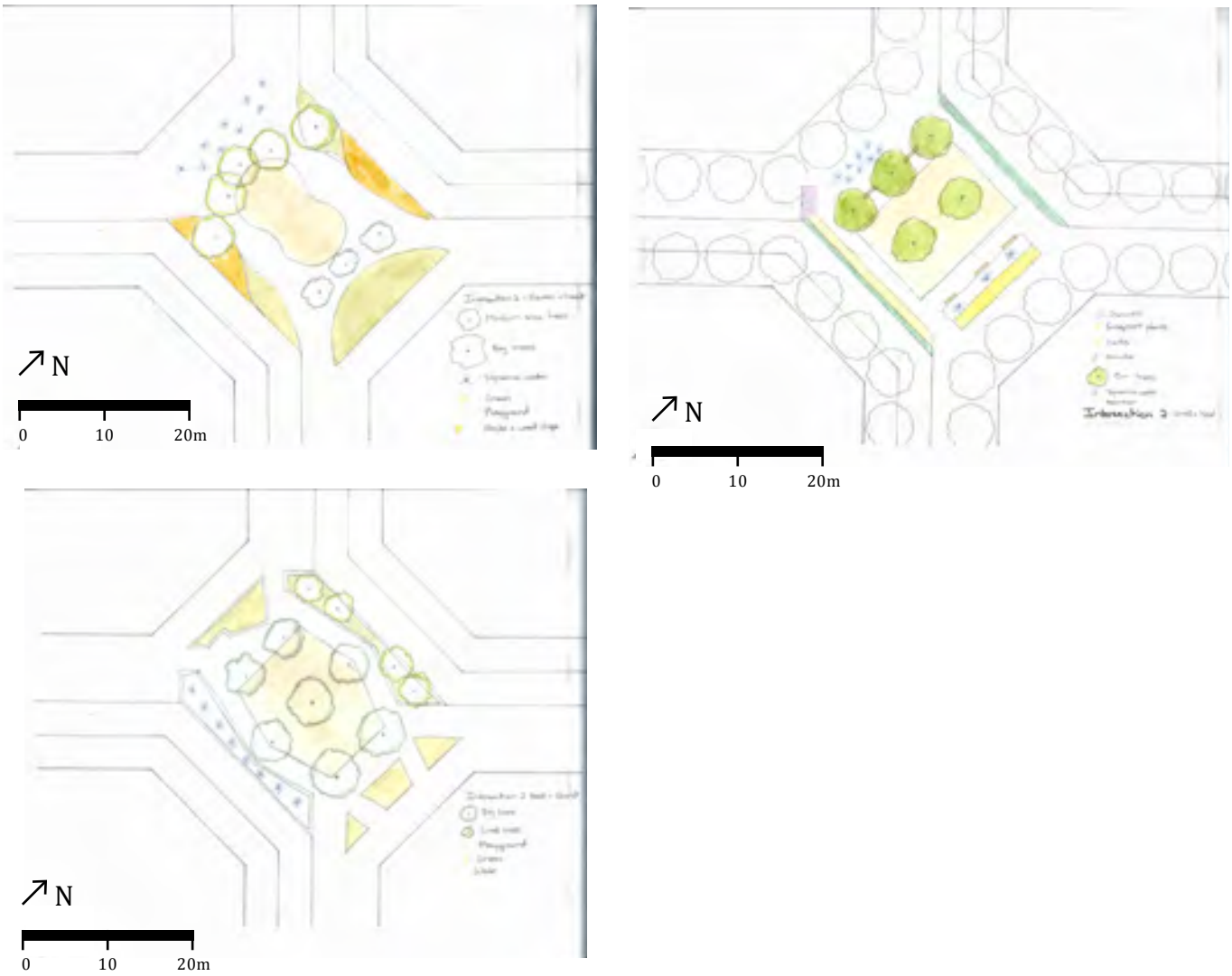
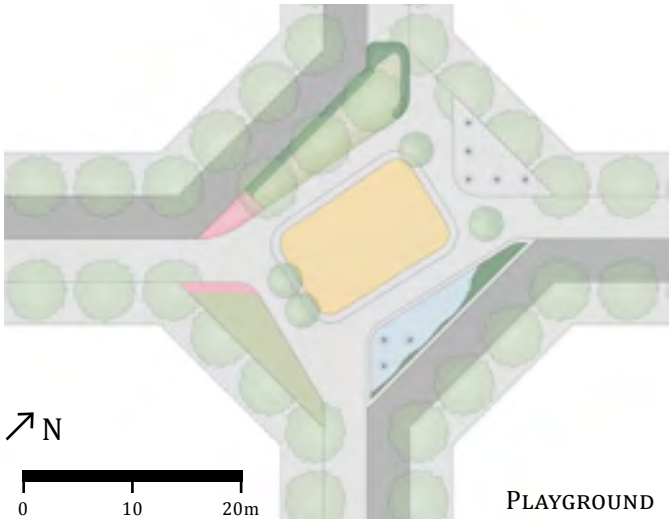
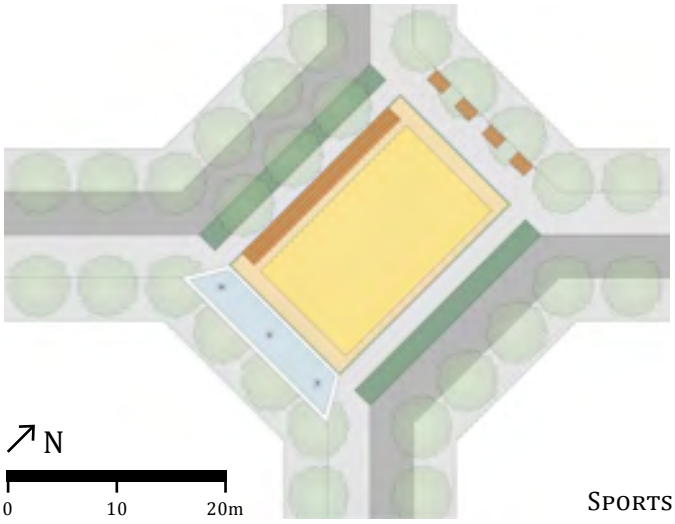


Fig. B2. Some design models per sense for neighbor node 2

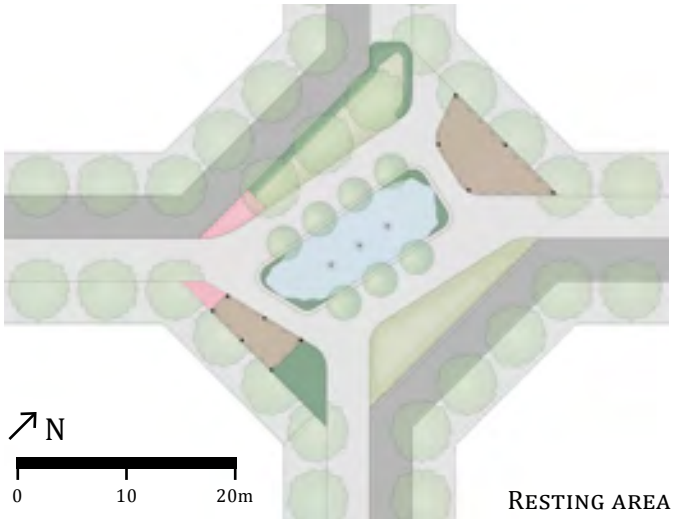
Appendix D: Integrated design models



Playground



Sports



Resting area

For the integrated models, different uses were explored while being tested with a shadow analysis and the evaluation matrixes per techniques.

The evaluation matrix per technique was used to determined which tools could be applied to create the "best" design for each function.

Fig. B4. Some Integrated design models for neighbor node 1

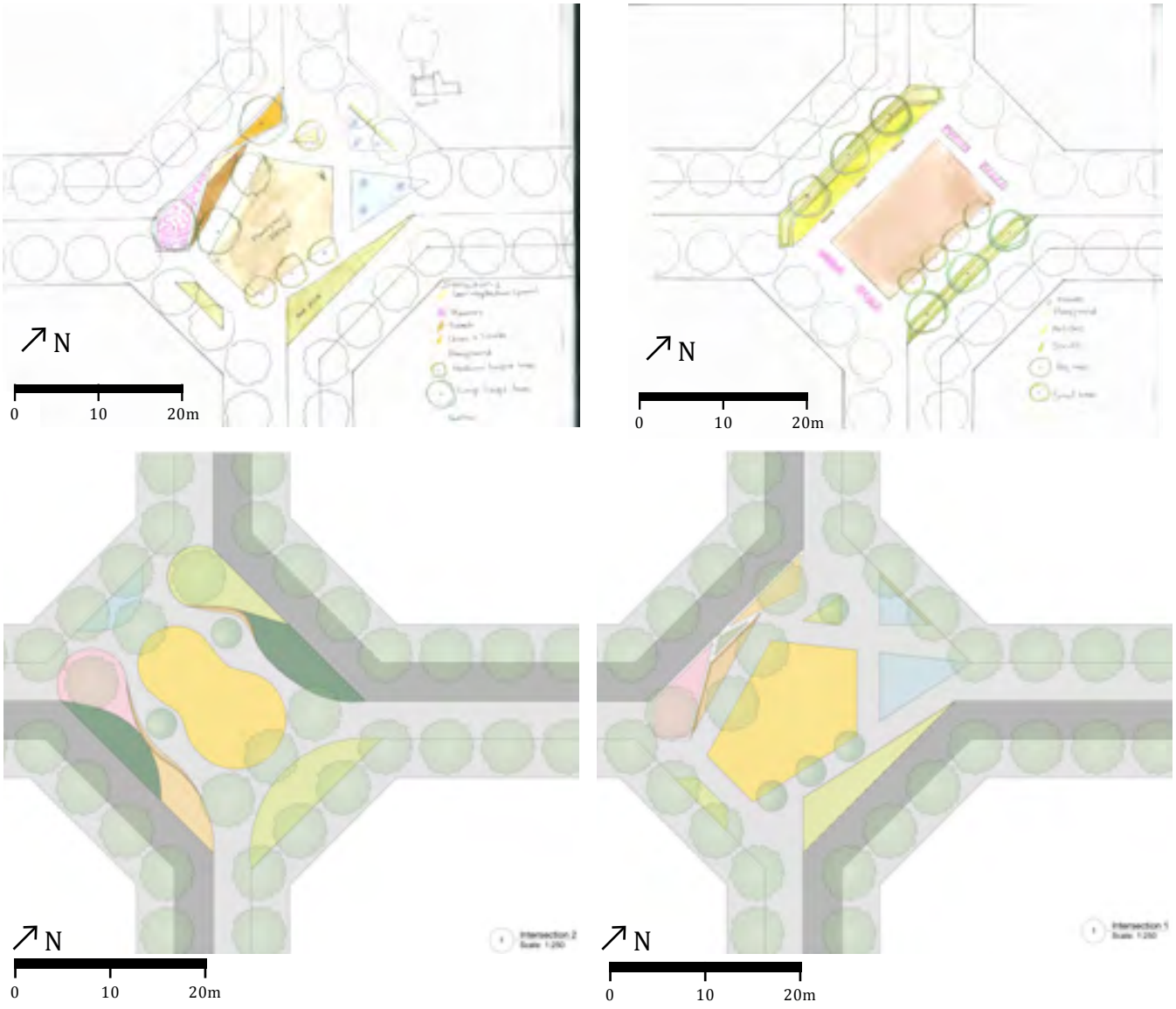


Fig. B3. Some Integrated design models for neighbor node 1 and 2

Appendix E: street trees of Barcelona

Source: Ajuntament de Barcelona, 2011

Species	Catalan	English	Ús	Mida	Porte	Tipus		Suitability in Barcelona
Acacia dealbata	Mimosa comuna	Silver wattle	O/P	M	IR	E		Problems taking root. Branches break easily
Acacia retinodes	Mimosa de fotografia	Swamp wattle	O/P	S	IR	E		
Acacia saligna (A. cyanophylla)	Mimosa blava	Coojong	S-O/P	S	IR	E		Branches break easily. Invasive
Acer buergerianum	Auró tridentat	Trident maple	S-O/P	S		D		
Acer campestre	Auró blanc	Field maple	S-O/P	M		D		
Acer monspessulanum	Auró negre	Montpellier maple	S-O/P	M		D		
Acer negundo	Negundo	Box elder	O/P	M	IR	D		Problems taking root. Branches break easily
Acer opalus	Blada	Italian maple	S-O/P	L		D		
Acer platanoides	Erable	Norwegian maple	S-O/P	L		D		Difficulty adapting
Acer pseudoplatanus	Plàtan falç	Sycamore	S-O/P	L		D		Difficulty adapting
Acer saccharinum	Auró argentat	Silver maple	S-O/P	L		D		Difficulty adapting
Acer x freemanii 'Autum blaze'	Auró de Freeman	Freeman maple	S-O/P	M	IR	D		
Aesculus hippocastanum	Castanyer d'Índia	Horse chestnut	S-O/P	L		D		Difficulty adapting
Ailanthus altissima	Ailant	Tree of heaven	O/P	L		D		Invasive
Albizia julibrissin	Acàcia taperera	Pink siris	S-O/P	M	IR	D		
Albizia julibrissin 'Ombrella'	Acàcia taperera	Pink siris	S-O/P	M	IR	D		
Alnus cordata	Vern italià	Italian alder	S-O/P	L		D		Difficulty adapting
Alnus glutinosa	Vern	Common Alder	S-O/P	L		D		Difficulty adapting
Archontophoenix cunninghamiana	Palmera de Cunningham	Bangalow palm	S-O/P	M		E		
Bauhinia forficata	Pota de vaca	Pata de vaca	S-O/P	M	IR	D		
Bauhinia candicans	Pota de vaca	Pata de vaca	S-O/P	M	IR	D		
Bauhinia purpurea	Pota de vaca	Orchid tree	S-O/P	M	IR	D		
Betula pendula	Bedoll	Silver birch	S-O/P	M		D		Difficulty adapting
Brachychiton acerifolius	Arbre de foc d'Austràlia	Illawarra Flame Tree	S-O/P	M		D		

Species	Catalan	English	Ús	Medida	Porte	Tipo		Suitability in Barcelona
Broussonetia papyrifera	Morera de paper	Paper mulberry	S-O/P	L	IR	D		
Carpinus betulus	Carpí	Common hornbeam	S-O/P	L		D		Difficulty adapting
Casuarina cunninghamiana	Casuarina comuna	River oak	S-O/P	L	IR	E		
Catalpa bignonioides	Catalpa comuna	Indian bean tree	S-O/P	L	IR	D		
Catalpa bungei	Catalpa de Bunge	Manchurian Catalpa	S-O/P	M		D		
Celtis australis	Lledoner	Southern nettle tree	S-O/P	L		D		Common in Barcelona. Around 15% of total
Celtis occidentalis	Lledoner americà	Hackberry	S-O/P	L		D		
Cephalotaxus harringtonia	Teix d'Hokkaido	Cowtail pine	S-O/P	S		E		Difficulty adapting
Ceratonia siliqua	Garrofer	Carob	O/P	M	IR	E		Unsuitable for streets
Cercis siliquastrum	Arbre de l'amor	Judas tree	S-O/P	M		D		
Chitalpa tashkentensis	Chitalpa	Chitalpa	S-O/P	M		D		
Chorisia speciosa	Arbre de la llana	Silver floss tree	O/P	M		D		Trunk with thorns
Citrus aurantium	Taronger amarg	Seville orange	S-O/P	S		E		Very vulnerable to pests and diseases
Citrus limon	Limoner	Lemon	S-O/P	S	IR	E		Very vulnerable to pests and diseases
Citrus reticulata	Mandariner	Mandarin	S-O/P	S	IR	E		Very vulnerable to pests and diseases
Cocculus laurifolius	Còcul	Laurel-leaved snail tree	S-O/P	M		E		
Corylus colurna	Avellaner turc	Turkish hazel	S-O/P	M		D		
Crataegus laevigata 'Paul scarlet'	Espinalb centreuropeu	Midland hawthorn	S-O/P	S		D		
Crataegus x lavalleei 'Carrierei'	Arç de Carrière	Lavelle hawthorn	S-O/P	S		D		
Crataegus monogyna	Arç blanc	Common hawthorn	S-O/P	S		D		
x Cuprocyparis leylandii	Xiprer de Leyland	Leyland cypress	S-O/P	L		E		
Cupressus arizonica (C. glabra)	Xiprer d'Arizona	Smooth American cypress	O/P	L		E		Unsuitable for streets
Cupressus macrocarpa (C. lambertiana)	Xiprer de lambert	Monterey cypress	O/P	L	IR	E		Unsuitable for streets

Species	Catalan	English	Ús	Mesura	Port	Tipus		Suitability in Barcelona
Cupressus sempervirens	Xiprer	Mediterranean cypress	S-O/P	L		E		
Cupressus sempervirens 'Stricta'	Xiprer	Fastigiate Mediterranean cypress	S-O/P	M		E		
Dodonaea viscosa	Dodonea comuna	Hopbush	S-O/P	S	IR	E		
Elaeagnus angustifolia	Arbre del paradís	Oleaster	O/P	M	IR	D		Unsuitable for streets
Eriobotrya japonica	Nesprer del Japó	Loquat	O/P	S		E		Unsuitable for streets
Erythrina crista-galli	Eritrina cresta de gall	Cockspur coral tree	S-O/P	L		D		
Eucalyptus camaldulensis	Euc. de fulla estreta	Murray red gum	O/P	L	IR	E		Invasive roots
Eucalyptus globulus	Eucaliptus comú	Tasmanian blue gum	O/P	L	IR	E		Invasive roots
Ficus benghalensis	Figuera de Bengala	Banyan	O/P	L		E		Invasive roots
Ficus carica	Figuera	Fig	O/P	M	IR	D		Invasive roots
Ficus elastica	Ficus de cautxú	Evergreen fig	O/P	L		E		Invasive roots
Ficus microcarpa (F. nitida, F. retusa)	Ficus de l'Índia	Indian laurel	O/P	M		E		Invasive roots
Firmiana simplex	Firmiana	Chinese parasol tree	S-O/P	M		D		
Fraxinus americana	Freixe americà	White ash	S-O/P	L	IR	D		Difficulty adapting
Fraxinus angustifolia	Freixe de fulla petita	Narrow-leaved ash	S-O/P	L	IR	D		Difficulty adapting
Fraxinus angustifolia 'Raywood'	Freixe de fulla petita	Narrow-leaved ash	S-O/P	M	IR	D		
Fraxinus excelsior	Freixe de fulla gran	Common ash	S-O/P	L	IR	D		Difficulty adapting
Fraxinus pensylvanica	Freixe de Pensilvània	Red ash	S-O/P	L	IR	D		
Ginkgo biloba	Ginkgo	Maidenhair tree	S-O/P	L		D		Avoid female plants, the fruit fouls pavements and smells unpleasant
Ginkgo biloba 'Fastigiata'	Ginkgo	Maidenhair tree	S-O/P	L		D		
Gleditsia triacanthos	Acàcia de tres punxes	Honey locust	S-O/P	L	IR	D		Presence of thorns. Replace with the 'inermis' thornless variety

Species	Catalan	English	Uso	Medida	Porte	Tipo		Suitability in Barcelona
Gleditsia triacanthos f. inermis	Acàcia negra inerme	Honey locust	S-Q/P	L	IR	D		
Gleditsia triacanthos 'Skyline'		Honey locust	S-Q/P	L		D		
Gleditsia triacanthos 'Sunburst'		Honey locust	S-Q/P	M	IR	D		
Grevillea robusta	Grevíl·lea comuna	Silk oak	S-Q/P	L		E		
Hibiscus syriacus	Hibisc de Síria	Rose of Sharon	S-Q/P	S		D		
Jacaranda mimosifolia	Xicranda	Jacaranda	S-Q/P	L		D		
Juglans regia	Noguera	Common walnut	Q/P	L	IR	D		Difficulty adapting
Koelreuteria paniculata	Sapindal	Golden rain tree	S-Q/P	M	IR	D		
Koelreuteria paniculata 'Fastigiata'	Sapindal	Golden rain tree	S-Q/P	M		D		
Lagerstroemia indica	Arbre de Júpiter	Crape myrtle	S-Q/P	S	IR	D		Difficult to plant
Laurus nobilis	Llorer	Sweet bay	Q/P	L		E		Vulnerable to diseases
Leucaena leucocephala	Aromer blanc	White leadtree	S-Q/P	M	IR	E		
Ligustrum lucidum	Troana arbòria	Glossy privet	S-Q/P	M	IR	E		Invasive
Liquidambar styraciflua	Liquidàmbar americà	Liquidambar	S-Q/P	M		D		Difficulty adapting
Liriodendron tulipifera	Tuliper de Virgínia	Tulip tree	S-Q/P	M		D		Difficulty adapting
Maclura pomifera	Maclura	Osage orange	Q/P	L		D		Unsuitable for streets
Magnolia grandiflora	Magnòlia	Evergreen magnolia	S-Q/P	M	IR	E		Needs a lot of water and nutrients
Magnolia grandiflora 'Pyramidalis'	Magnòlia	Evergreen magnolia	S-Q/P	M		E		Needs a lot of water and nutrients
Malus 'Everest'	Pomera everest	Apple	S-Q/P	S	IR	D		
Melia azedarach	Mèlia	Indian bead tree	S-Q/P	M		D		
Morus alba	Morera blanca	White mulberry	Q/P	L		D		Produces a lot of fruit, which foul s pavements
Morus alba 'Fruitless'	Morera blanca	White mulberry	S-Q/P	L		D		
Morus alba 'Kagayame'	Morera blanca	White mulberry	Q/P	L		D		Produces a lot of fruit, which foul s pavements

Species	Catalan	English	Uso	Medida	Porte	Tipo		Suitability in Barcelona
Morus nigra	Morera negra	Black mulberry	Q/P	L		D		Produces a lot of fruit, which fouls pavements
Nerium oleander	Baladre	Falta traducció	S-Q/P	S	IR	E		
Olea europaea	Olivera	Olive	Q/P	M		E		Unsuitable for streets
Ostrya carpinifolia	Òstria europea	Hop hornbeam	S-Q/P	M		D		
Parkinsonia aculeata	Parkinsònia	Palo verde	Q/P	S	IR	D		Branches with thorns
Paulownia tomentosa	Paulònia	Foxglove tree	S-Q/P	L		D		
Phoenix canariensis	Palmera de Canàries	Canary Island date palm	S-Q/P	L		E		Vulnerable to red palm weevil
Phoenix dactylifera	Palmera de dàtils	Date palm	S-Q/P	L		E		Vulnerable to red palm weevil
Photinia x fraserii 'Red Robin'	Fotínia de Fraser	Photinia	S-Q/P	S		E		
Phytolacca dioica	Bellaombra	Phytolacca	Q/P	L		D		Invasive roots
Pinus halepensis	Pi blanc	Aleppo pine	Q/P	L		E		Very vulnerable to attack by the processionary caterpillar
Pinus nigra	Pinassa	Austrian pine	Q/P	L		E		Difficulty adapting
Pinus pinaster	Pi marítim	Maritime pine	Q/P	L		E		Difficulty adapting
Pinus pinea	Pi pinyoner	Stone pine	S-Q/P	L		E		
Platanus PLATANOR® 'Vallis Clausa'	Plàtan	Plane	S-Q/P	L		D		
Platanus orientalis	Plàtan d'orient	Oriental plane	S-Q/P	L		D		
Platanus x acerifolia (P. x hispanica)	Plàtan d'ombra	London plane	S-Q/P	L		D		Very common in Barcelona, over 15% of total. Difficulty adapting
Podocarpus nerifolius	Podocarp comú	Brown pine	S-Q/P	M		E		
Populus alba	Àlber	White poplar	Q/P	L		D		Invasive roots. Branches break easily
Populus alba 'Pyramidalis'	Àlber piramidal	White poplar	S-Q/P	L		D		Invasive roots. Branches break easily
Populus nigra	Pollancre	Black poplar	Q/P	L		D		Invasive roots. Sheds large amounts of white fluff
Populus nigra 'Italica'	Pollancre gavatx	Lombardy poplar	S-Q/P	L		D		Branches break easily. Needs a lot of water

Species	Catalan	English	Uso	Medida	Porte	Tipo		Suitability in Barcelona
Populus simonii	Pollancre de Simon	Simon's poplar	O/P	M		D		Difficulty adapting
Populus tremula	Trèmol	Aspen	S-O/P	L		D		Invasive roots. Sheds large amounts of white fluff
Populus x canadensis	Pollancre del Canadà	Grey poplar	S-O/P	L		D		Invasive roots. Needs a lot of water. Sheds large amounts of white fluff
Prunus avium	Cirerer	Gean	S-O/P	M		D		
Prunus cerasifera	Mirabolà	Cherry plum	S-O/P	M		D		
Prunus cerasifera 'Pisardii' (P. cerasifera 'Atropurpurea')	Prunera vermella	Purple-leaf cherry plum	S-O/P	M		D		
Prunus domestica	Prunera	Plum	S-O/P	M		D		
Prunus serrulata	Cirerer del Japó	Oriental cherry	S-O/P	M		D		
Prunus serrulata 'Kanzan'	Cirerer de flor	Kanzan cherry	S-O/P	M		D		
Pterocarya fraxinifolia	Noguera del Caucas	Caucasian walnut	S-O/P	L		D		
Punica granatum	Magraner	Pomegranate	O/P	S		D		Unsuitable for streets
Pyrus calleryana 'Chanticleer'	Perera de Callery	Callery pear	S-O/P	S		D		
Quercus coccifera	Garric	Kermes oak	O/P	M		E		Unsuitable for streets
Quercus faginea	Roure valencià	Portuguese oak	O/P	M		D		Unsuitable for streets
Quercus ilex	Alzina	Holm oak	S-O/P	M	IR	E		
Quercus pubescens	Roure martinenc	Downy oak	S-O/P	M	IR	D		
Quercus robur	Roure pènol	English oak	S-O/P	L	IR	D		
Quercus robur 'Fastigiata'	Roure pènol	English oak	S-O/P	L		D		
Quercus suber	Surera	Cork oak	O/P	M		E		Difficulty adapting
Robinia pseudoacacia	Robínia	Black locust	O/P	L		D		Uneven growth. Invasive
Robinia pseudoacacia 'Bessoniana'	Robínia	Black locust	S-O/P	M	IR	D		
Robinia pseudoacacia 'Casque rouge'	Robínia	Black locust	S-O/P	M	IR	D		Branches break easily

Species	Catalan	English	Ús	Mesura	Porte	Tipus		Suitability in Barcelona
Robinia pseudoacacia 'Pyramidalis'	Robínia	Black locust	O/P	M		D		Breaks easily, invasive
Robinia pseudoacaia 'Umbraculifera'	Robínia	Black locust	S-O/P	M		D		Branches break easily
Salix alba	Salze blanc	White willow	O/P	L		D		Difficulty adapting
Salix babylonica	Desmai	Chinese weeping willow	O/P	M		D		Difficulty adapting
Salix elaeagnos	Sarga	Hoary willow	O/P	M		D		Difficulty adapting
Salix x sepulcralis	Salze plorós	Golden weeping willow	O/P	L		D		Difficulty adapting
Schinus molle var. areira	Pebrer bord comú	Pepper tree	O/P	L	IR	E		Unsuitable for streets
Schinus terebenthifolius	Pebrer bord del Brasil	Brazilian pepper	O/P	M		E		Unsuitable for streets
Styphnolobium japonicum (Sophora japonica)	Sòfora	Pagoda tree	S-O/P	M		D		
Syagrus romanzoffiana (Arecastrum romanzoffianum)	Palmera de la reina	Queen palm	S-O/P	M		E		
Tabebuia heptaphylla	Tabebuia	Pink trumpet tree	S-O/P	M		D		
Tamarix africana	Tamariu africà	African tamarisk	S-O/P	S	IR	D		
Tamarix gallica	Tamariu francès	French tamarisk	S-O/P	S	IR	D		
Tamarix ramosissima (T. pentandra)	Tamariu d'estiu	Summer-flowering tamarisk	S-O/P	S	IR	D		
Tetradium daniellii	Arbre de les mil flors	Bee-bee tree	S-O/P	L		D		
Tilia cordata	Til·lera de fulla petita	Small-leaved tree	S-O/P	L		D		Difficulty adapting
Tilia x euchlora	Til·lera de Crimea	Caucasian lime	S-O/P	L		D		Difficulty adapting
Tilia x europaea	Til·lera d'Holanda	European lime	S-O/P	L		D		Difficulty adapting
Tlia platyphyllos	Til·lera	Large-leaved lime	S-O/P	L		D		Difficulty adapting
Tilia tomentosa	Til·lera argentada	Silver lime	S-O/P	L		D		Difficulty adapting
Tipuana tipu	Tipuana	Tipu tree	S-O/P	L		D		
Trachycarpus fortunei	Margalló de la Xina	Chusan palm	S-O/P	S		E		
Ulmus americana	Om americà	American elm	S-O/P	L	IR	D		Difficulty adapting

Species	Catalan	English	Uso	Medida	Porte	Tipo		Suitability in Barcelona
Ulmus 'Dodoens'		'Dodoens' elm	S-O/P	L	IR	D		Difficulty adapting
Ulmus minor 'Umbraculifera'	Om	Field elm	S-O/P	S		D		Difficulty adapting
Ulmus pumila	Om de Sibèria	Siberian elm	S-O/P	L	IR	D		Vulnerable to Dutch elm disease. Breaks easily. Invasive roots
Ulmus resista 'New Horizon'	Om resista	Resistant elm	S-O/P	L		D		
Washingtonia filifera	Washingtònia de Califòrnia	Petticoat palm	S-O/P	L		E		
Washingtonia robusta	Washingtònia de Mèxic	Mexican fan palm	S-O/P	L		E		
Zelkova serrata 'Green vase'	Zelkova de Japó	Japanese Zelkova	S-O/P	L		D		

Key

Use

O/P: tree suitable for use in open spaces or parks
S: tree suitable for use in streets

Medida

L: large
M: medium-sized
S: small

Tipo

E: evergreen
D: deciduous

Porte

Parasol-shaped
Spindle-shaped
Columnar
Conical
Elliptic
Spherical
Uneven
Drooping
Ovoid
Palmiform
Pyramidal
Semi-ovoid
IR Uneven

Suitability as a street tree in Barcelona

Planting recommended, both as a replacement and for new planting

Planting subject to restrictions. Only as a replacement in those streets where the species is maintained. Avoid new planting

Avoid planting

Species under study